SURVEY OF GENETIC BASED APPROACH FOR MULTICAST ROUTING IN MANET

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Abstract— **An independent, self-governing group of mobile wireless hosts communicate through wireless links by forming a temporary network (Mobile Ad-hoc Network) in a dynamic manner without any fixed and centralized infrastructure. Since the nodes in MANET are not stationary, same path may not be taken always for routing between the sender and the receiver(s). So, routing in such situation is a complicated task. In addition, the resources of the wireless nodes are limited. With the intention of saving the resources of the nodes in the network, multicasting can be used instead of multiple unicast data transmissions whenever a node needs to send same data in parallel to several destinations. The group-oriented services are the primary ones that support today's need and trend of communication. In recent years, such services are provided with the help of MANETs. The residual energy of the battery of a mobile node is finite (before recharging is done), which is a constraint while developing multicast routing protocols. Genetic Algorithm (GA) presents an improved solution for the multi-constrained multicast routing problem. By choosing proper fitness function and values for metrics such as initial population size, crossover and mutation that closely relates to the chosen scenario, the genetic algorithm optimizes the routes in terms of selected metrics. This paper focuses to provide a survey and analyses the categories of multicast routing protocols. In addition, this also covers the details of the application of genetic approach in finding multicast routes.**

Keywords: **MANET, GA, MAODV, ODMRP.**

I. INTRODUCTION

Ad Hoc is a term from Latin which means "for this purpose". A temporary association of nodes for the purpose of communication becomes an ad-hoc network. MANETs are temporary networks of autonomous and independent mobile nodes with dynamic topology without any centralized network devices (say access points, base stations, etc.) that provide specific services in routing [1]. The nodes in MANETs are mobile and have a routing function to communicate with each other. Hence, each and every node in the MANET acts as a router. If two mobile nodes i.e. both the source and destination are present within the transmission radius, they can exchange data over the wireless radio frequencies. If the location of destination node is not in the transmission range of the sender, then the sender requires other node(s) to forward the datagram's by multi-point hopping to the destination node. The prominence of MANETs is due to its ease of deployment and non-restricted mobility. Furthermore, wireless nodes in MANETs have constrained resources like limited bandwidth, computing power, residual battery lifetime that enforces in developing various routing protocols in MANET to support different applications.

II. ROUTING IN MANETS

Routing protocols for MANETs need to account for several aspects. Since nodes can move around, enter and leave the network, the network topology can change rapidly, which in turn requires a lot of communication for a node to keep a static picture of the topology. Moreover, as mobile nodes operate on battery power, which limits the amount of data they can transmit, recharging is necessary.

Most mobile devices today have less processing power and memory than standard Personal Computers (PCs). Due to these constraints, routing protocols must minimize the number of packets used for maintaining the routes and must be able to adapt to changes in the topology. Another issue in MANETs is that links between nodes are not always bidirectional but can be unidirectional also.

A. *Multicasting*

Routing of data packets can be either unicast or multicast transmission. Unicast transmission denotes the method of attaining a feasible route from the source towards a destination node. On the other hand, multicast transmission denotes the process of attaining a feasible tree with root as source and leaf nodes as the destination(s). Multicasting is a more efficient technique in comparison with unicast routing in supporting group communication based applications and hence is an important aspect of future network development.

In recent years, many group oriented applications have gained a lot of importance that are developed to deploy in MANETs. Multicasting is used in videoconferencing, corporate communications, Military applications, Search and rescue operations, Temporary networks within meeting rooms and airports, Vehicle-to-vehicle communication in smart transportation, distance learning, Personal Area Networks connecting mobile devices like mobile phones, laptops, smart watches, and other wearable computers, and distribution of software, stock quotes, news, etc.

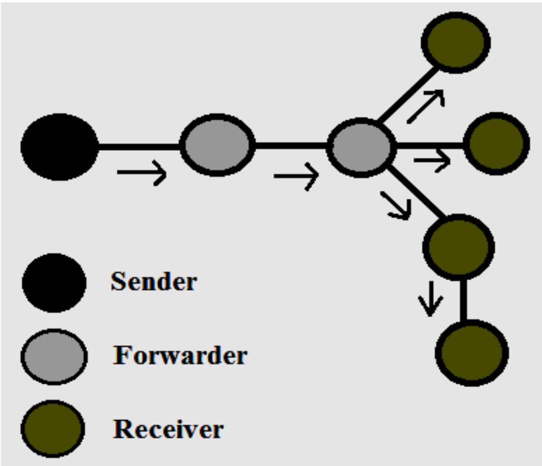

Fig. 1. Multicasting: Formation of feasible tree

B. *Benefits of Multicasting*

The usage of multicast transmissions within MANETs has several advantages. When multiple copies of same data packets have to be sent from a sender to multiple receivers in parallel, multicasting

- Decreases the cost of wireless communication.
- Decreases channel capacity consumption.
- Decreases sender nodes and routers processing.
- Decreases energy utilization.
- Decreases data delivery delay.
- Increases the efficiency of data transfer.
- Increases the throughput of wireless link between the sender and receiver(s).

C. *Need for Multicast Routing Protocols*

The topology of MANETs is dynamic. Hence, the locations of the nodes change with respect to time resulting in wireless-link failure across nodes. The nodes have to repair the routes rapidly to achieve node to node communication. So, the routing protocol for multicasting should handle, manage the link-breakages and find new optimal paths, if necessary, minimize the energy consumption at nodes and control traffic overhead. Numerous multicast routing protocols have been proposed to solve these problems. Every multicast routing protocol has its own advantages and disadvantages, and aims at a specific application.

III. CLASSIFICATION OF MULTICAST ROUTING PROTOCOLS

As discussed in the earlier section, due to the numerous advantages provided by multicast routing and to support different group applications, several multicast routing protocols have been designed. Various proposals classifying the multicast routing protocols exist in literature. O. Tariq [2] has categorized these protocols into flooding, hybrid, stateless, tree structure, mesh based protocols with the performance evaluation of these protocols in MANETs. Some major classifications are:

- Based on the path redundancy
- Based on the mode of route computation

- Based on the efficiency of energy
- Based on the QoS metrics

A. *Based on Path Redundancy*

This category is identified based on the number of paths available between a source and one among the destinations. This classification represents the redundancy of paths to the destinations and in turn indicates level of fault tolerance of the network. In this aspect, there are two major classes namely, Tree structure and Mesh-based routing protocols. However, researches carried out to combine the advantages of both of these classes of protocols have resulted in the development of hybrid-based approach.

In Tree-based approach, only one route exists from the source to any one of the destination nodes. Hence, a multicast tree is formed by considering all the routes from a sender to all the receivers. These protocols send least possible duplicate data packets through the edges of the multicast tree and hence effective in terms of bandwidth utilization. However, due to the movement of nodes, link failures occur and entire tree needs to be reconfigured, which results in some delay in the delivery of data packets. If there is more than one source, then the protocols must either form a shared tree or store multiple trees, one individual tree for every source. Using a shared tree for routing the data packets result in less optimal paths. Storing multiple trees leads to overhead both in terms of control and storage. Some of the protocols that belong to this category are MAODV, AMRIS, AODV, ALMA.

Tree-based protocols can in turn be categorized into two types based on the root of the multicast tree. They are source-rooted and core-rooted. Source-rooted protocols are the tree-based ones in which the root is the source and takes up all the tree establishment and reconfiguration tasks. This makes the source to have the entire topology information. Hence, there is a high overhead associated with these protocols. AMRoute is one of the source-rooted multicast routing protocols. Core-rooted protocols are the tree-based ones in which the core node is not a source but some special node that takes up the tree establishment, maintenance and data distribution tasks. Some of the core-rooted protocols are STAMP, ACMP, etc. Some of the tree-structured multicast routing protocols are stated below briefly to provide some idea about the features of these protocols.

1) *MAODV*: Multicast Ad-hoc on-demand Distance Vector is one of the tree-based reactive multicast routing protocols. It depends on the unicast routing protocol, AODV. In MAODV, Hello packets are flooded within the network with TTL set to one in order to ensure connectivity with the neighbours. Each node in the network maintain three tables namely; Request Table, Routing Table (RT) and Multicast Routing Table (MRT) [3]. Routing Table here has similar functionality as in AODV and mainly stores routing information. The multicast routing information of every multicast group is maintained and updated with the help of a sequence number. This sequence number is maintained in the group by the group leader by flooding group hello packets at regular intervals. The first node that joins the group becomes the group leader, by default. If this first node leaves the group, then some other node is elected as group leader. The drawbacks of MAODV are high overheads, low packet delivery ratio and long delays due to link failures in high mobility and traffic load scenarios. MAODV is not flexible as it relies on unicast routing protocol, AODV. Moreover, multicast group leader is a single point of failure in MAODV.

2) ALMA: Application Layer Multicast Algorithm is an application-layer tree-based destination-driven multicast routing protocol proposed by M. Ge [4]. ALMA uses link breaks as metric. All the group members form a multicast tree with edges as logical links. These logical links are paths between nodes at network layer. If there is any link failure due to mobility or congestion, the tree should be reconfigured. Join packets are sent to the existing group members by a new node that wants to join the group. Any existing member that wishes to get a fresh child replies and adds the node to the tree. If the new node gets several responses, it selects the group member that responds first. The node sends an explicit leave message to its children and parents in the tree in order to leave the group. Hello messages are sent to its parent by each node periodically and get a reply indicating the connectivity. If the node doesn't receive any response within time-out period, it assumes that the parent has failed and tries to join the tree again. The child may change its parent considering average round-trip time (RTT) as a parameter. The RTT of the new parent must be less than the threshold RTT. The disadvantage in ALMA is that though the loops are detected they are not fully removed.

In Mesh-based multicast routing protocols, more than one path exists from sender to any one of the receivers. These multiple paths form a mesh. Though a route to the receiver fails, data is sent through another available path in the mesh. Hence, the packet delivery ratio (PDR) is high. Moreover, the nodes are more resilient to link breakages and mobility. The delivery of data packets is done by the sender by broadcasting them within the mesh. The major drawback in mesh-based protocols is that this high redundancy of data packets due to broadcast results in increase in control overhead and high bandwidth consumption especially in high mobility scenarios. Some of the mesh-based protocols are ODMRP, CAMP, DCMP, FGMP, and NSMP. Two of the important mesh-based protocols ODMRP and DCMP are stated briefly to provide some basic idea about the features of these protocols.

3) ODMRP: On-Demand Multicast Routing Protocol is one of the reactive multicast mesh based protocols. On demand by source, group membership and routes are formed. Whenever the source is ready to send data but doesn't have established multicast routes to destinations, message with name Join-Query is flooded within the network. Join-Query is flooded at regular intervals in order to update routing and membership information. When any one of the destination receives Join-Query message, Join-Reply message is created and flooded to its neighbours. When this reply is received by any node, it checks whether its own id and next hop id are the same. If it is same, the node considers itself on the way to sender, sets FG_FLAG (Forwarding Group Flag) and hence becomes forwarding group member. In this way, mesh is formed. The source broadcasts data packets in the mesh. The data packets are forwarded by a node whenever it receives, if packet is not a replica in order to minimize the traffic overhead and load. The merits of ODMRP are high packet delivery ratio, low storage overhead and robustness to mobility. The main drawback is the overhead due to broadcast in mesh network.

4) DCMP: Dynamic Core-based Multicast Protocol is a source-initiated mesh-based protocol presented by S.K. Das [5]. DCMP doesn't depend on any unicast routing protocol unlike MAODV. In DCMP, when multiple sources want to send data, they are categorized as active, passive and core active. The active source nodes follow the method of periodic broadcasting of Join Request messages within the network. The target nodes send Join Reply message in reverse to the appropriate source node. In this manner, multicast group and mesh are established. The passive source nodes have no role in the formation of multicast routes. These passive nodes send the data through the shared mesh formed by core active nodes. DCMP has lower control packet overhead and supports scalability. However, there is a minor decrease in packet delivery ratio under low traffic scenarios.

Identifying the advantages provided by both tree and mesh-based protocols, hybrid approaches have been proposed. These hybrid-based protocols offer both robustness and efficiency. But the mobility of nodes may result in the formation of trees that are not optimal. Some of these hybrid protocols are EHMRP [6] and PUMA.

B. *Based on the Mode of Route Computation*

This category of multicast routing protocols is based on how and when the routes are computed and maintained. In this view, there are two classes of multicast routing protocols namely, Table-driven and On-demand.

Table-driven multicast routing protocol is one in which routes to all destinations are computed prior to data transfer. Each node stores this routing information in the routing table and gets aware of the network topology. This information is updated on a periodic basis to handle the dynamic changes in the topology. This periodic exchange of information between nodes increases the control overhead and reduces scalability of the network. After the network topology changes, the convergence of routing information at every node in the group needs to be taken care. So, this class of protocols is inappropriate for large networks.

Some of the multicast protocols that fall in this category are CAMP, AMRoute, and AMRIS. In the above stated examples, AMRoute and AMRIS are tree-based while CAMP is a mesh-based protocol. AMRoute does not prevent loops in routes. But AMRIS and CAMP ensure the routes to be loop free. These three protocols have fair scalability but suffer from control overhead due to the necessity of transmission of periodic updates.

On-demand multicast routing protocol doesn't pre-compute the routes but does it on demand by the source when required. This class follows an event driven mechanism. Whenever a source needs to communicate with the destination nodes and has no routes to them, it broadcasts the route request packets to its neighbors in the network. Any node that receives a route request packet sends the route information as reply to the sender through unicast transmission if it has path to the receiver. In this way, periodic control overhead is minimized but there may be a considerable delay near the source because of route computation on demand. However, this class of protocols supports scalability and is appropriate for networks with high mobility.

Some of the multicast protocols that come under this category are ODMRP and MAODV. Both of these are reactive protocols. ODMRP comes under the category of mesh-based while MAODV comes under core tree-based protocols. Both of these protocols have loop free paths and fair scalability. However, the control overhead in these protocols is less compared to the proactive protocols discussed above, especially in large networks. Hybrid protocols have been developed that combines the benefits of both proactive and reactive class of protocols. In some hybrid protocols, the nodes are grouped into several areas or zones. In areas with high mobility, reactive approach is used and in areas with moderate or less mobility, proactive approach is used. In some hybrid protocols, the route computation is table-driven for nodes nearby and on-demand for nodes that are far away from the source.

C. *Based on Efficiency of Energy*

Since, the nodes in MANETs are wireless and not stationary, they run on battery power with limited energy before the batteries are recharged. If the battery of any node in the network drains, it stops its functions resulting in routing problems. Hence, residual energy of a battery is an important parameter that has to be considered while developing efficient multicast routing protocols for MANETs. This class of protocols focuses on proliferating the lifetime of the nodes in the MANETs by using the battery power efficiently [7], [8]. Some of the protocols of this category are MWIA [9], RB-MIDP and D-MIDP [10]. Two specific approaches for achieving energy efficiency are briefed below.

1) Energy Efficient Multicast Routing: A notion on energy efficient multicast routing has been proposed by D. Li [11]. The idea presented is to assign weight to each node with its transmission power and form a graph such that weights are represented between edges. To achieve efficiency in energy, a multicast tree having minimum total energy cost has to be formed. It is an NP-hard problem. A cover set having all the non-leaf nodes is built level-by-level by choosing the shortest route from the sender to the nodes in the uncovered set. This heuristic approach by choosing the nodes with maximum energy develops the multicast tree efficiency.

2) Energy Conserving Routing in Wireless Ad hoc Networks: Another approach for achieving energy efficiency proposed by Chang and Tassiulas [12] is forming routes with minimum number of hops that leads to low energy cost. It may seem that finding the shortest distance will also decrease the utilization of the energy. But this method of forming shortest paths result in more energy utilization of the hosts along these paths and the battery energy of the remaining hosts in the network is left unused. Hence, they present a routing scheme in order to maximize the duration of the nodes considering mainly the source and destination groups and the traffic load in the routes between them. A category of flow redirection and augmentation algorithms are developed which address and maintain equilibrium between the energy resources and the energy utilization rates of the nodes. This approach increases the lifespan of the network in comparison with the use of minimum transmitted energy routing algorithm.

D. *Based on QoS Metrics*

This class of multicast routing protocols is made based on the constraints that must be met in order to support the functionalities of the group oriented applications. As group oriented applications use multicasting technique for routing, many variants of multicast routing protocols are proposed in literature by taking different metrics such as delay, bandwidth, traffic, control overhead, number of hops and battery energy into consideration. These variants are developed in order to meet specific requirements of the applications and in turn result in delivering quality of service. For instance, some video based applications need good packet delivery in correct sequence at the expense of some delay. MCEDAR (Multicast Core Extraction Distributed Ad-hoc Routing) [13] is multicast routing protocol that falls in this category.

This class of protocols not only concentrates on finding a route from the sender to the receivers, but also provides quality of service in terms of metrics considered during their design and development. Hence, these protocols should effectively assign and efficiently use the resources of the nodes. The QoS metrics can be categorized as path constraints (such as end to end delay, number of hops), link constraints (such as bandwidth) and tree constraints (such as jitter). Moreover, development of multicast protocols is very challenging because the QoS metrics are interdependent and conflict each other.

Since, the metrics are reliant on each other and some of them conflict each other, achieving QoS in multicast routing is a NP-complete problem. To resolve this problem, several heuristic algorithms such as Genetic Algorithms (GA) have been presented. The genetic algorithm ensures achieving routes that are globally optimal, using various arbitrary search points and simultaneously considering numerous candidate solutions. However, genetic approach suffers from certain faults such as slow convergence speed, lack of ability to search locally and early convergence. From the previous decade, the advancement in optimization theory led to development of Swarm Intelligence. Swarm Intelligence is a category of arbitrary search methods that address the global optimization problems. Ant Colony (AC) and Particle Swarm Optimization (PSO) are the paradigms that belong to this category and are the recent methods proven to be efficient in finding a solution for multicast routing in order to satisfy QoS metrics required by the group applications.

IV. GENETIC ALGORITHM

Genetic algorithm originated from the concept of natural selection and natural genetic, considers the set of all possible solutions, called population. However, other heuristic algorithms follow an iterative method considering only a single solution. Another variation is the randomness of genetic algorithm, hence called stochastic approach.

As the genetic algorithm has to build a population of solutions, it also acts as a searching algorithm for identifying the possible solutions. Encoding, crossover and mutation are the three operations available in the field of genetics. The outcome of an iteration of genetic algorithm is considered as a new generation and a new set of solutions is obtained by the combination and exchange of the data available from the preceding generation. The variables used in this algorithm are the genes present in a chromosome. Every chromosome gene denotes a probable solution.

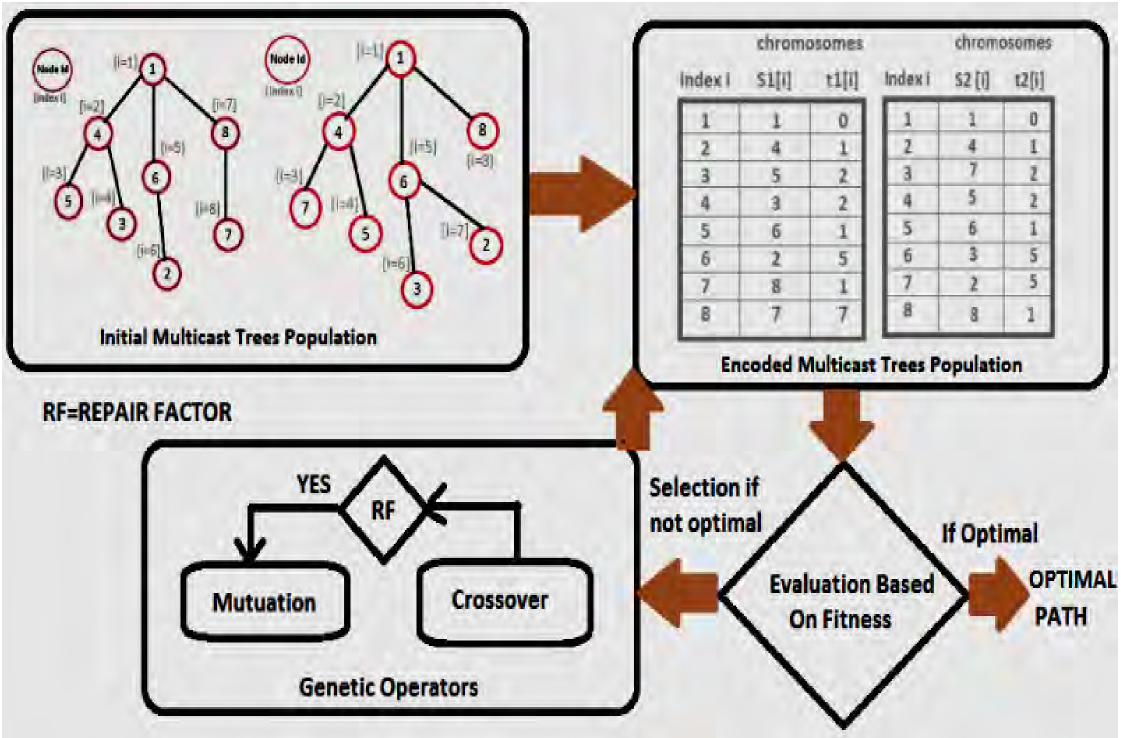

Fig. 2. Overview of genetic algorithm

. Genetic algorithm contains the following processes:

- Encoding
- Initial Population set
- Fitness Evaluation
- Selection
- Reproduction
- Crossover
- Mutation

An overview of genetic algorithm is presented above in Fig. 2. The steps involved in the algorithm are explained below.

A. *Encoding*

The initial step of genetic algorithm is encoding. First, a network topology is taken and a set of multicast trees (atleast two) are constructed by means of prim's algorithm. The multicast trees constructed are then encoded. There are several ways of encoding a multicast tree. The main encoding types are:

- Prufer Number Encoding
- Extended ST Encoding
- NPI Encoding

1) *Prufer Number Encoding*: A tree with n vertices considered for encoding is associated with a unique sequence of (n-2) numbers [14]. A simple iterative algorithm is used to generate sequence of numbers. The prufer number is obtained by stripping off the vertices from the multicast tree iteratively till two vertices are left. This encoding gives two strings Pn (prufer number string) and Pl (leaf node string) for a tree. The steps involved in prufer number encoding are:

- Assign unique number (starting from 1) to each node of the multicast tree of 'n' nodes.
- Select a leaf node (say A) from the tree that has least node number. Add the number of selected node to the string Pl.
- Find a node which is unique (say B) is connected to the leaf node A. Add node B's number to the string Pn only if this number is not present in the string Pl.
- Delete the leaf node A and the edge connecting the nodes A and B. Thus, the number of nodes left in the multicast tree is n-1. Now, node B becomes a leaf node.
- Steps b to d are repeated till the number of remaining nodes in the tree becomes two.

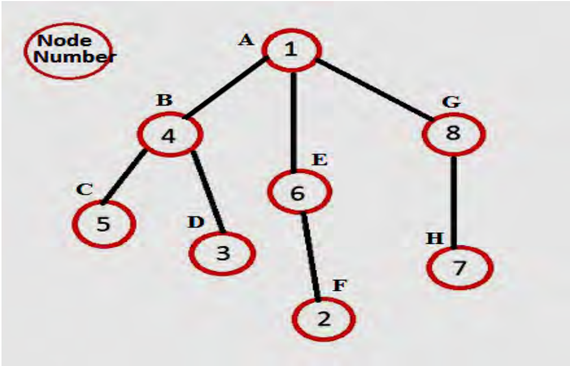

Fig. 3. Multicast tree topology of a network

From the above steps, the prufer number string Pn is generated. An example for prufer number encoding is given below. The prufer number encoding for the above multicast tree is as follows:

(i) Pn = 6, Pl = 2; (ii) Pn = {6, 4}, Pl = {2, 3}; (iii) Pn = {6, 4, 4}, Pl = {2, 3, 5}; (iv) Pn= {6, 4, 4, 1}, Pl = {2, 3, 5}; (v) Pn= {6, 4, 4, 1, 1}, Pl = {2, 3, 5}; (vi) Pn= {6, 4, 4, 1, 1, 8}, Pl = {2, 3, 5, 7}. For the topology shown in Fig. 3, the Prufer numbers are Pn = {6, 4, 4, 1, 1, 8} and Pl = {2, 3, 5, 7}.

The main benefit of this encoding method is the prufer string has only n-2 numbers for a considered multicast tree of n nodes. However, it is not advisable to use prufer number encoding for Steiner trees and incomplete graphs. The main disadvantage of this method is it doesn’t preserve locality information. Changing one number in Prufer string will change the topology of the multicast tree.

2) *Extended ST Encoding:* In this encoding method, integer strings called chromosomes, denote possible solutions that form a population [15], [16]. First, the nodes of the multicast tree should be given position indexes (by generally following in-order tree traversal). Encoding an indexed tree of n nodes using this method generates two strings s and t, each containing n integers. The sequence encoding of the multicast tree is denoted by the string s, whereas the topology encoding is denoted by the string t.

Steps for the extended st encoding of the multicast tree are:

- Define two integer arrays s[n] and t[n] (each containing n integers) and an integer i to represent the position index. The tree is traversed by in-order tree traversal.
- So, the first integer of array s, s[1] is assigned with the node id of the root of multicast tree. The position index of the parent of the node s[i] is denoted by t[i]. The first position t[1] is always assigned with 0, since the root node has no parent.
- For the remaining n-1 nodes, assign the node id of node at i^{th} index of the multicast tree to i^{th} element of array s, i.e. s[i]. Assign the index position of the father of node s[i] to the i^{th} element of the array t, i.e. t[i].

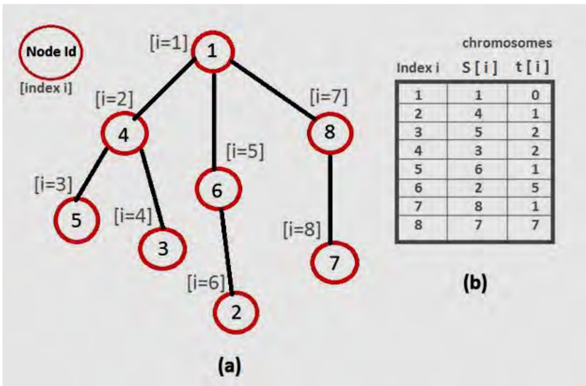

Fig. 4. (a) Multicast tree with position indexes (b) Extended ST encoding

An example for this extended method of sequence and topology encoding is illustrated. Fig. 4(a) shows the multicast tree to be encoded. Fig. 4(b) shows the position index with s and t integer arrays. Hence, the sequence string s is {1, 4, 5, 3, 6, 2, 8, 7} and the topology string t is {0, 1, 2, 2, 1, 5, 1, 7}.

3) *NPI Encoding:* This encoding method is known as Node Parent Index encoding. Each multicast spanning tree generates a unique representation using NPI encoding. This method needs an array whose length is 2n elements for a tree of n nodes.

Steps for NPI encoding of a multicast tree are:

- First, the nodes of the multicast tree should be given position indexes before encoding. To give position indexes, start from the root node and then follow either breadth-first search traversal or depth-first search traversal for the remaining nodes of the tree. In general, depth- first search order is used. Each node of the tree is given a NPI code as (2 * i) -1 where i is the position index of its parent node.
- Two continuous locations in the array are used for representing information of each node of the multicast tree. The node label (say A) is stored in the first location i.e. an even index in array and the NPI code of the parent of node A is stored in the second location i.e. odd index in array.
- The root node parent's position index is assigned 0, since root doesn't have any parent node.

The elements of all the odd indexes in the array represent the sequence of labels of nodes in the multicast tree in sorted order based on position indexes of the nodes. The elements of all the even indexes in the array together represent the tree topology in encoded format. This representation is known as NPI encoding. It is used widely in harmony based approach and is less significant to genetic based approach.

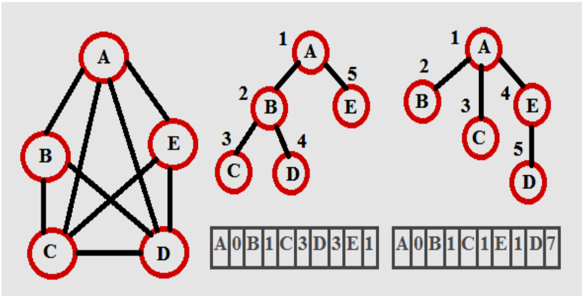

Fig. 5. Possible multicast trees of a network topology and their NPI encoding

B. *Initial Population Set*

In genetic algorithm, initially, a set of feasible multicast trees (at least two) are generated for the network topology considered by using prim's algorithm. These trees are then encoded using any one of the encoding types discussed in section III. A. So, each encoded string produced by encoding a multicast tree represents a multicast route. The strings that are generated from encoding process form initial population for the genetic algorithm to proceed with other operations like selection, crossover and mutation. This initial population acts as a base on which future generations are produced by reproduction of the fittest ones among them.

C. *Fitness Evaluation and Selection*

After the initial population is formed, the ones that survive better are chosen. For this selection, their fitness must be evaluated. Hence, a method (fitness function) is necessary in order to calculate the fitness of each solution in the population. This fitness function evaluates the efficiency offered by each individual solution in meeting the requirements (metrics like residual battery energy, delay and bandwidth) of the group application that is being developed. By selection process, the best ones are chosen for further iteration. But performing only these processes will not ensure in obtaining global optimality. The further steps of crossover and mutation will allow the solutions to exchange their information and hence search for paths that are more optimal.

D. *Crossover*

The term crossover is used extensively in genetic engineering. This notion can even be applied in finding paths that are more suitable, satisfying the specified constraints. In this method, the selected trees are combined to give rise to new tree. It divides up the chromosomes of parent trees and recombines them. The parent chromosomes that are selected for crossover from the chromosomes pool are the ones that are having greater fitness. The initial point and length of the segment of the parent chromosomes that are swapped and merged are chosen in a random way. The new child chromosome formed by crossover is added to the chromosomes pool.

1) *Crossover in Extended ST encoding*: After the formation of multicast trees, they are encoded using extended ST encoding method in order to produce two chromosomes s and t representing the sequence and topology of the tree. Then, these chromosomes undergo fitness evaluation and selection phases. Hence, for crossover, two s and t chromosomes that have greater fitness are selected and act as parent chromosomes. This crossover gives a new s and t chromosome representing a feasible new multicast tree. These new chromosomes generated undergo mutation phase, if necessary. Otherwise, they are added to the population of chromosomes and the cycle continues until an optimal solution is reached.

An example of crossover between the parent s and t chromosomes is illustrated below for better understanding. Figures 6 and 7 show the parent multicast trees and their corresponding parent s and t chromosomes. Since the node size of the multicast tree is chosen as eight, the length of the parent s and t chromosomes is also eight. In the example stated below, initial and end points taken for crossover is second gene and fourth gene respectively, making the length of crossover segment as three. As shown in Fig. 8, the crossover method for s and t chromosomes is different. Since the s chromosome represents the sequence of nodes, no repetition of numbers (node ids) is allowed. As the t chromosome represents the topology of the tree, it allows the repetition of numbers. For the t chromosome crossover, the genes from two to four are taken from first parent and remaining genes from the other parent. For the s chromosome crossover, the genes of child from two to four are from first parent. The child gets the remaining genes by copying genes from second parent. However, from the second parent, the child will not copy those genes that it already obtained from the first parent.

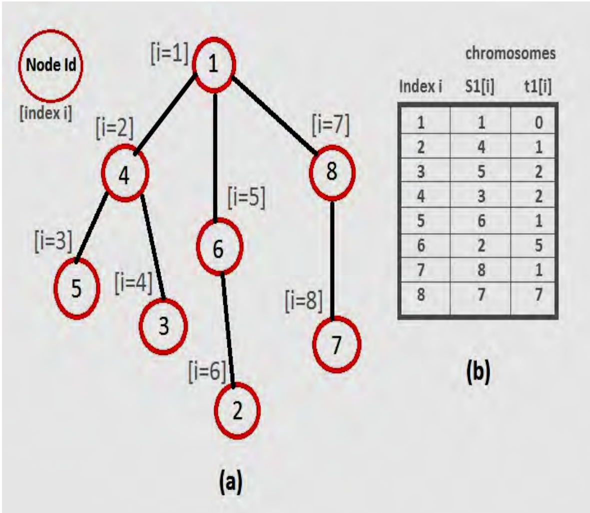

Fig. 6. (a) First parent multicast tree (b) First parent s and t chromosomes

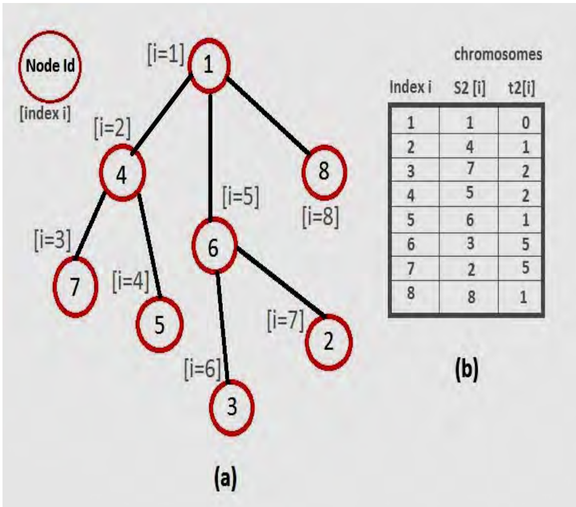

Fig. 7. (a) Second parent multicast tree (b) Second parent s and t chromosomes

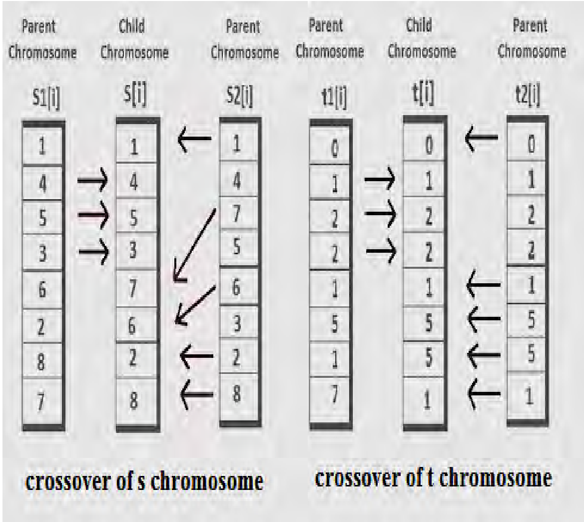

Fig. 8. Crossover of s and t chromosomes

E. *Mutation*

During the crossover of the parent trees, a child tree inherits the characteristics of the parents. This child tree undergoes mutation phase. Mutation is a process in which chromosome alternation i.e. reorganizing the genes of the chromosome is done in order to achieve specific characteristic in the organism. In this method, some of the node ids of the child multicast tree are rearranged in random way producing a new genetic structure. This feature of genetic algorithm prevents it from rapid convergence. Hence, mutation results in the generation of new multicast tree since the child produced after crossover is modified in this phase. The new tree is added to the population and the iteration continues until an optimal multicast tree is obtained.

Advantages of Mutation in genetic algorithm:

- Mutation is capable of testing and supporting a large population.
- Improper solutions don’t have any effect on the final solution as they are rejected during evaluation of fitness.
- It can work on both complex and loosely defined problems.

1) *Mutation in Extended ST Encoding:* The genes of the s and t chromosomes can be rearranged to meet specific requirement of the application (say residual battery energy of mobile node). An example of mutation process for the crossover child in Fig. 8 is shown in Fig. 9. Suppose the constraint is to increase the lifespan of the network, the battery energy of all nodes should be utilized in an equal manner. But in the multicast tree formed, the core nodes consume more energy as they have to send data to child nodes when compared to the leaf nodes. Hence, in order to bring uniformity in consumption of energy at all nodes, the core nodes have to be replaced by leaf nodes that have more energy. This replacement is done only when any one of the core node has less residual energy than the threshold energy that is set.

In the example, the core nodes can be obtained by taking the t chromosome genes (numbers). These numbers indicate the position index of the parent node. The genes of t chromosome are tg[ ]={1, 2, 5}. Hence the core nodes are s[tg[i]]. So, the core nodes are s[1], s[2] and s[5] i.e. {1, 4, 7}. The remaining nodes are the leaf nodes i.e. {2, 3, 5, 6, 8}. In the example, let us consider the energy of the core node 7 falls beyond the threshold. Then by mutation, a leaf node having greater remaining energy (say leaf node 2) replaces it. The resultant tree from mutation is shown below in Fig. 9.

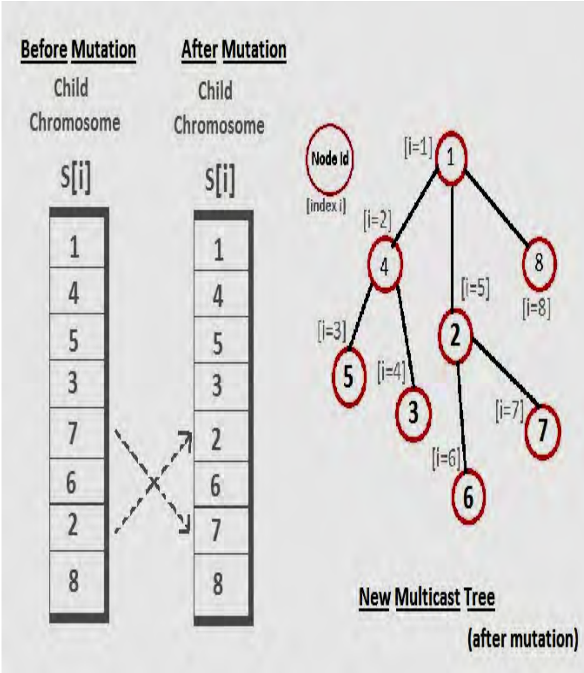

Fig. 9. The mutation process in chromosome

In this way, an iteration of the genetic algorithm is performed. By this, a new generation of multicast trees has been added to the population. This population is now considered for the fitness evaluation and selection. After the fitness evaluation, if any one of the multicast tree in the population reaches the threshold value set for the fitness function, the tree is considered as final one and globally optimal. If the threshold value is not met, then the next iteration of all these above described phases continues. Hence, genetic algorithm considers all feasible trees and selects an appropriate one from them.

Some the genetic approaches employed in multicast routing based on different parameters are briefed in section F.

F. *E^2 Multicast Routing Protocol*

As mentioned earlier, conservation of battery energy is one among the greatest constraints to be considered while designing multicast protocols in MANETs. This protocol focuses on decreasing the consumption of battery energy by nodes [17]. E^2 Multicast Routing Protocol is a variation of On-Demand Multicast Routing Protocol and has two stages. During the former stage, an approach that reduces the consumption of battery energy at nodes per data packet sent from source to the destination is used. During the latter stage, the protocol focuses on the battery energy available at all the nodes in the path. The datagram are sent to the destination nodes through the Forwarding Group. Taking this aspect into consideration is significant in order to ensure that energy utilization is even among all the nodes in the path.

G. *Genetic Zone Routing Protocol*

This protocol focuses on forming several shortest routes from source to the destination [18]. This feature deals with network fault tolerance and balancing the network routing load. Without genetic approach, the Zone routing protocol is a hybrid one. The advantages of hybrid protocol like less packet drop ratio, less delay, efficient use of node resources etc. However, if the destination is away from the zone, the nodes at the border of the zones search and form new path. Hence, Genetic approach is applied at the nodes present at the border of the zones in order to discover several shortest routes from the source to the destination. The shortest one among the remaining routes is selected as soon as a route failure occurs.

V. CONCLUSION

The emergence of MANETs has brought great development in the field of wireless networking. The mobility of the nodes has reduced the cost of infrastructure units such as access points and base stations. In the recent years, people stay connected and the need of group applications for communication has increased. To support this trend of communication efficiently in MANETs, multicasting is used for routing. Several multicast routing protocols have been designed, each one to meet specific requirements. It becomes essential for a researcher to carefully choose a multicast routing protocol appropriately. The different categories of routing protocols presented above give an overall idea on group formation, maintenance and data forwarding in the network. The use of genetic approach in finding the multicast routes bring optimality and expected performance of the protocol. This survey will be a source of information for the researchers working in multicast routing protocols.

REFERENCES

[1] S. Seas, Z. Yang, and J. He, "A survey on mobile ad hoc wireless network", *Information Technology Journal*, vol. 3, pp.168–175, 2004.

[2] O. Tariq, F. Greg, and W. Murray, "On the effect of traffic model to the performance evaluation of multicast protocols in MANET", in *Canadian Conference on Electrical and Computer Engineering*, 2005, pp. 404–407.

[3] E.M. Royer, and C.E. Perkins, "Multicast operation of the ad-hoc on-demand distance-vector routing protocol", *ACM MOBICOM*, 1999, pp. 207–218.

[4] M. Ge, S. Krishnamurthy, and M. Faloutsos, "Application versus network layer multicasting in ad hoc networks: the ALMA routing protocol", *Ad Hoc Networks*, vol. 4(2), pp. 283–300, Mar. 2006.

[5] S.K. Das, B.S. Manoj, and C.S.R. Murthy, () "A dynamic core based multicast routing protocol for ad hoc wireless networks", *Proceedings of ACM MobiHoc*, 2002, pp. 24–35.

[6] J. Biswas, M. Barai, and S.K. Nandy, "Efficient hybrid multicast routing protocol for ad-hoc wireless networks, local computer networks", *29th Annual IEEE International Conference*, 2004, pp. 180–187.

[7] J. Li, D. Cordes, and J. Zhang, "Power-aware routing protocols in ad-hoc wireless networks", *Wireless Communications, IEEE*, vol. 12(6), pp. 69–81, Dec. 2005.

[8] D. Axel, "Network Coding: an Overview", *Institute for Communications Engineering (LNT)*, pp. 1–19, 2005.

[9] K.S. Lau, and D. Pao, "Tree-based versus gossip-based reliable multicast in wireless ad-hoc networks", *CCNC, IEEE*, Jan. 2006, pp. 421–425.

[10] M.X. Cheng, J.H. Sun, M. Min, et al., "Energy-efficient broadcast and multicast routing in multi-hop ad-hoc wireless networks", *Wireless Communications and Mobile Computing*, vol. 6 (2), pp. 213–223, Mar. 2006.

[11] D. Li, Q. Liu, X. Hu, and X. Jia, "Energy efficient multicast routing in ad hoc wireless networks", *Computer Communications*, vol. 30 (18), pp. 3746–3756, Dec. 2007.

[12] J.-H. Chang, and L. Tassiulas, "Energy conserving routing in wireless adhoc networks", *Proceedings of IEEE INFOCOM*, 2000, pp.22–31.

[13] B.L. Sun, and L.Y. Li, "A QoS-based multicast routing protocol in ad-hoc networks", *Chinese Journal of Computers*, vol.27, pp. 1402–1407, 2004.

[14] A.T. Haghighat, K. Faez, M. Dehghan, A. Mowlaei, and Y. Ghahremani, "A genetic algorithm for steiner tree optimization with multiple constraints using Prüfer number", *Proceedings of the First EurAsian Conference on Information and Communication Technology*, 2002, vol. 2510, pp. 272–280.

[15] Y.M. Huang, T.C. Chiang, "A sequence and topology encoding for multicast protocol (STMP) in wireless ad hoc networks", *Proceedings of the Fourth International Conference on Parallel and Distributed Computing, Applications and Technologies*,2003, pp. 351–355.

[16] S.-Y Tseng, Y.-M. Huang and C.-C. Lin, "ST encoding: an efficient scheme for encoding trees in genetic algorithms", *Journal of Internet Technology*, vol. 6 (1), 2007.

[17] Yun-Sheng Yen, Han-ChiehChaob, Ruay-Shiung Chang, and AthanasiosVasilakos, "Flooding-limited and multi-constrained QoS multicast routing based on the genetic algorithm for MANETs", *Mathematical and Computer Modelling*, vol. 53, pp. 2238–2250, 2011.

[18] P.Sateesh Kumar, and S.Ramachandram, "Genetic Zone Routing Protocol", *Journal of Theoretical and Applied Information Technology*, pp. 789-794, 2008.