Integer Linear Programming with Ant-Colony Optimized Algorithm to Extend MANET Lifetime

Ben Bella S. Tawfik, Mohamed M.A. Elgazzar

Abstract –Network which is randomly sorted out remotely and organization that conveys without framework and experiencing low force battery is called Mobile Ad-hoc Network (MANET). Oneof the main objectives isto get thebest route from source to destination to minimize the node energy consumption. Linear Programming (Integer Linear Programming) and nature inspiration technique (Ant Colony Optimization) are two models that enhance energy consumption.The proposed models in our work are considered extension of our previous works with modified version and different measures [13]. We introduced a modified version for two models. In order to make the performance metric, two measures, namely, energy consumption and processing time are calculated.These measures aredone using as an experimental study. The First model is the enhancedLinear Programming model, the best route is selected from all possible combinatorial routes using the minimum total dissipated energy as an objective function and thefeasible region which satisfies a sequence of constraints. The second model is anenhanced ACO version, based on nature the source is the house of ant and the destination is the location of food.In this work routing selection use Ant-Colony with the Integer Linear Programming (ILP). In the research the Integer Linear Programming (ILP) is proved to be with longer lifetime compared with the ACO approach. In the meanwhile the ILP requires longer time to find the best route more than ACO approach. One of the main drawbacks of the ILP is after specific number of requests the packet losses are increasing. So, to get the best performance, the ILP is used till 500 requests then using ACO to reduce the packet losses and enhance the performance.

Keywords: MANET, Lifetime, Ant Colony, ILP

I. INTRODUCTION

MANET is one of the most important fields of networks and communication becauseof the popularity of mobile devices. In this wireless network, stationsareconnected without wire to a self-configured network, without having a settled foundation. Network is not static. Each station is free to move anyplace[1].Station (node) in MANET, with a specific amount of batteryenergy, is able to complete access to send data from one to another, and suppliesspecific services. From the startingdate of research in the area of MANET, savingthe dissipatedenergy was one of the basicobjectives. When thestationspends all its battery energy, it will not be capable to send or receive data and it becomes a dead node.Performanceof MANET has become great interest researchissue.MANETs forcemodern limitations in configuringthe routing algorithms.

These limitations include decreasing the consumed energy, cost decreasing, high reliability[2]. The main problem could be to measure the performance of the algorithms being proposed.

The optimization techniques contain various approaches for the minimization of the totalconsumedenergy and finding the optimistic route. In [10]some protocols have been designed to save more energy and deliver higher performance. The complexity of Linear Programming technique is formulatingthe objective function and a sequence of constraints. When the govern variables are integers (Binary Linear Programming) [3,4]. This is considered one of the most optimized techniques to solve the complex problem of MANET topology, and adapt with the most recent vitality utilization calculations innovation. It includeseither maximizing or minimizing the objective function, in relation toa group of constraints where they used the variables in the objective function in integer values [5,6,7]. The selected route is based on finding the values of the govern variables which makes the objective function minimum. Also, satisfies the defined constraints. Based on nature inspiration, Ant coloniesattitude is based on the ants looking for the optimisticroute from their home to the source of the food. The antwhich is ahead moves fromstation/locationto another not visited until all locations/nodes are visited. The steps are as follows, theants decidebetween the unvisited nodes to go, when they arrive at a node with a specific probability that depends on two factors: the amount of substance and the distance between the two nodes. The ants dissipate a specificamount of pheromone on their path after they have completed their route to reach the destination.The amount of substance (pheromones) that appears on the short paths gradually is increasing with time [1].The back ants choose their path which relies on the amount of the substance during the foraging phase.The Ant Colony Optimization (ACO) model is used to communicate between vehicles [8] and movingstations.ACO model is used in many applications. Sometime it is called soft computing. It maintains the energy saving which yields to extension of the network lifetime [1,7,10]. In this work, two different algorithms are proposed to focus on performancemeasures criteria namely, energy consumption, and processing time. The first algorithm isthe Linear Programming model. This technique has longer execution time after a group of requests because of the constraints (the feasible region). Many packets are lost. The Linear Programmingis considered the best energy saving in early requests [14, 15]. In the early requests (almost 500 for our topology), this Linear Programming Model will be used. The other algorithmdepends on path optimization using nature inspiration namely, Ant Colony Optimization to get the optimum path. Always, the solution is got, so a mixed model should be used.

Linear Programming is used in early requests, and then the ACO is used to avoid the packet loss.This paper is organized as follows, introducing the basic definitions of the both models.

Then the proposed models are introduced. The experimental results of the simulation are introduced. The point of merging the two models (request number) is selected which varies with topology. Finally, the paper ends with the conclusion in section four.

II. SYSTEM MODULES

2.1 *Integer Linear Programming Module*

With the introduced Linear Programmingmodule, our aim is to choose the optimisticpathfrom source to destination. The large hop count gives us more flexibilityto get the objective. It is limited with the topology intensity. The main objectiveis to minimize the total dissipated energy per each request. This is represented by the equation of total dissipated energy per request which include all the govern variables. Toget this path, it shouldmeet particular constraints, such as saving the consumed energy, and get the minimum delay (execution time).We consider the non-split case. The difficulty of this problem arise in formulation of problemwith its constraints as follows.

Output variables:
$$y_{mn}^{sd} =$$
$$\begin{cases} 1 & \text{if the route from source s to destination d goes through the edge (m, n)} \\ 0 & \text{otherwise} \end{cases}$$

Target function:

The target function is to minimize the total consumed energy per request as shown below.
$$Min \sum_{(i.j)} E_{ij}\, y_{ij}^{sd} \qquad (2.1.1)$$

Constraints:
a) Delay constraint:
$$\sum_{(i.j)} y_{ij}^{sd} \le H_{sd} \quad \forall (s.d) \quad (2.1.2)$$
This constraint is proportional to the execution time. It is confirming that the path never exceeds the hop count H_{sd}.

b) Bandwidth constraint:
$$\sum_{sd}\sum_i y_{ij}^{sd}\lambda_{sd} + \sum_{sd}\sum_j y_{ij}^{sd}\lambda_{sd} \le B\ \forall i \in V (2.1.3)$$
The channel Bandwidth, the receiving, and sending Bandwidth (bytes/sec) are limiting the packet receiving or sending (bytes).

c) Dissipatedenergy constraint:
$$d_{ij}^{\propto} X_{ij} \le P_{max}\,.\forall i \qquad i.j \in V \quad (2.1.4)$$
It depends on the Euclidian distance between nodes i and j, $\propto$ is considered to be 2.

d) Route constraints:
$$\sum_m y_{mn}^{sd} - \sum_n y_{nm}^{sd} = \begin{cases} 1 & \text{if s=m} \\ -1 & \text{if d=m} \quad \forall i \in V(2.1.5) \\ 0 & \text{else} \end{cases}$$
Route constraints ensure the validity route between each node pair.

e) Energy consumption distribution:

In theintroduced algorithm, the node selection is changed according to the previous consumption. By this new constraint, the selection of nodes in the path is varies with the probability related to the reserved energy in the node.

First, the topology is generated as discussed before. Assuming transmissionrange for each node with the same value (80 m), the neighbours of each station/node is defined (inside the same circle of range). Formulate the objective function (the coefficients are the square of the distance). The number of variables is the square of number of nodes. Also, the constraints are formulated dynamically. The problem is solved as Integer Linear Programming problem.

2.2 *Ant-Colony Optimization Module*

The proposed modifiedAnt Colony Optimization is based upon nature inspiration. Ants release more pheromones on short paths [1].Ants deposit a substance called pheromones, so on a short path it will be high intensity (amount per unit length). After particular time, the pheromones intensity is higher on the short segments. Usually slowly rises and the other ants select these ways. All the [0] [0] ants will assemble beneath positive input on the ideal way.First, the distance matrix is calculated.The two nodes have no edge, the distance between them is infinity. The edge matrix is defined initially with zero in case of no edge, and one when it is available (0-1 matrix). The pheromone concentration on theinfinity link is zero. The initial amount of the substancebetween any two nodes,m and n, is τ_0. For each link, this amount is changed when the ant passes from node m to n, as follows:$\tau_{mn} = (1-\rho)\tau_0 + \Delta\tau_{mn}$;where $\Delta\tau_{mn}$ is the pheromone's increasing value.

Second, the probability of selecting path is calculated for both intermediate stations as source stationdepend on receipt of the ant.For example, assume that the current node ismwhich receives a path reply ant for destination d from node n, the path probability can be defined is as

$$P_{mn} = \frac{[\tau_{mn}]^{\propto}[B_{mn}]^{\delta}[D_{mn}]^{\beta}[\eta_{mn}]^{\gamma}}{\sum_{I\epsilon N_m}[\tau_{mn}]^{\propto}[B_{mn}]^{\delta}[D_{mn}]^{\beta}[\eta_{mn}]^{\gamma}} \qquad (2.2.1)$$

$$[D_{mn}] = \frac{1}{delay(path(m.d))} \qquad (2.2.2)$$
$$[\eta_{mn}] = \frac{1}{hopcount(path(m.d))} \qquad (2.2.3)$$

The main strategy after formulating the problem with initialization is depending on picking the next node from current node from the highest selection probability. The enhancement of the conventional ACO modelis done by adding a pre-processing. In the pre-processing phase, the initial values of the algorithm parameters (initial τ, α, γ, β, ρ, and Q) should be selected to get the best optimistic path. The idea is to pick these values without trying all the values with minimum time. The values of these parameters rely on the topology.

2.3 *Power Consumption Subsystem*

The network could be described as random distributed nodes (stations) connected to each other using directed/undirected edges. This is called network topology. In the proposedalgorithm, the stations are distributed uniformly in a given area. For the transmission and receiving of packets, the station bandwidth is shared.In this subsystem, the selected route has a sequence of nodes/stations.

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The source node is spending energy in sending packet. The destination is consuming energy in receiving process only. The nodes which are in between have sending, and receiving energy consumption processes. In addition to this, the survival energy consumption for each node is to beconsidered.

The total energy E_{total} which is dissipated by a given node as follows [5, 6]:

$$Etotal = E_0 + E_{tx} + E_{rc} + E_{cp} \qquad (2.3.1)$$

Where;

E_0 , is the dissipatedenergy by a node to be survived.

E_{tx}, is the dissipated energyby a node to transmit a packet.

E_{rc}, is the dissipated energy by a node toreceivea packet.

E_{cp}, is dissipated energy by a node to compute process.

The transmitted energy consumptionisfunction of the distance between the beginning

nodes to the end locationnode during packet travel. The same for the reception energy consumption calculation is done for the receiving node [11].

$E_{tx} = K \cdot b \cdot d^\alpha$; K, is a constant = 100×10^{-12} j/bit. m^α (2.3.2)

$E_{rc} = L \cdot b$; L, is a constant = 50×10^{-9} j/bit (2.3.3)

Where;

  b, the size of the packet in bits

  d, the distance between any two nodes units in meters

α, the constant packet loss, we pick the value 2.

Using equation (2.3.1), the consumed energy in thestation while transmitting and receiving a packet of size in bytes (b) and for a distance in meter (d), is then given by equation (2.3.4).

$$E = L \cdot b + K \cdot b \cdot d^\alpha \qquad (2.3.4)$$

III.   ANALYSES OF THE RESULTS

3.1 Parameter Setting

In this phase, the proposed techniques are used to analyse the efficiencyof path in MANET with the optimistic minimum consumed energy and processing time. The proposed simulation cares about these two variables to measure the performance. The station coordinates are randomly uniformly distributed. It is proposed that *N*stations are distributed. All stations have the same specific initial energy as shown in table1.1. Poisson distribution function is used to generate the request set. In this research work, 15 stations are considereddistributed within a square of 200m length. More than 1500 requests are considered to get the lifetime simulation. The simulated inputs are shown in the following tables 1.1, and 1.2.

Table 1.1General Parameters

Name	Value
Topology Size	200X200 m^2
Station/node distribution	Uniform distribution
Transmission range	80 m
Initial Energy	0.5 Joule
Bandwidth	500 b/s
The maximum allowable hop-count	3

Table 1.2 ACO Algorithm Parameters

Name	Symbol	Value
Heuristic delay factor	γ	0.015
Heuristic cost factor	β	1
Pheromone evaporation coefficient	ρ	0.69
Initial pheromone value	τ_0	0.135
Pheromone increasing value	$\Delta\tau_{ij}$	0.06
Pheromone intensity increase factor		1

3.2 Simulation experiment and analysis of the Results

To evaluate the two models, designed network topology for two dimensional area of length 200×200 m^2 and 15 stations are done. The stations are distributed randomly using uniform distribution. All nodes/stations are assumed to have the radio range 80-meter. All the nodes within the same range are considered to be neighbours.The transmission range and are displayed as circle range arcs. Each station/node has neighbours to transmit to within the same range. This topology is stationary, in other words, inputs for both the proposed algorithm are fixed. In the table 2, the routes are obtained for 8 requests out of 1500 requests in both models given with energy consumption values of stations and the processing time, and the same values of traffic amount for each request from source to destination. The routes are depending on the optimistic route in the linear programmingalgorithm and depending on the four performance measures in ACO algorithm, namely, the pheromone amount, bandwidth,delay, andhop count
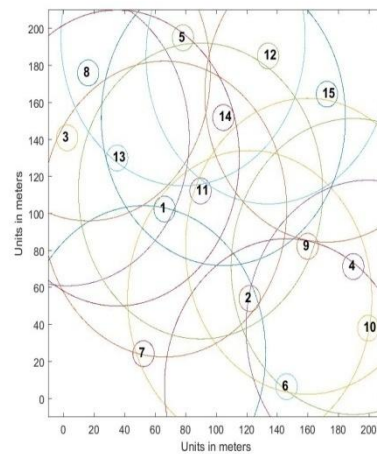

Figure1: Nodes locations over the terrain area

Table 2:Consumed Energy and Processing Time for Each Request

No	S	D	λ_{sd}	Linear Programming			Ant Colony		
				Path	E (mJ)	T(Sec)	Path	E (mJ)	T(Sec)

1	5	1	4	149.8078	5-->14	0.1694	1.7004	5-->14	0.2827	0.5148
2	3	1		150.4634	3-->11-->12-->1	1.6572	0.2496	3-->9-->10-->4-->1	4.3411	0.4680
3	1	1	3	150.2073	11-->8-->3	0.5020	0.2340	11-->3	1.2977	0.2184
4	1	1	3	149.7198	1-->12-->11-->13	1.4352	0.2184	1-->12-->2-->11-->13	3.4940	0.3432
5	1	3		150.0678	1-->4-->9-->3	2.2011	0.1716	1-->4-->10-->9-->3	4.3411	0.3276
6	5	1	3	150.3923	5-->12-->11-->13	1.7531	0.1716	5-->12-->2-->11-->13	4.0118	0.3120
7	2	6		150.0709	2-->11-->6	0.7516	0.1404	2-->12-->6	1.7341	0.2184
8	6	1	2	150.3549	6-->12	0.4612	0.1248	6-->12	0.7668	0.1716

From table 2, it can be concluded that the consumed energy for ILP model is higher than the ACO model. The route is changed according to the model. Comparison between the total consumed energy in each station after 600 requests versus the node/station number for eachalgorithm isshown in figure 2. From this figure, it can be concluded that the total consumed energy per station in ACO algorithm is greater than Linear Programmingalgorithm. This is logic result because looking for the route which satisfies the constraints takes time and the result is long route.
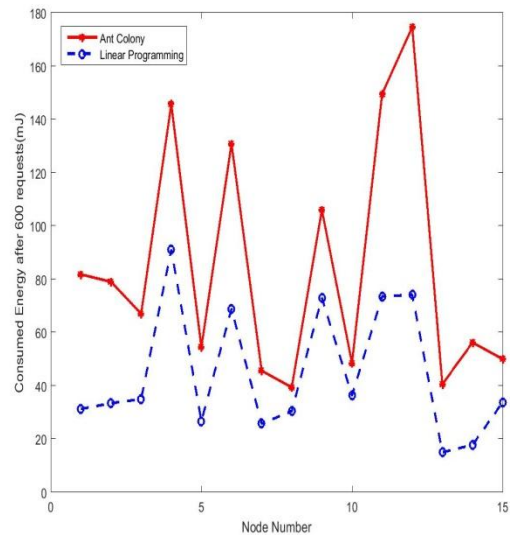

Figure 2: Consumed Energy of the Nodes after 600 requests for both models ACO, and ILP

From figure 2, node 12 will die first which will result in the end of network lifetime. Figure 3 studies the lifetime using node 12. For simulation purpose, the stating energy of the nodes are 125 mJ instead of 500 mJ.

From this analysis, the network dies in approximately request number 430 for ACO model. In the theoretical analysis the lifetime extends to 1882 requests in case of using the ILP model. The drawback of ILP model is the packet loss in case of not finding solution in the feasible region. So, we mix these two models to get the highest performance.
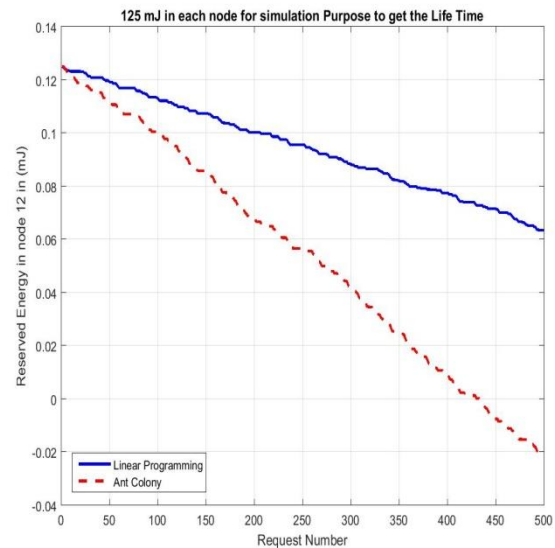

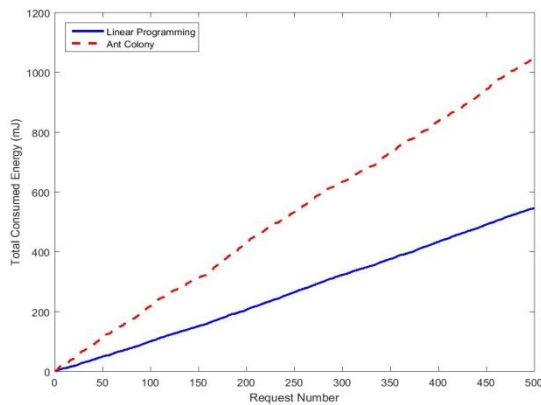**Figure 3:Lifetime analysis using node number 12, reserved energy**

Figure 4: The accumulated consumed energy versus the request number

IV. CONCLUSIONS

This work describes two models to get the optimistic route. The first model is Integer Linear Programming (ILP). This model based on minimizing the total consumed energy per request subject to a group of constraints. It is proved that the first group of requests is the best model in energy saving and the best Quality of Service. In the meanwhile after a group of requests (almost 500), finding the best route become difficult issue. This yields to losses of many packets. The second model which is nature inspired from Ant behavior (Ant Colony Optimization technique). Almost no packet losses but not the optimum energy saving. Mixing these two model get the best performance. In other words, the ILP is active in small number of requests (the beginning of network operation), and ACO in the larger ones.

The proposed ILP algorithm is modified by adding some constraints to enhance the route selection with minimum energy consumption. The second algorithm, after some improvements is the modified ACO. The enhancement is done by adding preprocessing step to select the best parameters.

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