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FINDING SHORTEST ROUTING SOLUTION IN MOBILE AD HOC NETWORKS USING FIREFLY ALGORITHM AND QUEUING NETWORK ANALYSIS

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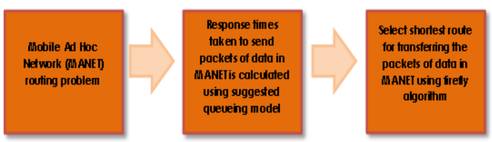
Graphical abstract



Abstract

Mobile ad hoc network (MANET) is a group of mobile nodes establishing a wireless network without using centralized and fixed infrastructure. In MANET, nodes may function as hosts and routers. The nodes can move freely and in arbitrary ways. The network topology in MANET is dynamic because of the frequent mobility of nodes, thus routing is challenging aspects in MANET. Routing protocol plays a role in choosing and selecting the optimal route for transferring the packets of data from the source node to the destination node efficiently. Mostly the previous routing protocols are not practical to this dynamic network topology. Therefore designing an efficient routing protocol for this dynamic network is vital issue. In this paper, the author has proposed an approach, which selects shortest route for transferring the packets of data from source node to the destination node combining firefly algorithm and queuing network analysis. Firefly algorithm can be applied to find the shortest route in this routing problem. The response times taken to send packets of data can be calculated using the suggested queuing model. The result reveals that attractiveness of node in MANET decreases with the increasing value of response time.

Keywords: MANET, routing protocols, queuing theory, firefly algorithm

1.0 INTRODUCTION

Mobile ad hoc networks (MANETs) can be defined as distributed systems that are comprised of mobile wireless nodes that are able to change locations and configure themselves rapidly, freely and dynamically [1]. MANETs as shown in Figure 1 are useful in areas where communications infrastructure is still incomplete or when that infrastructure is severely damaged. MANET technology can be implemented for communications at the time of disaster, fire rescue operations, or other scenarios that requires fast deployable communications [2]. One of the main difficulties in MANET is to find the optimal route between the source node to destination node [3, 4].

Due to node mobility, the process of finding the optimal route may be difficult. In the literatures, a number of routing protocols have been proposed. The routing protocols for MANETs can be classified as proactive and reactive protocols. In proactive routing protocols, each node is able to save the latest routing information in a routing table. Each node in the network can exchanges the routing table periodically with all other nodes. Meanwhile the reactive protocols create routes to destination node on demand [1]. Every routing protocol aims to transfer packets of data from source node to destination node successfully, maximizing network performance while minimizing the cost.

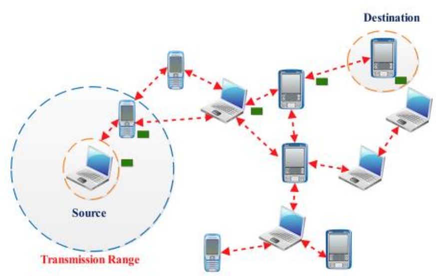


Figure 1 A basic mobile ad hoc network (Source: [5])

This paper proposes a new approach for MANET routing algorithm. The proposed approach combines firefly algorithm with queuing network analysis. Firefly algorithm is inspired by the characteristics of the firefly behavior. Fireflies communicate by flashing their light. Dimmer fireflies are attracted to brighter ones and move towards them to mate. This behavior of the firefly can be used to find the shortest path in networks. Queuing network analysis can be used as the model to evaluate response times in MANET. Currently, the routing algorithm for MANET using firefly algorithm and queuing network analysis has never been put forward and published. Therefore, this is the key motivating factor to develop the routing algorithm with combination of firefly algorithm and queuing network analysis in order to find the optimal route. Our primary purpose in this paper is to determine the shortest route between the source node to the destination node with minimum response times when delivering packets of data between mobile nodes.

The rest of the paper is organized as follows. The related works is depicted in Section 2 followed by a discussion on the firefly algorithm in Section 3. A new approach for MANET routing algorithm is discussed in Section 4. The result and discussion is written in Section 5. Finally, we conclude the paper in Section 6.

2.0 RELATED WORKS

In the last years, great literatures have been published in the field of routing in MANET. Researchers began to explore how the understanding of nature can be used to solve the routing problems in communication networks. There are a number of biologically inspired algorithms concepts that has inspired significant improved performance over traditional approaches. A brief review of these algorithms is given in this section.

Ant Based Control (ABC) algorithm is the most primitive research work on swarm intelligent routing [3]. The algorithm is done by Schnoonderwoerd *et al*. and works for a wired circuit switched network. ABC algorithm consider telephone network where it reserved a virtual circuit in order to establish connection between sender and receiver [3]. The next algorithm called AntNet [6, 7], inspired by artificial ant colony algorithm to resolve routing difficulties in wired networks. The algorithm discovers the network and the aim is to construct routing tables and keeping them adapted to traffic conditions [5, 6]. In terms of end to end delay AntNet is very slow and this is a main disadvantage. Ant Colony Based Routing Protocol (ARA) [7, 8] is a routing protocol based on AntNet. Packets of data as they move through the network maintain the route in ARA. ARA consist of three phases; which are the route discovery, maintenance, and failure handling. In the route discovery, the creation of routes requires forward ants and backward ants. A forward ant establishes the pheromone track to the source node and a backward ant to the destination node. In order to maintain the route between the source node and destination node, data packets are used in route maintenance phase. The source node will re-initiates a route discovery phase if the source node receives a route failure notification [9]. Another routing algorithm for mobile ad hoc networks is Probabilistic Emergent Routing Algorithm (PERA). PERA [10] is based on the swarm intelligence paradigm and is similar to the algorithms described in [6] and [11]. There are three kinds of ants use in the algorithm which are *regular forward ants*, *uniform forward ants* and *backward ants*. In the network, the algorithm assumes bidirectional links and all the nodes is fully cooperated [10].

3.0 BASIC FIREFLY ALGORITHM

Yang developed firefly algorithm in 2008 and it is one of the recent metaheuristic algorithm [12-14]. The firefly algorithm is based on the social behaviour of fireflies. In order to communicate, search for pray and find mates, fireflies use bioluminescence with varied light intensity patterns [15]. Firefly with greater light intensity patterns will attract the other fireflies to move toward it [16]. The firefly algorithm follows three rules which are [12-14]:

- All fireflies are unisex.
- The attractiveness of a firefly is related to its brightness or light intensity. The brightness of firefly will decreases with the increases of distance between fireflies. For a pair of fireflies, the less brighter one will move towards to the more brighter one, if there are no brighter one, then it will move randomly in the search space.
- The landscape of the objective function affected or determined the brightness of a firefly.

There are two important factors of the firefly algorithm which are the variation of the light intensity, and formulation of the attractiveness [12, 17]. The firefly algorithm can be presented in the following [13].

Firefly Algorithm

```
Objective function f(x),   x = (x1,....,xd)^T
Generate initial population of fireflies xi (i = 1,2,...,n)
Light intensity Ii at xi is determined by f(xi)
Define light absorption coefficient γ
while (t<MaxGeneration)
for i = 1:n all n fireflies
        for j = 1:n all n fireflies (inner loop)
        if (Ii < Ij), Move firefly i towards j; end if
          Vary attractiveness with distance r via exp[-γr]
          Evaluate new solutions and update light intensity
        end for j
end for i
Rank the fireflies and find the current global best g*
end while
Postprocess results and visualization
```

Figure 2 Pseudo code for Firefly Algorithm (Source: [13])

Attractiveness Function: The attractiveness of fireflies is proportional to their brightness or light intensity. The brightness or light intensity is decreased as the distance between fireflies increase. Therefore, the attractiveness of a firefly is determined by the following β[13, 14].

$$\beta = \beta_0 \, x \, e^{-\gamma r^2} \quad (1)$$

where the distance between any two fireflies denotes by r, the attractiveness at $r = 0$ is β_0 and a light absorption coefficient is γ. The distance between any two fireflies x_i and x_j is expressed as follows [13]:

$$r_{ij} = \|x_i - x_j\| = \sqrt{\sum_{k=1}^{d} (x_{i,k} - x_{j,k})^2} \quad (2)$$

where $x_{i,k}$ is the k-th component of the spatial coordinate x_i of i-th firefly and d is the number of dimensions.

Movement of Firefly: Firefly i is attracted toward the other brighter firefly j, then its movement is defined as below equation [13, 14]

$$x_i = x_i + \beta_0 \, x \, e^{-\gamma r_{ij}^2} \, x \left(x_j - x_i\right) + \alpha x \left(rand - \frac{1}{2}\right) \quad (3)$$

In equation (3), x_i is current position, $\beta_0 \, x \, e^{-\gamma r_{ij}^2} \, x \, (x_j - x_i)$ is the brightness of the firefly and the last term represent random motion [14]. The example results of firefly algorithm developed by Yang, and the location of fireflies are shown in Figure 3 [18].

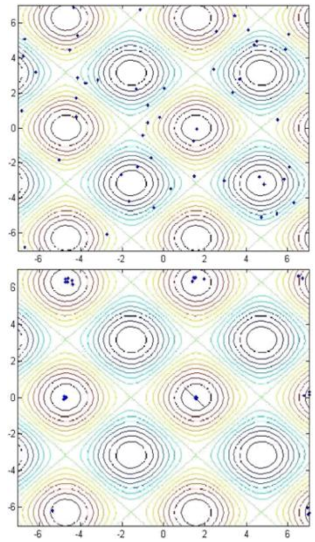


Figure 3 The locations of 50 fireflies (Source: [18])

4.0 MODELLING MANET ROUTING ALGORITHM USING FIREFLY ALGORITHM

The proposed routing algorithm based on firefly algorithm and queuing network analysis will be described in this section. The goal is to find the optimal route. The physical model of MANET is given in Figure 4. It shows several mobile nodes. The task is to find the optimal route from S to D.

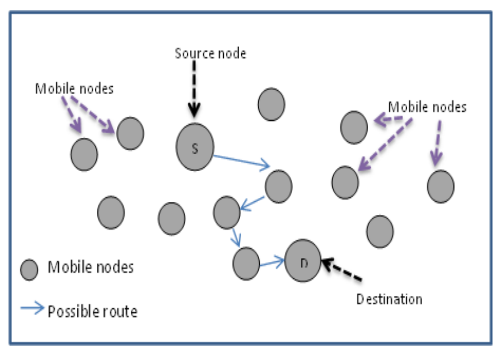


Figure 4 The physical model of MANET

Assume that if there are a number of mobile nodes wishing to communicate (refer Figure 4) where node *S* is the source and node *D* is the destination for the packets of data; then the routing protocols are important. Some critical decisions have to be made such as which is the shortest route from source node *S* to the destination node *D*. In this paper, shortest route means how we want to minimize the total length of the trip from node *S* to node *D* and at the same time with minimum response times. The mean waiting time at a node is the amount of time that user or transaction is expected to spend in a system waiting to be serviced. Meanwhile, the response time is the total time that user or transaction spends waiting and being serviced [19]. In this paper, factors affecting response time are number of hops, arrival rate and service time.

The queuing network model shown in Figure 5 will be used, in order to mathematically analyze the response times when packets of data from node *S* are being sent to its destination node *D*. We consider that, each node has a transaction (service) at any point in time. Transaction arrives at each node according to a Poisson process and consists of job. No packets are dropped in the network because each node in the network has infinite buffers. The nodes transfer the packets on first come first serve basis. The target is to find the minimum response times when delivering data between nodes.

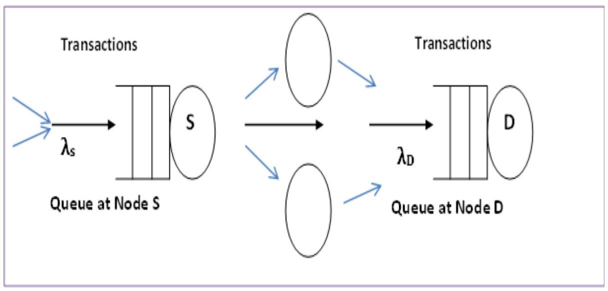


Figure 5 The conceptual queuing model of MANET

Lemma 1. *The response time in MANET is the total of the waiting time and the service time in the system at source and intermediate nodes. Each transaction needs to wait for* $\bar{W}$ *seconds at any node in order to receive a service of t seconds. Thus, the response time is given by*

$$\bar{R} = \bar{W} + t \tag{4}$$

where $\bar{W}$ is waiting time at a node [2, 19],

$$\bar{W} = \frac{\lambda.t^2}{1-\lambda.t} \tag{5}$$

t is the mean service time and λ is the arrival rate per node.

From Lemma 1, we get the average response time for all transactions from source node to destination node as follows:

$$R = \bar{R} + E(H) \tag{6}$$

where $\bar{R}$ is the response time at local node and E(H) is the expected hop count between a source node and destination node.

The routing algorithm in this paper is based on firefly algorithm [12, 20]. Referring to the algorithm (Figure 2), if there is brighter firefly, and then firefly with less bright will move towards the brighter one. The more attractiveness means the less distance between those two fireflies [21]. The fireflies in the algorithm are represented by the nodes in MANET. In order to communicate, the node will move towards the brighter node until it reaches the destination node *D*. If there is no brighter node, then it will move randomly. The firefly algorithm is used to find the shortest route in routing algorithm while queuing network analysis is used to find minimum response times between source nodes to destination node.

As shown in Figure 4, node *S* is the source node or starting point for the transmission of data and node *D* is the end point (destination node). Its response time is calculated when node *S* sends packets of data to node *D*. After applying the firefly algorithm, we develop the result of the brightness of each node based on the equation in Eq. (1) where *r* is the response time among nodes. Then we relate and compare results of the brightness of each node with the neighbour. The brightest node denotes the shortest distance. Thus, combining firefly algorithm and queuing network analysis will get the shortest route between source nodes to destination node. The overview of the whole process involved in this paper is given in Figure 6.

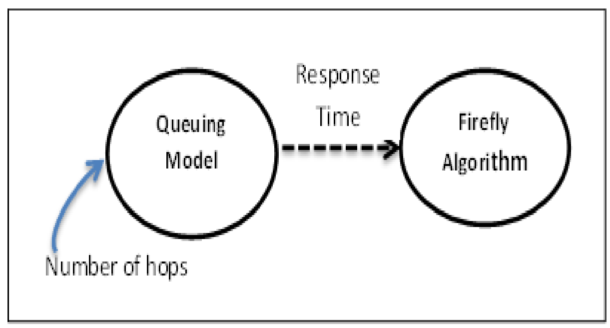


Figure 6 The overview of the whole proses

5.0 RESULTS AND DISCUSSION

The simulation program has been coded in MATLAB environment. It has been executed on a PC equipped with 1.70GHz Intel Core i5 processor with 4GB RAM. Table 1 listed out the parameters values used throughout this simulation.

Table 1 Example of parameter values

Parameter	Base Setting
β_0	1
γ	1
λ	0.5
t	0.06

Results obtained from the simulation program are summarized in Table 2. Variation values of the response times based on the hop count (three, five and eight) is shown in Table 2. Table 2 shows the increasing number of hop results in an increase in the response time. A large amount of delay can be contributed by each hop in forwarding packets of data. Furthermore, the more hops, the much longer time it takes to discover routes. It also can be seen that as the value of the response time increase, the attractiveness of the node decrease. Figure 7 displays the clear picture of result of Table 2.

Table 2 The result of the attractiveness of the nodes in MANET

No.	No. of hop	Attractiveness, $\beta(r)$	Response times, R
1	3	0.9661	0.1856
2	5	0.9088	0.3093
3	8	0.7828	0.4948

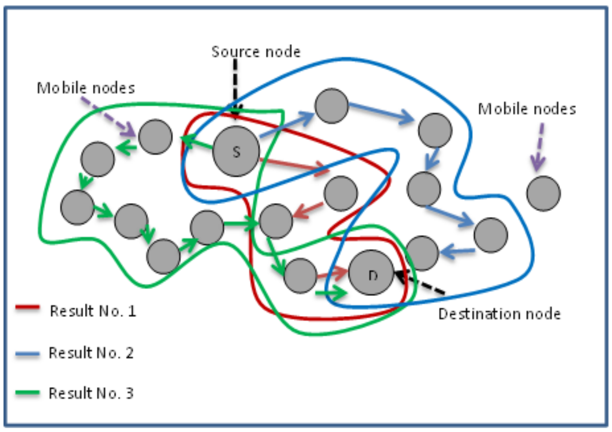


Figure 7 The result of the attractiveness of the nodes in MANET

Based on Table 2, it can be deduced that response time and attractiveness are inversely proportional because as response time increases, attractiveness decreases. The results were plotted and shown as in Figure 8.

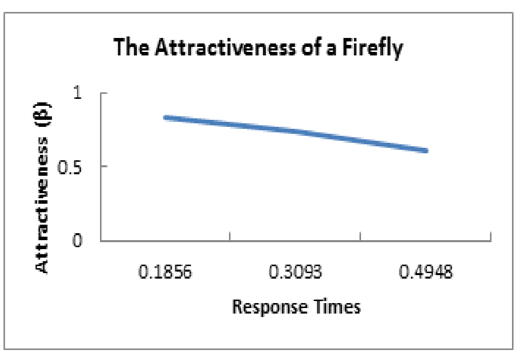


Figure 8 Attractiveness of a Firefly

Figure 8 shows the value of attractiveness decreases when the response times increases. Figure 7, 8 and Table 2 demonstrate the nature of the process where as the number of hop increases; the distance and response times among the nodes increases hence, decreasing the value of attractiveness of the node in MANET.

6.0 CONCLUSIONS AND FUTURE WORK

In this paper we have proposed an approach for MANET routing algorithm. The approach is based on firefly algorithm and combination with queuing network analysis. In MANETs, the communications between mobile nodes are using multi hop wireless links without infrastructure. The node needs a routing algorithm in order to communicate with each other. The routing algorithm in this paper is based on the firefly algorithm. Firefly algorithm is a metaheuristic algorithm and was developed by Yang [14, 20]. The firefly algorithm which is inspired by firefly behaviour is used to find the shortest route and queuing network analysis is used to find minimum response time between source nodes to destination node. Thus, we combine firefly algorithm and queuing network analysis in order to find the optimal route between source nodes to destination node. Future work will focus on simulation program with different value of response times based on variation values of arrival rate and service time. We also can compare the availability of the route in MANET between the ant routing algortihm with our proposed MANET routing algorithm.

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References

[1] J. Loo, *et al.* 2012. *Mobile Ad Hoc Networks : Current Status and Future Trends*. Taylor & Francis Group.

[2] A. H. Zakaria, *et al.* 2014. *Performance Analysis of Mobile Ad Hoc Networks Using Queuing Theory*. *First International Conference on Advanced Data and Information Engineering (DaEng-2013)*. Kuala Lumpur, Malaysia. 16-18 December 2013.

[3] L. J. García Villalba, *et al.* 2011. Auto-Configuration Protocols in Mobile Ad Hoc Networks. *Sensors.* 11: 3652.

[4] S. Kaur, *et al.* 2012. MANET Link Performance Parameters using Ant Colony Optimization Approach. *International Journal of Computer Applications (IJCA)*. 47.

[5] T. H. Ahmed. 2005. Simulation of Mobility and Routing in Ad Hoc Networks Using Ant Colony Algorithms. *Information Technology: Coding and Computing (ITCC 2005). Las Vegas, NV, USA*. 4-6 April 2005.

[6] S. S. Dhillon and P. Van Mieghem. 2007. *Performance Analysis of the AntNet Algorithm*. *Computer Networks.* 51(8): 2104-2125.

[7] A. Rout, *et al.* 2011. Optimized Ant Based Routing Protocol for MANET. *Proceedings of the 2011 International Conference on Communication, Computing & Security*. India. 12-14 February 2011.

[8] M. Gunes, *et al.* 2002. ARA-the ant-colony based routing algorithm for MANETs. Parallel Processing Workshops,

Proceedings. *International Conference on Parallel Processing*.

[9] J. Wang, *et al.* 2009. HOPNET: A Hybrid Ant Colony Optimization Routing Algorithm for Mobile Ad Hoc Network. *Ad Hoc Networks.* 7(4): 690-705.

[10] J. S. Baras and H. Mehta. 2003. A Probabilistic Emergent Routing Algorithm for Mobile Ad Hoc Networks. Wiopt'03: *Modeling and Optimization in Mobile, Ad Hoc and Wireless Networks. France. 3-5 March* 2003.

[11] D. Subramanian, *et al.* 1997. Ants and Reinforcement Learning: A Case Study in Routing in Dynamic Networks. *IJCAI (2)*.

[12] I. Fister, *et al.* 2013. A Comprehensive Review of Firefly Algorithms. *Swarm and Evolutionary Computation*. 13(2013): 34-46.

[13] X.-S. Yang. 2010. *Nature-Inspired Metaheuristic Algorithms:* Second Edition. Luniver Press.

[14] C. Liu, *et al.* 2012. A New Path Planning Method Based on Firefly Algorithm. *Computational Sciences and Optimization. 23-26 June 2012.*

[15] S. Talatahari, *et al.* 2014. Optimum Design of Tower Structures Using Firefly Algorithm. *The Structural Design of Tall and Special Buildings*. 23(5): 350-361.

[16] M. Ismail, *et al.* 2012. Firefly Algorithm for Path Optimization in PCB Holes Drilling Process. *Green and Ubiquitous Technology (GUT). Jakarta, Indonesia. 30 June-1 July 2012*.

[17] J. Yuan, *et al.* 2013. QoS Multicast Routing Based on Firefly Algorithm. *Computational Intelligence and Design (ISCID). Hangzhou, China. 28-29 October 2013.*

[18] J. Kwiecień and B. Filipowicz. 2012. Firefly Algorithm In Optimization of Queueing Systems. *Bulletin of the Polish Academy of Sciences: Technical Sciences.* 60(2): 363-368.

[19] E. Lazowska, *et al.* 1984. *Quantitative System Performance, Computer System Analysis Using Queuing Network Models*. Prentice-Hall.

[20] S. N. Kumbharana and G. M. Pandey. 2013. Solving Travelling Salesman Problem using Firefly Algorithm. *International Journal for Research in Science & Advanced Technologies.* 2(2): 053-057.

[21] S. Palit, *et al.* 2011. A Cryptanalytic Attack on the Knapsack Cryptosystem Using Binary Firefly Algorithm. *Computer and Communication Technology (ICCCT). India. 15-17 September 2011*.