

Topology control in Wireless sensor networks

A Thesis submitted in partial fulfilment of the requirement for award of the degree of

MASTER OF ENGINEERING
in Electronics and Communication

Submitted by

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DECLARATION

I, **Pallavi Singla** hereby declare that the work which is presented in the thesis entitled "Topology Control in Wireless Sensor Networks" in partial fulfillment of requirement for the award of degree of **Master of Engineering (ECE)** submitted at **Electronics and Communication Department, Thapar Institute Of Engineering and technology (Deemed to be university)**, Patiala is an authentic record of my own work carried out under the supervision of **Dr. Amit Munjal** and refers other researcher's work which are duly listed in reference section. The matter presented in thesis has not been submitted for award for any another degree of this or any other university.

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Abstract

Wireless sensor networks are the networks in which thousand of sensor nodes are deployed randomly. Sensor nodes has ability to process, gather and communicate the data. Sensor nodes are generally deployed in an area where it is not feasible for the humans to approach. As wireless nodes have limited battery capacity and if these nodes have additional mobility then there is high probability that the links in network will break very frequently this leads to degradation of the network performance. Topology control is one of the basic technique which arrange the nodes in effective manner either by distributing the nodes in specific regions, by changing transmission range or with any other method in order to reduce complexity of network and make communication easier. Moreover, fault can occur in the network at any time due to energy drain, mobility of nodes or due to collision of nodes in network. There is a requirement of topology control, specially for mobile networks so that faults don't occur in the network and communication can continue uninterrupted. If the network is not fault tolerant then it increases the packet loss as well as the energy consumption of the nodes and thereby reduces the throughput of the network. Moreover, if the node have additional mobility then there is high probability that the links in network will break very frequently and this leads to degradation of network performance. So, our research work in this thesis is focused on reducing the number of faults so that the packet delivery ratio can be increased and also to reduce the energy consumption of the node by reducing probability of link breakage. Topology control is one of the basic technique which arrange the nodes in an effective manner either by distributing the nodes in specific regions, by changing their transmission range or with any other method in order to reduce complexity of network and make communication easier. We have proposed an algorithm that select a link in way that reduces the energy consumption of node. In addition to the above research we have also used back propagation algorithm to improve the performance of network. This algorithm is mainly used in neural networks and it helps in reducing the error in topology control and thereby makes the network fault free and increases the network efficiency.

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Chapter 1

Introduction

Wireless Sensor Networks (WSNs) are the networks in which thousands of sensor nodes are deployed randomly in certain area of interest. The Sensor node architecture mainly consists of five components as shown in figure 1.1 that includes sensors which help in gathering of data, transceiver which helps in communication of data, micro processor by which different tasks are managed, memory in which data is stored and battery which supplies energy to all components. Wireless sensor networks are generally deployed in the region where it is not feasible for humans to approach. WSNs are self-configured and infrastructure-less networks which aim to collect the data and communicate that data where it can be observed as well as analyzed easily. WSNs are broadly used in many applications such as military, health monitoring, fire detection etc. Apart from this, WSNs face many challenges such as limited energy of nodes, complexity of network, scalability etc. Topology control is one of the methods which help the WSNs to perform well while dealing with these challenges [1].

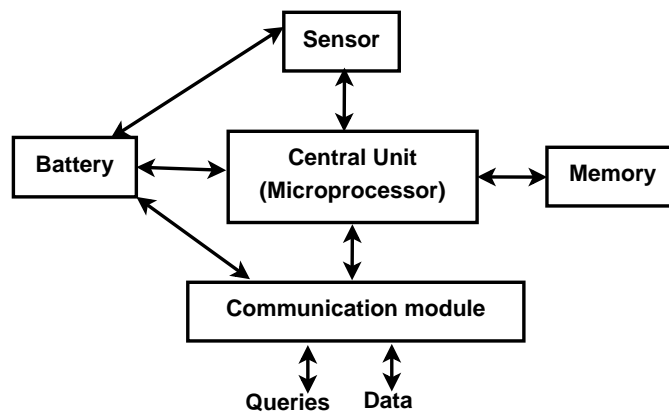


Figure 1.1: Sensor Node's Architecture

1.1 Topology Control

Topology Control is one of the best technique used in WSNs for the reducing the energy consumption of the network. It consists of three phases i.e. initialization phase, topology construction and topology maintenance phase as shown in figure 1.2. In the first phase initial topology is constructed by use of the maximum transmission power. In initially topology, each node is connected to all the possible links within the networks. Topology constructed by this phase is very complex and also consumes maximum energy. This phase is independent of the type of deployment of networks. Moreover in initial topology, the probability of collision is also very high. The second phase is topology construction phase in which the reduced topology is constructed by removing insufficient links and keeping only necessary links. This reduces the energy consumption of node and also the chances of collision and thereby makes the communication between the nodes easier. As and when second phase starts, then the third phase i.e. topology maintenance phase must initiate automatically. The third phase continues to monitor the reduced topology which is constructed in second phase, so that as and when link failure occurs it can triggers the second phase again. This phase ensures the network will be maintained timely.

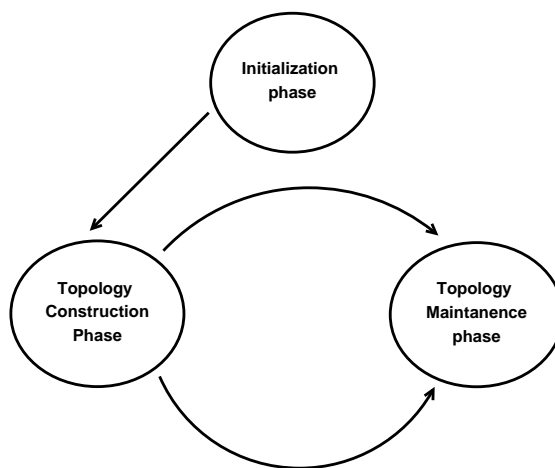


Figure 1.2: Phases of topology Control

1.2 Motivation for topology control

There are variety of sensor nodes with limited battery power that are deployed randomly in a certain area of interest for performing the desired task. These sensor nodes will initially try to form links with maximum neighbor nodes and as a result the network becomes complex and also the amount of energy consumption increases. It makes the overall network inefficient, so in order to increase the efficiency of network one should go for topology control which not only reduces the complexity of network but also increases the network usage in efficient manner. The different factors that motivates to work in the area of topology control are:

1. Energy conservation: This is one of the most important factor that motivates to use the technique of topology control as it enables to save the energy of the network while preserving the network connectivity. In Topology control the reduced topology is built by keeping only the sufficient links and removing all the unnecessary links. This is done so, that the network can work efficiently for longer time. In topology control either the reducing transmission power of nodes or by proper sleep schedule of nodes is made which enables to increase the amount of energy conservation.
2. Collision avoidance : The topology construction phase also helps in reducing the collision. Initially when the maximum power graph is constructed then the node degree is very high and network becomes very complex. The topology control algorithms helps in building the reduced topology so that network complexity can be reduced. Thus the reduced complexity of network requires lesser number of retransmission of packet. Number of retransmissions decreases when packets are delivered at proper time interval without any collision between packets. Lesser the collision between packets indicates better will be the network performance.
3. Increased Network Capacity: Topology construction phase also affects the network capacity. When the transmission power of nodes is reduced in the network then the hidden and the exposed terminal problem [2] also get eliminated. If the transmission power is reduced by the nodes in appropriate amount then data can be transmitted at proper time without causing any interference in the network. Lesser the interference means data transmitted directly to destination without any packet loss. So, more data

will be handle by network in same time interval. More the data handled means more will be network capacity.

1.3 Challenges in Topology Control

Topology control is one of the complex process and if it is not performed well then it may increase the network complexity as well as the network cost. There are two mechanisms in topology control i.e. topology construction and topology maintenance phase which runs in parallel and they exchange their information in order to make decisions about topology as well as to run algorithms in order to get desired results. Topology control faces many challenges some of which are described below. One of the major challenge is that communication overhead is generally high. So, the number of control packets which are exchanged should be minimized in order to reduce energy consumption as well as the communication overhead. The second challenge is the creation of Minimum connected dominating set(MCDS)[3]. The MCDS is the set with minimum number of link between the nodes. It is very difficult to design the MCDS which preserves network connectivity and coverage. The third challenge is Multi casting. Multi casting is process which is used to broadcast the same packet to multiple sinks. Multi cast the data in mobile WSNs with QoS is very difficult task in topology control. The fourth challenge is security i.e. the data communicated within the topology should be secure. As data transmission occur through multi hops and faces collisions so there should be surity that data packet reach as at destination securely. For this purpose sometimes authentication between the nodes is done to ensure data security. Moreover, the location and direction information is not known in advance for most of the mobile WSNs which causes collisions as well and takes more time to transfer the data to correct node.

1.4 Applications of topology control

WSNs are widely used in many applications [4]. As the usage of WSNs is increasing day by day so it is implemented in various applications. As different types of sensors can be used so there exists a variety of application in which WSN can be deployed. Some of the commonly used application of WSN are listed below.

1. Forest fire detection: Topology is deployed in the forest and in case forest catches fire. So, temperature, humidity and gas sensors will detect the fire and message is broadcasted between the nodes and fire prevention is done as earlier as possible.
2. Vehicle monitoring: Vehicle on road can be detected by deployed topology. According to the designed topology in mobile networks, vehicle location can be detected and continuously monitored by the messages being transmitted between them.
3. Health care monitoring: Various topology are deployed and they may be planted in human body or may be used on human surface which helps in overall monitoring of patient and help in diagnosis at proper time.
4. Security Applications: Topology is deployed in order to send data securely from source to destination. So by usage of various method like authentication key sharing etc. topology control fulfil this purpose.

1.5 Organization of thesis

The objective of this M.E thesis is to provide the importance of the topology control algorithms for WSN. So it can help the user to select a best topology control algorithm for the implementation in particular application. This thesis is organized in five chapters i.e. Introduction, Literature survey, RSSI based topology control algorithm, Improved DPV algorithm and lastly conclusion and future scope. The chapter 1 provides the detail information about WSNs , Topology control, motivation of topology control, succeeding with challenges that occur while designing the topology control algorithms and the applications. The chapter 2 focuses on the literature survey of existing topology control algorithms. The chapter 3 highlights the problem that occur while designing the topology control algorithm along with its proposed solution i.e. RBTC algorithm. This chapter also discusses the performance metrics and result of proposed algorithm with that of existing algorithm. The Chapter 4 includes the DPV algorithm, problems in DPV algorithm and back propagation technique and improved methodology i.e. Improved DPV. The performance metrics and the results are also discussed in this chapter and last Chapter 5 provides the conclusion and the future scope of this reaserch.

Chapter 2

Literature Survey

This chapter gives a detailed description about the literature that exists for the topology control algorithms. This chapter presents the classification of topology control algorithm as shown in figure 2.1 and on the basis of the classification different existing algorithm are summarized.

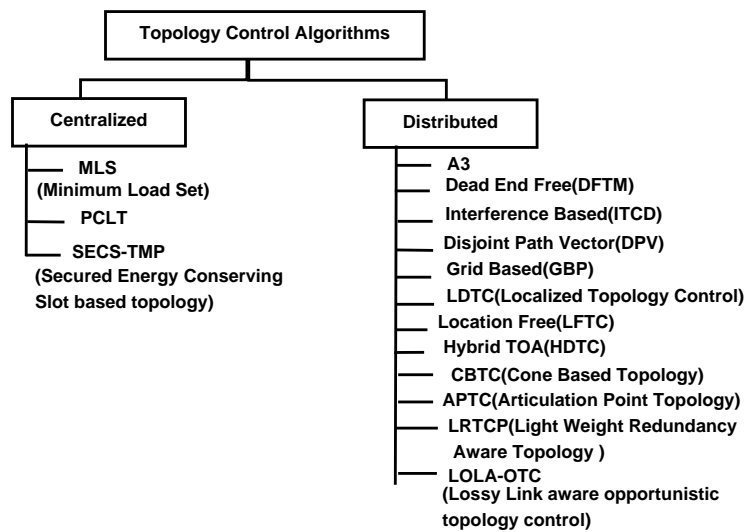


Figure 2.1: Broad classification of topology control algorithm

1. Centralized algorithm : In the centralized algorithm, there exist a coordinate that maintains the record of existing nodes and also each node is supposed to forward the required information to the coordinate node. The entire data of all these nodes is stored in the memory of coordinate node. The coordinate node is the backbone of the network and every node communicates with other node via coordinate node only. The example of centralized algorithm is shown in figure 2.2. Some of the existing

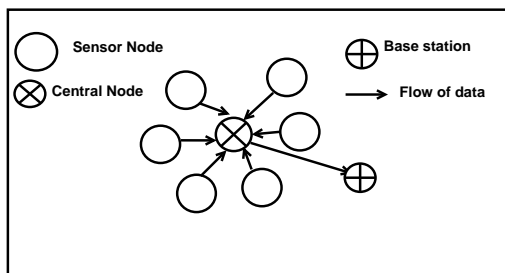


Figure 2.2: Example of Centralized algorithm

centralized algorithm for topology control are Probability Distribution and competition in same layer(PCLT)[5]Algorithm, Minimum Load set(MLS)[6]algorithm, Secured Energy Conserving Slot Based Topology Maintenance Protocol(SECS-TMP)[7].

2. Distributed algorithm: In distributed algorithm, any node can communicate with other node without sending the request to coordinate node. Each node plays same role and data can be accessed through each node as show in figure 2.3. The distributed algorithms are further divided into localized and non localized topology control.

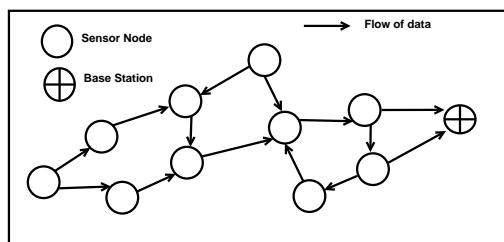


Figure 2.3: Example of Distributed algorithm

- (a) Location Based algorithms : In location Based algorithms, location of each sensor node is known to other sensor nodes using GPS or any other device. So with the help of location coordinates, data is transferred to other nodes. For example Soni et-al. [8] has used location to run its algorithm properly and get desired results
- (b) Direction based algorithm : In this type of algorithms, nodes are aware of direction other node is moving but don't know the location coordinates. For example Javadi et-al. [9] has used the direction information to run its algorithm.

Some of the existing distributed topology control algorithms are A3 [10], Dead End Free Topology Maintenance Protocol(DFTM) [11], Interference Based Topology Control Proto-

col(ITCD) [12], Disjoint Path Vector(DPV) [13], Grid Based Topology Control(GBP)[14], Localized Topology Control(LDTC)[15], Location Free Topology Control(LFTC)[16], Hybrid AOA/TOA Topology Control protocol(HDTC) [17], Cone Based Topology Control(CBTC) [18], Articulation Point Topology Control(APTC) [19] protocol, Light Weight Redundancy Aware Topology Control Protocol(LRTCP) [20], Lossy Link Aware Opportunistic Topology Control(LOLA-OTC) [21].

2.1 Centralized Algorithms

Various Centralized Algorithms are discussed below. These are the algorithm in which nodes depends on each other. As node has to report globally to the central node.

2.1.1 Probability Distribution and competition in same layer(PCLT)algorithm

Zhen hong et-al.[5] has given an algorithm for probability distribution of nodes that are competing in same layer (PCLT) in such a manner that it reduces the number of packets sent and also conserves the energy of the nodes. Here, the author has assumed that sink node is placed in center and it is not affected by any parameter like energy constraint, memory etc. All other nodes are randomly deployed with initial energy E_o and the distance between nodes is calculated by RSSI[5]. The PCLT algorithm is defined into three steps. In first step neighborhood discovery is done in which sink node send hello message to the uncovered nodes and based upon the time stamp of order of receiving the messages, different IDs are allocated to the neighbors. After receiving the message from the sink, neighbors will calculate their weight depending upon the energy of node and its distance from the parent node. Now neighbor will send short message to their parent node which contains id and weight of node. The node which is farthest from the sink will be given the highest priority to become active. Later on, the sink node on basis of weights of neighbors will prepare a list in decreasing order and forward it to all its neighbors. Now the neighbors will see their position in the list and accordingly set their priority. The node with highest priority will become active and inform this with short message to their brothers which have one parent. As the brother

nodes are unable to become active they will go to the reserving state. This is done because in any case if the active node doesn't receive the message in time then the reserving node can become active. As the new node become active it broadcast hello message to all the neighboring nodes. After completing this step, next step i.e. nodes competition will start in which node will first computes its new weight and compare it with its former weight. If new weight value is more than previous weight then ID message will be broadcasted to former parent and same is updated via short message to the new neighbors. The reserving node will be dropped by former parent and new parent is assigned to the reserving node. In the last step of the algorithm is node comparison. As now parent node had received their child messages then parent node will compute their child degree and send the same to former node. This procedure continues till the sink node get value of node degree so that the node at each layer can be known as probability is calculated and compared with some threshold alpha. The author also defines a variable that decides whether the reserving node will become sleeping node or active node. After applying PCLT algorithm author has analyzed that as the communication radius increases, the active node decreases and number of message decreases. This algorithm increases the network lifetime to small extent but somehow reduce the consumed energy.

2.1.2 Maximum load set(MLS)Algorithm

Huan Zhao et-al.[6] has given a heuristic topology control algorithm in order to reduce the energy consumption of network by gathering the data through mobile sink in a predefined trajectory. Nodes which lie on the sides of the trajectory are generally used for data transferring and are known as anchor nodes. All the other nodes are non anchor nodes which upload their data to anchor nodes. Authors assumed that energy consumed while receiving a data is constant for all nodes and representation of network is done by undirected graph. The network lifetime is considered as time before the first node dies. The authors main idea is to construct the spanning tree in such a way that a node will be added at each iteration not according to the shortest path but according to nodes having less load. In order to accomplish this task each node is examined one by one, starting from the leaf node and the candidate edge is set appropriately. The algorithm runs in the two steps i.e. primary

selection and the final selection. In primary selection, the appropriate candidate edge is set by visiting each leaf node and calculating the value of load on each node. In case if the two load sets have equal load due to some common edges then only different elements will be checked. In second step i.e. final selection, value of load is evaluated and the best candidate edge according to the optimal value of expectant load is selected. For this depth search process is applied by which all nodes are transversed and load set is compared with expectant load set. If the non-leaf node is visited again then the recalculation of load for atleast 4 nodes is done including nodes which was visits currently and also the nodes that were visited previously. But if node which is visited is leaf node then load is calculated assuming that fictitious node is added letting the communication radius same. This is also assumed that ancestor nodes are affected by adding fictitious candidate edge. The load set is then updated to gather the information of nodes in transversing path. After updation optimal candidate edge is determined with its load set and finally added to growing tree. The author reduces the load of nodes and also increases the network lifetime.

2.1.3 Secured Energy Conserving Slot Based Topology Maintenance (SECS-TMP) Algorithm

S.Raja Rajeswari et-al.[7] has given secured energy conserving slot based topology maintenance protocol(SECS-TMP) which aims to reduce the memory overhead, increase the network lifetime and conserve the energy. For this, the author has taken some assumptions i.e. all nodes are stationary except sink node, in any condition atleast a pair of node should be active and finally the base station(BS)node only has the key of all other nodes to check node authenticity. Nodes are always assumed to be either in one of three states i.e. sleeping, electing or operating state. Network lifetime is divided into equal time slot and base station(BS) is assumed to arrive at each region in the beginning of time slot and after the expiry of sleep timers. When network is initialized symmetric key is shared between BS and other nodes. Now before BS arrival, the required nodes are moved to operating state and other remains in sleeping state. Nodes which are in sleeping state will be allotted different time slots and these time slots are calculated depending upon the total nodes, desired number of nodes and configuration parameter in such a way that its expiry will be at time of BS arrival. After the expiry of sleep timer, node will enter the electing state. In electing state

node will forward the enquiry message to base station which is authenticated by symmetric key. The message also includes the value of counter which avoids the replay attack. When node receives status message then authentication is performed by verifying with MAC. If it verifies then state of node will be changed to operating state otherwise message is discarded. If number of message received by BS is equal to desired number of nodes then BS will send message. Hence author concludes that there is increase in network lifetime because of proper timeslot allocations and decrease in time and memory consumption due to secure and necessary data communication.

2.2 Distributed algorithms

In this section we will cover various distributed topology control algorithms. In these algorithm nodes dependency on other node is reduced and each node has given equal priority.

2.2.1 A3 Protocol

Pedro M.Wightman et-al.[10] has given A3 algorithm which aims to construct minimum connected dominating set (MCDS) so that lesser number of nodes will be required to maintain the connectivity of the network and to reduce the energy consumption. The A3 algorithm generally based on growing tree technique and uses the selection metric which depends on residual energy of the nodes and distance between them. The author executes A3 in three steps that includes Neighborhood Discovery, Children Selection and Second Opportunity. Firstly, CDS building process will be initiated by a node by sending hello message to the neighbors. As messages are received by some node which may be covered or uncovered, if uncovered node receives hello message then it is set as covered and sender node will become its parent and it reply back with the parent recognition message. If in any case, the covered node receives the hello message again then it will ignore it. If the parent node doesn't receive any response back from its neighboring node then it will switch to sleep mode. The step is children selection in which a timer is set for receiving the answers back from neighbors. As reply timer expires then the parent node will sort the list of candidates with the help of selection metric. The flow chart of A3 algorithm is shown in figure 2.4. According to

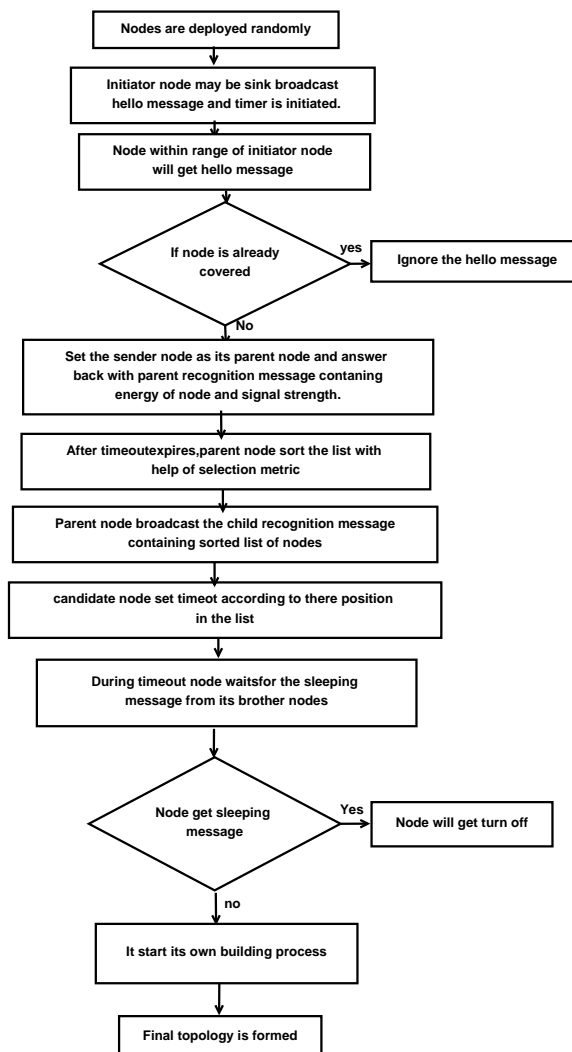


Figure 2.4: Flow chart of A3 protocol

sorted list, nodes will set their timer as per the allocated position. Nodes which are not in the list will wait for sleeping messages. If a node gets sleeping message it means it should turn off as neighboring node can do this work in better way. Nodes which left uncovered will only have access to start their own generation again. As here child nodes are selected but to avoid overhead and to maintain connectivity, second opportunity can also be used. In second opportunity hello message is broadcasted again in the network and some sleeping nodes wake up to cover some nodes and provides maximum connectivity. The selection metric calculates value of weight of the node based on RSSI and gives higher priority to node which is far from the parent node and also having high energy so that maximum coverage can be provided. The author here used atarraya simulator for analyzing the protocol and it change the value of Critical Transmission Range(CTR) and node density. The author concludes that lesser number of active nodes are required and the energy consumption also decreases even when

the network density increase. Moreover packets density also gets reduced. Hence author concludes that A3 protocol is sufficient to work within small area.

2.2.2 Dead End Free Topology Maintenance(DFTM) Protocol

Chih-Hsun Anthony Chou et-al.[11] has given a dead-end free topology maintenance(DFTM) protocol which overcomes the difficulty of handling the dead ends during geographical forwarding. It is very necessary to build DFTM protocol because if dead end occurs at some node then packet will be transmitted through other route which may cost more and require more energy. In DFTM all the nodes have fixed communication range and it is integrated

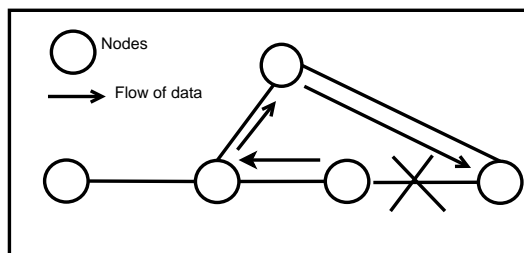


Figure 2.5: Dead end case example

with greedy parameter stateless routing (GPSR)[22]. The advantage of integration is that it is easy to find out the nearest nodes and in case the difficulty occurs then we can find out using perimeter right hand rule. The author defines this topology maintenance protocol using three steps : Dead End free verification, Dead-End free topology construction and topology maintenance. Firstly verification of DFTM is done with two conditions one is global dead end free(GDF) and second one is local dead end free(LDF). The first condition defines that there should be no dead end in whole network means network is globally verified. The second condition defines if a node is fully covered with its perpendicular bisectors and no other node comes between their bisector i.e. the network is also locally dead end free. After verifying this step, the next step is creation of DFTM. In order to create DFTM any node is randomly chosen as an initiator node which starts the process and becomes active node by default. This node will search out for other active nodes by broadcasting a message and wait for the replies. Based on the received reply messages it will create two sets : neighbor set(NS) and active neighbor set(ANS). After that LDF condition is verified on the NS. In case the LDF condition is verified then it will notify to its neighbors and DFTM is created. If LDF

condition is not verified then again an active node is set randomly and the same procedure repeats until condition is verified. As DFTM is created so maintenance of DFTM is also required. So, now third step i.e. topology maintenance will start. In global maintenance initially all the nodes are set as initiator means no nodes is active or sleep. So, all nodes have equal energy consumption and also have equal probability to become an active node. In local topology maintenance sometimes active nodes are not there due to many reasons may be their energy gets exhausted or any other reason. Then this DFTM algorithm makes use of sleeping nodes. In case the message is not received by the node from the other nodes then it is removed from ANS and another node will be chosen as an active node and the locally topology is maintained. The authors also computed the number of nodes that are sufficient to make the best DFTM. According to their calculations and observations if there are 2 or less than 2 active nodes then it is easy to create polygon and best DFTM can be created but if there are 3 active nodes then difficulty occurs and its worst condition for DFTM. Author hence concludes that DFTM reduces the active nodes upto 48 percent. Nodes are survived for long time and packet delivery ratio remains constant for the increase in simulation time. The case when dead end occurs is shown in figure 2.5.

2.2.3 Interference Based Topology Control Algorithm for delay constrained(ITCD) Mobile Adhoc Networks

Xinmingzang et-al.[12] has given an interference based topology control algorithm for delay constrained (ITCD) manets which is cross layer distributed algorithm and mainly focus on improving the network quality of service (QoS) by reducing delay, minimizing interference and removing unstable links from the topology. This algorithm is described in three steps that includes calculation of delay on different paths, secondly topology control of network and last step is controlling the mobility. When the source node sends a message then overall path delay in this message will encounter three different type of delays i.e. transmission delay, contention delay and queuing delay. Transmission delay is amount of time taken by the packet in which it is either transmitted successfully to the destination or dropped after certain retransmissions, contention delay occurs depending on contention window size and queuing delay is the amount of delay for which message remains in the queue at any given node. The first step of algorithm consist of calculation of delay on different paths which occurs due to

collision of data, back off time and attempted probability[12]. The power level is minimized by removing the links that causes instability in the network and threshold condition of signal to noise ratio is set for receiving the data successfully. The delay and interference between the nodes is minimized by changing the communication radius while maintaining the network capacity and interference . After that delay and interference conditions are monitored with mobility. If connection time between sender and receiver is more than value of delay between packets then only transmission can be ensured. The power level of node is adjusted according to the delay and interference constraint. In result the authors checked the performance of their algorithm in terms of packet delivery ratio, average end to end delay, routing overhead by varying the number of nodes. The result revealed that ITCD protocol works effectively for delay constrained MANETS by reducing the delay and interference.

2.2.4 Disjoint Path Vector(DPV) Algorithm

Hakki bagci et-al.[13] has given Disjoint Path Vector (DPV) algorithm for topology control in heterogenous network whose main motive is to reduce the overall power consumption of network and that of nodes by reducing the transmission range and maintaining k vertex super node connectivity [13]. There are two types of nodes that exist in the network according to energy level and are classified as super nodes and sensor nodes. Super nodes are nodes which are deployed at known locations and not energy constrained. Supernode can communicate directly to the base station, as well as can send the data from sensor nodes to other supernode if needed. On other hand, sensor nodes are the ordinary nodes. Initially network topology is represented by undirected graph is represented. The author defines the algorithm in five stages. Firstly an Init message is created by super nodes that contains super node ID and is broadcasted to sensor nodes. Sensor nodes update their path information by adding the path entry to super node. Sensor node path information table contains path to super node and the path cost. After updating path table, paths are sorted into ascending order. Once, the sensor nodes after updates the path information, then it will create a pathInfo message containing its ID as well as path information table. This PathInfo message is transmitted to all reachable neighbor by sensor node using maximum power. The node which receive the pathInfo message will calculate union of existing and new paths. Later on the disjoint path

set of the existing as well as updated union is calculated. The size of calculated disjoint path set can't be more than k as we need only k disjoint path. Now, the updated pathInfo message is sent by sensor node to all other nodes. If pathInfo message doesn't cause any update then sensor node will not send any pathInfo message. This is repeated till the improvement of cost become impossible and thereby the message transmission ends. On the other hand, if sensor node received the pathInfo message which has reached Time to Live(TTL) , then no new pathInfo message will be created even if update occurs, to ensure that the path have certain length limit. To ensure that nodes selected in disjoint path is marked as required neighbor, notify message is forwarded along with disjoint path. If in any case, node is not marked as required neighbor then it means link is not important and can be removed. For nodes, those dont have atleast k vertex disjoint path information cannot decide which node can be removed or kept, so they have to retain all the nodes. This helps us in ensuring k vertex super node connectivity. In the last, Transmission power is adjusted by node such that it can reach its farthest neighbor and final topology is created. Hence author concludes that there is reduction in total transmission power so, the network is energy efficient. The flow chart of algorithm is shown in figure 2.6 below.

2.2.5 Grid based Protocol(GBP)

Baoxian Zhang et-al.[14] has given grid based topology control(GBP) algorithm its main motive of this algorithm is to maintain global network connectivity by reducing the active nodes in the network. So in order to reduce the active nodes, two different types of grids are constructed i.e. cross sectional and diagonal grids. These grids are equally spaced. According to these grids, two algorithms were designed i.e. cross sectional topology control algorithm and diagonal topology control algorithm. Active nodes are represented by shaded regions and vice versa. It is assumed that nodes are uniformly distributed and link between two nodes will be considered only if geometric distance between two nodes is less than or equal to the transmission range. Here the author assumes that location information is known to all the nodes but topology information is not known. While designing cross sectional grid based topology control, Author considered that shaded neighbors are at equal distance. Initially origin is defined. The origin can be chosen randomly it may be at center of grid or may

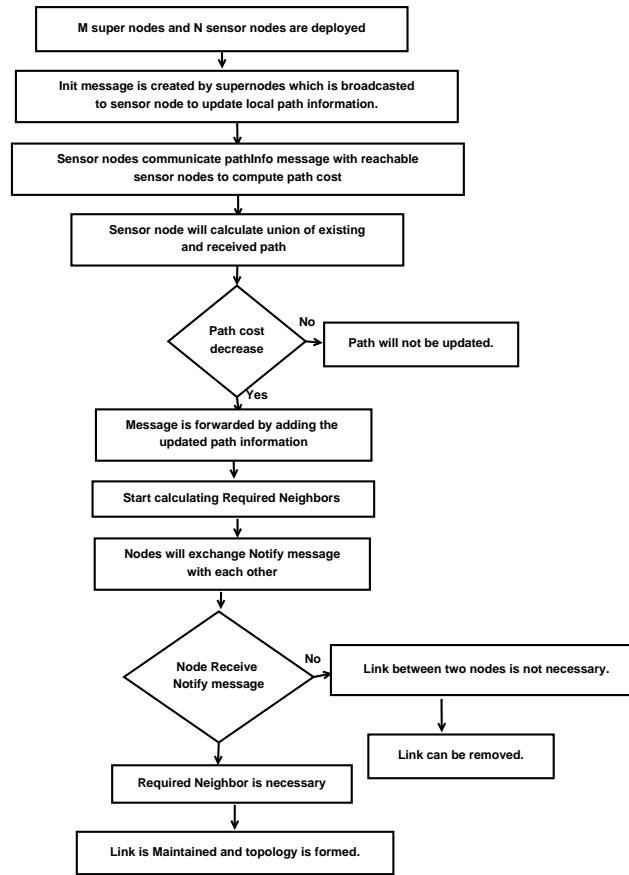


Figure 2.6: Flow chart of DPV algorithm

be at sink node of grid, depend upon the location of nodes. Secondly grid coordinates are calculated with the help of origin location, node location and the grid size length with the help of formula[14]. After obtaining grid coordinates, grid based structure is made. Now it is determined that how many rows and columns should be active in order to ensure network connectivity. So by observing author has analyzed that one row should be active in three rows to make the connected dominating set, similarly M columns should be equally spaced at distance of L_{col} columns. As the number of active rows and columns are different so their rotation are also different. It also tells either row should be shaded or not as well as it decides the rotation in different rows. The Number of shaded column is always less than number of shaded rows, ignoring the border effect. In next step diagonal grid based topology is made. As the grid side length is set by author that depend on transmission range of the nodes. If we further reduce the grid side length then no.of active nodes will increase as they can communicate directly with its diagonal grid neighbor. Such an increase in grid neighbors make possible design of new topology control algorithm. A new shaded grid set is created and diagonal grid is represented by starting and ending grid. If x grids are

not considered then there should be atleast one node in grid S so that connectivity can be preserved. The Method for connecting x grids and grids that belong to set of active grids is to add all grids on the network perimeter into shaded set of grid or we can also increase the multiple shaded diagonals that are perpendicular to those shaded diagonals. It is noticed that between two neighbor shaded diagonals there are four unshaded neighbors. So, Author concludes that diagonal topology is better than cross sectional. The number of nodes that survived throughout the network is larger in GBP.

2.2.6 Localized Topology Control(LDTC) algorithm

Jinsong Gui et-al.[15] has given a localized topology control algorithm(LDTC) which aims to construct a topology in which each node have a knowledge of its k -neighbors and then the distributed topology symmetry is proposed to enforce symmetry of topology. Authors here assumed that location information of nodes is known to entire nodes, network is heterogenous and the path loss exponent associated with each node can vary due to environmental changes. Each node has certain maximum power by which the omni directional transmission can be done. In order to construct the topology authors first searches the neighborhood topology by information issuance and collection. Here, the node uses maximum transmission power for broadcasting an information advertising packet(IAP). Nodes which receive the IAP message and is included as neighbor of current node. When IAP message is received by nodes then they respond with Information reply packet(IRP)after certain time stamp. After exchanging the IAP and IRP messages initial neighborhood graph is determined. For every pair of nodes, a bidirectional link is defined and maximum power symmetric topology is obtained. After knowing the physical as well as logical neighbors the node broadcasts the power advertising packet(PAP) to all its neighbors.For each node in neighboring set of node eligibility metric value is calculated by formula [15] . After that k neighbors are chosen according to the highest value of eligibility metric. In case the neighbors are less than k then all the nodes will be selected. Nodes have to set their transmission power in such a way that it can reach their farthest neighbor and broadcast it to their neighbor set. After that distributed symmetry algorithm is processed in which firstly logical neighbor set is checked by the neighbors. If node doesn't belong to logical neighbor set then it is added to set and finally power is adjusted

and the topology is constructed. Author concludes that there is reduction in the message overhead, energy consumption and end to end delay.

2.2.7 Location Free Topology Control(LFTC) Protocol

Jang-Ping Sheu et-al.[16] has given location free topology control protocol(LTCP) which aims to reduce the power consumption of the network and increases the throughput by solving hidden terminal problem. The network here is assumed to be homogeneous. This algorithm assumes that data transmission is accurate and received signal power is measured with radio propagation model. Algorithm consist of two phases. First phase is link determination phase in which nodes can communicate directly to other nodes by creating Direct Communication Set (DCS) of its own choice. Initially each node will broadcast hello message to other nodes with its maximum power. When a node receives hello message, it will immediately compute the energy cost required to send a packet .Every hello message contains sender id and vicinity table. The vicinity table consist of neighbor ID, direct communication cost, minimum communication cost and link type. Initially the vicinity table is empty. Upon hearing hello message vicinity table is updated. If there is no common neighbor(CN) between two nodes then link type is mark as 'd' otherwise it is marked as 'i'. If there is CN between nodes, next step is to identify the CN. If node takes CN as relay to communicate with other node then it is referred as relay CN. If a node takes CN in such a way that it minimizes the original energy cost between source and destination then that CN is referred as benifited CN. If none of these condition is true then the type of CN is irrelevant. According to the type of CN, the vicinity table is updated. Now the source node has received the hello message from all its neighbors. So transmission power is adjusted in such a way that it can directly communicate with all its neighbors within DCS. The second phase is interference announcement phase in which collisions that are caused by hidden terminal problem are avoided by using power required to transmit the data. The source node checks whether the interference is due to the collisions caused by hidden terminal or not. If hidden terminal problem causes interference then it will inform the directly linked neighbors by sending inform message which contains node id and power needed for data transmission. The source node uses power in such a way that it can reach its farthest neighbor node . If a node

overhears the inform message it will see either its a direct neighbor or indirect neighbor.If a message is from direct neighbor then it will be ignored. On the other hand, if message is from indirect neighbor then the transmission power of control packet is compared with maximum power needed for transmission. If control power is less than power needed, then power needed to send a control packet is set equal to maximum power needed to ensure the hearing of control packets. After completing both phases each node determines its suitable power needed for transmission for spatial reuse. Hence author analyses that collision ratio is reduced and energy conservation is more. Moreover, Throughput increases and transmission power reduces. This topology can work properly in mobile network.

2.2.8 Hybrid Topology Control Protocol(HDTC)

Chao-chi haung et-al.[17] has given a solution to the problem of frequent changes in topology by introducing hybrid Time Of Arrival(TOA)/Arrival Of Angle(AOA) Distributed topology (HDTC) scheme. This scheme avoids unnecessary exchange of information and change of group members also. This scheme consist of 2 phases. First phase is communication grouping phase. This phase is further splitted into 3 steps. The first step is initial selection of group member.In this step group member of particular node is decided by forward vector of that node. The cone degree of 2θ is bisected by vector. Angle condition is also taken in account if the angle lies between 0 to $\cos\theta$ then node will be added in group otherwise it removed. If speed of node is slow with respect to reference node then due to the gap between the nodes, node start oscillating. To reduce the frequency of occurrence of given scenario,a timer is initiated and timer value is renewed according to the angle information which pass the cone based test. In the next step current node will see the position and distance of neighboring node at a certain time. If after the expiry of the time slot the distance reduces, then that node will be added to group otherwise not. In the third step the node broadcast join message to its neighboring members. If the recipient of join message belongs to group created by the reference node then recipient node will be added to communication group. In other case, if message is received from other node then the node will become group member of that group with initial time stamp. Next phase i.e. the second phase involves the identification of routing group members using distance and direction information from the sink node. The

priority is given to those nodes which are moving in the same direction. After the formation of group in phase 1, information is forwarded to the node which is nearest to sink. Each node will have its own communication group members and the routing group members determined based upon the distance and direction information. In order to transfer the information to the target node, each node first check whether the target node belongs to its communication group or not. In case the target node is included in communication group list of node then data will be transferred directly to target. If not, then node broadcast the target information to all its group members. All the group members will calculate their distance from the target node and reply the same to the sender node. Node select the node that is nearest to the target node and will include it in the transmission list, in any case it is not included. The data will be forwarded to that member and member will join the transmission list. In this way each node after receiving the data will repeat the same process to locate target till the data is received by target node. The author concludes that as the group size is reduced as well as stability and adaptability of group is increased.

2.2.9 Cone Based Topology Control(CBTC) Algorithm

Li(Erran)Li et-al.[18] has given a localized Cone Based Distributed Topology algorithm (CBTC) in order to ensure the network connectivity. Node transmit with the minimum power in α degree cone such that each node can be approachable by atleast one node. Initially each node broadcast a hello message with minimum power and all the acknowledgement replies are collected. Then transmission power level is increased gradually to discover more neighbors. The list of neighbors with their location is known to each node. As neighbors are discovered, connectivity of each node is examined by checking list of nodes which are sorted according to angles. If angle is more than α between two nodes it defines that node is not connected to other node. The author also discusses three optimizations technique i.e. shrink back operation, asymmetric graph, pair wise edge removal for unnecessary removal of edges. This is done by removing high power nodes, removing asymmetric graph and removing the farthest edge from combination of three nodes while preserving connectivity. Failures of nodes are also checked out by sending beacon message that contains ID and transmission power of node. If a node doesn't receive the beacon message within certain time interval then it

indicates neighbor failure. The Author concludes that network connectivity can be preserved at an angle of $5\pi/6$ and network lifetime can also be increased by removing unnecessary edges.

2.2.10 Articulation Point Topology Control (APTC)

Min-TeSun et-al.[19] has given a localized topology control algorithm named as articulation point based topology control (APTC) in order to reduce the energy consumption as well as the communication overhead. Articulation points (AP) are used as initiators and a vertex is said to be AP iff its removal disconnects the graph. The author assumed that node ID and component number (CN) are maintained by each node. APTC is designed in four phases. In the first phase, detection of AP candidates is done which is easily identified by any of the algorithms [23, 24, 25]. If there exists an edge which connects two AP candidates then this is a critical link which should be removed before the network disconnects. After detecting AP's the next phase is component identification phase. In this phase, AP's are broadcasting the message with unique ID. When this message arrives at different neighboring nodes, then it is being checked whether the message is first arrived or not. If the message is visited for the first time then the received ID is added in the received broadcast messages otherwise its own CN is compared with receiver ID and the higher CN is designated to received broadcast messages. The neighbor will keep on broadcasting the initiator ID till the receiver node is an AP. After all iterations each node knows the component. This phase, several groups with same CN value are obtained and the next phase i.e. component wise Minimum Spanning Tree (MST) phase starts. In this phase, information is communicated within the group and the component information table is maintained. The components are attached with other components through AP candidates. So, it is necessary to have at least one AP with same ID as group component number. Now by removing the unnecessary edges, MST is obtained. In the last phase i.e. power adjustment phase the power levels can be determined by measuring the received power of NB.info message and also the new transmission range is determined from the component table. Each node saves energy by reducing its power and avoiding collisions thus a topology is constructed. As topology changes dynamically so maintenance of topology is needed and the MST building process is triggered by the AP candidates. This is done in case, node is somehow aware about topology changes. For maintenance

of topology the status of AP switching state is being checked. If the Non-AP is changed to AP then it defines new biconnected component creation. So, new AP will broadcast its CN. So that component identification can be triggered and new component wise MST can be created. If status is changed from AP to Non-AP then it indicates that the new route is explored, so the component identification procedure will be triggered and MST will be updated. If status is not changed then the node checks either it needs an update or not. If its not need any update, then AP need not to do anything. If ID of AP is highest then multiple biconnected component can be treated as one APTC. Hence author concludes that upto 30 percent of energy is saved by APTC while preserving connectivity and reducing the possibility of collision and the interference.

2.2.11 Light weight redundancy aware Topology Control protocol(LRTCP)

Bahia Zebbane et-al.[20] has introduced a Light Weight Redundancy Aware Topology Control Protocol(LRTCP) which turns off the redundant nodes and divides the network in the group and improves the network efficiency. This algorithm includes mainly two phases i.e. redundant nodes identification and leader election phase. In first phase energy dissipated is required to be sufficiently low so that it doesn't effect the second phase. Initially a beacon message containing the Node ID is broadcasted by each node and accordingly the Neighbor list (N list) will be built. Once the Nlist is finalized then first round begins. In this phase there are two rounds. In the first round each node determine its redundant neighbors and tries to form a group of nodes that ensure the network connectivity and each node will broadcast the discovery message to each other which contains node ID and its neighbor list (Nlist). Every node which receives the discovery message computes the redundant degree value. All the nodes whose redundant degree is positive are the part of same group. Now in order to ensure that the final topology is fully connected the author describes different eligibility rules (ER). The first rule allows the member of group to coordinate among themselves at time of election. Secondly each node try to find those group which covers its neighbor set so that in case of sleep mode, these neighbors are still reachable by one member of that group and last rule gives the surity that non-common neighbors are reachable by shared neighbors. Each group has knowledge about its own group members and not about other

group members. The second round is redundant neighbor identification phase which ensures that each node must be a member of one group only and all the member have same group member, in order to accomplish this rule an update message is broadcasted which contains node ID and list of group members. After receiving message, each node start updating their group list and this update is done only if there are different members in the group. The flow chart given in figure 2.7 shows how the algorithm works. The updation includes checking of uncommon members and determine the non common list, if non common list is not empty then members are added to the deleted list and later on sorted in ascending order. If DMlist is not empty then it removes the last member having non common members . In case if there are some members having same number of non common members then node will remove the member which has lowest node ID and update the list accordingly in second phase that is leader election phase. The second phase of the algorithm balances the node with load balancing strategy whose main aim is to increase the active time of the nodes . In this phase sleep awake scheduling is started and groups are represented periodically and the node with maximum energy will becomes leader. In this algorithm there are three states of nodes i.e. passive, active and sleep. Initially all the nodes are passive and after some random timer, election message is forwarded which contains energy level, node state and node ID. In passive state T_e timer is set out. If the message received from high energy node before the expiry of timer, then it cancels the T_e and enter the sleep state otherwise node enters into active state. Then according to the network lifetime which is computed from time to live(TTL) then node enters into the sleep state . The Author finally concludes that there is a large reduction in the number of messages that need to be flooded in the network, there is slight increase in the energy consumption.

2.2.12 Lossy Link Aware Opportunistic Topology Control Protocol(LOLA-OTC)

Tong Wang et-al.[21] has given the lossy link aware opportunistic topology control algorithm(LOLA-OTC) which utilizes the high quality lossy link to improve the performance of the network. It is assumed here that nodes are distributed randomly according to the Poisson distribution in Unit Disk Graph(UDG) and every node have the same probability density function. Each node communicates with other node by broadcasting Hello message and collects the

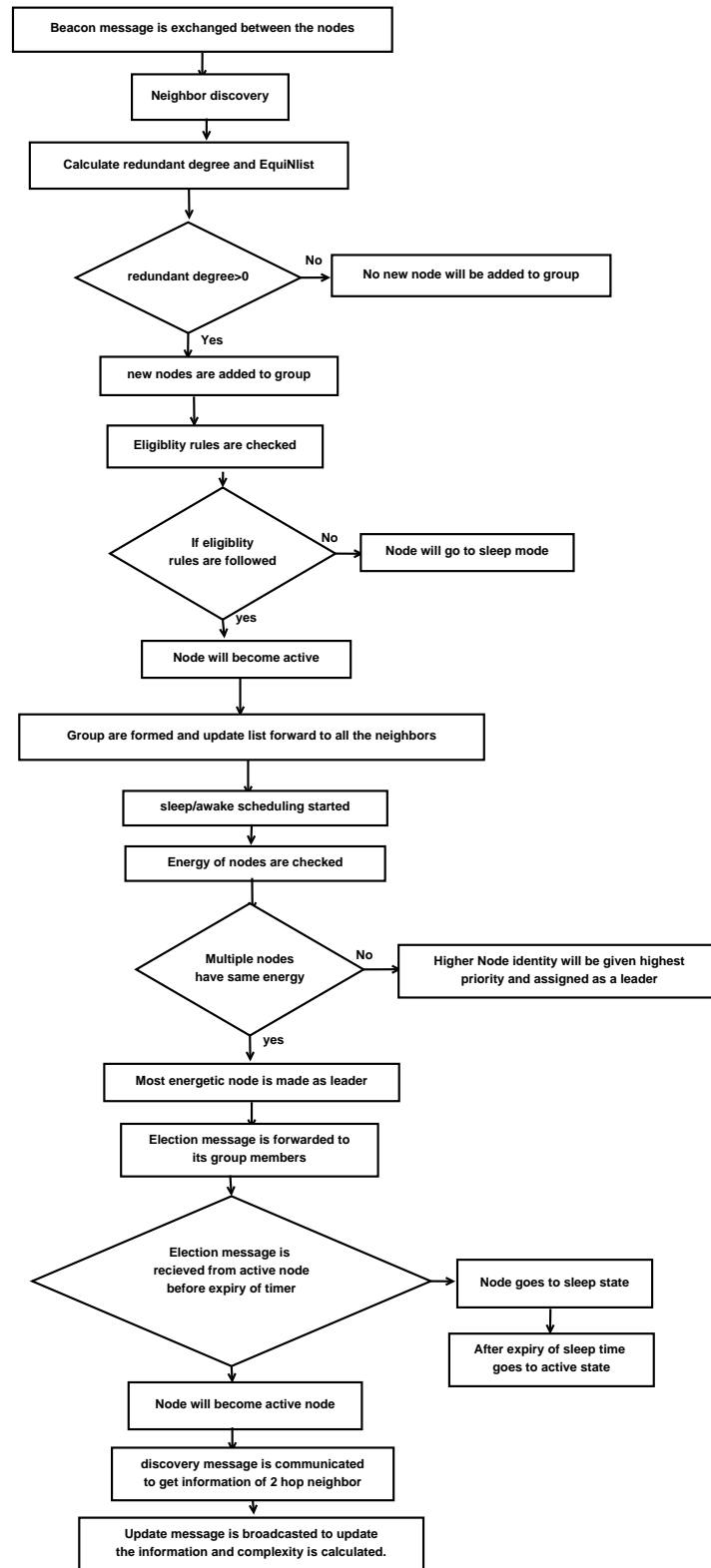


Figure 2.7: Flow chart of Light weight topology Control Algorithm

Acknowledgment (ACK) messages. Each node then records the angle information as well received power from received ACK message. After that node notices the neighbor angle and distance from other node. According to the gathered information of distance in quasi-UDG it is decided either node belongs to decisive neighbor set or transition neighbor set. According

to the angle information (AOA) it is being observed that which can cause error in their path during communication based on node strength and angle position . Accordingly different neighbors set are created and link probability is computed according to Obstacle shadow awareness ability based on Quasi UDG model(LIMOS)model. If the link from the neighbor set have value more than threshold value then that lossy link will be considered as quality link and they are selected for data transmission. Hence these high quality links are used for the data transmission. Hence author concludes that packet delivery ratio is increased while reducing the energy consumption.

Chapter 3

RSSI based topology control protocol (RBTC)

3.1 Problem statement

While dealing with topology control in mobile networks it is very difficult to ensure the packet delivery within proper time interval. As network is mobile so the location coordinates of nodes keep on changing in every millisecond. This result in late delivery of packets which further affects the network performance. Moreover, the network cost as well as the energy consumption increases while network efficiency reduces. So while designing the topology, packet delivery must be considered in order to achieve proper communication of the packets within time.

3.2 Problem solution

In order to make network efficient and ensure the packet delivery we have proposed an algorithm i.e. RSSI based topology control algorithm (RBTC). The main motive in this algorithm is enhance the network performance in such a way that maximum packets are transmitted while consuming the minimum energy.

3.2.1 RBTC Algorithm

3.2.1.1 Network Model

We have assumed that n nodes are deployed randomly where each node can communicate to a set of nodes that lies in its communication range. Moreover, some assumptions are taken while designing are illustrated below.

1. Network is assumed to be homogenous.
2. All Nodes are mobile with limited mobility.
3. Location of nodes is not known.
4. Mobility assigned to each node follows random way point model.

3.2.1.2 Proposed methodology

1. Neighborhood discovery: In this phase, all nodes will broadcast a hello packet that contains node ID and Transmission power level. The format of Hello packet is shown in fig 3.1. All the nodes which lie in the communication range of hello packet will compute

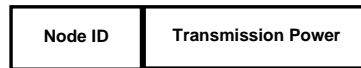


Figure 3.1: Hello packet format

their received signal strength say R_1 and respond the same via Hello_reply message along with the computed value R_1 . The format of Hello_reply is shown in figure 3.2. Now when source node receives reply message from receiver nodes correspond to its own



Figure 3.2: Hello_reply format

Hello message then it will compute the received signal strength again and is referred as R_2 and also computes the difference between R_1 and R_2 . We can see below in figure 3.3 that how RBTC algorithm works

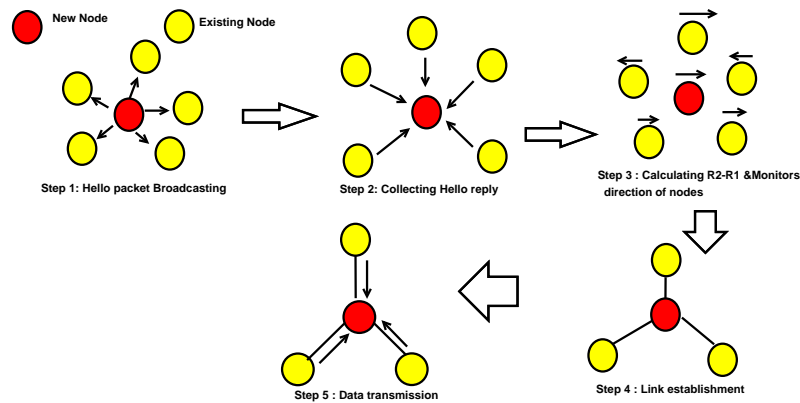


Figure 3.3: Proposed RBTC algorithm

2. Topology Construction: If the source node finds that the difference between R_2 and R_1 is positive then it indicates that respective pair of nodes are moving away from each other. Thus, source node will not add that particular node or we can say that there is no link establishment between that pair of nodes on the other hand if the difference is negative it indicates nodes are moving towards each other so, Link will be established between that pair of nodes. In worst case scenario, when all the nodes are moving away from a particular node then threshold value is set on the basis of their RSSI values and number of neighbors. Threshold value of RSSI is computed by taking the average of differences R_2-R_1 for that particular node. Nodes whose value is greater than this threshold value, a link will be considered and other links are rejected. By this criteria nodes have computed its neighbors with which topology is formed. After link establishment route discovery phase starts.

Now node will start broadcasting the Route Request(RREQ)packets to all its neighbors. All nodes will send their mobility along with RREQ packets. If the receiving node find the value of Relative mobility higher and also rate of change of RSSI is also positive, then node will not rebroadcast the RREQ packet to that route. The Relative mobility is computed as the difference between the node's own speed and the speed of node that has sent RREQ packets. This will ensure that link that is likely to be broken will not be the part of path. That means chances of link breakage gets reduced. The Destination node upon receiving the RREQ from other nodes will compute all the paths and reply with route reply(RREP) packet. The source node will select the least relative mobility path for data transmissions.

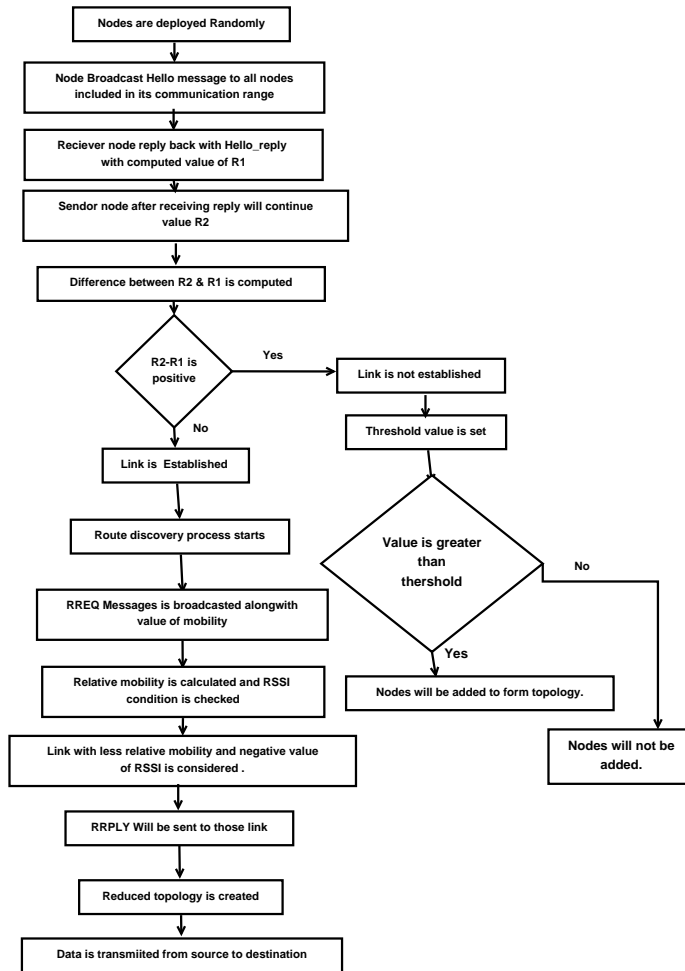


Figure 3.4: RBTC algorithm

In any case, Link failure occur due to any factor then routes are established again. The flow chart of algorithm is shown in figure 3.4

3.3 Simulation Results

The performance of RBTC is evaluated using NS-2 simulator [26] with the following simulator parameters as shown in table 3.1.

3.3.1 Performance metrics

This section describes the performance metrics that are considered for evaluating the performance of the RBTC protocol with FF-AOMDV protocol. Some of the metrics are as follows.

1. End to End Delay : It is defined as time taken by node in delivering the message to the destination successfully. The delay may be of many types, it may be queuing delay, contention delay, transmission delay etc.

Table 3.1: Simulation parameters

Parameters	Value	Unit
Number of nodes	50	Node
Node speed	0,2.5,5,7.5,10	Meter/second
Queue size	50	Packet
Simulation Area	1500*1500	meter square
Mobility Model	Random Way Point	
Packet Size	512	Byte
Transmission Range	250	Meter
Traffic type	CBR	
Initial energy	100	joules
Simulation time	5,10,15,20,25,30	seconds

2. Packet delivery ratio(PDR) : It is defined as the ratio of packets received at the destination to the packet generated at the source. This metric tells us about the quality and performance of network. Higher the PDR better will be the network performance.
3. Residual Energy : It is defined as the remaining energy that a node retain after performing the desired task of sensing, processing and communicating.
4. Throughput : It is calculated as the number of bits that have successfully received at the destination and is measured in kilo bits per second(kbps).

3.3.2 Simulation Results

This section describes the performance and comparison of RBTC algorithm with respect to FF-AOMDV [27] protocol by 4 different performance metrics.

3.3.2.1 Packet delivery Ratio

Fig 3.5 shows the impact of varying time with respect to packet delivery ratio for FF-AOMDV and proposed RBTC protocols. The analysis of this graph reveals that RBTC protocol outperforms the existing protocol by 24 percent. This is due to the reason that we have taken the concept of relative mobility which ensures that node will be connected only to the node having lesser mobility than its own mobility and moreover the two connected nodes are approaching each other, so this will ensure that link will not break. As the link breakage is reduced so the packets will be transmitted at higher rate and packet loss is reduced. So, the packet delivery ratio will be increased and hence the network becomes more efficient.

3.3.2.2 Delay

The fig 3.6 describes the behaviour of end to end delay with variation in time. The graph reveals that RBTC outperforms the FF-AOMDV protocol in terms of the delay and analysis proved that the improvement obtained is 17 percent in comparison to FF-AOMDV. This is because we have used best links in terms of direction, distance and mobility, so the time taken in transmission of packet reduces. Thus, the reduction in delay improves the overall

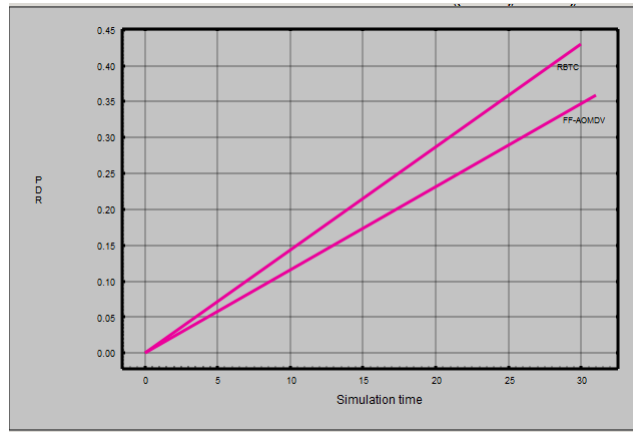


Figure 3.5: Packet delivery ratio w.r.t time

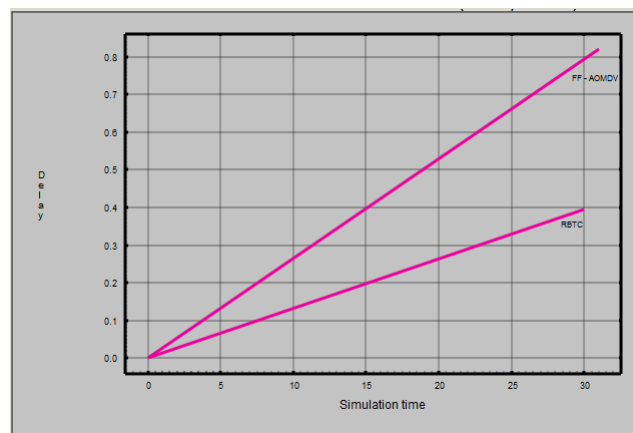


Figure 3.6: Delay versus time

performance of the network.

3.3.2.3 Residual Energy

The residual energy is the next performance metric which is compared with that of FF-AOMDV protocol and results obtained are shown in fig 3.7. The graph reveals that residual energy in RBTC protocol is higher than that of FF-AOMDV protocol. This is so because in FF-AOMDV protocol the highest energy node with shortest distance from the base station is preferred but the direction of nodes mobility is not considered but, in case nodes mobility are in opposite direction then the link breakage probability will be higher. Moreover, initializing the routing process will again consumes more energy and also reduces the network performance while in our algorithm process of the building topology is not initiated again and again so residual energy of the nodes is more in our algorithm.

3.3.2.4 Throughput

The another performance metric is throughput which is considered for evaluating the performance of our algorithm. The fig 3.8 shows the impact of varying simulation time on throughput for FF- AOMDV and RBTC protocols. The graph shows that the number of

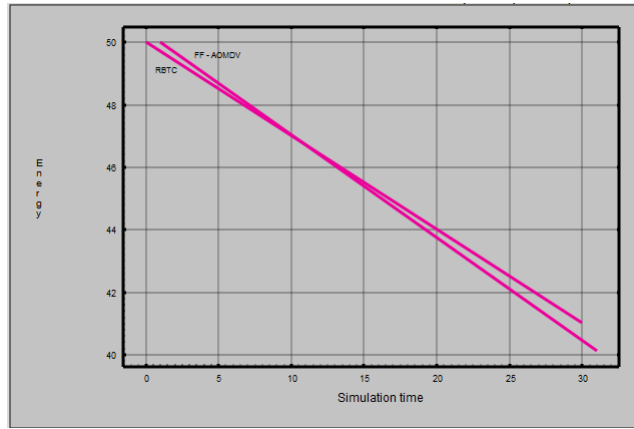


Figure 3.7: Residual Energy w.r.t time

bits transferred per second in RBTC algorithm is higher than that of the FF-AOMDV. In RBTC algorithm the chances of collisions are less due to lower value of mobility and higher PDR. As collisions are less so there is higher probability of sending bits in lesser time and thus larger number of bits will be transmitted in a certain time interval. The percentage

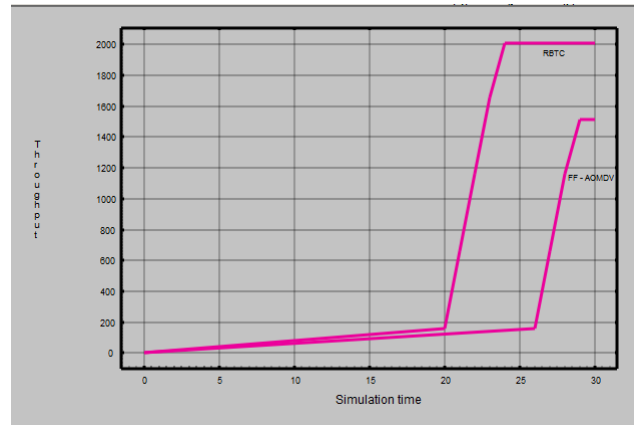


Figure 3.8: Throughput w.r.t time

improvement in throughput of RBTC algorithm is 31.8 percent in comparison to that of FF-AOMDV protocol.

Chapter 4

Improved DPV Algorithm

In this chapter we will discuss the existing DPV algorithm, problems that occur in DPV algorithm with its desired solution i.e. Improved DPV algorithm. The improved DPV algorithm further consists of two sections back propagation algorithm and the proposed methodology with its simulation results.

4.1 DPV Algorithm

Hakki bagci et-al.[13] has given Disjoint Path Vector (DPV) algorithm for topology control in heterogenous network whose main motive is to reduce the overall power consumption of network and that of nodes by reducing the transmission range and maintaining k vertex super node connectivity [13]. There are two types of nodes that exist in the network according to energy level and are classified as super nodes and sensor nodes. Super nodes are nodes which are deployed at known locations and not energy constrained. Supernode can communicate directly to the base station, as well as can send the data from sensor nodes to other supernode if needed. On other hand, sensor nodes are the ordinary nodes. Initially network topology is represented by undirected graph is represented. The author defines the algorithm in five stages. Firstly an Init message is created by super nodes that contains super node ID and is broadcasted to sensor nodes. Sensor nodes update their path information by adding the path entry to super node. Sensor node path information table contains path to super node and the path cost. After updating path table, paths are sorted into ascending order. Once, the sensor nodes after updates the path information, then it will create a pathInfo message containing its ID as well as path information table. This PathInfo message is transmitted to all reachable neighbor by sensor node using maximum power. The node which receive the pathInfo message will calculate union of existing and new paths. Later on the disjoint path set of the existing as well as updated union is calculated. The size of calculated disjoint path set can't be more than k as we need only k disjoint path. Now, the updated pathInfo message is sent by sensor node to all other nodes. If pathInfo message doesn't cause any update then sensor node will not send any pathInfo message. This is repeated till the improvement of cost become impossible and thereby the message transmission ends. On the other hand, if sensor node received the pathInfo message which has reached Time to Live(TTL) , then no new pathInfo message will be created even if update occurs, to ensure that the path have certain length limit. To ensure that nodes selected in disjoint path is marked as required

neighbor, notify message is forwarded along with disjoint path. If in any case, node is not marked as required neighbor then it means link is not important and can be removed. For nodes, those don't have atleast k vertex disjoint path information cannot decide which node can be removed or kept, so they have to retain all the nodes. This helps us in ensuring k vertex super node connectivity. In the last, Transmission power is adjusted by node such that it can reach its farthest neighbor and final topology is created. Hence author concludes that there is reduction in total transmission power so, the network is energy efficient. The flow chart of algorithm is shown in figure 4.1 below.

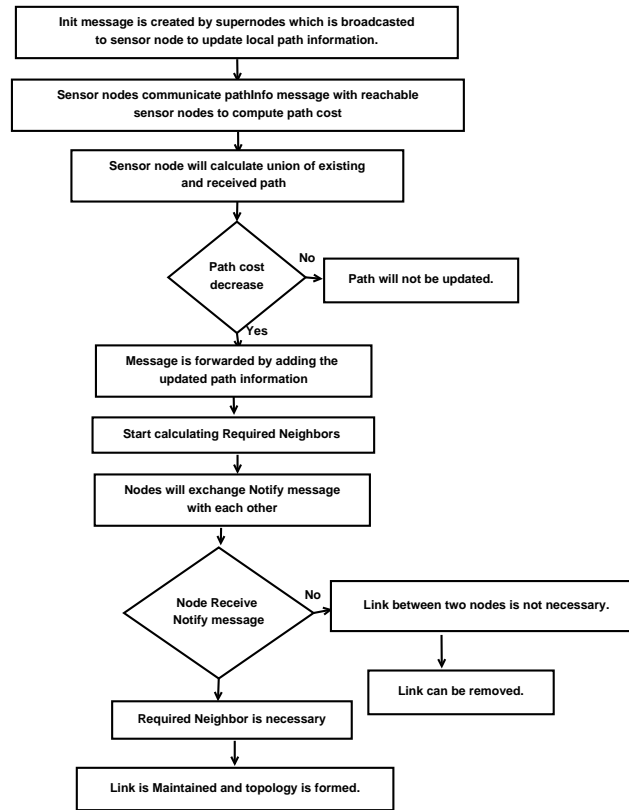


Figure 4.1: DPV algorithm

4.2 Problem statement

DPV Algorithm aims to reduce the fault and energy consumption in the network. But in order to fulfil this aim, author need to update the path information again and again. This process of updation of path and to rebuild the new path, increases the time complexity as well as the message complexity. Moreover it also involves calculations that are needed in order to accomplish the task.

4.3 Problem solution

The probable solution to the above problem and to improve the DPV algorithm we have make use of the back propagation algorithm [28] which helps in choosing the efficient cluster head [29] and select the optimal path for data transmission which avoids the delay during

data transmission and also makes the calculation easier. i.e. also known as Improved DPV algorithm.

4.3.1 Back Propagation

In WSN several thousands of nodes are deployed in particular area and they need to form a topology for effective communication. Once the topology is constructed the data communication is initiated between the pair of nodes. If the network is mobile then due to movement of nodes frequent partition and merger take place frequently. Thus, the topology information need to be updated timely. The back propagation algorithm is a technique whereby the errors in path are removed efficiently by properly selecting the cluster head. The back propagation updates the weight i.e. energy of nodes in the network to obtain the actual output by calculating the gradient descent of loss function as described in formula 1 given below.
$$\text{Output} = \sum_{x=0, w=0}^{x=n, w=n} x \cdot n \cdot w \cdot n + \text{bias}$$

Actual output is the output that is actually generated by the topology constructed.

Here x represents each node in topology and w represents the weight i.e. energy of each node. The error is calculated as the difference between actual output and the predicted output value.

Error = Actual output – predicted output.

Later on the derivative is computed. If the rate of a derivative is positive it indicates that existing weight is higher and newer weight should be smaller. So data is back propagated and new weights are updated. The process continues at a node until we don't get the desired weights for that node. The output of each iteration is compared with the next iteration and value of iteration at which the error is minimum is the final Euclidian distance. The back propagation [30] is shown in figure 4.2.

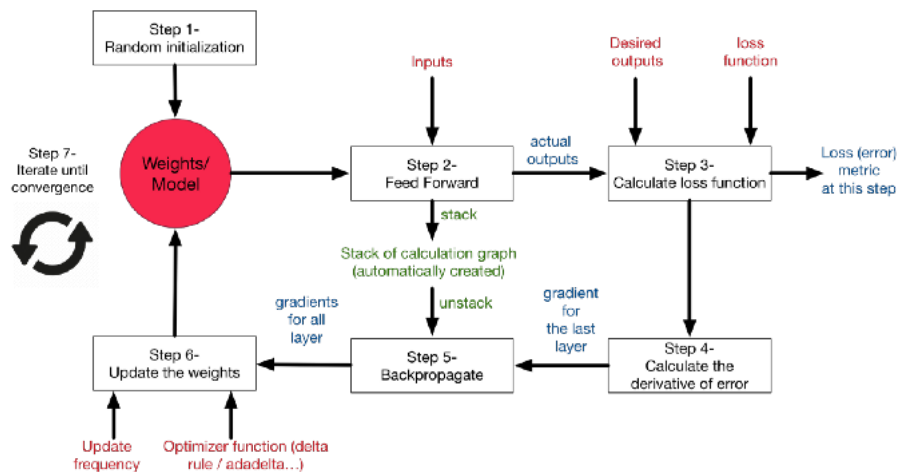


Figure 4.2: Back Propagation Algorithm

4.3.2 Proposed Methodology

The proposed methodology aims to improve the existing algorithm by reducing the faults as well as saving the energy consumption. This is done by choosing an efficient cluster head

for the communication with the help of back propagation algorithm. Initially nodes are deployed in heterogenous manner in which 5 percent of nodes are not energy constrained. After that sink node broadcast a message containing its own location coordinates. After receiving that message each node will compute the Euclidian distance from the base station and replied back the same to the sink node along with their node id. The sink node maintains the table containing the entries of distance and location of all the nodes [31] and then assigns a cluster head on the basis of distance and location. After that sink broadcast the message to all nodes containing cluster head ID and its location coordinates. After that clusters are formed by nodes according to the nearest cluster head as per location based clustering and equally spaced clusters are formed. As cluster head are selected so communication between the nodes will start. When nodes are communicating data with other nodes, energy will be consumed in transmission and reception of data packets. Now back propagation technique is applied. So, back propagation by choosing highest energy node which is capable of communicating the data efficiently without causing faults due to energy drain. According to energy of nodes and distance from base station, cluster head are updated and rotated after particular time interval. Maximum the energy of node, minimum will be the error and faster will be the communication. Node paths are updated simultaneously and communication continues as per existing algorithm. The proposed method is shown in figure 4.3. The back

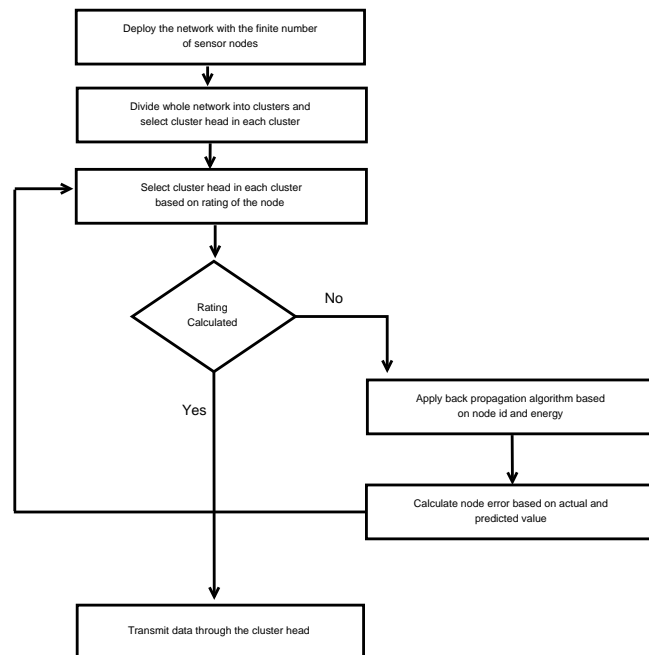


Figure 4.3: Modifications in algorithm

propagation algorithm is initiated in the starting of DPV algorithm after deployment of sensor nodes. Error are removed from the paths and then the steps of DPV are followed as per shown in the flow chart given above in figure 4.1.

4.4 Simulation parameters

The simulation of this algorithm is done in NS-2 software. The simulation parameter table 4.1 is given below.

Table 4.1: Simulation parameters.

Parameter	Description	Value
A	Network Area	250
L- BS	Location of Base station	(150,250)
N	Number of nodes	100
$E_{initial}$	Initial Energy	0.5 J
E_{fs}	Free space channel model	50 nJ/bit
E_{mp}	Multi path fading channel model	0.0013 pJ/bit/m ⁴
d_0	Distance thershold	87m
E_{DA}	Data aggregation energy	5 nJ/bit/signal
DP size	Data packet size in bit	4000
CP size	Control packet size in bit	200

4.5 Performance metrics

1. Delay: It is defined as time duration which nodes takes to receive the data packet. Larger the value of delay, poor will be the network performance.
2. Throughput: It is defined as the number of packets which are successfully received in the particular time slot.
3. Energy consumption: It is time until which network works. More will be the energy consumption lesser will be the network lifetime.
4. Packet delivery ratio : It is defined as the ratio of total packet received to total packet sent. Higher is the packet delivery ratio, more will the communication in the network and lesser will be the packet loss.
5. Total number of receptions: The total number of receptions is defined as the total number of control messages successfully received in the network.
6. Total number of transmissions: The total number of transmissions is defined as number of control messages that are successfully transmitted in the network.

4.6 Simulation Results

1. Delay: Fig 4.4 shows the variation of delay with respect to number of nodes. It is observed that delay of modified algorithm is 17 percent lesser than that of existing DPV algorithm. It outperforms the existing method by choosing the highest energy path which is closer to the base station. The time is only consumed in packet transmission but not in the constructing the path again and again. This reduces the time which is needed to sent the packet as well as the packet loss.

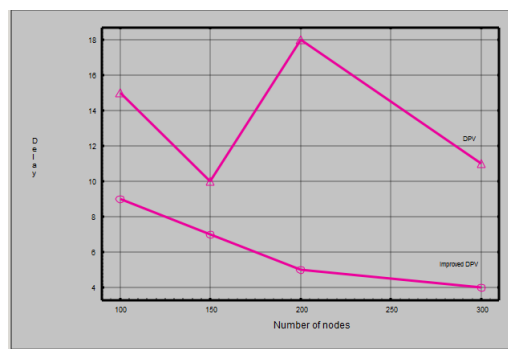


Figure 4.4: Delay versus number of nodes

2. Throughput: While implementing the modified DPV algorithm with back propagation model, the chances of link breakage reduces to much extent by choosing the maximum energy node which can communicate the data efficiently as seen in figure 4.5. This helps in successfully delivering the packets. Lesser will be link breakage large number

of bits will be transferred to destination at proper time interval. There is 35 percent improvement in throughput.

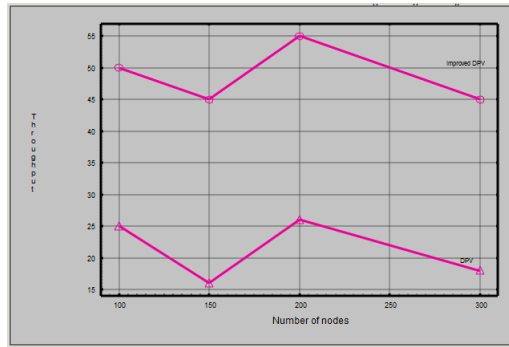


Figure 4.5: Throughput versus number of nodes

3. Routing Overhead: Packets are communicated efficiently in modified DPV with avoidance of packet loss. As packet loss is less, so the cost needed in transmitting the packets reduces. The number of packet that should be communicated in particular time interval decreases due to smooth transmission. As seen in figure 4.6 that there is 16 percent reduction of routing cost in modified DPV as compared to the DPV.

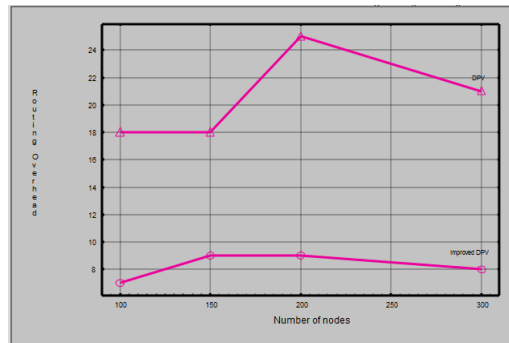


Figure 4.6: Routing overhead versus number of nodes

4. Packet delivery ratio : Fig 4.7 shows that after applying back propagation to the DPV algorithm there is improvement in PDR factor with 12 percent because of selection of best node on distance and energy basis. Nearest the node to base station and highest the energy, more efficiently and fastly packets will be transferred without any packet loss. More will be the packets transferred then highest will be PDR. Highest the PDR, then more efficient will be the network performance.
5. Energy: It is observed in figure 4.8 that as number of nodes increases, energy consumption increases to the certain level only. As network is free of fault and error free paths are chosen then there will be less probability of the link failure and energy will not be used in constructing the new path.

So energy will be used only in communicating the message So, energy needed to built

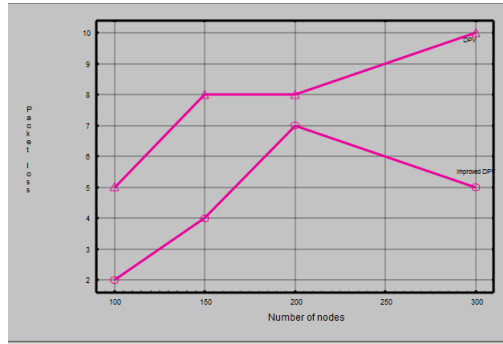


Figure 4.7: Packet Delivery Ratio versus number of nodes

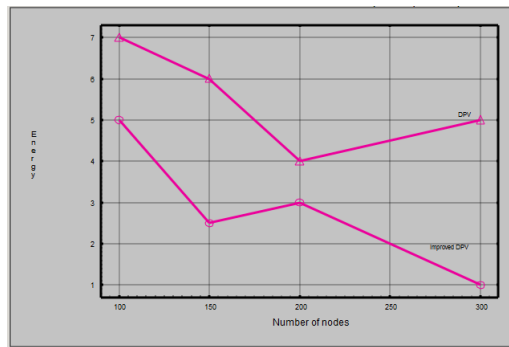


Figure 4.8: Energy versus number of nodes

a path reduces which indicates network will have less energy drain. Hence network lifetime increases.

6. Total Number of receptions : Fig 4.9 represents the number of packet received w.r.t to number of nodes. The number of packets that has been received is more in case of modified DPV. Modified DPV outperforms the existing DPV with 35 percent. As we know path information is updated periodically on both scenarios by which if there is chances of fault then according to path information they are changed before error. But this process takes large amount of time. But in our case the error are removed earlier

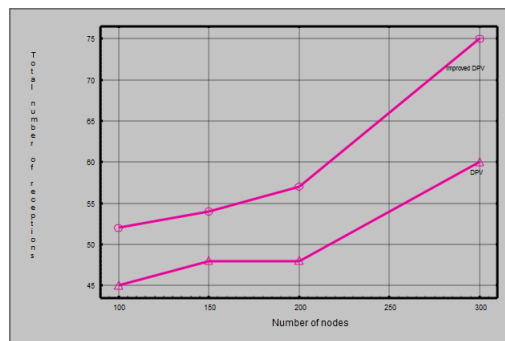


Figure 4.9: Total number of receptions versus number of nodes

from each path and hence path are made fault free w.r.t to each and every node. This reduces the time packet takes to reach the destination as well as packet loss is reduced.

So, higher number of packet are received at destination which improves the network performance. There is 33 percent of improvement in DPV algorithm.

7. Total number of transmission : As seen in fig 4.10 given below we can see number of transmission of packet in modified DPV is more than DPV algorithm. Less packet transmission is of link failures or if path information is not known to the node etc. As we are removing the error from each path by checking each and every path and

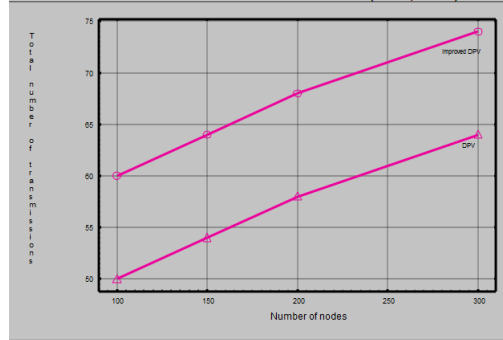


Figure 4.10: Total number of transmission versus number of nodes

considering each and every node either it is source node or intermediate node, so packets are transmitted efficiently to the destination. Higher number of packets are transmitted with lesser packet loss. There is 13.5 percent of improvement in DPV algorithm in terms of total number of transmissions

Chapter 5

Conclusion and Future works

The report on dissertation is extensively separated into three parts. The first part deals with the theoretical aspect about the problem that is faced in topology control and also analyzes the possible logical solution to that problem with its simulation results. The second part of this dissertation deals with the existing algorithms, their problems faced the suggested modifications that helps to improve the results. In this thesis work various topology control algorithms are studied. In this thesis we have proposed a RSSI Based Topology Control Algorithm (RBTC). RBTC algorithm is to improve the packet delivery ratio by monitoring the direction of the nodes in which they are moving by considering the distance factor. Due to its advantage of proper packet delivery it can be used in applications where there is urgent requirements of packet but due to low mobility of nodes this topology can't be deployed in the areas which are highly prone to various attacks. The other research work in this thesis includes the improved DPV algorithm. The improved DPV algorithm provides fault free paths that are used for communication and can blindly be used in case where there are energy issues as well as the case where fast transmission are required. This is because it consist of some of nodes that are not bound to energy constraint and communication is going on continuously avoiding the packet loss. This thesis mainly focuses on improving two factors PDR and energy constraint and also improved these factors to some extend. In future, we would like to put more efforts for maintaining the link stability especially in the case of high mobility networks. We would like to propose some topology maintenance algorithm that will increase the network throughput, network capacity while reducing the time complexity so that in case of emergency, messages should be communicated before time. Topology should be constructed in such a way that message complexity should be less and the message transmission should be fast.

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List of Publications

SCI Journal:

1. Singla Pallavi and Munjal Amit (2019), “ RSSI Based Topology Control Algorithm (RBTC),” in *Wireless Personal Communications* [Communicated].
2. Singla Pallavi and Munjal Amit (2019) “Topology control Algorithms For Wireless Sensor Networks: A Review,” in *Wireless Personal Communications*. [Communicated].