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Research paper

A New Routing Protocol in MANET using Cuckoo Optimization Algorithm

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Abstract

Background and Objectives: With the recent progressions in wireless communication technology, powerful and costless wireless receivers are used in a variety of mobile applications. Mobile networks are a self-arranged network, which is including of mobile nodes that communicate with each other without a central control Mobile networks gained considerable attention due to the adaptability, scalability, and costs reduction. Routing and power consumption is a major problem in mobile networks because the network topology changes frequently. Mobile wireless networks suffer from high error rates, power constraints, and limited bandwidth. Due to the high importance of routing protocols in dynamic multi-hop networks, many researchers have paid attention to the routing problem in Mobile Ad hoc Networks (MANET). This paper proposes a new routing algorithm in MANETs which is based upon the Cuckoo optimization algorithm (COA).
Methods: COA is inspired by the lifestyle of a family of birds called cuckoo. These birds' lifestyle, egg-laying features, and breeding are the basis of the development of this optimization algorithm. COA is started by an initial population. There are two types of population of cuckoos in different societies: mature cuckoos and eggs. This algorithm tries to find more stable links for routing.
Results: Simulation results prove the high performance of proposed work in terms of throughput, delay, hop count, and discovery time.
Conclusion: The cuckoo search convergence is based on the establishment of the Markov chain model to prove that it satisfies the two conditions of the global convergence in a random search algorithm. Also, the cuckoo search that suitable for solving continuous problems and multi-objective problems. We have done a lot of experiments to verify the performance of the Cuckoo algorithm for routing in MANETs. The result of experiments shows the superiority of the proposed method against a well-known AODV algorithm.

Introduction

MANET is a collection of mobile wireless nodes that are organized in a temporary network without any infrastructure and central management. Routers in these networks can move freely and organized themselves. Therefore, maybe the network topology changes frequently without any prior knowledge [1] This kind of networks can be used individually, or they can be connected to the Internet. Features such as multi-hop, mobility, supporting heterogeneity, limited power, and scarce bandwidth, make the designing of routing protocols a challenging task.

Due to the high dynamicity of these networks, maybe some routing protocols, require frequent control packet exchange to be informed about connection losing [2]. Mobile users want to make a connection in an environment that there is not any prior infrastructure. MANETs do not have any fixed communication infrastructure. Due to the lack of communication infrastructures such as access points (Aps) and a base station (BS), communication in such a network depends on forwarding nodes. Therefore, each node in the network except the role of the client could take the role of router and exchange data packets for other nodes [3].

In this kind of network, the network topology changes frequently because of node mobility. Besides, some nodes may join or leave the network, or maybe they alter to the sleep mode. Because of these characteristics, the main problem in MANETs is to route data packets efficiently. Energy consumption is another problem. Since most of the mobile hosts are equipped with batteries and have limited energy, energy consumption should be minimized to a lower extent. Many scenarios such as emergency operations, military operations, conferences, etc. can benefit from these kinds of networks because networks with fixed infrastructure cannot fulfill these requirements [3].

The dynamic nature of MANETs provided a very convenient area for applying heuristic and met-heuristic approaches. Many routing protocols have been proposed for these networks, but most of them make simple assumptions about the amount of mobility in these networks. Since, in different situations automaticity and informed interactions between nodes avoids link failure and cause the path reliability tile the end of the transmission phase, investigating the possibility of using heuristic and meta-heuristic approaches in MANET routing could be an attractive research topic [5].

In MANETs, network nodes do not have any prior information about network topology, and because of that, they are forced to discover the location of a destination node to communicate with other nodes. In other words, before transmitting data packets to the destination, the sender node has to perform some operations to discover the right location of the destination node.

In [6] suggested an Adaptive Nero-Fuzzy Inference System (ANFIS) and make use of some fixed and mobile agents. The proposed algorithm uses three kinds of agents: (a) fixed any-cast management agent, (b) fixed optimization agent, and (c) mobile any-cast route construction agent.

In [6] introduced a new algorithm called Multi-Channel On-Demand Routing with Coordinate Awareness (MCORCA). This algorithm uses several wireless channels to enhance network performance in MANETs. The proposed cross-layer approach uses channel assignment and collision avoidance strategies. This approach uses two kinds of channels one control channel for scheduling and another for data transmitting. MCORCA is an extended version of a request-based routing algorithm named ORCA for single-channel networks. In [8] proposed a multipath routing protocol for OSDM-TDMA mesh networks, which uses several paths to reach the destination. When these paths face a problem, they can replace each other immediately. In [9] had made some modifications on MMQR in which alternative paths make some changes in the network, and they will be ordered adaptively. They suggest a heuristic model for selecting attractors by which biological entities would be identified for dynamic environment changes.

With today's wireless technologies, most of the applications, need Quality of Service (QoS), self-organization, and self-healing services. Authors [10], consider the above mentioned problems, and propose a new cross-layer method that improves existing routing protocols. These improvements include adding new decision metrics to all network layers and using a fuzzy method with [11] proposed a new algorithm named Energy-Aware Span Routing Protocol (EASRP) which utilizes energy-saving approaches such as Span and Adaptive Fidelity Energy Conservation Algorithm (AFECA) approaches. Also, energy consumption could be reduced to a large extent because of a hardware circuit named Remote Activated Switch (RAS) for awaking nodes that are in sleep mode. These kinds of energy-saving protocols can work better than passive routing protocols. Even though, there are lots of problems that should be solved when using the EASRP algorithm whiten a hybrid protocol.

In [12] presented a novel AODV based routing algorithm called QoS Routing Protocol Based on AODV (AQA-AODV). This algorithm established routes based on the QoS requirements of a specific application. A mechanism for bandwidth estimation of a path and an adaptive scheme that could provide helpful feedback about the current status of the network is utilized. Therefore, special applications could optimally tune their transmission rate. Also, a route recovery (retrieving) approach has been suggested, which provides an error detection mechanism in path links and communication reestablishment. Authors [13] proposed a reliable and Markova Chain based multi-path algorithm, which has a great performance in terms of energy consumption. The proposed protocol computes multiple paths from source to destination and among them, a path will be chosen in a random manner which consumes a smaller amount of energy. Also, due to the transmission of data packets using random paths, this protocol makes the data flow safer.

Authors [14] proposed a fuzzy logic-based routing protocol for mobile ad hoc network MANETs. The proposed method uses the fuzzy logic strategy to selects suitable routes based on the energy level of the battery and speed of mobile nodes. The proposed method with the AODV protocol was simulated in OPNET simulator 10.5 and simulation results revealed that the proposed protocol outperformed the AODV protocol considering the throughput, data dropped, packet delivery rate, and hop count. Authors [15] proposed an intelligent algorithm to find the feasible route in an ad-hoc network. The proposed protocol uses the Cuckoo Search (CS) algorithm, to satisfying the constraint of QoS in MANET and select the QoS path based on a computation of the highest fitness value with three parameters such as routing load, remaining energy, and hop count. The proposed method was simulated with the Ant Colony Optimization protocol, Particle Swarm Optimization, and AODV protocol was simulated and their evaluation was accomplished based on important metrics, including mobility, scalability, and congestion. The Simulation result analysis shows that the proposed protocol is outperformed for all the above mentioned Metrics. Authors [16] proposed a new routing protocol in Manet networks to increase the efficiency of the network with a zone-Based method, which has been created by modifying the multi-path directing protocol AOMDV protocol, by improving power usage. This protocol uses metrics such as the power of battery consumption and network lifetime to selecting the best path from the multipath based on labels, node tracking, and power analysis. Proposed routing protocol uses an energy sensitive system. The Simulation result shows that the proposed method more reliable than is with AOMDV and AODV protocols.

Authors [17] proposed a method in Optimized Link State Routing (OLSR) protocol that select the best multi-point relay node for forwarding packet control to increase the QoS of the link while making a routing decision. The proposed protocol was simulated with an NS-2 simulator by varying the pause time of nodes, simulation time of nodes, and speed of nodes. Many simulations have been performed for evaluating the performance of the proposed protocols regarding throughput, end to end delay, energy cost per packet, and node's average remaining energy. Experimental results reveal that the protocol has a more efficient mechanism for routing and a more satisfactory solution for maximizing the throughput in MANET.

Cuckoo Algorithm

Cuckoo optimization algorithm [18] is a novel and powerful optimization method, which is suitable for continuous and nonlinear optimization problems. Like other evolutionary algorithms, cuckoo starts with an initial generation. The population of cuckoos has some amount of eggs that lay them in some host birds. Some eggs that are similar to the host bird eggs have more chances to be born and become a mature cuckoo. Other eggs will be recognized by the host cuckoo, and they will be destroyed. The amount of grown eggs determines the suitability of the nest of that region. More grownup eggs in a region result in more profit for that region. Thus, a region where the largest amount of eggs are saved is a parameter that cuckoo intended to optimize. The cuckoo optimization algorithm can be applied to purposes such as (a) districted and continuous optimization problems, (b) layout designing problems, (c) scheduling and sequence operation problems, (d) designing intelligent networks, and I problems that have many parameters for optimization, and their global solution could not be achieved by these methods. The superiority of the cuckoo algorithm in comparison to other algorithms is latent by multiple operations of cuckoo optimization operators, like lying eggs and migration. Other evolutionary optimization algorithms use operations that have a single purpose. However, in the cuckoo optimization algorithm, the defined operators have several purposes simultaneously.

Operation of Proposed Protocol

When a source node attends to send data to an away node, following step should be performed:

1. Source node 'S' checks its routing table to find a path to the destination. If the available path has the required amount of energy to send packets, then data will be sent through that path.

2. If there is no path toward the destination, a route discovery process will be started and a Route Request message (RREQ) is created continuing destination address and itself parameters. This message will be broadcasted on the network. It is worth noting, the proposed protocol before sending the message computed the reminded energy after sending the packet using (1) and will be added to the RREQ message, and the value of the fitness function is set to zero.

$$PR = PL - ((PS)/BW) * TP \quad (1)$$

where PR is the remaining energy, PL energy level of the battery, PS data packet size, BW available bandwidth, and YP is the required energy for data transmitting.

3. Through the path, each intermediate node that receives the RREQ message extracts the information and determines the suitability of the link by which the packet is received using the cuckoo optimization algorithm. In other words, it checks whether this node has a sufficient amount of energy for data transiting or not? The node has a sufficient amount of energy, and the value of the fitness function is greater than the threshold value does the same operation for the available bandwidth

parameter. For example, if there is enough bandwidth for packet transmitting, it means that the fitness function has a greater value in comparison to the threshold value. It means that the node has a good potential for data transmission. It should be noted, the value of fitness function for remained energy and bandwidth computed using (2) and (3), respectively. Furthermore, the cumulative value of the fitness function can be computed using (4).

$$FITP = PR/MAX\ PL \quad (2)$$

$$FITBW = ABW/MAX\ BWL \quad (3)$$

$$FIT = ((\alpha * FIT) + (FITBW + FITP)) \quad (4)$$

Where in (2), FITP is the fitness function for energy, PR is reminded energy, and MAX PL is the maximum level of the battery.

In (3), FITBW is the fitness function for bandwidth, ABW is the available bandwidth, and MAX BWL is the maximum level of bandwidth.

In (4), FIT is the general faintness function, α is the reduction confection for function convergence which is equal to 0.9. Also, the intermediate node checks to find a path to the destination in the routing table. If the path has existed, creates a Route Reply (RREP) packet, which includes the fitness value of the node and itself parameters, then sending them back to the previous node. If there is no path to the destination, the RREQ message will be broadcasted again.

When the RREQ message reaches the destination node, like intermediate nodes, it extracts itself parameters and fitness value from the packet and checks the suitability of the node using the cuckoo optimization algorithm. Furthermore, determines those paths that have higher fitness value using extracted information from the RREQ message. Four paths are selected as best paths, then one that has a higher fitness value will be chosen for data transmitting, and the other three paths are maintained as alternate paths for link failures.

The destination node creates an RREP message and copies the source address and destination address from the RREQ message and also adds its parameters and cumulative fitness function to the RREP message and sends it back to the source node.

Each node in the reverse path extracts parameters and adds its parameters to the RREP message to determine the suitability of the link. The source node uses the discovered path to send data to the destination.

The source code of proposed method show in below:

Proposed Cuckoo Search Algorithm

Procedure routing function (f(p), v=(P1,…. ,Pn)N)
Get available node of N Paths pi i=1,2,…….n for source and destination
While i≤N or(stop criterion)
Get intermediate node ni
Evaluate its fitness function F(ni) with (4).
If intermediate node to find a path to the destination in the routing table
Creates a Route Reply (RREP) packet and RREP message sends to the source node.
Else
RREQ message will be broadcasted again.
End if
Increment i
End While
If RREQ message reaches the destination node
Choose an optimized path with high fitness value.
Creates a Route Reply (RREP) packet and RREP message sends to the source node.
End if
The best solution is chosen or kept(Quality solutions nests);
The current best is rank to find solutions
The source node uses the discovered path to send data to the destination.
Post-process results and visualization
End

Simulating the Proposed Method

S. *Simulation Environment*

This paper uses the OPNET Modeler 10.5 [19] to implemented and verify the effectiveness of the proposed method and comparing it to the well-known AODV (Ad hoc On-Demand Distance Vector Routing) [20] algorithm and fuzzy logic-based reliable routing protocol (FRRP) [20] As shown in Fig. 1 network topology contains 30 nodes that are distributed in an 1127 * 1127 meter area. Furthermore, it is assumed that each node can turn in 0 to 359 degrees.

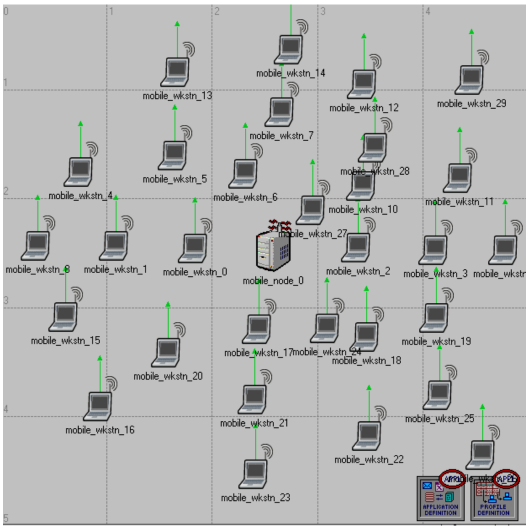

Fig. 1: Network topology for simulating network in an error-free state.

The rotating time is between 0 to 200 seconds and the movement of each node is 1 to 10 meters. Figure 2 shows a view of the node editor for the network model. Transmission range of each node equals 250 meters and the bandwidth is considered about 1 to 10 megabytes randomly.

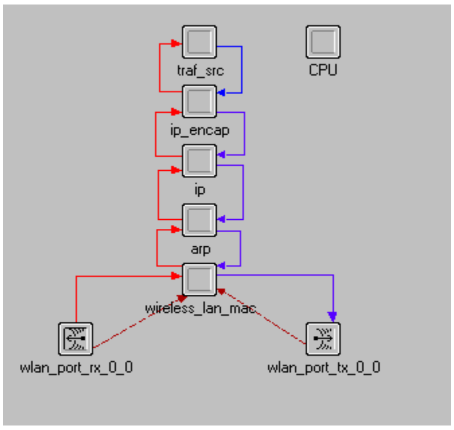

Fig. 2: Node editor for simulated model.

We use the following metrics to evaluate the performance of our algorithm. We want to analyze the performance of the proposed algorithm in two error-free and failure states.

Throughput: the amount of data that successfully passed through a network in a given time.

Received packets: number of successfully received packets to the destination.

Delay: the average time between the sending time of a packet and its receiving time of a pocket which is calculated for all packets.

The number of hops: the distance between source and destination in hops.

Route discovery time: the required time to find a path to the destination.

In the first scenario, we want to evaluate the performance of the proposed algorithm in terms of throughput for error-free and failure states. In the error-free state, all nodes that are participating in the network work without any specific problem. However, in a failure state may be some nodes get out from the network and encounter some serious problems. Now we want to evaluate the performance of our proposed algorithm against the AODV algorithm and FRRP to show the superiority of the proposed method. As it can be seen from Fig. 3 and Fig. 4, the cuckoo based algorithm has a higher throughput in both stats than AODV algorithm and after learning with fuzzy logic, FRRP protocol can determine appropriate links and in case the link is suitable, it can transmit data through that link. Hence, the throughput rate for FRRP scenario is more than the proposed algorithm. Also, in the mode with errors, after learning, FRRP protocol can select appropriate links for transmitting data and it can have more throughput rate.

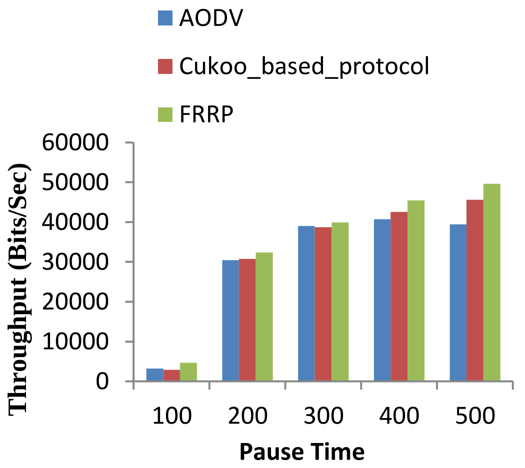

Fig. 3: Throughput of Cuckoo against AODV in error-free state.

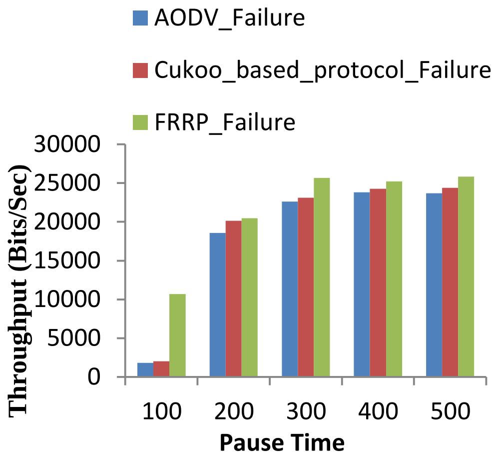

Fig. 4: Throughput of Cuckoo against AODV in failure stat.

In the second scenario number of successfully received packets are counted to show the great performance of our proposed algorithm in comparison with the AODV algorithm and FRRP algorithm. Based on detailed information about the cuckoo algorithm which selects more stable paths to the destination, this algorithm can deliver a greater number of packets to the destination than AODV algorithm also the FRRP protocol can determine suitable links for data transmission Than proposed algorithm. Figure 5 and Fig. 6 illustrate the performance evaluation of the proposed algorithm in error-free and failure stats.

Considering Fig. 7 and Fig. 8, it can be concluded that with the progress of simulation time, network delay will be decreased by the Cuckoo algorithm than AODV algorithm, and the reason is that suitable paths are chosen for data transmitting. In other words, the routes that deliver packets with high possibility are established and there is no need to discover routes again. Therefore, network delay decreases significantly.

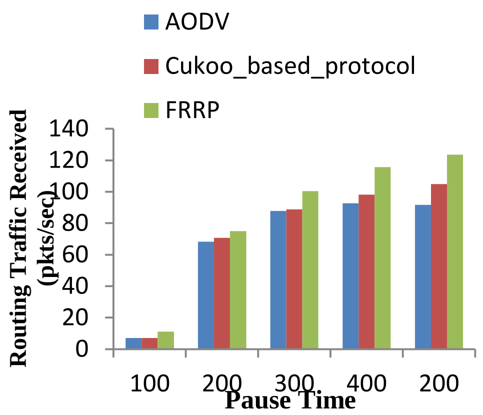

Fig. 5: Number of received packet in cuckoo algorithm and AODV in error-free state.

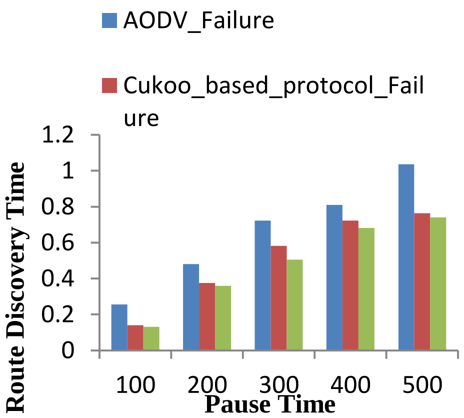

Fig. 6: Number of received packet on cuckoo algorithm and AODV in failure state.

Considering Fig. 7 and Fig. 8, it can be concluded that with the progress of simulation time, network delay will be decreased by the Cuckoo algorithm than AODV algorithm, and the reason is that suitable paths are chosen for data transmitting. In other words, the routes that deliver packets with high possibility are established and there is no need to discover routes again. Therefore, network delay decreases significantly. Computing available bandwidth and energy level increase the delay but in our algorithm, the delay has a great reduction which shows that the required time for computing and comparison is low and does not impact the performance of the network. In the first seconds, the suitable links are not specified yet and because of that network delay is high. Also FRRP protocol, after learning, can consider stability parameters and determine appropriate links from transmitting data. Moreover, in the failure mode, FRRP protocol selects appropriate links for transmitting data.

It is noted that cuckoo uses those paths they have a lower hop count. In other words, cuckoo makes paths that have a lower hop count in comparison to AODV and tries to choose the shortest path to decrease the consumed energy for data transmitting.

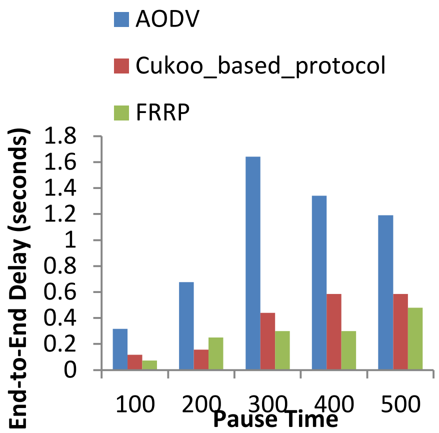

Fig. 7: Network delay for Cuckoo against AODV in error-free state.

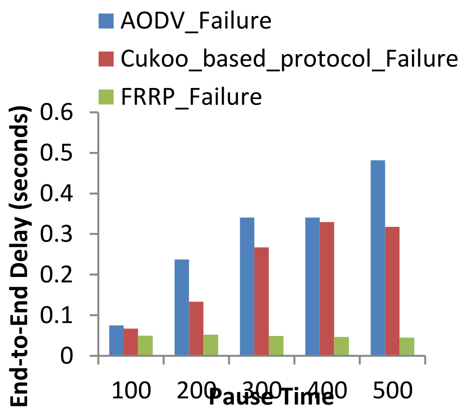

Fig. 8: Network delay for Cuckoo against AODV in failure state.

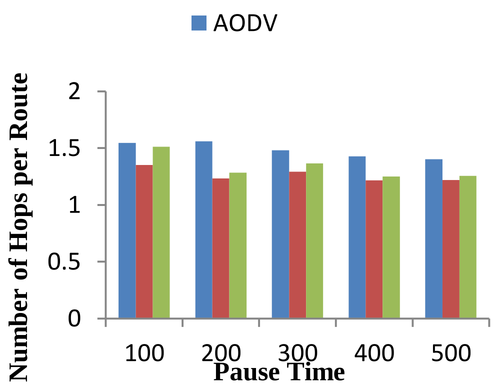

Fig. 9: Number of hop counts for each route in Cuckoo and AODV algorithm in error-free state.

Figure 9 and Fig. 10 show the achieved result from comparing cuckoo, FRRP protocol, and AODV algorithms in terms of hop count. In Fig. 11 and Fig. 12 network discovery time for Cuckoo, FRRP protocol, and AODV are computed and this parameter has a great reduction for the Cuckoo algorithm than the AODV algorithm.

This reduction arises from the fact that suitable links are recorded in the neighbor routing table of the nodes. Initially, network discovery time is high, and it is because the network is not fully trained with the Cuckoo algorithm, and suitable links are not determined yet.

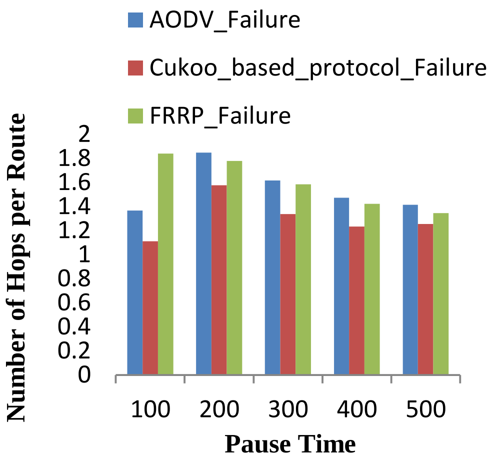

Fig. 10: Number of hop counts for each route in Cuckoo and AODV algorithm in failure state.

Also as shown in this figure, as the simulation time increases, route discovery time for FRRP protocol decreases in comparison with the proposed method. This is attributed to the FRRP protocol can determine suitable links for data transmission.

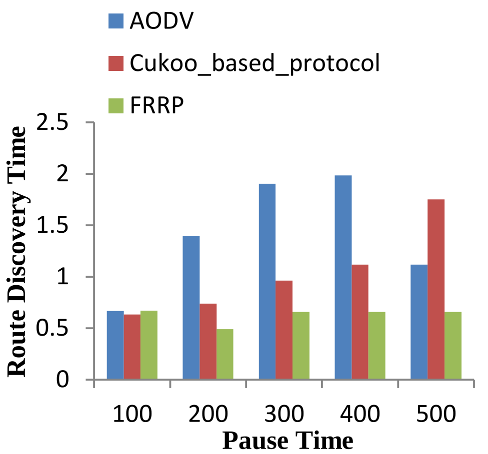

Fig. 11: Discovery time for Cuckoo and AODV in error-free stat.

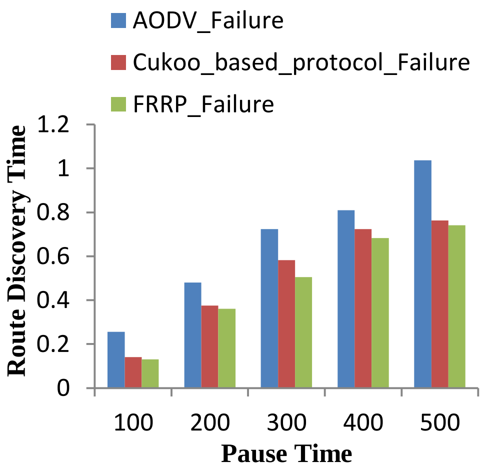

Fig. 12: Discovery time for Cuckoo and AODV in failure stat

Conclusion

MANETs have gained a significant attraction in the last decades. Routing in MANTs became a very challenging research area due to its special characteristics. In this paper, a new algorithm for routing in MANETs is proposed, which is based on the Cuckoo optimization algorithm. Cuckoo optimization algorithm [18] is a novel and powerful optimization method that is suitable for continuous and nonlinear optimization problems. Cuckoo search is a Metaheuristic algorithm that continuously iterating the optimal solution until the globally optimal solution is obtained, which helps to provides finding the optimal path. The cuckoo search convergence is based on the establishment of the Markov chain model to prove that it satisfies the two conditions of the global convergence in a random search algorithm. Also, the powerful attribute such as portability and platform independence of the cuckoo search is of profound significance it has strong global search ability. That suitable for solving continuous problems and multi-objective problems [22]. We have done a lot of experiments to verify the performance of the Cuckoo algorithm for routing in MANETs. The result of experiments shows the superiority of the proposed method against a well-known AODV algorithm.

Author Contributions

S. Tabatabaei designed the experiments, analysis the data and wrote the manuscript. H. Nosrati Nahook carried interpreted the results and revised the manuscript.

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This work is completely self-supporting, thereby no any financial agency's role is available.

Conflict of Interest

The authors declare no potential conflict of interest regarding the publication of this work. In addition, the ethical issues including plagiarism, informed consent, misconduct, data fabrication and, or falsification, double publication and, or submission, and redundancy have been completely witnessed by the authors.

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BIOGRAPHIES

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