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Performance study of reactive routing protocol in wildfire detection using mobile ad-hoc network

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ABSTRACT

The routing protocols play an important role in creating routes and sending packets between sensor nodes. There are many methods in the literature that presented and applied several protocols in various domains. However, there is a lack of using routing protocols in the detection of wildfire. Moreover, most methods have used a single number of sensor nodes, where there is a need to investigate the routing protocol based on different simulation parameters such as the number of sensor nodes. Therefore, in this paper, we propose a type of reactive routing protocol that is named location aided routing (LAR). The simulation of LAR protocol has been conducted based on a various number of sensor nodes in order to deeply study and investigate the LAR protocol in the detection of wildfire. In addition, different performance metrics are used for evaluating the performance of the LAR protocol. In the simulation, the performance of LAR protocol shows promising results in the wildfire detection.

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1. INTRODUCTION

Wildfire is considered a real risk that causes extreme damage to the environment and property all around the world, where this damage can be continued for a long time and it is difficult to stop it [1]. However, the result of forest fire is devastating destruction and leading even damage to the atmosphere. It has been noticed that 30% of CO2 can be spread in the atmosphere due to forest fire [2]. Furthermore, there are other extreme long-standing disastrous consequences of wildfire. For example, influences on regional weather patterns, global warming, and the extermination of fauna species and endangered flora [3]. Besides, there are big casualties that generated by the wildfire such as threaten humans, devastates the natural resources which resulting in huge financial losses [4]. Accordingly, easy and an effective approach and strategy to be used for the surveillance of wildfire is highly imperative. In this regard, there are several methods, and approaches that have been presented for monitoring and detecting the wildfire as early as possible such as monitoring towers [5], satellites [6], infrared sensors [7], and aircraft [8]. Nevertheless, the current approaches and techniques are still suffering from some drawbacks in terms of such as flexibility, early detection, cost, false alarm, and reactivity [9].

Mobile ad-hoc network (MANET) represents an encouraging solution, where this technology has been witnessed an increased attention by many researchers for the monitoring task in many various domains [10], [11]. Further, the sensor nodes in such technology have a small size, easy to deploy, as well as they are inexpensive [12]. The MANET technology is an infrastructure-less network that containing various mobile networked devices [13]. Figure 1 shows the architecture of MANET technology. The nodes in MANET are eligible for moving independently in different directions [14]. Additionally, these nodes can move in various speeds [15]. The MANET nodes can only connect with those nodes who are located within its communication radius [16]. Therefore, these nodes are cooperating with each other in order to deliver the packet from the source sensor to the target sensor.

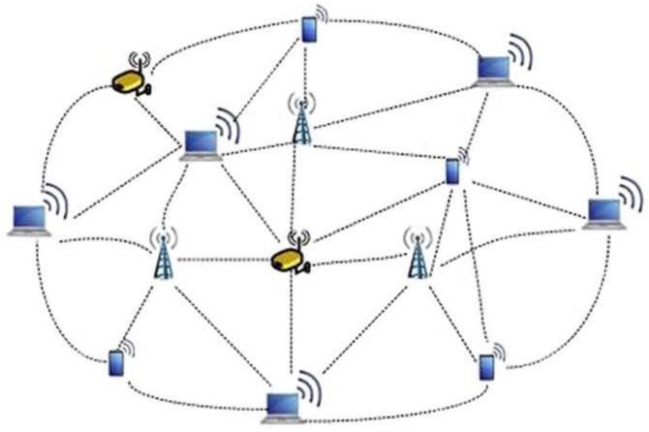

Figure 1. MANET architecture

Further, the MANET technology includes various routing protocols, where these protocols are responsible to create routes and deliver the packets [17]. The routing protocols in MANET can be categorized into three major categories namely, proactive, reactive and hybrid. Each categorize has many various routing protocols, where each protocol has its design for sending and forwarding packets [18]. Figure 2 shows the major categorizes of routing protocols [19].

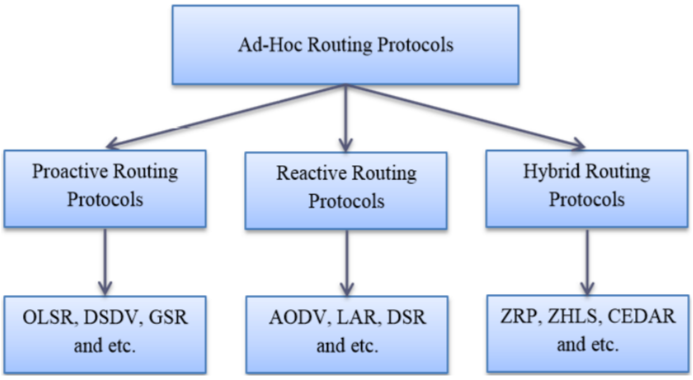

Figure 2. The categories of routing protocols

In the first category (i.e., proactive), the nodes have routing information in the form of table, where the routes will be generated before they are needed [20]. Besides, the second category (i.e., reactive), the nodes will create the routes once they are needed [21]. Whilst, in the third category (i.e., hybrid), the nodes work in both strategies of proactive and reactive [22]. Although there are some studies and works that have been used routing protocols in the detection of wildfire, these works have been used fixed parameters and ignored the use of different simulation parameters. For instance, various number of sensor nodes, and simulation time. The change of these parameters may affect mainly on the network's performance. Therefore, the main contribution of this paper can be summarised as follows: i) this paper presents the LAR protocol in the detection of wildfire with respect to the different number of sensor nodes. ii) the presented LAR protocol is evaluated in terms of well-known performance metrics.

2. RELATED WORK

There are several methods used various techniques for the purpose of detecting wildfire. These methods are aimed to prolong the network life or detect the fire at an early stage or increase the reliability. A group of researchers in [23], have presented a new routing protocol for the purpose of detecting the wildfire. The proposed protocol is based on the algorithms of ant colony optimization (ACO), where the new improved protocol is named energy-efficient and reliable ACO-based routing protocol (E-RARP). The E-RARP protocol can achieve elevated quality communication paths with respect to the energy efficiency, as well as it can guarantees the communication reliability. The proposed E-RARP protocol is aimed to decrease the delay of the network and also it aimed to prolong the network lifetime. Based on the experimental results have shown that the proposed E-RARP protocol has been overcame conventional methods of routing protocols using wireless sensor networks (WSNs) with a huge advancement of 14.71% for the network response time and 30.55% for the lifetime of the network. However, this method has been used fixed number of sensor nodes.

The Sakran *et al.* [19], have presented a type of proactive protocols which is called optimized link state routing (OLSR) protocol in the detection wildfire based on MANET technology. In this study, the proposed protocol has been evaluated and investigated in this field relaying on various number of sensor nodes. Furthermore, the OLSR protocol is evaluated based on four widely known of performance metrics. The proposed OLSR protocol has been shown encouraging results with the number of 50 of the sensor nodes.

In addition, the study in [24], has been presented a new routing protocol and then it has been applied in the detection of wildfire. The proposed protocol is based on the original OLSR, where the new proposed protocol is named power consumption efficient-optimized link state routing (PCE-OLSR). The OLSR has been developed in order to save the nodes energy and increase the network lifetime. To accomplish this, the developed protocol is sending the packet to those sensor nodes who are situated in the area of the fire. Hence, exploiting those nodes' energy entirely before they demolished by the wildfire. Thus, the energy of other sensor nodes within the network will be conserved and prolong the network lifetime. Based on experimental results, the proposed PCE-OLSR protocol has been outperformed the conventional OLSR method. However, the original OLSR protocol is outperformed the proposed PCE-OLSR in routing overhead. Moreover, the proposed method has been conducted based on constant number of sensor nodes.

A comparison among two different types of routing protocol has been presented in [25]. In this study, two types of protocols have been presented which are OLSR (i.e., proactive) and LAR (i.e., reactive). These protocols have been used and compared with each other in the detection of wildfire based on MANET technology. Also, there are many of evaluation measures that have been used to investigate the performance of these routing protocols. The experimental results have shown that both protocols have been gained encouraging results in the detection of wildfire. However, the simulation of LAR and OLSR protocols has been conducted based on single number of sensor nodes.

The Nandi [26] have presented a new model that aims to drastically decrease the number of lives lost by the wildfire. This model is based on WSNs which are placed in a widely distributed way over the forest area. In this presented model, every node can sense the temperature and humidity. Besides, each node has a speaker which is connected to a node microcontroller unit (Node-MCU). These sensor nodes gather data that is necessary for the prediction of wildfires. The data gathered is analyzed along with the wind direction by a deep learning algorithm which predicts the wildfire spreading direction. This prediction is utilized to discover a safe route for the animals to move away from the dangerous area by distressing sounds produced by the speaker. Consequently, the animals will move away from the wildfire for their self-preservation.

Considering the related work listed above, we can conclude that most studies have been performed based on fixed simulation parameters (e.g., a fixed number of sensor nodes or fixed simulation time). Which is considered as a not deep evaluation of routing protocols in the detection of wildfire. In the next sections, an introduction to the location aided routing (LAR) along with our proposed approach and the system design and simulation results are presented.

3. LOCATION AIDED ROUTING (LAR)

The LAR protocol is considered the first protocol which takes into account the location information of sensor nodes in the network [27]. In order to send the packets in this type of routing protocol from the source node (S) to the destination node (D), The S node will expect the area that includes the D node by using the location information for the D node. This area is circular and it is called the expected zone (EZ). Therefore, the D node will be expected at P_0 (X_0, Y_0) which refers to the location information and V refers to the average velocity for the D node. Furthermore, before the S node sends the packet to the D node, it determines four corners with the rectangular area which is called request zone (RZ) that includes the EZ. Figure 3 shows the EZ and RZ of the LAR protocol.

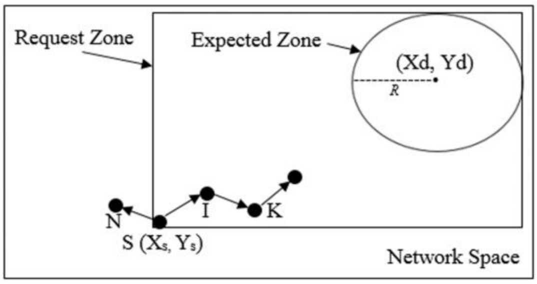

Figure 3. The *EZ* and *RZ* of the LAR protocol

This area of *RZ* is determined by the *S* node in order to reduce flooding packets within the network. In other words, when the *S* node sends the packet, only the nodes who are located inside the *RZ* will receive the packet. While, the nodes that are located outside the *RE*, will decline the packets. As shown in the figure above, the *S* node has transmitted a packet to its neighbors (i.e., other nodes). The *N* node will decline the packet because it is located outside the *RZ*. Meanwhile, the *I* node will receive the packet and also forward it to the *K* node because these two nodes are located inside the *RZ*. This packet will follow this process until it reaches the *D* node. In order to create a route from *S* to *D*, the *S* node will transmit a packet called route request packet (REQ). If this packet is received by the *D* node, the *D* node will send back another packet called route reply packet (REP). The REP will follow the same path that has been taken by the REQ. This strategy of LAR protocol is regarded to be highly efficient and also cost-efficient as compared to other conventional flooding methods that use a blind search for the whole network. However, if the REQ is not received by the D node or the REP is not received by the S node. They will be deleted and resend new REQ and REP.

4. SIMULATION DESIGN

In this study, the LAR protocol is studied and investigated in wildfire detection based on a various number of sensor nodes. There are different simulations that have been conducted in this study. The first simulation began with 10 sensor nodes and the last simulation is finished with 50 sensor nodes with an increment degree of 10 sensor nodes. Thus, the total number of simulations is 5. We have assumed that these sensor nodes have been deployed randomly in the simulation scenario which is regarded to be a square of 100×1000 m^2. In addition, the sensor nodes in all simulations are moving in a form of a circle with a radius of 125 m. Besides, these nodes are able to cover an area with a size of 250 m. In the normal conditions, the temperature of all sensor nodes is 250 ˚C and the temperature of nodes will be increased linearly when they are sensing the wildfire.

In this work, the simulation time is 1000 seconds. Besides, we have supposed that the fire is ignited after 200 seconds of the simulation time. Furthermore, the directions of fire and speed is assumed to spread in a form of circle with 0.5 m/sec radius, where the largest radius of the fire is 300 m. The fire is started in the center of the simulation scenario. Figure 2 shows the simulation scenario for 50 sensor nodes. Every 15 sec, the sensor nodes will be able to generate one packet. As well as, the data packet's lifetime is 15 sec. All simulations with respect to the number of sensor nodes are implemented by using MATLAB R2019a. In order to evaluate the performance of LAR protocol in the wildfire, we have used widely known performance metrics namely Packet delivery ratio (PDR), energy consumption, routing overhead, and End-to-End Delay (E2E Delay) [28]. These performance metrics can be computed as (1)-(4).

$$PDR\ (\%) = \frac{\sum No\ of\ packet\ received}{\sum No\ of\ packet\ sent} * 100 \quad (1)$$

$$Average\ energy\ consumption = \frac{\sum energy\ consumed\ in\ each\ node}{network\ initial\ energy} \quad (2)$$

$$Routing\ overhead\ \frac{No\ of\ routing\ packets}{No\ of\ routing\ packets + No\ of\ data\ packets\ sent} \quad (3)$$

$$E2E\ Delay\ (sec) = \frac{\sum (arrive\ time - send\ time)}{\sum No\ of\ packets} \quad (4)$$

5. SIMULATION RESULTS

In this work, the LAR protocol has been studied and investigated in the wildfire detection with respect to various number of nodes (i.e., 10, 20, 30, 40, 50). Furthermore, it is evaluated in terms of PDR, energy consumption, routing overhead, and E2E delay. Figure 4 displays the PDR results of the proposed LAR protocol with respect to the various number of nodes. When the number of nodes is 10, the proposed LAR protocol has been achieved 32.79% PDR. While, when the number of nodes is 20, 30, and 40, the PDR results of the LAR protocol were 36.84%, 60.41%, and 58.34%, respectively. In addition, the LAR protocol has been achieved the highest PDR when the number of sensor node is 50, where it has been obtained 64.03% PDR. Besides, the LAR protocol has been assessed in terms of the energy consumption. Figure 5 the energy consumption results for the proposed LAR protocol with respect to the dissimilar number of nodes. The LAR protocol has been consumed 67.30 Joules (J) when the number of sensor nodes was 10. Whilst, the LAR protocol has been consumed 123.57 J, 288.35 J, 414.35 J, and 531.11 J when the number of sensor nodes was 20, 30, 40, and 50, respectively. It is worth mentioning that when the number of nodes was 10, the LAR protocol consumed the lowest power. However, in the simulation of 50 nodes, the LAR protocol has been consumed the highest power. This is because the number of nodes has been increased and then the extra sensor nodes need more energy.

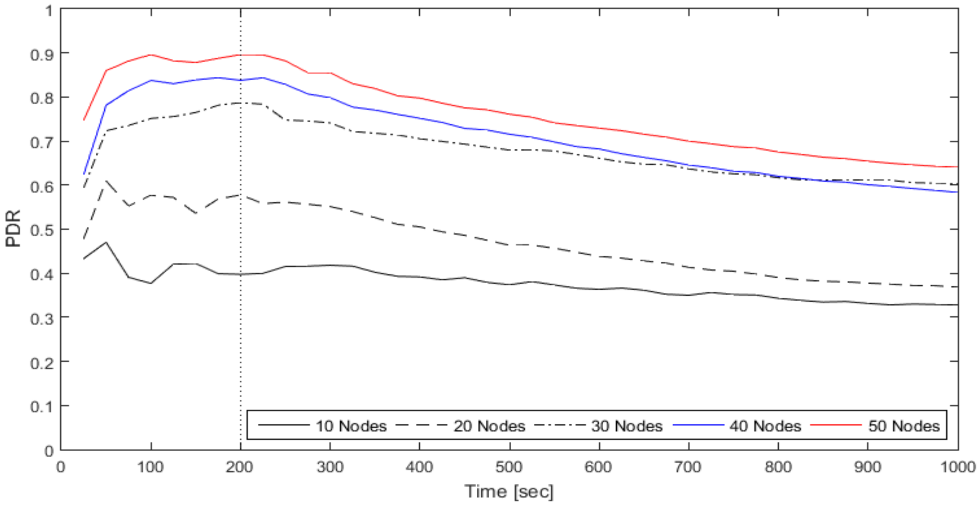

Figure 4. The PDR results

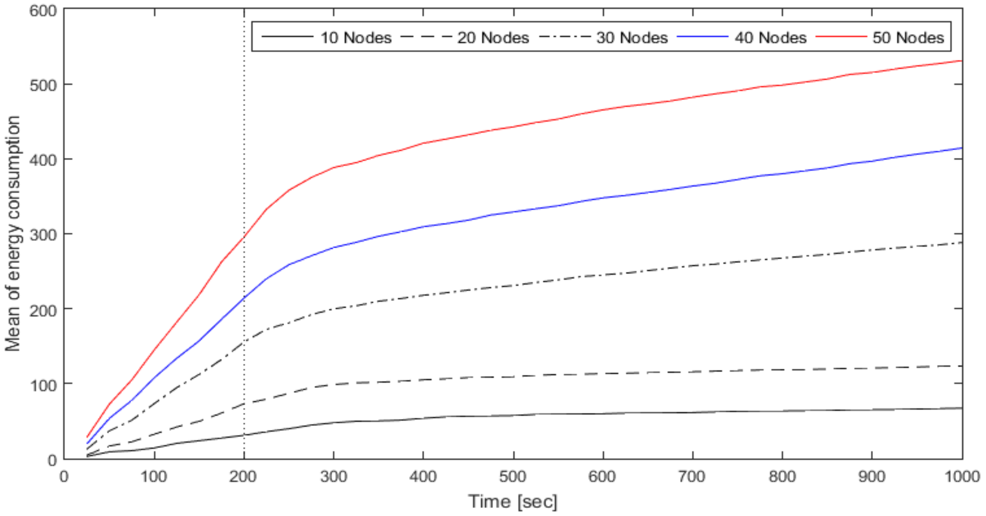

Figure 5. The energy consumption results

Further, the LAR protocol has been assessed in terms of the routing overhead. Figure 6 illustrates the evaluation results of overhead for the LAR protocol based on the various number of sensor nodes. The routing overhead for the LAR protocol was 13.48 when the number of sensor nodes was 10. Whilst, in the simulation of 20 nodes, 30 nodes, 40 nodes, and 50 nodes, the obtained overhead results of LAR protocol were 18.51, 18.44, 23.63, and 24.44, respectively. It is obvious that the LAR protocol has been achieved the lowest overhead in the simulation of 10 nodes, and this is because there was a small number of nodes. Finally, the proposed LAR protocol has been evaluated in terms of the E2E delay. Figure 7 depicts the E2E delay results for the LAR protocol by using the different number of nodes. In the simulation of 10 nodes, the E2E delay result of the LAR protocol was 306.81 sec. In the simulation of 20 nodes, the E2E delay result of the LAR protocol was 328.99 sec. While the E2E delay results of the LAR protocol in the simulation of 30 nodes, 40 nodes, and 50 nodes were 251.28, 253.62, and 242.75, respectively. However, due to the small number of nodes in the simulation of 10 nodes, the LAR protocol obtained the highest E2E delay.

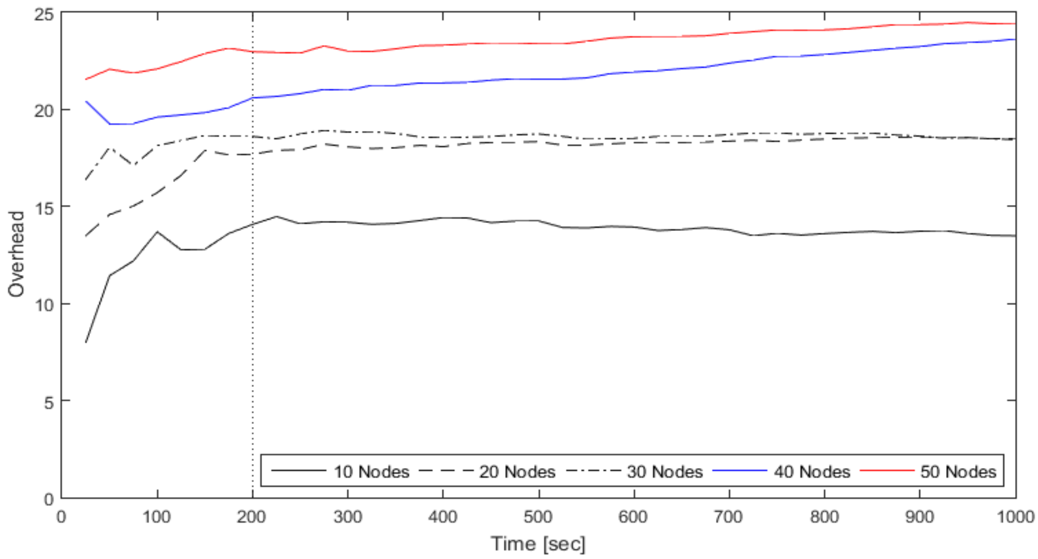

Figure 6. The overhead results

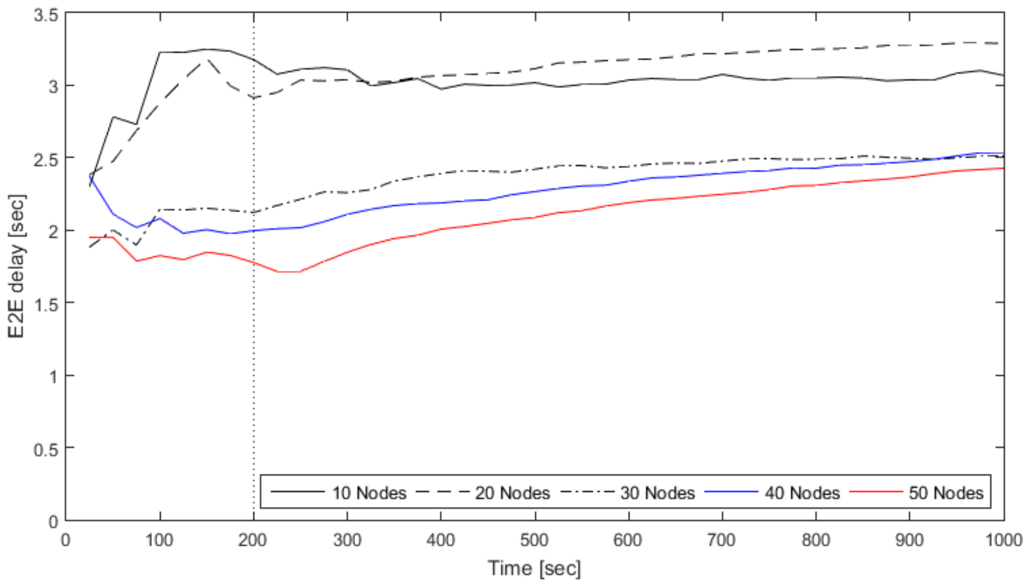

Figure 7. The E2E delay results

6. CONCLUSION

In this paper. we have studied and analyzed a type of reactive routing protocol that is named location aided routing (LAR) in the detection of wildfire based on MANET technology. In this work, the LAR protocol has been conducted based on a various number of nodes in the network. In other words, there were 5 simulations of LAR protocol, where the first simulation has been performed with 10 nodes and the last simulation has been performed with 50 nodes. Furthermore, we have used well-known performance measurements for the purpose of evaluating the performance of LAR protocol. Based on the simulations, the performance of the LAR protocol has shown promising results in forest fire detection. When the number of nodes was 50, the LAR protocol is showed the best results in terms of PDR and E2E delay. Besides, when the number of nodes was 10, the LAR protocol is showed the best results in terms of energy consumption and overhead. In future work, we plan to improve the performance of LAR protocol with respect to the energy consumption in order to prolong the network lifetime.

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