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Performance Evaluation of LAR and OLSR Routing Protocols in Forest Fire Detection using Mobile Ad-Hoc Network

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Abstract

Objectives: To provide an assessment of two different types of MANET routing protocols. **Methods/ Statistical Analysis:** One of the key applications of the MANET technology include the disaster responding and the rescuing applications. Forest fires need a constant monitoring and an efficient communicative system. MANET includes several routing protocols. In spite of there being a large number of protocols, their performance in such disaster situations is ineffective due to high costs and a practical inability to recreate this scenario in a lab. **Findings:** The routing protocol performance was assessed using the MATLAB software. The different evaluation metrics that were adopted included the energy consumption, packet delivery ratio, routing overhead, and the end-to-end delay. **Application/ Improvement:** In our study, we have simulated a model for the forest fire disaster and have assessed two different routing protocols, i.e., the reactive Location-Aided Routing (LAR), and the proactive Optimised Link State Routing (OLSR). These protocols were evaluated to determine which is the more effective and reliable protocol amongst the two, in the case a forest fire disaster occurs. Our results have shown that the reactive LAR protocol was much better as compared to the proactive OLSR protocol as it showed better results for the Packet Delivery Ratio (PDR), energy consumption, and overheads, while the OLSR protocol has lesser values for the End-to-End Delay (E2E-Delay) parameter.

Keywords: Forest Fire Detection, Location-Aided Routing Protocol, Mobile Ad Hoc Network, Optimised Link State Routing Protocol, Routing Protocols

1. Introduction

The MANET technology includes a set of independent mobile nodes that possess the capacity to communicate amongst themselves using radio waves[1,2]. The MANETs provide the consumer with the capability for communication without the use of any kind of physical infrastructure anywhere in the world – thus, establishing MANET to be an infrastructure-less network system.[3,4]

MANET technology can be installed easily without requiring detailed planning for implementing the functional network-based mobile network nodes. These mobile nodes would be in the form of any type of portable devices, like the laptops, smart phones or even tablets. All mobile nodes can communicate with each other using radio waves, where every mobile node possesses a wireless interface which makes these mobile nodes act like routers if the neighbouring mobile nodes are present within a covering area by the other mobile network nodes[5,6].

The MANET technology can be used in several applications that are favourable in the case of an emergency or rescue operations like the various disaster relief efforts, floods, forest fires, volcanoes, earthquakes, etc. The occurrence of these types of disasters results in a loss of communication and hence, it is very obvious that an effective alternative communicative system

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is needed. These occurrences require emergency relief operations which are reliable and rapidly deployed when the communication is damaged.

The forest fires are huge disasters which have a negative impact on the economic, social and ecological parameters, and they drastically affect human life along with the forest resources. The fires can be ignited by the human activities, climatic changes, or several other reasons. In the forest fire detecting networks, as a continued and a real-time monitoring of fires are needed, there is a huge amount of power consumption, specifically when the batteries have to be recharged or replaced. Furthermore, in forests, the huge amount of vegetation and the tree density affects the signal transmission; hence, for monitoring the forests, better and more dependable routing protocols like the LAR or the OLSR protocol is required. We have used these protocols in this study as they are very popular and widely used. Earlier studies[7] mention that the OLSR protocol shows a much better performance as compared to all other protocols. Similarly, even the LAR protocol displays a good performance[8], but both of these network protocols have not been used for detecting forest fires. Thus, in this study, we have evaluated the performance of both these network protocols for determining which is better and more reliable for detecting forest fires.

Earlier studies[9] compared the efficacy of three network protocols (DSR, DSDV, and AODV) for detecting forest fires. The different performance metrics which were compared included the packet delivery ratio, energy consumption, and the mean end-to-end delay after using the NS-2. Their results showed that the AODV routing protocol was much better than the DSR and DSDV for the packet delivery ratio parameter while, AODV displayed the lowest values for the end-to-end delay, and hence, it was considered to be the best network. In the case of energy consumption, the DSDV protocol displayed a better performance, and showed lower values than the AODV and DSR protocols, while AODV had highest energy consumption.

Another study[10] suggested the use of a proactive routing technique (EMA), which has a knowledge regarding the threat to the mobile nodes and hence, avoids all the broken or damaged nodes. The proposed network performance was compared to the OLSR protocol with the help of the OPNET simulation based on the energy consumption and the end-to-end delay metrics. Their proposed algorithm was implemented using the single and the multiple sinks. Their results showed that the EMA algorithm used with multiple sinks, displayed no added overhead as it avoided the damaged routes which were caused due to the forest fires, thus making their system more reliable and available for communication. Their algorithm was seen to be more resistant as compared to the standard protocol when more parameters were added according to the application, and it could be used with the reactive network protocols and the sensor nodes for further applications.

In one earlier study[11] the author, suggested a design framework having an optimal control approach for effectively carrying out a surveillance over huge disaster-hit areas using flying robots for determination of the actual extent of the damaged property. The paper focused primarily on the development of an Adaptive and an Energy-efficient Routing Protocol (AER) having a low energy dissipation and delay as compared to the Dynamic Source Routing Protocol (DSR). It was seen that the AER protocol could determine the most effective route by considering the signal strength, residual energy, and several other environmental parameters. When compared to the DSR protocol, the AER protocol had higher values for the packet delivery ratio, and lower values for the packet loss ratio and the delay, thus, making it a better protocol as compared to the DSR network protocol.

Additionally, in one earlier report[12] proposed a routing protocol which could proactively adapt the routes for detecting forest fires with the help of wireless sensor networks based on the various environment influences which could threaten the mobile nodes. This proposed algorithm was known as Environmental Monitoring Aware (EMA) routing which was assessed with the help of the OPNET network simulator. Their paper aimed to propose a routing technique which considered the threat to the nodes and adapted the routes before the node failure resulted in damaged nodes. Furthermore, they assessed the performance of this proposed routing algorithm and compared it to the AODV protocol, under similar circumstances. Their results indicated that the AODV protocol displayed a lower and a more varied incoming packet rate value through the complete simulation process. This indicated that AODV protocol showed less successful transmission, and the proposed EMA protocol had lower delays as compared to the AODV protocol.

A novel routing protocol, called as the Maximise Unsafe Path (MUP) was proposed by[13]. Their protocol aimed to extend the life of the network, by transmitting the data packets to the mobile nodes which are present in the danger zones and would fail soon and also by using the energy present in those nodes which would be damaged soon, thereby saving the energy present in the other undamaged nodes. The MUP protocol was implemented with the help of the COOJA simulation tool and was assessed with the RPL routing protocol for different fire extension speeds and was assessed for the network life, packet delivery ratio and end-to-end delay performance metrics. The MUP protocol consists of three different modules, like the neighbourhood management, critical event detection, and the routing management. The module for the critical event detection was used for detecting the occurrence of any critical events and then sending a warning to a network routing management module if a critical event is discovered. The next module, i.e., neighbourhood management helps in the detection of the subset of the forwarding candidate mobile nodes and also helps in preserving the routing tables. Finally, the last routing management module was a very important module that helped in forwarding the decisions and updated the forwarding choices. The MUP protocol provided an effective mechanism for specifying the fire threat for every sensor node present in the mobile network. Several threats affect the sensors which help in temperature monitoring. The MUP protocol introduced 4 different threats affecting the health of the mobile nodes, called as the SAFE, LOWSAFE, UNSAFE and ALMOST-FAILED. Also, the MUP network displayed better network life as compared to the RPL protocol, however, RPL performed better for the packet delivery ratio and the end-to-end delay metrics.

Also, the Hierarchy-Based routing protocol (HB-AODV) was proposed earlier[14], for disaster recovery, wherein the protocol could be used for presenting a mechanism for rescuing the survivors who were trapped in the many dispersed local sub-networks. This network also helped in deploying fast-moving nodes which represented the rescue vehicle teams that could cover the local sub-networks. Their proposed algorithm was assessed and compared to the reactive protocols, i.e., AODV, and DSR under two different circumstances, and their performance was gauged based on the performance metrics of end-to-end delay, packet delivery ratio, packet loss ratio and the routing overhead. The protocol's hierarchical structure consisted of 4 node types - source nodes, subnet heads, mobile nodes and destination nodes. The source nodes represented the rescue teams which could identify the victims (packets) that had to be transmitted to the (transmitter) central places (destinations for treatment). The subnet heads represented the head of the rescue team who coordinated between the members of the rescue team and the rapidly-transmitting monitoring team (fast mobile node) which enable a rapid transportation of all the victims to a central location (destination). Furthermore, the mobile nodes represented the fast-moving mobile node which helped in an immediate transport of the victims from the subnet heads to a central place. Finally, destination nodes represented the central location where the victims were brought for receiving treatment. Their results indicated that their protocol displayed much better results for the packet delivery ratio as compared to the AODV and the DSR protocol. Also, their protocol displayed lower values for the packet loss ratio and the end-to-end delay values as compared to the DSR and AODV protocol, however, the HB-AODV routing protocol displayed higher values for the routing overhead value as compared to the AODV and DSR. The summary of all related work has been presented in Table 1.

2. Optimized Link State Routing Protocol (OLSR)

The Optimised link state routing (OLSR) protocol[15] is a type of proactive routing protocol, wherein every mobile node intermittently transmits the routing table that allows every node to construct the all-inclusive view regarding the network topology. This episodic OLSR nature results in a huge overhead and for reducing this overhead, the protocol limits the mobile node number which can forward the network-wide traffic. Hence, it uses the MultiPointRelays (MPRs) that forward the messages and are able to optimise the flood operation. The mobile nodes selected as the MPRs are able to forward the control traffic and decrease the control message size. They are selected by the node, in a manner that it can reach the 2 hop neighbours using one MPR, and can forward the data packets if the control traffic that is received from an earlier hop has been selected as the MPR. The route changes, mobility causes, and the topology changes vary frequently and the Topology Control (TC) messages can be transmitted through the complete network. All the mobile nodes preserve a routing table which consists of routes for all the probable destination mobile nodes. This OLSR protocol does not inform the source instantly if it has detected a broken or a damaged link. The source nodes obtain this information from the intermediate nodes when they broadcast their next data packet.

Table 1. A Summary of all the Related Work

Author / Year	Routing Protocols	Disasters	Limitations
In [9]	DSDV, DSR and AODV	Forest fire detection	Their comparison made no mention about the best routing protocol to be used in detecting forest fires, as the AODV protocol displayed a better performance regarding the packet delivery ratio and end to end delay, but it failed in the parameter for energy consumption, thereby decreasing the life of the network.
In [12]	EMA and OLSR	Forest fire detection	Their algorithm made no use of a reactive routing protocol. More parameters could be added, like energy consumption (if 3 parameters displayed similar values, select neighbours with a higher energy for continuing the network as much as possible). The mobile nodes did not share any of their collected data with the other nodes, they simply compared the neighbours till they reached their destination node
In [18]	AER and DSR	Network involving Flying Robots for Monitoring a Disaster-Hit Area	1. No performance evaluation for energy consumption was carried out. 2. Their protocol comparison did not include any proactive routing protocol.
In [9]	EMA and AODV	Forest fire detection	1. The algorithm evaluation and comparison with the AODV protocol did not include any multiple sink scenarios. 2. They carried out no comparison of their algorithm with any proactive routing protocols. 3. The mobile nodes did not share any data with other nodes.
In [13]	MUP and RPL	Forest Fire Monitoring System	1. The MUP protocol chooses only these nodes which are located in dangerous zones; however a lot of data can be collected from the buffer area, which could result in a loss of data. 2. The mobile node burns before transmitting the relevant data. Hence, a higher priority alert data packet is dropped as the MUP does not take into account every alert data priority signal.
In [14]	HB-AODV, DSR and AODV	Disaster Recovery System	1. No comparison is carried out between their proposed protocol and the proactive routing protocol. 2. Energy consumption is not selected amongst the performance metrics studied. 3. Their proposed protocol failed in the routing overhead, which showed a better performance as compared to the other network protocols.

3. Location Aided Routing Protocol (LAR)

The LAR protocol is a type of the on-demand routing network protocol, with an operation similar to the Dynamic Source Routing (DSR). Unlike the DSR, the LAR utilises the geographic location information for restricting an area while discovering novel routes for a small area, known as the request zone. Rather than flooding all the route requests in the complete network, the nodes present in a request zone would forward the data. The source node estimates the circular area, (known as the expected zone), wherein the destination is likely to be present at a particular time[16]. The size and the position of the circular zone are determined depending on the earlier knowledge of the located zone with respect to the earlier destination node, the time connected with the earlier location and the destination average speed. The request zone is a very small rectangular area which includes the source and the expected zone. Several studies were carried out for changing the size and the shape of this request zone for improving the system performance. The route request data packet includes the four corner coordinates for initiating the route detectingmethod. The RREQ broadcast is however limited to the request zone. Hence, when any node, present in a request zone receives an RREQ, then, it can forward the data packet normally. But, if any node which is not present in this request zone obtains the RREQ; it tends to drop the data packet.

4. Environmental Model and the Fire Model

Without generalising, we have assumed the environment to be some forest area with dimensions (1000m×1000m) having 60 nodes that move in arbitrary directions. In Figure 1 illustrates the environmental model. The node velocity changes as per the uniform node distribution in the x, y plane.

Fire is stimulated to begin at one particular point in this environment (x_0, y_0) at time, t_0. The fire radius expands based on the below equation:

$$r = r_0\left(1 - e^{(-\alpha(t-t_0))}\right)$$

In the equation, r_0 represents the maximal fire radius after its expansion; t represents the present time; α denotes the tuning parameter which is dependent on the speed of the fire expansion.

The LAR and the OLSR were evaluated based on the performance metrics of energy consumption, end-to-end delay, packet delivery ratio, and the routing overhead. In this mode, the simulation time was 1000 seconds. In this study, we have presumed that the forest fire has been initiated after a period of 200 seconds, and it was seen that different routing protocols performed differently after fire ignition. The simulation parameters for the LAR and the OLSR protocol have been presented in Table 2 and 3 respectively

5. Performance Evaluation Measures

The performance metrics can be presented in many ways, like the performance metrics which are run by the delivery fraction of a packet, and the E2E delay that have been suggested earlier[17,18]. Despite these, with respect to the node mobility pattern, simulation is required[19] which suggests using a random waypoint mobility model for determining the delay.

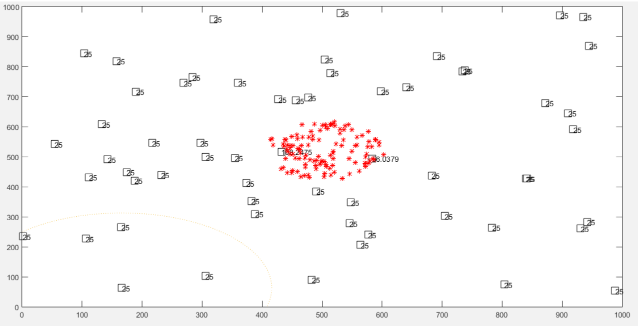

Figure 1. Environmental Model.

Table 2. The Simulation Parameters for the LAR protocol

Parameter	Values
Experiment duration	1000 [sec]
Rate of logging data	25 [sec]
The moment of fire	200 [sec]
Number of nodes	60 [node]
Coverage zone radius	250 [m]
Average size of packet	80 [bite]
Node initial temperature	25 [deg]
Node velocity	Randomly distributed in [7.5-12.5] m/sec
Fire radius	300 [m]
Environment dimensions	1000*1000[m^2]
Start point of fire	Randomly chosen to be near Env. centre
Simulator	MATLAB 2015
Data buffer size	100 [packet]
Data packet lifetime	10 [sec]
Interval arrival time	6 [sec]
Data packet generation mean	2 [packet]
Route request timeout	2 [sec]
Route request buffer size	1600 [packet]
Route reply buffer size	100 [packet]
Time unit	10 ms
Performance Metrics	Routing Overhead, Packet Delivery Ratio, Energy Consumption and End-to-End Delay.

5.1 Packet Delivery Ratio (PDR)

PDR refers to the ratio of the number of the delivered data packets that are received by the destination node to the data packets sent by the source application layer. This number specifies the packet loss rate and limits the network throughput to a maximal rate. PDR is a very important factor in a routing protocol in real environmental disasters like floods or earthquakes, where the error margin should be minimal. PDR can be calculated in the following manner:

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

Table 2. The Simulation Parameters for the OLSR protocol

Parameters	Value
Experiment duration	1000 [sec]
Rate of logging data	25 [sec]
The moment of fire	200 [sec]
Number of nodes	60 [node]
Coverage zone radius	250 [m]
Average size of packet	80 [bite]
Node initial temperature	25 [deg]
Node velocity	Randomly distributed in [7.5 12.5] m/sec
Fire radius	300 [m]
Environment dimensions	1000*1000[m^2]
Start point of fire	Randomly chosen to be near Env. centre
Simulator	MATLAB 2015
Data buffer size	100 [packet]
Data packet lifetime	10 [sec]
Interval arrival time	6 [sec]
Data packet generation mean	2 [packet]
Hello message buffer size	100
Time period of hello messages	2 sec
Neighbour table record validity time	6 sec
Minimum period of TC messages	2 sec
Time period of TC messages	5 sec
TC message buffer size	1000
Topology table record validity time	15 sec
Routing table size	100
Performance Metrics	Routing Overhead, Packet Delivery Ratio, Energy Consumption and End-to-End Delay.

5.2 End to End Delay (E2E DELAY)

The data packets arrive at the destination based on their average time. For this performance metric evaluation, the time point at which the first data packet is transmitted from some source is subtracted from the time point when this data packet reaches the destination. The E2E delay can be calculated in the following manner:

$$\text{E2E Delay (ms)} = \frac{\sum(\text{arrive time} - \text{send time})}{\sum \text{No of packets}} \qquad (2)$$

5.3 Routing Overhead

The routing metric, performance metrics can be described as the overall routing packet number which is divided by the total number of data packets delivered. This paper has analysed the mean routing packet number that is needed for delivering one single packet. This performance metric gives an idea about the additional bandwidth used by overheads for delivering the data traffic. Routing overhead impacts the network robustness with respect to the battery consumption by the nodes and the bandwidth usage. The routing overhead can be calculated in the following manner:

$$\text{Routing overhead (\%)} = \frac{\text{No of routing packets}}{\text{No of routing packets} + \text{No of routing packets sent}} * 100 \qquad (3)$$

5.4 Average Energy Consumption

The estimation of average amount of energy consumed by the network is a very important parameter. It can be estimated in the form of overall energy consumed by every network node divided by the initial amount of energy present. The initial amount and the final energy amount present in the nodes can be estimated after the simulation process. The average amount of energy consumed can be estimated in the following manner:

$$\text{Average energy consumption} = \frac{\sum \text{energy consumed in each node}}{\text{initial energy}} * 100 \qquad (4)$$

6. Simulation Results and Discussion

The assessment of the suggested model for detecting forest fires can be carried out using two routing protocols, i.e., Location-Aided Routing protocol (LAR), which is a reactive routing protocol and the Optimised Link State Routing(OLSR), which is a proactive routing protocol. In this paper, simulation was carried out using the MATLAB software, 2015, which is able to handle huge amounts of data efficiently. MATLAB is very commonly used software, because of its high capacity to carry out complex mathematical calculations and results in visualising the data. However, MATLAB has been applied mostly in data analysis, simulation, calculation or algorithm evaluation.

The LAR and the OLSR network protocols were assessed and compared for detecting forest fires using the mobile ad hoc network. Due to the differences between the protocols, the assessment and comparison of the protocols resulted in some interesting results.

According to the results obtained, the LAR protocol displayed better performance as compared to the OLSR protocol for the packet delivery ratio metrics Figure 2, LAR protocol has achieved PDR to 0.6852 and OLSR protocol has achieved PDR to 0.2917, wherein it can be seen that the LAR protocol received a higher amount of data as compared to the OLSR protocol. With regards to the energy consumption parameter, the LAR protocol displayed lower values as compared to the OLSR protocol Figure 3, where LAR protocol has achieved energy consumption value equal to 682.6 joules and OLSR protocol has achieved energy consumption value equal to 1833 joules.Because of the proactive nature of the OLSR protocol. The proactive type of routing protocols involve nodes that store the routing data in the form of tables, and the nodes have to update their tables routinely, hence requiring a larger amount of energy. Thus, the LAR protocols improve the life of the network. As shown in Figure 4, it can be observed that the LAR protocol has higher end-to-end delay as compared to the OLSR protocol. OLSR protocol has achieved average E2E Delay value equal to 0.9942 sec and LAR protocol has achieved average E2E Delay value equal to 2.215 sec.This can be due to the proactive nature of the OLSR protocol, wherein the nodes are seen to establish routes even before the routes are required. Thus, when data needs to be transmitted, it can be sent in a faster manner as compared to the reactive routing protocol. In Figure 5 displays the results of the routing overhead performance metrics, and it can be seen that the LAR protocol performance is lower than the OLSR protocol, LAR protocol has achieved overhead value equal to 25.95. While OLSR protocol has achieved overhead value equal to 152.1. LAR protocol maintains a similar value throughout the complete simulation run. As can be seen from the above results, both the routing protocols perform differentially for different performance metrics, after the fire has been ignited.

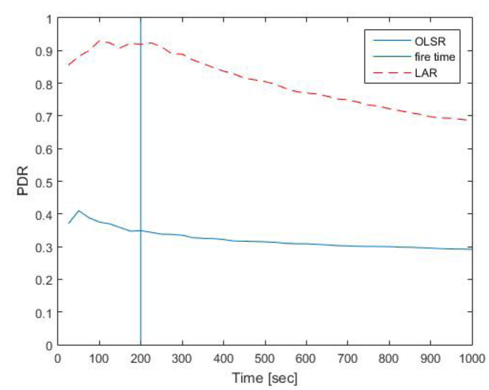

Figure 2. Comparison of LAR protocol and OLSR protocol in the packet delivery ratio.

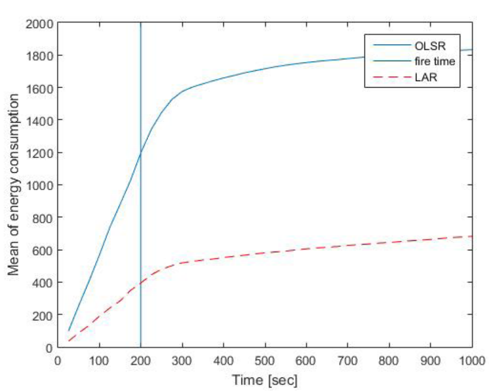

Figure 3. Comparison of LAR protocol and OLSR protocol in the energy consumption.

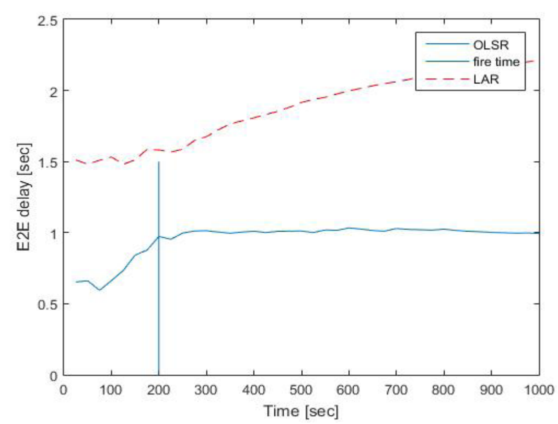

Figure 4. Comparison of LAR protocolandOLSR protocol in the end-to-end delay.

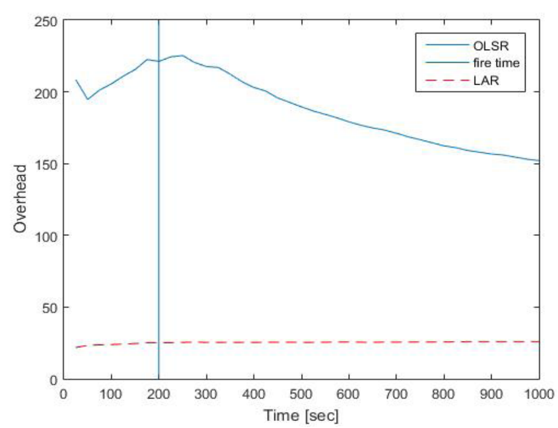

Figure 5. Comparison ofLAR protocol and OLSR protocol in the routing overhead.

7. Conclusion

In this study, a comparison was made between the performances of two different routing network protocols, i.e., Location-Aided Routing protocol (LAR), which is a reactive routing protocol and the Optimised Link State Routing (OLSR), which is a proactive routing protocol, with the help of a mobile ad hoc network. Different performance metrics were used for the evaluation of the best performance and they included energy consumption, packet delivery ratio, routing overhead, and the end-to-end delay. The evaluation between the two protocols was carried out using the MATLAB software. Our results indicated that the LAR protocol was a better protocol as compared to the OLSR protocol with regards to the energy consumption metric, wherein the LAR protocol consumed a low amount of energy. Thus, the LAR protocols improve the life of the network. Regarding the packet delivery ratio, the LAR protocol displayed higher values than the OLSR protocol. For the routing overhead performance metric, LAR protocol performed lesser than the OLSR protocol. Furthermore, there was no improvement in the values of the LAR protocol for the routing overhead metrics, throughput the simulation run. The LAR protocol has a higher end-to-end delay as compared to the OLSR protocol, which could be due to the proactive nature of the OLSR protocol. Hence, it could be established that the two routing protocols performed differently for the various performance metrics after the fire ignition. Hence, based on the results of the simulation run, it can be concluded that the LAR protocol performed better as compared to the OLSR protocol for detecting forest fires.

As mentioned above, the LAR protocol displayed a better performance as compared to the OLSR protocol. Hence, it could be concluded that the LAR protocol was more reliable and effective for detection of forest fires. Future work involves the comparison of the LAR protocol with several other network protocols in terms of detecting forest fires amongst other scenarios.

8. Acknowledgement

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