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A review of forest fire surveillance technologies: Mobile ad-hoc network routing protocols perspective

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ABSTRACT

Mobile Ad-Hoc Network (MANET) is a type of structure-less wireless mobile network, in which each node plays the role of the router and host at the same time. MANET has gained increased interest from researchers and developers for various applications such as forest fire detection. Forest fires require continuous monitoring and effective communication, technology, due to the big losses are brought about by this event. As such, disaster response and rescue applications are considered to be a key application of the MANET. This paper gives an extensive review of the modern techniques used in the forest fire detection based on recent MANET routing protocols such as reactive Location-Aided Routing (LAR), proactive Optimized Link State Routing (OLSR) and LAR-Based Reliable Routing Protocol (LARRR).

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1. Introduction

The ecological balance of the earth depends upon the forests. Sadly, a fire in the forest is normally only detected when it has generally spread over a substantial portion, making its regulation and stoppage difficult or even unfeasible at times. The outcome is devastating destruction and lasting damage to the atmosphere and environment (forest fires contributes to 30% of atmospheric carbon dioxide (CO2)) (Alkhatib, 2014), besides permanent damage to the ecology (vast amounts of CO2 (carbon dioxide) and smoke in the atmosphere). Additionally, other severe effects of forest fires are long-standing disastrous consequences such as impacts on regional weather patterns, the extermination of endangered flora and fauna species, and global warming. In addition to big losses that caused by the forest fires, where it destroys the natural resources, threaten humans and big financial losses. Therefore, the use of an effective technique, easy and inexpensive to monitor and prevent forest fire is extremely important. There are many of the researchers in MANET has been conducted in recent times (Bang and Ramteke, 2013, Torres et al., 2015). Advances in networking technology have made it possible for users to communicate wirelessly through MANET, which is an infrastructure-less network comprising several mobile networked devices (Quispe et al., 2013). The MANET network can be seen in Fig. 1. It shows how the network possesses a set of wireless mobile nodes that are capable of moving independently in any direction and location (Gupta and Gupta, 2012). The nodes within MANET are capable of moving in any speed and direction because they are organized differently. MANET nodes correspond to a destination node route. This is due to the fact that each of the network's nodes can only communicate to those nodes that are located within its transmission radius R. However, it is possible for the source and destination nodes to be located at a distance further than R.

In a multi-hop wireless ad hoc network, all the nodes work alongside each other so that they form a network without requiring any infrastructure like a base station or an access point. In a MANET, communication among nodes outside the transmission range is enabled if the mobile nodes are able to forward packets for each other. The nodes in the network can move independently and in any direction. These nodes can arbitrarily leave and join the network. As a result, a node will regularly go through changes in its link conditions with other devices (Chitkara and Ahmad, 2014). MANETS have certain routing protocols. These routing protocols specify the route and deliver the packets from the source to the destination (Aggarwal and Kaur, 2014). There have been several proposals for different routing protocols for MANETs. The goal of these proposed protocols is to improve and increase the efficiency of the network performance depending on the desired environments.

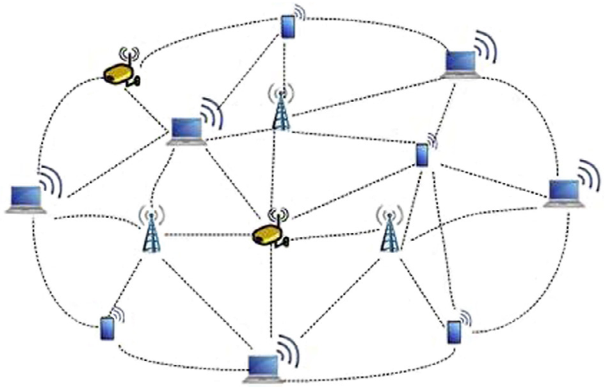

Fig. 1. Mobile ad hoc netweork architecture.

MANET has a vital role in several applications that require wireless networks and that could be utilized in the military battlefield, local level of a connection in the multimedia network using notebook computers to share the information, personal area network and Bluetooth (Kaur and Singh, 2017). Also, MANET can be used in the emergency and rescue operations for disasters like flood, forest fire, volcanic eruptions, and earthquake (Morreale et al., 2015, Quispe and Galan, 2014, Quispe et al., 2012). Forest fires, for example, are one of the biggest threats to forest resources and human life. A forest fire is one of the most serious environmental disasters. Fires are known to spread through vast distances and carry on for months. Many environmental risks are brought about by this event.

2. Factors influence forest fire disasters

The Forest decay process is regarded as one of the chief environmental problems, which cause a number of dangerous catastrophes that adversely affect human life. In recent decades, scientists concentrated on both the historical data and meteorological factors to estimate the probability of danger of fire based on models of fire indices (Hamadeh et al., 2015). Forest fires are a permanent and global occurrence with fire happening all year long in the southern or northern or both hemispheres. Though we are ignorant of the number of fires started each year, the majority of them are caused by human activities, the other usual cause of ignition of forest fires is being the lightning. Fire suppression and management cost billions of dollars annually (Flannigan et al., 2013). Four factors strongly affect the activity of fire: fuels, people, weather-climate, and ignition agents (Flannigan et al., 2005). Fuel quantity, kind, continuity, form, and moisture level are significant elements of fire incidence and spread. Fuel continuity is required for the fires to spread; there are suggestions that no less than 30% of the area must have fuel for a fire to spread (Hargrove et al., 2000). This is essential in many drier parts globally where a specific amount of precipitation is needed prior to the season of fire for the growth of plants to provide enough fuel accumulation that permits continuous fire coverage in the forest (Swetnam and Betancourt, 2010, Meyn et al., 2007). Climate and weather – including temperature, wind, atmospheric moisture, and precipitation – are critical factors of fire activity (Swetnam, 1993, Flannigan and Harrington, 1988). Some instances that stress the role of climate and weather include (Cary et al., 2006) who discovered that climate and weather best justified the amount of region burned using landscape models of fire, related to variation in fuel pattern and terrain. (Carcaillet et al., 2001) discovered that climate was the primary process causing the fires in the eastern boreal jungle during the Holocene. (Prasad et al., 2008) discovered that the average annual precipitation and the average temperature of the hottest quarter of the annual cycle were among the factors that best justified fire incidence in southern India. (Gillett et al., 2004) proposed that the rise in area razed in Canada over the last four decades is because of a human-caused upsurge in temperatures. (Flannigan et al., 2009), in an analysis of worldwide wildfire activity, discovered several research papers which propose that the areas razed and fire incidence will rise with a hotter climate and seasons of fire will be extensive. As stated earlier, people, fuels, weather and ignitions are primary aspects affecting fire activity; however, in several areas, it is weather, and in specific temperature, that is the key factor which explains much of the variation in the regional area burned (Parisien et al., 2011, Balshi et al., 2009). In many portions of the world, ignitions are not restricted as humans are broadly distributed across the region. The aspect of fuel is more complex and may certainly be a barrier to fire activity in sparsely vegetated global areas during some phases. Nonetheless, several fire-prone biomes have little or no fuel restrictions. The end result is that a hotter world would have added fire globally, according to the reproductions in this study (de Groot et al., 2013).

3. The phenomenon of surveillance and detection of forest fires

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. Forest fires detecting networks are needed for a continued and a real-time monitoring of fires (San-Miguel-Ayanz and Ravail, 2005). However, such networks require a huge amount of power, especially for the recharging or replacement of batteries. Furthermore, the tree density and a large amount of vegetation in the forests affect signal transmission. Therefore, forest monitoring requires better and more dependable routing protocols. In the past few years, an environmental catastrophe with global repercussions has been developed in Southeast Asia. Remarkably persistent and large fires in Indonesia have destroyed the tropical forest and peatland areas amounting to thousands of square kilometeres, casting a poisonous cloud of smoky fog over the area and releasing billions of tons of carbon dioxide into the atmosphere. The same type of fires has taken place every year for decades, but the major El Niño situation arisen in recent years is the most destructive since 1997 (Chisholm et al., 2016). The fires happen usually in the Indonesian and Sumatra regions of Borneo (Kalimantan). The event of 1997 burned 45,600 km^2 (Heil and Goldammer, 2001); the event of 2015 probably has burned rather less than this as monsoon rains started in November, but precise estimates are still unavailable. The fires have several causes with the main driver being cleared of land for agriculture. Forests catch fire easily after short dry periods (Gaveau et al., 2014). The damage to the environment due to the Indonesian fires is massive. The tropical jungles that are razed are some of the world's most diverse ecosystems biologically, giving shelter to thousands of species of plants and rare mammals. A major effect of the fires is the smog that spread to nearby countries, such as Malaysia, Singapore, and also the Philippines and southern Thailand. Around 40 million Indonesians have suffered from two months of virtually continuous exposure to dangerous levels of atmospheric pollution and tens of thousands have experienced respiratory diseases (Chisholm et al., 2016). Intermittent wildfires are typical of fire-adapted ecosystems globally. Sometimes wildfires can even be a major natural catastrophe. Increased fuel packing resultant from fire omission and other unsupervised activity, arson blasts, and growth of human settlements into fire-inclined vegetation due to population growth has caused numerous and more destructive wildfires (Liu et al., 2013). Between 1997 and 2008, every year on average around 370 M ha (1 M ha = 104 km2, 1 ha = 2.47 acres) areas of ecosystems including forests were burned worldwide (Giglio et al., 2010). The fires of 1997–1998 in Indonesia razed 8 M ha (Cochrane, 2003). The most recent disastrous wildfires in south-eastern Australia (Liu et al., 2010) destroyed about 0.22 M ha area of forest, ruined 750 homes in a single day, and people in excess of 200 were killed. Nearly 2 M ha area of forest and diverse ecosystems were destroyed annually between 1992 and 2001, for which damage was estimated to be worth billions of US dollars in the Unites States (Littell et al., 2009). Additionally, wildfires can cause adverse environmental effects. Wildfires released about 2.0 Pg C yearly between 1997 and 2009, about a third of the total carbon discharge (Van der Werf et al., 2010). However, (Liu, 2005) calculated an increase of approximately 50% in affected areas for the continental U.S. and around 100% in the western U.S. by the year 2050, while (Spracklen et al., 2009) quoted a rise of 54% in the western U.S. until that time.

4. Related work of forest fire detection technologies

There are many researchers and developers have high interest in the manage and prevention of disasters. Such a disaster, like a forest fire detection, using of algorithms and several of routing protocols which help to detect and reduces losses and limits its effects (Farber et al., 2015). A group of researchers (Dener et al., 2015) used wireless sensor network to analyze fire detection systems. They used two methods to set up fire detection systems. The first method is for detecting fire indoors while the second one is for detecting fire in the forest. Both these methods utilize a web-based application, allowing for fire detection at a distance and without the need for somebody to be present in the danger zone. This is made possible through the use of a web network and a mobile platform. However, there is a missing framework and lack of a simulation setup for the fire detection scenarios. Moreover, no evaluation of the network performance in terms of energy conservation was done, therefore decreasing the network's lifespan. (Alkhatib, 2014) conducted a review of all the methods and techniques utilized in the forest fire. The models of the results of the experiments done by the researchers were also discussed. There were studies and summaries of the techniques employed in forest fire detection. Surveys of the methods that they used in this field were also done and the advantages and disadvantages of all the aforementioned techniques were presented and discussed. Based on all of these, it was discovered that the best technique for forest fire detection would be a wireless sensor network. It has proven itself better than optical cameras and satellite systems.

(Koga et al., 2014) came up with a new monitoring system for forest fire detection that aimed to reduce the dropped rate of data, giving high priority for fire detection. This was achieved by directly specifying the data with high priority directly after fire detection and just before devastation takes place. Comparison between the proposed method and that of (Jamil et al., 2012) was done. It revealed that the proposed method was able to reduce the dropped average of data that have high priorities. Its nodes were able to just send the high priority data to nodes with low destruction probability and therefore decreased end-to-end delay. Compared to the conventional method, this method is also less affected by wind.

A management scheme for salvages and disaster-relief operations after the event was recommended (Srivastava et al., 2014) for implementation in three zonal stages, i.e. hospitals, first-aid treatments, and disaster-response or accident main sites, with relieving ambulances to shuttle between zones among the phases. A MANET provisioned in all stages to allow exchanges of communications between all sites have been schematically defined in reference-point group mobility (RPGM) convention. Network-routing performances are analyzed by a trio of varied protocols, i.e. OLSR which is a pro-active protocol variant, AODV which is a reactive form, and ZRP which is a hybrid form. Qualnet is utilized for simulating field scenarios. This research indicates that exchanges of communications between the stages can be influenced by the routing protocol set and the mobility scheme. The purpose of this study is to advise how to provision high-response network communications in disastrous situations. The associated operations entail multifaceted operations and a wide resource range in order to safeguard the populace and lessen property loss in such contingencies. Three scenarios have been set up to assess the recommended framework's performances and are examined along these lines: For the first, the movements of each node to the sole point of attraction and subsequent returns to the primary site are considered in term of cycles, which in this case describes nodal movements between accident/disaster areas and hospitals, as the equipped responders deliver victims and return to gather the rest. For the second, the movements of each node which transits to any of three points of attraction at random and then returns to the primary site are similarly considered. For the third, the movements of each node which transit to any of three points of attraction at random and then relocate to other such points are examined likewise. The AODV protocol's performances are measured when pause times increase as do packet-delivery ratios, whenever nodal movements decrease which leads to decrease overcrowding, and also whenever pause times increase, resulting in less end-to-end delays. The OLSR protocol's performances were determined when pause times increase, resulting in fewer nodal movements and decreased overcrowding, and therefore reduced PDR. As such, the OLSR protocol performs better than AODV with higher packet-delivery ratios, and OLSR performs better than either ZRP or AODV in effecting movements of groups. Hybrid protocols like ZRP behave differently, i.e. operations initially execute proactively but gradually alter in reactive form, and ZRP performances lessen when nodal movements become highly active.

Also, the Hierarchy-Based routing protocol (HB-AODV) was proposed earlier (Kashyab et al., 2014), 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 subnetworks. This network also helped in deploying fast-moving nodes which represent 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 among 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.

(Keshtgary and Rikhtegar, 2013) conducted a comparative assessment of the routing performances of the three protocol types AODV, DSR and DSDV in effecting forest-fire detections. Among the properties measured and appraised with NS-2 procedures were packet-delivery ratios, the average of all endpoint-to-endpoint delays, and energy efficiencies. The outcomes show that AODV provides superior performances in the first two metrics as it outperforms either DSR or DSDV in packet-delivery ratios and also produces on average the least end-to-end delays. DSDV performs better in energy efficiency than either AODV or DSR, and AODV in particular reports the highest energy expenditure.

(Bouabdellah et al., 2013) performed a comparative study of the Korean and Canadian methods of forest fire detection based on their execution speed and energy consumption. Details about the algorithms used and the hardware schemes for the two methods were explained. For the Canadian method, the account of the fire index is dependent on the Fire Weather Index (FWI). This means that all the sensor data need not be sent to the sink. As a result, there is fewer aggregated index and decreased energy consumption. This approach is based on the identification of daily weather in the daytime based on humidity, wind speed, temperature and rain within 24 h. Execution of the Korean method is dependent on Forest-fires Surveillance System (FFSS) developed by (Son et al., 2006). In this system, processes are developed and packets are received by the middleware from the transceiver. The results are then displayed. However, in terms of energy consumption and execution speed, the Canadian method was proven to be more superior in fire detection than the Korean method.

Also, two researchers in (Kumar and Kumar, 2013) have been proposed a comparison of the DREAM, LAR, and DSR routing protocols. The performances of these protocols were evaluated based on routing overhead, end-to-end delay, packet delivery ratio at the various numbers of nodes and drop packet ratio. NS-2 was then used to implement and evaluate the comparison of these protocols. Results from the comparison revealed that the LAR protocol performed less than the DREAM protocol and DSR protocol in terms of the drop packet ratio. Moreover, the DREAM protocol performed less than the DSR. In terms of end-to-end delay and routing overhead, the LAR protocol performed the least and the DSR protocol was the best. The LAR protocol was the best in terms of the packet delivery ratio, followed by the DREAM protocol and then the DSR. This research paper was able to conclude that the LAR protocol had the best performance out of the three.

(Paul and Sarkar, 2013) described and compared the AODV as a type of reactive routing protocol, ZRP protocol as a type of hybrid routing protocols, and the OLSR as a type of proactive routing protocols. The performance metrics that were used to form the basis of this comparison were the packet jitter, packet delivery ratio throughput, and end-to-end delay given an increasing number of nodes. Comparison of these routing protocols was carried out in both low mobility and high mobility scenarios. The results from the comparison of these routing protocols revealed that OLSR protocol performed better and was more efficient, especially in networks with high-density and high mobility. ZRP and OLSR protocols still worked well with low mobility. On the other hand, the AODV protocol had the worst packet jitter performance. It had an average performance in terms of end-to-end delay and packet delivery ratio.

In one earlier study (Abishek et al., 2012) the author, suggested a design framework having an optimal control approach to effectively carry out 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 a 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.

(Tsetsos et al., 2012) relied on the Meleager approach that was adopted by the visual fire detection system. The use of video cameras for fire detection has many advantages when compared with traditional methods. For example, it theoretically removes space limitation, reduces latency response, etc. The proposed approach made use of PTZ cameras to supervise the area and provide images. There are numerous techniques that take advantage of the visual features of fire and smoke, including but not limited to colour, texture, geometry, motion, and flickering. Additionally, facilitating and speeding up the fire detection process was done through the application of the scene segmentation technique. The first phase involved the implementation of the algorithms for colour and motion detection. In the second phase, advanced algorithms are implemented to decrease the false alarm average. Moreover, personalized alerts were utilized to better adapt to the detection process and improve system performance.

An efficient framework proposed by (Jain et al., 2012) uses a wireless sensor network to monitor and detect forest fires. The framework also makes a comparison between the square grid and hexagonal grid. The framework design has three main parts: network architecture, in-cluster communication protocol, and the sensor deployment planner. This framework responds quickly to forest fires and increases the sensors' lifetime. Moreover, it conducts an overall analysis that addresses all the aspects the WSN's life cycle, especially in the forest fire. The implemented algorithm has numerous characteristics: effectively managing wake and sleep cycles, efficiently administrating power, and increasing data flow when the transmission becomes unreliable. In this framework, the square grid needs lesser nodes compared to the hexagonal. Moreover, the hexagonal grid shows more overlap than the square grid. Therefore, the square grid performs better than the hexagonal.

In this paper, (Jamil et al., 2012) proposed a new routing protocol called the Maximize Unsafe Path (MUP). This protocol aims to extend the lifespan of the network. It accomplishes this by forwarding packets to nodes in danger areas and using the energy of the nodes that are expected to burn out soon. Therefore, the energy of the other nodes is saved. Implementation of the MUP was performed by the COOJA simulation tool. It was evaluated with the RPL routing protocol under varying speeds for the fire extension. An evaluation was done based on the following performance metrics: end-to-end delay, network lifetime, and packet delivery ratio. MUP has three effective modules: neighborhood management, critical event detection, and routing management. Critical event detection is a module implemented to detect any critical event and issue a warning to the routing management module. The neighborhood management module is used to detect the forwarding candidate nodes' subset and preserve the routing table. Lastly, routing management is a major module that plays an important role in updating forwarding choices and making forwarding decisions. A mechanism specifying the threat of fires on every sensor node in the network is provided for by the MUP. Sensors that measure temperature face different levels of threat. Four levels of threat are introduced by the MUP to the node health case. These four levels are as follows: SAFE, LOWSAFE, UNSAFE and ALMOST-FAILED. Based on network lifetime, MUP performed better compared to the RPL protocol. However, in terms of the packet delivery ratio and end-to-end delay, RPL has shown better performance than MUP.

In this study (Chen et al., 2017) the authors have proposed an algorithm called Cooperation Forwarding Data Gathering Strategy Based on Random Walk Backup (CFDGSBRWB). This algorithm aims to increase the lifetime of WSNs in building surveillance. The results of the proposed CFDGSBRWB algorithm have shown decreases in the packet loss, prolong the lifetime of the network as well as it is appropriate in wide-scale WSNs.

The method proposed by (Aslan et al., 2012) uses wireless sensor networks and the FireLib simulator to provide a comprehensive framework that can detect and monitor forest fires. Some of the factors included in the network are the wireless sensor network's architecture, the communication and clustering protocols, how efficient the sensor nodes are in consuming energy, the creation of network structure based on the environmental conditions, rapid-fire detection, and reliable forecasting of the speed and direction of the forest fire. In this proposed method, the goals of deploying the sensors are as follows:

- Lowering the probability of packet collisions
- Making the distances among the sensor nodes uniform to make sure that the nodes will consume about the same level of energy.
- Protecting the area by making sure that the network will cover all the areas with the lowest number of nodes.
- Detecting the fire as soon as possible by maximizing the sensor nodes' areas of coverage.

Authors (Liu et al., 2011) worked on a novel method that has been utilized to accurately detect fires using WSNs that rely on multi-criteria implemented via an artificial neural network. In their paper, the uses of WSNs gave rise to highly accurate multi-criteria detection of fires in the forests. The utilization of an artificial neural network gave the proposed system the ability to self-learn while maintaining low overhead. The proposed system also introduced a prototype comprising TelosB sensors. This development of the prototype makes for a highly accurate fire alarm. The paper also presented how the solar battery was developed and utilized in order to increase the lifetime of the sensor nodes. However, it is worth mentioning that the sensors in the proposed system are affected when the fire is very close to them, at around a distance of 10 cm or 20 cm. Therefore, a lot of sensors need to be deployed it in the forest. Moreover, the accuracy of the detection decreases when the fire is farther.

A proactive routing approach proposed by Wenning et al. (2010) is known as the EMA. This routing approach is made aware of the threat to the nodes and is, therefore, able to avoid broken routes. An OPNET simulation was used to compare the performance of the proposed algorithm with the OLSR protocol. The evaluation of the performance was also based on the parameters of end-to-end delay and energy consumption. Both single-sink and multiple sinks were used to implement the proposed algorithm. Based on the results, it was observed that when multiple sinks were used by the EMA algorithm, no additional overhead was observed and the improper routes resulting from the fires were avoided. Therefore, there is an improvement in both the network's availability and reliability. Compared to standard protocols, this algorithm is more resilient when more parameters are added to adapt with numerous applications. It can also be used with reactive protocols, and sensor node mobility in a lot of other scenarios.

Additionally, in Wenning et al. (2008) the authors 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 environmental 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 the AODV protocol showed less successful transmission, and the proposed EMA protocol had lower delays as compared to the AODV protocol. Table 1 illustrate the summary of the related work.

Although that the applicability of the standard MANET-based architectures and MANET routing protocols can be adopted for the forest fire detection. However, it still needs to advance solution for performance and reliability enhancement. Latest research that applied standard MANET form with the assistance of quadrotor for the forest fire detection and monitoring. It is worth mention that quadrotors have witnessed special interest in practice by the researchers and developers due to their ease of deployment and low maintenance costs (Yanmaz et al., 2017, da Silva et al., 2017b,a).

5. Forest fire detection based on MANET Technology

Developing MANET technology will allow users to connect through wireless communication and an infrastructure-less network of mobile devices. MANET could be utilized in various applications in emergency and rescue operations for disasters like floods, forest fires, volcanic eruptions, and earthquakes (Chisholm et al., 2016, Vladimirova et al., 2009). Therefore, detecting the fire before it enlarges is very important in avoiding these consequences.

Because forest fire detecting networks perform continuous real-time monitoring, they consume a huge amount of power, specifically when batteries need to be recharged or replaced. Furthermore, in forests, signal transmission is affected by the huge amount of vegetation and massive tree density (Alkhatib, 2014). As a result, communication channels are often degraded. One has to come up with an efficient method to relay such information. To accomplish this, a mobile ad hoc network was chosen since it can sense the hotness result of the fire and convey information with lesser energy consumption and packet loss. In addition to the characteristics of MANET, where the networks in MANET can be set up at any place and time, it provides access to information and services regardless of geographic position, independence from central network administration, self-configuring network, the nodes also act as routers, less expensive as compared to wired network, scalable-accommodates the addition of more nodes, improved flexibility, and its networks are robust due to decentralize administration (Chitkara and Ahmad, 2014, Ilyas and Fedoua, 2017). However, an efficient fire detection procedure based on MANET would require a more efficient and reliable protocol to detect a forest fire.

According to (Chennikara-Varghese et al., 2006), the routing of wireless radios in MANET usually takes place through multi-hop as the range of devices is restrained. In other words, the routing of a message generally takes place through mobile intermediate devices.

A number of routing protocols have been suggested for MANET. This is essential for the appropriate utilization and improvement of the network performance depending on the preferred environments and restricted radio bandwidth (Aggarwal and Kaur, 2014). In a MANET, the routing protocols are categorized into three main categories, Proactive Routing Protocols, Reactive Routing Protocols and Hybrid Routing Protocols. As the routing protocols that we have chosen are classified as proactive and reactive, so we will explain these two types of routing protocols.

5.1. Proactive routing protocols

The proactive routing protocols are built around conventional wire-line routing protocols. In proactive routing, the route to every destination in the network is calculated beforehand, so that the protocol is provided with an inclusive and comprehensive knowledge of the network topology. The link states are preserved and updated in the routing tables of nodes, so that the routes are calculated earlier. The routing information is distributed across all the nodes in the network during the operating time, regardless of the requirement for a route (Putta et al., 2010). Hence, proactive routing consists of the most fundamental characteristics of “link state” routing protocol where every node in the network upholds a view of the entire network topology as an expense for each link.

The proactive routing protocol is also known as a table-driven routing protocol, since it can be sub-divided further on the basis of construction, maintenance and updates of the routing tables (Broch et al., 1998). A few of the present proactive routing protocols are: Optimized Link State Protocol (OLSR) (Clausen and Jacquet, 2003), Fisheye State Routing (FSR) (Pei et al., 2000), Source Tree Adaptive Routing (STAR) (Garcia-Luna-Aceves and Spohn, 1999), Global State Routing (GSR) (Chen and Gerla, 1998), and Destination Sequenced Distance Vector (DSDV) (Perkins and Bhagwat, 1994).

5.2. Reactive routing protocols

In reactive routing protocols, the routing activities are instigated on an “on demand” basis. This reactive character of the protocols is considerably different from the conventional proactive protocols where routes between all source-destination pairs are established irrespective of the necessity for such routes. In reactive protocols, no routing information or routing activity is maintained at the network nodes during the absence of communication. A source node establishes a route to a particular destination node in the network only when there is a need to send data. The control overhead is high in an ad-hoc network as the link connectivity between the nodes is changing repeatedly. This aspect is addressed well by the reactive routing protocols than the conventional routing methodologies because instead of continuously maintaining a route between all pairs of network nodes, the reactive routing protocols establish the routes only when there is a necessity for the routes. Another name for reactive routing protocols is source initiated on-demand routing protocols. In these protocols, when a source node needs to send a data packet to another node in the network, the node tries to ascertain if there is a route available. If there are no routes available, this protocol then searches for the route in an on-demand manner. To achieve this, a route discovery process is initiated by the network and a route is established to transmit and receive the data packet.

The route discovery process generally constitutes of flooding the entire network with route request packets (Tarique and Tepe, 2006). The routes, thus discovered, are maintained by a route maintenance process. A few of the present reactive routing protocols are dynamic source routing (DSR) (Johnson et al., 2007), ad hoc on demand distance vector routing (AODV) (Perkins et al., 2003), location aided routing (LAR) (Ko and Vaidya, 2000).

6. Recent MANET routing protocols for forest fire detection

There are many of researchers such as (Keshtgary and Rikhtegar, 2013, Jamil et al., 2012, Wenning et al., 2010, Wenning et al., 2008) that have utilized several of routing protocols for the forest fire detection, but these protocols have been used the wireless sensor network technology. Where there is no

Table 1
Summary of the related work.

Authors/ Years	Routing Protocols	Disasters	Strengths	Weaknesses
(Dener et al., 2015)	–	Fire Detection Systems in Indoor Places and Forest Fires Detection Systems	1. Setup of fire detection systems using two different methods. Theme first involves detection fire indoors, while second method detects forest fires. 2. Use of web network and mobile platform for remote detection of the fire.	1. Framework is not present and the fire detection scenarios have no simulation setup. 2. Evaluation of network performance does not done in terms of energy conservation, and therefore network lifetime do not evaluated as well.
(Koga et al., 2014)	MUP	Forest Fire Monitoring	1. The proposed method was able to lessen the dropped average of data while also reducing end-to-end delay. 2. Compared to the conventional method, the proposed method has less affected by wind.	1. The comparison did not take into account the energy consumption of the safe nodes. 2. The simulation environment that was utilised for the comparison has not specified.
(Kashyab et al., 2014)	HB-AODV, DSR and AODV	Disaster Recovery System	1. The proposed protocol showed a better performance in terms of end-to-end delay, PDR, and PLR as compared to the AODV and DSR.	1. No comparison has carried out between their proposed protocol and the proactive routing protocol. 2. Energy consumption has not selected amongst the performance metrics studied. 3. Their proposed protocol displayed higher values for the routing overhead value as compared to the AODV and DSR.
(Keshtgary and Rikhtegar, 2013)	DSDV, DSR and AODV	Forest Fire Detection	1. The comparison has carried out between several of routing protocols, reactive and proactive.	1. Their comparison made no mention about the best routing protocol to use 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.
(Bouabdellah et al., 2013)	–	Forest Fire Detection	1. Details for the implemented algorithms have explained and schemes for the related hardware have provided for both methods. 2. It proved that the Canadian method for fire detection is better than the Korean method in terms of energy consumption and execution speed.	1. The scenarios for the simulation parameters do not specified as setup parameters. 2. The comparison did not take into account important parameters like reduction of false alarms rate, average end-to-end delay, and best path determination.
(Abishek et al., 2012)	AER and DSR	Network involving Flying Robots for Monitoring a Disaster-Hit Area	1. AER protocol has higher values for the packet delivery ratio, lower values for the packet loss ratio and the delay as compared to DSR protocol.	1. No performance evaluation for energy consumption has carried out. 2. Their protocol comparison did not include any proactive routing protocol.
(Jain et al., 2012)	–	Forest Fire Detection	1. The framework responds quickly to forest fires and lengthens the sensors' lifetimes. 2. Conducted an overall analysis that studied all the aspects of the WSN's life cycle of WSN, especially in the case of forest fires. 3. Based on framework, a square grid requires lesser nodes and therefore performs better than the hexagonal grid.	1. One drawback is the presence of broken routes because they lessen network reliability. 2. The algorithm's transmission is not completely reliable. 3. Data routing is only done for neighbouring nodes
(Jamil et al., 2012)	MUP and RPL	Forest Fire Monitoring System	1. MUP algorithm provided a better network lifetime performance than RPL protocol, where MUP increases the network lifetime more than RPL.	1. The MUP protocol chooses only these nodes, which are located in dangerous zones; however, many data can 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 has dropped, as the MUP does not take into account every alert data priority signal.
(Liu et al., 2011)	–	Forest Fire Detection	1. The utilisation of an artificial neural network allowed the system to self-learn and achieve low overhead. 2. Prototype for the TelosB sensors was developed.	1. The proposed system can only sense the fire when it is coming very close to the sensor node, approximately a distance of 10 cm-20 cm. As a result, a lot of sensors need to be deployed in the forest. Consequently, the accuracy of the detection is reduced when the fire is farther. 2. Using a solar battery is not a very appropriate solution for energy conservation.
(Wenning et al., 2010)	EMA and OLSR	Forest fire detection	1. Even when the EMA approach utilises multiple sinks, no additional overhead is produced. 2. Compared to standard protocols, it is more resilient even when more parameters are added in order to adapt to many different applications. 3. The network's reliability and availability is increased because it can avoid improper routes that result from the fires.	1. Their algorithm made no use of a reactive routing protocol. 2. 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). 3. 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.
(Wenning et al., 2008)	EMA and AODV	Forest fire detection	1. The proposed EMA method is aware of the node's destruction threat and adapts the routes accordingly before node failure results in broken routes. 2. The proposed EMA algorithm is providing slightly lower delays than AODV protocol.	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.

comparison between routing protocols has been invested the MANET technology in such a disaster. However, here we have been invested the MANET, due to its features that we have mentioned previously. Forest fires need a constant monitoring and an efficient communication system, hence, for monitoring the forests, better and more dependable routing protocols like the LAR or the OLSR protocol is required. These protocols are very popular and widely used. Earlier studies (Paul and Sarkar, 2013) 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 (Kumar and Kumar, 2013). Also, in the recent study (AL-Dhief et al., 2016) has mentioned a comparison between LAR and OLSR routing protocols in the detecting the forest fires. The results have shown that the performance of LAR protocol is much better than OLSR protocol in the forest fire detection. However, the authors have been considered their scenario is more appropriate, where the experiment duration was 1000 s and the environmental dimensions were 1000*1000 m^2 with 60 nodes have been deployed in the scenario and each node has coverage zone radius 250 m with rate velocity 7.5–12.5 m/s. Here we cannot determine which is most appropriate due to the forests have different size area. Therefore, the number of nodes, the node coverage zone and node's velocity can be determined depending on the environmental dimensions.

6.1. Location aided routing protocol (LAR)

Location Aided Routing (LAR) as one of the first adopted routing protocols that consider the location information when routing in the MANET (Ko and Vaidya, 2000). The method consists of a source node S with location information from the destination node D. This procedure provides an approximation of the expected zone or the projected destination region where the destination node D may be present. Node S takes into account the location of node D, which is at L0 (X0, Y0) at a time (t0), while the average moving speed for D is V. Where the circular expected region with a radius V (t1–t0), and centred at location L0 (X0, Y0) that is ascertained to be the expected zone by S.

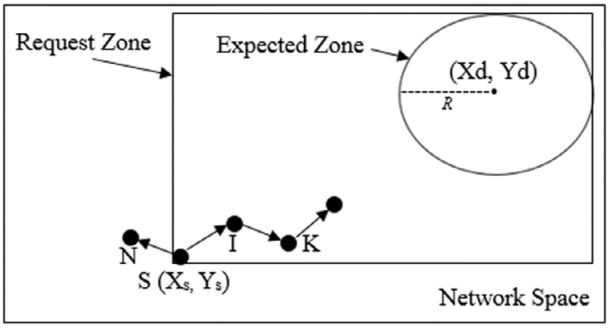

Fig. 2. Location aided routing protocol network space of request and expected zones scheme 1.

If the packets that are being forwarded to the nodes within the request zone do not arrive at the destination and then flooding takes place in LAR. Hence, if LAR has to function properly, the nodes should have the information about whether they are in the request zone or not, for them to either drop or persist to flood the packet. Two different systems to determine if a node is in the request zone or not have been suggested by researchers who conducted extensive research on LAR. The first scheme comprises a sender who sends a route request with the coordinates of a rectangle in the request zone, and a node that receives this route request but is not within the rectangle rejects the route request. If the receiving node is within the rectangle, it forwards the request onwards. When the route request reaches the destination, the destination node replies with a route reply message.

This implies that a route request originating from node S for node D will be forwarded by the nodes I and K when both I and K are within the rectangular request zone. On the contrary, if a node N receives the route request, but is outside the rectangular request zone, it will reject the request, this is illustrated in Fig. 2.

When the source node S fails to distinguish the location of the destination node D, the expected zone is set to be similar to the whole network. The ability of the source node S to ascertain a request zone is dependent on the S locations and expected zone. Fig. 3(a) and (b) depicts that the S is either outside or within each expected zone.

In order to enhance the probability of the request route reaching D, the request zone includes the expected zone. LAR is founded on flooding and it has any of the given adaptations. Only those nodes that are within the request zone in LAR will redirect the route request packet. Fig. 3(a) depicts a node (I1) that passes a route request packet to its neighbors on receiving a route request packet from S because it is within the request zone. However, when the request packet reaches (I2), which is out of the request zone, the request packet is rejected at once. This system is considered to be effective compared to the practice of a blind search by conventional flooding algorithms for the whole network and proves to be cost-efficient as well. To confirm the success of route discovery, the request zone will determine the ratio. The LAR algorithm is degraded to the fundamental flooding algorithm through

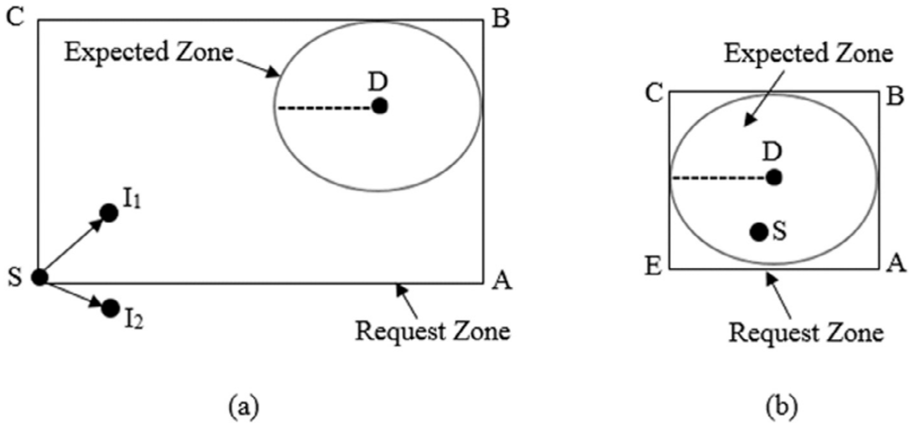

Fig. 3. Location aided routing protocol of spatial node effect (a) S is outside the expected zone. (b) S is within the expected zone.

the blind search of the entire network, when S fails to ascertain the location of D.

The second scheme does not overtly define the request zone when sending the route request. It instead redirects the route request packet depending on the distance information of the sending node from the destination node, which is integrated in the route request. This implies that when nodes N and I receive the route request packet from node S, both the nodes redirect the route request to their neighboring nodes. This is entirely because both N and I are nearer to (Xd, Yd) than to node S. When node K receives the route request from node I, node K rejects the route request, as K is farther away from (Xd, Yd) than to node I. Fig. 4 depicts how the nodes N and K take dissimilar actions using the two LAR schemes.

6.2. Optimized link State routing protocol (OLSR)

According to Clausen and Jacquet (2003), the Optimized Link State Routing (OLSR) protocol is a class of proactive routing protocol, in which every mobile node transmits the routing table from time to time to enable every node in the network to build an all-inclusive view of the network topology. This intermittent or episodic characteristic of OLSR leads to a huge overhead and, for minimizing this overhead; the protocol restricts the number of mobile nodes that can transmit the network-wide traffic. Therefore, the MultiPoint Relays (MPRs) mechanism is used to forward the messages that help to optimize the flood operation as well. The mobile nodes that are identified as the MPRs are able to transmit the control traffic and reduce the size of the control message. The control messages are chosen by the node in such a way that it can reach the 2-hop neighbors using one MPR, and if the control traffic that is received from an earlier hop has been selected as the MPR, it can forward the data packets. The topology changes, the route changes, and mobility causes alter frequently and the Topology Control (TC) messages are transmitted through the overall network. All the mobile nodes maintain a routing table that includes routes for all the potential destination mobile nodes. However, if the OLSR protocol has identified a broken or a damaged link, it does not inform the source immediately. The source nodes find this information from the intermediate nodes when the intermediate nodes transmit their next data packet.

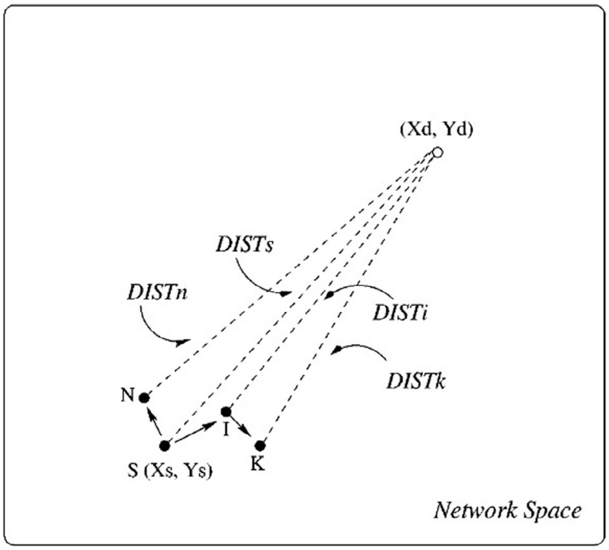

Fig. 4. Location aided routing protocol based nodes distance scheme 2.

6.3. LAR-based reliable routing protocol (LARRR)

A number of routing protocols have been suggested for mobile ad-hoc networks, with the objective of attaining efficient routing. These algorithms vary in their search approach to find a new route and/or adjusting an established route after the hosts move.

One of these routing protocols is Location-Aided Routing (LAR). LAR is a reactive routing protocol, which initiates the process of finding routes when there is a data packet to be sent. Building routes require sending control packets through the network (route request packets and route reply packets). In order to reduce the overhead resultant from these control packets, LAR protocol defines the concept of request zone where only the nodes inside this zone can rebroadcast the control messages. However, LAR protocol is a protocol used in normal cases where there are not any types of harmful situations such as fire, flooding, volcanoes and etc. The main target of this research is to design a new routing protocol considering dangerous cases around the nodes, but it is difficult to build a new protocol from scratch. Therefore, LAR protocol has been chosen to be a base for our work. In this work, LAR protocol has been adapted to route the data among wireless nodes for monitoring a fire in the forest. It has been assumed that every node is provided with a temperature sensor to measure continuously for the temperature of the node. However, LARRR needs additional information about the node's state to work well. The next section explains the different aspects of LARRR protocol.

6.3.1. Finding the route

As soon as a node generates a data packet, the process of building routes starts. Firstly, the node generates a route request packet containing the following information as shown in Table 2.

The node determines the request zone according to the location information available inside its location table. This packet is sent to the nodes located in the coverage zone of the node. Every received node rebroadcasts the packet after adding its address to the "Route" field if it is located in the request zone and it does not receive a packet with the same Id. The packet moves among nodes until it arrives at the destination node. As soon as the destination node receives a route request packet and for each route request packet, it generates a route reply packet containing the following information and sends it as shown in Table 3.

Table 2
Route Request Packet.

Source Node	Destination Node	Moment of Generation	Route	Request Zone	Packet Id

Table 3
Route Reply Packet.

Source Node	Destination Node	Moment of Generation	Route	Location Information	Route Temperature	Route Busyness

Every node in the coverage zone of the destination node receives this packet. If the node finds its address in the ‘‘Route” field, it updates the content of ‘‘Route temperature” and ‘‘Route busyness” by adding its own information and rebroadcasts the packet again. The packet also moves among nodes until it arrives at the source of the data packets. It is clear that the previous process takes some time (not instantaneous). Also, it is clear that there could be more than one route, or there could not be any route. Therefore, there is a period called ‘Time out period’ where the node should wait for and then take a decision to the next step.

If there are no available routes after this period, the node starts the process of finding routes again for another data packet. Any data packet must be removed if a period of time called (Data packet lifetime) has been elapsed without sending this packet. If there are routes to the destination, these routes must arrive during (Time out period). The node must choose the best route among these routes. Choosing the best route must guarantee to increase the PDR, decreasing E2E delay, decreasing the routing overhead and decreasing the energy consumption by the nodes to increase the lifetime of the network. In order to improve the energy consumption, it is clear that the node should choose the shortest routes. However, in the case of forest fire, it is better to choose routes which include nodes with high temperature because these nodes may fail soon because of the fire after a small period of time, so it is very efficient to consume these nodes energy before they fail and save the other nodes energy. Also, if the routes include nodes with high temperature are always chosen, the nodes on these routes will be very congested, which increase the E2E delay time. Therefore, choosing the best routes must take into account all the previous points. In order to choose the best route, every route is assigned a fitness value determining the quality of this route. The fitness value is computed from the following equation:

$$fitVal = RL + (1 - \max(Temp)) + \max(B) \tag{1}$$

where: RL is the route length, which is normalized to the number of nodes in the network. Max (Temp) is the highest node temperature on the route, which is normalized to 130 Co. Max (B) is the highest number of available packets inside the route’s nodes data buffers, which is normalized to the data buffer size.

It is clear that the node must choose the route that achieving the minimum fitness value. In order to decrease the overhead of the protocol, route request packets must be removed after a period of time. This period has been chosen to be $0.9*$(Time out period). Nodes used in these scenarios usually have limited resources. Therefore, there is no need to save all available routes. Nodes only save the best route during ‘‘Time out period”. It is assumed that the maximum temperature, which a node can tolerate is 130 degrees Celsius.

7. Performance evaluation measurands

There are many metrics which can be measured and used to evaluate the overall the performance of the network. A group of researchers (Al-Begain et al., 2003) and (Ramesh et al., 2010) have proposed different performance metrics such as the performance metrics that are run by the delivery fraction of a packet, E2E delay and etc.

7.1. Packet Delivery Ratio (PDR)

The ratio of the number of delivered data packets that are received by the destination node to the number of data packets sent by the source node. The value of PDR can be obtained using the following equation:

$$\mathrm{PDR}(\%) = \frac{\sum \text{No of packet received}}{\sum \text{No of packet sent}} * 100 \tag{2}$$

7.2. End to End Delay (E2E DELAY)

It is the average time of the data packet to be successfully transmitted across the network from source to destination. The value of E2E delay can be obtained using the following equation:

$$\mathrm{E2EDelay(sec)} = \frac{\sum(\text{arrive time} - \text{send time})}{\sum \text{No of packets}} \tag{3}$$

7.3. Routing overhead

The total number of control packets (routing packets) generated by the routing protocol during simulation. The value of the routing overhead can be computed by using the following equation:

$$\mathrm{Routingoverhead} = \frac{\text{No of routing packets}}{\text{No of routing packets} + \text{No of data packets sent}} \tag{4}$$

7.4. Average energy consumption

It can be calculated by dividing the overall energy consumed by every network node over the initial amount of energy present in the network. The average amount of energy consumed is calculated using the following equation:

$$\text{Average energy consumption} = \frac{\sum \text{energy consumed in eachnode}}{\text{networkinitial energy}} \tag{5}$$

7.5. Packet Loss Ratio (PLR)

The ratio of the difference between the number of data packets sent and the number of the data packet received. PLR is calculated as follows:

$$\mathrm{PLR}(\%) = \frac{\text{No of packets sent} - \text{No of packet received}}{\text{No of packet sent}} \times 100 \tag{6}$$

7.6. Average Throughput (TP)

The average throughput metric represents the average ratio of the successful data packets received to the total simulation time duration. TP is calculated as follows:

$$\begin{aligned} \mathrm{TP} = {} & \text{Number of Bytes Received} \times 8 \times \text{Simulation Time} \\ & \times 1000\ \text{Kbps} \end{aligned} \tag{7}$$

8. Conclusion

In the last decades, MANET has gained increased interest from researchers and developers for various applications such as forest fire detection where forest fires pose big threats to forest resources and human life. Moreover, forest fires cost millions of dollars to put out and result in massive losses of trees. They also bring about air pollution, which would often spread to neighboring countries. Therefore, detecting the fire before it enlarges is very important in avoiding these consequences. In this paper, we have identified and reviewed the recent techniques utilized in the forest fire detection. In addition, this paper has presented an overview of the recent MANET routing protocols used in the forest fire detection such as Location-Aided Routing (LAR), Optimized Link State Routing (OLSR) and LAR-Based Reliable Routing Protocol (LARRR).

In conclusion, based on this survey, the recent routing protocols mentioned above LAR, OLSR and LARRR have different performance. Where the performance of LARRR protocol shows an excellent contribution to the forest fire detection. Also in LARRR protocol, the routing criterion is combined with three numbers of hops, information energy, route busyness, and the temperature. Consequently, the LARRR protocol outperformed LAR and OLSR routing protocols in terms of PDR, E2E delay, routing overhead, average energy consumption, PLR, and TP. In comparison to LAR and OLSR protocols, LAR shows high positivity in this application. LAR protocol has outperformed OLSR in terms of the performance metrics except in E2E delay where OLSR is better than LAR in E2E delay and this is 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

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