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Optimized Model for Energy Aware Location Aided Routing Protocol in MANET

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Abstract

Energy optimization for MANETs is essential to prolong the life time of the network. Location Aided Routing (LAR) is one of the reactive routing protocols where the nodes use their location information to assist in routing. LAR is very efficient in maintaining a good packet delivery ratio and other network measures. However, one of the common problems in LAR is that its energy unaware or it does not utilize the energy information in the routing. In this article, a developed Energy Aware LAR (EA-LAR) is proposed and simulated. It uses energy in routing based on a criterion function designed based on five important factors in the network. EA-LAR uses a PSO with mutation to optimize the criterion function. The Performance metrics that have used are packet deliver ratio, end to end delay, and overhead and energy consumption. The results have shown that EA-LAR outperformed other benchmark of energy improved LAR protocol from perspective of most evaluation measures. Most importantly, the energy consumption for one packet has been reduced with a percentage of 93% when the number of nodes was 100 nodes with a PDR improvement of 67%. This developed model can be generalized to other protocols to reduce energy consumption.

Keywords: Mobile Ad-Hoc Network (MANET), Energy Aware LAR (EA-LAR), Particle Swarm Optimization (PSO), and Energy Optimization.

INTRODUCTION

A mobile ad hoc network (MANET) is a courteously self-configuration, infrastructure-less network of mobile devices connecting without wires. Each device in MANET is free to move independently in any direction, and will therefore change its links to other devices frequently[1]. Recently, MANETs have widely spread of mobile devices and the appearing of wireless communication which makes it become an important application. In various environments, MANETs are applied (indoor and outdoor). For indoor (e.g. companies, indoor robots) while outdoor (e.g. battlefield, automotive) [2, 3]

The components in MANETs like sensors, memories, CPU, radio interface etc. are used a battery to obtain the needed power supply. So, all the MANETs components are connected to a battery [4]; [5]. Carefully, the battery has to be used to avert the fast shutdown of the nodes. Therefore, any fail to do that, might leads to the packets are not transferred from node to other. Thus, numerous research has been carried out to beat on the problems that are caused by the limitation of the battery power, in additional to creating the optimal use of the battery to stretch the nodes' lifetime in MANET as well [6].

The routing protocol available in MANET specifies the route and delivers packets between two nodes that are from the source to the target [7-9]. Different routing protocols have been proposed for MANET. This is necessary to improve and utilize the network recourses for this purpose. However, many protocols have ignored the need to optimize energy utilization while doing routing. There are two main classes of routing protocols: reactive and proactive. Most routing protocols belong to either one of these two classes or they combine some aspects from both of them. A lot of researchers have worked on optimizing energy for proactive protocols because of its significant energy usage [10, 11]. However, less work has been carried on optimizing energy for reactive protocols. This article selects LAR which is one common reactive protocol, and it addresses its energy consumption aspect. Then, it provides an improved LAR with an energy awareness based on an optimization approach named particle swarm optimization or PSO.

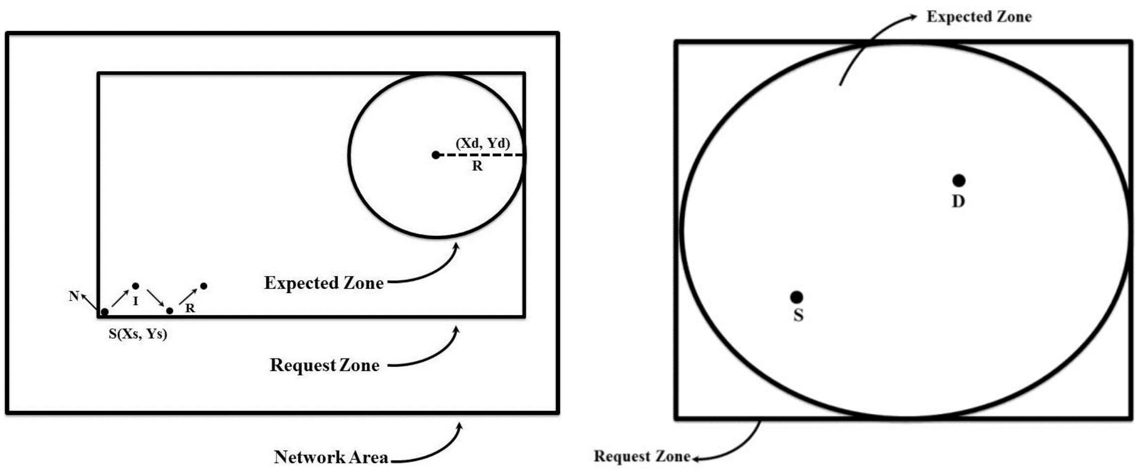
RELATED WORKS

By The Internet Engineering Task Force (IETF) there are numerous MANETs routing protocols have combined, some of them are reactive and the other are proactive. For reactive routing such as, Ad hoc on-Demand Vector (AODV) [12]; [13], Location-Aided Routing [14], and Dynamic Source Routing DSR[15], while for the proactive Optimized Link State Routing (OLSR) [12]. Less attention on the energy optimization was made by many protocols. Therefore, it's an attractive research area to improve further of these protocols for an energy conservation. Beneath the term of energy-aware routing, this research area has classified, and it refers to considering the energy consumption prior making a routing decision. Ignore the energy conservation aspect while performing routing, which cause wastage in the energy consumption and as a consequence causes less lifetime of the network.

For reactive routing protocols, different energy consumption improvement methods have been attempted. New location dependent on energy effective scheme using AODV by a group of researchers [16] have proposed. In this method, location dependent on LAR is used to improve the ability of the routing in AODV. The nodes in this network, do not keep track of their enegry status which leads to higher consumption of energy during the flooding of the packets. Hence, the maximum of the energy has been lost in network establishment. LAR decreases the chances of destination searching by keeping the register of the location of every node with esteem to others. The major objective of [16] is to optimize the energy consumption of AODV with LAR, normal AODV and AODV with LAR and Energy is illustrated and has observed that LAR decreases the consumed energy. Thus, increase the lifetime of network. The proposed approach decreases the routing packets flooding and increases the performance of AODV with LAR equally. The proposed approach optimize the ability of AODV routing as well as extend the life time of the network. This paper [17] focus on different existing schemes and on the energy-aware virtual machine placement optimization problem of a heterogeneous virtualized data canter. This study attempts to explore a better alternative approach to minimizing the energy consumption, it observes that Particle Swarm Optimization (PSO) has considerable potential. However, to effectively solve the virtual machine placement optimization problem, the PSO has been improved by redefining the parameters and operators of the PSO, adopting an energy-aware local fitness first strategy and designing a novel coding scheme. Using the improved PSO, an optimal virtual machine replacement scheme with the lowest energy consumption can be found. The proposed approach has been evaluated based on a simulated virtualized data centre that is composed of 1000 clusters. Each cluster contains 350 heterogeneous servers. The experimental results indicated that the proposed approach significantly outperforms other approaches, and can lessen 13%-23% energy consumption.

PREVIOUS APPROACH

In LAR protocol, the routing logic is based on two defined areas: Expected zone E and request zone R. The Expected zone refers to the region in which the destination node will belong while the request zone refers to the region in which any nodes belongs will have to route the RREQ packet. The bigger the request zone, the more flooding will happen in the network while the bigger the expected zone is equivalent to less confidence about the current location of the destination node due to nodes mobility. Figure 1. shows a geometrical representation for both E and R in two cases: source nodes does not belong to E and source node belongs to E.



A B

Figure 1 The expected and the request zone

Figure 1 expected zone and request zone for two cases: (A) source node does not belong to E (B) source node belongs to E.

In this work, the current assumptions will be considered:

a) Each node is aware of its current position.
b) Each node in the network keeps and updates the positions and energies of its neighbours.

c) The source node has the position of the destination node and will attach this position and its own position to the RREQ packet.
d) From 3, each node in the network holds the RREQ packet will be able to know the position of the source and the destination.

OVERVIEW OF PARTICE SWARM OPTIMIZATION PSO

The authors [18] have proposed an algorithm is called Particle Swarm Optimization (PSO). it's a meta-heuristic approach which aims to find the optimum solution, through creating a set of candidate solutions and iteratively moving them in the space depends on their fitness value. In the searching space, control the transfer of particles have used two criteria. The first criterion is the position of the best global solution while the second criterion is the best local solution in the particle history. In the searching space, these two factors are controlling the particles mobility in an iterative way to obtain the best solution. Equation 1, update the particle's velocity. Equation 2, update the particle's position.

$$v_i\ (k+1) = w * v_i(k) + c_1 * r_1 * P_{best}(x) - x_i(x) + c_2 * r_2\ * G_{best}(k) - x_i(x) \quad (1)$$

Where:

w Denotes the inertia

$\text{best}_{\text{local}}$ Denotes best local solution

$\text{best}_{\text{global}}$ Denotes best global solution

$$x_i(k+1) = x_i(x) + v(k+1) \quad (2)$$

PROPOSED APPROACH

LAR is not energy aware, or in other words, it does not consider energy while performing the routing process. It is known that R represents the region that is responsible of selecting the nodes to perform the routing. In LAR, this selection relies only on the geometrical distribution of the nodes while energy distribution is totally ignored. In our energy aware LAR or EA-LAR, the following mathematical function will be used as criterion to either select the node for routing or ignore it.

$$f(n_i) = w_1\theta_i + w_2 d_i + w_3 E_i \quad (3)$$

θ_i Denotes the angle of the subject node i with respect to the baseline between the node and the destination

d_i Denotes the distance between the subject node i and the destination

E_i Denotes the current energy of the subject node

$w_1 . w_2$ and $w_3 \in [0.1]$ Represents the weights

The variables given in equation 3 are illustrated geometrically in figure2.

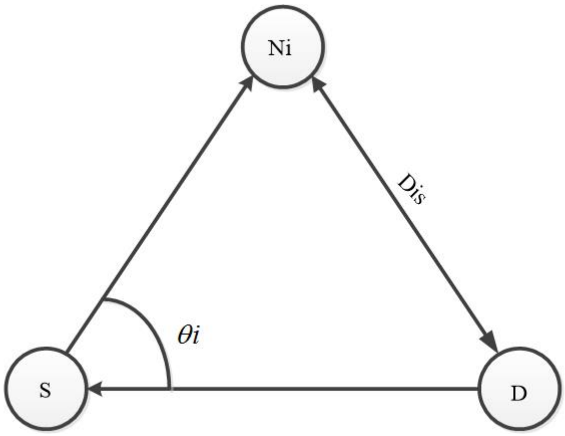


Figure 2: Geometrical Representation of the Criterion Function Presented in Equation 3

The function will be calculated for each node i and the value will be compared with a threshold T_i. If $f(n_i) > T_i$ then the node is eligible to perform the routing. Otherwise, the node is not eligible to perform the routing. In addition to $w_1 . w_2$ and w_3, there is two important parameters used for optimization in the network: 1-Flooding ratio(FR) decides how many nodes must forward the RREQ packet among the nodes which they will receive the RREQ from the intermediate mode. 2- Coverage zone ratio CZR which is a value $\in [0.1]$ and it determines the radius of the coverage zone after multiplying it by Max Coverage Zone. Therefore, the solution of the optimization is represented by this vector:

$$x = [w_1, w_2, w_3, FR, CZR] \quad (4)$$

Where the minimum value of consumed energy is met at the value of x^*

$$x^* = [w_1, w_2, w_3, FR, CZR] = \text{argmin}(\text{Consumed Energy}) \quad (5)$$

s.t PDR>=0.5

For optimization, PSO algorithm has been used (Basic PSO + mutation process). After optimization, the criterion function in equation -1- is defined and it is ready to be used for the routing. Among the nodes which they will receive the RREQ from the intermediate mode, assuming that two from three receiving nodes will forward the RREQ, the intermediate node sorts the values of F(nodes) in ascending order and then it chooses the first two values, assuming that $F(3) < F(1) < F(2)$, the chosen values will be $F(3)$ and $F(1)$. After that, the intermediate node puts the value of threshold $C =$

$\max(F(3).F(1))$ in the RREQ packet and it broadcasts it to all its neighbours. When node 3 receives the RREQ packet, it computes $F(3)$ (its own value of the Criterion Function) and compare it to the threshold value C in the RREQ packet, if $F(3) < C$ the node 3 will compute the new threshold and forward the RREQ. Otherwise, it will discard it. The same is for node 1. A block diagram to show the general optimization framework is depicted in figure 3. As it is illustrated, the optimization is responsible of searching in the solution space for the candidate solutions that will be provided to a LAR simulator for generating the network measures that will be provided to the objective function in order to calculate the fitness values of the generated solutions. Also, a pseudo-code to show how to use the criterion function is depicted in figure 4.

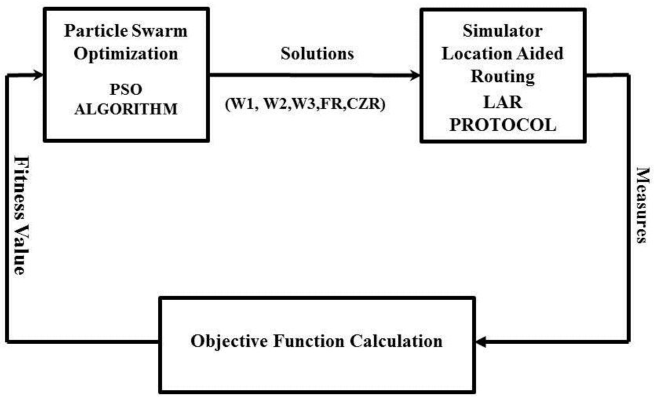


Figure 3: Diagram of the general optimization framework

If F(node) ≤ C

Calculate the new threshold

Add threshold to the RREQ

Forward the RREQ

Else discard the RREQ

End

Figure 4 Pseudocode the criterion function in each of the forwarding nodes

SIMULATION ENVIRONMENT AND PERFORMANCE EVALUATION

For simulation, MATLAB environment has been used to simulate the network which is able to handle huge amounts of data efficiently. MATLAB is very commonly used software, because of its high capacity to carry out complex mathematical calculations and results in visualising the data. In this study, the used velocity bounds for the weights $w_1.w_2$ and w_3 are not the same bounds in case of FR and CZR. Here, the weights are changing faster because what is needed is to try, as much as can, different values of weights while FR and CZR are almost fixed. The simulation time has been selected to be 100 sec. The environment dimensions in this simulation are 1000m×1000m and the number of nodes is 65 that have deployed in the simulation area. Table 1 shows other parameters for the simulation and optimization.

Table 1: The parameters of the simulation and the optimization

Parameters	Values
Environment dimensions (width×height)	1000 [meter] × 1000 [meter]
Node velocity	20 ∓ 2.5 [m/s]
Experiment Duration	100 [second]
Rate of Logging Data	10 [second]
Number of Nodes	65 [node]
Max Coverage Zone Radius	250 [meter]
Initial Energy of Battery	17000 [unit]
Delta of Threshold	0.05
Number of Iterations	1000
Number of Particles	40
Lower Bounds of particle's position	[0 0 0 0 0.25]
Upper Bounds of particle's position	[1 1 1 1 1]
Lower Bounds of particle's velocity	[-0.5 -0.5 -0.5 -0.2 -0.2]
Upper Bounds of particle's velocity	[0.5 0.5 0.5 0.2 0.2]
Personal Acceleration Coefficient c1	2
Global Acceleration Coefficient c2	2
Inertia Coefficient w	1
Damping Ratio of w	0.99
Mutation Rate	0.2

The performance metrics that have been used in this simulation are as follows

I. **Packet Delivery Ratio (PDR):** The ratio of the number of delivered data packets that are received by the destination node to the number of data packets sent by the source node.
II. **The energy consumption:** It calculated by dividing the overall energy consumed by every network node over the initial amount of energy present in the network.
III. **End to End Delay (E2E delay):** is the average time of the data packet to be successfully transmitted across the network from source to destination.
IV. **Routing Overhead (ROH):** is the total number of control packets (routing packets) generated by the routing protocol during simulation.

SIMULATION RESULTS AND DISCUSSION

For evaluation, EA-LAR has been compared with a benchmark approach of (Mishra, Gandhi, & Singh, 2016). Results have shown that EA-LAR has outperformed the benchmark.

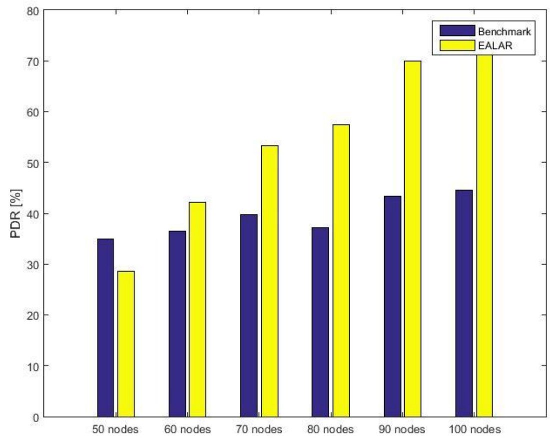


Figure 5: Comparison of the Packet Delivery Ratios

In the figure 5 it is obvious that the PDR in the EA-LAR is better than PDR in Benchmark as the number of nodes increased. Because of continuous update to the position of nodes whenever a new packet received correctly, the expected zone in most of cases in the benchmark is very small which in turn reduces the allowed zone for sending route request packets. This, in turn, harms the process of sending data packets in the benchmark especially when the path to the destination node is long. From the figure it can be observed that a percentage of improvement with 67% has been achieved when the number of nodes was 100 nodes.

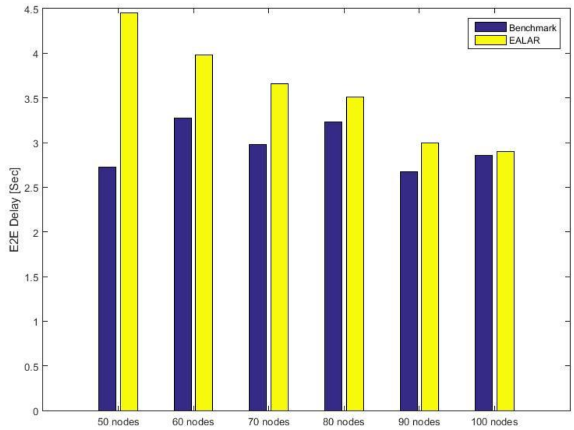


Figure 6: Comparison of the End to End Delay

Figure 6 showing the E2E delay is longer in case of EA-LAR and that is expected because benchmark failure probability increases when the distance between source node and destination node increases. Also, the benchmark fails to find a route between the source nose and destination node when there is no route near to the baseline. Therefore, the transfer succeeds in the case of short paths near to the benchmark.

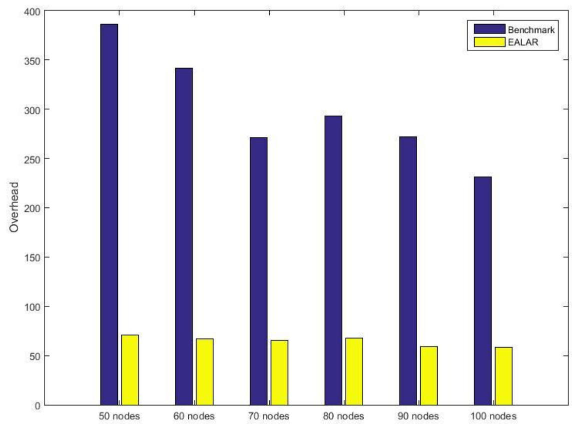


Figure 7: Comparison of the Overhead

In figure 7 the overhead in the EA-LAR is better than overhead in benchmark. The benchmark fails in most cases to find the route request packet arrives to its destination due to narrow allowed area for sending.

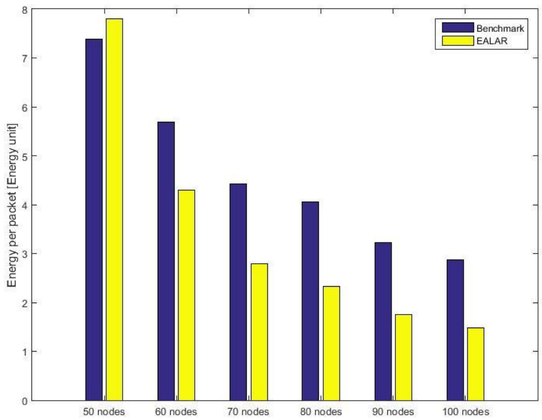


Figure 8: Comparison of the Energy per Packet

In the figure 8 the required energy for sending one packet in the EA-LAR is better because the protocol in the benchmark wastes energy sending a lot of route request packet (control packets) without true beneficial in the PDR. More specifically, the percentage of improvement in the energy consumption is 93% when the number of nodes was 100 nodes.

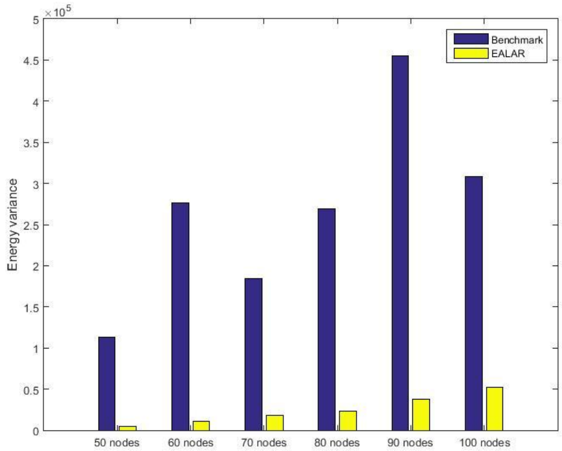


Figure 9: Comparison of the Energy Variance

Figure 9 showing the variance of energy in the EA-LAR is very small comparing with the benchmark which reflects that the energy is more balanced in the network which in turn helps increase the life time of the total network. The energy variance has been reduced with a percentage of 82% when the number of nodes was 100.

CONCLUSION AND FUTURE WORK

In this article, a developed energy aware LAR or EA-LAR is proposed and simulated. It uses energy in routing through a criterion function designed based on five important factors in the network with PSO for optimization. The criterion function is calculated at each intermediate node to decide if it is eligible to send RREQ, also, to decide which nodes have to receive this packet. Then, PSO optimization is used to optimize the parameters in the criterion function along with two additional parameters for controlling the flooding in the network and the coverage of each node. Results show that EA-LAR outperformed other benchmark of energy improved LAR protocol from perspective of most evaluation measures. the energy consumption for one packet has been reduced with a percentage of 93% when the number of nodes was 100 nodes with a PDR improvement of 67%. The results showed that the developed criterion function and its optimization have played an efficient role in optimizing energy consumption in LAR protocols with improving the network performance measures such as PDR, E2E delay, and overhead. This has been studied thoroughly in the network with different values of number of nodes. Future work is to add other influencing factors to the optimization such as nodes mobility characteristics and to link them with the routing process in the context of preserving energy.

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