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An Intelligent Energy Efficient Routing Protocol for Mobile Ad-Hoc Network

D. Helen and D. Arivazhagan

Department of Information Technology, Academy of Maritime Education and Training (AMET), AMET University 135 East Coast Road, Kanathur, Chennai - 603112, India; helensaran15@gmail.com, it_manager@ametindia.com

Abstract

Objectives: To develop an energy-efficient routing protocol for Mobile Ad Hoc Network (MANET). **Methods:** The research work includes the Bee Colony Optimization (BCO) technique for evolving energy efficient routing algorithm. The Intelligent Cross-Layer approach based Bee Routing (ICLBR) is inspired by BCO in order to discover the optimal path for data transmission. The ICLBR Intelligent Cross Layer Approach based Bee Routing algorithm is used to overcome the congestion problem, link failure and energy loss using cross layer approach. The effectiveness of the route has been evolved with the parameter of node degree and connectivity ratio. **Findings:** This paper proposes an ICLBR algorithm to discover the energy efficient route in order to increase the network lifetime for MANET. The ICLBR is experimented in NS2.34, to systematically validate the routing algorithm. The experimental results show that the ICLBR improves the packet delivery ratio by 9.08% and minimizes the average end-to-end delay is by 5.16% over the Ad hoc On-Demand Distance Vector (AODV) routing protocol. **Improvement:** The proposed ICLBR mechanism able to enhance the network resource and also improves the network lifetime as compared to the state-of-art works.

Keywords: Connectivity, Mobility, Node Degree, Optimization, Systematically

1. Introduction

The greatest advantage of MANET is it forms spontaneously and dynamically without any fixed central administration[1].The MANET routing protocol[2] can be categorized as proactive, reactive and hybrid routing protocol. The proactive routing protocol sends the control packet periodically to gather the routing information. Such information is periodically appraised in the routing table. For instance Optimized Link State Routing (OLSR) protocol[3]. A Reactive routing protocol is an on-demand routing protocol, it establishes the route during the route discovery process. It may not sustain any routing information. Example for a reactive protocol is Dynamic Source Routing (DSR)[4]. The hybrid routing protocol contains the both properties of proactive and reactive routing protocol. This advantage may increase the overall system performance. Example: Zone Routing Protocol (ZRP). In MANET nodes are operated by limited energy[5], developing an efficient routing protocol is the major design criteria for MANET. If one node flop due to power,then the entire network topology will change. The paper proposes a new routing protocol which is inspired by natural honeybee's mechanism. There is a complexity in endowing natural intelligence at the network layer in self-organizing MANET. The problem statement should be outlined as, to find the efficient protocol, which is evolved from the principles of BCO. This approach may provide an efficient, scalable solution to enhance the MANET performance.

2. Problem Statement

In MANET, routing is a most challenging job due to unpredictable topological change. In MANET nodes are functioning with a restricted battery power and nodes in the network topology act as router in order to send and receive the data packets. If a node flops due to energy then the entire network topology may change. This may

**Author for correspondence*

increase the network complexity[7]. Owing to nodes limited battery power, there is necessity to design an energy based routing algorithm for dynamic networ[8,9]. The proposed method adopts the nature's self-maintaining network mechanism from the honeybee's insect society. Thus the robustness and effectiveness of biological agent used to enhance the routing protocol.

3. Inspiration from Nature

The BCO inherits the behavior of honey bees[10] and adopts the searching behavior of bees. The bees searching technique provide the optimal solution for searching process. The nature of bee pattern is observed and applied in MANET routing, which provide the best solution. The BCO technique does not use more control packet in order to uphold the routes in the network, which is most suitable for infrastructure-less dynamic MANET. The nature-inspired routing algorithm consumes the limited resources for communication[11].

4. Overview of BeeAdhoc Architecture

The BeeAdhoc is a new paradigm of Swarm Intelligence (SI).The SI is a moderately new technique to solve the routing problem in MANET from the inspiration of social behavior of insects such as bees[12]. The BeeAdhoc is a reactive routing protocol based on four different BeeAdhoc types of agents: packers, scouts, foragers and bee swarms. The packers are responsible to store all the foods in a bee hive, reside in the network nodes are received and store the packets from the transport layer. The role of forager is to find data packet, after finding the data packet the packers will be killed. The scouts determine the new routes between the source and the destination nodes using Time-To-Live (TTL) mechanism. After finding the destination, the scout is back to the source using the same route and recruits the foragers for its route by dancing. The honey bees are communicating by dances in order to find the direction and distance between the nodes. The quality and quantity of the resources are recognized by the dances[13]. The forager carries the packets to the neighboring node through the predefined route that is designated by the source node. Foragers examine the quality of the route and report back to the upcoming foragers at the source node[14].

5. Methodology

The ICLBR algorithm is modest and reliable routing protocol for MANET. The ICLBR uses the network resources more efficiently by increasing the throughput of a node while transmitting and reduce the number of control packet during data transmission. The source identifies the average number of neighboring node by node degree which is defined in equation (1),(2) . And the connected nodes are identified by node connectivity ratio defined in equation (3). Source node n_s broadcast the scout packet along with TTL to the entire j neighboring node in the network in order find the destination n_d. The scout packet flies over the possible routes r_j to reach the destination n_d. The scout packet flies over in order to avoid the unnecessary rebroadcasting the scout uses the TTL. If the TTL expires the corresponding scout packet will be rejected, which indicating the unstable link between the source node n_s and the destination node n_d. After reaching the destination node n_d the scout reply packet send back to the source n_s through same travelled path. The foragers discover the possible route based on the link quality (stable link). Finally, the worker bees gather the network routing information which is discovered by the foragers. The forager chooses the optimal route for data transmission.

6. System Description and Model Assumption

6.1 Network Model

The *n* nodes are randomly placed in the network terrain area *A* within their communication range r_o. The network area is defined as "$\pi\ r_o^2$".The network size is known by $\alpha=n/A$. It indicates the number of nodes in the network topology. The MANET is represented by a graph (G), G=G (V, E).The set of nodes represented by V= {1,2,…, n} and edges is represented by E for wireless transmission.

6.2 Degree of Node

The degree of node (*D*) identifies the number of neighboring node for node *i* .It represents the number of communication link established for node *i*. The degree of node *D*=0, is an isolated node (i.e) there is a lack of neighbor nodes for node *i* .

In graph G the node *i*, minimum degree is denoted as ,

$D_{min}(G)= \min\{D(i)\} \quad \{\text{for all } i \in G\}$ (1)

The average node degree is ,

$$D_{avg}(G)=\sum_{i=1}^{n}\frac{D(i)}{n} \quad (2)$$

6.3 Node Connectivity

If there is k path exists between the source and destination node such a network graph (G) is known as "k-connected" graph otherwise it is disconnected. In k-connected each node communicates through either single hop or multi-hop communication. The disconnected network has several sub networks, where the nodes make a connected sub network but it cannot communicate with other sub networks. In k-connected (k=1,2,3…) network every pair node connected with at least *k* mutual independent paths. The network is k-connected and the removal of disconnected network is represented by (k-1)[15]. The connectivity of *k* is denoted by *k* of *G*[14]. Thus the connectivity ratio defined as follows,

$$CR = \sum_{i,j\in G}\frac{CR_{i,j}}{N(N-1)} \quad (3)$$

Where, *N* denotes the number of nodes in the network. The connected network topology is denoted by graph G. If there is any path available between node *i* and *j*, then $CR_{i,j}$ is equal to one. Otherwise $CR_{i,j}$ is equal to zero.

6.4 Route Optimality

The BeeAdHoc algorithm discovers the multiple paths for the given destination. The scout discovers a new path for the BeeAdhoc destination node. In k-edge-disjoint path the source and the destination node communicated with n hop. The function g [i-n] which gives the total number of available path of length i between the source and destination node. The probability for finding the q optimal paths from total g[x] is,

$$OPD(X(n)) = \frac{p!}{j!\,(p-q)!}\Delta^{j}(1-\Delta)^{g[0]-q} \quad (4)$$

Where X[n] denotes the number of *n* hop paths discovered successfully. g[0] denotes the optimal path. Δ denotes the optimal path. (1 – Δ) denotes number of failures in the path.

6.5 Predictable Path Establishment

The expected possibility for finding the path is based on its length.

$$PE\{X\} = \sum_{i=0}^{n} w[i](1-(1-\Delta\,(P)i)g[i] \quad (5)$$

W[i] - normalized weight of path length i.

7. Cross Layer Approach

The traditional way of routing at various layers is not suitable for MANET because of is dynamic nature, unpredictable link quality and limited resource availability. In order to enhance the networking function, it is necessary to accomplish the optimizations using the data available at different layers. The cross-layer approach act as interface and share the information between the layers. The cross-layer paradigm makes the routing more reliable and the cross-layer model in MANET increases the routing stability.

The cross-layer approach makes the routing more effective by estimating the link stability. The advantage of the cross layer approach is used to access the information among the physical layer and MAC layer. The node information can be retrieved from cross layer. Using this information the stability of the neighboring nodes is identified within their transmission range. Therefore, the precaution can be taken before the link failure or node failure and alternate path can be taken for data transmission. Therefore the packet loss can be overcome and node consumes less energy.

8. Result and Discussion

The proposed protocol implemented in discrete event simulator NS2.34[16].The simulation is performed with 100 nodes, which are moving in 1000x1000 areas for 200s. The transmission range is 250m traffic. Table 1 represents the simulation parameters.

8.1 Packet Deliver Ratio (PDR)

The packet delivery ratio represents the number of packets successfully transmitted between the source and the destination node.

$$PDR = \frac{\sum(No.of.Received\ Packets)}{\sum(No.of.send\ packets)}$$

Table 1. Simulation parameters

Parameter	Values
Network size	1000x1000
No .of. Nodes	100
Signal propagation Model	Two-ray ground
Traffic Type	CBR
Packet Size	512 bytes
Transmission range	250m
Link bandwidth	2Mbps
Simulation time	200s
Speed	5-30 m/s

8.2 Throughput

The throughput demonstrates the better network connectivity. The total amount of packets successfully delivered from one point to another point in the given time.

$$Throughput = \frac{Size\ of\ Packet}{Time}$$

8.3 End to End Delay

The time taken to deliver the data packets to the corresponding destination is defined as end to end delay. This delay also includes route discover delay and queuing delay.

$$Delay = \frac{\sum(Arrival\ Time - Delivered\ Time)}{\sum(Total\ data\ packets\ received)}$$

The Figure1 shows that the ICLBR increases the PDR 3.5 %over AODV protocol.

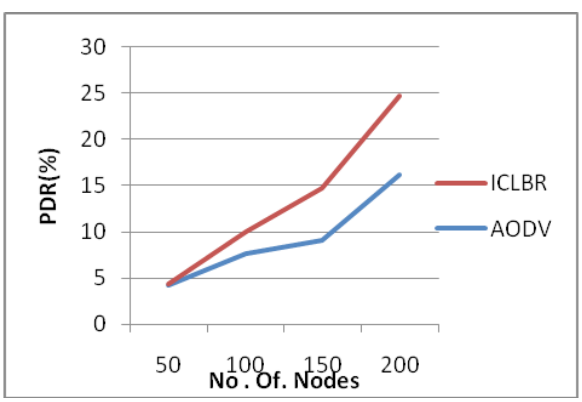

Figure 1. Number of nodes vs. PDR.

11. Conclusion

In order to enable the transmission within a MANET, an effective routing protocol is essential to determine the route between the nodes. The energy efficiency is one of the issues in MANET. The proposed paper uses the BCO to develop efficient routing protocol. The simplicity of bee colony mechanism makes the result more productive by reducing the number of control packets and save the energy during data transmission between the source node and the destination node.

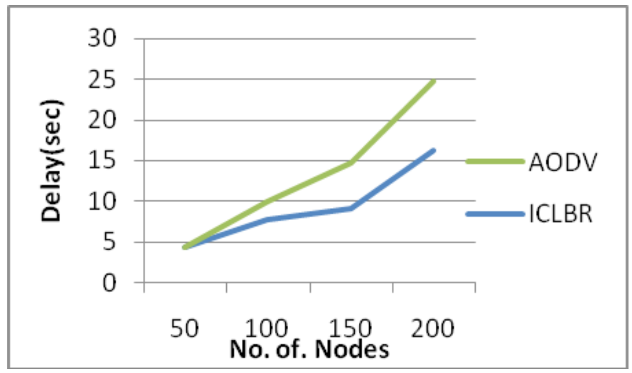

Figure 2. Number of nodes vs. delay.

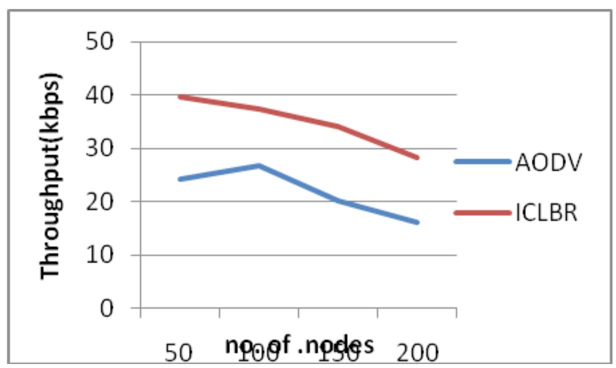

Figure 3. Number of nodes vs. throughput.

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