Enhanced Grade Diffusion for Node Recovery in Wireless Sensor Networks

Thesis submitted in partial fulfillment of the requirements for the award of degree of

Master of Technology

in

Computer Science and Engineering

Submitted By

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CERTIFICATE

I hereby certify that the work which is being presented in the thesis entitled, "Enhanced Grade Diffusion for Node Recovery in Wireless Sensor Networks", in partial fulfillment of the requirements for the award of degree of Master of Engineering in *Computer Science and Engineering* submitted in Computer Science and Engineering Department of Thapar University, Patiala, is an authentic record of my own work carried out under the supervision of *Dr.Sushma Jain* and *Ms. Sukhchandan Randhawa* and refers other researcher's work which are duly listed in the reference section.

The matter presented in the thesis has not been submitted for award of any other degree of this or any other University.

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This is to certify that the above statement made by the candidate is correct and true to the best of my knowledge.

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Abstract

Wireless Sensor Networks (WSNs) are the most widely used networks to monitor distributed remote environments. In WSNs, when nodes lose touch within the network, they fail to operate. There are various reasons due to which this can occur, such as, in the event of software crash or hardware failure, the failures of a communication system or the loss of network connectivity occur. Any failure or disruption or split of network region that stops the node from communicating with the network is considered as *node failure*. Number of researchers has addressed the issue of recovering the Faulty Nodes (FNs). The aim of the Grade Diffusion (GD) algorithm is to recover the FN by rerouting the whole path. This gives quick solution to the problem but is very expensive in terms of power efficiency of the whole network as the rerouted path can be comparatively long and requires more energy to route packets. Recovery of nodes using different mechanisms like LeDiR (Least-Disruptive topology Repair) and GD has been the main solution to the node failures in the running networks. In this thesis GD based Particle Swarm Optimization (PSO) is implemented to re-route the paths. That originally reroutes the path by selecting the best path through consideration of the situational best replacement of the node in place of failing node. Such path selection often leads to bad distribution of energy in the network in later stages. Usage of PSO allows energy distribution in the network uniformly to utilize the maximum lifetime of the Wireless Network. The optimized path selection using PSO allows the protocol to maintain energy levels in the network by choosing the path which is most efficient in terms of energy consumption. The comparative analysis of the proposed technique has been done with the existing techniques. The results have been evaluated in the terms namely, network lifetime, delay, throughput and energy. The implementation of routing protocol, node failure and optimization of paths using GD has been simulated in MATLAB.

ABBREVIATIONS

Abbreviations	**Full Forms**
ACK	Acknowledgement
BS	Base Station
DARA	Distributed Actor Recovery Algorithm
DD	Direct Diffusion
DoS	Denial of Service
EGD	Enhanced Grade Diffusion
FN	Faulty Node
FNR	Fault Node Recovery
GD	Grade Diffusion
LeDiR	Least Disruptive topology Repair
QoS	Quality of Service
RIM	Recovery through Inward Motion
SN	Sensor Node
WSN	Wireless Sensor Network

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Chapter 1

Introduction

1.1 Wireless Sensor Networks

A Wireless Sensor Network (WSN) is a network consisting of spatially distributed autonomous devices victimization sensors to observe physical or environmental conditions [1][6]. Refinement in micro processing, wireless technology, sensible sensors have increased processing, wireless communications, and detection capabilities. A wireless detector network typically contains a whole bunch of detector nodes equipped with sensing, computing, and communication devices like short-range communication devices over wireless channels [5]. These nodes could also be distributed over an oversized area. In such associate degree application, the major goal of the WSN is to gather information from the atmosphere and send it to a sink node. In Wireless detector Network, every Detector Node has restricted machine Power to transfer live information to Base Station (BS). In Wireless detector Network each detector node has an inclination to close up, due to computational power, hardware failure, package failure, status and energy depletion. Fault tolerance is a crucial problem in WSNs. Hence, maximizing the network lifespan by minimizing the energy consumption is a crucial challenge in WSN. Routing technique performs a major role in the WSN. Due to large number of Sensor Node (SN) embedded in the network, it becomes very arduous to assign the global ids to each SN's. In many situations, multiple sources are needed to send the data to a particular BS. The nodes near to the sinks consumes large amount of energy and hence eventually die. This causes partitioning of the network; consequently, the lifetime of the network gets to reduce. The main constraint of the SN is energy [10]. It's hard to replace the batteries in many applications so, an energy-efficient routing protocol is required for WSN. The redundant data received by the BS from various SN's must be eradicated as it consumes large amount of energy. There is no fixed infrastructure of WSN which makes it very dynamic due to major reasons namely, energy and mobility [7].

A WSN is a mixture of numerous tiny SNs which can be located in ad-hoc network in an unattended scenario and for the purpose of collecting, analyzing, computing plus transmitting actual time records to a middle processor node for improved evaluation and assertion technology.

In WSNs**,** *sensor node* or *source node* is responsible for sensing of ecological phenomenon and reporting back to central data collection point or the sink. Sink might only or one of the more sinks. A *Sink* or *BS* is a node which collects all the data and then uses it to process the information collected into meaningful decisions.

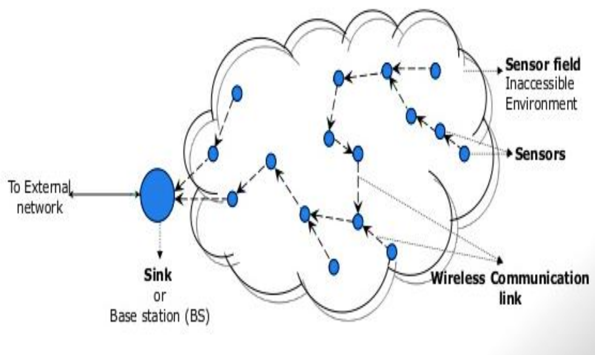


Figure 1.1: Wireless Sensor Networks

A WSN experience the side effects of two types of node failures. The first type of failure is the *random node failure or breakdown* which is faced due to few internal issues in node or battery depletion. The second failure type is a *vicinity failure* in which the nodes covering a place fail altogether due to catastrophe like a seismic tremor, fire, bomb blast or meaningful Denial of Service (DoS) assaults. In both scenarios, once identified, FN (Faulty Nodes) should to be expelled from rest of the WSN and are no longer utilized for sending packets. Hence, other nodes need to replace these FNs. Currently, strength and efficiency is the most important metrics within the layout for collection, processing and communication.

WSN can also fail due to number of reasons, which includes the following: the communication route would possibly encounter a network split; the WSN sensing range might experience a leak; the batteries of some sensor nodes might be depleted, requiring extra relay nodes; or the nodes in WSN may demolish due to use for long period of time. The external nodes transmit the event statistics to the sink node via the internal nodes (the SN near the sink node) in a WSN. The internal nodes will have more data to send and consume more energy at a faster pace. If all such kind of nodes get exhausted out of energy, then it will not be possible to send the event statistics to the sink node and results in network hole problem. The power consumption of the sensor nodes in WSNs is unavoidable [9]. So there is a need of recovery mechanism which can recover the faulty nodes and provide appropriate level of coverage and connectivity. WSNs have sensing, computation and communication capabilities which are highly used in large number of different applications. Monitoring applications cover various areas like military detection, health monitoring, business, environmental, public/industrial and habitat monitoring etc. On the other hand, tracing applications include habitat monitoring, military, public/industrial and business applications etc [23].

Many techniques or protocols are being proposed for routing which governs transmission of the data within the SNs in the desired network. The communication in the network does not happen peer to peer because of the large physical distances in the nodes of the network. We need to make the communication paths in which the information goes from one node to the next node and finally reaches the destination, such mechanisms that govern the path selection are called routing protocols. Many routing protocols including the DD and the GD have been proposed for routing [2]. The purpose of DD is to improve the hop count it takes to reach a particular sink from particular location in network [4]. Along with setting of the neighbors for reduction of load GD also assigns the paths for routing of efficient wireless data transmission. GD has the property of routing and rerouting in the case of failure [3]. All nodes can be selected from the grade table. The main focus is to select the most appropriate neighbor. The node with the maximum energy left among all node qualifies to be the best neighbor and has the highest chances of selection.

The Fault Node Recovery (FNR) algorithm intends to produce energy in the economical and effective ways of communication in WSN [6]. Hence, the algorithmic program relies on the mixture of GD algorithmic program and also the genetic algorithmic program. The FNR algorithmic program will replace the deactivated detector nodes and additionally reused routing ways. Within the simulation, the FNR algorithmic program also decreases the speed of packet loss and reduces the speed of energy consumption.

PSO algorithm is one of the premier ways of optimizing the problem which need insight solution oriented approach. [1] [5]. The PSO is one such algorithm which uses the behavior of bird in finding the food for solving problems using the objective function which to be maximized or minimized.

1.2 Routing Protocols in WSNs

There are countless routing protocols and algorithms for defining how the communication is going to take place within nodes [8]. The path chosen by a node to send the data packets to the end user depends upon the underlying routing mechanisms. The various routing mechanisms based on network structure are: *Flat Routing*, *Hierarchical routing* and *Location based routing* as shown in Figure 1.2.

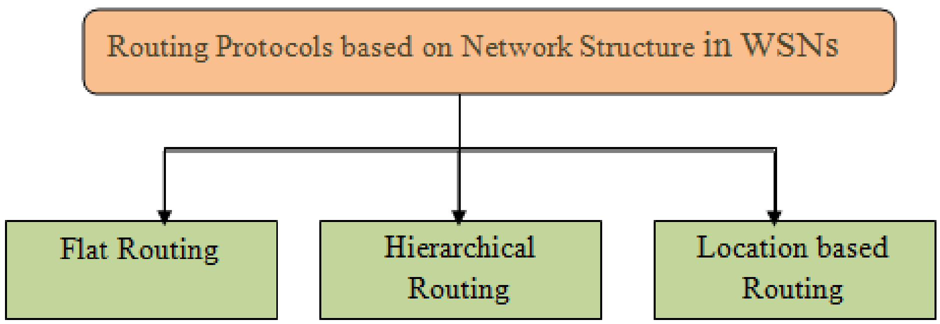


Figure 1.2: Routing Protocols based on Network Structure in WSNs

In *Flat Routing*, every node generally plays a similar role and sensor nodes collaborate along to perform the sensing task [39]. Due to high density of such nodes, it's not possible to assign a global identifier to every node. This consideration has led to data centric routing, wherever the BS sends queries to bound regions and waits for data from the sensors placed within the designated regions. Earlier works on data centric routing, e.g., SPIN and directed diffusion is proposed to avoid dissipation of energy through data negotiation and elimination of redundant data.

Hierarchical or Cluster-based Routing, originally proposed in wireless networks, are well-known techniques with special benefits associated with scalability and efficient communication. In hierarchical design, higher energy nodes are used to process and send the data, while low energy nodes are used to perform the sensing within the proximity of the target [40]. This implies the creation of clusters and assigning special tasks to cluster heads which will greatly contribute to overall system scalability, lifetime and energy efficiency. Hierarchical routing is an efficient way to lower energy consumption among a cluster, by performing data aggregation and fusion in order to decrease the number of transmitted messages to the BS. However, most techniques in this category decide "who and when to send or process/aggregate" the information, channel allocation etc., which might be orthogonal to the multi-hop routing function.

In Lo*cation based routing*, sensor nodes are addressed by means of their locations. The distance between neighboring nodes are often calculated on the basis of incoming signal strengths [40]. Relative coordinates of neighboring nodes can be obtained by exchanging such information between neighbors. Alternatively, the location of nodes could also be available directly by communicating with a satellite, using Global Positioning System (GPS), if nodes are equipped with a small low power GPS receiver. In order to increase the energy efficiency, some location based schemes proposed that nodes should go to sleep mode if there's no activity. More energy savings can be obtained by having as many sleeping nodes within the network as possible. The problem of designing sleep period schedules for every node in every localized manner.

1.3 Node Recovery Schemes

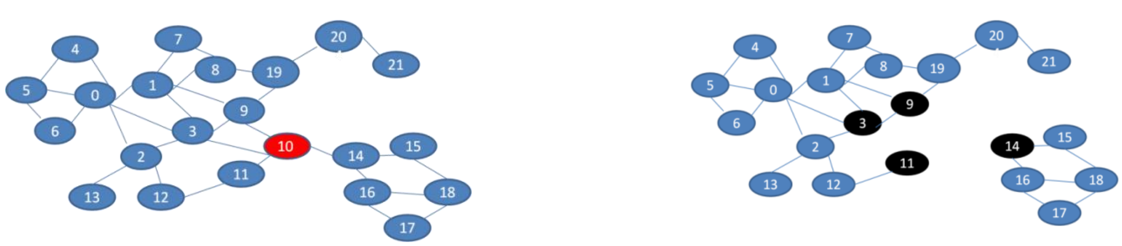
Node recovery Schemes gives the importance of inter-node connectivity, SNs generally update their nearby neighbors before stirring so the network can be accustomed accordingly. However, sudden SN collapse, caused by the harsh surroundings or depletion of the SNs sequence, will disturb network working. The FN can split communication in the network and make some of SNs neighbors difficult to get to. In the most unpleasant scenarios, the network may get division into many disjoint blocks and results in nonfunctional network. Therefore, SN should be bright to perceive and recover from the disappointment of one of their peers. The network should remain responsive to detected events, so the recovery process should also be lightweight and work quickly, with minimal overhead. However, since some SNs may be powerless to reach others, a well-organized, non-centralized recovery method becomes extremely knotty.

1.3.1 Recovery through Inward Motion (RIM)

RIM algorithm is restricted disseminated algorithm used for the recovery of network partition. The fundamental is to move the neighbor nodes of failed nodes towards inner direction of the faulty node with the goal that nodes will find one another and recovery of failed node can happen and has three main disadvantages: (i) a substantial range of moved nodes are required for the failure recovery, (ii) extensive system topology is modified throughout recovery, (iii) no coverage issue alongside connectivity is considered in this approach.

1.3.2 Least Disruptive topology Repair (LeDiR)

When sensor nodes get exhausted due to energy drainage, the nodes become FNs which further results into network partitioning and connectivity loss. The fundamental reason is that the topology of the system is not optimized with respect to the area to be covered and coverage. One of the compelling recovery approaches is to self-sufficiently repositioning the set of the SNs to restore network connectivity. Earlier, techniques either force high SN movement overhead or extend number of the between performing actor data routes. LeDiR depends on the area of a node concerning to the network to start a recovery procedure that moves some nodes and guarantees that no route across any of the two nodes is developed. LeDiR uses base route disclosures scheme inside the network that forces no moreover pre-failure communication overhead. LeDiR [24] depends on the smallest block movement. By smallest block movement means that the block of nodes which are immediate to the failure location take part in the recovery process, as shown in Figure 1.3.



(a) (b)

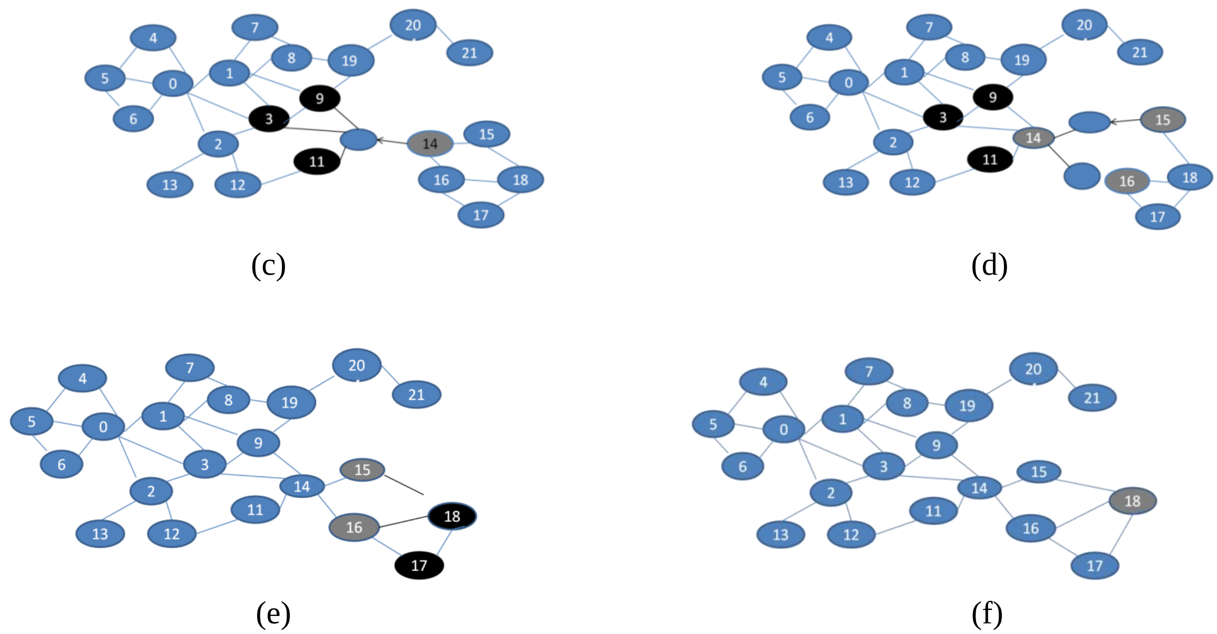


Figure 1.3: LeDir Movement Mechanisms

Steps in LeDir

1. Detect the node failure
2. Smallest block identification
3. Replacing the failure node
4. Subordinate Movement

1.3.3 Distributed Actor Recovery Algorithm (DARA)

DARA algorithm endeavors to revive the connectivity of divided inter-actor network once a node fails [25]. DARA doesn't give a system to discover cut-vertices. It's accepted that this data is accessible at the node which can need the information of the entire topology. The best candidate determination is done responsively and needs much calculation, which is exceptionally essential for the delay of sensitive applications, the significant issue happen with cyclic network topologies.

1.3.4 Grade Diffusion Algorithm (GD)

The energy efficiency of WSNs depends upon the underlying routing techniques. There are various routing techniques such as GD, DD [36] and Ladder Diffusion (LD). The route is created for each SN using GD algorithm however it also detects neighbor nodes to handle the transmission or communication in case of failure of any node. From the set of neighboring nodes each SN can choose a node when one of the previously selected node results in node failure due to low energy level. Then a sensor node which is not having a lot of load (amount of data) currently less than 4 neighbor nodes and also has sufficient battery backup (>50%) is selected. That is, routing path is quickly updated by the use of GD algorithm and data is send to the sink node.

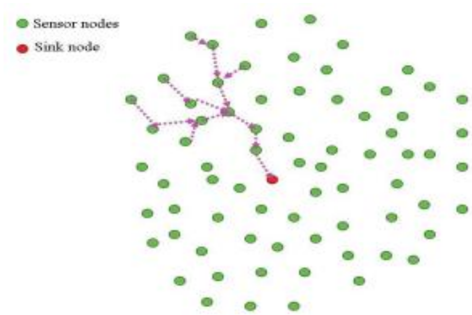


Figure 1.4: Routing in WSN

In GD algorithm the grade creation packets or enquiring query packets should be broadcasted primarily. Then, the nodes provide the communication statistics to the destination node, following to the operational algorithm, while appropriate events occur. The sensor routing paths with source and sink nodes are shown in Figure 1.4.

The GD algorithm broadcasts the information to the direct neighbor set only. After this, based on hop count or algorithm nodes are picked up. Route REQuest packet (RREQ) frequency is minimized subsequently and results in lesser amount of energy as compared to DD in case of increase in traffic. However issue still remains, as the number of routes calculated will increase, the energy consumption will eventually increase and nodes become no longer in use as shown in Figure 1.5.

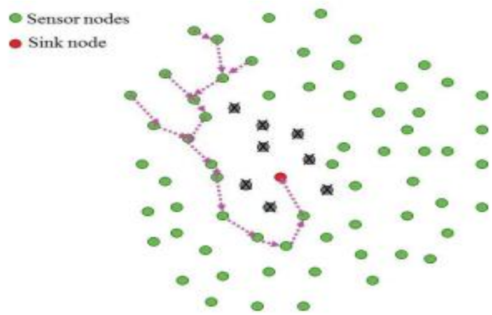


Fig.1.5: Path Routing with node failure

1.4 Particle swarm optimization

PSO is a computational strategy that optimizes the problem by iteratively giving the solution for that problem which improves the solution at each iteration to provide the best solution. Candidate solution is considered to get the solution for the existing problem [35]. The solution to the problem is being given by considering two parameters that is the particle's current position and the velocity of the particle. The further movement of every particle is impacted by the current position which is the best position known and is referred toward the best position in the swarm. Also leads the swarm towards the optimal solution. PSO is a stochastic optimize approach and also similar as the genetic algorithm. In PSO random solutions are being provided by the system which each time upgrades the solution. Each particle not only keeps the track of its position but also consider the other particles too. Then the comparison of the particle with its neighbor and itself is done to get the best solution which is being achieved so far. The value of attained solution is called as p-best. PSO consists of the particles which are accelerating i.e. changing their velocity. The lbest and the gbest are the best of the particles and the swarm respectively.PSO has been used successfully by many researchers and in various areas which provides better and faster results as compared to other methods.

1.5 Structure of thesis

Rest of the thesis report is organized as:

Chapter 2: This chapter presents the literature survey which includes the various node recovery techniques, network optimization approaches and number of fault node recovery algorithms in WSNs.

Chapter 3: This chapter describes the gaps find during literature survey along with the problem statement.

Chapter 4: This chapter discusses the proposed solution in detail.

Chapter 5: This chapter focuses on the implementation results.

Chapter 6: This chapter concludes the work done, contribution and gives future directions.

Chapter 2

Literature Survey

A number of FNR algorithms have been proposed by researchers. Various algorithms have been proposed to achieve QoS parameters in WSNs. The review of such works has been presented in this section some of these are discussed below:

Chen *et al.* [1] proposed and examined a localized fault detection set of rules to detect the defective SNs. The probability of accurate prognosis could be very high even within existence of large number of FNs and complexity of the algorithm is low.

Akkaya and Younis [2] presented an overview of the most recent rerouting protocols for WSNs and gives a classification of the various techniques pursued. Basically, three vital classes investigated particularly facts centric, hierarchical and vicinity-based. Every routing protocol is outlined and specified under the proper class. In addition, protocols use the current day methodologies for satisfaction of the provider.

Buratti *et al.* [3] studied research challenges by revealing a top level perspective of WSNs technologies and elementary packages for implementation. In interesting, some particular programs, together with in light of environmental monitoring, are specified and design techniques are highlighted. A contextual analysis in light of a genuine execution is proposed. Patterns and attainable advancements are followed. Accentuation is given to the IEEE 802.15.Some cases for performance parameters of 802.15.4-based systems are demonstrated.

Sheikhpour *et al.* [4] reviewed remarkable energy economical clustering conventions for heterogeneous WSNs and compared these conventions on different metrics like, vicinity consciousness, clustering technique, heterogeneity stage and clustering qualities.

Tanwar *et al.* [5] ordered different heterogeneous directing conventions for WSNs in light of different predefined parameters. Relative correlation of different conventions with other existing cutting edge conventions is given regard to different execution assessment parameters, for example, Cluster Head (CH) Selection, Security and Energy Efficiency. The general classification helps the clients to choose one of the conventions from various classes in terms of benefits.

Tripathy and Chinara [6] introduced a study of the advanced bunching procedures in WSNs. These strategies have been analyzed in terms of pros and cons. It is expected that the wireless

SNs are arbitrarily deployed and the directions of the BS and the measurements of the SNs deployment area are known.

Han *et al.* [7] proposed a system to improve the general execution of Heterogeneous Wireless Sensor Networks (HWSNs). Among these conventions, various leveled HWSN Routing conventions can improve the execution of the group. The most ordinarily utilized three various leveled HWSN conventions are Multi-Hop Communication Routing (MCR) convention and Energy Efficient Prediction Clustering Algorithm (EEPCA). These have been compared with existing Low-Energy Adaptive Clustering Hierarchy (LEACH) and Stable Election Protocol (SEP). The quantity of rounds for which a node lives (called the steady length) and the quantity of data packets dispatched to sink, are crucial components.

Chi *et al.* [8] discussed that it is necessary to repair the network in specified bandwidths. The data storage system ensured the recovery in the given bandwidth but it is also very important to give equal importance to time while recovering the failure. In this work MTR which is minimum time repair scheme has been proposed which not only repair the failure in the given bound of bandwidth but also satisfies the time limit of the scheme.

Abuelenin *et al.* [9] presented that WSN as a fair and very effective tool in modern day technology to implement fast and serious observation tasks. Due to the wireless nature and less human intervention the failure of nodes creates a problem for the technology development related to WSNs. This work proposed the recovery of the node using the GD algorithm which has the neighbor node to recover the failed path and rerouting the paths for continuous routing. The results are based on number of hops, energy, etc.

Prabu and Maheshwari [10] presented an approach for the WSNs that are battery operated network and causes the network to stop working as the battery exhausts. The network may reduce the performance or completely stop working if the energy of the node reduces than a given amount. This nature of the WSNs make them less suitable for long term tasks as they are very short termed in term of battery. To reduce this problem the LZW compression technique is proposed which cause the data to compress before transmitting into the air. As the compression happens the stream is reduced in size and is easily transmitted without the use of much energy.

Cong [11] proposed an optimization algorithm for better coverage of the area thorough the given range of nodes. By the application of PSO in judging position of the SNs in best coverage, the network steps up to show result by improving the quality of service.

Elhabyan and Yagoub [12] described the formation cluster for efficient routing in WSNs is a prime method for improving communication in the network. Clustering helps to lower the amount of energy consumed by all SNs as major work is done by the cluster head. The use of PSO also, improves the clustering further so that the clusters formed are best fits. This shows the capability of PSO in optimizing the problem which needs a multidimensional view because in clustering there is a need to have a look at more than one effecting parameter.

Kulkarni *et al.* [13] presented the usage of PSO in the network for the judgment of various parameters of ad hoc network. To predict the parameter of interest a modified PSO algorithm is stated that is modified specially for improving performance of PSO by estimation of parameters.

Zhang and Zhong [14] described a brief description of the various kinds of optical multicast protection approaches for the full recovery of the SNs and the link failure. Various approaches have been discussed including tree-protecting p-cycle, node and link protecting p- cycle. Among these approaches node and link protecting approach which is extended approach for ordinary p-cycle approach.

Li *et al.* [15] presented a novel technique for recovering SNs in the network in most efficient manner. The approach is capable for all types of networks. Identification of the best nodes has been done to detect the most energetic node and the most promising node of the network. Re-clustering is one of the solutions being proposed by the author for the normal execution of the task in the network and also provides the node recovery so as to relay the information correctly.

Bouhafs *et al.* [16] proposed a node recovery scheme for data dissemination. The mechanism removes the FNs and the less energetic nodes which degrades the performance of the network. Work has been done to recover the nodes and it is possible to recover only when it is in the range of the radio energy. For peer to peer connection comparisons have been made to get the routing path for the communication.

Shih *et al.* [17] proposed a FNR algorithm to enhance the lifetime of WSNs when some of the SNs shut down. The algorithm is based on the GD algorithm combined with the genetic algorithm. The algorithm can result in fewer replacements of SNs and more reused routing paths.

Jeong and Chappel [18] A Hybrid approach has been proposed by the authors which is the combination of the two techniques, one is the GD and another is the genetic algorithm. The proposed algorithm works to detect and recover the FNs in the network. Replacement of the SNs is being done by the algorithm for obtaining good results in the terms of two parameters namely energy and data loss. This algorithm not only reduces the replacement cost but also makes sure to reuse the path for further rerouting in the WSNs.

Keerthana and Pamila [19] focused on Processing and transmission of the data being done in the WSNs. It consists of sensing devices called SNs with power as one of the main constraint. When the energy level of the SN decreases, leaks will appear in WSNs due to which data is not transferred to another node during transmission. Hence, for further transmission of data the other sensor nodes will be loaded. The work done by the authors help the researchers to understand the available lifetime enhancement techniques and to come up with the idea for improving their performance or to propose a new approach for lifetime enhancement of WSNs.

An and Cam [20] provided a scheme named Route Recovery by One-Hop Broadcast (RROB) which eradicates the FNs from the selected path by rerouting the path without the use of any mediator. The main idea is to reconstruct a path between sink and the source. To remove traffic RROB uses the adjacent SNs of the FNs to replace the FNs.

Aliout *et at.* [21] presented a mechanism to diagnose the SNs failure in WSN; and method differentiates various reasons for the decrease in the performance of SNs and also suggests different steps to successfully transmit the data and recovery the FNs in the WSNs. An algorithm which not only diagnose the FNs but also recovers the nodes with the routing protocol named as LEACH that not only detects but also localize SNs.

Yanfei *et al.* [22] presented an extended design of ZigBee in WSNs. The ZigBee network consists of various tasks and different processors to handle different tasks. The main node deals with a single task only. A serial port is required to communicate data to the processor. Hence, various processors including the main node deal with the data transmission which not only saves the information of the network but also interacts with the host device.

Modares *et al.* [23] discussed various issues, applications, security principles and security protocols in WSNs. Many security issues related to the different layers of the wireless network have been explored.

Abbasi *et al.* [24] proposed an algorithm named LeDiR which is one of the generally utilized algorithms in recuperation of SNs. LeDiR depends on the neighborhood perspective of SNs with a specific end goal for generating a recuperation idea which migrates minimal count of SNs and also guarantees that no other way between any pair of SNs is developed. The main focus is being laid on the data path without changing its length and forces no extra pre-disappointment correspondence overhead.

Abbasi *et. al* [25] presented DARA, a disseminated performing SNs recuperation calculation, which selects to effectively reestablish the availability of the on-screen character arrange that has been influenced by the disappointment of an on-screen character. Two variations of the calculation are produced to address one-and two-network prerequisites. The thought is to distinguish minimal arrangement of performing artists that ought to be repositioned with a specific end goal to restore a specific network range.

Abbasi *et al.* [26] exhibited an algorithm named as DARA that reestablishes availability of on-screen character that have been influenced by the disappointment of a performing actor. The thought is to recognize minimal arrangement of on-screen characters that ought to be repositioned keeping in mind the end goal to build up availability among disjoint system segments. DARA endeavors to limit the extent of the recuperation procedure and reduce the development overhead forced on the included performers.

Akkaya [27] introduced an idea to identify FNs that causes network partition. A restoration process for the connectivity of the nodes is proposed which actually repositions the SNs to avoid network gap. The goal is to recover FNs with minimum movements with a specific end goal to reestablish the network. PADRA protocol is being used to handle the failure which replaces the FNs.

Scazzoli *et. al* [28] exhibited RACE, which is one of the novel systems to Restore Actor Connected Coverage with lessened recuperation overhead and also recognizes basic/non-basic on-screen characters in light of two-jump data to better evaluate the extent of the disappointment and advance the recuperation strategy. Neighbors of a fizzled on-screen character utilize an agreeable disappointment location plan and just play out a restricted scale system reconfiguration to embrace any dispossessed sensors left inaccessible (revealed by a performer) because of disappointment of a non-basic on-screen character.

Singh *et. al* [29] introduced a concept in which firstly, give knowledge to the best in class responsive network reclamation calculations. At that point, a Nearest Non-basic Neighbor (NNN) calculation; a limited and conveyed receptive methodology for reconnecting system allotment has been discussed. In NNN, every performer intermittently decides its criticality in light of two-bounce data and also trades with its neighbors. In the event of a basic performing artist disappointment, the neighbors recognize and trigger an availability reclamation technique that includes controlled and facilitated hub movement. NNN want to uproot non-basic hubs amid migration so as to minimize recuperation overhead regarding separation development and message coordination. We investigate the execution of receptive plans through hypothetical examination and reenactments.

Abbasi *et. al* [30] proposed a mechanism named as SMOG which not only built the network topology model but also centralizes it by using probabilistic data structures. The mechanism can be built for hundred SNs. Bloom filters have been used to represent the neighboring information.

Abuelenin *et. al* [31] an algorithm named as FNR based on GD using shortest save path has been proposed. The SNs have been arranged and routed with smallest shortest path which not only reduces the energy consumption but also provides the shortest path. The algorithm provides a solution when some SN fails. Routing table with shortest path has been used to keep the SNs in the working condition for longest interval of time.

Belabed and Bouallegue [32] proposed an algorithm that is an improved and adapted extension of the weighted clustering algorithm. The algorithm is used to elect the Cluster Heads in the WSNs. Each SN has been assigned with a weight and that weight of each SN has been broadcasted if that satisfies the condition and then it becomes the part of the network.

M S and Patil [33] an FNR algorithm has been proposed to enhance the lifetime of WSNs. This algorithm works when the SNs shut down that not only discovers the FNs but also discovers the route when the path between the source and the destination becomes non-functional because of some FNs in the network. Resulting in fewer SN replacements and with more reused routing path with the network. The main focus has been laid on reducing the replacement cost of the SNs in the network.

Savvides *et. al* [34] a novel approach for adhoc networks based on localization of sensors has been proposed as ALOHA. A distributive iteration algorithm has been used to discover the SNs and their locations. The study of fine-grained localization has been studied as it is not sensitive in nature. A distributive fashion has been recommended for the proposed technique which increases the system's robustness.

Chuang and Wu [35] unique scheme has been proposed for the location of SNs provided by the closed neighbor of SNs that is basically at the unknown position. The usage of PSO algorithm an effective localization scheme has been proposed for WSNs. The modified scheme has been used for the reduction of error accumulation. Main focus has been laid to get the good ratio of locating unknown SNs.

Intanagonwiwat *et. al* [36] a DD has been proposed in which all SNs are application aware. Paths have been selected to unable the diffusion in DD. Best paths have been selected to achieve energy savings in the network. The DD has been used for remote surveillance. The main advantage of DD is that it is energy efficient and can work when unoptimized path has been selected and also it becomes stable under the *R* network dynamics.

Shih *et. al* [37] proposed a Reduced Identical Event Transmission algorithm. The algorithm is decision based and decides which SN has to participate in the event in order to save energy. The SNs with more energy are given more priority in the network.

Sundaran [38] A novel approach for enhancement of network lifetime by detecting the FNs has been prposed. The algorithm is combination of the GD and the genetic algorithm. This algorithm replaces the deactivated FNs and additionally, reroutes the ways by reusing the path.

Chapter 3

Problem Statement

3.1 Gap Analysis

1. In the existing work, it has been noticed that the failure of the SN is either as a result of communication system failure or battery depletion. The researchers considered rerouting as a recovery process which further increases the complexity and is not energy efficient too.
2. Every detector node has restricted wireless processing and transmitting power to transfer the information to the base station or information assortment center. Hence energy is one of the main parameter which has to be considered to avoid failure of the node due to less energy. Energy parameter has been not considered.
3. The present protocols are not smart enough to recover from node failure in the most effective manner. There can be a predictive approach which finds the solution that are long term and maintain the network energy better so as to maximize the network lifetime.
4. In the existing approaches no physical movement of the nodes exists, which leads to more energy consumption.
5. The energy consumption in the existing approaches is quite more and also suffers from the problem of network coverage hole, long delays and less throughput in the network while transferring the messages.

3.2 Problem Statement

Each node is having particular transmission range *R* in which it can send and receive data packets. When sensor nodes shut down due to energy utilization, the nodes become a FN which results in network partitioning. Topology of the network is not optimized with respect to the area to be covered. The existing technique DARA has a problem that during its implementation path between nodes get extended. The existing RIM technique shows inward movement and the effective area under the coverage of node decreases. LeDiR is a confined and dispersed technique. It uses existing path disclosures scheme inside the network. Also in this technique there is enforcement of the non auxiliary pre-failure communication overheads.

In GD algorithm there is no movement of nodes and has only considered rerouting as a recovery process. The energy consumption while rerouting is not considered. So the problem which is not is not being considered is of mobility of SNs. If the SNs become mobile it is easier to recover the node failure and the energy status must be considered before routing.

Another problem is to optimize the network and the ultimate solution of the problem is not maintaining the routing paths ultimately but looking for the path improvements which prolong the lifetime of the networks. So, we propose Enhanced GD for node recovery and Enhanced PSO in order to get better solutions, energy utilization, throughput and less delay in wireless sensor networks.

3.3 Objectives

- To study various existing node recovery techniques and network optimization techniques in the WSNs.
- To implement energy efficient node recovery algorithm in the WSNs.
- To validate the proposed methodology in the simulated environment.
- To analyze and compare performance of the proposed algorithm with the existing approaches in the terms of various QoS parameters.

Chapter 4

Proposed Approaches

4.1 Proposed approach for Node recovery

The calculation and comparison of parameters namely, energy, throughput, delay and network lifetime are performed which includes four steps as described below:

Step 1: Node failure identification

Whenever there is a reasonable gap between the nodes in the network, its throughput starts to degrade which indicates there is something wrong in the network, it further suggests that there might be a FN in the network. A test which communicates with the nodes is done to find the failing node.

Step 2: Selection of backup node

After the identification of the failing node, there is a need to find the backup node which will replace the FN. The backup node is selected on the basis of its nature of being an actor or mobile and nearest to the failing location.

Step 3: Selection of subordinate node

After the backup location is selected the search of subordinate is started in order to maintain the gap created by the backup movement.

Step 4: Final movement

Number of subordinate movement depends on the size of the gap created by the backup movement. The movement of subordinate will be half the distance of the backup node.

The proposed EGD technique is a hybrid approach based on GD and LeDIR approach. The flowchart and pseudo code of proposed technique is shown in Figure 4.2 and in Figure 4.3 respectively.

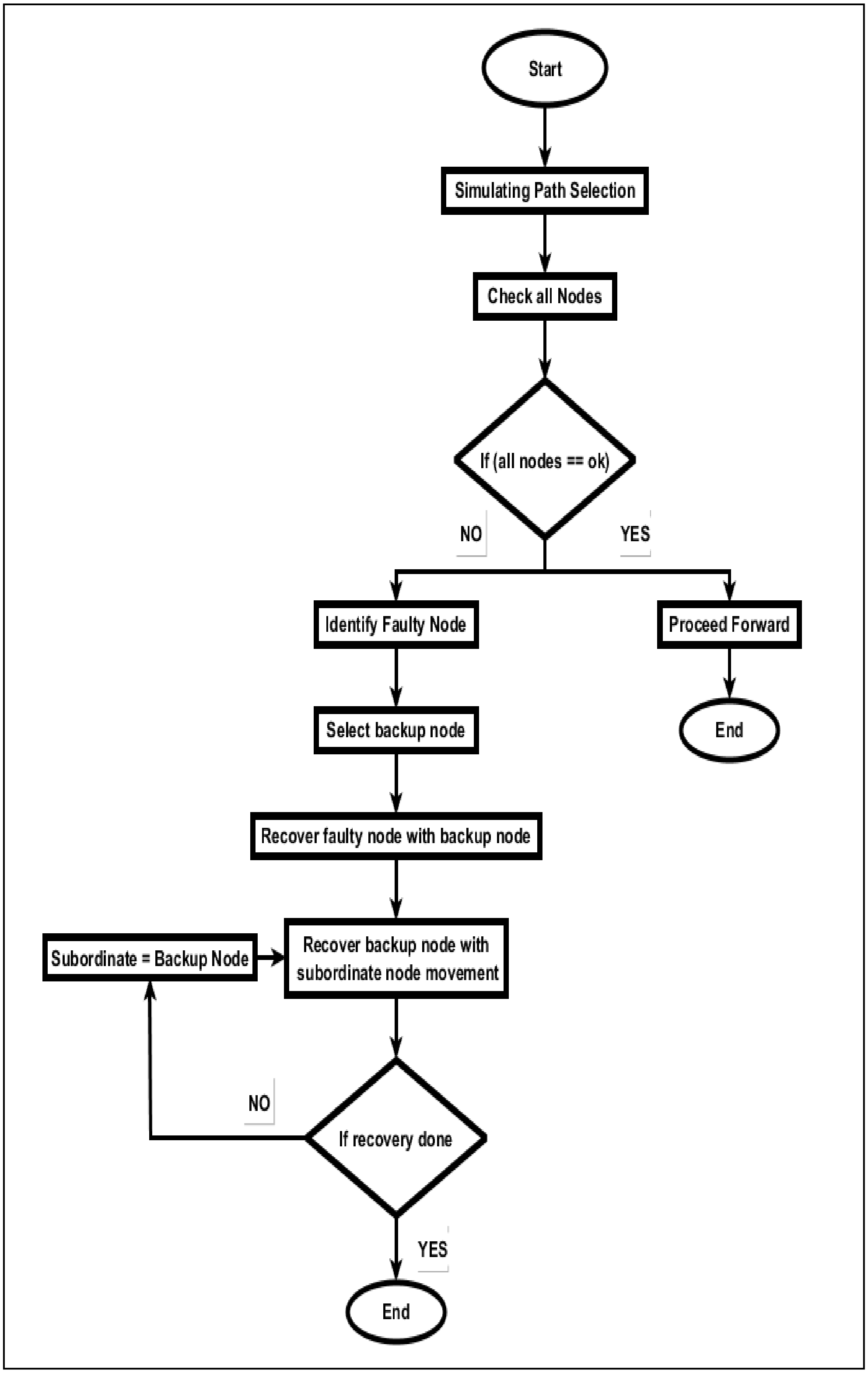


Figure 4.1: Flowchart of the proposed Enhanced Grade Diffusion for node recovery

```
1: Select Source S
2: Select Destination D
3: for i=1:number_of_nodes
4: path(i)=nearest neighbor path
5: end for
6: min(path)=ds
7: for i=1:number_of_nodes
8: If (n(i)==failure)
9: end if
10: end for
11: If (all nodes OK)
12: continue routing
13: else
14: Fn=n(i)
15: for i=1:number_of_nodes
16: Dis(i)=Distance from Fn
17: end for
18: Pn=min(Dist(Fn,i->n)) // Check for the nearest replacement
19: // replace Fn by Pn through movement
20: Cn=min(DisT(Pn,i->n))// Check the nearest replacements
21: //as the children can be more than one
22: //replace Pn by Cn partially i.e. half movements
23: If (Child also is partitioning)
24: Repeat steps 20, 21 and 22 before to step 25
25: continue routing
26: end if
27: continue routing
28: end if
```

Figure 4.2: Pseudo code of Enhanced Grade Diffusion for node recovery

4.2 PSO based Path Shifting Approach

In the proposed work, the idea is not only changing the solution from rerouting to node recovery but to consider the long term effect of the solution that has been implemented for this purpose. The use of PSO for implementing path selection process after failure of the node in the routing path has been proposed. In this work once the node fails in the process of routing, the search for the new path begins, firstly by finding the most probable n number of paths. The paths are dependent on the present situation of various SNs in the network by nearest neighbor routing. The path selection process can be improved by adding the energy left in each node. After the selection of paths, objective function formulates the energy of the path with the help of length of the path and the individual energies of the nodes.

PSO initially takes population as an input but makes continuous changes in the candidates of the population for betterment of the results. Each particle moves in the direction of a specified point in search of the best position and in the process of that it keeps on changing its velocity and cost. Each particle movement velocity, direction and the distance travelled is influenced by the Local Best (LB) and the Global Best (GB) of the existing population. The step by step description of proposed work is shown below:

Step 1: Identification of the failure node

The node failure in the network can happen either by the means of battery power exhaustion or some natural calamity. Generally, we detect the coverage loss and decrease of throughput continuously to detect the failure in the network. Once the anomaly has been detected, the network is examined by test signals to get the particular node number which has failed. The faulty node is termed as FN and the failure location is termed as Fl.

Step 2: Fitness function

The objective function defines the fitness or the cost of the best optimized path which is then matched with all the possible paths found in the simulation. Then the path whose cost is closest to the best optimized path is selected as the path for rerouting in the EGD which has been proposed. So the best possible path is found not only from the current situation but for the future prospect also. The optimization of the path will be affected by only the values which are given by the objective function. The objective function depends upon the three factors namely, number of nodes involved (Nn), average residual energy (E_{rav}) of the defined network and the average distance (D_{av}) travelled per hop.

$$f(x) = \frac{D_{av}}{N_{hops}} + 1 \Big/ \left(\frac{E_{rav}}{N_{hops}}\right) \tag{4.1}$$

Where, D_{av} = Average Distance

N_{hops} = Number of Hops

E_{rav} = Average Residual Energy

Step 3: Defining the simulation parameters

The parameter to be defined for the PSO involves the definition of the 8 parameters as illustrated in Table 4.1.

Table 4.1 various parameters for PSO

Parameter	**Values**
Number of iterations (Maxit)	100
population size(npop)	50
upper bound(Vmax)	30
lower bound (Vmin)	1
decision variables size (Vsize)	20
inertial coefficient	1 with 0.99 % damping
personal acceleration coefficient	2
global acceleration coefficient	2

Step 4: Initialization of PSO

The initialization of PSO has five properties of each particle. The properties are Velocity, GB Cost, GB Position, LB Position and LB Cost. Also the Particles are repeated number of times as the size of the population. The initial velocity of the particles is set to be zero. The position is randomly defined for all particles. Cost of the particle is evaluated using the objectives. Best position is current position and the best cost is the current cost of the particle.

Step 5: The main iterations of PSO

The main iteration of PSO works by continuously updating the cost according to the objective function, velocity of the particle and the position of every particle in the each iteration considering the following equations:

For Velocity:

$$v_{ij}(t+1) = w * v_{ij}(t) + r_1 c_1 \left(p_{ij}\left(t - x_{ij}(t)\right)\right) + r_2 c_2 \left(g_j\left(t - x_{ij}(t)\right)\right) \quad (4.2)$$

where, v = velocity

$r_1 c_1$ = random local acceleration coefficient

$r_2 c_2$= random social acceleration coefficient

w = inertial coefficient

i = particle number

j = iteration number

t = time

x = position

p = local best position

g = global best position

For Position:

$$x_{ij}(t+1) = x_{ij}(t) + v_{ij}(t+1) \quad (4.3)$$

Step 6: Path Shifting

The final stage of the work is to shift the path from the previous path in which the node had failed to the new hop. After the changing of path, the simulation is done to calculate the parameters of results such as throughput energy etc.

4.3 Energy model:

The radio energy consumed is given by the calculation of energy to transmit one bit packet of information which given by equation no. (4.4) and (4.5):

$$E_{Tx} = lE_{elec} + le_{fs}d^2 if d < d0 \quad (4.4)$$

$And,$

$$E_{Tx} = lE_{elec} + le_{mp}d^4 if d > d \quad (4.5)$$

Where E_{elec} is the energy consumed per bit to run the transmission or the reception circuit. Where, d is defined as the distance between the source and the sink node. For the distances less than threshold, free space (fs) model is used else the other model i.e. the multi path (mp) model is used with energy constants e_{fs} and e_{mp} for both free space and multi path models.

Another proposed EGD technique is a hybrid approach based on GD and PSO approach. The flowchart and pseudo code of proposed technique are shown in Figure 4.3 and in Figure 4.4 respectively.

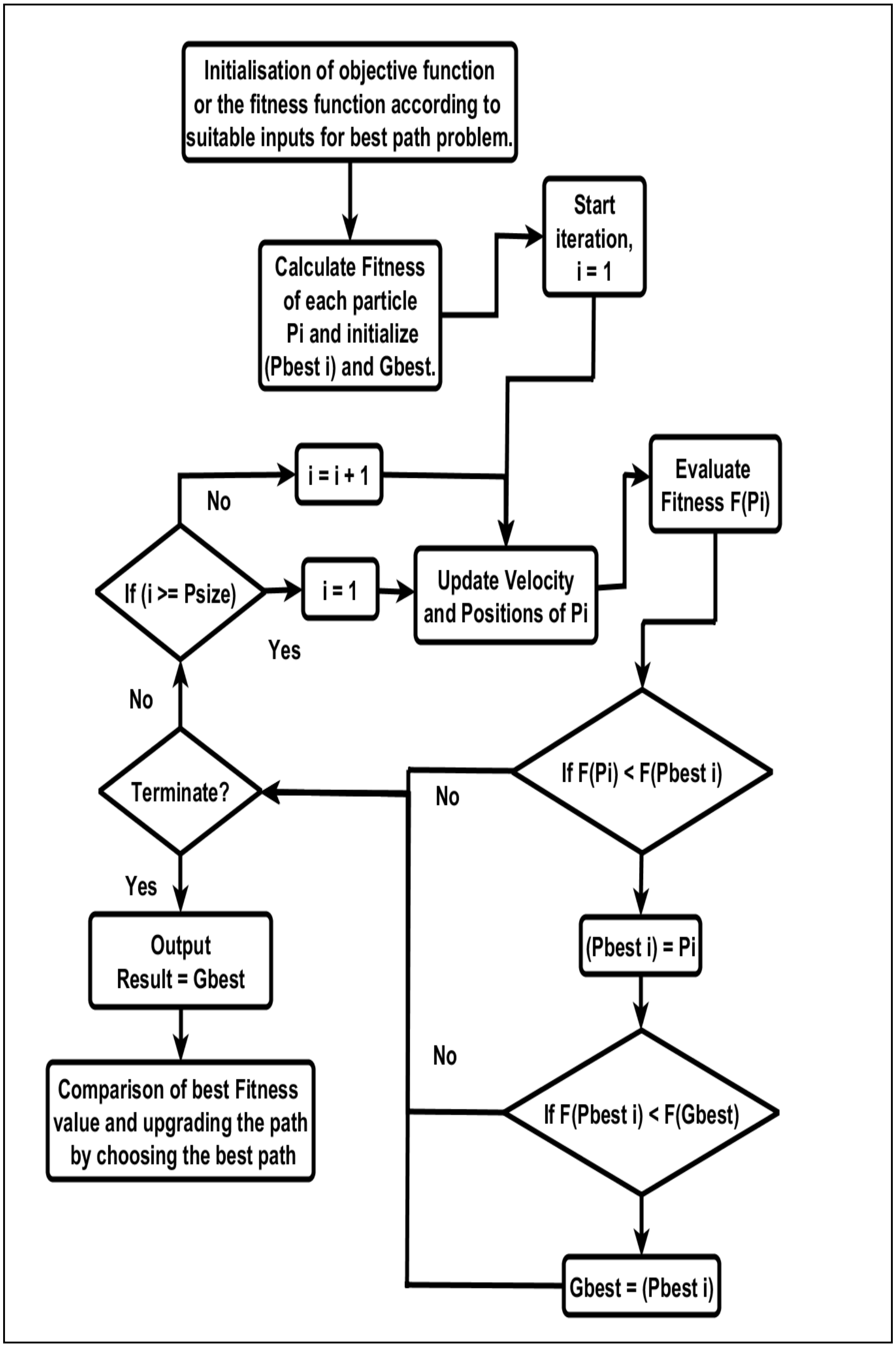


Figure 4.3: Flowchart for PSO based Path Shifting Approach

1: Definition of the objective or fitness function

2: Find best fitness according to the energy model proposed

3: for all particles i = 1, ..., S do

4: uniform distribution initialization of each particle: xi ~ U(blo, bup)

5: Initialize the particle's bp = initial position: pi ← xi

6: iffn(pi) <fn(g) then

7: swarm's bp g =pi

8: Initial velocity of particle vi = 0

9: While the final criteria is not met

10: for each particle i = 1, ..., S do

11: for each dimension d = 1, ..., n do

12: Randomize values from sample space are fed as particle position

13: Velocity is updated using eq 2

14: Position is updated using eq 3

15: iffn(xi) <fn(pi) then

16: pi=xi

17: iffn(pi) <fn(g) then

18: g=pi

19: BGFV=g // Best global fitness value

20:Compare the n paths fitness with best fitness from PSO

21:Update the best path

22:*End*

Figure 4.4: Flowchart for PSO based Path Shifting Approach

Chapter 5

Simulation Results

With the help of simulated environment, various approaches have been compared. We have considered two cases, one for the node recovery and another is the optimization for the path selection.

5.1 Results for Node recovery approach

In proposed Enhanced Grade Diffusion (EGD) technique, energy is considered while rerouting is performed to improve the GD algorithm and also mobility of nodes is involved if needed. The simulation tool used for experiment is MATLAB R2013B. 200 nodes are deployed in 400*400 area randomly as shown in Table 5.1. After the selection of sender and receiver nodes best communication path between them is found and communication between nodes takes place. The simulation result shows three criterion i.e. *initial scenario, node failure* scenario and *after node recovery* scenario as shown in Figure 5.1, 5.2 and 5.3. In initial scenario the communication between selected sender and receiver node is shown. In node failure scenario one of the communication path nodes gets fail which is shown in red color and new path for communication is selected after that, node recovery scenario is shown in which FN is recovered and communication takes place from same path which is selected before node failure.

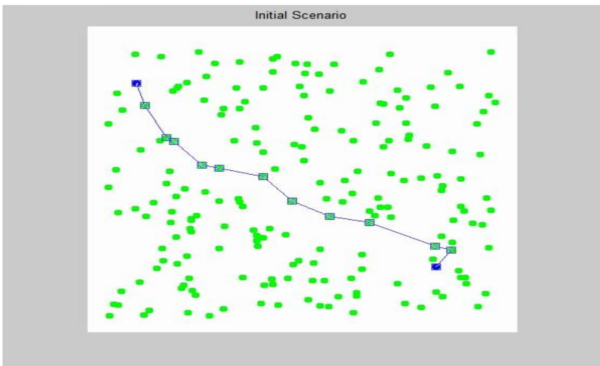


Figure 5.1: SN deployment Initial Scenario

Once the sender and receiver nodes are selected, then communication path is established as shown in Figure 5.1 and communication between nodes takes place.

Table 5.1: Simulation settings for Experimental Setup

Simulation Parameters	
Total no. of nodes	200
Area of deployment	400x400 Meter
Count of Sinks	1
Location of sink	Dynamic
Node's initial Energy	2 Joules
Packet Size or Length of Packet (l)	2000 bytes
Average Network Lifetime	200 Rounds
No. of Iterations	100
E_{elec}	50nJ/bit
E_{fs}	10nJ/bit/m2
E_{mp}	0.0013pJ/bit/m4

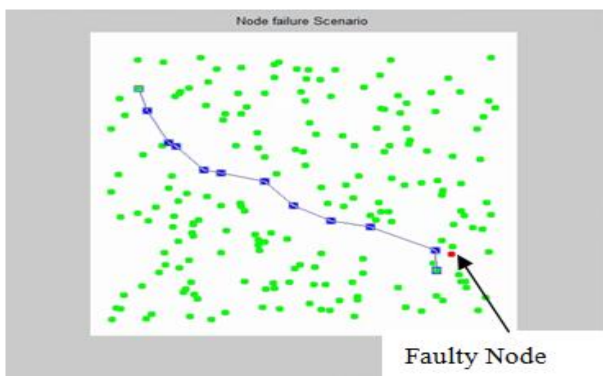


Figure 5.2: Node Failure Scenario

The Node Failure Scenario is shown in Figure 5.2, after the communication path is selected and communication takes place, node failure scenario is taken into consideration. After the node failure, new path is selected for communication as shown in Figure 5.3.

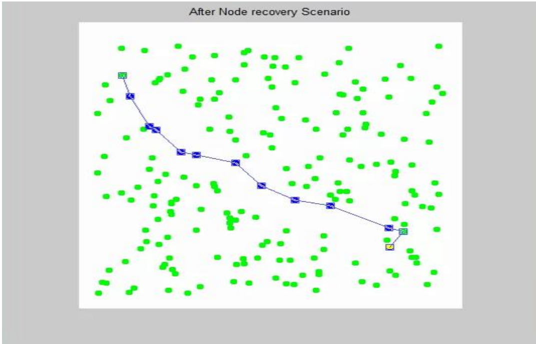


Figure 5.3: After Node Recovery Scenario

Test Case 1: Analysis of RIM, DARA, GD and EGD in terms of Energy left

After Node Recovery and node failure Scenario, node recovery scenario is taken into consideration for recovery of FN for communication through best suitable path. The first selected path is again revived by recovery of failed node.

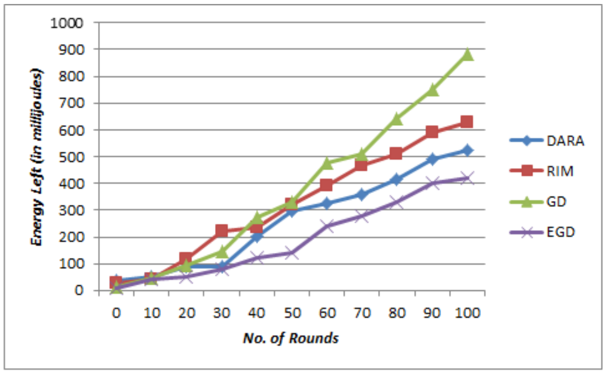


Figure 5.4: Energy (in millijoules)

The Energy (in millijoules) is shown in Figure 5.4 for the proposed EGD technique and existing DARA, GD and RIM techniques. Figure 5.4 shows residual energy after recovery (EGD) is 884.33 milliJoules whereas residual energy for existing GD technique is 418.08 milliJoules. The values of energy are derived from the equation no. (5.1)and (5.2).

$$E_{Tx} = lE_{elec} + le_{fs}d^2 if d < d0 \quad (5.1)$$

And,

$$E_{Tx} = lE_{elec} + le_{mp}d^4 if d > d \quad (5.2)$$

Test Case 2: Analysis of RIM, DARA, GD and EGD in terms of Throughput

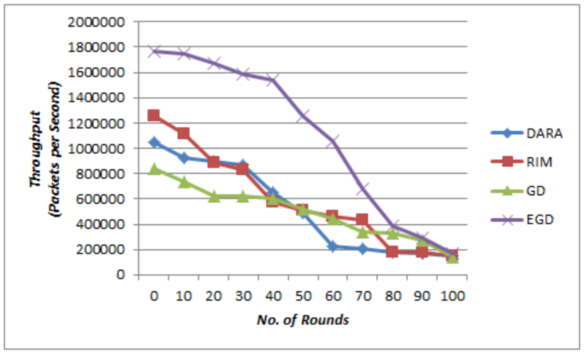


Figure 5.5: Throughput (No. of Packets transfer per Second)

Throughput (No. of Packets transfer per Second) is shown in Figure 5.5 proposed EGD technique and existing DARA, GD and RIM techniques.

Where, Throughput (T)

$$T = E * C_n \quad (5.3)$$

E= Energy, C_n=Network carriage capacity

Figure 5.5 shows throughput after recovery (EGD) is 164587 packets per second whereas throughput for GD is 143931 packets per second. The values of throughput are derived from the equation no. (5.3).

Test Case 3: Analysis of RIM, DARA, GD and EGD in terms of Delay

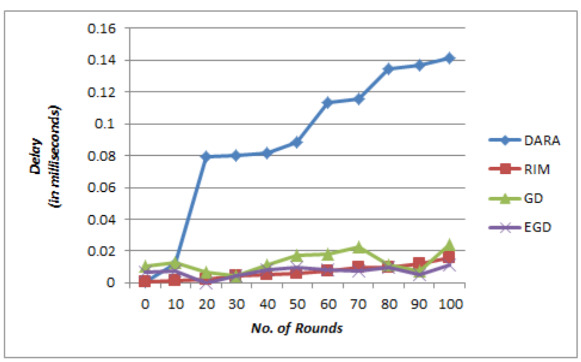


Figure 5.6: Delay (in milliseconds)

The Delay (in milliseconds) is shown in Figure 4.6for proposed EGD technique and existing DARA, GD and RIM techniques. The values of delay are derived from the equation no. (5.4).

Where, Delay (D)

$$D = \frac{1}{T} \tag{5.4}$$

Figure 4.6 shows delay for recovery in EGD is 0.0113 milliseconds whereas for existing GD is 0.0239 milliseconds.

Test Case 4: Analysis of RIM, DARA, GD and EGD in terms of Network Lifetime

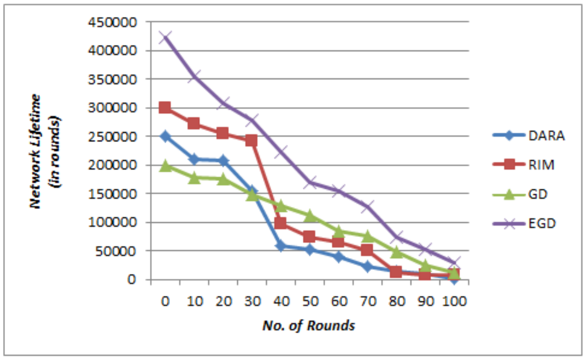


Figure 5.7: Network Lifetime (in rounds)

Network Lifetime (in rounds) is shown in Figure 5.7 for proposed EGD technique and existing DARA, GD and RIM techniques.

where, Network Lifetime (NL), Network Lifetime after recovery (NL_C) are related as follow

$$NL_C = \frac{E_C}{E_P} * 100 \tag{5.5}$$

Network Lifetime before recovery (NL_p)

$$NL_p = \frac{E_P}{E_P} * 100 \tag{5.6}$$

Here,

E_C=Energy after recovery,

E_P=Energy before recovery

The Figure 5.7 shows Network Lifetime for proposed EGD is 28957 rounds whereas Network Lifetime for existing GD is 12498 rounds. The values of network lifetime are derived from the equation no.(5.5) and (5.6).

Table 5.2: Comparative Performance Analysis of Existing and Proposed Technique

Parameters	**Previous**			**Proposed**
	DARA	**RIM**	**GD**	**EGD**
Energy (in milliseconds)	522.5	627.0	884.33	418.06
Throughput(Packets per Second)	149201	153342	143931	164587
Delay (in milliseconds)	0.141	0.016	0.0239	0.0113
Network Lifetime (in rounds)	2118	8609	12498	28957

The results of proposed EGD node recovery algorithm shows have promising results as compared to the existing GD, DARA and RIM algorithms. The results of GD algorithm are improved by using recovery technique for node in WSNs.

5.2 Results for PSO based Path Shifting Approach

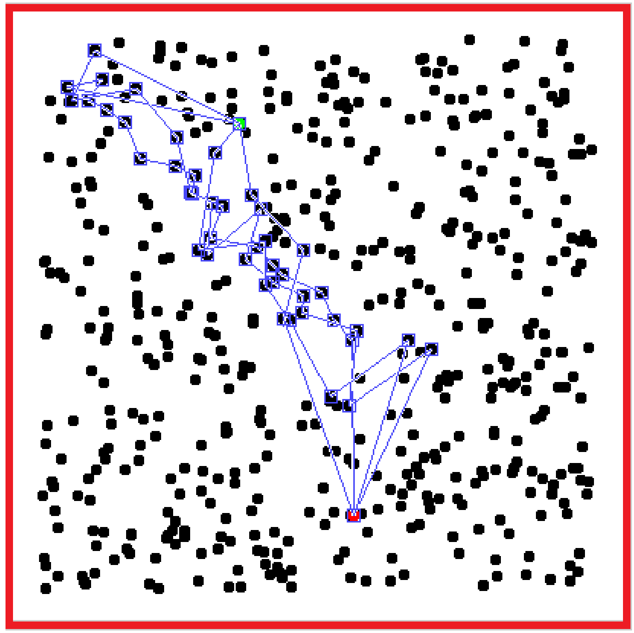


Figure 5.9 multiple paths

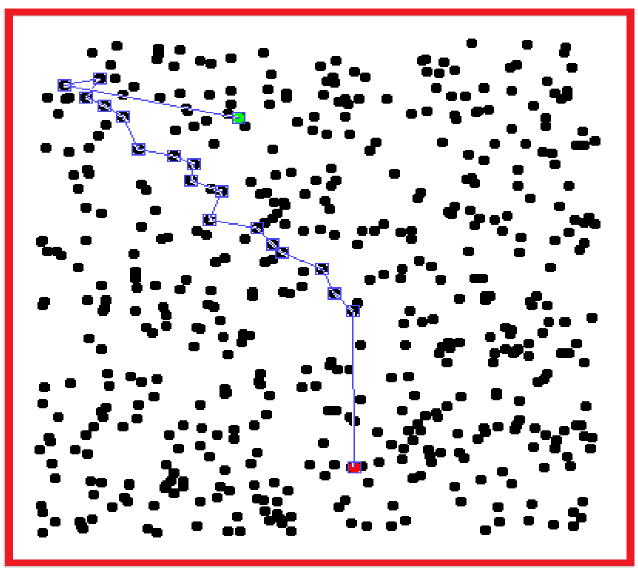


Figure 5.9: selected path for recovery rerouting

Figure 5.8 shows the multiple paths that are possible for going from one point to another but deciding the priority of a path is complex process which is being dealt by calculating the life of a particular path using Grade diffusion and Particle Swarm optimization. The destination node and the source node are represented by green and red color respectively. The blue node indicates the

FN. Paths are shown in light blue lines. Figure 5.9 shows the selected path for recovery rerouting.

Test Case 5: Analysis of GD and GD with PSO in terms of Energy left

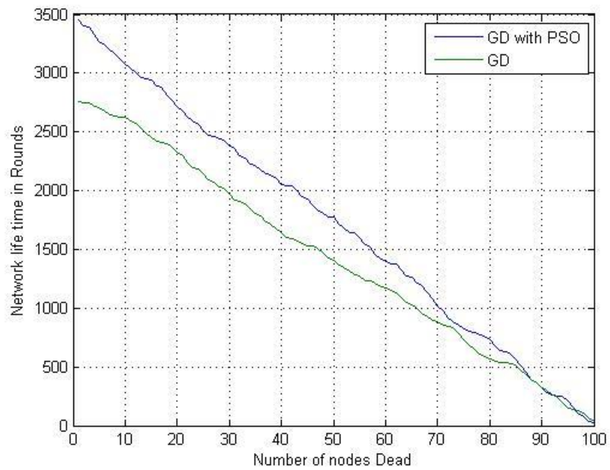


Figure 5.10: Shows the lifetime comparison of the GD and GD with PSO

Chapter 6

Conclusion and Future Scope

6.1 Conclusion

Node recovery is considered as one of the most condemning issue in WSNs. There are number of existing node recovery algorithms such as DARA, RIM and GD etc. In order to improve working of these algorithms, GD method has been proposed earlier. The results of proposed node recovery algorithm have shown promising results as compared to the previous GD algorithm. The results of GD algorithm are improved using node recovery algorithm for WSNs. The comparisons with previous algorithms are made by using parameters namely energy, throughput, delay, network lifetime.

6.2 Contribution

A novel node recovering mechanism is proposed i.e. Enhanced Grade Diffusion (EGD) which aims to give solution to the problem by actually recovering the FN by using its own neighbors in the network using LeDiR technique which involves node recovery using backup node and subordinate node movements. The results of experimental evaluation shows that the proposed EGD approach consumes 47.27% less energy, having 47.26% more throughput, 47.28% less communication delay, and 47.16% more network lifetime as compared to existing approaches. The use of PSO as an optimization algorithm has improved the performance of the network as compared to nearest replacement in GD by a considerable margin. Results confirm the improvements in GD. In the lifetime calculation the GD with PSO network runs for more rounds than normal GD. In the proposed work the optimization is used to determine the best path among more than one path.

6.3 Future Scope

Further research using other optimization algorithms for further improvement of results can done using various heuristic approaches. In future the process of selection of node within one path can be optimized to have the best paths to choose from when we select the best path.

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List of Publications

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