Optimized LOADng Routing Protocol Parameters Using Black Widow Optimization Algorithm for IoT

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Abstract

With the dawn of Internet of Things (IoT), interconnected things and smart applications have significantly reduced human intervention in accomplishing tasks. Yet, due to its openness, heterogeneity, limited resources and extensiveness, it suffers from several issues such as lesser capacity links, energy consumption, resource optimization etc. Routing of packets in such constrained environment is yet challenging. Lightweight On-demand Ad hoc Distance-vector Routing Protocol—Next Generation (LOADng) protocol is an extended version of AODV protocol. Unlike AODV, LOADng is lighter version which forbids the intermediate nodes on the route to send a route reply (RREP) for the route request (RREQ) which is originated from the source. A resource constrained IoT network demands minimal routing control overhead with no packet loss. The optimal selection of routing protocol parameters can improve quality of service (QoS) of such constrained environments. So, in this paper we present optimization of the parameters of LOAD grouting protocol using black widow optimization (BWO) algorithm for IoT. Simulation results depict that the LOADng-BWO outperforms the conventional LOADng protocol in terms of delay, overhead and delivery ratio.

Keywords

LOADng, IoT, Black Widow Optimization (BWO), Routing Overhead.

Introduction

The IoT is a wide idea that has stood out from the research community as of late. The term IoT can be utilized to depict a pervasive and ubiquitous network where gadgets trade data between one another without the prerequisite for human mediation (Chaudhary et al.,
This organization can be utilized by applications of a wide assortment and with fluctuating destinations, for example, smart homes and urban communities (Agarwal et al., 2019), modern mechanization (Rehan et al., 2020), shrewd business sectors (Angeline et al., 2018), and medical care frameworks (Fernandez et al., 2014). Notwithstanding, simultaneously, the IoT has caught the consideration of the business world and society. IoT ideas lead to a few specialized difficulties that limit its broad adoption.

In IoT, sensors in gadgets are the vital piece of IoT structure. Consequently, mix of sensor networks with Internet, as a feature of IoT, works with countless smart network applications, for example, medical services support for distant regions, air contamination checking, ecological observing, and traffic congestion control and in this way, improves the life quality. In any case, accomplishing energy proficiency of sensor nodes and sending data packets from the sensor-based IoT gadgets to the server with a base conceivable delay is an incredible test (Salman et al., 2016). Among many network configuration issues like localization, scheduling of packet and data aggregation, routing the packets among IoT gadgets or sensors is exceptionally significant since it involves data delivery and energy effectiveness of such enormous network (Khanna et al., 2020).

IoT network, characterized by decentralized and restricted resources nature, is subjected to difficulties while designing algorithms for it that eventually limits its broad adoption. Considering these complications, it has been challenging to design routing protocols to fetch desired results and performance in the IoT environment. Along these lines, this work focuses around optimization of LOADng routing protocol suitable for IoT scenarios (Clausen et al., 2017). LOADng derived from AODV routing, is a reactive routing protocol dependent on route discovery utilizing RREQ and RREP messages (Sobral et al., 2019). Consequently, when a node needs to send an information message and the route to the destination is obscure, it should start a new route discovery process. In contrast to AODV, LOADng eradicates intermediate RREPs and precursor lists which reduces the complexity and control packet size. There are 12 major parameters of LOADng that can be estimated optimally for refining QoS in IoT. These parameters have some specified range from which the optimal value must be selected for the target QoS parameter. Nevertheless, to enhance the performance of the LOADng, the pursuing contributions are presented in this work.

- To enhance the performance of LOADng, Black Widow Optimization (BWO) algorithm is presented.
• Using this algorithm, the values of the parameters of LOADng protocol such as NET_TRASVERSAL_TIME, RREQ_JITTER, RREP_ACK_TIMEOUT and R_HOLD_TIME are chosen optimally.
• The evaluation of the proposed scheme is analyzed in terms of delivery ratio, delay and overhead.

Remaining sections of the paper are sorted as pursues. Section 2 surveys recent articles which presented research on routing in IoT. Section 3 presents optimized LOADng protocol using BWO algorithm for IoT. Results of the work are described in section 4. The conclusion of the paper is explained in section 5.

Related Works

In this segment, some recent research works which presented research on routing in IoT are reviewed. Abdellatif Serhani, Najib Naja and Abdellah Jamali (2019) had the objective to overcome the issue of routing due to the mobility of sensor node. To obtain the objective, they had presented reinforcement learning based adaptive routing protocol abbreviated as AQ-routing. Using this approach, routing metric of each node has been updated by detecting the mobility level at various points. The proposed protocol had included an innovative model which was developed with Q-learning scheme and an innovative metric known as Qmetric. Due to the proposed method, they had enhanced the link stability and packet delivery ratio.

N. Krishnaraj and S. Smys (2019) had the goal to enhance the power efficiency of the multihoming mechanism in IoT. So, the authors had developed an effective routing scheme in the multihoming mechanism. The proposed scheme included as Ant Colony Optimization ODMDV algorithm. The proposed routing protocol had provided better QoS policy and energy efficiency to the users. Due to the proposed method, they had decreased delay and energy consumption in multihoming networks.

Amol V. Dhumane1 and Rajesh S. Prasad (2017) had the objective that to increase the energy efficiency of the IoT network in terms of routing. To attain this objective, they had presented a multi-objective fractional gravitational search algorithm. Using this algorithm, the authors had selected the best cluster head for energy aware routing. For selecting the optimal cluster head, multi-objective functions such as energy delay and lifetime of link are used in the algorithm. Results of the literature depicted that the proposed algorithm obtained better network lifetime than the conventional algorithms.
Nitesh Chouhan and S. C. Jain (2020) had aimed to increase the energy efficiency and network lifetime of the IoT assisted WSN. To obtain this aim, the authors had presented Tunicate swarm Grey Wolf optimization algorithm based multipath routing protocol. Initially, they had selected optimal cluster head using Fractional Gravitational Search algorithm. Then, multipath routing was done using the Tunicate swarm Grey Wolf optimization algorithm. In this routing algorithm, the authors had considered trust factors and QoS parameters as fitness parameters. Due to the proposed schemes, the authors had obtained maximum network lifetime and maximum residual energy.

As congestion in IoT degrades the quality of network in terms of packet delivery ration and QoS, Saeid Jedari Jazebi and Ali Ghafari (2020) had proposed shuffled frog leaping algorithm abbreviated as SFLA based routing mechanism for IoT. Using the algorithm, the authors had found the content depend path between the pair of source and destination nodes. Using a suitable data aggregation method, lifetime of the network was improved as well as energy consumption was reduced. Results of the article depicted that the proposed method optimized the throughput, power consumption and network lifetime.

Fakhri Alam Khan, Awais Ahmad and Muhammad Imran (2018) had the objective to improve the network stability by suggesting effective routing scheme in IoT. To obtain their goal, the authors had proposed a modified percentage LEACH routing protocol abbreviated as PR-LEACH. The proposed routing protocol increased network lifetime by decreasing communication between sink node and cluster heads. For cluster head selection, the proposed protocol included threshold calculation and distance parameter of nodes from sink. Due to the proposed method, they had achieved high throughput.

Saif ul Islam et al (2020) had the goal to reduce overhead of geographic routing schemes in IoT. So, the authors had presented an energy effective geographic routing protocol abbreviated as EEG. The proposed protocol focused on energy consumption and network throughput. Using the protocol, node localization problem was solved by applying mean square error algorithm. Besides, routing overhead was decreased by limiting the nodes to keep information of single neighbour. By presenting the proposed geographic protocol, the authors had managed delivery ratio and energy consumption of the network efficiently.

**Optimized LOADng Routing Protocol Using BWO Algorithm for IoT**

**3.1. Overview**

Figure 1 depicts the workflow diagram of the proposed scheme. As shown in the figure, the IoT devices gather the data from the surroundings and send the collected data to the
destination. If the source is far away from the destination, it forwards the data through the intermediate devices between source and destination. So, in IoT, routing is the major challenge for minimizing the overhead and delay of the network. For routing, LOADng routing protocol is utilized in this paper. This protocol is the second version of AODV protocol. To enhance the performance of the LOADng, (Hayyolalam et al., 2020) black widow optimization (BWO) is presented. Using this algorithm, the values of the parameters of LOADng protocol such as NET_TRASVERSAL_TIME, RREQ jitter, RREP_ACK_TIMEOUT and R_HOLD_TIME are chosen optimally with the aim of plunging control overhead and delay.

![Figure 1 The workflow diagram of the approach](image)

### 3.2. LOADng Routing Protocol

As the LOADng protocol is the second version of AODV protocol, it includes the basic operation and characteristics of AODV. The routing process includes the route discovery packets such as Route Requests denoted as RREQs which is originated by the source device and Route Replies (RREPs) which is originated by the destination. Also, LOADng includes the unicast hop-by-hop forwarding of RREPs to the source. In this protocol, if the route between source and destination is failed to connect the communication, a local route repair message i.e., Route Error denoted as RERR message will be forwarded to the source.

In LOADng protocol, intermediate nodes are not allowed to reply to the RREQ even though they contain active routes towards the destination. Only destination is permitted to response to the RREQ. Gratuitous RREPs can be eliminated while confirming loop freedom as RREQ or RREPs a single unique, monotonically incrementing sequence number. This protocol never updates precursor list. Thus, RERR is only forwarded to the source if the data packet fails to reach the next hop on the route.
3.2.1. Control Messages

This protocol contains the following four types of control messages:

**RREQ**: This packet is generated by the source and forwarded to the destination. It has the address of the destination.

**RREP**: It is generated by the destination after receiving the RREQ from the source. As RREQ has the address of destination, destination is responsible to send reply for RREQ.

**RREP-ACK (RREP Acknowledgement)**: It is generated by the LOADng router. After receiving RREP from the neighbour, the router acknowledges to the RREP by the RREP-ACK message.

**RERR**: This packet is generated by a router on the route when a link is failed to forward the data packet.

3.2.2. Major Operations of the Protocol

LOADng protocol maintains the operations of AODV such as route discovery and route maintenance. These operations are described as follows:

**Route discovery**: In this phase. The source floods the RREQs messages through the network. This message will be forwarded until reach the destination. As shown in the Figure 2, the source S forwards RREQ to the destination D via intermediate nodes A and B. Besides, as shown in the Figure 3, the destination only responds to the RREQ of the source with a RREP which is forwarded in unicast.

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**Figure 2** Flooding the Route request (RREQ)

**Figure 3** Route reply (RREP)
Route maintenance: If a route between the source and destination fails, route maintenance will be executed. The failure of route is recognized when the data packet is not forwarded to the next hop to the destination. In this protocol, RERR is generated when the route fails. This RERR is forwarded in unicast towards the source. After receiving the RERR, the source initiates to discover new route. As this protocol eliminates precursor list, it employs end to end signalling. So, RERR is only forwarded to the source if the data packet fails to reach the next hop on the route.

Although LOADng provides efficient routing in IoT, its performance can be further improved in terms of routing overhead and delay. To enhance the performance of the LOADng, we focus to optimize the parameters which are listed in the Table 1. For optimizing these parameters, we present BWO algorithm. The next section explains the optimal section of the values of LOADng parameters using BWO.

Table 1: LOADng parameters

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>NET_TRASVERSAL_TIME</td>
<td>Maximum time for packets to traverse from one end to the other in the network</td>
</tr>
<tr>
<td>RREQ Jitter</td>
<td>Maximum jitter for the transmission of RREQ</td>
</tr>
<tr>
<td>RREP_ACK_TIMEOUT</td>
<td>Minimum time for which LOADng router should wait for an RREP_ACK for considering the link to be unidirectional</td>
</tr>
<tr>
<td>R_HOLD_TIME</td>
<td>Maximum time for a route is maintained in the routing table after the last transmission of a packet on this route</td>
</tr>
</tbody>
</table>

3.3. BWO based LOADng Routing Protocol

BWO can be portrayed through the one of a kind mating attributes of dark widow spiders. In BWO, the principal phase of the restrictive stage known as cannibalism. Spiders can be characterized as air-breathing arthropods that have eight legs additionally with venomous teeth. From the various kinds of organisms, these species are the 8-legged creature the bigger order which rank seventh fragmented species variety. From November 2015, taxonomists can record haphazardly 114 families with 4700 spider species. Moreover, dimension has been incremented within experts as to how complete these relations can be divided. This algorithm begins with an initial population of spider and every spider denotes a solution. These initial spider pairs attempt for reproducing the new generation during the procreate process. In this algorithm, the female black widow noshes male throughout and afterward mating. After that, the female black widow produces egg in sacks. After 11 days, new generation of spider comes out of egg sacs. Cannibalism process involves eating of
male spider by the female spider and spiderling competition for survival. The basic characteristics of BWO are described as follows,

**Initial population:** In this algorithm, each spider is considered as solution for the problem. The initialization of BWO is denoted as follows,

\[ W = \left[ X^1, X^2, \ldots, X^{N_{var}} \right] \]  

(1)

Where, \( N_{var} \) is denoted as a dimension of parameters, \( X^1, X^2 \) denote as the floating-point number and can be defined as follows:

\[ X^N = \{ S_1, S_2, S_3, S_4 \}^N \]  

(2)

Where, \( S_1 \) denotes the NET_TRANSVERSAL_TIME within the range [1-10s], \( S_2 \) denotes the RREQ Jitter within the range [0-1s], \( S_3 \) denotes the RREP_ACK_TIMEOUT within the range [1-10s] and \( S_4 \) denotes the R_HOLD_TIME within the range [1-10s].

**Fitness calculation:** After initializing the solutions, each solution is evaluated according to the fitness function. The fitness function is formulated as follows,

\[ F(W) = f \left[ X^1, X^2, \ldots, X^{N_{var}} \right] \]  

(3)

To mimic the algorithm, the candidate widow matrix is created with the early populace of spiders. Then, pairs of parentages were arbitrarily designated to execute the breeding process via breeding which the male black widow is plagued via the female before and after.

In this approach, to attain the optimal LOADng parameters, the solution is evaluated with the following fitness function,

\[ F(W) = \max \left( w_1 \cdot PDR - w_2 \cdot RO \right) \]  

(4)

Where, PDR defines the packet delivery ratio, RO defines the routing overhead, \( w_1 \) and \( w_2 \) denote the weight parameters. As Equation (4) addresses the maximizing function, RO is indicated with negative sign.

**Update the solution:** In this algorithm, the solution is updated using the following processes:
Procreate: In this algorithm, the pairs are independent. To reproduce new generation, they begin to mate in its web. Generally, 1000+ eggs are produced in every process of mating. At last, the spider babies grow and become strong. Besides, to reproduce new generation, an alpha array ($\alpha$) is produced as long as widow array of random numbers. Using $\alpha$ and pairs ($X^1$ and $X^2$), offspring is generated as follows,

$$\begin{cases} Y^1 = \alpha * X^1 + (1 - \alpha) * X^2 \\ Y^2 = \alpha * X^2 + (1 - \alpha) * X^1 \end{cases} \quad (5)$$

Above process can be continued at various occasions by haphazardly picked numbers that may not be copied. Finally, the array is arranged dependent on fitness parameters and the rate of cannibalism. Moreover, the ideal solutions are gathered to the new generated population.

Cannibalism: In this algorithm, the three various kinds of cannibalism are given. The initial one is known as sexual cannibalism that operation of a female widow chucks her husband before or after breeding. Second one is sibling cannibalism where weaker siblings are eaten by the stronger spiderlings. In particular cases, third cannibalism is observed, where mother is eaten by the baby spiders. Depend on the fitness value, weak or strong spiderlings is estimated.

Mutation: In this operation, the mute pop number is automatically chosen with the population. Every solution is chosen randomly transfers two elements in the structure of array. Depend on the mute pop, the rate of mutation is estimated.

Convergence: Like other algorithms, the stop condition is verified with three stages such as (1) arriving at the predefined accuracy level, (2) adherence of no variety in the value of fitness, and (3) a few iterations. This algorithm is practical in few optimization problems, the ideal solutions can be gathered. The stop condition was likewise verified.

The adaptive projected technique is utilized to select the optimal LOADng parameters. The BWO algorithm is enhanced with the help of the fitness function to empower the maximum PDR and minimum RO by selecting the optimal LOADng parameter. The complete flow diagram of the proposed method is illustrated in Figure 4.
Algorithm: Selection of optimal LOADng parameters using BWO algorithm

Input: LOADng parameters, procreate rate, cannibalism rate and mutation rate

Output: Optimal LOADng parameters

1. Initialize the widow or candidate solutions.
2. Calculate fitness for each solution using (4).

**Procreating and Cannibalism**

3. Choose two solutions as parents randomly from population 1.
4. Produce children based on the equation (5).
5. Demolish father.
6. Demolish some of the children depend on the cannibalism rate
7. Store the rest of the solutions into population 2.

**Mutation**

8. Determine the quantity of mutation children depend on the mutation rate.
9. Choose a solution from population 1.
10. Mutate the solution’s one chromosome and produce a new solution
11. Store the new solution into population 3.

**Updating**

12. Update the solution as population=population2+population 3
13. Steps 2-12 are proceed until attaining the optimal solution or optimal parameters of LOADng.
14. Otherwise the algorithm terminated based on the convergence.

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**Results and Discussions**

The proposed LOADng protocol based on BWO is simulated in the NS2. Table 1 illustrates the simulation setting. As shown in the table, varied number of nodes are deployed in the...
simulation area with the size 1000m X 1000m. Besides in this simulation, 802.11 MAC standard and constant bit rate (CBR) based traffic source are used. The data packets are transmitted at the rate of 500kbps and the size of each packet is 512 bytes. For routing the data packet, the LOADng routing protocol is used. Simulation time for each approach is 100 secs. Besides, the values of the parameters of BWO algorithm are defined in the table. The values of procreate rate, cannibalism rate and mutation rate are 0.6, 0.44 and 0.4 respectively. These values are defined in. Table 3 shows the optimized values of LOADng parameters.

Table 2 Simulation setting

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Assumptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Nodes</td>
<td>50-100</td>
</tr>
<tr>
<td>Area</td>
<td>1000m X 1000m</td>
</tr>
<tr>
<td>MAC</td>
<td>802.11</td>
</tr>
<tr>
<td>Packet size</td>
<td>512 bytes</td>
</tr>
<tr>
<td>Rate</td>
<td>500Kbps</td>
</tr>
<tr>
<td>Traffic Source</td>
<td>CBR</td>
</tr>
<tr>
<td>Simulation time</td>
<td>100secs</td>
</tr>
<tr>
<td>Propagation</td>
<td>TwoRayGround</td>
</tr>
<tr>
<td>Antenna</td>
<td>Omni antenna</td>
</tr>
<tr>
<td>Routing protocol</td>
<td>LOADng-BWO</td>
</tr>
</tbody>
</table>

BWO algorithm

<table>
<thead>
<tr>
<th>Parameters</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Procreate rate</td>
<td>0.6</td>
</tr>
<tr>
<td>Mutation rate</td>
<td>0.4</td>
</tr>
<tr>
<td>Cannibalism rate</td>
<td>0.44</td>
</tr>
</tbody>
</table>

Table 3 Optimized values of LOADng parameters

<table>
<thead>
<tr>
<th>Parameters</th>
<th>P2P</th>
<th>MP2P</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>For 50 Nodes</td>
<td>For 100 nodes</td>
</tr>
<tr>
<td>NET_TRAVERSAL_TIME</td>
<td>2.8</td>
<td>4</td>
</tr>
<tr>
<td>RREQ MAX Jitter</td>
<td>0.4</td>
<td>0.5</td>
</tr>
<tr>
<td>RREP_ACK_TIMEOUT</td>
<td>0.4</td>
<td>0.6</td>
</tr>
<tr>
<td>R_HOLD_TIMEOUT</td>
<td>8</td>
<td>6</td>
</tr>
</tbody>
</table>

4.1. Performance Analysis

The performance of the proposed LOADng-BWO routing protocol is analyzed under two scenarios that are point to point scenario (P2P) traffic and multipoint to point (MP2P) traffic. The performance of LOADng is evaluated in terms of delay, control overhead and deliver ratio. Besides, the proposed LOADng-BWO routing protocol is compared with the conventional LOADng routing protocol.
4.1.1. Scenario 1: Point to Point (P2P) Traffic

In this scenario, the pair of one source and one destination is considered. The comparison between different routing protocols in terms of delay is shown in Figure 5. The average delay of LOADng-BWO is reduced by 28% than that of LOADng protocol as the parameters, NET_TRAVERSAL_TIME and RREQ_JITTER, of LOADng have been optimally selected using BWO algorithm. The packet delivery ratio of LOADng-BWO is similar to that of LOADng. Figure 6 shows the comparison between different routing protocols in terms of overhead for varying number of nodes. As shown in the Figure 7, compared to LOADng protocol, overhead of the LOADng-BWO protocol is reduced to 15%. The optimized value of RREQ_JITTER and R_HOLD_TIME, results in reduced number of collisions and control packets thereby reducing control overhead.
4.1.2. Scenario 2: Multipoint to Point (MP2P) Traffic

In this scenario, multi-source nodes and one destination node are considered i.e., one destination node is considered for varied number of source nodes (49-99) in this simulation. Figure 8 depicts the comparison of the delay of the various routing protocols for varying number of nodes. The delay of LOADng-BWO is reduced to 67% than that of the LOADng protocol as the parameter RREQ_JITTER is optimized using BWO in LOADng. Compared to LOADng, delivery ratio of the LOADng-BWO is increased to 14% as illustrated in Figure 9. Besides, compared to LOADng, the proposed LOADng-BWO protocol achieves 56% lesser overhead in Figure 10.
To overcome the issue of routing overhead and delay in IoT, an optimized LOADng is presented in this paper. To enhance the performance of LOADng, the parameters such as NET_TRANSVERSAL_TIME, RREQ_JITTER, RREP_ACK_TIMEOUT and R_HOLD_TIME have been chosen optimally using BWO algorithm. The performance of the optimized LOADng has been evaluated under different scenarios P2P and MP2P and has been analyzed in terms of delay, delivery ratio and overhead. Results of the paper depicted that the proposed LOADng-BWO routing protocol achieved 28%, 100% and 15% of delay, delivery ratio and overhead respectively under P2P scenario. Moreover, it
achieved 67%, 14% and 56% of delay, delivery ratio and overhead respectively under MP2P scenario. Further, work can be done to assess and improve the energy consumption and network lifetime of LOADng routing protocol with these optimized parameters.

References


