AN OPTIMIZED HIDDEN NODE HANDLING APPROACH FOR IMPROVING THE COVERAGE AND NETWORK EFFICIENCY IN WIRELESS MULTIMEDIA SENSOR NETWORKS

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Under the Supervision of Dr. Khaled Elleithy

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ABSTRACT

Wireless Multimedia Sensor Networks (WMSNs) are comprised of sensor nodes that form the momentary network and do not rely on the support of any orthodox centralized infrastructure or administration. Such a given situation mandates that every sensor node gets the support of the other sensor nodes in order to advance the packets to the desired destination node, and specifically to the sink node. Successful transmission of online multimedia streams in wireless multimedia sensor networks (WMSNs) is a challenge due to their limited bandwidth and power resources. The existing WMSN protocols are not completely appropriate for multimedia communication. The effectiveness of WMSNs vary as it depends on the correct location of the sensor nodes in the field. Thus, maximizing the multimedia coverage is the most important issue in the delivery of multimedia contents. The nodes in WMSNs are either static or mobile. Thus, the node connections change continuously due to the mobility in wireless multimedia communication that causes an additional energy consumption and synchronization loss between neighboring nodes. The focus is on hidden node problems in WMSNs and how they can affect the network performance. Hidden nodes occur in the networks when nodes that are invisible to each other communicate with another node that is visible to these nodes at a particular period. Eventually, a collision may occur and the node will be unable to receive any packets. In addition, this study looks at the effectiveness of the optimal orientation for the sensor nodes in the environment. This work introduces an Optimized Hidden Node Handling (OHND) approach. The OHND consists of three phases: hidden node handling, message exchange, and location and view handling. These three phases aim to maximize the multimedia node coverage and improve energy efficiency, hidden node handling capacity, and packet delivery ratio. OHND helps multimedia sensor nodes to compute the directional coverage. Furthermore, an OHND is used to maintain a continuous node– continuous neighbor discovery process to handle the mobility of the nodes. To evaluate the performance of the proposed algorithms, the results are compared with other known approaches. The results demonstrate that nodes are capable of maintaining direct coverage and detecting hidden nodes in order to maximize coverage, achieve power efficiency, reduce the end-to-end delay, and improve the throughput. Finally, this study provides an efficient solution for handling the hidden node problem in case mobility.

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CHAPTER 1: INTRODUCTION

Wireless Multimedia Sensor Networks (WMSNs) are capable of capturing audio-video information by using low-cost cameras embedded with sensor nodes. Multimedia sensors provide substantial information related to a particular area of interest. However, multimedia applications experience problems due to online media transmission challenges. Several sources of energy waste include idle listening, overhearing, packet loss due to collisions, and packet overhead in the multimedia sense. One of the major sources of energy waste is the packet collisions that happen when two nodes try to transmit packets simultaneously. As a result, this causes a partial or complete packet loss at the recipient node. The lost packets need to be discarded or retransmitted, which could be the source of the excess energy consumption waste and Quality of Service (QoS) degradation. To enable the on-demand multimedia services, it is important to focus on multimedia-supported algorithms in WMSNs to determine the hidden node problems and compute the directional coverage. WMSNs consist of promising technology that can resolve several solutions, and cover health applications, commercial, and civilian applications. WMSNs involve a large number of low cost and small sensors that are equipped with wireless communication as well as computation capabilities. However, despite their benefits, WMSNs are problematic because of energy limitations brought about by the sensor nodes. The energy expenditure of these WMSNs depends on factors such as data processing, wireless communication, and environmental sensing. Therefore, most of the routing protocols aim particularly at accomplishing energy preservation. Most of the routing protocols that are designed for WMSNs follow the attainment of energy efficiency but are practically incompatible for provision of QoS in the WMSNs. Moreover, network density, severe bandwidth limitations, limited node power, and topology dynamicity have led to many limitations related to the management of WMSNs. A hidden node problem happens when the two nodes that are invisible to each other communicate with another node that is visible node to each other. Eventually, there is degradation of three performance metrics as discussed below:

- Throughput: Denotes the sum of traffic that is proficiently received by a given recipient node and it will be decreased because of the collisions.
- Energy-efficiency: Reduces because every collision leads to another retransmission.
- Transfer Delay is the period from the initiating of a message until it reaches the recipient node that enlarges because of several retransmissions of a particular collided message.

A recent research by[1] has demonstrated that around 40% of packets are lost because of hidden node collision. Such a percent rises as the number of hidden nodes increase. Therefore, the execution by these wireless sensor networks is enhanced when the nodes that are hidden are eliminated after being detected in the networks. Mobility support in WMSNs is not a simple matter, irrespective of the working level, as it involves and affects the network components. Among the current proposals, none of them demonstrated an effective solution for handling the node problem in case of mobility.

1.1 Research Motivation

- Successful transmission of online multimedia streams in WMSNs is a big challenge (limited bandwidth and power resources).
- The existing Wireless Sensor Network (WSN) protocols are not completely appropriate for multimedia communication.
- The hidden-node problem has been shown to be a major source of performance degradation (QoS) in WSN but it is even more severe in WMSNs.
- The effectiveness of WMSNs varies, and it depends on the correct view of its sensor nodes in the field that should maximize multimedia coverage.
- Once a better location coverage and hidden node solution for multimedia sensors are discovered, the results will help to improve the capabilities of WMSN applications.

1.2 Potential Contributions

This study proposes an optimized hidden node handling approach for Improving the coverage and network efficiency in (WMSNs). Our approach consists of three phases: hidden node handling, message exchange phase, and location and view handling. This protocol provides an efficient solution for handling the hidden nodes problem in WMSNs that leads to the improvements in the network throughput and reduces the delays and the power consumption. This protocol improves the view of the multimedia sensors and minimizes the effects of obstacles. It takes advantages of the overlapping areas to improve the sensed information that can be beneficial for some applications such as the tracking applications. It results in maximizing the coverage of the sensed environment. Handling the hidden nodes problem in case of mobility has been addressed in this work because it helps improve the QoS support and extends the network lifetime. In addition, this study introduces mobile and energy efficient quality of service protocol for WMSNs, and the focus will be to study hidden node problems in WMSNs in case of mobility. When nodes that are invisible to each other communicate with another node that is visible to these nodes at a certain period, collision occurs in the networks. Eventually, a collision may occur and the node will be unable to receive any packets.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

Many routing protocols have been proposed for wireless sensor networks. These routing protocols are generally based on energy efficiency. However, the recent advances in complementary metal-oxide semiconductor (CMOS) cameras and small microphones have led to the development of WMSNs as a class of wireless sensor networks that pose additional challenges. The transmission of imaging and video data needs routing protocols with both energy efficiency and QoS characteristics in order to guarantee the efficient use of the sensor nodes and effective access to the collected data. In addition, with integration of real time applications in the WSNs, the use of QoS routing protocols is not only becoming a significant topic but is also gaining the attention of researches. In designing an efficient QoS routing protocol, the reliability and guarantee of end-to-end delay are critical events while conserving energy. Thus, considerable research has been proposed for designing energy efficient and robust QoS routing protocols. This work presents a state of the art research work based on QoS routing protocols for WMSNs that have already been proposed. This work categorizes the QoS routing protocols into probabilistic and deterministic protocols. In addition, both categories are classified into soft and hard real time protocols by highlighting the QoS issues including limitations and features of each protocol. Furthermore, this study compares the performance of known routing protocols using network simulator-2 (NS2). This work also focuses on the design challenges and future research directions and it highlights the characteristics of each QoS routing protocol.

The network routing protocols in WSNs perform similar objectives to distribute network reachability information. They may share the complete routing table or exchange certain information. Most existing routing approaches use dynamic information, but in some cases, static information is more suitable [2]. However, the major objectives of introducing routing protocols for WMSNs are for prolonging the sensor network battery life time, ensuring the connectivity under several scenarios, enhancing the network survivability, handling energy consumption efficiently, reducing complexity and latency, and improving WMSN performance [3]. The routing protocols differ due to their scalability and performance features. From another perspective, WMSNs face several restrictions due to limited power supply, computing capability, high traffic volume, and limited bandwidth [4]. Several performance factors affect and influence the WMSN routing protocol design, such as data aggregation, network deployment, data delivery model, and network dynamic. These design factors consume excess energy as well as affect the scalability and QoS.

The performance of a routing protocol is associated with an architectural design that can be dynamic or static [5]. In network dynamic, the role of sensor nodes and sink is important. On the other hand, mobility of the sinks and cluster-heads is also essential. Node deployment affects the routing performance. The deployment may be self-organized or deterministic [6]. In self-organizing, the sensor nodes are randomly scattered and generate an infrastructure in an ad hoc fashion. In deterministic positions, the sensors are manually placed and data are forwarded through pre-defined routes. The routing protocols are based on data delivery mechanism with respect to the reduction of energy consumption and route permanence [7] . Data aggregation is an issue at the routing level because sensor nodes may generate same packets from multiple nodes that can cause the network to be flooded and waste more energy [8]. This problem can be handled by using functions such as min, max, suppression, and average. These functions can be applied partially or fully for each sensor node that causes substantial energy savings. This technique can obtain traffic optimization and energy efficiency using well-organized quality of service routing protocols [9].

Several efficient routing protocols in different categories have currently been introduced for the WMSNs [10]. However, there is still a need for more research to be conducted by introducing not only energy efficient routing protocol but also that focuses on other areas [11]. Factors to be considered when developing a routing protocol include an energy balanced network, nodes mobility, and integration of fixed with mobile networks, and QoS [12].

QoS is important when designing routing protocols, particularly in critical applications such as healthcare and the military [13]. Many of the introduced algorithms have been analyzed by using simulation tools, e.g., NS2 or OPNET. Some of these algorithms might be implemented in real deployments such as the Topology Dissemination Based on Reverse-Path Forwarding Protocol (TBRPF) [14], Implicit Geographic Forwarding (IGF) [15] in military networks, Energy-aware Temporarily Ordered Routing Algorithm (E-TORA)[16] in health departments, algorithms Two-Tier

Data Dissemination (TTDD) [17], Column-Row Location, and Routing On-demand Acyclic Multipath (ROAM)[18]. Not all these are completely functional in mobile environments, which can be improved to control mobility and excess energy consumption. This survey focuses on QoS routing protocols with classification, strength and weakness, deployment of QoS protocols in specific applications, and research direction for improving the QoS routing protocols.

2.2 Categorization and Classification of Quality of Service Routing Protocols

Based on the research issue, QoS routing protocols have been classified into two categories, which are probabilistic and deterministic, and these include soft real time and hard real time QoS routing protocols. This will help researchers to choose the best QoS routing protocol according to the requirements of the application to reduce energy consumption and obtain better throughput given in Figure 2.1.

In probabilistic routing protocols, the routing between sources to destination depends on the probability of the last lower rebroadcasted rate. In the probabilistic approach, the sensor node transmits the message with a known probability [19]. The transmission probability involves different factors such as hop-distance from source to destination, the number of hops where packet is already traveled, time in which sensor node already forwarded the packets, and the number of neighbor nodes. The probability-based protocols perform directed and controlled flooding. Thus, multiple packets are copied. In addition, probabilistic protocol uses the knowledge of history. Unlike probabilistic protocols, the deterministic protocols keep the complete information of node trajectories, encounter probability of nodes, and the period in which a decision is forwarded [20]. Both probabilistic and deterministic routing protocols are also classified into soft and hard real time. Soft real time protocol can miss a few data points that do not affect the performance. If some bits are missed, performance is eventually degraded. On the other hand, hard real-time absolutely hits every deadline, such as nuclear systems, medical applications, military applications, and avionics.

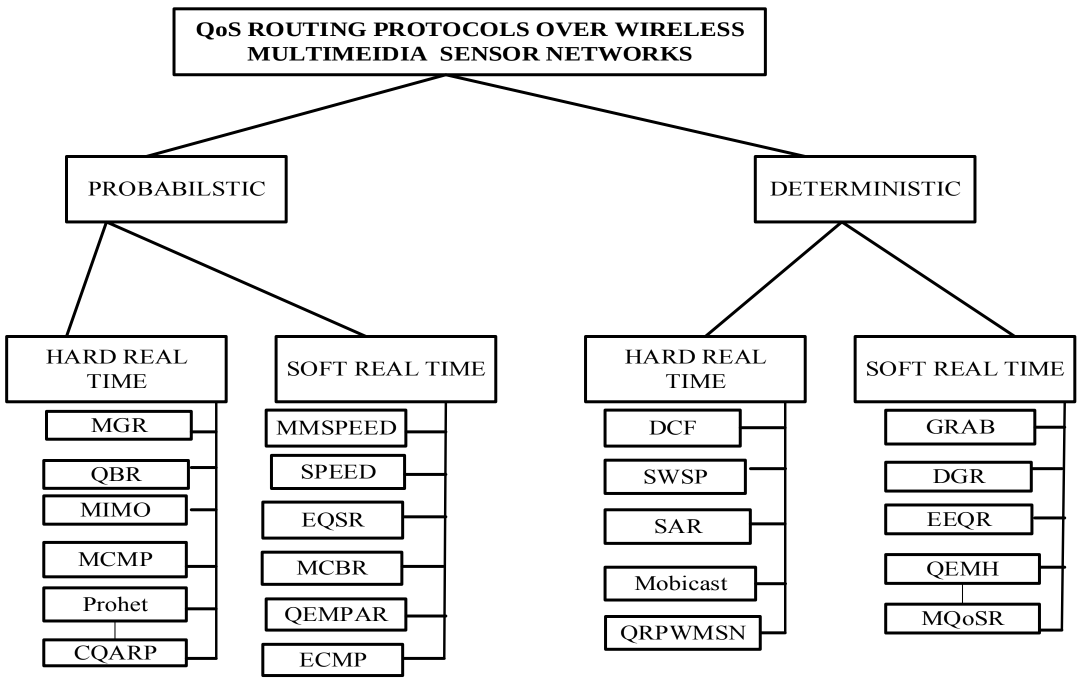


Figure 2.1. classification of quality of service (QoS) routing protocols

2.2.1 Probabilistic Routing Protocols (Hard Real Time)

Multimedia Geographic Routing (MGR) introduces the new architecture called mobile multimedia sensor network (MMSN) in [21] that is based on the Mobile Multimedia Geographic Routing (MGR) scheme. In this scheme, the mobile multimedia sensor node (MMN) is used to improve sensor network ability for event description. The purpose of this protocol is to reduce energy consumption to satisfy limitations on an average end-to-end delay of specific applications in MMSNs. The main goal of this protocol is to handle the delay to guarantee the priority for QoS provisioning. The protocol continuously attempts to reduce the energy consumption in order to prolong the sensor lifetime.

This helps to exploit the energy delay adjustments for design of this protocol. However, the key operation of this protocol is to choose the suitable location of current node for next hop. To complete this, MGR estimates the distance of the desired hop for the next hop selection that can be obtained by dividing the distance between current to the sink node. MGR ensures the QoS delay and reduces about 30% of energy consumption and prolongs the network lifetime as compared to classical geographic routing. MGR is more scalable than other protocols because it has the capability to control the mobility depicted in Figure 2.2.

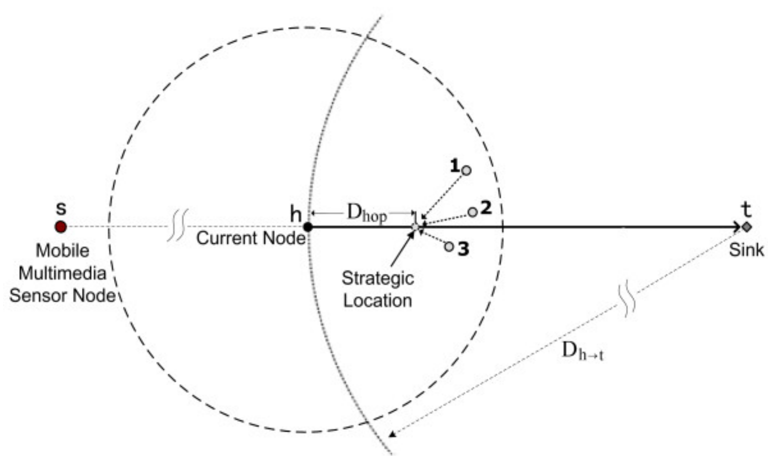


Figure 2.2. The Strategic Location Selection in MRG [21]

QoS based routing (QBR) protocol [22] is a real-hard probabilistic-based routing protocol introduced for supporting the event and periodic-based data reporting. QBR is composed of the features of geographic routing with QoS provisioning. The data packets are forwarded in the network based on the type of the packet. QBR sets different priorities levels for each type of data packet. Thus, multiple transmission queues are introduced for handling the priorities of data packets. In addition, the node is picked based on residual energy, high link quality, and the path with minimum load. The selection process of nodes consists of one-hop neighbor node that helps reduce additional energy consumption. In handling the congestion within the network, the ring or barrier mechanism that aggregates and captures the data packets is introduced. The barrier operation involves the barrier formation, shrink, repair, enlarge and termination. Despite these significant features, QBR is unable to meet the required QoS parameters. The main concern with this protocol is the use of extra control messages, which affect the throughput and consume additional energy.

Multiple Inputs and Multiple output (MIMO) is proposed in [23]. In MIMO, the data is collected in Multi-Hop Virtual MIMO through multiple source nodes and transmitted to a distant sink using multiple hops. The clusters are used to organize the sensors given in Figure 2.3. The cluster head transmits the data to cluster nodes that are related to a specific cluster. An Additive White Gaussian Noise (WGN) is used in such a transmission with squared power path loss because of short intra cluster transmission range.

Further, the cluster nodes translate and transmit data to a cluster head to the next hop due to orthogonal Space-Time Block Code (STBC). Multi-hop Virtual MIMO shows that an average reduction of the channel between each cluster head and cluster node is estimated during construction of the clusters so that it employs an equal Signal-to-Noise

Ratio (SNR) policy to distribute the transmitted energy due to its spectral performance efficiency and simplicity.

The Multi-Constrained QoS Multi-Path routing (MCMP) protocol is proposed in [24] to handle the QoS requirements. The MCMP uses braided paths to forward the packets to the sink station, which help maintain the QoS parameters such as end-to-end delay and reliability. The protocol structure is based on the linear integer programming, which formulates the end-to-end delay as an optimized problem. The MCMP routing algorithm builds the detailed link information for memory, sustainable computation, and overhead for the resource restricted sensor nodes. MCMP uses the local link metrics and distance to estimate the path metric. Local link metrics can help to obtain the network scalability. The goal of MCMP is to employ multiple paths to improve the network performance using moderate energy consumption. However, the protocol always prefers to choose the path that consists of the minimum number of hops to fulfill the essential QoS parameters. As a result, the protocol leads to the additional energy consumption.

The Probabilistic routing protocol for Heterogeneous sensor networks (ProHet) is introduced in [25] as a probabilistic hard real-time approach that can handle the asymmetry links in a dispersed fashion using local information. It uses low overhead with a guaranteed delivery rate. The working process of ProHet consists of two phases: the preparation phase that identifies the neighbor relationships and determines the reverse path for the asymmetric links and the routing phase that selects the nodes in order to forward the message and send the acknowledgement. ProHet uses bidirectional routing abstraction to determine the reverse path for each asymmetric link. It then applies a probabilistic policy to select forwarding nodes based on chronological data using local information. The advantage of this protocol is to reduce energy consumption and to guarantee the delivery rate in wireless hybrid sensor networks [26]. As with the previous QoS protocols, ProHet focuses only on hot spot and energy consumption as discussed in [27]. Also, ProHet lacks mobility support and decreases the throughput.

Cluster-based QoS Aware Routing Protocol (CQARP) is a probabilistic hard real-time QoS routing protocol introduced for cluster-based wireless sensor networks in [28]. This protocol employs a queuing model to tackle the non-real-time and real-time traffic. The protocol focuses on least end-to-end delay, improving the throughput and prolonging the network lifetime. The protocol involves the cost function with each link and applies the K-least cost path algorithm to determine the set of the efficient routing paths. Each path is verified against the end-to-end delay limitations. Once a path satisfies the limitations, it is selected as the path for sending the data to sink node. All the nodes are assigned a similar bandwidth ratio, which can create problems because some of the nodes require higher bandwidth. The strength of this protocol is to improve the throughput and prolong the network lifetime. Also, the issue of bandwidth assignment was resolved by using a different bandwidth ratio for each node. However, transmission delay was not considered and the protocol lacks mobility support. The working process of the protocol is depicted in Figure 2.3.

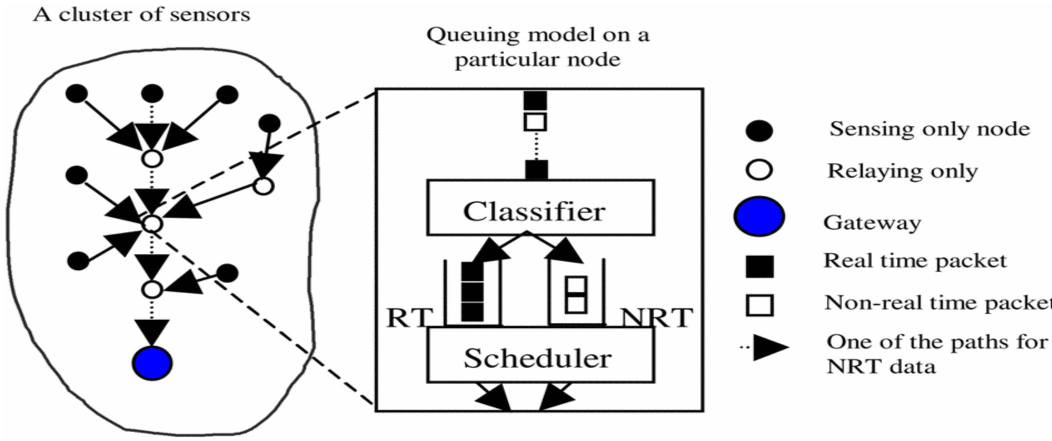


Figure 2.3. Queuing Model in the Cluster-Based Wireless Sensor Networks [28]

2.2.2 Probabilistic Routing Protocols (Soft Real Time)

Multi-Path and Multi-SPEED (MMSPEED) Protocol is introduced to guarantee the probabilistic QoS in [29]. The QoS provisioning is done into two domains: reliability and timeliness. The reliability domain supports many reliability requirements using probabilistic multipath forwarding, and the timeliness domain can be achieved by ensuring multiple packet delivery. These mechanisms are realized in a localized manner without using global network information. The local geographic packet forwarding is improved with a dynamic benefit that compensates for local conclusion imprecision as a packet travels to its destination. The key goal of MMSPEED is to guarantee end-to-end requirements with a localized manner that supports the adaptability and scalability for large scale dynamic WSNs. It also ensures QoS differentiation in both timeliness and reliability domains. MMSPEED greatly improves both timeliness and reliability. However, MMSPEED uses greedy forwarding and geographic routing, which may not improve the performance of the network. In addition, it is not a good option for long life applications because in such applications, the data transmission exceeds the required energy.

Stateless Protocol for real-time communication (SPEED) is introduced to maintain QoS for WSNs, based on soft real-time end-to-end guarantees. SPEED controls the congestion during heavy traffic load [30]. The Stateless Geographic Non-Deterministic Forwarding (SNFG) routing module is used in SPEED, which works with a combination of four other modules at the network layer. SNFG maintains traffic delivery speed across a WSN using a two-tier adaptation, including traffic delivery at the networking layer and packet regulation at the MAC layer. SPEED consists of several components including Neighborhood Feedback Loop (NFL), application Programming Interface, backpressure rerouting, delay-estimation scheme, last mile processing, Nondeterministic Geographic Forwarding (NGF) algorithm, and last mile processing. SPEED consumes slightly more energy than other QoS protocols because it delivers more packets under heavy congestion. The strength of SPEED reduces end-to-end delay.

The energy efficient and QoS aware multi-hop routing protocol (EQSR) maximize the network lifetime [31]. In EQSR, delay sensitive traffic is handled and forwarded effectively to the sink node using a service differentiation concept. The goal of EQSR is to improve throughput and to reduce the end-to-end delay by using multiple paths. The protocol uses residual energy, node buffer size, and signal-to-noise-ratio for determining the best next hop. In addition, EQSR uses a data aggregation model to handle the real-time and non-real-time traffic. EQSR uses a path discovery phase that consists of initialization phase, a primary path discovery phase, and an alternative paths discovery phase.

The path discovery phase is based on directed diffusion [32]. The sink node uses the multiple paths discovery to determine the set of neighboring nodes, which can send the data towards the sink from the source node. Furthermore, EQSR applies a procedure of path refreshment, path selection, traffic allocation, and data transmission for maintaining the QoS and handling the different types of traffic.

Message-initiated Constrained-Based Routing (MCBR) maintains the QoS requirements [33]. MCBR is composed of explicit specifications for route constraints, QoS provisioning, and constraint-based destinations for handling the messages and the set of QoS based meta-schemes. The routes are set up through network flooding from the source to the destination. The data message is transmitted from the source to the destination through the route that fulfills the QoS provision for a given data message. The general purpose of a meta-data routing scheme in MCBR is to improve the end-to-end delay and throughput. In addition, MCBR involves two kinds of meta-routing strategies: search-based and constrained-flooding. However, the additional use of control packets for both types of routing strategies causes a significant overhead. In order to reduce this overhead, the QoS-aware learning-based routing protocol is proposed in [34].

Another probabilistic soft real time multi path routing protocol named QoS and Energy Aware Multi-Path Routing Algorithm (QEMPAR) was introduced to support the real-time applications [35]. The goal of this protocol is to increase the network lifetime. The approach assumed that all the nodes were randomly distributed in the intended environment. Each node was assigned a unique ID. The node energy was considered equal at the beginning of the simulation. In addition, the nodes were aware of their location by using GPS and could handle the energy consumption. Based on this assumption, the nodes could communicate with other nodes beyond of their radio range. In this protocol, the energy consumption model was used to determine the suitable link, path discovery, and paths assortment; in addition, the tiny packets were sent using different paths. The strength of this protocol is to prolong the network lifetime. However, throughput is affected due to increase of the latency. In addition, no mobility is considered in this protocol and using GPS makes it cost ineffective.

Energy constrained multi-path routing (ECMP) is the extension of MCMP [36]. ECMP is proposed to frame the QoS routing problem to reduce the energy consumption. The protocol focuses on the playback delay, reliability, and geo-spatial path selection limitations. The tradeoff between less energy consumption and the minimum number of paths is shown for improving the QoS requirements. The main purpose of driving the ECMP model is to utilize the resource constraints efficiently to replicate not only resourceful bandwidth utilization but also insignificant energy consumption in its stringent terms. The ECMP selects those paths in the network, which satisfy the QoS requirements. However, fulfilling the QoS provisioning, routing overhead is introduced in terms of additional energy consumption and computational complexity. The overhead can affect the performance of those applications that require a certain delay and a bandwidth.

2.2.3 Deterministic Routing Protons (Hard Real Time)

Directional Controlled Fusion (DCF) protocol is introduced for data fusion and load balancing while maintaining QoS [37]. The key parameter in a multipath fusion factor provides trade-offs between multipath-expanding and multipath converging. To guarantee the QoS for several applications, one source node is chosen as reference source per round based on standards such as distance from the target region center, maximum remaining energy, and distance to the sink. The first stage for source node is to start a Reference-Source-Selection-Timer (RSS-Timer). Random value for each RSS-Timer is set on specific criteria. In this phase, a small value of RSS-Timer specifies that a source has advanced admissibility as a reference source. The next step is to monitor the RSS-Timer. The source whose value terminates first is chosen as a reference source. It also broadcasts an election notification message (ENM) within the targeted region. When nodes from another source get this message, they attempt to withdraw their RSS-Timers and determine the reference source location. The next phase in the reference source is to begin the building of the reference path and initiate the side sources attempt to transfer control packets.

Sleep/Wake Scheduling Protocol (SWSP) is introduced to preserve energy. It turns off the radio during idle time and wakes up just before the start of the transmission of the message [38] . It uses synchronization between the sender and the receiver. Thus, nodes wake up concurrently to communicate with each other. The existing synchronization mechanism gets accurate synchronization instantaneously after exchange of synchronization messages. However, there is a random synchronization fault due to non-deterministic elements in the system. A consequence of these faults is that the clock will not propagate with time and will fail to be analogous to real message transmission time. Thus, an ideal sleep/wake scheduling algorithm is introduced. It attains that a message capturing capability threshold by using less energy consumption. Additionally, multi-hop communication is performed.

The sleep/wake scheduling protocol is systematized into a cluster-based hierarchy, and each cluster is comprised of multiple cluster members and a single cluster head. The key issue of this protocol is to recognize one of the cluster members as a cluster head in one cluster. For example, "C" is cluster head of "E," yet at the same time, it is also a member of "A" as shown in Figure 2.4. The member nodes are synchronized during the synchronization period and the transmission period.

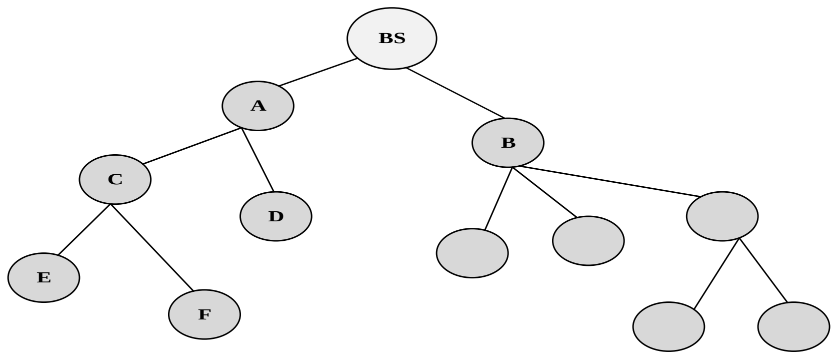


Figure2.4. Three Level Cluster Hierarchy [38]

Sequential Assignment Routing (SAR) is the first routing protocol for WSNs that initiated the idea of QoS in the routing decisions [39]. SAR decides the routing process based on three factors: 1) QoS on each path, 2) energy resources, and 3) the precedence level of each packet. SAR uses multi-path and localized path restoration techniques to avoid single path failure. The goal of the SAR algorithm is to reduce an average weighted QoS metric during the WSN's lifetime.

Mobicast is the deterministic hard real-time mobile object tracking protocol introduced in [40]. The protocol uses a multi-cast routing and dynamically tracks the mobile object. In this technique, a mobile user is guided to locate the mobile object correctly without sending flooding requests to localize the mobile object. This protocol helps to preserve the energy consumption to prolong the network lifetime. In this approach, source and target names are used for mobile users and mobile objects, respectively.

The WSN helps the source node identify the target node and keeps the tracked information of a targeted node. The approach is based on active and sleeping modes. The source node is not required to communicate to the current location of the targeted node when detecting the location. This protocol applies a face routing process explained in [41] that is based on the idea of Gabriel Graph discussed in [42] for chasing the target correctly. It also focuses on velocity of the targeted node and its moving direction. The protocol saves energy as compared with other object tracking WSN protocols. However, mobility scenarios are not completely explained and a latency issue still exists.

QoS-based routing protocol for wireless multimedia sensor network (QRPWMSN) is introduced in [43] to perform routing on each data packet according to existing QoS standards by considering the delay, energy efficiency, and reliability. This protocol is based on the geographical information model. The protocol uses a genetic algorithm and a queuing theory. QRPWMSN weighs each delay in order to consume less energy by maintaining the reliability for determining the best efficient path. All the nodes are fixed and possess individual identifiers as illustrated in Figure 2.5.

The advantage of this protocol is to improve the transmission with less congestion However, the protocol is complicated due to its use of the individual identifier that can increase the latency and reduce the throughput. In addition, it does not have mobility support and consumes a substantial amount of energy for any transmission.

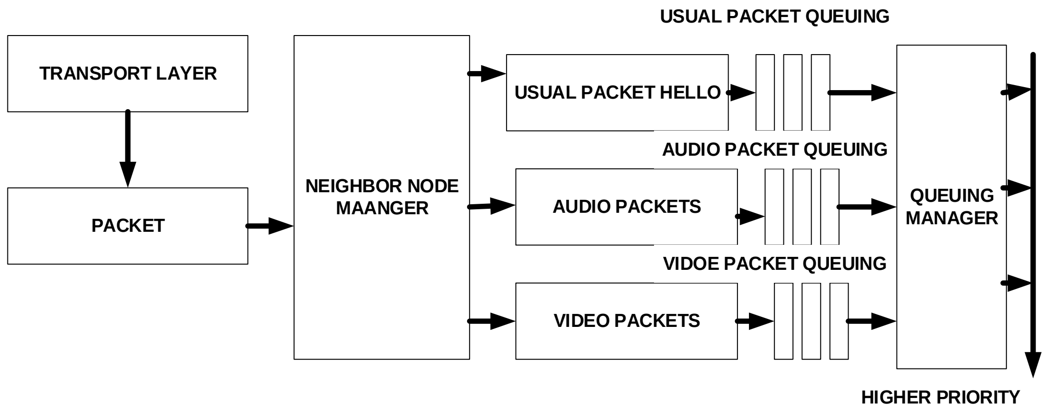


Figure 2.5. Queuing Theory for Proposed Algorithm [43]

2.2.4 Deterministic Routing Protons (Soft Real Time)

GRAdient Broadcast (GRAB) is specifically designed for robust data delivery in order to control unreliable nodes and imperfect wireless links [44]. GRAB constructs and maintains the cost field by broadcasting advertisement (ADV) packets. When a node gets an ADV packet comprised of the cost of sender, it computes its cost by accumulating the link cost between sender-to-sender cost advertisements. The node compares this cost with the previously verified one and then sets a new cost. When the node gets a smaller cost than the older one, it transmits an ADV packet containing the new cost. GRAB handles bandwidth by using an amount of credit taken in each data packet that lets the sender regulate the strength of data delivery. The benefit of GRAB is to reply upon the communal efforts of the multiple nodes to distribute data without any data dependency on any individual node. However, it increases overhead by using redundant data.

Directional Geographical Routing (DGR) Multipath routing protocol is introduced in [45]. DGR is suitable for real time video streaming over energy constrained nodes and a bandwidth from a small number of detached video sensor nodes (VNs) to a sink by merging a forward error correction (FEC) coding technique. In DGR, an active node VN broadcasts the packets to its direct neighbors while concatenating FEC packets of a video frame and all the data. When nodes get concatenated packets broadcasted by the VN, they choose their own payload based on the sequence numbers and identify the corresponding packets of nodes. Subsequently, nodes unicast the allotted packets to the sink through corresponding individual paths. In DGR, multipath routers set three paths the between source and the sink. Furthermore, each path uses a different first direct neighbor. This architecture can be efficient to route the video traffic of the network. The simulation results prove that DGR gets low latency that is equal to 0.05msec. It also increases network lifetime and provides better-received video quality. The video peak signal to noise ratio could be improved up to 3dB.

Energy efficient and QoS aware routing (EEQR) is deterministic real-soft routing protocol introduced in [46]. Guaranteeing the QoS, the data prioritization is performed based on the message type. Two types of sink nodes were used: static and mobile. The static sink nodes handle the delay-sensitive messages while mobile sink nodes handle the delay tolerant messages. The objective of EEQR is to improve network lifetime and coverage efficiency. In addition, it focuses on the QoS parameters such as end-to-end delay, packet loss ratio, and throughput. EEQR is based on the multi-hop communication that reduces the end-to-end delay and bandwidth consumption. Packet prioritization mechanism handles the data gathering issue. Incoming traffic of the network is ranked according to the packet content significance. Proposed EEQR is divided into phases and sub-phases. The primary phases include setup and steady. The sub-phases comprise of eight sub-phases. The setup phase involves the initialization, route update, and clustering three sub-phases. The steady phase consists of six sub-phases: data prioritization, data forwarding to cluster head or super node, data forwarding to static sink, mobile sink movement decision, forwarding queue weight to mobile sink, and mobile sink data gathering.

QoS based and Energy aware Multi-path Hierarchical Routing (QEMH) protocol is introduced in [47] to fulfill the QoS requirements and energy consumption. QEMH is designed based on the hierarchical mechanism for consuming the minimum energy. The protocol consists of two phases. In the first phase, the QEMH selects the cluster head node based on two metrics: node distance from the sink station and residual energy of the node. In second phase, QEMH performs the routes discovery process by using multiple conditions such as buffer size, residual energy, distance to sink, and signal-to-noise ratio.

Once a node detects an event, it then sends the data to the cluster head node. The responsibility of the cluster head node is to further forward it to the sink station along the paths. QEMH uses the weighted traffic allocation approach to distribute the network traffic amongst the existing paths to increase the throughput and end-to-end delay. In this approach, the cluster head node distributes the traffic between the paths based on the end-to-end delay of each path. The QEMH measures the end-to-end delay during the paths discovery process. QEMH aims to prolong the network lifetime as load balancing that helps to balance the energy consumption uniformly throughout the network. Furthermore, QEMH deploys the queuing model to handle the real-time and the non-real-time traffic.

Multi-objective QoS Routing (MQoSR) protocol is introduced [48] and is based on geographic routing mechanism. The protocol uses a heuristic neighbor selection procedure that combines the geographic characteristics with the QoS requirements to obtain QoS improvement for several applications. The QoS provision issue for routing is articulated as path and link-based parameters. The link-based parameters are divided into delay, reliability, distance to sink, and energy consumption. The path-based parameters are presented in form of reliable data transmission, end-to-end delay, and network lifetime. MQoSR applies a different selection policy for each QoS requirement. The node selects the next hop node based on the requested requirements and the link conditions for improving the QoS provisioning. MQoSR is purely based on the on-demand routing mechanism, which makes the multiple node-disjoint paths. The MQoSR decides the cost of each link based on link cost function, and total link cost function.

2.3 Simulation Setup and Performance Evaluation

This section shows the performance for some of the known routing protocols: SPEED, Mobicast, MMSPEED, SAR, MGR, and MIMO. The performance of the protocols is measured using network simulator-2 (NS2). We constituted the network size of 400 m x 400 m.

We assumed that the homogenous nodes are disseminated in the flat type network. Each node initially uses 5 joules energy. The nodes are responsible to forward the data to the base station. The base station is located at point (0, 500). The size of the packets is 128 bytes. The residual energy of each node after 6 cycles is calculated to prolong the network lifetime. The performance analysis of the routing protocols is made using the following assumptions.

- A static sink node (base station) is set that is farther from the sensing field.
- Each node possesses the uniform energy.

- Each node has a variable sensing capability and sensing the field with the variable rates and is responsible to forward the data to sink node.
- 50% nodes are mobile.
- Each sensor node has a same communication capacity and computing resources.
- The location of sensor nodes is determined prior to starting the simulation.

The rest of parameters are explained in Table 2.1.

Table 2.1 Simulation parameters and its corresponding values

PARAMTERS	VALUE
Size of network	400 × 400 square meters
Number of nodes	450
Queue-Capacity	30 Packets
Mobility Model	Random way mobility model
Maximum number of retransmissions allowed	03
Initial energy of node	5 joules
Size of Packets	128 bytes
Data Rate	300 kilobytes/second
Sensing Range of node	35 meters
Simulation time	5 minutes
Average Simulation Run	06
Base station location	(0,500)

Based on the simulation, we considered the following metrics for comparison:

- Average delivery rate
- Average energy consumption
- End-to-end delay
- Lifetime

- **Average delivery rate**

One of the significant metrics for evaluating the performance of the routing protocols is an average delivery rate. We compare the performance using the node failure probability and an average delivery ratio are shown in Figure 2.6. We observe that the performance of the routing protocols is comparatively similar, but MIMO has a slightly higher performance than other routing protocols. We notice that these routing protocols experience the problems due to node failure. As a result, the protocols reduce the performance. The reason of reducing the performance of the protocols is the lack of load-balancing algorithms.

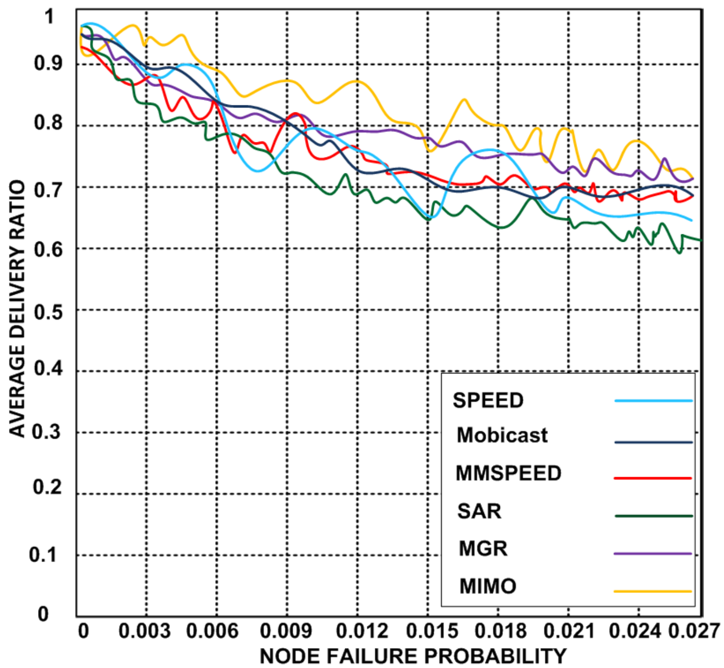


Figure 2.6. Average delivery ratios vs different node failure probability

- **Average energy consumption**

We measure the energy consumption of each protocol using node failure probability. We observed that the performance of each protocol is almost similar. However, MMSPEED, and SAR show slightly higher performance than other routing protocols, but at the 0.027 probability rate, the energy consumption of each routing protocol is the same. The energy consumption could affect the QoS provisioning. The result depicted in Figure 2.7 demonstrates that the routing protocols consume the additional energy resources due to node failure probability. The node failure probability could be improved using the optimized approaches.

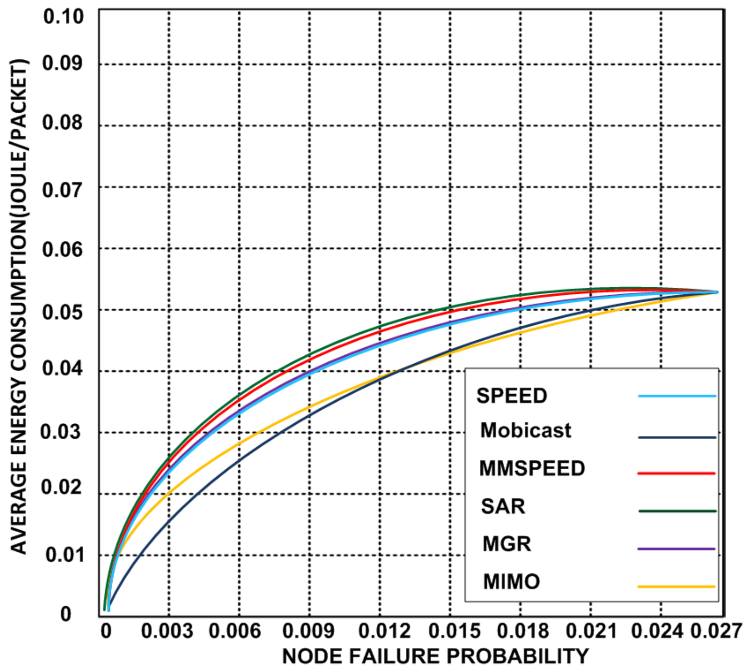


Figure 2.7. Average energy consumption VS node failure probability

- **End-to-end delay**

End-to-end delay is another significant parameter for analyzing the performance of QoS based routing protocols. We show end-to-end delay of each routing protocol in Figure 8. Based on the results, we observed that when the time interval increases, the end-to-end delay performance of each routing protocols is affected.

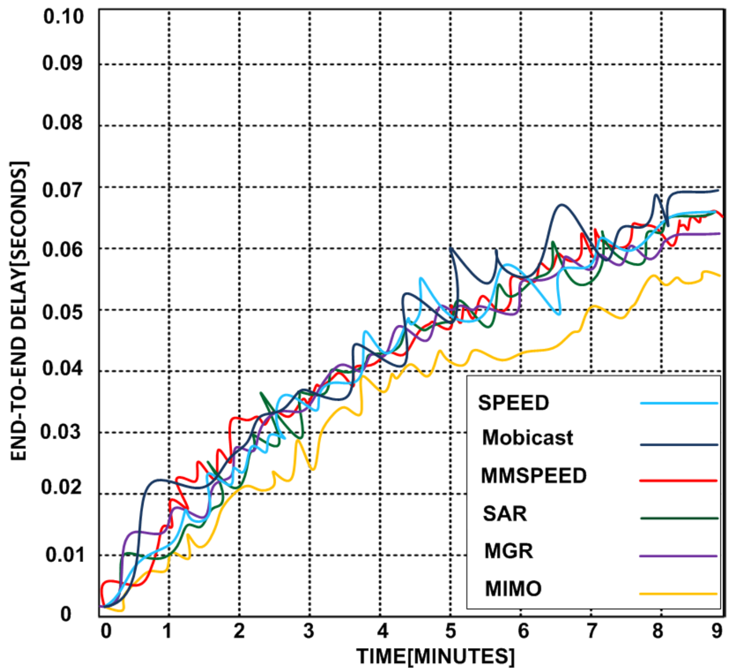


Figure 2.8. End-to-end delay of routing protocols at the different time intervals

In this experiment, variable packet sizes are used for the arrival rate at the sender side. One of the interesting measurements deals with both non-real time and real time data traffic. Based on the results, we observed that MIMO shows a slightly lower end-to-end delay when compared with the other routing protocols. However, end-to-end delay of MIMO can also be considered higher within the scope of the routing performance.

- **Lifetime**

The primary goal of the WMSNs is to improve the network lifetime because the sensor node possesses limited power and other resources. In this experiment, we measured the performance of these routing protocols using a different network size as depicted in Figure 2.9.

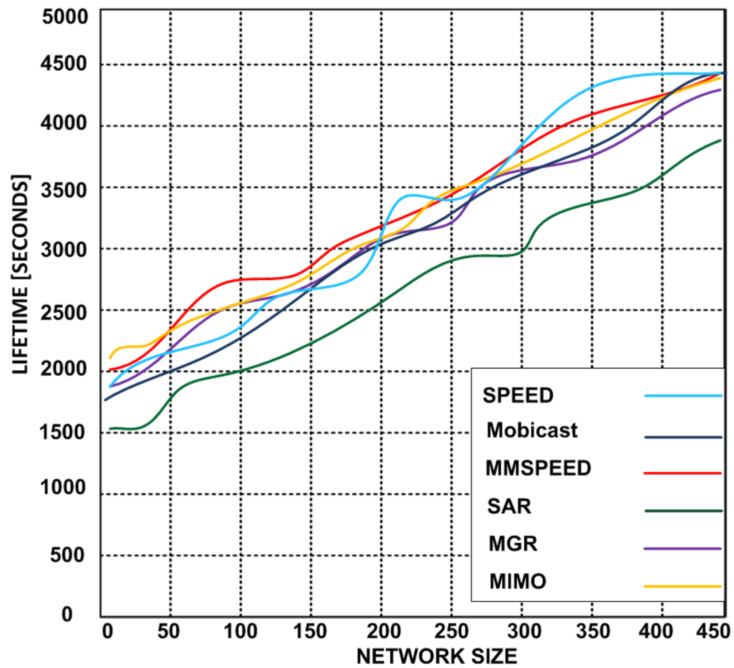


Figure 2.9. Network lifetime using different routing protocols and network size

Based on the results, we observed that the performance of each competing routing protocol is similar except for the SAR routing protocol. The SAR routing protocol degrades the network lifetime. However, overall, the network lifetime using these routing protocols is not encouraging. Thus, there is a need for optimized routing protocols to prolong the network lifetime.

2.4 Challenges and Open Research Issues

Most of the existing QoS techniques support only QoS aware routing protocols. QoS aware routing is a crucial part for maintaining the QoS framework to improve the lifetime of wireless networks. The data delivery paths are analyzed using knowledge resource accessibility along with other requirements under QoS routing schemes.

Numerous issues need to be considered when designing the QoS routing protocols for WMSNs. We have determined important factors that can improve the design.

- Parameter selection (The delay, bandwidth and path computation).
- Timeliness and reliability.
- QoS state maintenance and propagation.
- Scalability and mobility.
- Maintaining the network adaptability and balancing the efficiency for low latency.

Many routing protocols were introduced, but some of focus on maintaining QoS. In general, the main job of WSN is to sense the environment and to send the sensed data to the base station. Therefore, QoS provisioning in WMSN faces significant challenges:

- Heterogeneity: This is one of the big challenges in WMSN for maintaining the QoS because used sensors for detecting the events are different from each other. There are applications that require heterogeneous sensors to monitor the events and to capture images and videos for moving objects such as handling the disaster situation, surveillance system and military battlefield environment. These applications generate the data from sensors at varying rates based on different QoS limitation and delivery models. Hence, these diversified WMSNs may impose significant challenges for the provision of the QoS.

- Limitation of resources: The efficient energy utilization is one significant challenges for maintaining the QoS. When sensor nodes are communicating, they may drain the battery. This situation can be worse when sensor nodes are underground as they are not replaceable and rechargeable.
- Bandwidth utilization: This is a challenge in WSNs generally because WSNs involves real time and non-real time traffic. Thus, the bandwidth allocation should be maintained to balance the traffic flow between real time and non-real time communication. However, introduction of multimedia will pose more challenges because there will be higher traffic and more bandwidth demands to process such type of data
- Network adaptability: The link failure and node failure can be caused by mobility. As a result, the network topology changes, which is a concern. The network encompasses the densely deployed hundreds to thousands of nodes in a landscape of interest. In this situation, the number of sensor nodes may join or leave the network that affects the QoS.
- Data Redundancy Sensor nodes are deployed in the area of interest for sensing the situation, but most of the generated data is redundant, and this redundancy affects the reliability and fault tolerance process. As a result, energy is wasted. Data fusion and data aggregation are solutions to handle the redundancy. For instance, the sensors generate the same image and point to same direction that aggregated. However, data fusion techniques and data aggregation could create problem for QoS design.

- Unreliable Medium: The radio is the communication medium in WMSN that is less reliable inherited the features of Medium Access Control (MAC) protocols. Furthermore, the wireless links are also affected because several environmental factors including signal interference and noise.
- Assorted Data Pattern: This is an important issue for designing the QoS routing protocol because data can arrive in the form of periodic and= non-periodic. The sensing data can periodically be created in applications at unpredictable times due to exposure to serious events. Similarly, sensory data can be generated at regular intervals such as the monitoring process of real time environmental applications. This diversified nature of data creates the significant challenges for QoS WMSN routing protocols.
- Multiple Base Stations and Sinks: Most WMSN applications involve a single base station and sink, but some applications require multiple base stations and sinks, such as the military and disaster recovery applications. In this situation, WMSNs should be capable to handle the mixed QoS level with multiple base stations or sinks [49]. Several techniques are available in literature to handle different kinds of issues to improve the QoS. However, issues still exist that need to be resolved for QoS provisioning.

In addition to the challenges for QoS, we also consider important directions and research issues that need to be highlighted. Mobility is one of the major threads for

QoS provisioning because sensor network models are based on the assumption that consider sink as static, but this assumption cannot be accurate for all types of scenarios. For example, a battlefield scenario consists of mixed types of sensor nodes: static and mobile. Therefore, in this situation, sink and sensor nodes should be provided mobility support. Furthermore, network topology also keeps on fluctuating dynamically. It is more important to address the mobility and dynamicity of WMSNs, as they need to be considered before designing QoS routing protocols.

The placement of the heterogeneous multimedia sensor node is another research area for QoS provisioning [50]. Thus, secure data routing is a significant aspect that needs to be considered for WMSNs. In all these conditions, WMSN is a challenge in designing the QoS routing protocols. Based on a detailed survey, we have compared the characteristics of existing QoS routing protocols explained in Table 2.2.

Table 2.2. evaluation and comparison of QoS routing protocols over WMSNs.

RoutingProtocol	Energy Aware	Mobility	Scalability	DataAggregation	Location Awareness	Query Based	Real-time Multi-media Support	QoS
MMSPEED	No	No	No	No	No	yes	Yes	Yes
ProHet	Yes	No	No	Yes	No	Yes	No	Yes
ECMP	Yes	No	No	No	No	No	No	Yes
CQARP	Yes	No	No	No	No	Yes	No	Yes
QEMPAR	Yes	No	No	No	No	Yes	No	Yes
SPEED	No	No	No	No	No	Yes	Yes	Yes
MGR	Yes	Yes	No	No	No	Yes	No	Yes
SAR	Yes	No	No	No	No	Yes	No	Yes
QEMH	Yes	No	No	No	No	No	Yes	Yes
QRPWMSN	No	No	No	Yes	Yes	Yes	No	Yes
DCF	No	No	No	Yes	Yes	Yes	No	Yes
QBR	No	No	No	Yes	Yes	No	Yes	Yes
DGR	Yes	No	No	No	Yes	Yes	No	Yes

GRAB	**Yes**	**No**	**No**	**No**	**Yes**	**Yes**	**No**	**Yes**
SWSP	**No**	**No**	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**
MQoSR	**No**	**No**	**No**	**No**	**Yes**	**No**	**No**	**Yes**
MIMO	**No**	**No**	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**
Mobicast	**Yes**	**Yes**	**Ys**	**No**	**Yes**	**Yes**	**Yes**	**Yes**
EEQR	**Yes**	**No**	**No**	**No**	**Yes**	**No**	**No**	**Yes**
EQSR	**Yes**	**No**	**No**	**Yes**	**No**	**No**	**Yes**	**Yes**
MCBR	**Yes**	**No**	**No**	**No**	**No**	**No**	**Yes**	**Yes**
MCMP	**No**	**No**	**No**	**No**	**No**	**No**	**Yes**	**Yes**

2.5 Conclusion

This section conducted a comprehensive survey of QoS routing protocols in WMSN. The QoS routing protocols are classified into deterministic and probabilistic categories. Both categories are classified into soft and hard real time protocols. We highlighted critical challenges posed by the unique features of WMSNs. In addition, we reviewed QoS routing protocols with strength and weaknesses in WMSNs and discussed the challenges and open research issues that will help the research community to deal with them in the future. In addition, we have simulated known routing protocols using NS2 and compared their performance. Finally, we have evaluated the characteristics of each routing protocols using several parameters.

CHAPTER 3: BUFFER-OVERFLOW AND NOISE-HANDLING MODEL: GUARANTEEING QUALITY OF SERVICE ROUTING FOR WIRELESS MULTIMEDIA SENSOR NETWORKS

3.1. Introduction

Wireless Sensor Networks (WSNs) are the collection of sensor nodes that form a momentary network without the support of any centralized administration or infrastructure. In such a situation, it is mandatory for each sensor node to obtain the support of other sensor nodes to advance the packet to its desired destination node, particularly to the sink node or base station. One significant challenge in designing the WMSN is introducing an energy efficient routing protocol that may transmit information despite limited resources. Another significant problem is determining the resources of the next hop node in advance. The routing protocols in existing literature mainly focus on prolonging the network lifetime.

This research introduces the buffer-overflow distance-aware and noise-handling (BODANH) model to guarantee the QoS for multipath routing over wireless multimedia sensor networks. BODANH involves three components: buffer allocation, distance measurement, and signal-to-noise-ratio. This model prevents the loss of data and avoids the congestion caused by buffer-overflow and identifies the node distance prior to route discovery that helps determine the location and distance between nodes when the node is either movable or immobile.

The performance of this model is compared to other QoS routing protocols. Simulation results demonstrate that our model surpasses the other routing QoS routing protocols in terms of throughput and the remaining live nodes in static and mobility scenarios.

Due to the rapid advancement in emerging technologies particularly in micro electro-mechanical systems, small scale energy devices, low power integrated digital circuits, small scale energy supplies, microprocessors, and low power radios have provided the platform for low cast, low energy, and multifunctional wireless sensor nodes that can perceive and respond to deviations in physical phenomena [51]. Each sensor node is equipped with a tiny microprocessor, radio transceiver, small battery, and a set of transducers, which are used for obtaining information that redirect the vicissitudes in the surrounding environment. Wireless sensor networks involve a number of tiny sensor nodes that coordinate with each other to perform critical tasks (e.g., object tracking and environment monitoring) and deliver the collected data to the sink node or base station [52]. The areas of wireless sensor network applications include healthcare, battlefield, surveillance, environmental monitoring, or detection of fire [53]. However, network density, limited node power, severe bandwidth limitations, dynamicity of the topology, and large-scale deployments have caused challenges in the management of WSNs. In addition, buffer overflow and noise have also posed challenges including congestion, data loss, performance dilapidation, and excess. Limited memory space causes buffer overflow and data packets start to drop [54]. As a result, retransmission is required for the lost data packets [55]. Thus, additional energy is consumed. The recent advances of low cost, miniature size cameras or microphones have led to the development of WMSNs as a class of wireless sensor networks. WMSN is a network of wirelessly interconnected sensor nodes that can capture images, video, and audio data from the surrounding environment and send that to the sink. WMSNs attracted attention because they enhance the exiting WSN applications and enable new applications such as multimedia surveillance sensor networks, traffic avoidance, enforcement and control systems, and advanced health care delivery. In order to guarantee the successful transmission of the multimedia content, the routing protocols need to be energy efficient and QoS support [56]. Buffer detection is largely an open issue in WMSNs due to limited computational capabilities and limited memory resources.

The sensor nodes handle low data volume in low data rate applications [57]. However, multimedia-driven applications are required to determine the status of a buffer prior to sending the data to the next hop because sensor nodes may be loaded due to such applications and the buffer may start to overflow. In addition, buffer overflow invites congestion that may cause a reduction in network efficiency [58-60]. To handle congestion, it is important to determine the sufficient free buffer space prior to delivering the data packets to next hop nodes. Several approaches are available in literature for conventional networks. However, these approaches are too complicated to be introduced in resource constrained WMSNs. Additionally, WMSNs vary in nature from wired network because nodes in WMSN hold a single queue that is connected with a single transmitter. Furthermore, the noise and distance of nodes are also more important for the discovery of the path for guaranteeing the QoS provisioning [56].

Most approaches used to discover paths are based on the residual energy of the node. These approaches are not suitable in certain situations, such as when the sensor node is farther from the sink node and holds high residual energy; however, long distance and noise weaken the signal strength. As a result, the node does not receive all sent packets [61]. Trade-offs are an efficient use of the buffer and energy of sensor nodes, which are highly desirable when designing multi-path routing that guarantees the QoS provision for WMSNs [62]. This paper attempts to address the congestion and data overflow caused by buffer limitations. Furthermore, we consider noise and determine the distance including the location of the node that helps in the discovery of an optimized path. The contribution involves the BODANH mathematical model that improves the throughput and extends the network life.

The remainder of the chapter is organized as follows. The next section presents a proposed model called buffer-overflow, distance-aware and noise-handling model. This is followed by the simulation setup and performance study of the result. The last section provides a conclusion for this work.

3.2 Buffer-Overflow, Distance Aware, and Noise Handling Model

Guaranteeing the QoS routing in wireless multimedia sensor networks is a challenging problem due to limited properties of the sensor node. Our aim is to present the BODANH model in a manner that improves the throughput and prolongs the network lifetime. Thus, we focus on detecting the capacity of buffer prior to sending the data packets as well as determining the node distance and handling the noise. The BODANH model includes the following features:

- Buffer allocation
- Distance measurement
- Signal-to-noise ratio

A. Buffer Allocation

Each sensor node S=(S1 , S2 , S3 , Sn) measures all traffic flows 'F(m,n)' passing through each link L=(L1,L2, . . . , Ln) , ∀ L1, L2, . . . , Ln ∈L. Where Fnt(m,n) is the measurement of the new time interval, and Pk(Pk1, Pk2, Pk3, . . . , Pkn) is the number of packets. Let us assume number of packets Pk(Pk1, Pk2, Pk3, . . . , Pkn) received by S1 from sensor node S2 over the link L1 during the time interval 't∆'. Thus, the size of buffer measured in new interval can be obtained as:

$$Fnt(m,n)=Pk1 \in Pk1S1(Pk) \quad (1)$$

Where 'S1(Pk)': Already existing packets in the buffer of sensor node.

If sensor node 'S1' is congested either due to bottleneck (heavy traffic) or full buffer, then the buffer limit for each sensor node can be calculated as follows:

$$b\rho(S)=F(Pk)\rho(s)+S1 \in SS1\{F(Pk)\}\ r(Pk) \quad (2)$$

Where 'bρ': Buffer limit, 'F(Pk)': The number of transmitted packets out of the buffer, 'r(Pk)': The rate of packets transmitted in per second, 'ρ(s)' : The source of the data , and' S1{F(Pk)} : Buffer limit of 'S1' sensor node.

The sensor node forwards the packets that can be measured locally, if ρ(s) =1 then 's' is the data source otherwise ρ(s)=0. The sensor node 'S1' advertises the buffer limit ‘bρ’ to the sensor node ’S2' possibly by using piggybacking in the acknowledgement packet. In response, the sensor node ’S2' applies a rate limit (actual rate on path) ‘BΔpath’ that is bounded by a rate limit. If the sensor node ’S1' itself is data source, it will assign the buffer to node ’S2' as follows:

bρ(S1)= 11+S1 ∈ SS1{F(Pk)} r(Pk) (3)

If the neighbor node attempts to enforce a buffer rate limit, it may cause congestion; if the buffer capacity of the receiving node is full, then it administers rate limits. This process is applied to the data sources. Finally, all the exaggerated data sources are able to adjust the packets rates based on the allotted fair bandwidth. Note that only congested node administers the rate limit that is updated periodically.

When the congestion state proceeds to sensor node ‘S1’, the buffer rate limit is stopped. This situation can occur by raising the buffer rate limits of sensor node ’S1’. The sensor node ’S1' is capable of identifying the situation of the congestion by detecting the fullness of the buffer. When that situation happens, the sensor nodes fix the buffer rate limits to be bρ(S)) and bρ(S1), rather than over-setting them. As a result, a sensor node discontinues enforcing buffer rate limits once its congestion state is detached (buffer is deflated) and the data rates at which the node accepts packets from the neighboring nodes are less than the buffer rate limits.

B. Distance Measurement

Based on the transmission rate 'StΔ' of each sensor node in the sensing area of the sensor network, the clustering process is initiated between clustering nodes and cluster head nodes for determining the optimal path. This process involves the messaging that holds the information regarding the location of the sink node '□s' in wireless multimedia sensor networks. In addition, all the sensor nodes detect their locations '$\mathcal{D}_p$' from the sink.

The base station sends the message inside the network, the nodes that receive the signal that start calculating the distance from the base station (sink). The process of calculating the distance is performed using Euclidian distance formula given in equation (4):

$$r(S1)=\mathcal{D}_p(\square s)-\mathcal{D}_p(S1)2 \quad (4)$$

Where 'r(S1)': Distance of sensor node from sink node, '$\mathcal{D}_p(\square s)$' : Location of sink node, $\mathcal{D}_p(S1)$: location of sensor node '(S1)' after detecting the distance.

Our goal is to determine an optimized disjoint (primary) path and braided paths for data communication. Thus, the sensor node that possesses the shortest distance '$r\alpha(S1)$' connects itself with the disjoint path. However, the sensor node that has extended distance '$r\beta(S1)$' from the sink joins the braided path. Our approach is applied with lower and higher levels clusters in hierarchy. Let 'r(S1)' be the distance between source node and sink node and 'Δt' be the transmission rate and 'E(S1)' be transmitted energy of sensor node that is proportional to the received signal strength. Thus, transmitted power 'ΔTp' of the node for each cycle can be obtained as

$$\Delta Tp= r(S1)\mu\sigma*\Delta t \quad (5)$$

where 'μ': constant value that is considered as the requirement of signal strength, and 'σ' : distance loss factor. In this contribution, we only assume ideal MAC and only interference is detected due to background that is set to be at the constant rate. Hence, the received signal strength reduces the signal to noise ratio. Thus, the energy consumption for sending one unit of data over the medium with distance ‘r(S1)' can be obtained as

$r(S1)\mu\sigma = E(S1) * 1\Delta t$

$r(S1)\mu\sigma - E(S1) * 1\Delta t = 0$

$r(S1)\mu\sigma - E(S1)\Delta t = 0$

$r(S1)\mu\sigma = E(S1)\Delta t$

$$E(S1) = r(S1)\mu\sigma * \Delta t \quad (6)$$

In the wireless network, a major source of signal loss is attenuation. Fundamentally, the transmission data rate increases then communication range decreases. Thus, bit error rate is one of the important parameters that can be mapped into anticipated signal-to-noise ratio (SNR) explained in the next section.

C. Signal-To-Noise-Ratio (SNR)

If data transmission rate increases, then error rate also increases. In this situation, transmitter 'Tx' requires higher SNR value to obtain the same bit error rate at the receiver side. Thus, the relationship between SNR ‘ŔΔ’ and transmitter power 'Txp' can be obtained as

$$\acute{R}\Delta = TXpNp\ \varphi \quad (7)$$

Where φ: channel attenuation, and Np: Noise power. We can define noise power as follows:

$$Np = Nd * Tsr \quad (8)$$

Nd: Noise power density, 'Δtx': Transmission rate, ə̧ : modulation pattern size, ∃Δ: Energy per bit , and Tsr:Transmission symbol rate can be obtained as

$$Tsr=\Delta tx ə̧ \quad (9)$$

Therefore, SNR is determined for background noise as:

$$\acute{R}\Delta = \exists \Delta Nd * ə̧ \quad (10)$$

3.3 Simulation Setup and Performance Analysis

In order to examine the performance of buffer-overflow the distance-aware and noise-handling models, the wireless multimedia sensor network was created to cover the area of 600 m x 600 m. The performance of BODANH is compared with other QoS routing protocols: Mobicast [40], QoS and Energy Aware Multi-Path Routing Algorithm (QEMPAR) [35], and Cluster-based QoS aware routing protocol (CQARP) [28]. The network topology considered the following metrics:

- A dynamic sink is set.
- Each node is initially assigned to uniform energy.
- Each node senses the field at the different rates and is responsible for transmitting the data to the sink node or base station.
- The sensor nodes are 10% to 60% mobiles.
- Each sensor node involves the homogenous capabilities with the same communication capacity and computing resources.
- The location of sensor nodes is determined in advance.

The previously mentioned network topology is suitable for several applications WSNs, such as home monitoring, reconnaissance, biomedical applications, airport surveillance, fire detection, home automation, agriculture, and animal monitoring. The real application of this introduced model is in airport surveillance where the sensor nodes are either static or mobile, which are used for monitoring the travelers and staff members. The simulation was conducted by using network simulator-2. The scenario consists of 400 homogenous sensor nodes with initial energy 4 joules. The base station is located at point (0, 1100). The packets size is 256 bytes. Initial energy of node is 4.5 joules. The rest of parameters are explained in Table 3.1.

Based on simulation, we are interested in the following metrics.

- Throughput with stationary nodes
- Throughput with and different nodes
- Remaining alive nodes (lifetime) with mobility in days

Table 3.1: Simulation parameters and its corresponding values

PARAMTERS	VALUE
Size of network	600 × 600 square meters
Number of nodes	500
Distance from the base station to the center of WSN	1100 meter
Mobility Model	Random way mobility model
Maximum number of retransmissions allowed	03
Initial energy of node	4.5 joules
Size of Packets	256 bytes
Data Rate	250 kilobytes/second
Sensing Range of node	40 meters
Simulation time	9 minutes
Average Simulation Run	10
Base station location	(0,500)

A. Throughput with stationary nodes

Throughput is an average-mean of successfully delivered data packets. Once simulation time increases, then throughput performance starts dropping, but BODANH is not highly affected as compared to other routing protocols, which are QEMPAR, Mobicast, and CQARP. After completion of simulation time, BODANH reduces only 2Kb/sec throughput while other competing protocols reduce from 12.5 to 17.75 Kb/sec. Based on the obtained result, we prove that our model is effective when nodes are stationary. Figure 3.1 shows the throughput with stationary nodes.

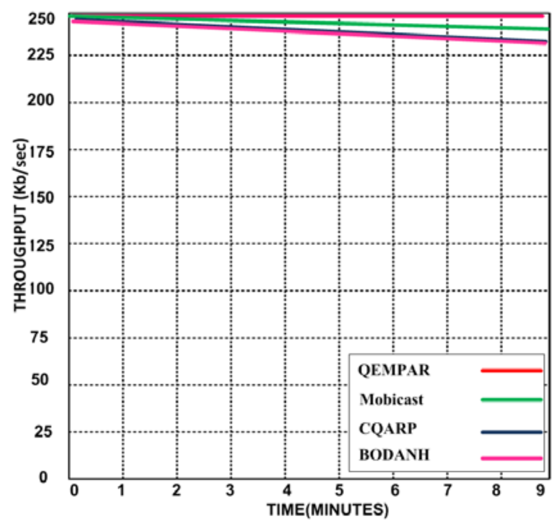


Figure 3.1. Throughput with stationary nodes

B. Throughput with different mobility ratios

The mobility affects throughput performance. The throughput performance of the network reduces when the ratio of mobile sensor nodes (mobility of nodes) start to increase. Figure 3.2 shows that mobility affects the performance of all competing protocols; however, the throughput of BODANH is still higher than other QEMPAR, Mobicast, and CQARP routing protocols. In fact, higher mobility ratio causes lower packet delivery ratio. A drop in transmission of the packets causes the retransmission of the packets. As a result, additional energy is consumed for sending the lost packets.

C. Remaining alive nodes with stationary nodes

We describe the number of remaining live nodes in Figure 3.3 after performing some simulation rounds (environment sensing rounds) using stationary nodes. Once simulation rounds increase, then the energy of the nodes depletes. As a result, the nodes start to die.

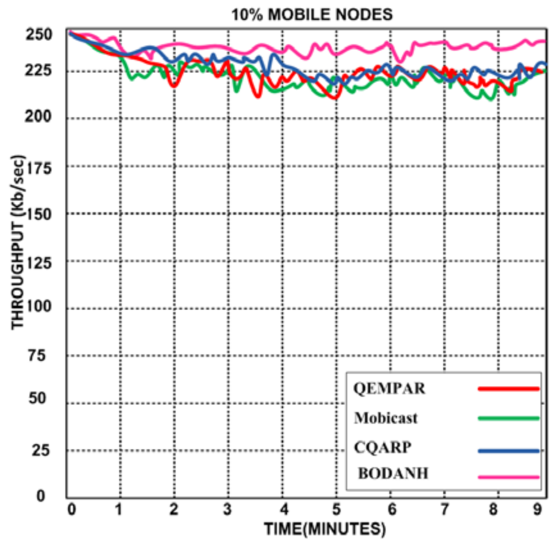


Figure 3.2 (a). Throughput with 10% mobile nodes

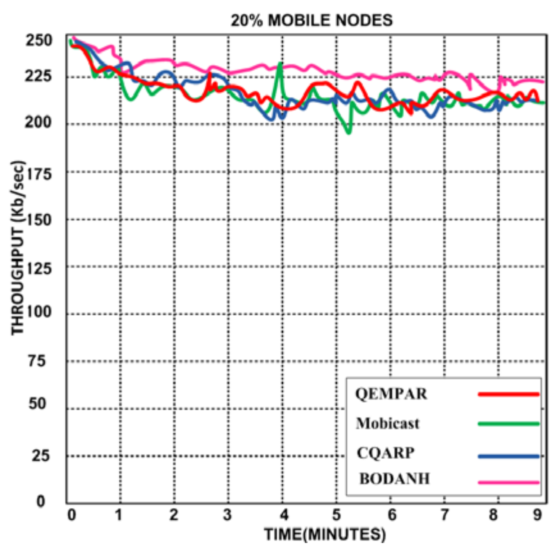


Figure 3.2(b). Throughput with 20% mobile nodes

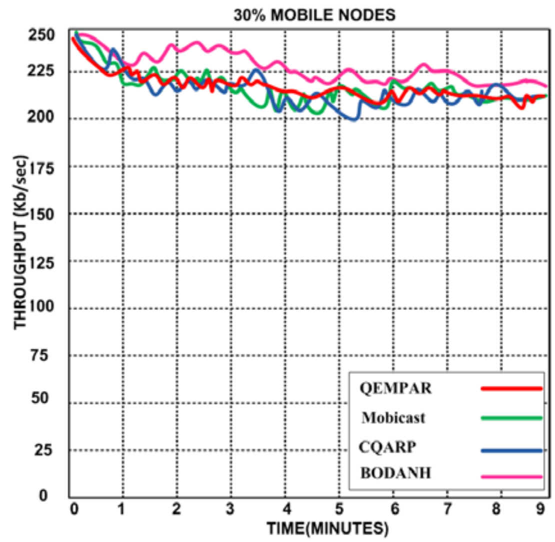


Figure 3.2(c). Throughput with 30% mobile nodes

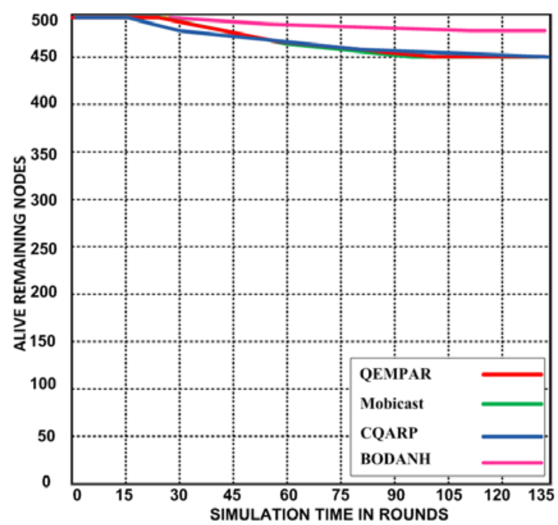


Figure 3.3. Alive remaining node VS sensing routs with static nodes

BODANH outperforms QEMPAR, Mobicast, and CQARP. At the end of 135 simulation rounds, BODANH has a remaining 483 alive nodes whereas other protocols have a remaining 450 alive nodes. Simulation results demonstrate that BODANH loses 3.4% nodes but competing protocols lose 10% nodes.

D. Remaining alive nodes with mobility

The mobility affects the performance of the network, but performance can be improved using an effective model. Figure 3.4 shows the behavior of the network in our proposed BODANH and other competing QEMPAR, Mobicast, and CQARP routing models.

We use 10%, 20%, 30%, 40%, and 50% mobile sensor nodes and measure how many nodes survive after completion of sensing rounds. With the increase of mobile sensor nodes, the network starts to lose the nodes. This situation gets worse with higher number of mobile sensor nodes; all the participating protocols are affected. However, BODANH outperforms other competing routing protocols. We demonstrate that BODANH improves the network lifetime despite the mobile sensor nodes.

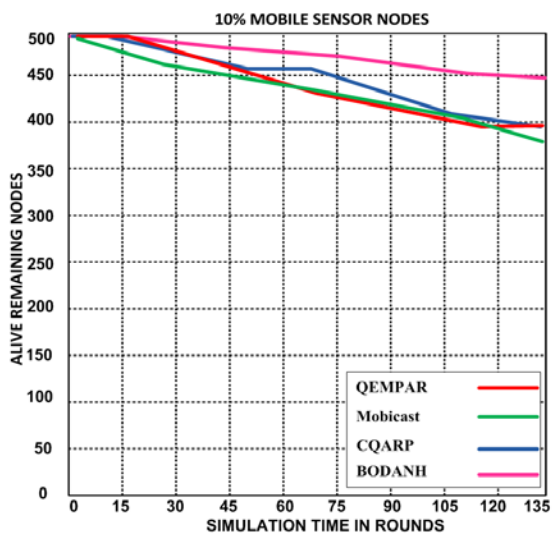


Figure 3.4(a). Alive remaining node VS sensing routes with 10% mobile sensor nodes

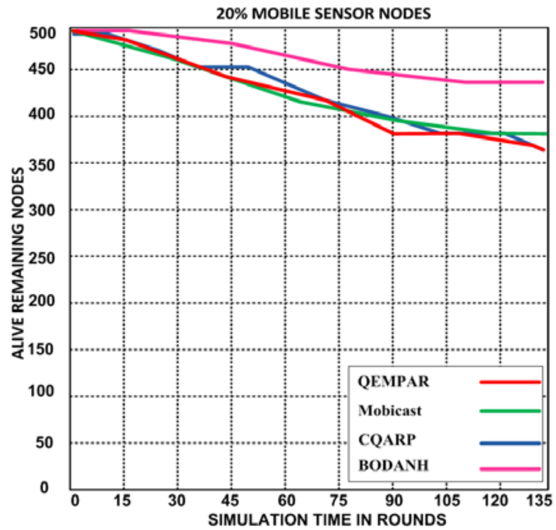


Figure 3.4(b). Alive remaining node VS sensing routs with 20% mobile sensor nodes

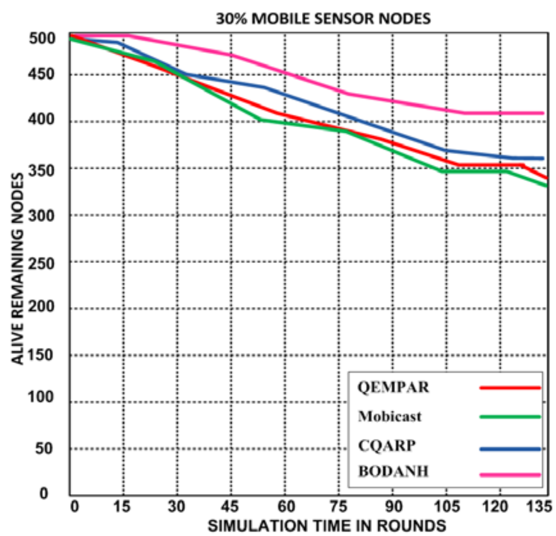


Figure 3.4(c). Alive remaining node VS sensing routs with 30% mobile sensor nodes

3.4 Conclusion

This paper introduces a buffer-overflow distance-aware and noise-handling model to guarantee the QoS provisioning for wireless multimedia sensor networks. This BODANH model creates a reliable discovery route based on buffer allocation, distance measurement, and signal-to-noise-ratio. These features of model reduce congestion, improve the throughput, and extend the network lifetime. The tradeoff is between mobility and network lifetime and throughput. The performance of BODANH has been compared with other routing protocols, which are QEMPAR, Mobicast, and CQARP in terms of throughput and number of remaining live nodes. To validate the effectiveness of a model, ns2 was used to simulate an airport surveillance system. Based on the simulated results, BODANH outperforms the other participating routing protocols. BODANH obtains 11.4% throughput and 6.8% to 19.6% network lifetime in the static and mobility scenarios. The outcome validates that the BODANH model is a better choice for improving the network lifetime and guaranteeing QoS provision. In future, the BODANH model will be extended by incorporating more features in order to validate other QoS metrics.

CHAPTER 4: AN OPTIMIZED HIDDEN NODE HANDLING APPROACH FOR IMPROVING COVERAGE AND NETWORK EFFICIENCY IN WIRELESS MULTIMEDIA SENSOR NETWORKS

4.1 Introduction

WMSNs are capable of capturing audio-video information by using low-cost cameras embedded with sensor nodes. The multimedia sensors provide substantial information related to a specific area of interest [63]. However, multimedia applications experience problems due to online media transmission challenges. Several sources of energy waste include idle listening, overhearing, packet loss due to collisions, and packet overhead in the multimedia sense [64]. One of the major sources of energy waste is the packet collisions that happen when two nodes try to transmit the packets simultaneously. As a result, this causes a partial or complete packet loss at the recipient node. The lost packets need to be discarded or retransmitted, which could be the source of the excess energy consumption waste and QoS degradation [65]. To enable the on-demand multimedia services, we need to focus on multimedia-supported algorithms in WMSNs to determine the hidden node problems and compute the directional coverage. The existing

IEEE 802.15.4 standard is based on the blind back off carrier sense multiple approach with collision avoidance (CSMA/CA), where the nodes check the channel before sending the data frame. If the channel is free, then the node initiates the transmission process; otherwise, it reattempts after a certain time. However, this approach is only suitable when the nodes hear each other, and that could be a rare case in WMSNs. In most cases, the network coverage is much larger than the single node's coverage area [66]. In general, a well-defined coverage area does not support WMSNs because the propagation characteristics are uncertain and dynamic. In this situation, the node is unable to determine the receiver side. The results could be the probability of hidden node collisions. The restrictions of the multimedia sensing proficiencies relate to the location coverage and hidden node problem [67]. Once a better location coverage and hidden node solution for multimedia sensors are discovered, the results will help to improve the capabilities of WMSNs applications. Additionally, WMSNs restrictions are caused by tall buildings, mountains, and trees. Hence, directional coverage of multimedia sensors could be completed once they are deployed in an area of interest. However, proper directional location for multimedia sensors requires correct field information prior to deployment of sensors. It is also likely that multimedia sensors might change their location due to mobility over time. This problem can be resolved by dynamic updates of the locations through location information exchanges [68]. However, multimedia applications have limitations that will affect the successful media transmission in the sensor networks. Node connectivity is subject to change because of wireless commotions [69]. When a sensor is responsive to its immediate neighbors, it must uninterruptedly upload information about its surroundings.

The connectivity is a severe problem subject to the mobility change when the network has been set up. The sensors nodes try to identify new neighbors to address mobility problems, but a hidden node problem is a hurdle. Initial neighbor node discovery is typically performed when the sensor node has no proof regarding the configuration of its immediate neighbors [70]. In this situation, the sensor node is unable to communicate with either the base station or the sink station. Thus, immediate neighboring nodes should be detected as soon as possible to set a path to the base station and contribute to the operation of the network [71]. Hence, in this state, more wide-ranging energy use is justified.

In order to handle the hidden node and coverage problem, our approach contributes the Obstacle-driven Negative Effect Strategy (ONES) method that handles the negative effect of the obstacles. The proposed method is designed for those scenarios where the number of the relays is less than those of relays required for building steady links. In addition, it is particularly suitable for those multimedia sensor networks that suffer due to several disconnected subdivisions of the network that are experiencing the issue of obstacles among the subdivisions. The method is validated by applying several assumptions and definitions. This helps reduce energy consumption and maintaining the QoS.

Furthermore, our approach contributes the optimized hidden node approach that involves the hidden node handling, message exchange phase, and location handling. Our approach is different from existing hidden node approaches as we focus on the multiple discoveries of nodes rather than a single discovery of node. The approach is particularly designed for a distributed network as most of the existing approaches follow the central-based network in the node discovery process, which is also expensive for location updating. We focus on improving the QoS and extending the network life. Thus, a network is divided into different subdivisions and is controlled by a coordinator node, as the subdivision process helps multimedia sensor nodes cover the entire area efficiently. The network life extension is justified with the proper selection of a controlling node using metrics such as residual energy, data forwarding capacity of the node, distance of the node from the base station, and memory allocation. These metrics are assigned the specific weightage that provides enough chance for each node to be a coordinator and balance the network. Handling the problem of overlapped subdivisions in the network, particularly when a new joining node attempts to be a part of either subdivision, is a critical issue that has also been handled by a priority-based synchronization.

The random wake-up procedure is applied to reduce the option of repeating collision amongst the nodes in the same subdivision. The beauty of our random wake-up process that it provides an opportunity for each node to coordinate with its neighborhood nodes to avoid collision and initiate a faster discovery process for the new joining hidden node. In addition, each node applies an active discovery process to detect its coordinator node, whereas in the existing approaches, the coordinator (head node) is responsible for detecting its nodes in its subdivision, which puts an extra burden on the coordinator node. However, our approach handles this issue by assigning responsibility to each node to detect its coordinator node in each subdivision. Unlike existing approaches, our work also contributes the novel location handling procedure that helps detect the maximum view, node boundary, and viewpoint of multimedia sensor node; existing approaches either apply a node boundary or node view to detect the location. We introduce an Optimized

Hidden Node Handling (OHND) approach. The OHND consists of three phases: hidden node handling, message exchange, and location and view handling. These three phases aim to maximize the multimedia node coverage, and improve energy efficiency, hidden node handling capacity, and packet delivery ratio. OHND helps multimedia sensor nodes to compute the directional coverage. Furthermore, an OHND is used to maintain a continuous node–continuous neighbor discovery process to handle the mobility of the nodes. The proposed algorithms are implemented by using a network simulator (NS2). The simulation results demonstrate that nodes are capable of maintaining direct coverage and detecting hidden nodes to maximize coverage and multimedia node mobility. To evaluate the performance of our proposed algorithms, these results are compared with other known approaches. The remainder of the work is organized as follows. Section 2 presents the salient features of the most related work. Section 3 presents an obstacle-driven negative effect strategy method. Section 4 presents optimized occlusion-free viewpoint and an energy efficient hidden node handling algorithms. Section 5 discusses the simulation setup and experimental results. Finally, Section 6 has the conclusion.

4.2 Related Work

In this section, related WMSN approaches are discussed. Previous works discuss maximizing the coverage area and detecting the hidden nodes in the fields of wireless sensor networking, ad-hoc networks, and robotics. However, little research has been done in WMSNs. Some research addresses an omnidirectional coverage problem in WSN [72], but it is not suitable for a bidirectional and an occlusion-free viewpoint. Numerous applications require bi-directional coverage, but existing coverage models are only suitable for traditional WSNs and do not support WMSNs. Hidden nodes problem occurs if two packets are exchanging date, and in the state of sharing the wireless channel in competitive mode, a high possibility exists for collision while communication; that will lead to retransferring the data frequently [73]. It will also use more energy that reduces the efficiency of the sensor. The hidden-node collision is a major problem that reduces the wireless networks performance [74].

Where two packets exchange data in the state of sharing a wireless channel in a competitive mode, there is a high probability of collision while communication that will lead to frequent retransfer of data. In effect, it will lead to consumption of more energy and eventually lower the efficiency of the sensor. The problem of hidden node has been demonstrated to be critical since it lowers the wireless networks' performance.

Mechanisms used for handling hidden nodes can categorized as follows[75]:

- **The busy tone mechanism**

Under the above category, a node hearing a continuous transmission relays a busy tone on a certain channel to its adjacent neighbors to prevent transmission when the channel is being used. The mechanism was initially brought forth to provide a solution referred to as the Busy Tone Multiple Access (BTMA) for a star network that has a sink node. The extension mechanism for a distributed peer-to-peer network has been postulated in RI-BTMA (Receiver-Initiated Busy Tone Multiple Access) and in DBTMA (Dual Busy Tone Multiple Access). One disadvantage of this mechanism is the requirement of a channel that is separate, resulting to an additional complexity and cost of hardware and therefore decreasing the cost-effectiveness of the WSN.

- **Request-To-Send/Clear-To-Send Mechanism**

The concept of creating a reserve channel between a sender and a receiver via a control signal handshake mechanism was initially posited in Split-Channel Reservation Multiple Access (SRMA). RTS/CTS mechanism is based on this idea and was early proposed in MACA protocol. The channel reservation is established by the sender that sends a Request-to-Send (RTS) frame and waits for CTS (Clear-To-Send) frame from the initial destination prior to beginning of the effective transmission. Various refinements comprising MACAW, DCF, FANA, and IEEE were proposed. The DSMA (Double Sense Multiple Access) mechanism was put across, combining the RTS/CTS with the busy tone approach. The DSMA approach is unfit for WSNs because of these reasons:

- ✓ The data frames found in Wireless Sensor Networks are as small as the frames in RTS/CTS resulting to the similar collision possibility.
- ✓ RTS/CTS exchanges consume power for the sender as well as receiver.
- ✓ RTS/CTS is constrained to unicast transmissions and this doesn’t include the broadcasts. It can result in additional throughput reduction because of hidden-node issue.

- **Carrier-Sense Tuning**

The concept involves tuning recipient sensitivity limit of the transceiver that stands for the least energy level that shows the activity of the channel to have wider radio coverage. Increased sensitivities of the receiver enhance a sender to discover the transmission of nodes further away, hence resulting in delaying the transmission and therefore avoid overlapping.

- **Node Grouping**

This mechanism comprises grouping nodes as per the hidden node relationship in a way that every group has nodes that are "visible" (bi-directional connectivity) to each other.

An initial study regarding the coverage of multimedia sensors is described in [76]. In this work, the authors proposed a routing protocol with the field of view camera placed on the floor. The video sensors are used by oceanographers to monitor the shallows. Furthermore, triangular view segments are used for calculating the coverage of wireless multimedia sensor networks in [77].

The neighbor discovery node process is proposed in [78] to regulate the new nodes from the base station. This approach only focuses on finding hidden nodes and not on energy consumption. The base station starts the node discovery process by broadcasting a HELLO message, and the node initiates the registration process after receiving the HELLO message. The node can switch channels to find the best HELLO message, which helps to locate the hidden nodes. In order to reduce the neighbor node discovery time, [79] introduced the HELLO message-based approach to identify the hidden nodes, but energy efficiency was not considered. In [80], an energy efficient node discovery algorithm was introduced based on temporal patterns of coincidences in order to reach other nodes. However, all these approaches address the wireless sensor network issues rather than multimedia wireless sensor network issues. In [70], the authors proposed the use of Voronoi diagrams and Delaunay triangulation to detect the best and worst coverage area in WMSNs. Another approach based on deploying an additional sensor node is introduced in [81] to maximize the coverage area. In this proposed approach, a two-stage process was used for handling of phase coverage boundaries and obstacles by applying the formula $\sqrt{2 \times R}$ (where R: sensing radius of sensors).

In [68], virtual centripetal force-based coverage-enhancing algorithm was proposed for WMSNs. In this work, the grid theory, centripetal force model with essential mass and overlapping idea of the sensors are discussed. This algorithm shuts off any idle multimedia sensory to maximize the network coverage. Furthermore, the network is extended by redistributing sensors and by applying centripetal force based on the circular motion. The authors of [82] introduced a secure neighbor discovery process and attempted to protect the wireless sensor networks from different types of threats. The approach comprises a scalable key-distribution protocol that protects the neighbor nodes in the presence of malicious nodes. This aims to improve the secure neighbor discovery to guard the attacks of hidden nodes. The static network is deployed for securing the one-hop neighbor discovery process. However, the work does not address energy efficiency. The Line of Sight Method (LOSM) [83] is introduced for the wireless personal area network based on visible light communication technology. It handles the issue of the hidden nodes in IEEE 802.15.7 and in particular focuses on QoS parameters such as end-to-end delay and message loss. The idle-pattern-based approach is introduced in which the idle patterns are sent by the network coordinator to perpetuate the communication with other network sensor nodes. However, the work did not focus on energy efficiency and multimedia contents. An Efficient Algorithm for Hidden Node (EBSAHN) [84] is proposed for the wireless sensor networks. This approach is based on an efficient Grouping Scheme that helps add a new node into the wireless sensor network. Furthermore, it avoids the hidden node collision avoidance. The Hidden Node Problem (HNP) [85] is introduced in the wireless sensor network. This approach aims to generate the hidden node relationship for all nodes and allot the hidden nodes into different clusters. In this approach, time for super-frame is divided into sub-periods, and size of the sub-period depends on the number of the hidden nodes into the cluster. The approach is primary based on improving the QoS. The Clustering-Based Mechanism for Detecting the Hidden Nodes (CMDHN) [86] is proposed for resolving the HNP in the wireless sensor networks in order to improve the network performance. Furthermore, delay, throughput, and energy consumption are major parameters focuses. All existing approaches attempted to determine the hidden nodes and coverage problems but did not properly focus on energy efficiency, scalability, QoS, multimedia-content support delivery, and accuracy in multimedia sensor nodes. The characteristics and limitations of existing approaches are highlighted in Table 4.1.

Table 4.1 Characteristics and limitations of the existing approaches.

Existing Protocols	Bio-Directional	Omni-Directional	Single-Directional	Energy support	HN Handling	Scalability	Multimedia Support	QoS
EPAC		X		X				
ENSPTC		X		X				
CPV			X			X		
OWCDF		X						X
WBC	X				X		X	
DTM			X		X			
VCFEA				X				
ELA			X	X				
SND)					X			
LOSM					X			X
EBSAHN	**X**			**X**	**X**			
HNP			X		X			X
CMDHN	X				X			X

4.3 Overview in Mobility Impact

Different types of mobility can have a significant effect on the collection of data. Mobility that has a meaningful effect on the data collection depends on the motion of the mobile element [87]. Deterministic and random patterns form the two major patterns of uncontrolled mobility. The deterministic mobility model has a main characteristic of regularity in the mobile element (ME) contacts that enters the transmission of the sensor nodes at a particular (and mainly periodic) time. According to [88], the contact can occur if the ME is put on a shuttle with an aim of public transportation.

Random is the other type of uncontrolled mobility and is characterized when contacts do not regularly occur. However, they have a probability of distribution. For example, Poisson arrivals relating to an ME have been elaborated by [89]. Generally, a node has to continuously perform discovery in order to increase chances of contacts detection.

The controlled mobility utilizes nodes that may change place in an active way since they can control their speed and trajectory. Consequently, motion becomes an added component that can be efficiently used for the design of data collection procedures specifically to Wireless Multimedia Sensor-MEs. An important note about controlled mobility is that it can make certain issues concerning collection of data less significant. For example, the issue of discovery can be somewhat eased because the mobile elements can be directed to meet other nodes at certain instances. Also, the contact intervals of is less problematic because the mobile elements can stop at the nodes after they gather the buffered data. Furthermore, various issues come up in this context, mostly in relation on how to plan the ME arrivals at the sensors that include defining speed and trajectory of the ME while attaining the satisfaction of specific QoS) constraints that include reducing buffer overflows and latency and maintaining the consumption of energy as low as possible.

4.4 Optimized Hidden Node Handling Approach (OHND)

An Optimized Hidden Node Handling (OHND) approach is introduced for distributed WMSNs because the sensor nodes are deployed in a disseminated manner within a realistic environment. However, centralized location deployment is not appropriate for WMSNs because these networks encompass a large number of multimedia nodes. Furthermore, updating the location is expensive within a centralized approach when compared to a distributed approach. Our approach consists of three phases:

- **Hidden Node Handling**
- **Message Exchange Phase**
- **Location Handling**

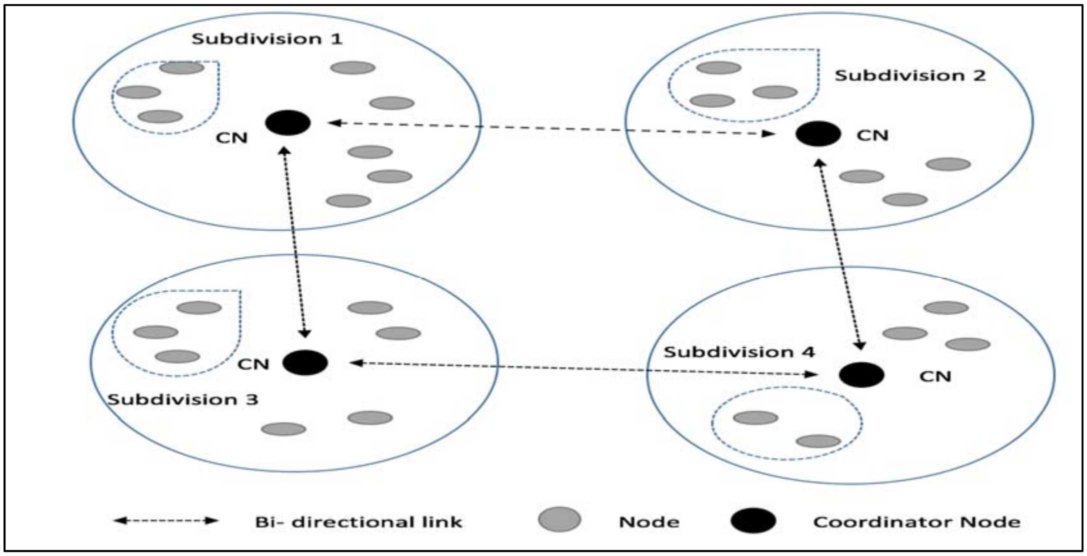


Figure 4.1. the proposed subdivision methodology

4.4.1 Hidden Node Handling

Handling a hidden node in WMSNs is the critical problem that affects the network performance. Hence, the efficient neighbor discovery process helps in hidden node handling. This phase focuses on a continuous neighbor discovery process to determine the hidden nodes. Each sensor node uses a coordination-driven approach, and we chose the 1-hop multiple neighborhood discovery process rather than the specific node-discovery in the network that helps detect all hidden nodes at the1-hop neighborhood. As a result, the network consumes a minimum amount of energy and has a collision-free process. The network is divided into different subdivisions, and each subdivision is controlled by a coordination node. However, our approach selects the coordination node based on the residual energy, data forwarding capacity of the node, distance of the node from the base station, and memory allocation. Each node continues to play a role as the coordinator until it possesses the higher weightage as compared with other nodes of the subdivision. The higher weightage is calculated by assigning different values as residual energy is assigned 33% weightage, the nearest distance of the node from the base station gets 25%, the data forwarding capability gets 15%, and the memory allocation resource gets 27% weightage. We tried to use different combinations of the weightage for each metrics, but we obtained the optimal results with our chosen weightage numbers. Thus, each coordination node is responsible for detecting the new hidden node when joining the network. Each new joining node is required to send a synchronization message to the coordination node and each subdivision has only one coordination node, which means there is less possibility of collision to handle synchronization message. In case a new joining node sends the coordination requests to two different subdivisions, if a node is located close to the subdivisions that are overlapped, the coordinator node that receives the first synchronization message entertains the node. On other hand, the coordination node that receives a later synchronization message responds to the new joining node, but that node has already become part of the other subdivision. As a result, the possibility exists for energy waste of the coordination node. However, the wasted energy of the coordination node is negligible. The coordination node replies to the new node and sends a message to all the nodes in the same subdivision to store records about the new joining node. After getting a message from the new node, all the nodes send acknowledgments to the coordinator node. The goal is to confirm the new node request and inform all the nodes in the same subdivision about the new member, and the new node has the information about the other neighboring nodes. The synchronization message is dispersed over the entire links of the network to link with the coordination node. This is the way that the coordination node determines if a new joining node is identified. When the coordination node has information about a new joining node that is broadcast within its subdivision nodes, the coordinating node will send out a message to all the nodes in the same subdivision. After that, each subdivision is divided into groups, where in each group all the nodes are visible to each other. By doing that, nodes in each group can communicate without the concern of the hidden node problem. The synchronization process of a new joining node with the coordination node process is depicted in Figure 4.2.

The hidden node handling process applies a random wake-up procedure to reduce the option of repeating collisions amongst the nodes in the same subdivision. In this phase, each node coordinates with its neighborhood nodes during the wake-up period to avoid collisions and make a faster discovery process of any new joining hidden node. The wake-up time period is very small, and the time of forwarding the HELLO message is even smaller. In this case, there is a possibility that two nodes can be active at same time and initiate the neighbor node discovery process. Therefore, we use a scheduling method to control the wake-up process of two nodes at the same time. During the scheduling, the nodes are required to be synchronized with each other and report to the coordination node. During the scheduling, each receiving node chooses time slots and obtains the data during those time slots. The time slot process is performed without contradicting the schedule of the other node. This is the reason that the neighbor nodes are subdivided into different subdivisions, where each node chooses its slot assigned to that subdivision. Each sensor node decides randomly when to initiate the transmission of a HELLO message. If its message does not strike with another HELLO message, the node is referred to as a discovered node. We can also determine residual energy and the load of each node after the node discovery process occurs.

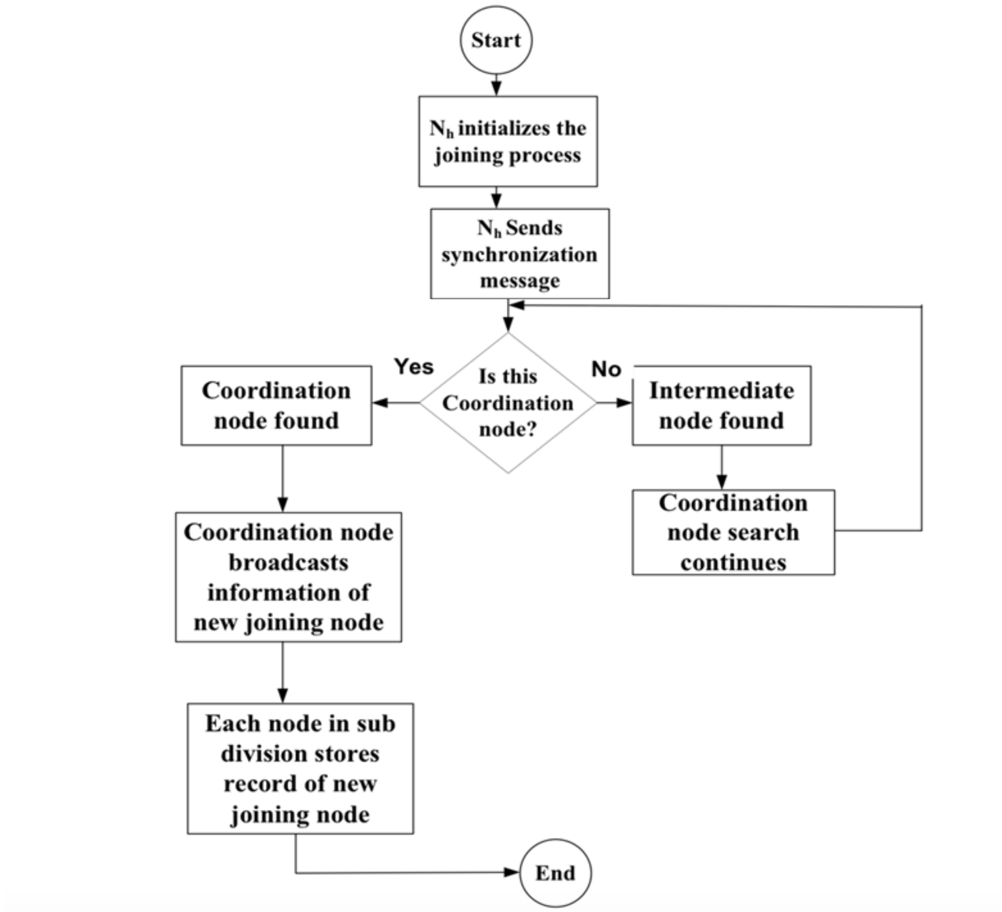


Figure 4.2. Coordination node synchronization process.

Let us assume that each sensor node communicates at the distance of the single-hop node to detect the hidden nodes. Each sensor node sends the HELLO message 'Hm' at the distance 'd' within the subdivision 'Sd' and is located at the N × N area of WMSN. The residual energy of the two types of multimedia sensor nodes, the coordinator node 'C' and the non-coordinator node 'Cn', can be determined as follows.

The coordinator node performs four types of jobs that include the synchronization with newly joined nodes, broadcasting the information of newly joined nodes inside the subdivision, scheduling the transmission of subdivision, and data collection from non-coordinator nodes of the subdivision. The synchronization process between the newly joined node and the coordinator is explained in Algorithm 1.

Algorithm 1: Priority-based synchronization process between coordinator and newly joined nodes
Initialization: (C_{n1}: coordinator node-1; C_{n2}: coordinator node-2; N_j: newly joined-node;B_m: beacon message for joining the subdivision; S_n: node synchronization process; N_{sdi}: subdivision of the network; ℓ: listening) Input: (B_m) Output: (S_n) Set N_j attempts for N_{sd} // New node intends to join the subdivision of the network $N_j \perp B_m$ // New node sends beacon message for joining the network B_m ℓ C_{n1} && C_{n2} // Beacon message sent by new node, but it is heard/listened by two coordinator nodes when two subdivisions are overlapped. ***If*** C_{n1} *ℓ* $B_m \in N_j$ then // If coordinator node-1 gets beacon message from new node for joining the subdivision. C_{n1} ʐ $N_j \in N_{sd}$ // coordinator node-1 allows 'ʐ′ the new node to be part of subdivision C_{n2} Ɩ' N_j // coordinator node-2 discards 'Ɩ' the request initiated by new node Else if C_{n2} ʐ $N_j \in N_{sd}$ // If coordinator node-2 gets beacon message from new node for joining the subdivision C_{n2} ʐ $N_j \in N_{sd}$ // coordinator node-2 allows 'ʐ′ the new node to be part of subdivision C_{n1} Ɩ' N_j // coordinator node-2 discards 'Ɩ' the request initiated by new node Endif Endelse

Here, we determine the energy consumed for four types of jobs. Thus, the residual energy of 'C' and 'Cn' can be calculated as follows:

$$C_{es} = [d^2\{(M_s \times (E_r)) + (M_s \times (E_a))\} \times S_n] \tag{11}$$

Equation (11) shows the consumed energy by coordinator node for synchronization:

$$E_b = E_r + E_a \tag{12}$$

Equation (12) shows the consumed energy for broadcasting the message (disclosing the information of newly joined nodes to the subdivision nodes):

$$E_s = \sum_{S_n=1}^{k} (E_r + E_a) \times d^2 \tag{13}$$

Equation (13) shows the consumed energy by coordinator node for scheduling with subdivision nodes:

$$E_{dc} = [d^2\{(M_s \times (E_r)) + (M_s \times (E_a))\} \times S_n]^2 \tag{14}$$

Equation (14) shows the consumed energy by coordinator node for collecting and forwarding the data.

Table 4.2 shows the details of the notations used and their respective explanations.

Table 4.2. Notations used and their description.

Notation	Description
C_{es}	Consumed energy of coordinator node for synchronization
M_s	Number of synchronized messages by each newly joining node
E_r	Energy consumed by radio of multimedia sensor
E_a	Energy consumed for amplifying
S_n	Number of synchronizing nodes
d	Distance between coordinator and newly joined node
E_b	Energy consumed for broadcasting
E_s	Energy consumed by coordinator node for scheduling
C	Coordinator node
Cn	Non-coordinator nodes
C_{ie}	Coordinator's initial energy
C_{re}	Residual energy of coordinator
E_{dc}	Energy consumed by coordinator node for data collection
Sd	Subdivision
N_l	Node load
N_{hello}	Number of hello message by node
N_{bm}	Maximum buffer size of node
N_h	Hidden node

We can determine the residual energy of the coordinator node and non-coordinator nodes based on the energy consumption for four tasks given by Equations (15) and (16), respectively:

$$C_{re} = C_{ie} - (C_{es} + E_b + E_s + E_{dc}) \quad (15)$$

$$NC_{re} = C_{ie} - (C_{es} + E_b + E_{dc}) \quad (16)$$

Determining the node's load is significant for hidden node discovery. The load factor $'\mathrm{N}_l'$ requires the buffer capacity that is calculated d by using the Equation (17).

$$N_l = \left[\frac{N_{hello}}{N_{bm}}\right] \quad (17)$$

4.4.2 Message Exchange Phase

In this phase, the multimedia sensor nodes exist at a 1-hop neighborhood node that initiates the message exchange process to gather the information about the neighboring nodes. All sensor nodes use unicast addressing methodology that refers to the neighbor handshake indication (NHI) process. The NHI contains the identity of the nodes and the current location of the multimedia sensor node. Let us assume that the mobile multimedia sensor node comprises an identical standpoint and a list of overlapped neighbor nodes that are accessible in the same sensing position that yields the NHI. This aims to guarantee that each multimedia sensor node should detect their neighbor's hidden nodes and their location:

$$T_n = \sum_{i=0}^{N} (N_{ni}) \quad (18)$$

In Equation (18), the total neighbor nodes $'T_n'$ are calculated to determine the exact number of all 1-hop neighbor nodes. Each neighbor node $'N_n'$ sends on NHI message that can be obtained by

$$N_n = \int_{j=1}^{1} (N_{id}) + C_l \tag{19}$$

In Equation (19), multimedia sensor node unicasts the neighbor handshake indication process that contains node identity $'N_{id}'$ and the current location $'C_l'$:

$$N_n \rightarrow R_m = \int_{i=1}^{1} (N_{id}) + C_l \times \sum_{N_n \in \beta}^{T_n} (\beta) \cdot N_n \tag{20}$$

In Equation (20), each neighbor node returns the message $'R_m'$ with a node overlapping report $'\beta'$ including the current location of each neighbor node.

- Location Handling

The location handling of the sensor node is of paramount significance for continuous communication. Thus, several events can be implicitly adjusted and responded to only if the correct location of the event is detected. The location handling plays a key role for understanding the multimedia- application- contents. There are three advantages of detecting the location of the multimedia sensor node. First, location handling is required to determine the event of the interest. For example, the location of a fire, location of an intruder, or the location of the opponent’s tank in the arena are critical for deploying the relief troops and rescue squads. Second, location handling enables several application services, such as helping doctors to gain the information of medical gears and personnel in smart hospitals. Third, the location handling helps in several system functionalities, such as network coverage checking, geographical routing, and location-based information querying. This phase helps to detect a sensor's maximum view. Location handling involves the node boundary and viewpoint. In the node boundary, we detect the area in which the node is capable of broadcasting the message. The viewpoint covers the degree of the node from 0 to 360 in which the node can be located at any degree. First, the node attempts to determine the location of the neighbor node within the boundary by broadcasting the message. If a node fails to locate the node within the boundary, then it initiates the neighbor distance search process by checking the distance of the node viewpoint of the neighbor node. Last, if the previous process fails, then an obstacle-distance process is used. If the first two processes and later process fail, then the sensor node uses an optimized occlusion free viewpoint to determine the largest viewpoint. Figure 4 shows a complete node boundary process with the obstacles. The intersection of the curves on the given node boundary are displayed by including points A and B for the first obstacle, C and D for the second obstacle, and E and C for the third. Hence, the multimedia sensor node can determine whether there exists the obstacles Ψ that can be expressed as

$$\Psi \cap < A\mathbb{R}\mathrm{B} = 0\,, \Psi \cap < D\mathbb{R}\mathrm{C} = 0\ \&\ \Psi \cap < E\mathbb{R}\mathrm{C} = 0$$

then "Ψ" is visible to the viewpoint that refers to an AB clockwise curve; CD, and EC are available on the blocked curve of the viewpoint within the multimedia sensor node. This procedure not only finds the visible viewpoint, but it also helps detect the non-overlapped viewpoints. Similarly, the overlapped areas are detected by applying the node boundaries.

Table 4.3 shows the details of the notations used and their respective explanations.

Table 4.3. Notations and their description.

Notations	Description
$\theta\ell_e$	Average location error
l_{e1}	First estimated location
l_{e2}	Second estimated location
l_{a1}	First actual location
l_{a2}	Second actual location
T_{sn}	Total number of multimedia sensor nodes
Ψ	Obstacles
$\theta\ell_t$	Average location handling time
l	Total locations of all multimedia sensor nodes
$\mathbb{R}$	Boundary range

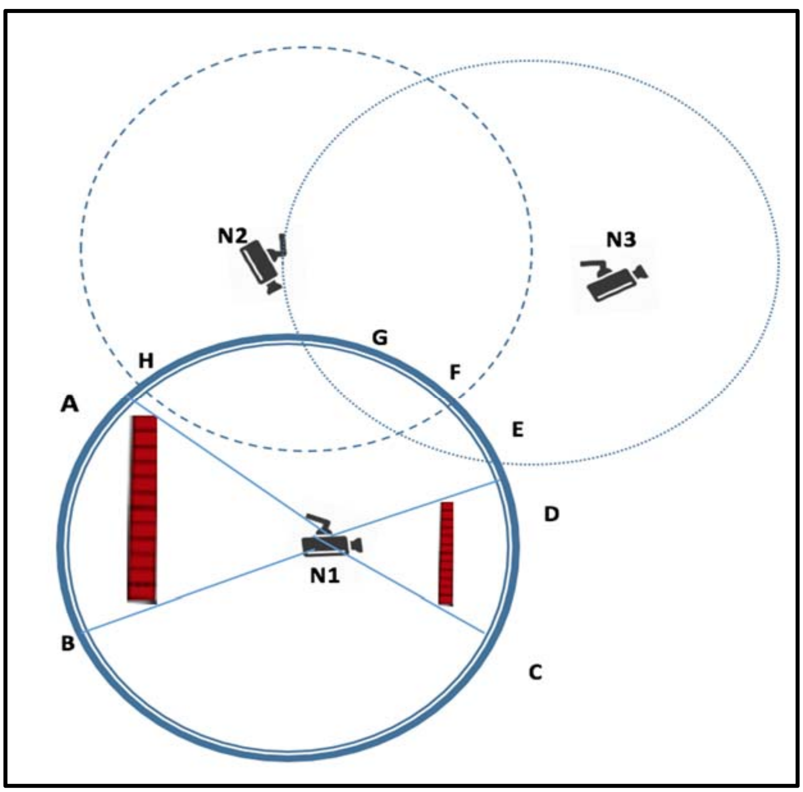


Figure 4.3. Obstacles within the node boundary and viewpoint.

4.5 Mobile and Energy Efficient Routing Protocol for Handling Hidden Nodes (MEQRO)

To handle the hidden node problems in case of mobility, we introduce Mobile-energy Efficient–Quality of Service Routing Protocol (MEQRO). Our solution is based on the grouping mechanism and dynamic updates for the moving nodes. As the nodes change their locations from one place to another, we cannot predict the hidden nodes. For this reason, hidden nodes should be detected rather than predicted. In this work, the network is divided into subdivisions and each one contains regular nodes and a CN (Coordinated Node). This node has directional radio connectivity to all other nodes in the same subdivision. The CN is a unique node that helps to manage the communication in every subdivision and contains a higher energy capacity. The CN also keeps a coordinator table that stores data concerning the node ID, the number of the node, as well as the group number. Nodes members are grouped as non-visible node (hidden) and visible node. The hidden node is bi-directional; that is, the first node is hidden to the second and vice versa. Each node maintains a given relationship table. It keeps the node ID number as well as the link information. When a new node wants to join a network, it sends an association request to the CN, which informs all the neighboring nodes about the new member and they receive a new message from it. Then, the new node sends a message to all neighbors. After that, these nodes report to the CN, and based on that, the CN will assign the appropriate group to the new node where all the nodes are not hidden. If no such a group exists, the CN will create a new group for that node. By doing that, all nodes in each group are visible to each other and can communicate without hidden node problems.

A node should begin transmitting the data immediately when it is assigned to a specific subdivision; the main goal is to minimize the possibility of collision in the network. Only the neighboring nodes will take part in the collection of hidden nodes that can help to reduce the communication overhead among the nodes. When a new node leaves or joins the network, there will be no regrouping of nodes in every subdivision. guaranteeing QoS provision. In future, the BODANH model will be extended by incorporating more features to validate other QoS metrics.

CHAPTER 5: SIMULATION SETUP AND PERFORMANCE ANALYSIS

5.1. An Optimized Hidden Node Handling Approach for Improving Coverage and Network Efficiency in WMSNs Experimental Results

To validate the effectiveness of our proposed optimized hidden node handling approach for WMSNs, we performed the simulation by using network simulator-NS2. The network is constructed to cover 1200 × 1200 square meters. The 270 multimedia enabled nodes are randomly distributed with homogenous capabilities. The initial energy of each node is set at 100 joules. The simulation aims to identify the coverage and network efficiency in the presence of hidden nodes. Furthermore, the performance of OHND is compared with other known mechanisms handling the issue of hidden nodes: Line Of Sight Method (LOSM) [83], Efficient Beam Scanning Algorithm for Hidden Node (EBSAHN) [84], Hidden Node Problem (HNP) [85], and Clustering-Based Mechanism for Detecting the Hidden Nodes (CMDHN) [86].

We designed three scenarios that include both hidden nodes and no hidden nodes. In the first scenario, each multimedia sensor node hears 20 out of 30 of the other multimedia sensor nodes. This gives a 66.666 % probability of detecting the hidden nodes without wasting additional energy. In the second scenario, 10 out of 30 multimedia sensor nodes can hear other nodes, and this gives a 33.33% probability to detect the hidden nodes. In the third scenario, all end nodes that contribute in the network can listen to each other. The distance between each multimedia sensor node is set at 40 meters. These three scenarios demonstrate expected, worst, and ideal scenarios, respectively. All nodes are completely constructed using the angle $\theta = 70^0$ and the 30 meter sensing range that is set for each multimedia sensor node. The communication capability of each sensor node is set at 50 meters. We set 22 obstacles in the first scenario. In the second scenario, 14 obstacles were set. The third scenario had no obstacle. In scenarios 1 and 2, the viewpoint of the multimedia sensor nodes was affected. The remaining simulation parameters are given in Table 5.1.

Table 5.1. Simulation parameters and its corresponding values.

Parameters	Value
Size of network	1200 × 1200 meters
Number of multimedia sensor nodes	270
Maximum number of retransmissions allowed	3
Initial energy of node	100 Joules
Size of packets	512 bytes
Sensing range of node	30 meters
Number of obstacles	14 and 22
Simulation time	12/14/20 minutes
Base station location	(0,700)

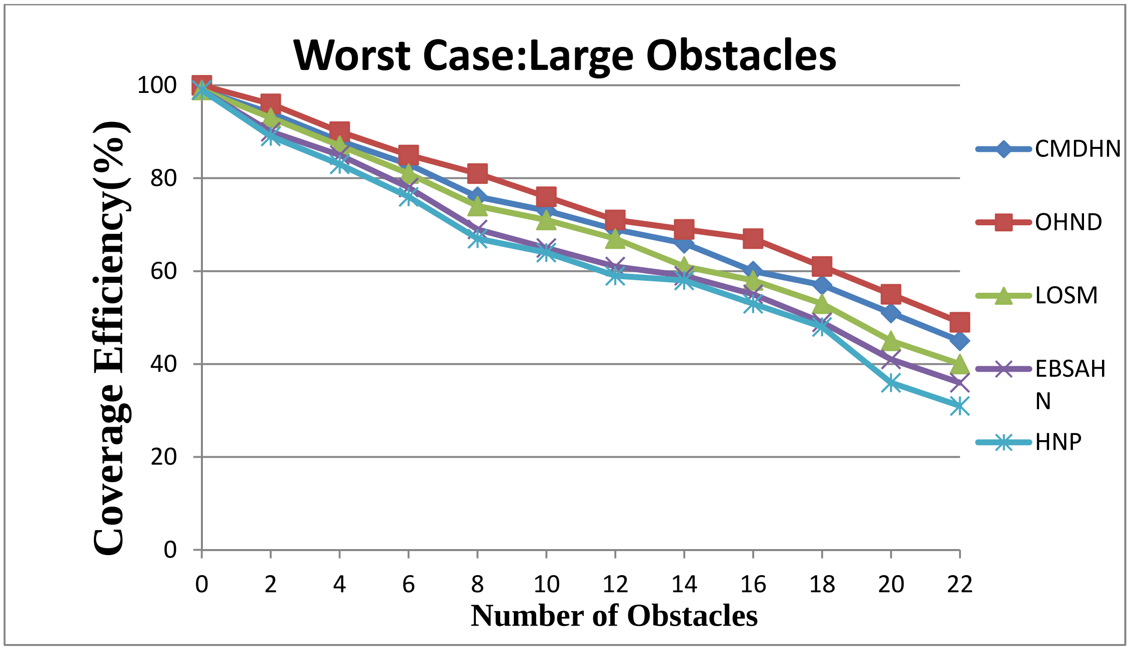
Based on simulation, we obtained these results:

- Multimedia Throughput Efficiency
- Successful Packet Delivery Ratio
- Network Accuracy
- Energy Consumption with Hidden Nodes

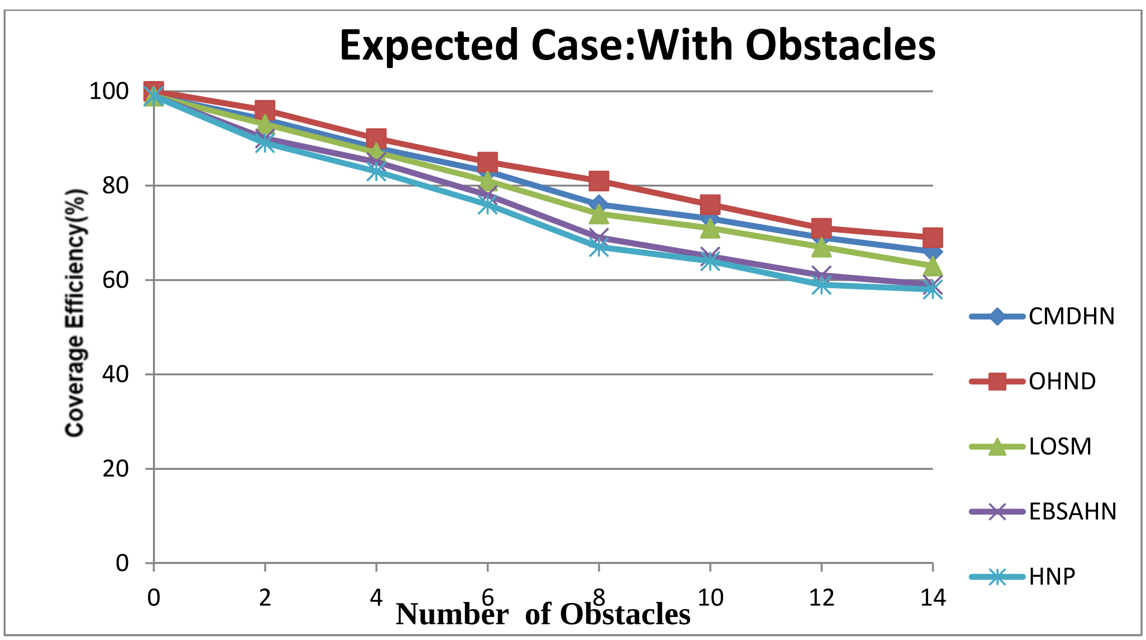
5.1.1. Multimedia Throughput Efficiency

To confirm the multimedia throughput-efficiency of our proposed optimized hidden node handling, we created three scenarios: worst case, expected case, and ideal case. In the worst-case scenario, we used 22 maximum obstacles depicted in Figure 5a. In the expected case, we used 14 obstacles as depicted in Figure 5b, and there were no obstacles in the ideal case depicted in Figure 5c. Furthermore, we compared the performance of OHND with LOSM, EBSAHN, HNP, and CMDHN. The communication time is set at 18 min in the three scenarios for all competing approaches. We observed in Figure 5.1.a–c that when the number of obstacles increases, the throughput efficiency decreases. However, throughput efficiency of our proposed OHND is better than other competing approaches. Our results demonstrated that the approach of the OHND significantly improved the throughput efficiency of the multimedia sensor network. The reason for improvement in throughput efficiency, in our case, is the use of the obstacle-driven negative effect strategy method that handles the negative effect of the obstacles. Our approach is particularly suitable for WMSNs that suffer due to several disconnected subdivisions of the network that are experiencing obstacles among the subdivisions.

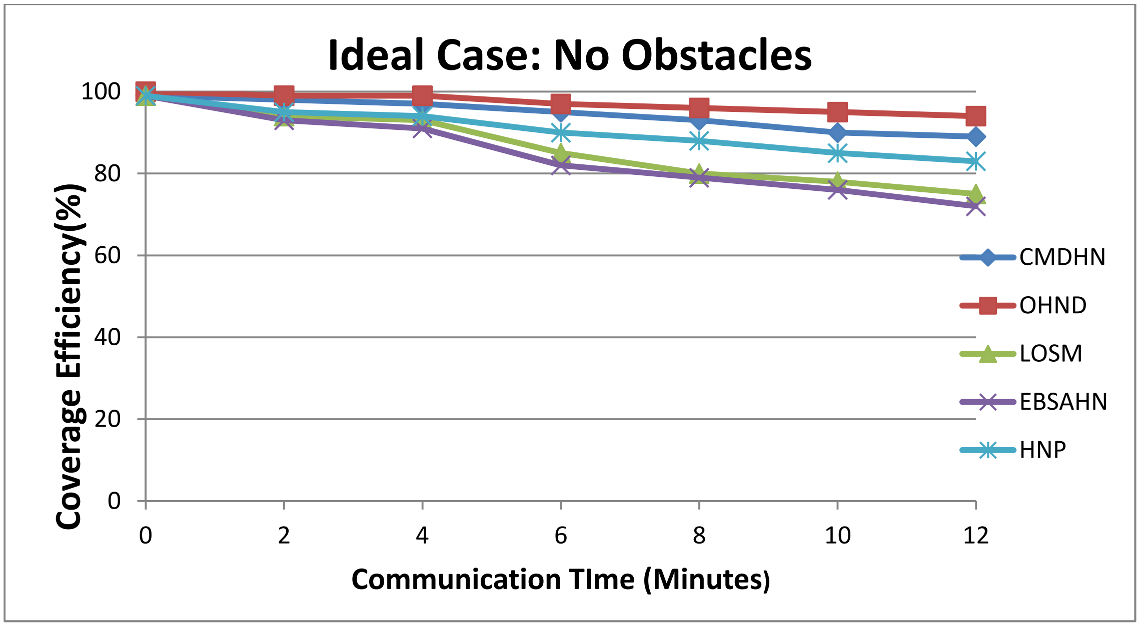
Furthermore, the multiple discovery of nodes rather than single discovery of node substantially improved the performance.



(**a**)



(**b**)



(c)

Figure 5.1. (a) Multimedia coverage in existence of 22 obstacles. (b) Multimedia coverage in existence of 14 obstacles. (c) Multimedia coverage efficiency without the existence of obstacles.

5.1.2 Successful Packet Delivery Ratio

One of the drawbacks of the hidden node in WMSNs is to drop the packets due to collisions. As a result, the quality of service is significantly affected. Figure 5.2 demonstrates the results of our proposed OHND and its comparison with LOSM, EBSAHN, HNP, and CMDHN approaches. The performance is measured by using a various number of events. When the number of events increase, the, successful packet delivery ratio begins to reduce. However, this approach is more stable when compared with other competing approaches as it has 93.4% of success rate after detecting 18 events, but other approaches have 82.24%–89.2% after monitoring the same number of events. In other approaches, the lost packets cannot be transmitted. In the presence of the hidden nodes, packets are lost. As a result, there is a possibility of collision that reduces the packet delivery ratio.

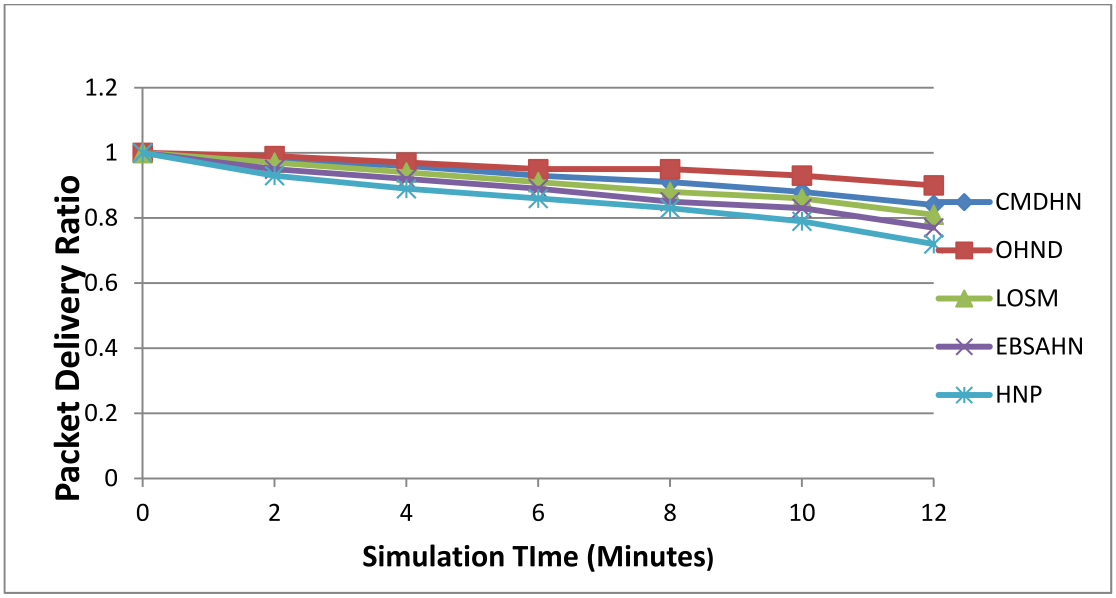


Figure 5.2. Successful packet delivery VS number of monitoring events.

5.1.3 Network Accuracy

Network accuracy is highly affected due to the presence of hidden nodes. Thus, end-to-end delay including processing, propagation delay, and time synchronization between the two end-to-end-points are extended. As a result, the network does not perform as expected and throughput performance is greatly degraded. In Figure 5.3, we determined the network accuracy of our proposed OHND and compared it with other competing approaches. When the number of hidden nodes increases, the network accuracy of our proposed approach is marginally reduced. On the other hand, the network accuracy of competing approaches is highly affected. In our case, our approach shows 96.1% network accuracy after detecting the 18 hidden nodes. HNP shows lower network accuracy with an increased number of the hidden nodes; other approaches also show lower network accuracy. The result demonstrates that our approach has an edge over competing approaches.

The reason for better network accuracy in our case is the use of a random wake-up procedure that reduces the option of repeating collision amongst the nodes in the same subdivision. The beauty of our random wake-up process is to provide a chance for each node of coordination with its neighborhood nodes in avoiding a collision and initiating a faster discovery process for a new joining hidden node.

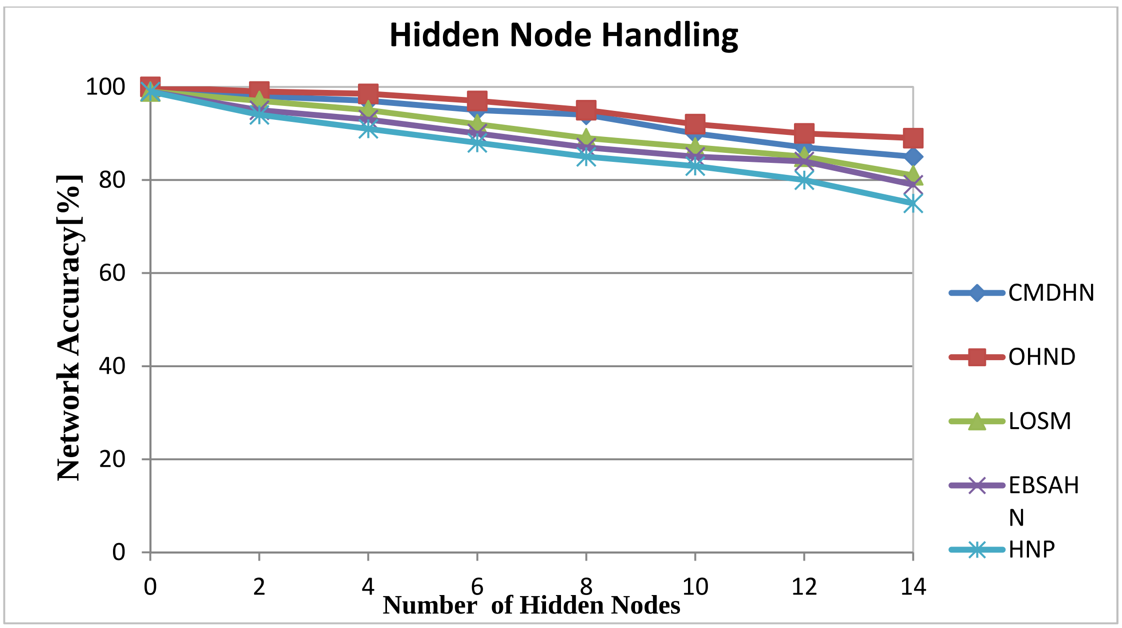


Figure 5.3. The network accuracy in presence of hidden nodes of OHND and other competing approaches.

5.1.4 Energy Consumption with Hidden Node

The performance of the OHND approach was evaluated by using 500 rounds with a constant frame size of 512 data frames (including payload and data frame format). We performed several runs to determine the energy consumption of our proposed approach. Figure 8 demonstrates the energy consumption of our proposed approach and compares it with other competing approaches in the presence of hidden nodes using a maximum of 500 rounds. Based on the results, we observed that when the number of hidden nodes increases, the energy consumption rate also increases. However, our proposed OHND consumes less energy when compared to other competing approaches. HNP consumes less energy between 4–9 nodes, but when the number of hidden nodes increases, it performs poorly. OHND consumes an overall of 4.5 Joules with 18 hidden nodes using 500 rounds. However, other approaches consumed from 4.7-5.8 Joules for 500 rounds with a similar number of hidden nodes. The results demonstrate that our approach could also extend the network lifetime by saving more energy when compared to other approaches as shown in figure 5.4.

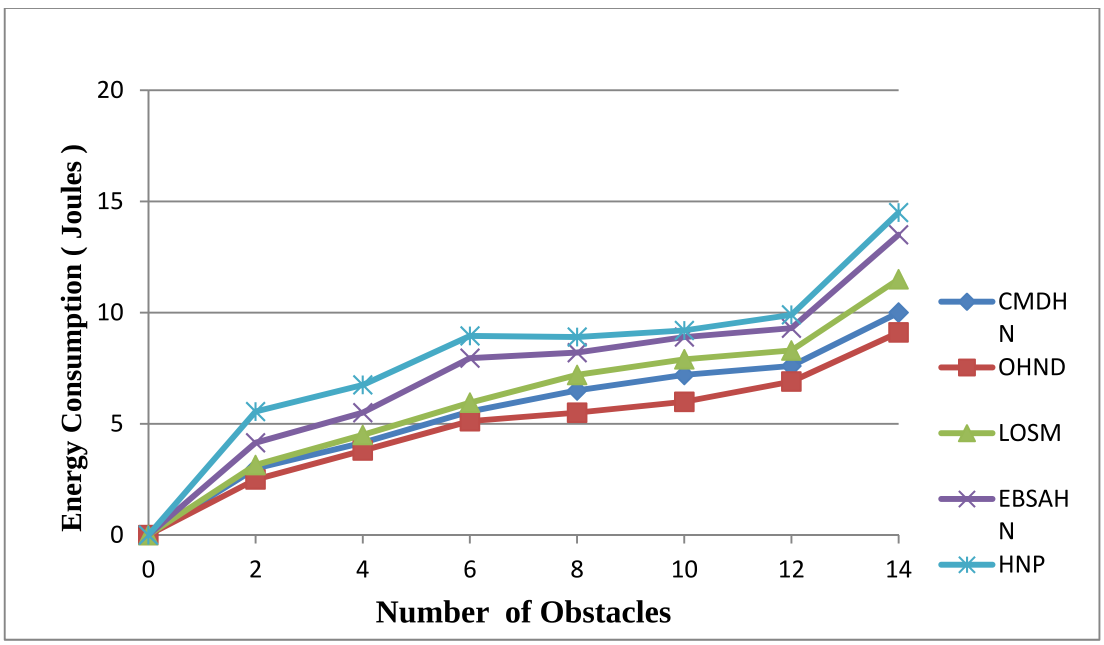


Figure 5.4. Energy consumption vs number of hidden nodes.

5.1.5 End to End Delay

The delay represents the period from the initiating a message until it is received by a destination node. Figure 5.5 shows end-to-end delay for the routing protocol in our simulation. It is found that during initial period of simulation, the OHND protocol yields the least delay at approximately15-30 ms compared to all other routing techniques whose average initial delay was in the range of 21-42 ms. Towards the end of the simulation, the OHND delay observed was around 56 ms, which is less than all other routing techniques in our experiment. This clarifies the faster response for OHND with minimum routing overhead even with the change of network simulation parameters.

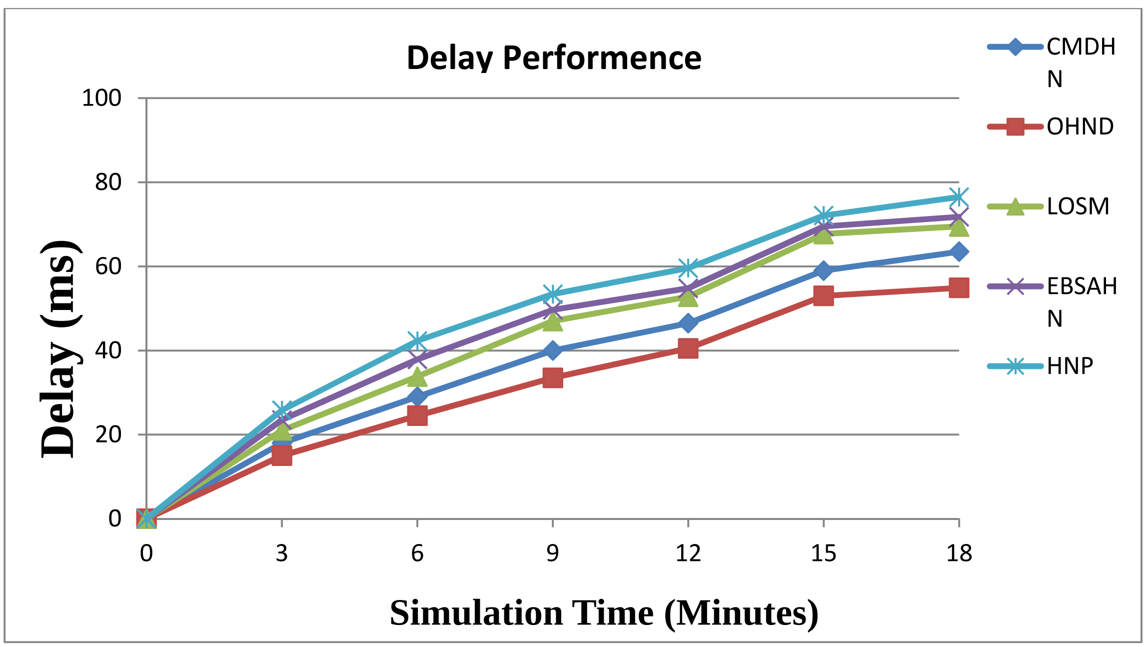


Figure 5.5. End to End Delay Performance

5.2 Mobile and Energy Efficient Routing Protocol for Handling Hidden Nodes (MEQRO) Analysis:

To confirm our protocol performance, we used network simulator NS2. We have created the WMSNs to cover 120 X 120 square meters. The goal of our simulation is to evaluate the consumed energy, the throughput, and the delay for our proposed work. In addition, we also compared our protocol with the Hidden-Node Avoidance Mechanism (HNAME)[75]. The simulation parameters are shown in Table 5.2:

In our simulation, we considered in the following performance metrics:

- Energy Consumption
- Throughput
- End to-End Delay

Table 5.2: The Parameters Simulation

PARAMTERS	VALUE
Network size	120 × 120 m²
Number of nodes	75
Maximum number of retransmissions allowed	03
Packets Size	256 bytes
Data Rate	260 kbps
Sensing Range of node	45 meters
Average Simulation Run	10
Location of Base station	(0,800)

5.2.1 Energy Consumption

The node energy decreases with the increasing number of hidden nodes. It is noteworthy that in Figure 5.6 MEQRO protocol can conserve 20% more energy than HANME for a higher number of hidden nodes.

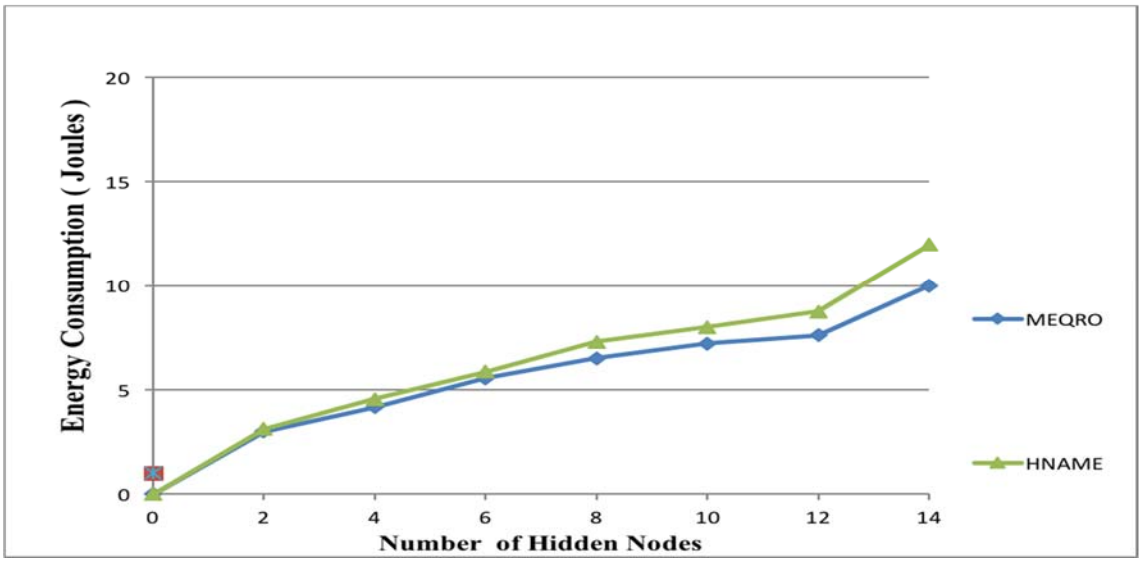


Figure 5.6: Energy consumption statistics

5.2.2 Throughput

The overall network throughput or the amount of traffic successfully received is captured for both the routing protocol. In MEQRO, the maximum throughput was approximately 176 kbps compared to its counterpart HNAME having 161 kbps as highest throughput as shown in Figure 5.7 The overall throughput performance with MEQRO was slightly better than HNAME.

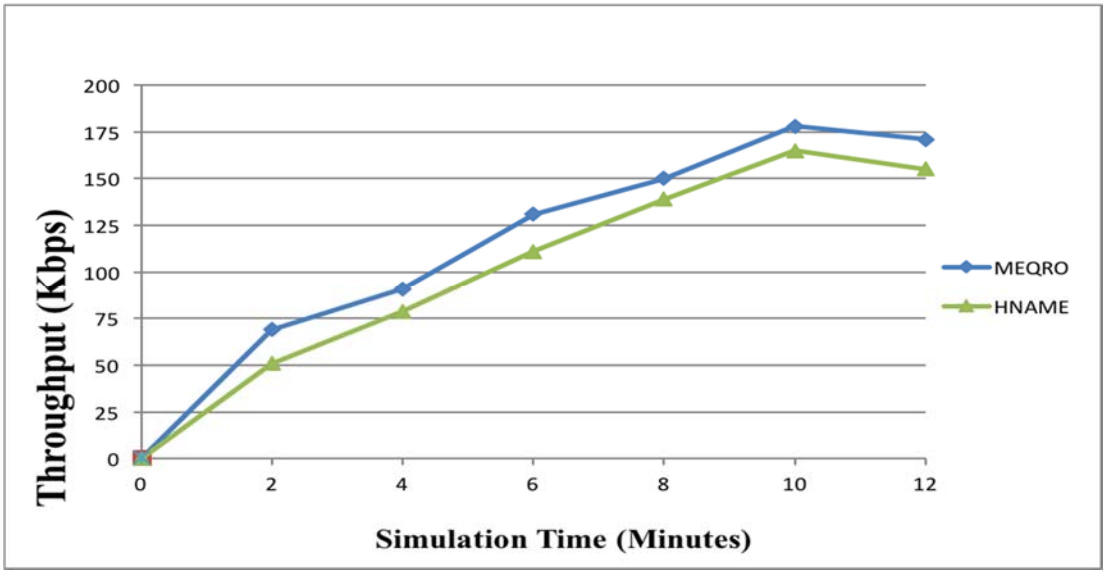


Figure 5.7: Throughput analysis

5.2.3 End-To-End Delay

The delay represents the period from the initiating a message until it is received by a destination node. Figure 5.8 shows the average delay that both the routing protocols encounter in our experiment. During the initial period of simulation, the MEQRO protocol yields a lower delay of about 20-30 ms compared to HNAME whose average initial delay was in the range of 27-41 ms. Towards the end of the simulation, the MEQRO delay observed was around 60 ms, which is again lesser than HNAME techniques. This indicates that the faster response for MEQRO compared to HNAME with minimum routing overhead.

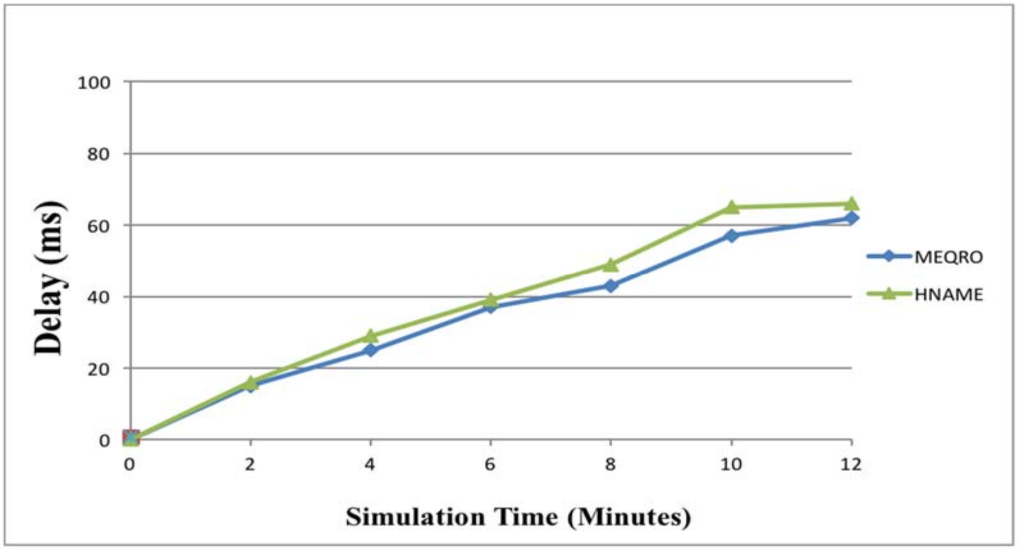


Figure 5.8: Delay performance analysis

CHAPTER 6: CONCLUSIONS

The hidden node problem creates a threat to any type of MWSN application. This research project introduces an Optimized Hidden Node Handling approach to improve the quality of service of the WMSNs (OHND). Our approach consists of three phases: hidden node handling, message exchange phase, and location handling. These three phases resolve the hidden node problem and improve the network performance and QoS provision. The message exchange phase is responsible for detecting overlapped and non-overlapped areas of MSNs. The location handling phase determines the correct location of each multimedia node that helps improve the coverage efficiency of MSNs. Furthermore, the hidden node handling phase identifies the load and residual energy of the nodes when performing the discovery process. In addition, our solution provides an efficient way for handling the hidden nodes in case of mobility. The frequent updates can help to identify the hidden nodes in the network that improves the QoS provision and extend the network lifetime.

To determine the strength of our proposed OHND, we used NS2 and compared the performance with other competing approaches: LOSM, EBSAHN, HNP, and CMDHN. The results demonstrate that our OHND improved multimedia coverage, energy consumption, and the packet delivery ratio when compared to other approaches. Furthermore, OHND has a hidden node handling capacity that is 0.8%–4.1% higher than other approaches. The simulation results confirm that our proposed approach can determine hidden nodes for WMSNs application. This approach could be a better choice for surveillance systems because of the extended network lifetime. In addition, it can be used for different WMSN applications.

Furthermore, Mobile and Energy Efficient Quality of Service Protocol (MEQRO) is proposed for improving performance of the network in terms of energy consumption, delay, and throughput. Our approach is based on continuous subdivision member information process. The continuous subdivision member discovery is important to handle the hidden nodes when they are mobile. If a node changes its location, the coordinator table will detect that change and start the process of grouping again. We compared the performance of our MEQRO protocol with HNAME approach. The simulation results show that our proposed MEQRO protocol can conserve more energy, enhance the throughput of the network performance, and reduce delay when compared with the other protocol. The results of the simulation demonstrate that our proposed protocol can determine hidden nodes for WMSNs in case of mobility.

In future research, we will implement our proposed OHND in a hardware-based environment. Since the mobility adds some limitations for handling the hidden node problems, we will further investigate this issue to improve our results. In addition, we will study the idea of having multiple sink nodes and how it can affect the network performance.

REFERENCES

[1] Y. Jennifer, B. Mukherjee, and D. Ghosal. "Wireless sensor network survey" Computer networks, vol. 52, pp. 2292-2330, 2008.

[2] N. Pantazis and D. Vergados, "A survey on power control issues in wireless sensor networks" Communications Surveys and Tutorials, IEEE, vol. 9, pp. 86-107, 2007.

[3] K. Akyildiz, W. Su, Y. Sankarasubramaniam, and E. Cayirci, "Wireless sensor networks: a survey" Computer networks, vol. 38, pp. 393-422, 2002.

[4] M. Alnuaimi, F. Sallabi, and K. Shuaib, "A survey of Wireless Multimedia Sensor Networks challenges and solutions" International Conference on Innovations in Information Technology, pp. 191-196, 2011.

[5] S. Ehsan and B. Hamdaoui, "A Survey on Energy-Efficient Routing Techniques with QoS Assurances for Wireless Multimedia Sensor Networks" Communications Surveys & Tutorials, IEEE, vol. 14, pp. 265-278, 2012.

[6] M. Hammoudeh and R. Newman, "Adaptive routing in wireless sensor networks: QoS optimisation for enhanced application performance" Information Fusion, vol. 22, pp. 3-15, 2015.

[7] Q. Yang, S. He, J. Li, J. Chen, and Y. Sun, "Energy-efficient probabilistic area coverage in wireless sensor networks" IEEE Transactions on Vehicular Technology, vol. 64, pp. 367-377, 2015.

[8] Y. Chen, J. Shu, S. Zhang, L. Liu, and L. Sun, "Data fusion in wireless sensor networks" Second International Symposium on Electronic Commerce and Security, vol. 2, pp. 504-509, 2009.

[9] K. Akkaya and M. Younis, "A survey on routing protocols for wireless sensor networks" Ad Hoc Networks, vol. 3, pp. 325-349, 2005.

[10] C. Villada and Y. Donoso, "Multipath Routing Network Management Protocol for Resilient and Energy Efficient Wireless Sensor Networks" Procedia Computer Science, vol. 17, pp. 387-394, 2013.

[11] M. Abazeed, N. Faisal, S. Zubair, and A. Ali, "Routing Protocols for Wireless Multimedia Sensor Network: A Survey" Journal of Sensors, vol. 2013, p. 11, 2013.

[12] S. Ratnaraj, S. Jagannathan, and V. Rao, "OEDSR: Optimized Energy-Delay Sub-network Routing in Wireless Sensor Network" IEEE International Conference on Networking, Sensing and Control, vol. 15213, pp. 330-335, 2006.

[13] K. Zongwu, L. Layuan, S. Qiang, and C. Nianshen, "Ant-like game routing algorithm for wireless multimedia sensor networks" 4th International Conference on Wireless Communications, Networking and Mobile Computing, pp. 1-4, 2008.

[14] B. Bellur and G. Ogier, "A reliable, efficient topology broadcast protocol for dynamic networks" Eighteenth Annual Joint Conference of the IEEE Computer and Communications Societies, vol.1, pp. 178-186, 1999.

[15] S. Son, B. Blum, T. He, and J. Stankovic, "IGF: A state-free robust communication protocol for wireless sensor networks" University of Virginia Dept. of Computer Science Tech Report, pp.11, 2003.

[16] F. Yu, Y. Li, F. Fang, and Q. Chen, "A new TORA-based energy aware routing protocol in mobile ad hoc networks" 3rd IEEE/IFIP International Conference in Central Asia on Internet, pp. 1-4, 2007.

[17] H. Luo, F. Ye, J. Cheng, S. Lu, and L. Zhang, "TTDD: Two-tier data dissemination in large-scale wireless sensor networks" Wireless Networks, vol. 11, pp. 161-175, 2005.

[18] J. Raju and J. J. Garcia-Luna-Aceves, "A new approach to on-demand loop-free multipath routing" 8th International Conference on Computer Communications and Networks, pp. 522-527, 1999.

[19] B. Elbhiri, R. Saadane, D. Aboutajdine, "Stochastic distributed energy-efficient clustering (SDEEC) for heterogeneous wireless sensor networks" International Journal of Ad Hoc and Ubiquitous Computing, vol. 7, issue 1, pp. 4-11, 2011

[20] E. Bulut, W. Zijian, and K. Szymanski, "Impact of Social Networks on Delay Tolerant Routing" IEEE Global Telecommunications Conference, pp. 1-6, 2009.

[21] C. Min, M. Guizani, and J. Minho, "Mobile multimedia sensor networks: Architecture and routing" IEEE Conference on Computer Communications Workshops (INFOCOM WKSHPS), pp. 409-412, 2011.

[22] M. Fonoage, M. Cardei, and A. Ambrose, "A QoS based routing protocol for wireless sensor networks" IEEE 29th International Performance Computing and Communications Conference (IPCCC), pp. 122-129, 2010.

[23] Y. Yong, H. Zhihai, and C. Min, "Virtual MIMO-based cross-layer design for wireless sensor networks" IEEE Transactions on Vehicular Technology, vol. 55, pp. 856-864, 2006.

[24] S. Ben Alla, A. Ezzati, A. Beni Hssane, and L. Hasnaoui, "Hierarchical adaptive balanced energy efficient routing protocol (HABRP) for heterogeneous wireless sensor networks" International Conference on Multimedia Computing and Systems (ICMCS) pp. 1-6, 2011.

[25] C. Xiao, D. Zanxun, L. Wenzhong, H. Yuefei, W. Jie, and S. Hongchi, "ProHet: A Probabilistic Routing Protocol with Assured Delivery Rate in Wireless Heterogeneous Sensor Networks" IEEE Transactions on Wireless Communications, vol. 12, pp. 1524-1531, 2013.

[26] J. Leu, T. Chiang, M. Yu and K. Su, "Energy Efficient Clustering Scheme for Prolonging the Lifetime of Wireless Sensor Network with Isolated Nodes" IEEE Communications Letters, vol. 19, no. 2, pp. 259-262, 2015.

[27] A. Behzadan, A. Anpalagan, and B. Ma, "Prolonging Network Lifetime via Nodal Energy Balancing in Heterogeneous Wireless Sensor Networks" IEEE International Conference on Communications (ICC), pp. 1-5, 2011.

[28] K. Akkaya and M. Younis, "An energy-aware QoS routing protocol for wireless sensor networks" 23rd International Conference on Distributed Computing Systems Workshops, pp. 710-715, 2003.

[29] E. Felemban, G. Lee, and E. Ekici, "MMSPEED: multipath Multi-SPEED protocol for QoS guarantee of reliability and. Timeliness in wireless sensor networks" IEEE Transactions on Mobile Computing, vol. 5, pp. 738-754, 2006.

[30] T. He, J. Stankovic, C. Lu, and T. Abdelzaher, "SPEED: A stateless protocol for real-time communication in sensor networks" 23rd International Conference on Distributed Computing Systems, pp. 46-55, 2003.

[31] J. Ben-Othman and B. Yahya, "Energy efficient and QoS based routing protocol for wireless sensor networks" Journal of Parallel and Distributed Computing, vol. 70, pp. 849-857, 2010.

[32] X. Huang and Y. Fang, "Multiconstrained QoS multipath routing in wireless sensor networks" Wireless Networks, vol. 14, pp. 465-478, 2008.

[33] Y. Zhang and M. Fromherz, "Message-initiated constraint-based routing for wireless ad-hoc sensor networks" First IEEE Consumer Communications and Networking Conference, pp. 648-650, 2004.

[34] J. Martínez, A. García, I. Corredor, L. López, V. Hernández, and A. Dasilva, "Trade-off between performance and energy consumption in wireless sensor networks" Springer Self-Organizing Systems, vol. 4725, pp. 264-271, 2007.

[35] S. Heikalabad, H. Rasouli, F. Nematy, and N. Rahmani, "QEMPAR: QoS and energy aware multi-path routing algorithm for real-time applications in wireless sensor networks" International Journal of Computer Science Issues, vol. 8, issue 1, pp. 466-471, 2011.

[36] A. Bagula and K. Mazandu, "Energy constrained multipath routing in wireless sensor networks" International Conference on Ubiquitous Intelligence and Computing, pp. 453-467, 2008.

[37] M. Chen, V. Leung, and S. Mao, "Directional controlled fusion in wireless sensor networks" Mobile Networks and Applications, vol. 14, issue. 1, p. 220- 229, 2009.

[38] W. Yan, S. Fahmy, and N. Shroff, "Energy Efficient Sleep/Wake Scheduling for Multi-Hop Sensor Networks: Non-Convexity and Approximation Algorithm" 26th IEEE International Conference on Computer Communications, pp. 1568-1576, 2007.

[39] K. Sohrabi, J. Gao, V. Ailawadhi, and G. Pottie, "Protocols for self-organization of a wireless sensor network" IEEE personal communications, vol. 7, pp. 16-27, 2000.

[40] H. Tsai, C. Chu, and T. Chen, "Mobile object tracking in wireless sensor networks" Computer communications, vol. 30, pp. 1811-1825, 2007.

[41] Q. Huang, S. Bhattacharya, C. Lu, and G. Roman, "FAR: Face-aware routing for mobicast in large-scale sensor networks" ACM Transactions on Sensor Networks (TOSN), vol. 1, pp. 240-271, 2005.

[42] B. Bhuyan, H. Sarma, N. Sarma, A. Kar, and R. Mall, "Quality of Service (QoS) provisions in wireless sensor networks and related challenges" Wireless Sensor Network, vol. 2, p. 861, 2010.

[43] A. Ghaffari and V. A. Takanloo, "QoS-Based Routing Protocol with Load Balancing for Wireless Multimedia Sensor Networks Using Genetic Algorithm" World Applied Sciences Journal, vol. 15, pp. 1659-1666, 2011.

[44] F. Ye, G. Zhong, S. Lu, and L. Zhang, "Gradient broadcast: A robust data delivery protocol for large scale sensor networks" Wireless Networks, vol. 11, pp. 285-298, 2005.

[45] M. Chen, V. Leung, S. Mao, and Y. Yuan, "Directional geographical routing for real-time video communications in wireless sensor networks" Computer communications, vol. 30, pp. 3368-3383, 2007.

[46] B. Nazir and H. Hasbullah, "Energy efficient and QoS aware routing protocol for clustered wireless sensor network" Computers & Electrical Engineering, vol. 39, pp. 2425-2441, 2013.

[47] M. Reza, H. Behzad, and M. Majid, "QoS Based and Energy Aware Multi-Path Hierarchical Routing Algorithm in WSNs" Wireless Sensor Network, vol. 4, issue. 2, pp. 31, 2012.

[48] H. Alwan and A. Agarwal, "MQoSR: A Multiobjective QoS Routing Protocol for Wireless Sensor Networks" ISRN Sensor Networks, pp. 12, 2013.

[49] M. Akbaş and D. Turgut, "Lightweight routing with dynamic interests in wireless sensor and actor networks" Ad Hoc Networks, vol. 11, pp. 2313-2328, 2013.

[50] D. Kandris, M. Tsagkaropoulos, I. Politis, A. Tzes, and S. Kotsopoulos, "Energy efficient and perceived QoS aware video routing over wireless multimedia sensor networks" Ad Hoc Networks, vol. 9, pp. 591-607, 2011.

[51] J. Pantazis, S. Nikolidakis and D. Vergados, "Energy-Efficient Routing Protocols in Wireless Sensor Networks: A Survey" IEEE Communications Surveys & Tutorials, vol. 15, pp. 551-591, 2013.

[52] T. Bokareva, W. Hu, S. Kanhere, B. Ristic, N. Gordon, and T. Bessell, "Wireless sensor networks for battlefield surveillance" the land warfare conference, pp. 1-8, 2006.

[53] M. Hefeeda and M. Bagheri, "Wireless sensor networks for early detection of forest fires" IEEE international conference on Mobile adhoc and sensor systems, pp. 1-6, 2007.

[54] H. Shwe, H. Gacanin, and F. Adachi, "Multi-layer WSN with power efficient buffer management policy" IEEE International Conference on Communication Systems (ICCS), pp. 36-40, 2010.

[55] K. Malarvizhi, M. Brindha, and M. Kumar, "Evaluation of energy efficient routing in wireless multimedia sensor networks" 2nd International Conference on Electronics and Communication Systems (ICECS), pp. 1387-1391, 2015.

[56] A. Alanazi and K. Elleithy, "Real-Time QoS Routing Protocols in Wireless Multimedia Sensor Networks: Study and Analysis" Sensors, vol. 15, pp. 22209-22233, 2015.

[57] W. Shu, K. Padmanabh, and P. Gupta, "Prioritized buffer management policy for wireless sensor nodes" International Conference on Advanced Information Networking and Applications Workshops, pp. 787-792, 2009.

[58] M. Ahmad and D. Turgut, "Congestion avoidance and fairness in wireless sensor networks" IEEE Global Telecommunications Conference, pp. 1-6, 2008.

[59] S. Chen and N. Yang, "Congestion avoidance based on lightweight buffer management in sensor networks" IEEE Transactions on Parallel and Distributed systems, vol. 17, pp. 934-946, 2006.

[60] M. Rashid, M. Alam, M. Razzaque, and C. Hong, "Reliable event detection and congestion avoidance in wireless sensor networks" International Conference on High Performance Computing and Communications, pp. 521-532, 2007.

[61] S. Ganesh and R. Amutha, "Efficient and secure routing protocol for wireless sensor networks through SNR based dynamic clustering mechanisms" Journal of Communications and Networks, vol. 15, pp. 422-429, 2013.

[62] P. Spachos, D. Toumpakaris, and D. Hatzinakos, "QoS and energy-aware dynamic routing in wireless multimedia sensor networks" IEEE International Conference on Communications (ICC), pp. 6935-6940, 2015.

[63] J. Levendovszky and H. Thai, "Quality-of-Service Routing Protocol for Wireless Sensor Networks" Journal of Information Technology & Software Engineering, vol. 4, p. 2, 2015.

[64] S. Ehsan and B. Hamdaoui, “A survey on energy-efficient routing techniques with QoS assurances for wireless multimedia sensor networks” IEEE Communications Surveys and Tutorials, vol. 14, pp. 265–278, 2011.

[65] J. Liang, M. Liu, and X. Kui, "A survey of coverage problems in wireless sensor networks" Sensors & Transducers, vol. 163, p. 240, 2014.

[66] V. Bhandary, A. Malik, and S. Kumar, "Routing in Wireless Multimedia Sensor Networks: A Survey of Existing Protocols and Open Research Issues" Journal of Engineering, pp. 27, 2016.

[67] L. Cobo, A. Quintero, and S. Pierre, "Ant-based routing for wireless multimedia sensor networks using multiple QoS metrics" Computer networks, vol. 54, pp. 2991-3010, 2010.

[68] R. Madan and S. Lall, "An energy-optimal algorithm for neighbor discovery in wireless sensor networks" Mobile Networks and Applications, vol. 11, pp. 317-326, 2006.

[69] Z. Serhan and W. Diab, "Energy-efficient QoS routing in wireless multimedia sensor networks" IEEE 29th International Conference on Advanced Information Networking and Applications (AINA), pp. 223-230, 2015.

[70] V. Dyo and C. Mascolo, "Efficient node discovery in mobile wireless sensor networks" International Conference on Distributed Computing in Sensor Systems, pp. 478-485, 2008.

[71] R. Jurdak, P. Baldi, and C. Lopes, "Adaptive low power listening for wireless sensor networks" IEEE Transactions on Mobile Computing, vol. 6, pp. 988-1004, 2007.

[72] P. Chaturvedi and A. Daniel, "An energy efficient node scheduling protocol for target coverage in wireless sensor networks" 5th International Conference on Communication Systems and Network Technologies (CSNT), pp. 138-142, 2015.

[73] U. Pešović, J. Mohorko, K. Benkič, and Z. Čučej, "Effect of hidden nodes in IEEE 802.15. 4/ZigBee wireless sensor networks" 17th telecommunications forum (TELFOR), pp. 161-164, 2009.

[74] M. Kim and C. Choi, "Hidden-node detection in IEEE 802.11 n wireless LANS" IEEE Transactions on Vehicular Technology, vol. 62, pp. 2724-2734, 2013.

[75] A. Koubâa, R. Severino, M. Alves, and E. Tovar, "H-NAMe: A hidden-node avoidance mechanism for wireless sensor networks" IFAC Proceedings, vol. 42, pp. 10-19, 2009.

[76] S. Soro and W. B. Heinzelman, "On the coverage problem in video-based wireless sensor networks" 2nd International Conference on Broadband Networks, pp. 932-939, 2005.

[77] J. Adriaens, S. Megerian, and M. Potkonjak, "Optimal worst-case coverage of directional field-of-view sensor networks" 3rd Annual IEEE Communications Society on Sensor and Ad Hoc Communications and Networks, pp. 336-345, 2006.

[78] S. Megerian, F. Koushanfar, M. Potkonjak, and M. Srivastava, "Worst and best-case coverage in sensor networks" IEEE Transactions on Mobile Computing, vol. 4, pp. 84-92, 2005.

[79] C. Wu, K. Lee, and Y. Chung, "A Delaunay triangulation based method for wireless sensor network deployment" Computer Communications, vol. 30, pp. 2744-2752, 2007.

[80] Z. Jing and Z. Chao, "A virtual centripetal force-based coverage-enhancing algorithm for wireless multimedia sensor networks" IEEE Sensors Journal, vol. 10, pp. 1328-1334, 2010.

[81] A. Keshavarzian, E. Uysal-Biyikoglu, F. Herrmann, and A. Manjeshwar, "Energy-efficient link assessment in wireless sensor networks" 23rd Annual Joint Conference of the IEEE Computer and Communications Societies, pp. 1751-1761, 2004.

[82] S. Bagchi, S. Hariharan, and N. Shroff, "Secure neighbor discovery in wireless sensor networks" International Journal of Distributed Sensor Networks, vol. 8, pp. 763187, 2007.

[83] C. Bosch, I. González, D. Rodríguez, and C. Casañas, "Evaluation of the Effects of Hidden Node Problems in IEEE 802.15. 7 Uplink Performance" Sensors, vol. 16, p. 216, 2016.

[84] M. Hwang, S. Sheu, Y. Shih, and Y. Cheng, "Grouping strategy for solving hidden-node problem in IEEE 802.15.4 IR-WPANs", first IEEE WICON, pp 26–32, 2005.

[85] H. Zhang and S. Yoo, "Fast recovery from hidden node collision for IEEE 802.15.4 IR-WPANs" 7th IEEE International Conference on Computer and Information Technology, pp 393–398, 2007.

[86] R. Rohini and R. Gnanamurthy, "Performance analysis to improve quality of service using cluster based hidden node detection algorithm in wireless sensor networks" Intelligent Automation & Soft Computing, vol. 22, pp. 203-209, 2016.

[87] T. Lambrou and C. Panayiotou, "A survey on routing techniques supporting mobility in sensor networks" 5th international conference on Mobile ad-hoc and sensor networks, pp. 78-85, 2009.

[88] M. Di Francesco, S. Das, and G. Anastasi, "Data collection in wireless sensor networks with mobile elements: A survey" ACM Transactions on Sensor Networks (TOSN), vol. 8, p. 7, 2011.

[89] A. A. Somasundara, A. Kansal, D. D. Jea, D. Estrin, and M. B. Srivastava, "Controllably mobile infrastructure for low energy embedded networks" IEEE Transactions on Mobile Computing, vol. 5, pp. 958-973, 2006.