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Research Article

Artificial Intelligence Technique Based Effective Disaster Recovery Framework to Provide Longer Time Connectivity in Mobile Ad-hoc Networks

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Abstract:

Communication plays a vital role for effective management and for the execution of disaster response and emergency recovery efforts must be able to exchange information with each other from anywhere, at any time to successfully fulfill their missions. Therefore, it is important to configure emergency communications networks in disaster conditions using ad-hoc networks. This proposed framework collects the information and communication before or after a disaster. The aim of this research work is to propose a possible practical communication model by using ad-hoc network configuration technologies using Greedy Randomized Adaptive Search Procedure (GRASP) with the proposed algorithm. The development of this research work is to improve information exchange and facilitate coordination among emergency services and disaster field offices, state/level entities and private industry. This is accomplished by the integration of existing information systems, implementation of new efficient technologies and interconnection of established networks with artificial based techniques.

1. Introduction

A natural disaster is an unforeseen and inevitable event that can occur anywhere in the world. Natural disasters, floods, hurricanes, tornadoes, earthquakes and tsunamis. Once disasters occur all the telecommunications facilities will not be available. Telecommunication may not be possible after a disaster, which can lead to cut off from information exchange. Nowadays many people connect through the internet using smart phones and make calls and send text messages through social network operations such as facebook, instagram, etc., Rendering services through mobile towers after a massive disaster is expensive and can take a long time. A Mobile Ad-hoc Networks (MANETs) is a decentralized network of mobile devices that communicate with each other without the need for a centralized infrastructure as depicted in Figure 1. The network is dynamic and self-configuring, allowing devices to join or leave the network at any time. Nodes are the devices in the network that communicate with each other, such as smartphones, laptops, and tablets. Links are the wireless connections between nodes that enable communication within the network. In a MANET, the source is the node that initiates the communication by sending data packets. It is where the data originates from and is transmitted to other nodes in the network.The destination is the intended receiver of the data packets sent by the source. It is the node that the source wants to communicate with and where the data packets are ultimately delivered.The transmission range refers to the maximum distance within which a node can communicate directly with other nodes in the network. Nodes within the transmission range can exchange data packets directly, while nodes outside this range may require intermediate nodes to relay the packets.The salient feature of this technology is, it can be established without any infrastructure support. During disaster situations, people regularly make calls with their family and friends to update their situations. Since the density of people in a mobile network will come up with heavy traffic.

Though the mobile towers are not damaged and overburdened and unable to handle the flow of communication. Hence, an effective routing scheme is important to reduce the traffic congestion. The topography of the network in disaster areas is always unpredictable in changes because the people move around with mobile devices. There are some common obstacles and change in the device direction may happen as people disconnect from a network. As mobile battery power is limited, victims are not generally connected to a network for a longer time. Still, a problem occurs when other devices don't have any single neighbor to act as a ground to the destination device.

The main technical objectives in context of disaster management study are summarized as follows: (1) To develop and enhance sustainable institutional disaster risk management capacities, frameworks and its mechanisms, and supporting the development and implementation of government policies, (2) To provide uninterrupted communication in the disaster affected places to expedite the rescue operation, (3) To provide the exact geographical position of victims to the rescue team and facilitate the dissemination and exchange of disaster risk management expertise, experience and information, (4) To provide emergency communication and timely relief and response measures. After reviewing the previous works related to the risk management, a new algorithm focusing on the wireless device, ad-hoc network and longer time connectivity are formulated as a code format. Then, computer simulation is carried out to validate the effectiveness of the proposed method showing the end-to-end delay and packet loss.

***Figure 1**. Mobile Ad-hoc Networks*

This paper focuses on implementing a framework for enhancing the dissemination of the communication effectively without any interruption in MANETs. There are two types of wireless networks, viz., infrastructure and infrastructure-less based networks. The infrastructure-based networks work with the help of a centralized device such as access points or mobile towers but infrastructure-less networks do not require any fixed infrastructure support. It can be set up quickly at any time when it is needed. Ad-hoc wireless sensor architecture is developed for disaster survivor detection to take necessary measures in a limited span of time [1]. The outcomes of this research work focus on integration of wireless sensor network architecture and telecommunication infrastructure, very much useful to save the life of thousands of people in critical emergency situations. Smartphone and Personal Digital Assistant (PDA) based disaster management systems were proposed for peer-to-peer communication only [2]. The path can be highly unstable and may change (make or break) quickly. Computer mediated disaster communication systems using rapidly deployable mobile computing and wireless communication technology and to realize a prototype of a decentralized disaster management system and information network. The methodology used for their work such as structured questionnaires, unstructured interviews, country case studies, regional case studies, interactive discussions with the stakeholders and technological development including simulations [3]. The management of rescue and relief operations using wireless mobile ad hoc technology architecture was explored. The manager of rescue operations represents the server in this architecture [4]. Whereas the clients are the rescuers involved in the operation. Post disaster situations demanding efficient communication and coordination among rescue teams were examined. Exchange of real time information among responders and emergency management centers is crucial for saving lives. In such scenarios, MANETs are suitable for providing communication mechanisms, as they are easy to deploy and do not require elaborate infrastructure [5]. However, their simulation results showed that both the mobility model and routing protocols affect the communication between the stages.

Each node operates as an end system and also as a router for all other nodes in the MANETs communication. MANETs have difficulty in sending and receiving data packets when nodes are not in communication range [6]. Stable path is identified by using parameters such as delay, hop, reliability and security, etc. But node density plays a vital role in affecting the Quality of Service (QoS) parameters of the network. Linear optimization-based quality analysis splits the load according to quality of the routes [7]. It was framed by considering the network parameters such as Peak-Signal-Noise-Ratio (PSNR) and path cost. Initially, source node finds N nodes disjoint paths till destination. Probe packets from source to destinations are sent to know the network condition. MANETs routing protocol takes the responsibility to coordinate and control the mobile nodes for delivering the data packets from source to destination. It begins MANETs transmission by broadcasting requests to the neighboring nodes during route discovery process. It is performed in different ways based on the functionalities of routing protocols. To improve routing, link quality was evaluated using Dynamic Source Routing (DSR) protocol [8]. When a node receives Route Request (RREQ) from neighboring nodes, it matches the node's ID with received RREQ. Then, it sends back a Route Reply (RREP) packet to the sender node for establishing a path. Otherwise, it keeps on sending RREQ packets until it reaches the destination. In MANETs, there are many critical issues such as energy consumption, high End-to-End Delay, low Packet Delivery Ratio (PDR), security attacks, unstable links, etc., that need to be addressed for improving the routing performance. Unstable links is an important issue because radio links are likely unreliable due to nodes' mobility. These unstable links lead to rerouting which creates more routing overhead. Link stability refers to the ability of a link that can survive for a longer time. In other words, it is the ability to take less time for repairing the link locally through the selection of an alternate link. The link stability between any two nodes depends on when they are within the communication range or if the signal strength crosses the certain threshold. Mobility causes link failure which leads to path rediscovery. A link is said to be active when the radio range of a link satisfies with the minimal requirements of the successful transmission. Path stability depends on the availability of all links for establishing the path.

A lightweight Proactive Source Routing protocol (PSR) [9] for forwarding the data in MANETs. In PSR, each node maintains breadth-first search spanning tree which was periodically exchanged among neighboring nodes for updating network topology information. It allows a node to have full-path information to all other nodes in the network. In PSR, if a link failure occurred at any node, it found the failure of the link from the source node. Predicted Probabilistic Coefficient Link Stability (PPCLSS) scheme routing was developed for MANETs [10], in which, link loss was found based on the number of packets forwarded from a mobile node to the average dynamic distance between two mobile nodes with the mobility proportion. It considered the energy utilized paths for transmission of a packet and the average path lifetime. An algorithm is developed [11] to select a set of neighbors with respect to link stability and battery capacity. It has stronger route stability and lower probability of link failure because it selects links with higher Link Expiration Time (LET). Cross layer design algorithm is implemented [12] based on stable and energy-efficient routing technique in which QoS monitoring agents collected and calculated the link reliability metrics viz., LET, Probabilistic Link Reliable Time (PLRT), Link Packet Error Rate (LPER) and Link Received Signal Strength (LRSS). These types of metrics assisted to find the most reliable link and to reduce the number of path reconstructions. In addition, Residual Battery Power (RBP) metric was implemented to maintain the energy efficiency in the network. Finally, Route Selection Probability (RSP) was calculated based on these estimated parameters using fuzzy logic.

The stability-oriented routing algorithm was used [13] to discover the stable paths for transferring data packets via intermediate nodes. Focus was given to discover a stable route that should flood only the minimum number of control packets. Two important parameters were considered for neighboring node stability [14], i.e., Mobility and Link loss path mobility. The node link loss was measured by using Signal-to-Noise Ratio (SNR) and Bit Error Rate (BER). Trustworthy nodes were used to build a stable route between source and destination. Secure-dEd-Reflection-Inducement-eState (SERIeS) implemented [15] to enhance the link stability and security in MANETs. The path between source and destination was discovered with the help of a learning agent after network formation. This agent used the link state database to identify the correct path which contained the detailed information about the node's bandwidth, queue length and energy. Once the path had been established, the data communication was performed between the corresponding nodes. Cluster based Multicast Ad-hoc on-Demand Routing Protocol developed [16] for increasing link stability in MANETs (LSMAODV) to select the reliable neighboring nodes. The predictable information of nodes in the network decreased the delay and enhanced the efficiency. In LSMAODV, three clusters were created, and one node from each cluster was selected as cluster head based on the packet priority. Finally, a link with high probability of longer lifetime between the nodes was selected. The QoS metrics such as delay, energy consumption, End-to-End delay, packet loss and overhead were minimized. The stability is predicted [17] of links to enhance the reliability of the communication between source and destination. Individual link stability was computed between two neighboring nodes to extend the link connectivity with minimum link updated time. To avoid link failures, there is the need to clearly predict the mobility of all the nodes. The stable link was chosen based on availability of path for maximum time. Moralism technique predicted the nodes' total travel time in the communication range of requesting nodes [18]. The successful transmission of periodic packets

was used to enhance the link stability for stable path selection. An algorithm for Local Link Failure Recovery (LLFR) developed [19] for ad-hoc networks that established the path locally at the point of link failure. In such cases, a reliable link-failure recovery was the main criteria that determined the performance of the network in terms of QoS parameters. The LLFR was used in each node to collect RREP. In the RREP, Buffer Table (RBT) stacks in the highest order of signal strength, which gets triggered during link failures. Once the link failure was detected, the intermediate nodes searched for an alternate path around the faulty area by choosing the first RREP, which was stacked in RBT and established a new route to the intended destination for sending the data packets without any time delay. Multipath routing based on link availability, neighboring nodes queuing delay, nodes' mobility and bit error rate was considered [20]. AODV protocol to find the path of the data transfer [21,22].
Initially, authentication was required between the mobile nodes to prevent the various inside and outside attacks. When the mobile nodes were mutually authenticated, it led to the reliable data transmission between the mobile nodes. It was designed to provide the best path according to signal strength. The path which has maximum signal strength was chosen as a final path. It helped to reduce the link failure problem. Several metrics to find the node and link lifetime with energy-depletion rate and mobility-evaluation rate of the nodes [23], respectively. Lifetime prediction routing and signal stability-based adaptive routing were two mechanisms used to implement DSR. Estimated link stability based on link connectivity changes [24] which were performed on the network layer.

2. Material and Methods

2.1 EDRF: A Proposed Algorithm

The Geographical Information System (GIS) enabled mobile phones as base stations to know the status of the victim places and update the victim information. Researchers have already explored the advantages of using ad-hoc networks for several critical applications like, military communication, disaster communication, vehicular networks etc. smartphones are now coming up with increasing computing capability, high storage capacity and multiple wireless communication interfaces (GSM/Wi-Fi/Bluetooth etc.). This paper aims to create an alternative mobile communication backbone in a disrupted communication environment like disaster using GRASP.

2.2 Set up Wireless Devices

The first step of this project is to set up sensor devices (smart phones) that are able to discover the services offered in the working platform and interact with all of them. In disaster occurred areas there will be some wireless devices to represent a group of rescue teams who must collaborate to recover the people.

```
# Initialize data structures
Node_ID = Φ; Neighbor(s) = Φ; LET = Φ; Max_LET = Φ; Min_LET = Φ; Max_CL = Φ;
#"S" Computes Max_ML on link [i], link [i+1],.., link[n]and link [j], link [j+1],.., link[m]
for each node in MANETs:
   node.RoutingTable = empty
struct Node {
   ID
   RoutingTable
}
# Create a Route Request (RREQ) packet
   RREQ = create_RREQ (source, destination)
   # Broadcast the RREQ to neighbors
   Broadcast (RREQ)
# Wait for RREP or timeout
# When a node receives an RREQ
function ReceiveRREQ(RREQ, sender):
   if RREQ.destination is this node:
      # Create a Route Reply (RREP) and send it back to the source
      RREP = create_RREP (RREQ.source, this node)
      Unicast (RREP, sender)
   else:
      # Forward the RREQ to neighbors (if not already processed)
      if not already_processed(RREQ):
         forward (RREQ)
struct RoutingTableEntry {
   Destination
   NextHop
   HopCount
   Valid
   SequenceNumber
  Link Expiration Time (LET)
 Maximum Links (ML)
}
```

2.3 Deploying the Ad-hoc Network (GPS/GIS) Enabled Device

The smartphones control each mobile device on the location. Initially, one smart phone acts as a main device. Every mobile device knows exactly which device stores and exchanges the information and where it is located.

```
Begin
for (i  0;i<total_ links;i++)
for (j  0;j<total_links; j++)
If (link [i]of ML > link [j]of ML) then
CALL Max_ML (ML)
Else (link [i]of ML == link [j] of ML) then
CALL Max_LET (LET)
Endif
End
End
CALL Link_Est(); //Check whether the calculated links fails or does not
End {EDRF}
function RouteDiscovery(source, destination):
    if source is destination:
        return
# When a node receives an RREP
function ReceiveRREP(RREP, sender):
    if RREP.destination is this node:
        # Update routing table with the new route information
        update_routing_table(RREP.source, sender, RREP.hop_count, RREP.Link Expiration Time, RREP.Number of Connected Links)
    else:
        # Forward the RREP towards the source (if not already processed)
        if not already_processed(RREP):
            forward(RREP)
```

2.4 Longer Time Connectivity

In case the main device gets a failure that must be effectively managed to ensure the platform remains fully operational even in the main device failure. This is achieved by combining the following two features;

Main Device Backup: This feature allows the main device to keep all data copy fully to ensure that if it fails another device can take over for continuous communication.

2.5 Connection Continuity

In the case of a main mobile device failure, another new mobile is automatically started as the new main controller and can recover its data from the stale main mobile device. In the EDRF algorithm, nodes collect information such as Link Expiration Time (LET), Connected Links (CL), Min_LET, Max_LET, Node ID and Max_CL in order to ensure stable links to construct a path. These metrics are used to enhance the stability links MANETs. Proc EDRF (total_links).

Proc Max_CL (CL)

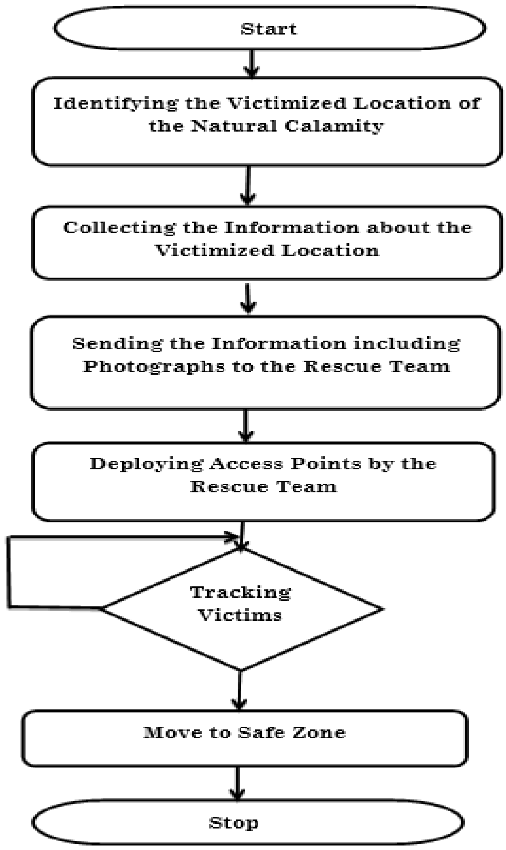

Figure 2. *Flowchart for Disaster Recovery Resilience*

```
Begin
If (n (link[i])) > (n (link[j]))
Max (ML) (n (link[i])) Else if (n (link[i])) < (n (link[j]))
Max (ML) (n (link[j]))
Else
Establish the link with Maximum LET End if
End {Max_ML}
Proc Max_LET (LET)
Begin
If (n (link[i])) > (n (link[j]))
Max (LET) (n (link[i])) Else if (n (link[i])) < (n (link[j]))
Max (LET) (n (link[j]))
End if
 End {Max_LET}
Proc Link_Est ( )          // Identify the link failure
Begin
If (Link_Fails on Link [i]) then
Select alternate link locally from routing table End if
End {Link_Est ( )}
# Route maintenance process
function RouteMaintenance():
    for each entry in routing table:
        if entry.Valid and route is not used for a long time:
            entry.Valid = false
```

3. Results and Discussions

Network Simulator (NS-3) is deployed to evaluate the operations of the proposed EDRF algorithm. The EDRF calculates the results with a higher number of connected nodes such as 50, 100, 150, 200, 250,300 as depicted in Table 1. The computed results for LSMAODV, LLFR and the proposed EDRF are provided in this section and comparison is also done. This simulation used the same model of disaster area as in [19]. In this scenario for disaster recovery, 2,000 * 2,000m of area in the city of Bangalore has been simulated. To obtain the best scheme, it has been simulated LSMAODV [18], LLFR [19] and our proposed routing selection scheme using NS-3 simulation tools to verify our work.
In this simulation, performance analysis was carried out by an increment of the number of nodes in the simulation area and the increased number of connection nodes. Three schemes were considered for comparison: LSMAODV, LLFR and the proposed EDRF scheme. The performance metrics, end-to- end delay and packet loss ratio were presented and analyzed.

3.1 End-to-End Delay

Performance metrics are used to evaluate the performance of the proposed algorithm. The EDRF is compared with LSMAODV, LLFR and EDRF based on the various performance metrics like End-to-End Delay and Packet Delivery Ratio (PDR). It is defined as the average time of the data packet to be successfully transmitted from the source to destination. End-to-End delay is significantly reduced in EDRF compared to LSMAODV and LLFR even as the number of link connections is increased whereas, the minimization of delay is less in EDRF due to the chosen path with Max_CL which reduces the link re-establishment delay and link failure. LSMAODV and LLFR suffer from a frequent link failure and need link reestablishment frequently as it chooses a path with Max_LET and maximum energy which result in an increasing average End-to-End delay. As a result, End-to-End Delay of EDRF is improved relative to AODV and DSDV. This is because of the link selection strategy carried out by the EDRF. It chooses the links considering the Max_CL and Max_LET. In case the existing protocols, select a link with the maximum LET, maximum energy and minimum hop count as the best path. It leads to the disconnection of links during mobility. The End-to-End delay of EDRF is reduced compared to LSMAODV and LLFR. This is due to the reduction in link re-establishment. As a result, EDRF selects the most stable path during link failure occurrence. It considerably reduces the total number of required messages for link re-establishment. The comparison of the proposed algorithm EDRF with LSMAODV and LLFR with respect to average End-to-End delay under varied number of links in a given path is shown in Figure 2. End-to-End delay is the time that packets take to travel from the source to the destination. This includes the delay caused by route discovery, buffer queuing because of congestion and packet retransmission. Figure 2 presents the results of 50 - 300 nodes density in the Bangalore city area. From the line chart, it can be seen that the proposed scheme slowly increased the end- to-end delay as the number of nodes increased. However, the proposed scheme had a smaller delay than LSMAODV and LLFR. Figure 2 shows that the link reestablishment delay needed for LSDMAODV, LLFR and the proposed EDRF to establish a stable path during the distinct number of links connection. There are different scenarios used for simulation as depicted in Figure 2. When the Scenario 1 has fifty nodes in a path, the path establishment delay for LLFR, LSMAODV and EDRF are 0.5ms, 0.2ms and respectively whereas the proposed EDRF needs 0.0001ms. When the scenario 2 has hundred connections in a path, the path establishment delay for LLFR, LSMAODV need 0.25ms, 0.23ms, respectively whereas the proposed EDRF needs 0.21ms. In the scenario 3 has hundred and fifty connections in a path, the path establishment delay for LLFR, LSMAODV need 0.29ms, 0.25ms, respectively whereas the proposed EDRF needs 0.22ms. In the scenario 4 has two hundred connections in a path, the path establishment delay

Table 1. *Simulation Parameters*

Parameter(s)	Value(s)
Simulation area (mxm)	2000x2000
Simulation time (s)	1000
Mobility model	Random way point
Mobile node placement	Random
Pause time (s)	0 – 2
Transmission range (m)	250
Number of nodes	50, 100, 150, 200, 250, 300
Number of connections	20
Network schemes	LSMAODV, LLFR and EDRF
Transport layer protocol	Transmission Control Protocol (TCP)
Nodes speed (mps)	Uniform (0 – 2)

for LLFR, LSMAODV need 0.35ms, 0.33ms, respectively whereas the proposed EDRF needs 0.25ms. In the scenario 5 has two hundred and fifty connections in a path, the path establishment delay for LLFR, LSMAODV need 0.45ms, 0.43ms, respectively whereas the proposed EDRF needs 0.41ms. In the scenario 6 has three hundred and fifty connections in a path, the path establishment delay for LLFR, LSMAODV need 0.5ms, 0.48ms, respectively whereas the proposed EDRF needs 0.43ms.Explain the result of figure 2 in detail (three curves).

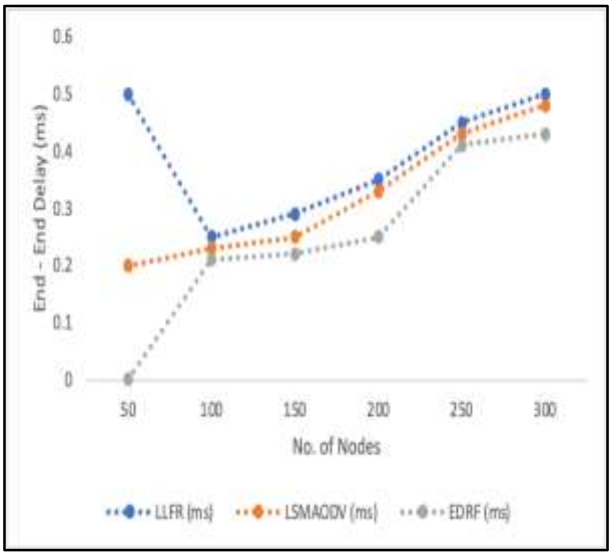

Figure 3. *End-to-End delay for 20 connections*

3.2 Packet Loss

It is defined as the ratio of the total number of data packets received at destination to the total number of packets sent by the source. The performance of the EDRF packet loss under various numbers of links in a given path as shown in Figure 3. In EDRF, multiple parameters with maximum connected links of the paths are taken into account which avoids frequent link failure due to the node's mobility and the most stable path is also identified with Max_CL. Hence, the packet drop due to link failure is reduced and this enhances the PDR when compared to LSMAODV and LLFR. When the Scenario 1 has fifty nodes in a path, the path loss for LLFR, LSMAODV and EDRF are 20%, 18% respectively whereas the proposed EDRF loss is 15%. When the Scenario 2 has hundred nodes in a path, the path loss for LLFR, LSMAODV and EDRF are 25%, 23% respectively whereas the proposed EDRF loss is 20%. In the Scenario 3 has hundred and fifty nodes in a path, the path loss for LLFR, LSMAODV and EDRF are 28%, 27% respectively whereas the proposed EDRF loss is 25%. In the Scenario 4 has two hundred nodes in a path, the path loss for LLFR, LSMAODV and EDRF are 29%, 28% respectively whereas the proposed EDRF loss is 26%. In the Scenario 5 has two hundred and fifty nodes in a path, the path loss for LLFR, LSMAODV and EDRF are 30%, 27% respectively whereas the proposed EDRF loss is 23%. In the Scenario 6 has three hundred and fifty nodes in a path, the path loss for LLFR, LSMAODV and EDRF are 45%, 38% respectively whereas the proposed EDRF loss is 30%.

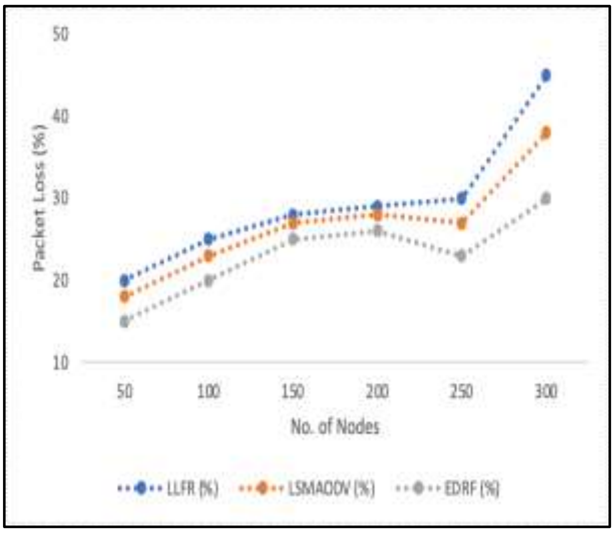

Figure 4. *Packet Loss-Ratio for 20 connections*

4. Conclusions

In this paper, EDRF algorithm has been proposed to reduce the delay and packet loss during data transfer. There are six network scenarios used for the network simulation. According to the Figure 4, the existing algorithm has to repair eight links for stable path construction whereas proposed has to repair three links for stable path construction. Hence, the proposed algorithm yields better results than the existing algorithms. The Proposed EDRF selects a stable path from failure links to destination for sending data packets. It reduces the delay and packet transfer to transfer the data packets.The simulation results prove that the proposed EDRF reduces the End-to-End delay and decreases packet loss. In general, the proposed EDRF enhances the link stability with respect to a higher number of connected links.Verification methods in parameter choice and computer simulation have proved stable in path selection, thereby enhancing the link stability in MANETs. Each node computes the metrics such as Node ID, Min_LET, Max_LET and CL, which are mainly used to reduce the number of link reestablishment delay. The scenarios and discussions show that the proposed EDRF algorithm reduces link re-establishment delay to find an alternate path for routing the packets.

The main results in the proposed EDRF overcome the challenges like reducing the delay and packet loss in data transfer. It also reduces the packet loss which is very important for data transmission in MANETs. Besides, if the number of link or nodes are increased, the proposed EDRF gives better results. It also avoids the unnecessary link failures. The simulation reveals that the proposed EDRF reduces the number of link failures among the multiple paths by maximum number of connected links. Ultimately, the proposed EDRF enhances the link stability in MANETs with respect to maximum connected links and link expiration time.
Future works in MANETs, there are issues such as energy consumption, QoS, security attacks, link stability, etc., that need to be addressed for improving communication. Link Stability is important because radio links are likely to be unreliable due to node mobility. This instability leads to increase rerouting which further escalates routing overhead. The evaluation of link stability and its availability in wireless network is an important feature to consider the link or path establishment.
The major challenges in designing routing protocols for MANETs are mobility of nodes, resource constraints and error prone radio channel. Eventually, the proposed path selection algorithm helps to enhance the link stability in MANETs. In EDRF, the interference issue is involved in establishing a stable path, as it has more neighboring nodes which can be examined. The topic discussed in the paper is interesting and reported a number of works [25-40].

Author Statements:

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- **Data availability statement:** The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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