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New Energy Efficient Routing Protocol in Wireless Sensor Networks Using Firefly Algorithm

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Abstract
Energy constraint has become the major challenge for designing wireless sensor networks. Network lifetime is considered as the most substantial metric in these networks. Routing technique is one of the best choices for maintaining network lifetime. This paper demonstrates implementation of new methodology of routing in WSN using firefly swarm intelligence. Energy consumption is the dominant issue in wireless sensor networks routing. For network cutoff avoidance while maximize net lifetime energy exhaustion must be balanced. Balancing energy consumption is the key feature for rising nets lifetime of WSNs. This routing technique involves determination of optimal route from node toward sink to make energy exhaustion balance in network and in the same time maximize network throughput and lifetime. The proposed technique show that it is better than other some routing techniques like Dijkstra routing, Fuzzy routing, and ant colony (ACO) routing technique. Results demonstrate that the proposed routing technique has beat the three routing techniques in throughput and extend net lifetime.

Keywords
Adaptive Routing, Wsn, Network Lifetime, Firefly Algorithm.

I. INTRODUCTION

Recent developments in recent years show serious progress in wireless networking. These developments made the wireless sensor networks useful for several applications such as such as medical and health, security surveillance, habitat monitoring, military reconnaissance, disaster management, industrial automation, etc.[1],[2],[3],[4]. Wireless sensor networks are extremely revolved for monitoring physical environment. Due to energy constrains and low capabilities of nodes. Energy reservation plays as serious key in these networks [1]. when multi-hop communication is used, this would reduce the sending distance in addition for net lifetime increase [2],[3],[4],[5],[6]. WSN are compose of a group of sensor nodes. Sensor nodes have limited resources. Each node consists of four parts: a processer, sensor, transceiver, and battery. The most part exhaust power is the transceiver. Sensor nodes have the responsibility of gathering data from physical environment and send it to sink. sensors send data to sink in each time duration. The collected data may be temperature, pressure, image, video, etc. This makes the global monitoring using WSN [5],[6]. Due to limited resources of nodes serves the designers to do network energy treatment. Energy exhaustion must be managed and balanced. One of the best techniques is routing. Balancing energy exhaustion leads lifetime and throughputs maximization. If energy exhaustion is not well managed, net lifetime reduced extremely and network partition reach fast [5],[6]. The main objective of routing method is choosing the best route from a sensor node to sink. Avoiding send path with same route can make energy exhaustion balance and therefore the lifetime will be increased. If the same path is used for sending data, like Dijkstra routing, network partition time would be small due to power spent for some nodes and except others. Change data path every time will make energy exhaustion balance and

increase network lifetime.
In this paper an adaptive routing method is suggested. The main goal of the suggested method is guarantee energy exhaustion balance and maximize network lifetime. The suggested algorithm introduces new improved routing algorithm using firefly optimization technique. The algorithm suggests determination of optimal path from nodes to sink so that energy is balanced which will leads to maximize network throughput and lifetime.
The paper is organized as follows. Section II demonstrate related work. Section III demonstrates suggested method. Section IV states experimental settings. Section V demonstrates simulation results. Section VI states the conclusion.

II. Related work

The design of energy efficient system is the primary consideration in WSNs. Routing protocols is widely used in WSNs to minimize energy exhaustion and maximize network lifetime. Routing techniques is responsible for finding the optimum path to send packets from sensor nodes to sink. The feasible routing protocol is related for finding the optimal path while ensuring minimum energy consumption. Finally, network lifetime is prolonged. Prolonging network lifetime has gained significant interest in recent years.
K. R. Sharma et al. [7] proposed a firefly algorithm which its mission to solve routing algorithm in WSNs. The algorithm used a simplified cost function that uses the packet drop factor with residual energy. The suggested algorithm is compared with BAT algorithm. The results showed that the proposed algorithm is better than BAT algorithm in terms of throughput, PDR and packet loss ratio.
The work proposed by K. Gupta and Amandeep [8] proposed an algorithm that uses the firefly optimization for hierarchal clustering network problem. The algorithm has been applied for finding the best cluster head in homogenous or heterogenous paradigm. The algorithm is repeated every time period to find the best clustering distributing of sensor nodes. The results showed an improvement in network stability and how network is improved when using LEACH and TEEN protocols.
R. Elavarasan and K. Chitra [9] suggested a firefly algorithm for solving the localization problem in WSNs beside using an optimized routing. This work is implemented in three stages which are the clustering stage, optimum routing stage, and nodes mobility is applied. The main objective of this algorithm is adopting how clustering mechanism is optimized to find better node location to implement better link quality with work balance. Simulation results show an improvement in network life time and throughput.
The work proposed by Mamatha K. and Kiran M. [10] proposed a firefly algorithm for self-organizing in mobile WSN. The suggested algorithm used multi-objective parameters cost function which depends on energy and distance of nodes. The distance function is used for optimizing the location of mobile nodes in network. The node with nearest distance and highest energy is selected. Results show better connectivity and an improvement in network lifetime.
Muhammad F. et al. [11] proposed a dynamic firefly mating algorithm for implementing FFRP routing protocol for underwater WSNs which is used for monitoring applications. The algorithm is used for finding the optimum path for sending data by self-organizing method in large scale networks. Multi hop routing is considered in these networks. Simulation results demonstrates that the suggested routing scheme has improve the network reliability and efficiency by balancing load traffic.
The work proposed by Q. Ding et al. [12] suggested a routing protocol that based on machine learning algorithms. The hypothetic manners of ML are used for making the decision for path selecting criteria. The decision is established using MDP method, then the ML algorithms has used to formulate the optimum solution. Simulation results showed that the network reach high efficiency and rank high throughput metrics.
S. Leabi and T. Abdalla [13] proposed an adaptive fuzzy logic routing algorithm for maximizing lifetime in wireless sensor networks. The fuzzy logic is used to find the optima path to send packets from sensor nodes towards the sink. They propose a fuzzy algorithm to find the optimum path from sensor nodes to sink in a manner that ensure energy consumption balance. This manner ensure that the lifetime is prolonged and thruputs are increased. Results show an increase in network lifetime compared with classical methods. The proposed algorithm is intelligent and efficient and regarded as new introduction in the area of routing protocols in WSNs.
S. Leabi and T. Abdalla [14] proposed a swarm intelligence routing protocol for maximizing lifetime in WSNs. This protocol involves using ant colony algorithm (ACO) as routing method to find the optimum path from nodes to sink. This method ensures that the optimum path from sensor nodes to sink is reached along with balancing energy consumption. Balancing energy consumption led to prolong network lifetime. Results show a great increase in network lifetime compared with shortest path methods. This method is intelligent and efficient and can be regarded for new area of routing methods.

III. The proposed method

The suggested routing protocol comprise firefly algorithm. The purpose of this technique is reach energy consuming balance to enforce maximization of net lifetime. Firefly algorithm is hired to compute optimum route for transmitting data from sensor nodes toward sink. In this paper we suppose a scheduling that mimics time driven routing. This means every node can send packets to sink with optimum path within time cycle. Using this schedule, the optimum route determination involving sending data packets for whole nodes is reduplicate in either round. The submitted methodology involves fixed area dimensions. The nodes are randomly deployed in this field. whole nodes have full information concerning their locations and neighbor's locations under sending distance furthermore location of base station. The supreme transmission range and the initial energy are identical for whole nodes.

Efficiency and reliability of energy direction are the most WSNs design challenges. Managing energy exhaustion represent a crucial challenge for WSNs design. It awards the network lifetime which is the most substantial metric for WSNs evaluation. We can define the net lifetime, period from net start running until first sensor deplete its power. The lifetime is the extreme design defiance in WSNs. One of the substantial techniques that is used to maximize lifetime is by developing network routing algorithm.

This paper submits a developed routing algorithm. The proposed routing utilized by using two metrics. The first is node residual energy, and the second is the shortest hop to sink. The submitted algorithm taking charge of determining the optimal route from nodes towards sink and ensuring balancing energy consuming. Balancing energy exhaustion leads to extend network lifetime. So, the suggested routing technique involve finding the optimum route that ensure nodes energy exhaustion balance.

The global structure of the submitted methodology is demonstrated within Fig.1. The submitted methodology acts as details that follows. In time a node desire transmits packets toward sink, the algorithm collects all neighbor nodes firstly, and by a mechanism it finds the feasible nodes (FN) for every sensor node and collect back the bad ones. The feasible neighbor nodes would give a share in latter process that returning optimum route for broadcasting packets. Feasible nodes missing in which at least one node means that there is no path for sensing data packets and network partition has been reached. Feasible nodes are chosen as the nearest nodes to the sink with regard to current node. The submitted algorithm uses the firefly algorithm to find the optimal path from nodes to sink by utilizing two metrics, the residual energy and shortest hop to sink. firefly algorithm involves using two metrics, light intensity and distance to other fireflies. In the proposed algorithm light intensity will represent residual energy (RE) and distance (SH) will represent the distance of nodes to the sink. Sending data packet will represent firefly's movement from one to another. Probability fitness function takes into consideration these two metrics. The following fitness function is proposed and is considered in the simulation. So, the algorithm determines highest probability value from the feasible nodes (FN) and select its node to send data packets (which represent the movement of a firefly to another).

$$f(n) = \frac{w_1 * RE(n)/w_2 * SH(n)}{\sum_{i=1}^{N}(w_1 * RE(n)/w_2 * SH(n))} \tag{1}$$

Where; w1 and w2 are the weights for used metrics, RE is the remaining energy, SH is the shortest hop, n is the current node, N is the total number of feasible nodes (FN). This function is considered for seeking for best next hop for the current node. Firefly insect make flashes for short time out of a process called bioluminescence. It is involving the attractiveness of possible prey or partner as well as for the matter of tip off against predator. This makes the intensity of twinkle becomes a substantial parameter for other firefly insects. Firefly algorithm demonstrated using three laws [15]:

1) Fireflies of any gender could make attractiveness for other firefly. 2) An attractiveness factor is considered which lean on brightness of the twinkle, so as fireflies move towards more attractive ones. 3) The brightness of fireflies is calculated through an objective function. In this formulation, the residual energy is attributed to the attractiveness. The proposed algorithm compute function rates for feasible nodes. According these values, the algorithm selects the feasible node that rank max rate for selecting as next hop. Then join it into OPT list with in same time flag it identical for current node. The submitted method subsequently checks the current node insomuch as inside base station domain. True case makes process finish with best route identical to OPT listing. False case makes current one is then use submitted methodology for determination next optimum node to send packet. The submitted method reiterated for every one desire send data. The algorithm selects the node that has highest probability value calculated using the fitness function.

Yang [16] is the first who inserted Firefly algorithm. This method simulates the interaction of fireflies using their flashlight. All fireflies are assumed as unisex in this algorithm. This mean that any firefly can attracted with any either firefly depending on others brightness. The algorithm is stated below.

Algorithm: The intended firefly algorithm [16]

Begin
Objective function
Generate an initial population of fireflies (represent scattered nodes in the zone area)
Formulate light intensity I so that it is associated with (light intensity (attractiveness) represent node residual energy)
Define absorption coefficient
While (t<MaxGeneration)
For i=1:n (all n fireflies)
For j=1:I (n fireflies)

If ( ),

Vary attractiveness (RE) with distance r (SH) via move firefly I towards J;

(Represent distance from node to sink (SH) and (RE) and find best f(n) value)

Evaluate new solution and update light intensity; (update energy exhaustion for each node)

End If

End for J

End for I

Rank fireflies and find the current best; (find the optimum path)

End while

Post-processing the results and visualization (use the optimum path)

End

The following equation states the update formula [16].

$$X_i^{t+1} = X_i^t + \beta_0 e^{-\gamma r_{ij}^2}(X_j^t - X_i^t) + \alpha_t \varepsilon_i^t \quad (2)$$

Where; X_i is the initial population of fireflies, r is distance, γ is the light absorption coefficient, β is the attractiveness, α is a randomization parameter, is a vector of random numbers drawn from a Gaussian distribution or uniform distribution.

IV. Experimental setting

Simulation is achieved by using MATLAB. A 100mx100m topological zone area is used in the simulation. A 100 randomly scattered nodes for the topological zone area. The topological area has one fixed sink with position of (90mx90m). Each node work with max transmission distance amounting to 30m. Each node starts with initial energy amounting to 0.5J. The used value of packet length is amounting to 200-bit. The hop count limit has the value of 15 hops. The values of w1 and w2 are 0.2 and 2, respectively. The first order radio paradigm submitted via [17] is used for simulation as follows:

$$E_{TX}(pkt_{length}) = E_{elec} * pkt_{length} + E_{amp} * pkt_{length} * d^2 \quad (3)$$

$$E_{RX}(pkt_{length}) = E_{elec} * pkt_{length} \quad (4)$$

Table I explain symbols for this paradigm.

To evaluate this routing method packet delivery ratio (PDR) has been involved. Routing protocol is good with PDR is more than 0.96 percent. The PDR can be calculated using the following equation [13],[14].

$$PDR = \frac{No.\ of\ Successfully\ delivered\ Packets\ to\ Sink}{Total\ No.\ of\ Packets\ Sent} \quad (5)$$

TABLE I.
REPRESENTATION OF PARADIGM SYMBOL

SYMBOL	REPRESENTATION
E_{TX} , E_{RX}	Power depletion for broadcasting data, send and receive
pkt_{length}	No. bits for either packet
E_{elec}	Per bit power depletion, set to 50 nJ/ bit
E_{amp}	Per bit per meter square power depletion, set to 100pJ/bit/m2

V. Results

The simulation is achieved for the mentioned topological zone area. The result of the submitted routing is compared by Dijkstra method, Fuzzy routing method [13], and ACO routing method [14]. Dijkstra routing method is well known technique. It involves determining shortest path from node to sink. sometimes it called shortest path algorithm. So, the same path from nodes to sink is involved. This makes the use of some nodes continually and except others. This will enhance the reach to network partition quickly. The mention of Dijkstra routing algorithm is to make a comparison with classical routing algorithm. Lifetime is evaluated by alive nodes no. out of either round. Some network metrics is compared for the two routing protocols like lifetime, partition time, and PDR.

Fig.2 illustrates the zone area of randomly scattered nodes. This area has dimensions of 100mx100m. A 100 randomly scattered nodes for either topological area. The topological area has one fixed sink with position of (90mx90m).

Fig.3 demonstrates network lifetime with regard to both zones till network partition. The figure. shows that the proposed routing algorithm beat Dijkstra, Fuzzy, and ACO methods. Furthermore, demonstrates maximization with lifetime equal to 2781 round with PDR 0.993. while Dijkstra routing rank 1001 round with PDR 1, Fuzzy routing rank 1932 round with PDR 1, and ACO routing rank 2259 round with PDR 1. Round is sample of time that all nodes send packets to sink. Furthermore, optimal path is reached and energy consumption is balanced for the suggested FFA routing method. Network partition is fast for Dijkstra routing due to the use of same paths. Fuzzy and ACO methods involve balanced energy exhaustion but partition time is less the suggested FFA routing. And this demonstrates the improvement of the proposed routing algorithm. Table II states lifetime, partition time, with PDR for results and for the four submitted methods.

Fig.4 demonstrates residual energy for the compared routing algorithms for the submitted areas. The suggested FFA routing algorithm has residual energy lower than the other methods due to use of more nodes and energy consumption lead to balance. And this reflect energy consumption is Dijkstra routing is not balanced. Fuzzy and ACO methods have

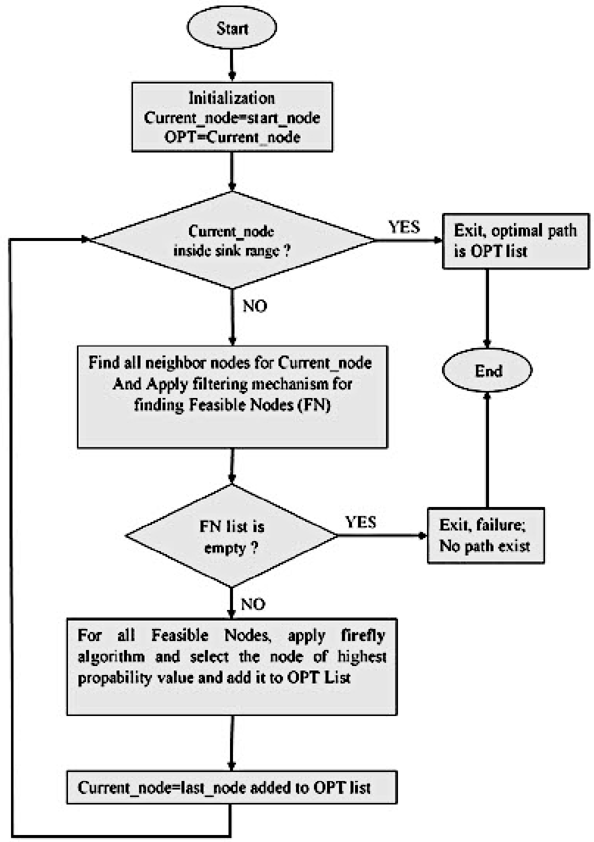

Fig. 1. Generic framework of suggested methodology

balanced energy consumption but the suggested FFA beat them in energy usage.

Fig.5 demonstrates the average consumed energy. The suggested algorithm consumes more energy than Dijkstra, Fuzzy, and ACO methods due to the efficient in energy consumption balance. Network partition time support this result, as the network partitioned more than time for the proposed algorithm. And this improves the suggested idea.

Fig.6 demonstrate the packet delivery ratio (PDR) that give the meaning of how many success packets that the sink received. The suggested algorithm shows a PDR value of about 0.993 for the zone area. Although the unity PDR value for Dijkstra routing, Fuzzy Routing, and ACO routing but the lifetime increased in the suggested algorithm and beats the other three methods.

Fig.7 demonstrates hops max number that involved by network. Within this figure, proposed algorithm involves usage of more hops for assuring energy balance and this results in lifetime maximization. This figure demonstrates the max number of hops for the suggested FFA method is greater the other three methods, and this is how the suggested method adapt itself and distribute energy consumption on more nodes for making energy consumption balance as mentioned before.

Fig.8 demonstrates networks simulation time. simulation time for the proposed algorithm is less than the other three routing methods, and this prove that this suggested algorithm does not affect the operation of optimal path computation. And this demonstrates the ability for realizing the suggested FFA methods in practical sensor nodes networks. And also, this ensures that the low capability sensor nodes hardware can process this routing algorithm in ease.

TABLE II.
NETWORK THROUGHPUTS

Routing Method	Zone	Lifetime	Partition Time	PDR
Dijkstra Routing	A1	1001	2452	1
Fuzzy Routing	A1	1932	2400	1
ACO Routing	A1	2259	2260	1
Suggested FFA Routing	A1	2781	2782	0.993

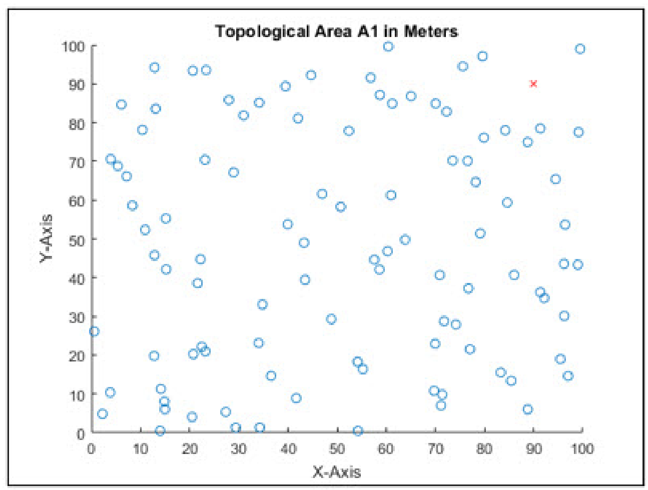

Fig. 2. Zone Area A1 of scattered nodes

VI. Conclusion

Wireless sensor networks involve low power resources in their life cycle. The process of maintaining energy consumption using new routing algorithms meet crucial issue. This paper proposes a firefly routing algorithm to ensure energy consumption balance and overall energy preservation so as for increase the lifetime of the networks. Two metrics has been used for simulation which are the residual energy and shortest hop to sink. The proposes algorithm used network throughputs to maintain energy exhaustion. Outcome offer an improvement within lifetime equals to (2781 round) for the zone area.

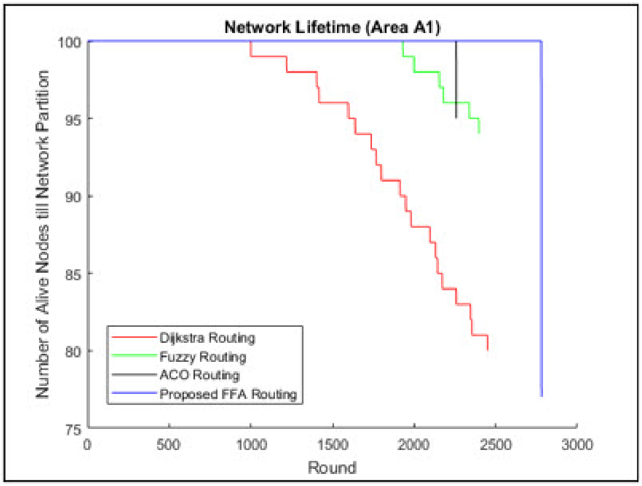

Fig. 3. Network lifetime

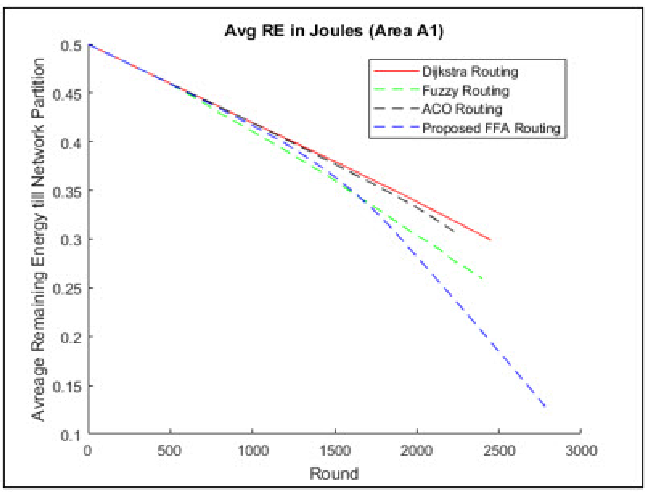

Fig. 4. Rate of residual energy

The proposed algorithm is compared with classical Dijkstra routing that has lifetime equals to (1001 round) and some intelligent routing methods like Fuzzy routing that has lifetime equals to (1932 round) and ant colony routing that has lifetime equals to (2259 round). Furthermore, outcome offer good improvement of the suggested routing algorithm against the other three algorithms and can be introduced as one of the good routing algorithms that maximize lifetime.

Conflict of Interest

The author have no conflict of relevant interest to this article.

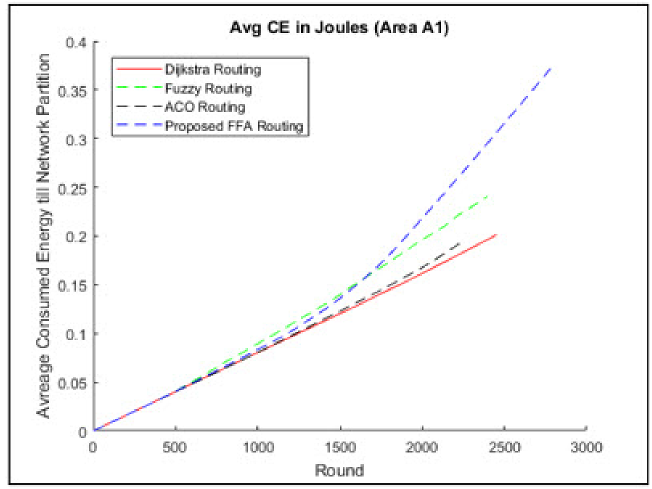

Fig. 5. Rate of consumed energy

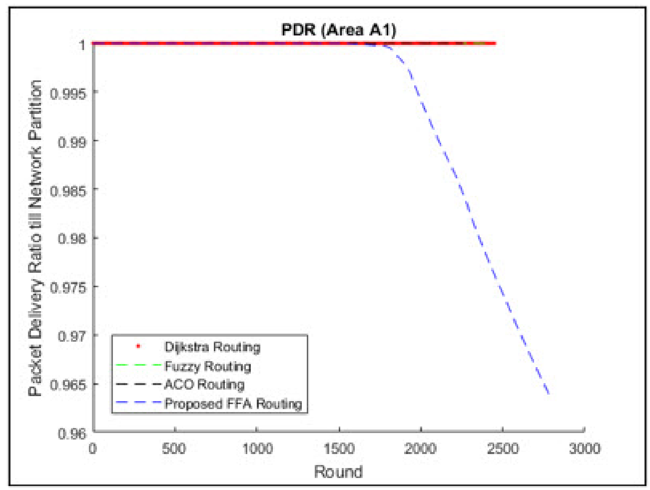

Fig. 6. PDR

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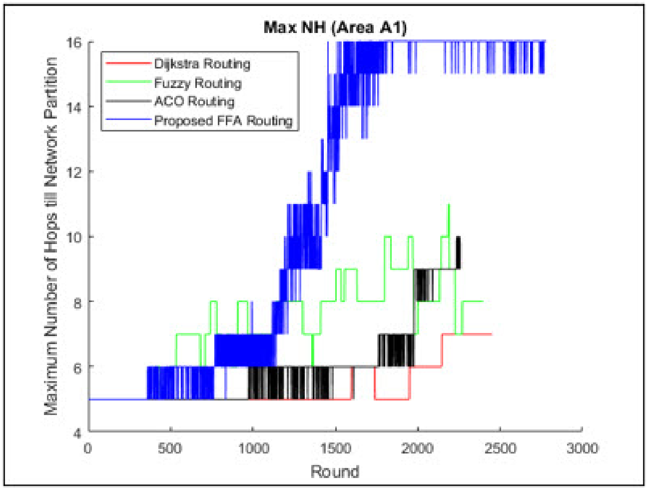

Fig. 7. Max number of hops

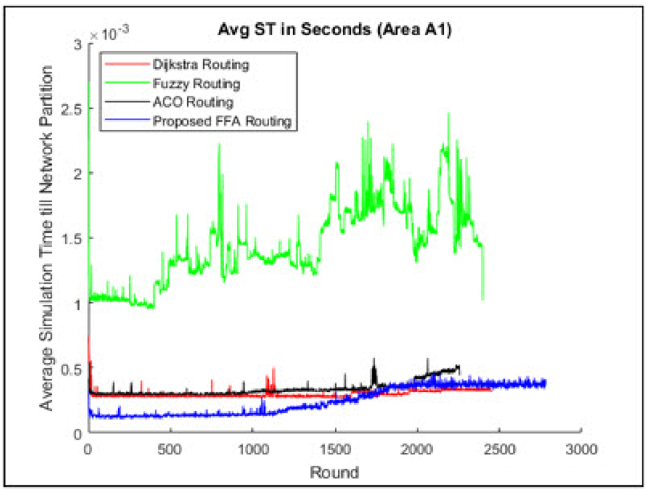

Fig. 8. Rate of simulation times

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