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Fault Node Recovery Algorithm for a Wireless Mesh Networks

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Abstract – **The main purpose of mesh networks is the capability of working without infrastructure. During the function, the wireless mesh network may suffer from frequent node failure which degrades the operation of network. Node failure detection and node recovery is very essential in performance of Wireless Mesh Network. The proposed work gives a various techniques used for detection of node failure and the techniques used for node recovery of Wireless Mesh Network. The work proposed uses a fault node recovery algorithm in order to enhance the lifetime of a Wireless Mesh Network when some of the nodes shut down.**

Index Terms – Wireless Mesh Network (WMN), Node failure, Node Recovery.

I. INTRODUCTION

As various wireless networks has evolved into the next generation in order to give a better services, a key technology called Wireless Mesh Networks (WMNs), has evolved recently. In WMNs, nodes are comprised of mesh routers and mesh clients [2]. All the nodes in WMN are not only operates as a host but also operates as a router to forward packets on behalf of other nodes that may not be in direct wireless transmission range of their destinations.

WMN is a optimistic wireless technology for many applications such as broadband home networking, community and neighborhood networks, enterprise networking, building automation etc. It provides security at great attention as a possible way for cash strapped Internet Service Providers (ISPs), carriers and others to roll out robust and reliable wireless broadband service access in a way that needs minimal advance investments.

With the capability of self-organization and self-configuration, WMN can be deployed incrementally, one node at a time, as needed [16].

As, the number of nodes installed are increased, the reliability and connectivity for users also rapidly increases. Also, the intension of deploying WMNs is to do something as reliable and affordable access networks in underdeveloped regions.

WMNs have gained importance because of fast deployment, easy maintenance and low cost of investment when compared to traditional wireless networks.

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The aim of deploying WMN is to design a network with low-cost access initiative (often by ISPs) to aid the development of communities. In WMN, as mesh routers are added, the coverage area and robustness of network also increases. The advantages of WMN consistently motivate researchers to study their features for better performance.

Contemporarily, there are two variations of mobile wireless networks. First type is "infrastructure network". It is a fixed network with wired gateways. Base stations acts as the bridges for these networks. The applications of this type of networks include office local area network (LAN)

The second type is "infrastructure-less network". On the other side this network is also called as "self-organized networks". Usually these networks have mobile radio nodes. Therefore, there is no need of having an existing network infrastructure or central system management. In case of requirement of immediate infrastructure, these networks can be opted which are very suitable.

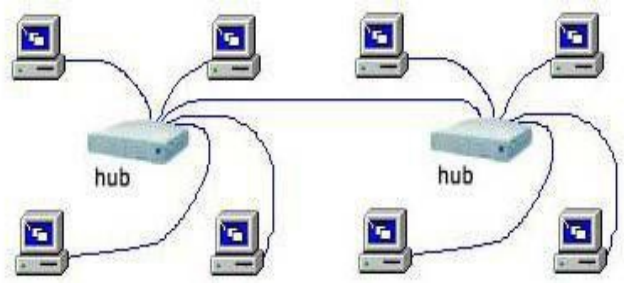

Fig.1. Wireless Mesh Network

Fig.1 shows how WMN functions, by sharing an internet connection across Local Area Network (LAN). As shown in Fig.1, only one node in WMN is more sufficient to directly wired to the internet. Nearest cluster of nodes will collect the internet connection from the node which is directly having wired connection with internet, i.e., wired node shares internet connection to nearest cluster of nodes. Then the process repeats from one cluster of nodes to other nearest cluster of nodes and so on.

It is not necessary to have every individual node to have wired connection with anything. There is a necessity of power supplies such as batteries, AC plugs and if it is outdoor, then solar panels are needed. The nodes which are placed outdoor should be enclosed with waterproof protective shield and can be placed anywhere including roofs, pools, telephone, etc.

WMNs provide more effective sharing in internet connectivity because as more number of nodes installed, it helps the signal to travel further. As number of nodes increase in the network, internet connection for the user becomes faster and stronger.

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The Mesh Topology has a unique design in which each and every computer or node in a network connects to every other computer or nodes. Thus, it creates a point-to-point connection between every device in the network. The main aim of mesh design is providing high level redundancy. If any one of the network cable fails, there is always an alternative path for the data to get to its destination.

Every node in a network can transmit and receive messages. In mesh network, node also functions as a router and can relay messages to its neighbors. Through this relaying process, messages or a packet of wireless data can find its path to the destination by passing through intermediate nodes with reliable communication links.

In case of node failure in WMN, fault node detection and node recovery is very important. So, when there is a node failure, there is a chance of degrading the performance of WMN. Failures in WMN is due to variety of causes, some of them are as follows: break in routing path, leakage in WMN sensing area, node batteries might get depleted, more number of relay nodes requirement, or after using a network for long period of time the nodes might get wear out.

II. RELATED WORK

There are some previous approaches worked on node detection and recovery in sensor networks, link failure in WMNs, etc. This paper proposed an algorithm which helps in replacing inoperative nodes or nodes which have depleted batteries. The proposed algorithm also helps in reusing maximum number of routing paths. Hence, by this network lifetime enhances and node replacement cost also reduces. The various traditional approaches like node failure in WSN, link failure in WMN, Self organization of WMN, Fault Tolerance in WMN and so on are explained below.

A. Fault Node Recovery Algorithms

In a Wireless Sensor Network (WSN), hundreds or thousands of sensor nodes are placed which are equipped with sensing, computing and communication devices like short range communication devices in a wireless channels. Nodes deployed in a large area of network can do area monitoring for some phenomenon of interest. In such application, the purpose of WSN is to receive data from environment and pass it to a sink node. There are two algorithms proposed by author of this paper which are namely, Grade Diffusion Algorithm and Direct Diffusion Algorithm. This work has been proposed by authors called Hong Chi Shih and others [1].

Reply Request (RREQ) packets will be broadcasted from source node to its neighbor nodes in Grade Diffusion Algorithm. These neighbor nodes will broadcast packets further to its neighbor nodes and this process repeats until RREQ packets reaches destination node. In this approach due to huge transmission of data, power consumption increases and the battery life of nodes decreases and so nodes in the network will become no longer functional.

The disadvantages in the Grade Diffusion Algorithm will overcome by Directed Diffusion Algorithm. Here the source node will broadcast packets to its neighbors and these nodes will further broadcast to its first neighbor set. Then, the nodes are picked based on hop count or rules. The amount of RREQ exchange reduces here and thus power consumption also reduces compared to Grade Diffusion. But, problem still persists because the number of routes discovered increases which in turn, battery life of node decreases in the network. Therefore, nodes become obsolete sooner.

In the paper proposed by authors Hong Chi Shih and others [1], Fault Node Recovery Algorithm is used in order to enhance the lifetime of a WSN when some of the sensor nodes are shut down due to route discovery process. This algorithm is a combination of Grade Diffusion Algorithm with Genetic Algorithm. This algorithm replaces fewer sensor nodes which dead and routing paths which are more reused.

The sensor nodes in the WSN's, have limited energy resources because it use battery power supplies. The future work mentioned by author is in addition to the routing, the importance of node replacement, reducing replacement cost, using repeatedly most routing paths when some sensor nodes are dead.

B. Fault Tolerance In Wireless Mesh Networks

As WMN is used in many applications of networks, we have to find the solutions necessarily for making it fault tolerant. The researchers should focus on the requirement for making a strong backbone network. This paper has been proposed by the author Jyoti Gupta and others [4] will be lightening the areas not covered so far in WMN for dealing with base station failures.

Their paper presents a survey report on the comparison of various strategies used for handling base station failures and link failures. It also provides an outline as to how to recover from failures.

Since WMNs are typically used as wireless Backbones, they have the nature that the wireless communication is not constant. Here, some of the approaches taken in mind by many researchers for managing base station failures and link failures are discussed.

With the increasing need of WMN, recovering from link failures and base station failures has become one of the most significant issues. In this survey, the author Jyoti Gupta and others [4] reviewed the WMNs, link failures in WMNs, base station failures and the solutions for them.

C. Link Recovery Schemes In Wireless Mesh Network

The work proposed by Kalyani Pendke and S.U. Nimbhorkar [5] explains that WMN provide effective communication as there is a growing need for the cost effective and highly dynamic large-bandwidth networks over large coverage area.

One of the most advanced networks used for communication is Wireless Mesh Network. During operation, the WMN may suffer from link failure frequently. In turn, it decreases the performance of network. Link failure detection is the most important part during the operation of WMN. The

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paper proposed [5] by an author presents the review of different techniques used for detection and recovery of link failure in WMN.

Techniques for Link recovery in WMN

The performance of WMN decreases largely as there is a link failure. Therefore, link recovery is very important. Different techniques are used for link recovery in WMN and some of them are as follows:

- Initial Resource Allocation Method
- Greedy Channel Assignment Method
- Fault Tolerant Routing Protocol
- Autonomous Reconfiguration System (ARS).

Techniques for Self Re-configurability in WMN

Link failure results in a poor performance of WMN. So, link recovery can be done by the hand operated network management system. But, this process is very expensive and implementing this process is also very difficult in case of dynamic link failure. The solution for above problems is self re-configurability of network.

Paper proposed by an author [5] explains two different approaches to detect link failure in the WMN. One is, Neighbor Discovery Mechanism and the other is, Cross layer Approach. The paper proposed by author [5] also presents the survey on various techniques used for link recovery. Finally, author discusses the use of multipath routing for recovery of WMN.

D. Autonomous Reconfiguring Failures In Wireless mesh Networking

This paper has been proposed by Ms. Jensilin Mary [6]. Here, WMNs are being developed actively and deployed widely for a variety of applications. They have also been evolving in various forms to meet the increasing capacity demands. However during their lifetime, multi hop WMNs experience frequent link failures caused by channel interference, dynamic obstacles, and/or applications bandwidth demands. These failures cause severe performance degradation in WMNs or require expensive manual network management for their real time recovery.

The paper proposed by Sanjay Pawar and Vinod Kimbahune [7] provides a study of Multi-hop WMN experience link-failure due to channel interference, dynamic obstacles etc. which causes performance degradation of the network in WMN.

A considerable amount of work has been done for solving the problem in WMNs and maintains the healthy networks. And Networks reconfiguration used a planning algorithm that keeps necessary network changes (to recover from link failures) as local as possible as opposed to change in entire network settings. Scheduling algorithms and existing channel assignment provide guidelines such as throughput bounds and schedule ability for channel assignment during a network deployment stage.

This paper presents Autonomous Reconfiguration System (ARS) that helps a WMN to reconfigure autonomously from link failure. Also ARS help in generating reconfiguration plan. ARS implements the reconfiguration plan that satisfies QoS constraint.

E. Self Organizing Wireless Mesh Network

A communication network with radio nodes which is organized in a mesh topology is called as wireless mesh network or WMN. They are used for variety application such as building automation, transportation, citywide wireless Internet services etc. The WMN experience link failure due to application bandwidth demands, channel interference etc. These failures will cause performance degradation. Reconfiguration is needed to preserve the network from dynamic link failure. The resource allocation require global configuration changes, greedy channel assignment algorithm might not be able to realize full improvement. The proposed work is for reconfigure the network at the time of dynamic link failure.

Autonomous reconfiguration system (ARS) is used to reconfigure the network. The system generates necessary changes in channel assignment in order to recover from link failure. The performance is evaluated using different types of quality parameters such as throughput, PDR, delay. Comparing with existing schemes this will provide fast recovery.

A wireless mesh network is a communication network having mesh routers and mesh clients connected in a mesh topology. Dynamic link failure due to interferences will lead to network performance degradation. The paper proposed by P. Sharanya and Jennifer S. Raj [11] explains how link failure is avoided using autonomous reconfiguration system. This will provide a fast recovery from link failure using reconfiguring the network. This ARS technique will improve the network performance compared with existing technology. This will give a fast recovery from the dynamic link failure.

III. FAULT NODE RECOVERY ALGORITHM IN WMN

In the current approach, a route discovery approach is proposed by considering two different algorithms. One is Grade Diffusion (GD) algorithm and the other is Fault Node Route Discovery (FNRD) algorithm. FNRD algorithm reduces amount of power consumption and number of nodes becoming obsolete (dead) will be less as compared to Grade Diffusion algorithm.

GD algorithm will determine set of nodes known as "grades" which has two values namely 0 or 1. Each node will become 1 if battery is greater than threshold otherwise it will be 0.

FNRD algorithm will also determine set of nodes based on considering highest battery power in the forward nodes and also based on distance vector algorithm.

The process of finding the set of nodes whose battery power is less than threshold is called Fault Node

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Determination. The nodes will be replaced with new nodes of same node id this process is called Fault Node Recovery.

The routes of GD algorithm discover source routes i.e., the sender node learns the complete ordered sequence of network hops necessary to reach the destination. At a conceptual level, each packet to be routed carries this list of hops in its header. The key advantage of a source routing design is that intermediate nodes do not need to maintain up-to-date routing information in order to route the packets that they forward, since the packets themselves already contain all the routing decisions.

Route Discovery works by flooding a request through the network in a controlled manner, seeking a route to some target destination. In its simplest form, for example, a source node called A attempting to discover a route to a destination node called D. Source node A broadcasts a Route Request (RREQ) packet, that is re-broadcasted by intermediate nodes between A and D until it reaches D. In turn, node D answers by returning a Route Reply (RREP) packet to A. Many optimizations to this basic mechanism are used to limit the frequency and spread of Route Discovery attempts. A single transmission of a RREQ is all that is needed to re-propagate the request to all its neighbour nodes.

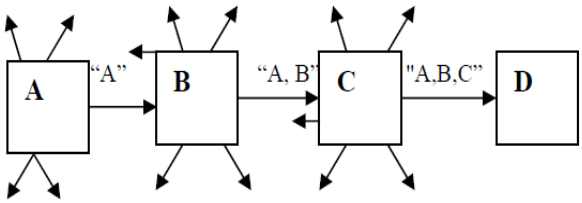

Fig. 2. Route Discovery using Grade Diffusion Algorithm

FNRD algorithm is responsible to route a single packet from source node to destination node and it is integral part of Fault Node Detection (FND) and Fault Node Recovery (FNR) Algorithm to send packets from source node to destination node.

In FNRD algorithm shown in Fig. 3 clearly explains that, the nodes in the network maintains a single hop list, which contains the ids of all nodes within its transmission range. When a source node wants to send control packet to the sink, it includes a packet threshold with initial value N in each control packet. Then, the RREQ packet is flooded to the single hop list. Each neighbour will then send the RREQ packet by picking the nodes which has highest battery power. This process is repeated until the link is established till the destination.

If packet threshold reduces to zero, then, Distance Vector (DV) method is considered. It is clearly shown in Fig. 4. DV algorithm is a process followed by picking a node which helps us to reach the destination faster.

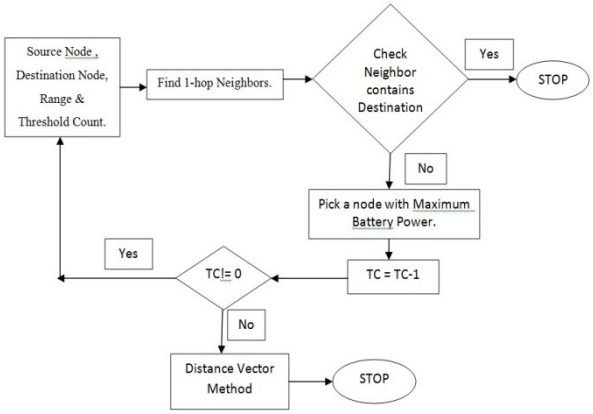

Fig. 3. Fault Node Route Discovery algorithm using Distance Vector method

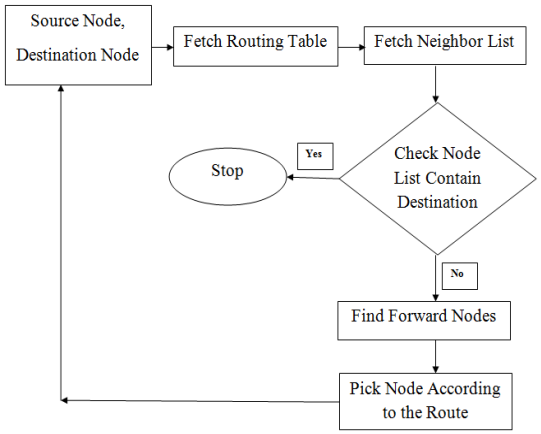

Fig. 4. Distance Vector Algorithm

The main aim of using DV algorithm shown in Fig. 4 in FNRD algorithm is, DV method avoid spending much of round trip time in the network. Instead control packets reach the destination node faster by picking farthest neighbor from source node.

In FNR algorithm, we first scan the nodes from the first node onwards and link is established to collect data from each single hop list. Then, the mutation is computed by comparing the battery power with the threshold. Each node is assigned a grade value of 0 or 1. 1 is assigned if the battery power of node is less than threshold, otherwise it will be assigned with a value of 0. A chromosome map is created, in which it will contain key as node id and value as the grade value. Set of nodes are determined from the map which have a value as 1. The process is repeated until all nodes have been scanned. Thus, we can find fault nodes in the network and the process is called FND and the algorithm used here is FND algorithm.

The nodes can be recovered by taking the set of nodes which are dead (obsolete) from the chromosome map, and replaces them with new one with the same node id. This process of recovering node is called FNR and the algorithm used here is FNR algorithm.

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IV. SIMULATION

Simulation of the fault node recovery algorithm was performed to verify the method. The experiment was designed based on placing all the nodes in the network randomly. The scale of the coordinate axis for each dimension was set based on number of nodes in the network.

Number of nodes considered was 100 for 200 events. Initial battery power on each node was set to 200 milliwatts. Also in this work we Considered source node as 10 and destination node as 65 in network. The range of transmission of control packets was given to 30 meters. The threshold count (TTL) ranges from 1-10 for networks, TTL considered was 4. Environment factor and attenuation factor was considered 0.5 and 0.2 consequently. Battery energy required for transmission, energy required for amplification and energy required for transmission considered 1, 05 and 1 millijoules. Threshold battery was given 198 milliwatts. The battery power should be given for recovered nodes, so given battery power is 500 milliwatts.

Comparisons have been made between two different algorithm i.e., GD algorithm and FNRD algorithm which is an integral part of FND and FNR algorithms. The comparisons have been made between these two algorithms in order to check the performance of each with respect to parameters such as power consumption, energy consumption, number of hops, time taken, dead nodes information, number of alive nodes and dead nodes after 200 events.

In Fig. 5 shown below, it clearly says how nodes are deployed in a mesh network randomly. Here, in this network topology (i.e., mesh) every node will have a information of all other nodes in its Routing Table.

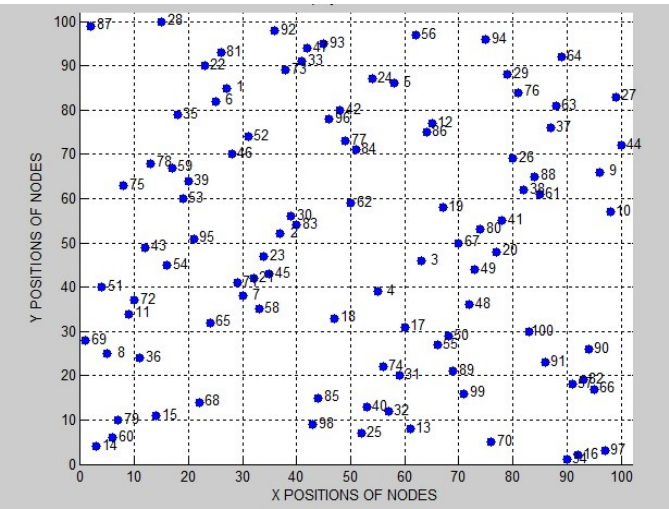

Fig. 5. Node Deployment in WMN

After number of events occurs in the network i.e., 200 here, dead nodes occur. Fig. 6 clearly depicts the number of dead nodes occur in network after 200 events(iterations).

Next, we have considered power consumption and energy consumption for route discovery process in both GD and FNR algorithms. It is shown in below Fig. 7.

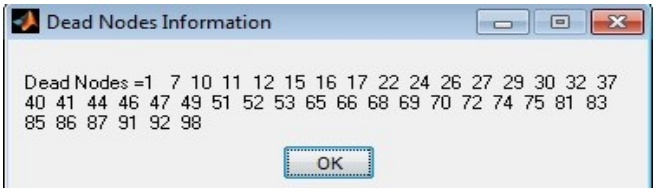

Fig. 6. Dead Node Information.

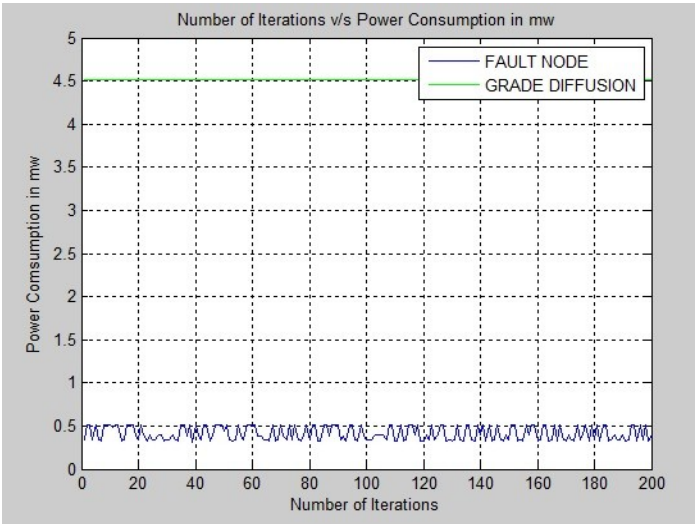

Fig. 7. Number of Iterations v/s Power Consumption in mw.

From the Fig. 8 above, it s clearly understood that FNR algorithm consumes less power than GD algorithm in discovering optimized route during Route Discovery process. Power consumption is calculated by using a formula given below:

$$TP_c = \sum_{i=1}^{l} P_{cl} \qquad (1)$$

In (1):
TP_c = Total Power Consumed.
P_{cl} = Power Consumed per node.

$$P_{cl} = \frac{P_t}{1+d^{0.5}} \qquad (2)$$

In (2):
P_t = Power required for transmission.
d = Distance between nodes.

Fig. 8 shows the comparison plot of GD and FNR algorithm with respect to Energy Consumption. Energy consumption is calculated using formula as shown below:

$$TE_c = \sum_{i=1}^{l} E_{cl} \qquad (3)$$

In (3):
TE_c = Total Energy Consumed.
E_{cl} = Energy consumed per node.

$$E_{cl} = 2 * E_{tx} + E_{amp} * d^{\partial} \qquad (4)$$

In (4):
E_{tx} = Energy required for transmission.

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E_{amp} = Energy required for amplification.
d = distance between nodes.
∂ = Attenuation Factor.

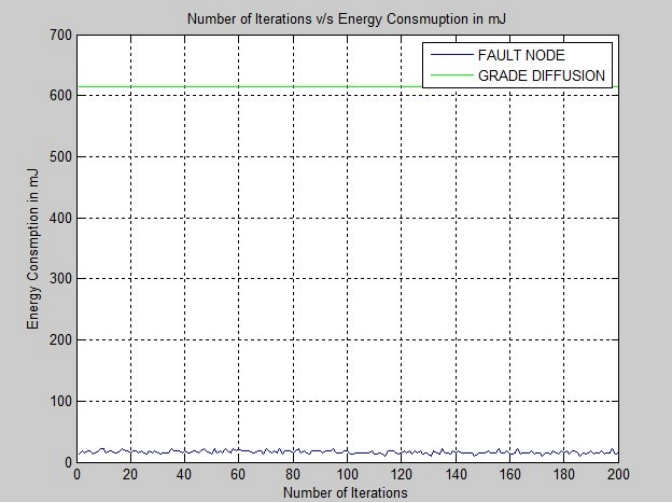

Fig. 8. Number of Iterations v/s Energy Consumption in mw.

Then we compare parameters such as time taken, number of alive nodes and number of dead nodes. Later the dead nodes are recovered to desire battery power by using FNR algorithm.

Thus with no doubt we can say that, FNR algorithm performance is much efficient in enhancing the lifetime of the network than in GD.

V. CONCLUSION

In real wireless mesh networks, the nodes use battery power supplies and thus have limited energy resources. In addition to the routing, it is important to research the optimization of node replacement, reducing the replacement cost, and reusing the most routing paths when some nodes are non-functional.

This work proposes a Fault Node Recovery algorithm for WMN. So far, on the basis on my survey, many researchers have worked on link failures in WMN. New approaches have to be made to handle node failures in WMN.

In future, we can create many innovative algorithms for fault node detection and recovery. The work proposed in this paper uses Fault Node Recovery (FNR) algorithm in order to detect and recover the fault nodes in Wireless Mesh Networks.

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