Improved MANET Routing Protocols Performance by Using Hybrid Cat and Particle Swarm Optimization (CPSO)

Ahmed Adnan Hadi
Computer Techniques Engineering Department, Al-Mustaqbal University College, Hillah, Babil, Iraq.
Department of Electrical Engineering, Razi University, Kermanshah, Iran.

Seyed Vahab AL-Din Makki
Department of Electrical Engineering, Razi University, Kermanshah, Iran.

Received September 09, 2021; Accepted December 08, 2021
ISSN: 1735-188X
DOI: 10.14704/WEB/V19I1/WEB19148

Abstract

The technology that used in communicating data and voice among certain mobile network nodes using wireless medium and radio spectrum transmission is called Mobile networking. Generally, Mobile refers to the intent, portable and lightweight devices that may be carried by their movie users. In this paper, we proposed a hybrid version of the swarm optimization model to improve the MANET routing protocols. The proposed optimization sets optimal parameters for the MANET networks. The proposed model combines between Particle Swarm Optimization (PSO) and Cat Swarm Optimization (CSO). The methodology which will be developed in this research can be used for revealing the MANT networks or mobile sensor networks the study involve enhance mechanism(s) that can be used to avoid degraded routing issues to increase the performance. The result the obtain by proposed model satisfy best result compared with both PSO and CSO.

Keywords

Ad-hoc Network, Routing protocol DSR, AODV, MANT, Cat Swarm Optimization, and Particle Swarm Optimization.

Introduction

Each of the terms wireless ad hoc network (WANET) or mobile ad hoc network (MANET) represents wireless networks that contain groups of mobile devices connected without predefinition (Sarao, 2018). It can be used in various applications, for example, (Alkahtani & Alturki, 2021): Smartphone ad hoc networks (SPANs), Vehicular ad hoc networks (VANETs). The technical name of MANT or WANET is ad hoc network.
because these networks do not depend on predefined routes and connections (unfixed infrastructure). All things considered, each node participates in steering by sending information for other nodes, so determining which nodes forward information is dynamic and depends on the availability of the network and the steering calculation used. The number of nodes, the number of links and the mobility rate are important parameters that are an essential in a mobile ad hoc network (MANET) is characterized as a collection of mobile devices that communicate and interconnect with each other without depending on any prior framework (Al-Dhief et al., 2018). The concentrated or unified organization is less found in MANET (Kuruvila et al., 2006). They use self-creating, self-organizing and self-managing networks without the fixed infrastructure to establish the connections (Abdullah et al., 2019). Therefore, each node acts as both a host and a router, since the wireless transmission range of each node is limited. Figure 1 shows an example of the architecture of MANET.

![Figure 1 Example of MANET](image)

MANETS offer one of the unique advantages and adaptability to specific conditions: They can be sent to any location quickly and at any time. These remarkable advantages led to a rapid interest in MANETS among military, police and emergency services, especially in disorderly or unfriendly conditions (Luo et al., 2002; Sarao, 2018). Business applications began to emerge before, depending on constantly evolving standards, for example, IEEE 802.11. The routing protocols utilized in MANET are: static and dynamic (Al-Dhief et al., 2018). The static routing protocol is technically applied to the fixed network topology. The physical link that exists between nodes in a LAN network is a good example of a static routing protocol where both end nodes are fixed (Ilyas, 2003). If the node and the link topology have mobility characteristics, it may be an ad hoc network and a dynamic routing protocol is applied. A network protocol is a set of systematic rules that govern the flow of data between different devices on the same network (Mishra et al., 2019). Protocols are used in networks for routing, data exchange, communication and sharing of network resources. To regulate routing in the network MANET, there are two categories of routing protocols: reactive or proactive (Sarao, 2018). The most popular protocols of reactive routing approach are: Dynamic Source Routing (DSR) and the Ad Hoc On-Demand Distance Vector (ADOV) (Alabdullah et al., 2019; Mustafa et al., 2020;
Sarao, 2018). The Ad Hoc On-Demand Distance Vector (ADOV) belongs to the family of proactive routing. Figure 2 illustrates the types of routing protocols based on topology.

The protocols that belong to the reactive routing group are essential for dynamic network topologies, while the proactive routing protocols are better suited to minimize bandwidth usage while achieving longer convergence times (Mustafa et al., 2020). The first type of routing protocol based on topology (AODV and DSR) required low processor, memory, bandwidth, and battery utilization then DSDV routing protocol.

The both Cat Swarm Optimization (CSO) and Particle Swarm Optimization Algorithm (PSO) are well-known Metaheuristic algorithm, that is have highly successful in solving several hard optimization problems in different fields (Ahmed et al., 2020; Alfoudi, 2021; Yefa Mai et al., 2017). The Metaheuristic algorithm potentially suffers significantly from stuck at local optimum as a result of limitation in search progress (exploration and exploitation) (Topal & Altun, 2016). The move from one poison to another towards acceptable best solution basically depends on exploration and exploitation (Alnabhan et al., 2017; S. Kumar et al., 2006). Therefore, the enhancing of Metaheuristic algorithm must optimize exploration, exploitation, or both (Al-saeedi, 2016).

**Motivation**

Although several solutions to routing problems for ad hoc networks have been proposed, they are all intended to operate in optimization. Without a good understanding of the interactions between the number of nodes, pause time, and link nodes, poor network design decisions can lead to weaker than expected less effective routing guarantees (Sarao, 2018). Most ad hoc protocols implicitly assume that nodes are cooperative and behave well. This naive assumption causes the protocol to perform different performance measurements in a dynamic environment. Due to the fundamental difference between MANETS and wired networks, existing approaches cannot be transferred without adapting them to perform these protocols in different scenarios (Alabdullah et al., 2019). Many new obstacles unique to MANETS need to be addressed, including node mobility,
lack of infrastructure, lack of central authority, multiple node functionality, energy constraints, inaccurate link-state information, and limited bandwidth to guarantee QoS in MANET. This required extensive collaboration between nodes to establish the route in different scenarios (S. Kumar et al., 2006).

**Contribution**

In this paper, a novel hybrid swarm optimization (CPSO) is proposed which might potentially promote optimize search progress of the proposed model to enhance the MANET routing protocol. The proposed system is combined between two swarm optimization Cat Swarm Optimization (CSO) and Particle Swarm Optimization (PSO). We have assumed that the search space is shared between both CSO and PSO. The system started with CSO, when it sucked at local optimal the search machine switch to PSO, the switching conversely until reached to satisfied requirement. The proposed method has provided several promising achievements:

- Adaptive a hybrid metaheuristic using Cat and PSO methods with the performance of different MANET protocols and scenario.
- Find out the optimal path from many scenarios for MANET mobility environment and protocols.
- Satisfy a higher rate for network parameters such as max bandwidth, low delay, minimum PDR and low loss packets.

**Literature Review**

The development of MANET routing protocol techniques for managing mobile nodes with high efficiency. Several studies have proposed various methods to improve and develop the MANET routing protocol performance. Most of the research work to optimize the performance of MANET from the aspect of optimizing the connectivity during mobility. The metaheuristic algorithms are optimal methods to optimize the behavior of nodes contacting other nodes when they are moving at a certain speed.

(Alnabhan et al., 2017) proposed swarm ant colony optimization (ACO) to determine the optimal path for exchanging traffic between nodes in MANT. The DSR and ADOV routing protocol is MANET protocol was used to control the network. They improve one aspect of the routing protocols and ignore the most important parameter of the protocol like mobility rate, number of connections, and number of nodes. The use of deflating parameters of the protocol is not adaptable to every MANET scenario.
In (Daas & Chikhi, 2018) performance evaluation frameworks aimed at finding optimal position-based routing protocols. The performance analysis performed in this work focused on several metrics, including delay, throughput, packet transmission rate, and power consumption. A performance evaluation framework that aims to find optimal position-based routing protocols. The performance analysis performed in this work focused on several metrics, including delay, throughput, packet transmission rate, and power consumption.

The authors in the (García-Nieto & Alba, 2010) used GA, to optimize the three metrics of VANET: the transmission time, the number of lost packets and the amount of transmitted data. In addition to the stagnation problem, there is still a problem in the proposed system. The authors do not improve the most important parameters of routing protocols such as the number of connection links, the mobility rate and the number of nodes.

(Lü et al., 2014) used metaheuristics to optimize the configuration of routing protocols before network deployment. The authors compared the effects of three metaheuristics—Particle Swarm Optimization (PSO), Differential Evolution (DE), and Genetic Algorithm (GA)—on the performance of MANET when using AODV as a routing protocol. They prove that PSO achieves the best improvement in the performance of the network. In this system, the stagnation of the leakage in the swarm optimization methods is not solved.

(Alkahtani & Alturki, 2021) analyzed the performance of AODV and DSR in different areas with the same node density (100 nodes). The results of the AODV protocol are close to those of the DSR protocol, depending on the mechanisms of these protocols. There is no optimization of the routing protocol parameters. Use the static value of the network to study the performance of the routing protocol.

**Research Method**

This section consists of four main subsections. Section 3.1 introduces the PSO algorithm and the procedure of general steps. The LAR protocol framework and its principles are presented in Section 3.2, the RREQ mechanism is explained in Section 3.3, and the optimization mechanism is elucidated in Section 3.4.

**Particle Swarm Optimization**

The PSO considers one of kind of the P- Metaheuristic Optimization algorithm is inspired by the animals that live in social group (Alfoudi, 2021; Eberhart & Kennedy, 1995). The
features that make PSO is better than other P-Metaheuristic easy to implement, use a simple mathematical model with few numbers of optimization equation (Lü et al., 2014). The PSO has two major parameters in the searching process is velocity and position (candidate solution). The technical process that distinguish PSO from other Metaheuristic algorithms each particle has two candidate solution current solution (position) and best local solution \( p_{best} \) (Mohamed Ali et al., 2021). The two solutions in the same particle increase the exploration ability of PSO. The particles share to find global best solution \( G_{best} \). Equation (1) the calculates new position of particle in PSO pool (Mirjalili & Lewis, 2013).

\[
    x_i^d(t + 1) = V_i^d(t + 1) + x_i^d(t) \tag{1}
\]

Where: \( x_i^d(t + 1) \) is the new position of the particle, \( x_i^d(t) \) is the specified current position of the particle, \( V_i^d(t + 1) \) is a new velocity function.

The Equation (2) uses calculate the new velocity of the particle at optimization iteration \( t+1 \).

\[
    V_i^d(t + 1) = w(t) * V_i^d(t) + c_1 r_1 \left( p_{best}^d - x_i^d(t) \right) + c_2 r_2 \left( g_{best}^d - x_i^d(t) \right) \tag{2}
\]

Where: both value of \((r_1, r_2)\)is a random value, the constants values \((c_1, c_2)\) are set value \((1.25)\) according to (Al-saeedi, 2016; Mirjalili & Lewis, 2013), The \( V_i^d(t) \) is velocity of the particle at iteration \( t \), \( w(t) \) weight inertia at iteration \( t \).

**Cat Swarm Optimization (CSO)**

Cat swarm optimization (CSO) is a swarm optimization algorithm, which was introduces in 2006 by Chu et. al. (chuan Chu et al., 2006). It stimulates the cat behavior in find beat. Technically, the CSO algorithm is based on two modes tracing and seeking modes (Ahmed et al., 2020). The cat in CSO contains three value positions, flag, and cost value. Generally, the position of the cat is a candidate solution with diminution equal to the optimization problem. The cost value is the accuracy or fitness value that figure out by the cat. The flag is classified as the cat either seeking or tracing mode (Ahmed et al., 2020). The Seeking Mode based on the equation (3) (chuan Chu et al., 2006).

\[
    P_i = \frac{|FS_i - FS_b|}{FS_{max} - FS_{min}}, \text{ where } 0 < i < j \tag{3}
\]

In the tracking mode the cat updated the velocity and position. The cat update it velocity \((v_{k,d})\) according to equation (4) (chuan Chu et al., 2006).
\[ v_{k,d} = v_{k,d} + r_1 \times c_1 \times (x_{\text{best, } d} - x_{k,d}), \text{ where } d = 1, 2, ..., M \]  \hspace{1cm} (4)

\( x_{\text{best, } d} \) is the position of the cat, that has the best fitness in the cat pool; \( x_{k,d} \) is the position of cat \( k \). \( c_1 \) is a constant and \( r_1 \) is a random value in the range of \([0, 1]\)

The cat moves to new position \((x_{k,d})\) based on equation (4) (chuan Chu et al., 2006).

\[ x_{k,d} = x_{k,d} + v_{k,d} \]  \hspace{1cm} (5)

The final solution would be the best position in one of the cats due to CSO keeps the best solution till it reaches the end of iterations.

**Ad Hoc On-Demand Distance Vector (ADOV)**

ADOV is a reactive routing protocol for MANET and various mobile networks (Al-Dhief et al., 2018; Habboush, 2019). It has many good features that make it suitable for use in MANET networks, such as dynamic, self-starting multi-hop routing between mobile nodes that want to establish and maintain an ad hoc network (Luo et al., 2002). AODV enables the creation of routes to specific destinations and does not require nodes to maintain these routes when they are not actively communicating (S.S. Kumar et al., 2018). AODV avoids the problem of "counting to infinity" by using objective sequence numbers. This makes AODV loop-free. The routing messages in the AODV routing protocol has not information about the entire route path over the network, but only about the source and the destination. Figure 3 shows the broadcasts of a route request (RREQ) packet in the MANET network.

![Figure 3 AODV broadcast RREQ](http://www.webology.org)

**Dynamic Source Routing (DSR)**

DSR is a routing protocol that regulates the path of packets in MANET from source to destination. It allows nodes to dynamically discover a source route over multiple network hops to any destination node (Al-Dhief et al., 2018). Route discovery and route
maintenance are the main phases that mainly make up the DSR routing protocol. The mobile hosts in DSR protocol, when they want to send packets, need to consult their route cache to decide whether they already have a route to the destination. If the route from the source to the destination exists in the network, a packet is sent to the host (Daas & Chikhi, 2018; Mustafa et al., 2020). If the host node does not have a route, the route does not exist, or the route has not yet expired, it initiates route discovery by sending a route request packet containing the address of the destination along with the address of the source mobile host and a unique identification number. Therefore, the nodes in the network use the DSR routing protocol when receiving the packet each node has to the route for the destination exist or not (Al-Dhief et al., 2018; Nghi et al., 2019). If it does not, it adds its address to the route record of the packet and then forwards the packet along with its routing links (Ahmad et al., 2020). The route of a packet is generated in two cases: first when the request reaches to the destination, second when the intermediate node cache contains an unexpired route to the destination (Ilyas, 2003). Figure 4 illustrates the delivered packet by DSR routing over the MANET network.

![Figure 4 DSR broadcast RREQ](image)

**Proposed Hybrid Cat and Particle Swarm Optimization (CPSO)**

The method used in this study is to improve the performance of MANET routing protocols by metaheuristic Optimization Methods. In this study, two routing protocols are used which are: AODV and DSR. The proposed optimization model selects or sets the optimal parameters of MANT routing protocols. The metaheuristic optimization models often suffer from falling into a local optimum. This phenomenon is called stagnation in the field of optimization. To reduce the stagnation in the proposed model, the exploration is increased. Increasing the diversity of the proposed solutions is the optimal method to help the metaheuristic algorithm to overcome stagnation. The hybrid model produces a population with high diversity - different proposed solutions - and also produces models
that have better characteristics than the algorithms used to build the model. The proposed system involves four steps:

A. Initialization of the proposed model is mainly based on determining the size of the random population. A random population starts with a size specified by the user and a certain dimension according to the optimization problem.

B. In this step, the proposed system allows the COA to start searching for the first local optimum. If the search stagnates, the system automatically switches to the PSO search process. The best solution is to switch to the PSO only.

C. If the PSO falls within the local optimum and there is no improvement in the candidate solution, the system automatically switches the search process to COS with the current best solution found by the PSO. When switching, the system lets the swarm optimization algorithms keep their parameters (population, speed) and changes only the best solution.

D. If both swarm optimization algorithms (COA, PSO) do not change the best solution. The proposed system will restart the algorithm settings (population and speed).

Figure 5 illustrates the steps of proposed system.
**Evaluation Metric**

In this paper we proposed new benchmark that is used to test the proposed algorithm basically depends on the number of sent, receive packets, and delay. It technically consists of parts, the ratio of sent and received packets, the number of drop packets, the percentage of successful packets, and delay.

A. The Ratio of Sent and Receive (SR): This metric measures the percentage of sent and receive packets. The proposed optimization model searches on minimum object function therefore, the SR is calculated in eq 6:

\[
SR = \frac{1}{S+R} 
\]  

(6)

Where S is a number of the sent packets, R is a number of the sent packets.

B. Drop packets (DP): The DP represent the number of the unreached packet to the destination. It is found by subtraction the number of sent from the received packets.

\[
DP = S - R
\]

(7)

As long as the system receives packets close to the sender, it is better.

C. Percentage of Successful Packets (R/S): In the ideal system the amount of sent packets are equal to receive. To satisfy the minimum object function we subtract the R/R from 1. Equation 8 calculate the R/S.

\[
\frac{R}{S} = 1 - \frac{R}{S}
\]

(8)

The summation of SR, DP R/S, with delay, construct the object function \( f \).

\[
f = SR + DP + \frac{R}{S} + Delay
\]

(9)

Table 1 shows the interval bounders of parameters of object function:

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Best</th>
<th>Worst</th>
</tr>
</thead>
<tbody>
<tr>
<td>SR</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>DP</td>
<td>Depends on sent and receive packet</td>
<td></td>
</tr>
<tr>
<td>R/S</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>
Finding and Discussion

The proposed system test over 10000 scenarios with different parameters of MANT routing protocol. Two well-known metaheuristics (PSO and CSO) algorithms are compared with proposed model. The general optimization parameters is set as: Number of iteration = 10, problem diminution = 3, population size = 20. Upper bounders of each particle = 5, and lower is -5. The main parameter of PSO algorithm is set as: the constants values ($c_1$, $c_2$) are set value (1.25), weight inertia at iteration 0.5. The main parameter CSO algorithm is set as: number of cat (NUM_CATS) = 6, the percentage of seeking cat (MR) = 2, seeking memory pool (SMP) = 3, and percentage - seeking range of the selected dimension (SDR) = 10. The hybrid proposed model (CPSO) shared the with PSO and CSO in parameters. The optimal result that satisfied by PSO model was worsted compared with CSO and our proposed model (CPSO). The best scenario achieved by PSO number of node (19), number of connection (10), and speed rate is (10). The PSO’s scenario sent (162) packets and received (109). The delay in its scenario is (6023.5 Sec). The results that getting by CSO was moderate compared with CPSO. The best scenario that selected by CSO was (132) packets scented over (19) nodes and (10) connections with average speed rate of node is (10). The received packets get by CSO is (13) packets with (52.36 sec) delay time of this scenario. The best results of our proposed system is fulfill the best MANET scenario with (19) nodes, (4) connections, and the rate speed of mobile node is (4). The object values that detected by CPSO are: sent (48) packets, received (47) packets, and delay (6.13 sec). Table 2 illustrates the compleitive of PSO, CSO, and proposed CPSO in terms drop packets (DP), percentage of successful packets (R/S), delay.

Table 2 Compere result over 30 runs of PSO, CSO, and CPSO

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>DP</th>
<th>R/S</th>
<th>Delay (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSO</td>
<td>53</td>
<td>0.346</td>
<td>6023.3</td>
</tr>
<tr>
<td>CSO</td>
<td>1</td>
<td>0.0076</td>
<td>52.36</td>
</tr>
<tr>
<td>CPSO</td>
<td>1</td>
<td>0.0076</td>
<td>6.13</td>
</tr>
</tbody>
</table>

The CSO and proposed CPSO approximate same performance in term of drop packets due to the strength of CSO in searching on the best feasible solution in search space and this feature inherited to the CPSO to improve the search progress. Figure 6 shows the drop packets of over scenario that selective by PSO, CSO and CPSO.
Conclusion

The optimization multi objective tries to find an optimal path form many scenario of delay, packet loss, through pet and PDR. The main objective it’s to find an optimal routing for many protocols such as DSR, AODV, DSDV. The results will show a superior with optimizer than the standard routing protocol. For the future works we suggest to implement the scenarios by NS2 dynamically.

References


