Energy Consumption of Swarm Intelligence inspired Routing Algorithms in MANETs

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Abstract

Swarm Intelligence (SI) inspired routing algorithms have become a research focus in recent years due to their self-organizing nature, which is very suitable to the routing problems in Mobile Ad hoc Networks (MANETs). The network information can be collected and updated in a decentralized and dynamic way through the localized cooperation among these swarm agents. In this paper, we, for the first time, provide a comprehensive comparison about current SI inspired routing algorithms in MANETs in the aspects of network metrics and simulation environment. Then, we make a detailed study about the energy consumption of the SI inspired routing problem in MANETs. Based on this study, we present the selection criterion of the intermediate nodes so as to be energy efficient. Experimental results are provided with reasonable verification.

Keywords: MANETs, Swarm Intelligence, Routing, Energy Consumption.

1. Introduction

Unlike traditional wired networks or wireless infrastructure based networks, Mobile Ad-hoc Networks (MANETs) consist of a collection of mobile devices which form a network without the support from any fixed infrastructure. In MANETs, the devices can serve either as a base station or an intermediate node to forward the packets via multi-hop routing mechanisms. Due to the inherent processing and communication constraints within the mobile devices as well as the dynamic nature of topology, the research about routing algorithms is still a challenging task in the realm of MANETs.

Different from the traditional routing protocols, the SI inspired algorithms are self-organizing and localized in nature. By adopting the concept of stigmergy, which means an indirect communication among different ant agents, the network information can be collected and updated in a local, decentralized and dynamic way.

Up to now, a great deal of work has been done in the field of SI inspired routing algorithms in MANETs. In the next section, we will give a diagrammatic comparison about those representative algorithms. Then, we will present our study about the energy consumption problem of routing in MANETs, which has not yet been carefully studied. Based on one of the energy consumption models, we will give a suitable routing selection criterion about the intermediate nodes in MANETs. Finally, some of the preliminary experimental results are provided so as to validate our conclusion.

2. Comparison of SI inspired Routing Algorithms in MANETs

Swarm Intelligence inspired routing algorithms have being a research focus in recent years due to their self-organizing nature [1], which is very suitable to the routing problems in MANETs. Among these algorithms, [2] is a routing algorithm for MANETs which is based on the concept of SI and especially on the ant colony based metaheuristic. In [3], a probability based routing selection model is proposed so as to avoid traffic congestion and make load-balancing. The authors in [4] extend their rich experience about the SI inspired routing from wired network to MANETs and provide us comprehensive simulation results about the network performance. As important as [4], the authors

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of [5] also have long research history about the SI inspired routing mechanism. The minor difference is that this kind of biological inspired algorithm draws some inspiration from bees rather than ants. As one of the latest SI inspired routing algorithms in MANETs, [6] is a hybrid routing protocol. For the first time, the authors applied ANSI to both pure and hybrid ad hoc network and achieved satisfactory results.

After our comparative study about all these SI inspired algorithms mentioned above, we present a diagrammatic study about these algorithms in both network parameter and environment, as is shown in Table 1 and 2 respectively. From these tables, we can see different network parameters are studied under various environments in these algorithms. It is worth noting that energy consumption is mentioned as the future work by many of the authors. So, it motivates this paper.

TABLE 1. COMPARISON OF VARIOUS SI INSPIRED ROUTING ALGORITHMS

Algorithm Name	Simulation Tool	Packet delivery ratio	Delay	Routing Overhead
ARA[2]	NS-2	YES		YES
PERA[3]	NS-2	YES	YES	
AntHocNet[4]	QualNet	YES	YES	YES
BeeAdHoc[5]	NS-2	YES	YES	YES
ANSI [6]	QualNet	YES	YES	YES
Algorithm Name	Delay Jitter	Goodput	Throughput	
ARA[2]				
PERA[3]		YES	YES	
AntHocNet[4]	YES			
BeeAdHoc[5]				
ANSI [6]	YES	YES	YES	

TABLE 2. COMPARISON OF VARIOUS SI INSPIRED ROUTING ALGORITHMS

Algorithm	[X,Y] (m^2)	N	R (m)	Vmax (m/s)	Pause Time(s)
ARA	1500 *300	50	250	10	0,30,60, 120,300
PERA	500 *500	20	250	20	50, 100
AntHocNet	3000 *1000	100	300	20	[0,480]
BeeAdHoc	2400 *800	50	250	[1,20]	60
ANSI	[1100^2] [2460^2]	[50, 25]	250	20	10
Algorithm	Time (s)	Conn Num.	Packet Size(Byte)	Packet Rate(p/s)	
ARA	900	10	[64,1024]	4	
PERA	900	4	*	1	
AntHocNet	900	20	64	1	
BeeAdHoc	1000	1	64	10	
ANSI	300	N/2	64	1	

3. Swarm Intelligence inspired Routing in MANETs

The Swarm Intelligence inspired routing phase can be divided into three sub-phases, which are route set-up, route maintenance and link failure handling phase, as stated in most of the representative algorithms. During the route setup phase, the ant agents are periodically sent out to collect network information. Once there is a route request and the destination node is not available, the source node will initiate a route setup phase. Different from the other representative algorithms, we plan to associate the probability of choosing next hop node with the remaining energy and others, like the hop number and timestamp etc. So, the study of energy consumption is essential to our future research. The route maintenance phase and link failure handling phase are similar to the other parameters and here we mainly focus on the study of energy consumption as the first step.

As we mentioned earlier, since most of the current research work about SI inspired routing in MANETs have not yet studied the performance of energy consumption, we take it as our primary research motivation here.

3.1 Energy Consumption Model

Here, we use one of the energy consumption model from [7] as below. The energy needed to transmit, receive and forward n_b bits of packets are calculated in (1), (2) and (3) respectively.

$$E_T = n_b(E_{elec} + E_{amp} \times d^{\alpha}) \quad (1)$$

$$E_R = n_b \times E_{elec} \quad (2)$$

$$E_F = E_R + E_T = n_b(2E_{elec} + E_{amp} \times d^{\alpha}) \quad (3)$$

Here, $E_{elec} = 50nJ/bit$, $\alpha =$ 2 or 4. If the distance d is smaller than a distance threshold d_T, a free space fading (d^2 power loss) model is adopted and $E_{amp} = \varepsilon_{fs} = 10pJ/bit/m^2$. Or else, a multipath fading (d^4 power loss) model is adopted and $E_{amp} = \varepsilon_{mp} = 0.0013pJ/bit/m^4$. Here, we let:

$$\varepsilon_{fs} \cdot d^2 = \varepsilon_{mp} \cdot d^4. \quad (4)$$

So, we can get the distance threshold (d_T) as 87.7 meters.

3.2 Study of Energy Consumption

Now, we will study the factors which influence the energy consumption from source node to the destination node. Taking Fig. 1 as an example, there are N=30 nodes randomly deployed in a [1000, 1000] m^2 area. Let $d_{AB} = A$, $d_{BC} = B$, $d_{AC} = C$ and $A \le B < C$ (also it could be $B \le A < C$ since A and B are replaceable here). We simply put n_b as one bit and we can easily calculate the bit number according to the traffic model in real situation.

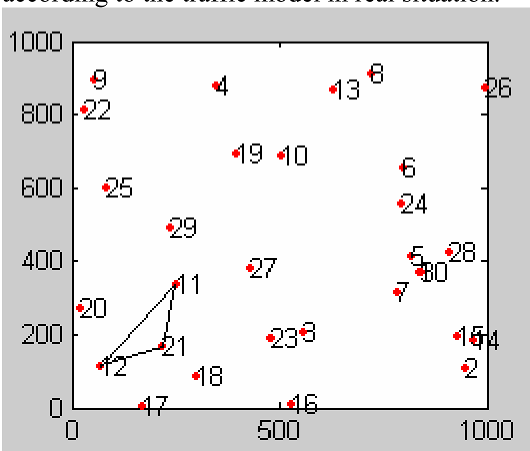

Fig. 1. 30 nodes deployment

First, we will study the one hop instance, where the relationship between $E_A + E_B$ and E_C is studied. Then, we can extend it to multi-hop circumstances. We average our simulation results for 10 times and here, we simply provide one instance so as to make it intuitively easy to understand, as is shown in Table 3.

Table 3. Comparison of one hop energy consumption (J)

Case 1: $C<d_T$ A, B< d_T	E(2,15)= $1.79*10^{-7}$ E(2,14)+E(14,15) =$2.78*10^{-7}$
Case 2: $C>d_T$ A, B> d_T	E(11,12)=$9.42*10^{-6}$ E(11,21)+E(21,12) =$2.17*10^{-6}$
Case 3: $C>d_T$ A, B< d_T	E(7,5)= $2.64*10^{-7}$ E(7,1)+E(1,5) =$2.82*10^{-7}$
Case 4: $C>d_T$ A< d_T<B	E(3,27)=$2.88*10^{-6}$ E(3,23)+E(23,27) =$2.38*10^{-6}$

Table 3 lists 4 cases about the energy consumption between $E_A + E_B$ and E_C according to their special position of node A, B and C. In Case 1, the distance between node A and C is smaller than the distance threshold d_T. It is an ideal situation since we can simply communicate from node A to node C without the help of any intermediate nodes. The energy consumption is in the order of 10^{-7} and it is also less than the summation from multi-hop nodes. In Case 2, the distance between Node 11 and Node 12 is C=291 meters, and A=159 meters, B=172 meters. From equations (1)-(3), we obtain E_C = $9.4*10^{-6}$, which is about four times larger than $E_A + E_B$. It is worth noting that the energy consumption is in the order of 10^{-6} to transmit only one bit data.

We can see that if A and B are both smaller than the distance threshold d_T, the difference between $E_A + E_B$ and E_C is small. Usually, we can neglect it and take either of the instances. If one of the intermediate distance is larger than d_T, the difference between $E_A + E_B$ and E_C is larger than the first case. The difference degree is about ten times larger. And if all the distances are larger than d_T, the difference is the largest among all the cases. In Case 3, C is larger than d_T while A and B are both smaller than d_T. We can see that E_C is smaller than $E_A + E_B$ and the difference between them is also small. Finally, in Case 4, we observe that there are situations when $A<d_T<<B$, it could be better to transmit the data through multi-hop nodes rather than to transmit the data through one-hop.

So, here, we can draw one conclusion that the difference between $E_A + E_B$ and E_C will not be very large if A and B are not much larger than the distance threshold. However, if one of the distance or both A and B are larger than the threshold, it is a wise choice to use multi-hop transmission. Now, we can extend this conclusion to the multi-hop instance and try to validate it.

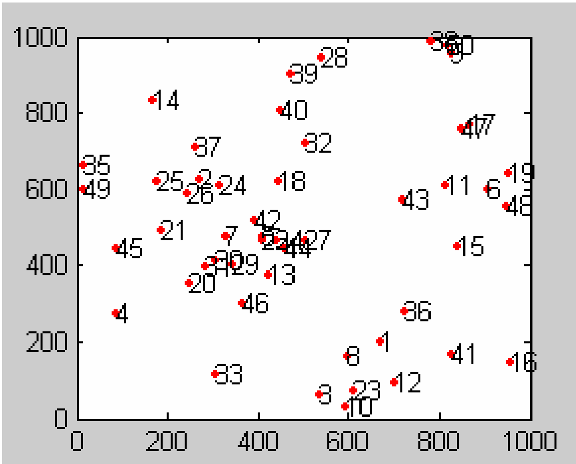

Fig. 2. 50 nodes deployment

Next, we will increase the network connectivity and introduce 50 nodes deployment in a similar way as Fig. 1, which is shown in Fig. 2. We will compare the energy consumption in the context of multi-hop routing during one communication traffic.

From Table 4, we can draw a similar conclusion as in Table 3, which is that the energy consumption will not be too large if the communication distance is not much larger than the distance threshold. In other words, if we choose those nodes with communication distance smaller or a little larger than the distance threshold, the energy consumption is reasonably acceptable. So, we are willing to save much energy at the cost of a few more hop numbers. Once again, it validates our selection criterion about the intermediate nodes during the routing phase.

Table 4. Comparison of multi-hop energy consumption (J)

Case 1: $C>d_T$ A, B..$<d_T$	E(20,29)+E(29,22)= $2.47*10^{-7}$ E(20,31)+E(31,30)+E(30,29)+E(29,22) =$5.35*10^{-7}$
Case 2: $C>d_T$ A< ..< d_T<B	E(26,42)+E(42,46)= $4.14*10^{-6}$ E(26,24)+E(24,7)+E(7,30)+E(30,29)+E(29,46)=$1.14*10^{-6}$
Case 3: $C>d_T$ A, B..$>d_T$	E(43, 36)+E(36, 16)= $1.60*10^{-5}$ E(43,11)+E(11,15)+E(15, 36)+E(36,41)+E(41, 16)=$4.95*10^{-6}$

4. Conclusion and Future Work

For the first time, we make a comprehensive comparison of various SI inspired routing algorithms in MANETs in the aspects of network parameters and simulation environment. The energy consumption about SI inspired routing algorithms is studied afterward based on one famous energy model. From the experiments of both one hop and multi-hop instances, we provide an intermediate node selection criterion which is quite energy-efficient.

In the near future, we plan to incorporate this node selection criterion into the routing phase so as to make our routing algorithm energy efficient.

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