IEEE Access
Multidisciplinary | Rapid Review | Open Access Journal

Received August 28, 2020, accepted September 10, 2020, date of publication September 14, 2020, date of current version September 25, 2020.

Digital Object Identifier 10.1109/ACCESS.2020.3024093

Improving AODV Routing Protocol for Image Transmission Over Mobile Video Sensor Networks

MUHSIN ATTO[1,2], RAMADHAN J. MSTAFA[1,2], (Member, IEEE), AND AHMED ALKHAYYAT[3]

[1]Department of Computer Science, Faculty of Science, University of Zakho, Duhok 42002, Iraq
[2]Department of Computer Science, College of Computer and IT, Nawroz University, Duhok 42001, Iraq
[3]Department of Computer Technical Engineering, College of Technical Engineering, Islamic University, Najaf 54001, Iraq

Corresponding author: Ramadhan J. Mstafa (ramadhan.mstafa@uoz.edu.krd)

ABSTRACT Wireless Sensor Networks (WSNs) have become extremely popular for sensing, collecting, and transmitting data across different environments. In particular, the AODV protocol is widely used to improve the behavior of WSNs in various applications. A bottleneck in the protocol's performance is the amount of data that need to be moved between different nodes. This bottleneck becomes evident in applications based on multimedia contents, such as images or videos, in which huge chunks of data need to be delivered over long distances. In this article, we propose a new method to enhance the performance of the AODV protocol. Simulation results show that the proposed method improves the performance of the AODV protocol for image-based applications. The technique increases the quality of the delivered images, extends the network's lifetime, and reduces the delay and the network overhead associated with providing such images.

INDEX TERMS AODV, routing protocols, images transmission, wireless video sensor networks.

I. INTRODUCTION

Mobile Adhoc NETworks (MANETs) are infrastructure free based wireless networks where nodes need to share informations to get the whole network connected. Nodes may be able to move from one position to a another while sending and receiving data. In this case, data could be lost when the selected route for the data transmission is broken [1], [2]. Therefore, efficient routing protocols are crucial to keep data transmitted while nodes change their locations [3]. This means that nodes need to provide a local connection in order to share information about the network condition. This includes updating routing tables to discover better routes for the data transmission, when needed [4].

A MANET can be classified as one of the three different types of network: Vehicle Area Network(VANET), Wireless Sensor Networks(WSNs) and Mesh Networks [1]. In this article, Mobile Video Sensor Networks (WVSNs) are considered, due to the challenges involved in designing routing protocols for such networks. This is because large amount of data need to be delivered over long distance, such as images or videos [5]–[8].

The associate editor coordinating the review of this manuscript and approving it for publication was Zhanpeng Jin.

Based on the structure of the MANET, routing protocols are classified into two types: *proactive* and *reactive* protocols [9]. In the proactive routing protocols, links between each pair of the nodes in the network are already established. In this case, routes between the source and destinations are available in advance, before data is transmitted. These protocols can reduce delays associated with delivering data because nodes do not need wait to discover routes, before sending data. However, the overheads in the network are increased, as there is a need to share a lot of control messages. Hence, these protocols are not suitable to be used where a large amount of data needs to be transmitted in the target applications. An example of these protocols is Optimized Link State Routing protocol (OLSR) [1].

In the reactive routing protocols, routes between nodes are discovered only when data needs to be transmitted. In this case, nodes request to discover routes when they need to send data. Consequently, these protocols could reduce delay to deliver data and increase the number of the delivered packet as the network overhead is reduced by only requesting routes, when required. An example of reactive routing protocol is (Adhoc-On demand Distance Victor(AODV) protocol [10].

The AODV protocol has been used in different studies to improve MANETs for different applications [1], [10] and [11]. This is mainly because that AODV is able to provide the dynamic connection in the high mobility based scenarios. However, this protocol still needs to be improved for the high traffic applications, such as multimedia.

In this article, a new method to improve the quality of data is proposed as mechanism for making AODV protocol more efficient. Crucially, the proposed method can be implemented with no extra costs. Simulation results show that the proposed method enhance a WVSN for the target application, by improving the quality of the delivered data, reducing delay associated with delivering data and minimizing the network overhead [11].

The rest of the paper is structured as follows: Related work and the research problem are given in Section II. The new proposed method and the improved AODV are described in Section III. Wireless Video Sensor Networks and Images evaluation are given in Section IV. Performance Evaluation and Simulation results are debated in Section V. Conclusion is presented in Section VI.

II. RELATED WORK

Data in a MANET may need to be transferred over long distance, before it is received by its final destination. This shows that data may get lost before it is delivered. [12]. This is due to the fact that topology of such networks are changed very often and links between nodes could be broken. Based on this, new routing protocols have been designed to provide the required performance where data needs to be delivered, over long distance, under high mobility based scenarios.

The AODV routing protocol has been selected for many research studies related to a MANET. However, different methods have been proposed to improve AODV for different applications, where different scenarios were considered. These methods mostly deal with finding new routes discovery methods so that data is delivered as soon as possible, when the main route is broken. Based on this, many schemes to implement new techniques to find better routes in AODV have been proposed in recent years [11], [13] and [14].

Zamani and Soltanaghaei [11] proposed new approaches to to improve the performance of the AODV protocol, based on different algorithms. These new approaches are given below:

- **Back up alternative Routes (AODV-BR) Protocol**: In this protocol, new alternative routes are designed based on overhearing route reply(RREP) messages. These routes are discovered with no extra overhead in the network. In AODV-BR, when broken links are detected, nodes in the active route apply a single data broadcast to their neighbours, which sends the packets to destination via the alternative route. After data is sent, a new Route Error (RERR) message is send back to the source node, to re-request a route discovery phase. This increases the overhead in the network by duplicating data packets that travel through alternative routes.
- **Local Repair (AODV-LR) Protocol**: This protocol repairs the broken links without sending RERR messages back to the source node. This protocol suggests that there is no need for any data retransmission from the source nodes, if a broken link can be repaired locally. However, local link repairs may increase the number of data path hops and thus increase the delay. In additional, other nodes in the active nodes will not be informed about the new updates from the new route.
- **AODV-ABR: Protocol:** In this method, when a node detects a broken link, it runs a handshake process between the neighbours to repair the broken path, rather than applying a one-hop data broadcast. The handshake process is completed by two control messages: BRRQ (Backup Route Request) and BRRP (Backup Route Reply).
- **AODV-ABL Protocol**: This protocol implements an adaptive backup routing protocol along with local repair. In this case, backup routes will be created by overhearing reply messages (RREP) and data packets. Each node has a main and an alternative routing tables. AODV-ABL sends data according to the routes in the main routing table and stores the alternative routes in the backup routing table.

A new protocol(SAODV) to improve AODV where more than one routing information are considered, before route is selected, is proposed in [13]. In SAODV, different routing criteria are combined to improve the selected route. These combination include the length of the path and information from the network condition. Based on this, the new route is optimized for the target applications.

Another approach to decrease the overall delay (End-to-End delay) and increase the Packet Delivery Ratio (PDR) is implemented in [14]. This protocol apples Dijkstra Algorithm to find the shortest path when data is transmitted. A new hybrid algorithm to increases throughput, where more data can be delivered, is used in this approach.

The P-Method for against network layer attacks in MANETs, based on hop count and Round-Trip Time, is proposed in [15]. The proposed algorithm is implemented to increase the security of the AODV, under different scenarios. The given results showed that P-Method improves the original AODV by increasing the rate of the delivered data packets, reducing attacks and increasing the network throughout.

An optimal method to predicate the poor links and then reduces frequent occurrence of the broken links, is given in [16]. This protocol keeps sending data and transfers to the alternative route before the link is actually broken, when needed. This increase the performance of the AODV by reducing the delay associated with delivering data and increasing the number of the delivered data.

A. ANALYSIS OF THE RELATED WORK AND RESEARCH PROBLEM

The basic idea about new methods for the given related works are using alternative routes when the route to the destination is not found in the main route. This could happen when some nodes moved or damaged. This means that when the broken links are discovered, there will be another route to deliver data, instead of just dropping the data, as it is the case in the original AODV. However, there are possible cases when both the main and alternative routes could be broken at the same time. This is due to the fact that the node discovered the broken link has only one alternative route to keep sending data.

Therefore, a new method to find different alternative routes can improve the performance of the AODV. In additional, all the related works given above consider applications where a simple data is transmitted. However, some applications may need to collect data based on the multimedia transmissions. In this case, a new protocol needs to deal with a huge amount of data where the detected events are transmitted from the source nodes over long distance to a final destination. This means that AODV needs to be improved where the target applications need to deliver multimedia contents, such as images and videos.

Based on this, the problem which motivated us to propose this work is to improve the original AODV, by proposing a new method to improve a broken links discovery method. The new method lets nodes have *n* single hop neighbours alternative routes to deliver data, when broken links are detected. In additional, to implement a new method to increase the quality of the delivered data, where multimedia contents are considered.

In this article, images transmissions are considered for the target application, where the images of the detected events can be captures and delivered over a long distance to a final destination. These applications are considered as they need efficient routing protocols, where data is transmitted.

Based on this, the following are novel contributions this article aims to make:

1) Improving AODV protocol by discovering new alternative routes for each node in the active route, when broken links are detected.
2) Improving the the performance of the AODV, by combining information from routing and MAC layers, before data is transmitted.
3) Applying the improved schema to simulate images over WVSNs, were image of the detected events can be transmitted to a sink, over a long distance.

III. AODV PROTOCOL AND THE PROPOSED METHODS

In the AODV protocol, before data is transferred from the source nodes to the destination nodes, a new route is discovered. This involves two techniques, route discovery and route maintenance. In the route discovery, nodes request new routes to to send data, when they do not have any available routes. When intermediate nodes receive route request messages, they broadcast these messages, if they do not have routes to the given destination. However, when nodes receive route request messages for the destination which have a route, they reply with route reply messages. Upon source node receiving the route reply messages, data is transmitted [16].

The route maintenance step includes discovering a new route when current links are broken. If any node discovers a broken route while data is transmitted, all the node involved in the active route must be informed. In the following sections, more details about AODV and the new proposed method will be given.

A. ROUTES DISCOVERY IN THE AODV PROTOCOL

When source node wants to send data, it searches its routing table if it has any valid routes to the given destination. In case route is available, data is transmuted. In case no routes are found, source node creates a new route request message (RREQ) and sends this messages to the network. This control message has destination address, source address, sequence numbers for the source and destination and time to indicate when this request must be dropped. In additional, this message includes route request id which is used to prevent duplicate sending route request messages.

When nodes in the network receive RREQ messages, they update their routing tables to obtain fresh and valid routes to the AODV source node. However, if no route is found by the intermediate nodes, these messages are broadcast to the rest of the nodes in the network. This process is continue until either route to the given destination is found or given route request is expired. In order to avoid sending the same RREQ, the pair of source id and RREQ id is used. This provides the unique id for each RREQ message. Sequence numbers are used for the data freshness. This helps to update the routing tables with the last updated information from the network.

When a route is discovered by a node which has route to the destination or by the destination itself, a new control message is replied back to the source node. This message is called Route REPly(RREP). When intermediate nodes receive RREP messages, they update their routing tables with a valid route and sequence numbers to the given destination. Then, this message is unicast over other nodes in the network until it received by a source node. Upon source node receives the RREP message, data is transmitted over the discovered route.

B. ROUTE MAINTENANCE IN THE AODV PROTOCOL

In order to keep the whole network connected, nodes must provide local connection between their neighbours over a period of time. This is important to make sure if any neighbour is still active, in case needed. In AODV, nodes send hello messages to their neighbours over a single hop communication, to update their routing tables with the last updated information from different nodes. In this case, if no activity, such as data transmission, control messages or new hello message are received, from these nodes, routing tables are updated. This means that, the active routes could be broken, while data is transmitted.

When broken links are discovered (nodes damaged or moved), new control messages are used to inform the nodes in the active route about the broken links. These control messages are denoted by Route ERRor (RERR) messages. In this case, all nodes in the active route update their routing tables based on the received RERR messages. When source node receives RERR, it requests a new route for the target destination, in required.

C. DATA TRANSMISSION IN THE AODV PROTOCOL

As mentioned before, in the AODV protocol, nodes use different control messages, such as RREQ, RREP, HELLOW, to provide the connection and discover routes for data transmission, where needed. In order to deliver data, nodes use SEND and ACK control messages when data is transmitted and received between source and destination nodes, over long distance. In this case, source node waits a period of time before retransmitting the same packet. If no ACK control message is received, then the same packet is transmitted. Each packet is allowed to be transmitted in a limited number of tries.

D. THE PROPOSED METHODS IN THE IMPROVED AODV

In recent years, new methods have been designed to improve the performance of the AODV protocol, by proposing new alternative routes, when the main route are broken, while data is transmitted. These approaches use controls messages, such as RREP and RREQ, to find new routes to deliver data. This means that each node could have two routing tables: main and alternative routing tables.

Based on the related work given in this article, non of the given methods consider high data traffic based applications. This includes multimedia based applications where huge chunks of data is transmitted. This concludes that a new method is required to let the AODV protocol keeps sending data using alternative routes, where broken links are discovered.

Therefore, a new method is required to improve WSNs using the AODV protocol for the application given in this article. Based on this, this article proposes a novel method to improve the AODV protocol for the applications, where multimedia transmissions are considered. In this article, the original AODV protocol is improved by proposing the following methods:

E. NEW ALTERNATIVE ROUTES

A new technique is designed in this article to find different alternative routes for each node involved in the active route, over a single hope communication. These routes are created based on the hello messages from nodes in the current route. When nodes replying RREP to a source node, they send hello messages to all neighbours, over a single hop communication. This is important to provide the local connection between nodes in the network.

In the proposed method, hello messages headers are extended to include additional information, where route from each node in the current route to the target destination could be obtained. In this case, when each active node replays RREP, it sends a hello message to its available neighbours. When neighbours receive these hello messages, they update their routing table with a valid route to the destination. The framework for the proposed method is given in Figure 1. As shown in this figure, N2 and N3 are selected as alternatives routes for the node B. N1 and N4 are selected as alternative routes for node A. In this case, all neighbours will have valid

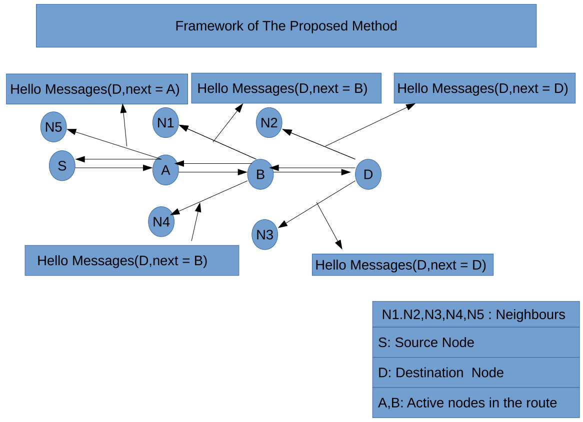


FIGURE 1. **Framework of the Proposed Method.**

routes from the source of the hello message (active node) to the target destination.

When a broken link is detected by one of the active node in the current route(for instance, node A or B, as shown in the proposed framework), then a new alternative route is locally discovered. In this case, only a single hop broadcasting is required to find a new route to send data. This means that no extra overhead is produced in the proposed method. This will decreases the overhead generated by sending back the RERR messages to the source nodes, compared to the original AODV, where all nodes in the current route need to be informed.

If no route is available from all neighbours, then a new error message is send back to the source node to request a new route. However, most of the cases, there will be at least one neighbour available for the alternative routes, when the active route is broken. This is because all the neighbours were updated with the information from the network, where the main route was constructed. This concludes that, in the the worst case, all nodes in the active route will need to be informed about the broken links, as it is the case in the original AODV protocol.

F. CROSS LAYER BETWEEN ROUTING AND MAC PROTOCOLS

The AODV protocol uses a simple MAC protocol where collision in the network is not avoided. In this case, most of the not delivered data is due to the high collision from sending a huge data in the network. This means that, a new method to reduce data collision will improve the performance of the AODV to deliver more data [5].

In order to reduce the collision from sending data at the same time, an efficient MAC protocol is crucial to be integrated with routing protocols [17]. Based on this, a new method is implemented in the improved AODV to combine information from MAC and routing layers, before data is transmitted. This method aims to decrease the data collision over a single hop communication, where more than one nodes send data at the same time. This could decrease the delay associated with delivering data and then increase the number of the delivered data packets.

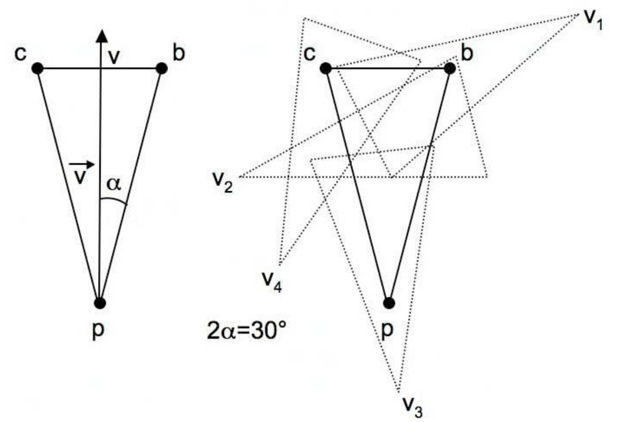


FIGURE 2. Field of View and Cover sets for Video sensors.

The proposed MAC protocol is a Time Division Multiple Access (TDMA) based MAC protocol, where data collision could be avoided by allocating nodes with different time slots. This means that nodes access the shared channel at different times. This increases the number of delivered data over a single hop communication and hence improves the performance of the AODV, where a heavy data traffic based application is considered [18].

IV. WIRELESS VIDEO SENSOR NETWORKS AND SENSING COVERAGE MODELS

WSNs have a lot of design challenges which need to be considered where new protocols are designed. These include a limited amount of energy and storage provided with each sensor. In additional, new challenges are posed when multimedia contents, such as image and videos, need to be transmitted in the WSNs. This is because a huge amount of data is required to be transmitted when multimedia are delivered from the sensor nodes to a sink, over a long distance. A WSN to transmit the multimedia contents is called Wireless Video Sensor Network (WVSN) [5], [19].

A. VIDEO SENSOR AND THEIR REPRESENTATION IN WVSNs

Each video sensor(v) in the WVSNs is an equipped with at least one small camera which is able to capture any events in its an area of interest. Each video sensor in a WVSN can be represented by its Field of View (*FoV*) [20]. A FoV is then defined by a triangle of *apb*, as shown in the Figure 2, where p is the position of the video sensor(v), *a* and *b* define the distance and a direction that a sensor node v can monitor events within the area of interest [21]. Video sensors are able to change their FoVs to monitor different areas, when it is required in the target applications.

WVSNs could have hundred or even thousand of video sensors to monitor the target applications, where a long distance is monitored. In this case, different video sensors may sense the same locations, which is called **k-coverage**. A number *k* represents the number of the nodes sensing the same locations. A new technique is required to let some of these nodes go to sleep where no events are occurred, to save energy, and let others monitor the target area. This could increase the lifetime of the network. This means that some nodes could replace other nodes where they sharing the same locations in the network. Based on this, author in [22] and [23] suggested a new method to solve these issues, which is called **Cover Set**. **Cover Set** for the video sensor(v) is denoted by *Cov(v) = N)*, where **N** is a number of the nodes sharing the same area with a sensor v.

Cov(v) for a video sensor v is calculated as shown in the figure 2 [22]. Therefore, $Cov(v) = \{v_1, v_2, v_3, \ldots, v_m\}$, where v_i covers at least one of the points (a,b,p) in the FoV(v), where $1 < i < m$. For example, Cov(v) = $\{v1, v2, v3, v4\}$, as shown in Figure 2. After cover set is calculated, a node with the higher cover set can use its maximum capture rate. This helps other nodes to go to sleep, to save energy [21].

Nodes use their capture rates based on a technique proposed in [22]. This technique shows how the frame capture rate is increased based on the criticality level of the target applications. In [22], authors suggested that a video sensor with a large cover sets could use its maximum frame capture rate to do the better events detection. This is due to that fact that when this sensor is damaged or died, one or more nodes in its cover sets can replace it. However, the more frame capture is, the more energy will be consumed [5], [24]. This could decrease the lifetime of the network.

Therefore, a new approach was designed in [23] to increase the frame capture for each video sensor based on the cover sets and level of critically of the target application. This approach is called **Bezier** method. This method was designed to dynamically change the frame capture rates based on the cover sets and the number of the detected events in the target application. An overview about how this method works is given in Figure 3.

As shown in in Figure 3, bezier method increases frame capture rates within the range **A** and **B**. This method consists of tree points **P1, P2 and P3**. These points represent the the level of risk or critical in the target application. This depends on the number of the cover sets which the current video sensor v has. Frame capture rates within the range **B** define the high critical level of the target application. This is the case when a lot of events are expected to be seen in the monitored area. However, capture rates within the range **A** represent the low level of critically for the target application. More details about these techniques and how they are designed, can be found in [22].

B. IMAGE TRANSMISSION AND EVALUATION OVER WVSNs

WVSNs are designed to monitor the target application where multimedia transmissions, such as images and videos, can be used to capture the detected events. The information about the detected events must be forwarded to a sink, over a long distance. At the sink, these images or videos can be displayed, where the required action can easily be done, based on the detected events.

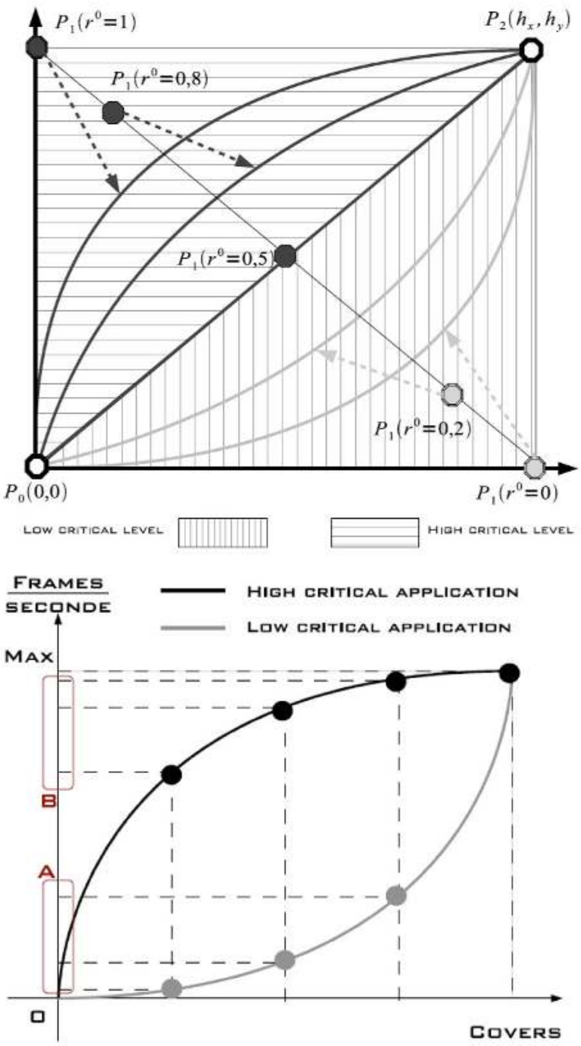


FIGURE 3. Bezier Methods to Increase the Frame Capture rate for Video Sensors [22].

A framework to simulate images for the detected events in the area of interests is implemented in [21]. This framework is aimed to evaluate the quality of the delivered images from the source nodes to a sink, over a long distance. This is useful for evaluating the performance of different routing protocols. In this case, each video sensor can send an image when it detects any event within its FoV. Nodes can also be forced to send images, when it is necessary in the target applications [24]. An example of how the environment could be monitored by a WVSN is given in the Figure 4. This figure shows how video sensor nodes sense and monitor the target environment within their FoVs.

Therefore, video sensors sense the environment using their equipped cameras and capture the images of the detected events, if there is any. These images are send back to a sink. The received images at a sink can be displayed so that information from the detected events can easily be seen [5]. The quality of the delivered images, delay associated with transmitting such images can be seen, when these images are displayed at a sink.

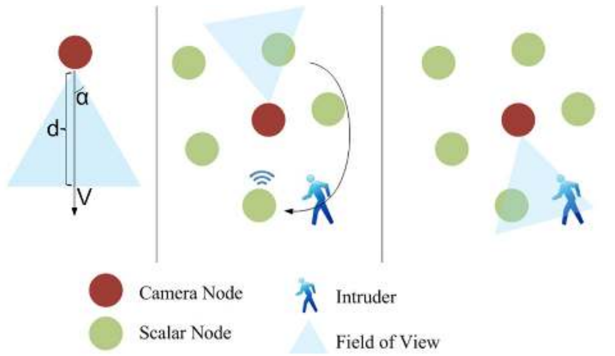


FIGURE 4. A typical Example to show how a WVSN senses and monitors the Target Area [5].

When events are detected by source nodes, a lot of data packets representing these events must be delivered to a sink, over long distance. Hence, some data packets, representing the detected images, may not be delivered. This shows that the quality of the delivered images may not be good enough to display the detected events. This means that, new efficient routing protocols are crucial to be designed to improve the quality of the delivered images, reduce delay associated with delivering these images and extend the lifetime of the network.

Based on this, in this article, the AODV protocol is improved to increase the quality of the delivered images from the source nodes to a sink, reduce delay and extend the lifetime of the entire network. Different simulation scenarios, frameworks were used to simulate the given protocols for image based applications. These scenarios and simulation results are shown in Section V.

V. PERFORMANCE EVALUATION AND SIMULATION RESULTS

In this section, simulation scenarios and results for the given routing protocols are debated. The performance of the original AODV and the improved AODV were evaluated, based on different performance factors. These factors include the quality of the delivered images, number of the data packets delivered to a sink, delay associated with delivering such images. In additional, Network's lifetime and network overhead were taken into consideration, where these protocols were simulated.

Castalia simulator on top of the Omnetpp simulator [20], [25] was used to simulate and evaluate the protocols given in this article. The Castaia simulator was selected in this article as it is one of the well known simulator which could be found and used for simulating MAC and routing protocols, using WSNs [19].

In additional, a very powerful framework to simulate images transmission based on Castalia is implemented in [23]. This framework is very useful when researchers want to use their works to simulate multimedia based applications, where videos or images could be transmitted. The multimedia evaluation used in the application given in this article is based on the framework given in [23].

TABLE 1. Simulation Parameters.

Parameter	Value
Number of Nodes	20-50
Size of Network($Meter^2$)	75
Protocols	AODV, ImprovedAODV
Number of Camera	1
Size of an image	28 data packets
Data packet size	256 bytes
dov	35 m
Line Of Sight for Camera	0–360 degrees
Maximum Camera Capture rates	3.0 (fps)
Minimum Camera Capture rates	0.01 (fps)
Maximum cover sets	8
Mobility Speed	10m/s
Image Type	BMP (128x128)
Number of cameras for each node	1
aov	75 m
Initial Energy	2 D batteries
Real Radio	CC2420

A. SIMULATION SCENARIOS AND PARAMETERS

Nodes deployed and distributed randomly into the target environment. An application to simulate the target environment, based on images, was used to sense and collect information from the monitored area. More details about this application is given in Section IV.

Each node was forced to send one image to a sink, where an event is captured. At the sink, the delivered images were displayed so that the information about the detected events can be visually seen. These included a number of the delivered data packets for the corresponding images, source nodes which sent given images and delay associated with delivering such images. This helps users to see how given protocols perform, regarding the quality of the delivered images. The rest of the simulation parameters are given in the Table 1.

The following performance evaluation factors were considered when these protocols were simulated and evaluated:

1) Quality of the delivered images.
2) Delay associated with delivering these images.
3) Network's lifetime.
4) Network's overhead.
5) Packet loss rates due to different factors.

B. QUALITY OF THE DELIVERED IMAGES

In order to measure the performance of the given routing protocols, quality of the delivered images were considered, as one of the evaluation factor. When images are transmitted from source nodes to a final destination over long distance, there is a possibility that the quality of these images will be effected. This is due to the fact that some data packets may not be delivered to a final destination.

In order to increase the number of data, efficient routing protocols are necessary to be designed. To test given routing protocols regarding the quality of the delivered images,

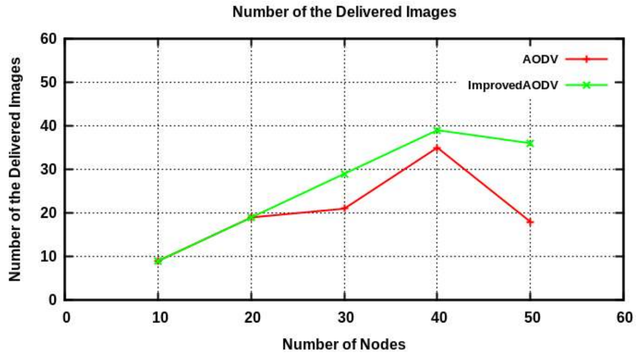


FIGURE 5. Number of the Delivered Images using AODV and the improved AODV.

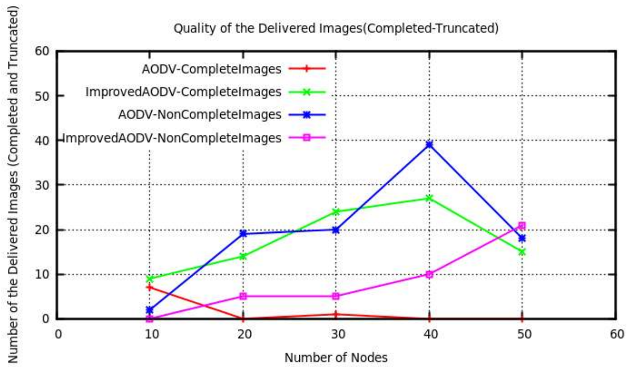


FIGURE 6. Quality of the the delivered images(Completed and non Completed).

the following performance measurements were considered in this article:

1) **Number of the received images:** The improved AODV was simulated based on the number of the delivered images, compared to the original AODV. Simulation result is shown in the Figure 5.
2) **Completed and non-completed Images:** Number of the images delivered with different qualities were simulated and measured. Simulated result about this is shown in the Figure 6.
3) **Total number of the delivered data packets:** This shows the total number of the delivered packets for all images. Results regarding this is shown in the Figure 7.
4) **Packet Delivery Ratio(PDR):** This includes the total number of the successfully delivered packets to the number of the packets were send by source nodes. Simulation result regarding the performance of the given routing protocols in term of PDR is shown in Figure 8.

$$PDR = \frac{ReceivedDataPackets}{SentDataPackets}$$

5) **Packets Signal Noise Ratio (PSNR):** This metric is used to measure the quality of the delivered images, compared to the original images. Simulation result about this is described in Figure 9.

Figures 5, 6 show that both AODV and improved AODV protocols perform similarly regarding the delivering images from the source nodes to a sink, when a low number of nodes

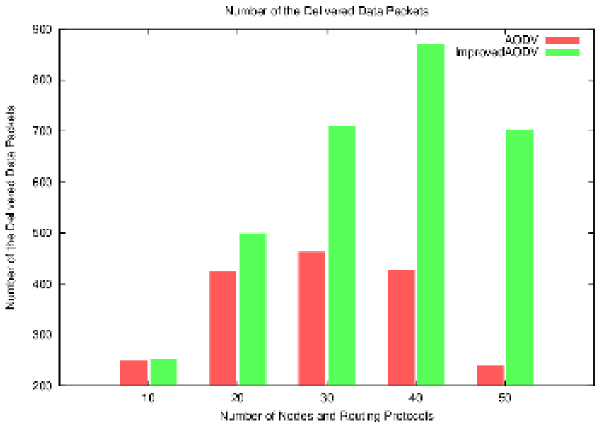


FIGURE 7. Number of the Delivered Data Packets.

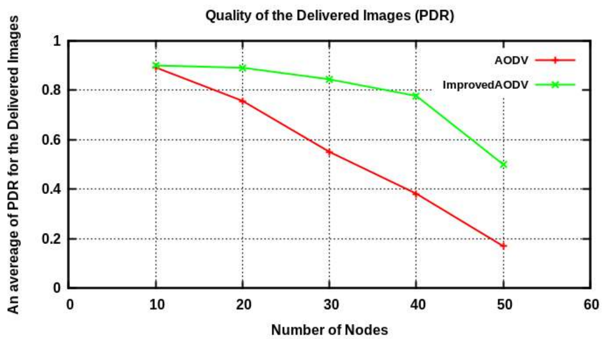


FIGURE 8. Quality of the the delivered images(PDR).

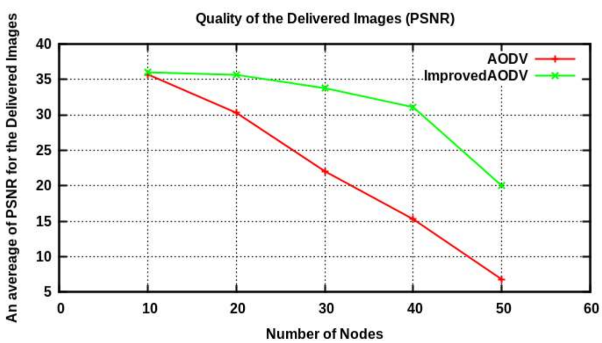


FIGURE 9. Quality of the the delivered images (PSNR (dB)).

and a short distance were considered (*Nodes* = 10). This is due to fact that nodes could deliver data using a short path which let most data packets to be delivered.

However, the improved AODV protocol performs better than the AODV protocol when a long distance and a high number of nodes were considered (*Nodes* >= 20). This is because the improved AODV protocol selects alternative routes and switch to them once the broken links were detected. However, the AODV protocol does not support this feature and then most of data packets were ignored, where broken links were detected.

Figures 7, 8 and 9 also show that the improved AODV protocol performs better than the AODV protocol in terms of delivering images with better quality. This improvement is due to the following features:

FIGURE 10. Original Image for the Performance Evaluation.

- In the improved AODV protocol, one of the neighbour is selected as alternative route to deliver data, when broken links were detected. In the improved AODV protocol, a new method was designed to implement **n** alternative routes for each node in the current route. Therefore, one of the alternative routes will be switched automatically when a broken link is detected. This concludes that data will most likely be delivered. This is because the node which needs alternative route will have at least one available neighbour to deliver data.
  This shows that the improved AODV protocol does not drop packets when broken links were detected, compared to the original AODV, while data is dropped, if no route is discovered. This shows that, number of delivered packets is increased when the improved AODV protocol is used and hence the quality of the delivered images are optimized.
- In the improved AODV protocol, cross layer information from the network condition are combined, before data is delivered. This helps nodes to send data using better routes. Therefore, the number of the delivered packets could be increased. This is due to the fact that collision from sending data is reduced, based on the information from the network condition [26]. Based on this, number of the delivered data packets is increased and then the quality of the delivered images is optimized. However, nodes in the original AODV protocol use a simple MAC protocol where collision is not avoided and then number of the delivered data is minimized. This decreases the quality of the delivered images.

To do more simulation evaluation and measurement for the given protocols, some images delivered at sink with more details are given in Figures 11 and 12. In these figures, PSNR quality measurement, a source node and delay for the delivered images are shown. It can be seen that nodes deliver images with better quality and less delay using the improved AODV protocol. For instance, as shown in given images, some brown spots are shown when some data packets were not delivered.

Figure 11 shows that source nodes (25,27,32,37,38 and 44), using AODV, could deliver one complete image (PSNR = inf) and 5 non-completed images ($11 < PSNR < 16$). However, the same source nodes deliver 3 images with (PSNR = inf), 2 with very good quality (PSNR > 23) and one with PSNR = 14.102. The reasons behind this performance

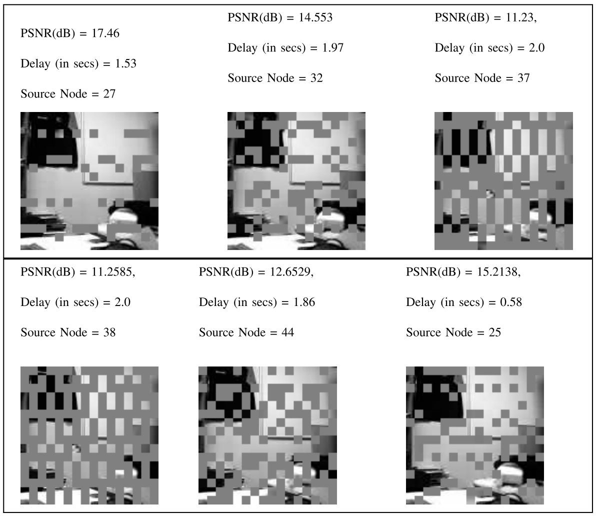


FIGURE 11. Images quality at the sink at various PSNR, delay from different source nodes using the AODV protocol.

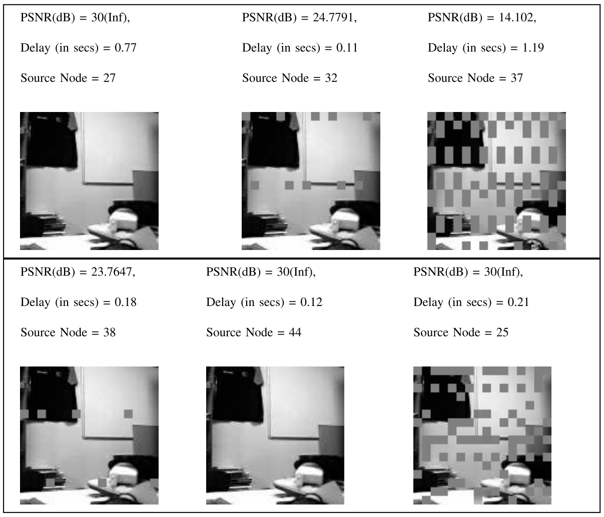


FIGURE 12. Images quality at the sink at various PSNR, delay from different source nodes using the improved AODV protocol.

are shown above. In additional, these figures show that the improved AODV protocol delivered given images with a delay less than the original AODV. The original image, which was used for performance evaluation given in this article, is given in the Figure 10.

C. DELAY FOR THE DELIVERED IMAGES

When the target environment is monitored in any WSN, the delay that users is updated with the detected events is very crucial. Therefore, given routing protocols must deliver these information to a sink within a short delay. This depends on the target application.

Based on this, given routing protocol were measured based on the delay associated with delivering images from the source nodes to a sink, where different factors where considered. Theses factors included a large number of nodes and different size of networks. Results from the simulation is given in Figure 13.

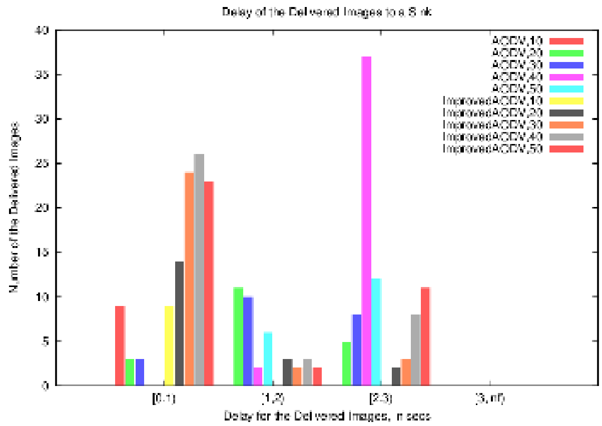


FIGURE 13. Delay of the the delivered images(in secs).

Figure 13 indicates that the improved AODV protocol delivered images with a delay less than the original AODV protocol. This performance is due to the following:

- Alternative route in the improved AODV protocol do not let data to be dropped when broken links were detected. However, in the AODV protocol, nodes need to request a new route from the source nodes to the destination, whenever broken links were detected.
- In the improved AODV, nodes combine MAC and routing related information before data is transmitted. This reduces collision from other nodes in the network and hence delay associated with delivering images is reduced. However, in the AODV, a simple MAC is used and then collision is not avoided. This concludes that delay for delivering data is increased.

D. ENERGY CONSUMPTION AND NETWORK LIFETIME

Nodes need to be alive as much as possible, otherwise, the application may not fulfil its purpose. Therefore, when new protocols are designed for WSNs, energy consumption must be taken as one of the important design factors. Efficient routing protocols have been designed to extend the lifetime of the network while providing the required performance at the same time. More energy is consumed, less nodes will be alive [18].

Lifetime of the network can be defined in different cases, based on the target applications. Some application define the time when the first node is damaged as a Network Lifetime. This includes applications where all nodes are required to be active. Some applications define the time when x percentage of the nodes are dead [19]. However, in this article, lifetime for any node is considered to be the maximum time that this node can alive, based on the consumed energy within the simulation time, as shown in (1) and (2).

$$Lifetime(n)(insecs) = \frac{simulationTime * initialEnergy(n)}{ConsumedEnergy(n)} \quad (1)$$

The lifetime of the nodes calculated in (1) is given in seconds. Therefore, in order to measure the lifetime of the nodes in more realistic way(i.e in days), result (time) from the

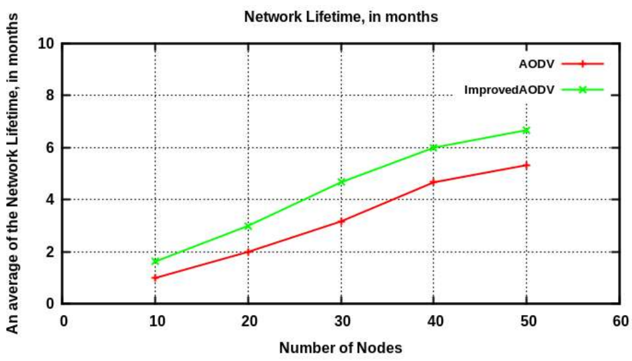


FIGURE 14. Network lifetime, in Months.

equation (1) must be calculated into days,(1 day = 86400 seconds), as shown in (2). This is due to the fact that each day has 86400 seconds *(day = 24(hrs)*60(minutes)*60 (seconds))*.

$$Lifetime(n)(indays) = \frac{\frac{simulationTime * initialEnergy(n)}{ConsumedEnergy(n)}}{86400} \tag{2}$$

Network Lifetime of the entire network is defined as an average of the lifetime of the all nodes in the given network [17], as shown in (3).

$$NetworkLifeTime(indyas) = \frac{\sum_{n=1}^{nodes}[Lifetime(n)]}{nodes} \tag{3}$$

where n is a node in the network. An *initial energy* is the energy provided to node n. A *consumed energy* is the amount of energy consumed by the node n. *Nodes* is the total number of nodes in the Network.

Therefore, the improved AODV and AODV protocols were measured based on their performance to save energy. This performance is shown in Figure 14. This figure shows that the improved AODV protocol performs better than the original AODV to extend the lifetime of the network. This performance is due to the fact that in the improved AODV, nodes uses MAC information to let them use the wireless channel so that some nodes are active while others go to sleep. This reduces the amount of energy consumed by nodes and hence extends the lifetime of the entire network.

E. NETWORK OVERHEAD

Network overhead is defined by the total number of the control messages used by the network layer, where data is transmitted. All routing protocols use different control messages to find the route before data is transmitted. In AODV, RREQ, RREP, RRER, HELLO, DATA and DATAACK messages are used when the required route for the data is discovered. In this case, these messages produce an overhead in the network when they are broadcast in the network. The more messages are sent, the more overhead will be produced. This could effect the number of the delivered data.

In this article, the given AODV and the improved AODV protocols were measured based on their performance in term of the network overhead. A result to show this performance

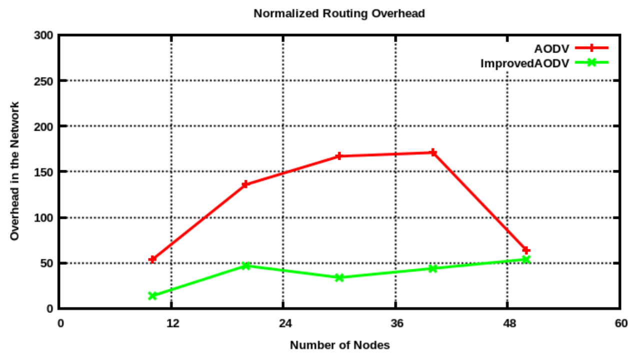


FIGURE 15. Normalized Routing Overhead.

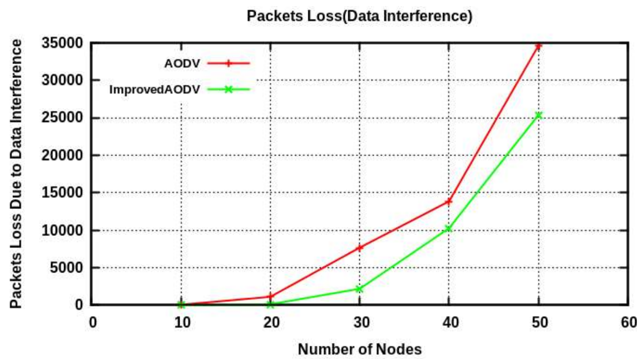


FIGURE 16. Packets Loss Rate(Data Interferences).

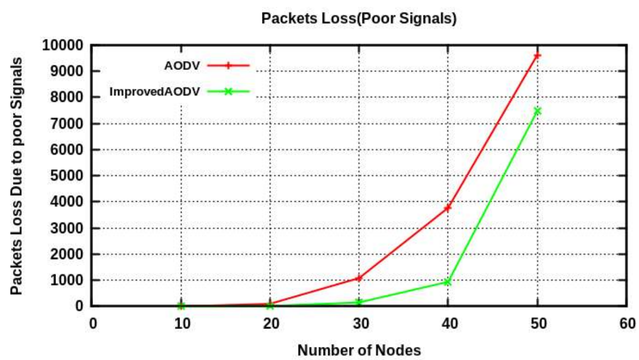


FIGURE 17. Packets Loss Rate(Poor Signal).

is given in Figure 15. This figure shows that the improved AODV protocol reduces network overhead, compared to the original AODV. This performance is due to the fact that the AODV needs to send more control messages than the improved AODV, where the required route for the data is discovered or when broken links are detected. For instance, when broken links are detected REER messages must be broadcast from the node detected the broken link back to the source node. However, in the improved AODV protocol, only this could happen when no alternative route is found.

F. PACKET LOSS RATE FACTORS

Data could be lost before it is delivered to a final destination due to different factors. These include data interference from different nodes, poor signals and where destination is

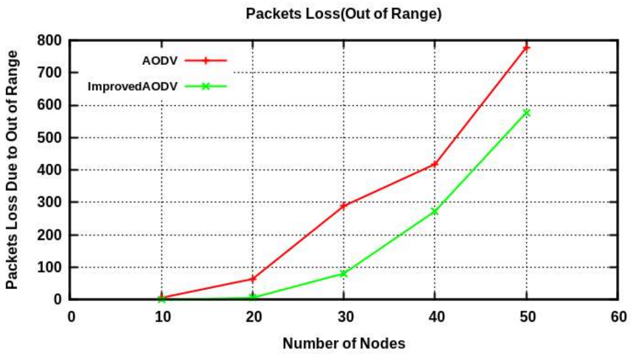


FIGURE 18. Packets Loss Rate(Out of Range).

not reachable from the source nodes. Therefore, given routing protocols were simulated and evaluated based on these factors. The simulation results are given in Figures 16, 17 and 18.

Figures 16, 17 and 18 show that the improved AODV protocol increases the number of packets delivered to a final destination, where different factors were considered. This is due to that fact that the improved AODV protocol combines information from MAC and routing layers before data is delivered. In this case, data collision, interferences from different nodes is reduced. In additional, routes with better signals are selected where data is delivered.

VI. CONCLUSION AND FUTURE WORK

WVSNs have different applications where the target area can be monitored based on the multimedia transmissions. In such applications a large amount of data needs to be transmitted. Based on this, different routing protocols have been designed to improve the performance required for such applications. In this article, the AODV protocol was improved to increase the quality of the transmitted images from source nodes, over long distance, while delay associated with these images are reduced. The proposed method was aimed to improve the broken links discovery methods where the alternative routes can be found, before data were dropped. In additional, information from the MAC and routing protocols were combined, before data is transmitted. Simulation results showed that the proposed method lets AODV protocol increases the quality of the delivered images, while delay with delivering such images is also reduced. Lifetime of the network is extended and overhead in the network is minimized. This work can be extended to deal with video based applications, such as security based applications using WVSNs. In this case, the proposed protocol must be improved more to provide the required performance for the target applications.

REFERENCES

[1] A. M. Bamhdi, "Efficient dynamic-power AODV routing protocol based on node density," *Comput. Standards Interface*, vol. 70, Jun. 2020, Art. no. 103406. [Online]. Available: http://www.sciencedirect.com/science/article/pii/S0920548919304453

[2] N. Kim, S. Cho, and J.-S. Park, "Data collection protocol for sensors networks based on molecular communications," in *Proc. Int. Conf. Electron., Inf., Commun. (ICEIC)*, Jan. 2019, pp. 1–2.

[3] Q. Wang, D. Lin, P. Yang, and Z. Zhang, "An energy-efficient compressive sensing-based clustering routing protocol for WSNs," *IEEE Sensors J.*, vol. 19, no. 10, pp. 3950–3960, May 2019.

[4] T. K. Saini and S. C. Sharma, "Recent advancements, review analysis, and extensions of the AODV with the illustration of the applied concept," *Ad Hoc Netw.*, vol. 103, Jun. 2020, Art. no. 102148.

[5] M. Atto and C. Guy, "Routing protocols and quality of services for security based applications using wireless video sensor networks," *Netw. Protocols Algorithms*, vol. 6, pp. 119–147, 08 2014.

[6] J. Kong, X. Hong, Y. Yi, J.-S. Park, J. Liu, and M. Gerla, "A secure ad-hoc routing approach using localized self-healing communities," in *Proc. 6th ACM Int. Symp. Mobile Ad Hoc Netw. Comput.*, New York, NY, USA: Association for Computing Machinery, 2005, pp. 254–265, doi: 10.1145/1062689.1062722.

[7] D. Lin and Q. Wang, "A game theory based energy efficient clustering routing protocol for WSNs," *Wireless Netw.*, vol. 23, no. 4, pp. 1101–1111, May 2017.

[8] D. Lin, W. Min, and J. Xu, "An energy-saving routing integrated economic theory with compressive sensing to extend the lifespan of WSNs," *IEEE Internet Things J.*, vol. 7, no. 8, pp. 7636–7647, Aug. 2020.

[9] R. Sadakale, N. V. K. Ramesh, and R. Patil, "TAD-HOC routing protocol for efficient VANET and infrastructure-oriented communication network," *J. Eng.*, vol. 2020, pp. 1–12, Jul. 2020.

[10] P. Pal, P. Sarkar, S. Deb, and G. Bhattacharya, "Analysis of AODV protocol in MANET," *Int. J. Comput. Appl.*, vol. 177, no. 24, pp. 1–6, Dec. 2019.

[11] E. Zamani and M. Soltanaghaei, "The improved overhearing backup AODV protocol in MANET," *J. Comput. Netw. Commun.*, vol. 2016, pp. 1–8, Jan. 2016.

[12] U. Lee, J. Kong, M. Gerla, J.-S. Park, and E. Magistretti, "Time-critical underwater sensor diffusion with no proactive exchanges and negligible reactive floods," *Ad Hoc Netw.*, vol. 5, no. 6, pp. 943–958, Aug. 2007. [Online]. Available: http://www.sciencedirect.com/science/article/pii/S157087050700025X

[13] W. Zhang, X. Xiao, J. Wang, and P. Lu, "An improved AODV routing protocol based on social relationship mining for VANET," in *Proc. 4th Int. Conf. Commun. Inf. Process. ICCIP*, 2018, pp. 217–221.

[14] M. Shrivastava, M. Sahu, M. Rizvi, and K. Ahmad, "Iaodv: An improved aodv routing protocol for manet," *Int. J. Adv. Res. Comput. Sci.*, vol. 9, no. 2, pp. 167–174, Apr. 2018.

[15] S. Zandiyan, R. Fotohi, and M. koravand, "P-method: Improving AODV routing protocol for against network layer attacks in mobile ad-hoc networks," *Asian J. Comput. Sci. Inf. Technol.*, vol. 14, pp. 95–103, Jun. 2016.

[16] M. Deepa, P. Krishna Priya, and S. Sivakumar, "QoS-enabled optimized adaptive multipath AODV protocol," *Social Netw. Comput. Sci.*, vol. 1, no. 2, pp. 1–9, Mar. 2020.

[17] C. Guy and M. Atto, "MAC protocols and mobility management module for healthcare applications using wireless sensor networks," *Int. J. On Adv. Netw. Services*, vol. 7, no. 1, pp. 308–318, 2014.

[18] M. Atto and C. Guy, "Wireless sensor networks: MAC protocols and real time applications," in *Proc. 13th Annu. Post Graduate Symp. Converg. Telecommun., Netw. Broadcast.*, Liverpool, U.K., Jun. 2012, pp. 1–6.

[19] H. M. Atto and C. Guy, "Routing protocols for structural health monitoring of bridges using wireless sensor networks," *Netw. Protocols Algorithms*, vol. 7, pp. 1–23, Apr. 2015.

[20] C. Pham, A. Makhoul, and R. Saadi, "Risk-based adaptive scheduling in randomly deployed video sensor networks for critical surveillance applications," *J. Netw. Comput. Appl.*, vol. 34, no. 2, pp. 783–795, Mar. 2011.

[21] Z. He and D. Wu, "Performance analysis of wireless video sensors in video surveillance," in *Proc. GLOBECOM IEEE Global Telecommun. Conf.*, Dec. 2005, p. 5.

[22] C. Pham, "Network lifetime and stealth time of wireless video sensor intrusion detection systems under risk-based scheduling," in *Proc. Int. Symp. Wireless Pervas. Comput.*, Feb. 2011, pp. 1–6.

[23] C. Pham, "Fast event detection in mission-critical surveillance with wireless video sensor networks," in *Proc. IEEE RIVF Int. Conf. Comput. Commun. Technol., Res., Innov., Vis. Future (RIVF)*, Nov. 2010, pp. 1–4.

[24] C. Guyeux, J. Bahi, A. Makhoul, and C. Pham, ''Secure scheduling of wireless video sensor nodes for surveillance applications,'' in *Proc. Int. Conf. Ad Hoc Netw.*, vol. 89,Sep. 2011, pp. 1–15.

[25] D. Pediaditakis, Y. Tselishchev, and A. Boulis, ''Performance and scalability evaluation of the castalia wireless sensor network simulator,'' in *Proc. 3rd Int. ICST Conf. Simulation Tools Techn.*, 2010, p. 53.

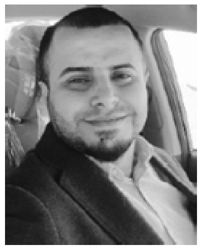
[26] Y. Tselishchev, A. Boulis, and L. Libman, ''Experiences and lessons from implementing a wireless sensor network MAC protocol in the castalia simulator,'' in *Proc. IEEE Wireless Commun. Netw. Conf.*, Apr. 2010, pp. 1–6.

MUHSIN ATTO received the B.S. degree in computer science from Dohuk University, Dohuk, Iraq, in 2004, the M.Sc. degree from Uppsala University, Sweden, in 2009, and the Ph.D. degree from the School of Systems Engineering, University of Reading, U.K.

He is currently a Lecturer with the University of Zakho, Iraq. He has published more than ten articles in different international journals and conferences. His research interests include wireless sensor networks, mobile networks, and ad-hoc networks with emphasis on designing MAC and routing protocols providing the required quality of services for different applications. One of his papers was selected as the Best Paper in conference.

RAMADHAN J. MSTAFA (Member, IEEE) was born in Duhok, Iraq. He received the B.Sc. degree in computer science from the University of Salahaddin, Erbil, Iraq, in 2003, the M.Sc. degree in computer science from the University of Duhok, Duhok, in 2008, and the Ph.D. degree in computer science and engineering from the University of Bridgeport, Bridgeport, CT, USA, in 2017.

He is currently a Lecturer with the University of Zakho, Iraq. His research interests include image processing, mobile communication, wireless sensor networks, security, watermarking, and steganography. He has published several articles in international journals and conferences in his areas of expertise. He also has more than 12 years of teaching experience in different universities and technical institutes in Iraq. He is a member of several technical and honorary societies, such as the IEEE Computer Society and ACM. He has a role as a Reviewer in many prestige journals such as the IEEE TRANSACTIONS, Elsevier, Springer, Springerplus, MDPI, and *PLOS ONE* international journals.



AHMED ALKHAYYAT received the B.Sc. degree in electrical engineering from AL KUFA University, Najaf, Iraq, in 2007, and the M.Sc. degree from the Dehradun Institute of Technology, Dehradun, India, in 2010. He is currently the Dean of international relationship and the Manager of the word ranking with Islamic University, Najaf. His research interests include network coding, cognitive radio, efficient-energy routing algorithms and efficient-energy MAC protocol in cooperative wireless networks and wireless local area networks, and cross-layer designing for self-organized networks. He contributed in organizing several IEEE conferences, workshop, and special sessions. To serve his community, he acted as a Reviewer for several journals and conferences.