ISSN : 0976-8491 (Online) | ISSN : 2229-4333 (Print)

Routing Optimization Using Hybrid GA and PSO

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Abstract
MANET became the main target of researchers as a promising technology for a broad range of applications owing to self-configuring and self-organizing capability in numerous networks. One vital space of analysis at intervals Ad-Hoc networks is energy consumption issue. The PUMA (protocol for unified multicasting through announcement in MANET establishes and maintains a shared mesh for each multicast group. Nodes in MANET networks are primarily battery operated so have access to restricted quantity of energy. This may lead nodes to drain their energy completely within short period, due to this lack of energy, communication between the two nodes get blocked. In this paper we propose hybrid of Genetic Algorithm (GA) and Particle Swarm Optimization (PSO) to consider only those nodes in the routing which have less distance from destination and thus have high energy (based on their fitness function).

Keywords
Mobile Ad-Hoc Networks (MANETs), Protocol For Unified Multicasting Through Announcements (PUMA), Genetic Algorithm (GA), Particle Swarm Optimization (PSO)

I. Introduction

A Mobile Ad-Hoc Network (Manet) is a group of mobile & wireless nodes which cooperatively form a network independent of any fixed infrastructure or centralized base stations, a node directly communicate with nodes within wireless range. Mobile Ad-Hoc Networks (MANETs) represents the decentralized paradigms where clients themselves sustain the network within the absence of a central infrastructure.

Nodes in Manet network are basically battery operated and thus have access to a limited amount of energy. Each device in a MANET is liberal to move independently in any direction, and therefore change their links to alternate devices. The primary challenge in building a MANET is mobilization every device to continuously maintain the data needed to properly route traffic. This kind of networks could operate by themselves or could also be connected to the larger Internet.

A. Features of MANET

1. Rapidly deployable and self configuring.
2. No requirement of existing infrastructure.
3. Wireless links.
4. Nodes are mobile due to which topology can be very dynamic.
5. Nodes should be ready to relay traffic since communicating nodes could be out of range.
6. A MANET is a standalone network or it is connected to external networks (Internet).

B. Routing Protocols in MANET

1. Reactive Protocols

Reactive protocols get to line up routes on-demand. In this, if a node needs to initiate communication with a node to that it has no route then this routing protocol can try and establish such a route.

1. Pros and Cons:

- Does not use bandwidth except when required(finding a route).
- Much network overhead within the flooding method once querying for routes.
- Initial delay in traffic.

2. Examples

- Admission Control enabled On demand Routing (ACOR) .
- Ad-hoc On-demand Distance Vector (AODV) (RFC 3561).
- Dynamic Source Routing (RFC 4728).
- Flow State in the Dynamic Source Routing.
- Dynamic Manet On-demand Routing (RFC 4728).
- Power-Aware DSR-based.

B. Proactive Protocols

A proactive protocol approach to MANET routing seeks to maintain a constantly updated topology. Whole of the network should be known to all nodes. It results in a constant overhead of routing traffic, but not any initial delay in communication.

1. Pros and cons:

- Control traffic leads to constant overhead.
- Routes are always available.

2. Examples

- B.A.T.M.A.N. – Better approach to mobile Ad-Hoc networking.
- OLSR Optimized Link State Routing Protocol RFC 3626.
- Babel, a loop-avoidance distance-vector routing protocol RFC 6126.

C. Hybrid Protocols

Hybrid protocols are the protocols which combine the proactive and reactive approaches.

Initially the routing is established with some proactively prospected routes and so serves the demand from to boot activated nodes through reactive flooding. The selection of methodology requires predetermination for typical cases.

1. Pros and Cons:

- Advantage depends on range of alternative nodes activated.
- Reaction to traffic demand is dependent on gradient of traffic volume.

2. Examples:

- ZRP (Zone Routing Protocol) ZRP uses IERP as reactive and IARP as pro-active component.

II. Description of Puma

A. Overview

PUMA supports the IP multicast service model which means it enables any source to send multicast packets addressed to a given multicast group without joining the group and without knowing the constituencies of the group. PUMA uses receiver-initiated approach that is the receivers join a multicast group using the address of a special node called the core node.

PUMA uses the distributed algorithm (similar to spanning tree algorithm) to elect one of the receivers of a group as the core and to inform every router in the network of a minimum of one next-hop to the elected core of each group [2].

Each receiver node is connected to the elected core node through the shortest paths between them and all the nodes that lies within these shortest paths between the receiver and the core node forms the mesh.

Data packets are sent by the senders to the group through the shortest paths between the sender and the core node. By the time the data packet reaches a mesh member, it is flooded within the mesh, and nodes maintain a packet ID cache to drop duplicate data packets.

B. Multicast Announcement Packet (MAP)

PUMA uses a single control message called as Multicast Announcement Packet (MAP) for all its functions [2]. Each MAP contains a mesh member flag and is set when the sending node belongs to the mesh (M_flag), distance to core specifies the distance of the node from the core (it is 0 for core), Group ID represents the address of the group, Core ID represents the address of the core, sequence number which specifies the sequence number of the MAP and a parent field which represents the preferred neighbor to reach the core.

M_flag	Distance to core
	Group ID
	Core ID
	Sequence Number
	Parent

Fig. 1: MAP Format

C. Core Selection

In PUMA whenever a receiver joins a multicast group, it first checks whether or not it has received the multicast announcement for that particular group. If the node has, then it starts transmitting the multicast announcements with the same core (core of the multicast announcement it receives) for the group and if the node has not received the multicast announcement for that particular group then it considers itself as a core of the group and transmits multicast announcements periodically to its neighbors specifying itself as the core of the group (sets its distance to core 0).

[2] Further the nodes propagate the best multicast announcements from their neighbors (the multicast announcement with the higher Core ID is considered better). Among all the receivers, the one which joins the group earlier than others become the core of the group but if all the receivers joins at the same time, then the one which has the highest ID becomes the core of the group.

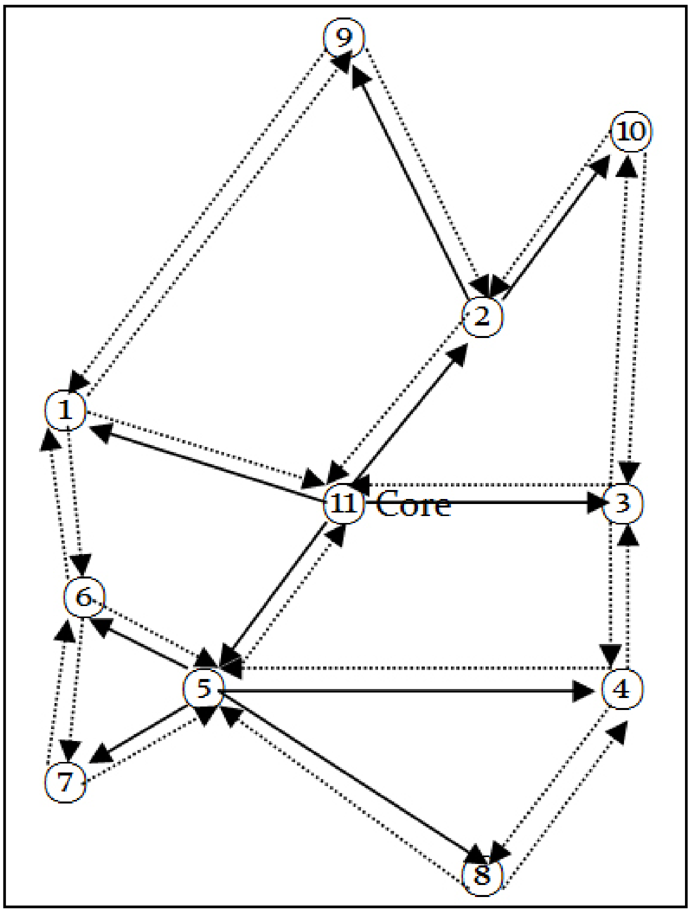
D. Connectivity List

When a node becomes the core of the group, it transmits periodically the multicast announcements for that group and when a multicast announcement travels through nodes in the network it establishes connectivity list at each node in the network. With the help of the connectivity lists nodes establishes the mesh and transmits data packets from senders to receivers.

Data which the node receives from all the multicast announcements is stored in the connectivity list. A node has only one entry in its connectivity list from a particular neighbor for a given group which means a fresh multicast announcement form a neighbor (i.e the one with higher sequence number) overwrites the entry of the other (the one with lower sequence number). Every entry of the connectivity list not only stores the muticast announcement but also the time and the neighbor from which that muticast announcement is received.

When the multicast announcements have same core ID then the one with highest sequence number is considered better, if the sequence number is also same then the one with smaller distance to core is considered better, but if the distance to core is also same then the one which arrives earlier is considered the best. [2] After selecting the best multicast announcement, the node generates its own multicast announcement having following fields:

1. Core ID: The core ID in the best multicast announcement.
2. Group ID: The group ID in the best multicast announcement.
3. Sequence number: The sequence number in the best multicast announcement.
4. Distance to core: One plus the distance to core in the best multicast announcement
5. Parent: The neighbor from which it received the best multicast announcement.



Neighbor	Mutlicast Announcement		Time
	Distance to core	Parent	(ms)
5	1	11	12152
1	1	11	12180
7	2	5	12260

Fig. 2: Illustrates the Propagation of Multicast Announcements and the Building of Connectivity Lists

The solid arrows indicate the neighbor from which a node receives its best multicast announcement. Node 11 is a core node. In fig. 2 Node 6 has three entries in its connectivity list for neighbors 5, 1 and 7. However it choose the entry it receives from 5 as the best one as it's distance is shortest to core and has arrived earlier than from node 1. Now node 6 uses this entry for generation of its own multicast announcement, which specifies Core ID = 11,Group ID = 224.0.0.1, Sequence Number = 79, Distance to Core = 2 and Parent = 5.

E. Mesh Establishment and Maintenance

Receivers in PUMA set the mesh member flag to TRUE within the multicast announcements which they send and considers themselves as a mesh – members and the non-receivers considers themselves as mesh-member only if they have atleast one mesh child in their connectivity list. Now a neighbor in the connectivity list to be mesh child should fulfill following three conditions:

1. If mesh member flag of the neighbor is set.
2. The distance of the neighbor to the core is more than nodes own distance to core.
3. The multicast announcement associated with this entry was received at intervals a period of time adequate two multicast announcement intervals.

In fig. 3 Node M is elected as the core and all nodes in the network know their distance to the core by adding one to the best entry in their connectivity list. The receiver nodes (I, F, A, B, D and M) in their multicast announcements sets the mesh member flag to 1. Upon receiving the multicast announcement from F, nodes G and H consider themselves mesh-members. Node F qualifies as a mesh child for both of them, because its distance to the core (3) is larger than their own (2). In the same way the nodes C, E J, K and L also consider themselves as mesh members. Because a mesh-member serves as a mesh child of all nodes that have a distance to the core less than its own, it leads to all of them changing into mesh members.The Fig. 3 results in the inclusion of all shortest paths from the receiver to the core in the mesh. From receiver F two paths of distance 3 exists to the core M(F-H-L-M and F-G-L-M) and these are parts of the mesh [2].

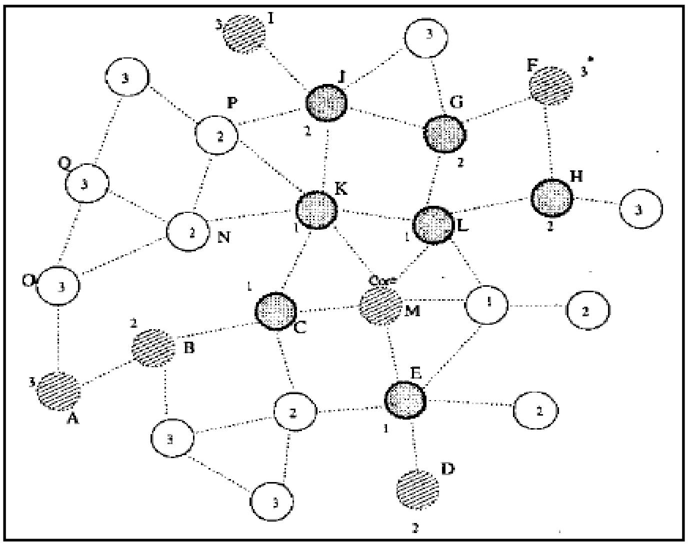


Fig. 3: Mesh Establishment in PUMA [2]

F. Forwarding Multicast Data Packets

The Parent fields enables the non-mesh members to forward multicast packets to mesh of the group formed. A node which forwards a multicast information packet it receives from its parent for the neighbor is that the node itself. Hence, multicast knowledge packets move hop by hop, till they reach mesh members. In fig. 3 Nodes O and Q indicate in the multicast announcements that their parent is node N. Similarly, node P indicates in its multicast announcement that its parent is K. Assume that nodes O and P are senders. Now node N does not forwards a data packet from P, but forwards from O, because only O has informed N that it considers N as it's parent. Although node J is not the parent of P, it forwards the packet when it receives from P, as mesh members does not check their connectivity list for forwarding a packet due to which, the receiver I gets the packet sooner and node J does not rebroadcast the packet when it receives for the second time from K, because the ID of the packet is stored in it's packet ID cache.

III. Related Work

Mesh-based and tree-based multicast routing protocols such as MAODV [3], PUMA [2-3], ODMRP [4] and AMRIS [5] have been studied to understand the way, how the multicast routing protocols used to establish communication environment in MANET.

In [2] comparsion is done between PUMA, ODMRP and MAODV. ODMRP and MAODV are the representatives of mesh-based and tree-based multicast routing in ad hoc networks. The result based on various parameters like varying mobility, number of senders, group members, number of multicast groups and traffic load shows that in PUMA the packet delivery ratio is higher than MAODV and ODMRP, with less control overhead.

Genetic Algorithms (GA) and Particles Swarm Optimization (PSO) are both population based algorithms that have proven to be successful in solving very difficult optimization problems [6]. However, both models have strengths and weaknesses. The PSO algorithm is conceptually simple and can be implemented in a few lines of code. PSOs also have memory, whereas in a GA if an individual is not selected the information contained by that individual is lost. In PSO the collaborative group interactions enhance the search for an optimal solution, whereas GAs have trouble finding an exact solution and are best at reaching a global region.

[7] gives a genetic algorithmic approach for the Shortest Path (SP) routing problem. This paper uses variable-length chromosomes

(strings) and genes (parameters) for encoding the problem.

In MANET, generally nodes are battery operated due to which nodes tend to drain their energy even in idle mode. This may lead the node to drain their energy completely within short period comparing with general mobile network and hence communication between nodes get blocked and the performance of the routing protocol and network lifetime get affected. To mitigate this problem [9] proposed a new algorithm which utilizes the network parameters relating to dynamic nature of nodes like energy drain rate, relative mobility estimation to predict the node lifetime and link lifetime by integrating route lifetime prediction algorithm along with the Particle Swarm Optiminzation (PSO).

[8] proposed PSO-GA hybrid multicast routing algorithmic rule which mixes PSO with genetic operators. The planned hybrid technique combines the strengths of PSO and GA to appreciate the balance between natural selection and sensible data sharing to supply robust and efficient search of the solution space. Two driving parameters area unit utilized within the adjustable hybrid model to optimize the performance of the PSO-GA hybrid by giving preference to either PSO or GA. The planned algorithm is employed with an efficient dynamic element that's capable of handling dynamic situations arising attributable to either amendment within the multicast group membership or node/link failure while not the reconstruction of the multicast tree. Simulation results shows that the proposed hybrid algorithm can overcome the disadvantages of particle swarm optimization and genetic algorithm, and deliver a higher QoS (Quality of service) performance. Results show that the proper combination of GA and PSO does outperform both the quality PSO and GA models.

IV. Genetic Algorithm

Genetic Algorithm is a technique that finds true and approximate solutions of optimization and search problems. Genetic algorithm have a population of candidate solutions and each of these candidate solutions represents a chromosome. Chromosomes are further divided into genes or which are also known as each character in the string. In genetic algorithm set of chromosomes are evaluated on the basis of fitness function from the population. The genetic algorithm consists of:

A. Initialization of Genetic Algorithm

Initially several individual solutions are haphazardly generated to form an initial population. The size of the population depends on the character of the problem, however generally contain thousands of attainable solutions.

B. Fitness Function

It measures the quality of the solution being represented. The fitness function is problem dependent.

C. Selection

Throughout every sequential generation, a proportion of the prevailing population is chosen to breed a replacement generation. Individual solutions are selected by fitness process, where fitter solutions(as measured by a fitness function) are doubtless to be selected. Based upon certain paremeters the rate the fitness of each solution is checked hence selects the best solutions.

D. Genetic Operators

In the next step the second generation population of solutions is generated from those which are selected earlier through a combination of genetic operators: crossover (also called recombination) and mutation crossover is a genetic operator used to vary the programming of a chromosome or chromosomes from one generation to the consecutive. It's analogous to replica and biological crossover, on which genetic algorithms are mostly based. Crossover consists of involving more than one parent solutions and producing a child solution from them.

Mutation being a genetic operator maintains genetic diversity of a population of chromosomes from one generation to next. It's analogous to biological mutation. In Mutation there's alteration of one or additional gene values in a chromosome from its initial state. Mutation may results in entirely changed solution from that of previous one. Hence GA may results in better solution using mutation.

For producing each new solution, a pair of "parent" solutions is chosen for breeding, from the pool selected previously. Producing a "child" solution by applying the above methods of crossover and mutation and a new solution is generated which shares several of the characteristics of its "parents". Everytime the new parents are selected for generation of new child, and therefore the method continues till a new population of solutions of applicable size is generated.

These processes results to the next generation population of chromosomes which is different than that of initial generation. This procedure results increase in the average fitness of the population, so only the most effective organisms for breeding are selected from the first generation, beside alittle proportion of less fit solutions.

V. Particle Swarm Optimization

Particle Swarm Optimization (PSO) is a computational process that optimizes a problem by iteratively attempting to boost a candidate solution in reference to a given live of quality. Optimization of problem is done by PSO by having a population of candidate solutions i.e particles and moving these particles around inside the search-space in line simple mathematical formulae over the rate and position of the particle.

The movement of every particle is under the impact of its local best known position however, is also guided toward the most effective known positions in the search-space, that are updated as better positions known by other particles. This is often expected to move the swarm toward the effective solutions.

A. Algorithm of PSO

A basic variant of the PSO algorithmic program works on taking a population which reperesents a swarm of candidate solutions known as particles. Particles are moved around according to a few simple formulae in the search-space. The movements of the particles are compared with the best known position i.e with their own best known in the search-space and also with the entire swarm's best known position. Once improved positions are being discovered these can in turn be used to guide the movements of the swarm. The method is continual and by doing therefore it's hoped, however not bonded, that a satisfactory resolution can eventually be discovered.

VI. Objectives

In this paper, we propose a hybrid GA and PSO algorithm so as to find shortest path between the source and destination and to consider high energy nodes in the path to send data from source to destination.

GA is used to find the shortest path and PSO gives the best particles (nodes) based on energy and distance to be included in the path so that the communication between the nodes does not get blocked due lack of energy.

This algorithm helps us to improve the network lifetime and also enhance the route discovery mechanism of PUMA protocol.

VII. Proposed Algorithm

A. Proposed Hybrid GA and PSO Algorithm

Variable length chromosomes are used, their genes represents nodes included in the path between the source and destination nodes. Each locus of the chromosome gives an order of a node. So, gene of the first locus represents source node. N represents the total number of the nodes in the network, so the length of the chromosome should not exceed the maximum length N.

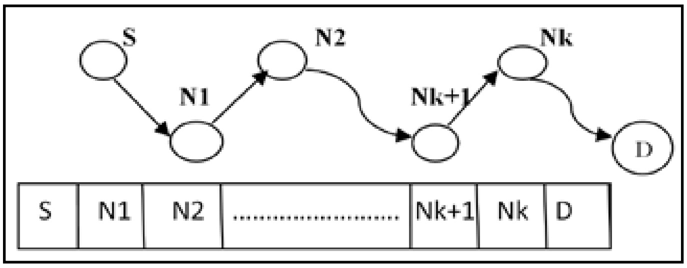


Fig. 4: Example of Chromosome and Routing Path

Fig. 4 shows a chromosome (routing path) from node S (source node) to node D (destination node)

STEP 1 Initialize of Population (Number of Nodes)

In this proposed algorithm we first initialize the number of nodes making up a network.

STEP 2 Selection- Calculate the Fitness Based on Energy and Distance

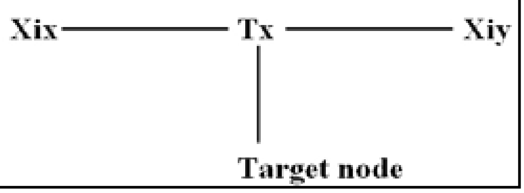
Initially we apply same energy to each node. The distance of each node is checked from the destination, the nodes which are near to destination will consumes less energy to route the data packets.

Applying PSO, the fitness function is evaluated for each particle (node) in the swarm (network) and is compared to best previous result of that particle to find pbest and is also compared to fitness of best particle i.e gbest among all particles in the swarm to.

The selection operator helps to improve the average quality of the population by giving the chance to high quality chromosomes to get copied into next generation.

$$f(i) = \sum_{i=1}^{N} E(i)$$

$$Dav = \sum_{i=1}^{N} \sqrt{(Tx - Xix)^2 + (Ty - Xiy)^2}$$



Select the nodes on the basis of fitness function. The population size of selected nodes must be even and positive.

STEP3 Find Probability Matrix for Crossover and for Interchanging Nodes as Selected in Root

The crossover checks the current solutions to find the better solutions. To find shortest path crossover results in exchange of each partial route of two chosen chromosomes to give a offspring that represents only one route.

In the proposed algorithm we choose two chromosomes having atleast one common gene (node) other than source and destination node.

The example of crossover for the proposed algorithm is shown in the fig. 5 in which two chromosomes exchanged their partial route to give an offspring that represents a route.

STEP 4 Generate a Subroute on the Basis of Crossover Probability

STEP 5 Apply Mutation and Select New Root for Every Chromosome or Population Included

In order to perform mutation one gene (node) is selected randomly as a mutated node and one of the nodes which are directly connected to mutated node is selected as the first one of the alternative partial-route.

The example of mutation for the proposed algorithm is shown in fig. 6 which gives the shortest path between source and destination.

STEP 6 Every Subroute Forming is Saved in Pop Matrix for Next Best Route

STEP 7 Repeat Step 4, 5, 6 Until the Total Population is Selected

STEP 8 If any Duplication of Nodes Exit Between Two Routes, Discard the Routes and do not Perform Mutation Process, Otherwise Connect the Routes to Make Up the Mutated Chromosome

STEP 9 Start the Transmission According to Best Specified Route Chosen

VIII. Conclusion

One vital space of analysis at intervals ad-hoc networks is energy consumption issue, so to overcome this problem this paper proposed a hybrid GA and PSO algorithm which tries to consider only those nodes in the routing which are close to the destination so that less amount of energy is consumed by the nodes to route the data packets hence the routing will not get affected due to lack of energy of nodes.

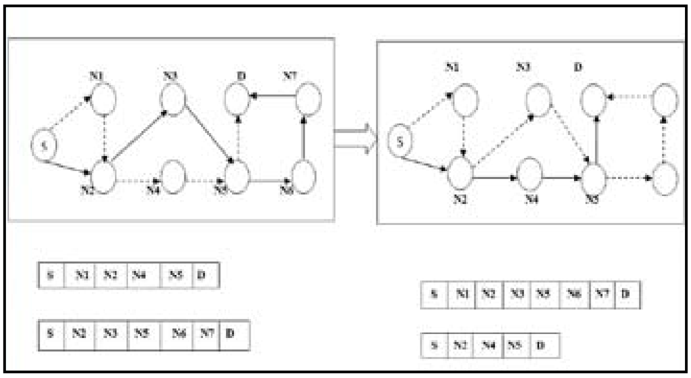


Fig. 5: Example of Crossover [7]

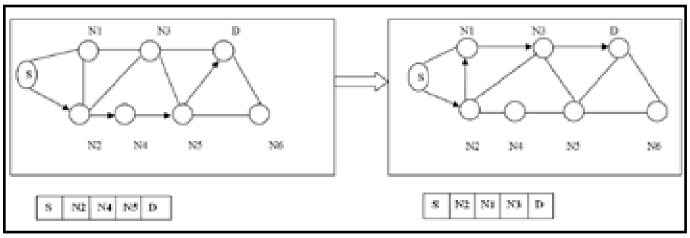


Fig. 6: Example of Mutation [7]

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