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Research article

INTEGRATING AFRICAN BUFFALO OPTIMIZATION ALGORITHM IN AODV ROUTING PROTOCOL FOR IMPROVING THE QOS OF MANET

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Abstract
A Mobile Ad-Hoc Network (MANET) is made up of wireless mobile nodes that do not require a central infrastructure or administration to establish a network. It is possible for the MANET nodes to function as a router or host. MANET works with an independent multi-hop mobile network which can be used in several real-time applications. Thus, an important issue associated with MANET is the identification of paths with high-level Quality of Service (QoS), like topology. The purpose of having a QoS-aware protocol in MANETs is to enable the discovery of paths that are more efficient between the source and destination nodes of the network and hence, the need for QoS. In this paper, a novel algorithm which can be used in the African Buffalo Optimization (ABO) to improve the QoS of routing protocol MANETs. With ABO, path selection is optimized in the Ad-hoc On-demand Distance Vector (AODV) routing protocol. Results of the test revealed that when ABO is used in AODV, delay and energy-aware routing protocol is manifested.
Keywords: Mobile Ad-Hoc Network (MANET), Quality of Service (QoS), Ad-hoc On-demand Distance Vector (AODV), African Buffalo Optimization (ABO).

抽象: 移动 AD-HOC 网络（MANET）由无线移动节点组成，无需中央基础设施或管理来建立网络。MANET 节点可以用作路由器或主机。MANET 与独立的多跳移动网络协同工作，可用于多种实时应用。因此，与 MANET 相关的一个重要问题是识别具有高级服务质量（QOS）的路径，如拓扑。在 MANET 中具有 QOS 感知协议的目的是使得能够发现在网络的源节点和目的地节点之间更有效的路径，并因此需要 QOS。本文提出了一种新的算法，可用于非洲水牛优化（ABO），以提高路由协议 MANET 的 QOS。使用 ABO，路径选择在 AD-HOC 按需距离矢量（AODV）路由协议中得到优化。测试结果显示，当 ABO 用于 AODV 时，表现出延迟和能量感知路由协议。

关键词：移动 AD-HOC 网络（MANET），服务质量（QOS），AD-HOC 按需距离矢量（AODV），非洲水牛优化（ABO）。

I. INTRODUCTION

Mobile Ad-hoc Network (MANET) which is made up of the mobile node, is a self-starting dynamic network, in which packets are voluntarily transmitted by every participating node to the destination by means of wireless transmission. [1] In MANET, it is presumed that all the nodes are dynamic and having comparative speed in a random direction. [2] Therefore, ensuring that the path from one node to another lasts for long is difficult. The use of MANET in emergency operations such as monitoring of animal habitat, military operations and disaster and relief operation is highly beneficial. [3] More so, MANET can be used in a situation whereby there is a need for the establishment a communication network for the purpose of seminar or conference in a new place with no existing infrastructure; MANET serves as an alternative. [4]

The provision of quality of service in mobile and wireless networking environments has become necessary due to the advent of real-time applications and the global use of the mobile and wireless network. QoS in MANET is influenced by different parameters like end-to-end delay, throughput, jitter, packet delivery ratio, etc. [5] In order to improve the parameters, the algorithm, protocol and mechanisms are modified.

The main contribution of this paper is the integration of the ABO algorithm with AODV routing protocol with the aim of improving the general QoS requirement by optimizing the mechanism of path selection. It is important to note that there are so many advantages possessed by the ABO algorithm, which include efficiency, convenience, reliable with a simple algorithm that can be applied in the exploration and exploitation of search space with MANET environment.

This paper is made up of seven sections. The next section contains related work. In Section 3, the material and methods are presented, while section 4 contains an illustrates the proposed model. Section 5 contains the simulation environment, while the result and discussion are described in section 6. In section 7 the conclusion of the study is discussed, and the future work is present.

II. RELATED WORK

The QoS of routing protocols has many weaknesses which include, security issues [6], high consumption of energy [7], delay [8], overhead [9] and lots more. It is based on the presence of these weaknesses that many researchers have proposed algorithms that can be applied in MANETs. [10], [11], [12] Below is a list of some of such algorithms:

It is essential for mobile wireless networks to be power aware, especially MANETs. In MANETs, the lifetime of the battery is prolonged through the reduction of power consumption by nodes. [13] proposed a source-based algorithm known as the energy-efficient delay-constrained multicast routing algorithm, which prioritizes the consumption of energy and end-to-end delay in the selection of routes. Operations like mutation and crossover are directly applied to trees in the proposed algorithm, thereby simplifying the coding operation and omitting the process of coding/decoding. The overall consumption of energy of a multicast tree can be reduced using the heuristic mutation technique.

In order to improve the QoS routing, and integration of the fuzzy logic with genetic algorithm was carried out by [14]. It is not possible for the exact information of the global network to be protected for nodes of a real dynamic network. Therefore, QoS parameters were fuzzed and then using genetic algorithm became fuzzed for the optimization of the fitness function. In another study that focused on multiple QoS routing algorithm, an algorithm was introduced based on the genetic algorithm. [15]

One of the several kinds of intelligent methods applied in QoS multiple routing is an

Evolutionary Optimization (EO) strategy. In their work, they proposed an evolutionary multi-purpose quick method as a Multi-Objective Evolutionary Algorithm (MOEAQ) to enable the discovery of QoS optimized path. They found that the proposed algorithm outperformed the original version in terms of convergence and a high level of diversity. More so, it was observed that the proposed algorithm is capable of producing more favorable outcomes in comparison with a popular routing algorithm that is based on GA. Several intelligent methods can be compared to perform QoS routing. [16]

Based on the swarm behavior of animals, another new and state-of-the-art field is the swarm intelligence that was introduced. [17] Natural evolution is triggered by the cellular model from the individual's perspective, through which a definite (search, learning and optimization) problem solution is encoded. Evidence has been provided for the Cellular Automat's (CA) ability to efficiently resolve different complex systems like MANET as well as other issues in different applications like routing. [18]

III. Material and Methods

A. Ad-hoc On-demand Distance Vector

Title Ad-hoc On-demand Distance Vector (AODV) is one of the reactive protocols that have the capability of routing as the need arises. The main purpose of AODV is to decrease routing load, and it is a kind of distance vector routing that does not require the presence of nodes for the maintenance of routes from source to destination. For the discovery and maintenance of routes, various route messages like Route Reply (RREP), Route Errors (RERR), Route Request (RREQ), and Route Errors (RERR) are used. A destination sequence number is used by AODV for each route that the destination node creates for any request to the nodes, and afterwards, the discovery of a route possessing maximum sequence number is made, and chosen for the maintenance of the link. [19] A new route is discovered when the route request message is sent by the source node to neighbouring nodes that are within the network till an active route is found or destination is reached. The moment a route is discovered; a route reply is sent back to the source node. Communication occurs among the nodes that are on an active route; they occasionally send hello messages to intermediate neighbours. In an event that the reply message is not received by the node, then the node is deleted from the list and a route error message is sent to all the members within the route. [20], [21] The mechanism of route establishment in the AODV protocol is illustrated in Figure 1 below.

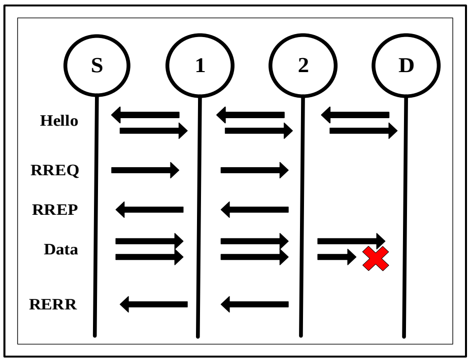

Figure 1.The AODV protocol

B. African Buffalo Optimization

On the meta-heuristic algorithms that have been developed in recent times is the African Buffalo Optimization (ABO), which was proposed by [22]. The ABO is capable of mimicking and using the efficient management and communication style of the herd during migration. In the process of decision-making, they demonstrate voting behaviour, and the decision of the majority controls their mobility. The use of two sounds (maaa and waaa) is employed in their mobility for the purpose of exploring and exploiting. The buffalos are made to remain on for the purpose of exploiting the current location since it has adequate pasture and safety. On the other hand, the use of the "waaa" sound is employed in the exploration of other locations due to the fact that the pasture of the current location may be inadequate. The search of the buffalos is optimized using these sounds so as to get the food regions that are fruitful. A mathematical representation of this is given according to (1) and (2) respectively.

$$mk+1 = mk + lp1\ (bgmax - wk) + lp2\ (bgmax.k - wk) \quad (1)$$

where mk denotes a "maaa" sound with a specific reference to a buffalo k (k = 1,2,3, … n) , the best buffalo within the herd is represented by $bgmax$, while $bgmax.k$ denotes the best location which an individual buffalo k finds, $lp1$ and $lp2$ represent the parameters of learning ∈ [0,1]. Through the use of (1), $mk+1$ indicates that the buffalo has relocated from the current location mk to a new location that is reflective of the large memory capacity in the migration lifestyle. The mathematical representation (2) achieves the real adjustment of herd mobility.

$$wk+1 = (wk+mk)\ /\lambda \quad (2)$$

where the migration to a new location is denoted by $wk+1$, wk represents the values of the current exploration representing "waaa" sound, while mk is the current exploitation values, and λ connotes a parameter that specifies the unit of time the interval over the buffalo movement and is often set to 1. The ABO algorithm is described by the algorithm below through the initial placement of random of the kth buffalos within the solution space. Based on the adjustment made to the buffalo's mobility during the iterations, the last optimum result is obtained. Each buffalo's value of fitness is obtained during each iteration, with the optimum one being allocated to $bgmax$ (i.e., the best global one), while the best for each individual is allocated to $bgmax.\ k$ (i.e., the best local one). The location of each buffalo is updated by the buffalos themselves, and the movement of the buffalo occurs based on the optimum neighboring buffalo according to (1) and (2). Through this update, the mobility of the buffalos towards the best solution is enabled and tracked see figure 2 illustrate ABO procedure.

Algorithm: ABO algorithm

Step 1: Initialization

Randomly initialize k^{th} buffalos' location on solution space

Step 2: Evaluation of buffalos' fitness value and assigning the herd's best to bg_{max} and individual buffalo's best to $bg_{max.k}$

Step 3: Update (exploitation move)

Update the buffalos' fitness value according to (2)

$$m_{k+1} = m_k + lp1\ (bg_{max} - w_k) + lp2\ (bg_{max.k} - w_k)$$

Step 4: Update (exploration move)

Update the movement of buffalo according to (3)

$$w_{k+1} = \frac{(w_k + m_k)}{\lambda}$$

Step 5: Is bg_{max} updating? Yes, go to step 6. No, go to step 1.

Step 6: Check the validation of stopping criteria; if satisfied? Yes, go to step 7. No, go to step 2

Step 7: Return the best solution so far.

Figure 2.The ABO procedure

problems, and afterwards, they compared the results of their Improved Genetic Algorithm (IGA) with Genetic Algorithm (GA). In a study carried out by [24], the convergence of African Buffalo Optimization was studied in terms of the trade-off between exploration and exploitation. More so, the use of ABO was employed in solving the problem of a travelling salesman. [25] In their study, the described the functionality of the algorithm in terms of its ability to solve this kind of problem, and they also carried out a comparison of the hybrid algorithm and colony algorithm. More so the ABO was compared with the randomized insertion algorithm that performed better as a solution to the problem. However, it was found that the speed of the ABO is higher. The results of their study showed that the ABO demonstrated higher efficiency compared with others such as GA, ACO, and PSO in terms of obtaining the nearest solution in all the test cases that were investigated.

IV. B-AODV

Generally, two kinds of messages known as RREP and RREQ are used by the AODV routing protocol to create a path. For the discovery of all the possible routes to the destination, the RREQ is broadcasted by the source node. After the RREQ message is received by the destination node, an RREP message is then sent by the destination node to the source node. Nonetheless, the path selection by AODV is dependent on the first RREP with less delay instead of using other parameters like nodes level of energy. Through the use of this mechanism, the nodes in the path get exhausted, and the chances of link failure are increased. The QoS of the network is negatively affected by the link failure, as it leads to a higher rate of energy consumption, throughputs and end-to-end delay. For the buffalo to ascertain the kinds of objects, many buffalos are sent in diverse directions within the search space. In addition, the water, security of a location and quantity of grass are all calculated by the buffalos. In order for the buffalo to make a selection of the best position for the herd, it employs the use of two kinds of sounds. Through these messages, the condition of the location within the search space is known. When the pasture is good, the buffalo makes the “maaa” sound, while a dangerous location is indicated by the “waaa” sound. Most specifically, the ABO is assisted by these parameters in discovering and determining the objects within the space.

In this study, it is observed that there are many similarities between the buffalo’s nature and the process of routing in MANET in terms of identifying the optimum location to pasture. As earlier stated, MANET has a different kind of routing protocols, and all of them are aimed at establishing the best route from the source nodes to the destination nodes. The process of routing involves making a path by sending of RREQ message to the network, while the RREP message is received from the destination node by the source node. Subsequent to this, the path is selected by the routing protocol based on certain criteria like minimum delay, minimum hop count, the maximum level of energy, etc.

In the current study, an integration of the ABO algorithm and AODV routing protocol is carried out with the aim of improving the selection of path, rather than the mechanism of selection that uses minimum delay as criterion. In the proposed B-AODV, path selection is done using the three most significant parameters which include a number of hops, delay and energy. With these parameters, the chances of a link failure can be reduced thereby building a path that is robust, while enhancing prorogation of network lifespan. When this is achieved, the loss of packet reduces while the data which the destination node receives increases.

The mechanism of B-AODV is represented in the following algorithm. It is an illustration of the steps involved in the selection of rout in B-AODV protocol. In the first place, an RREQ is broadcasted by the source node for the purpose of discovering a particular destination. The second step involves the destination node sending an RREP to the source; this mechanism is used in the discovery of every possible route between the source and destination nodes. In the subsequent step, all routes are kept by the B-AODV, which also performs an evaluation of their quality using three parameters including delay, energy and number of hops. More so, based on high quality the routes are sorted by the B-AODV. Lastly, the best route is chosen for the forwarding of data to destination nodes.

$$No.of\ h瑚ps = \sum_S^D nn \quad (3)$$

$$Delay = \sum_S^D \Delta T / nn \quad (4)$$

$$Energy = \sum_S^D Energy_{nn} / nn \quad (5)$$

where $\Delta T = Time_{receive} - Time_{sent}$, nn represent the number of nodes within the path. The source and destination nodes are represented by S and D, respectively.

Pseudocode of B-AODV

```
00  begin
01  while (t < Max number of iterations)
02      Initial population by ABO algorithm;
03      Randomly initialize K_th buffalos' location on the search space;
04      Compute the source and destination nodes;
05      Analysis of the sound that comes from each buffalo in the search space;
06  if (sound == "waaa")
07      go to step 02;
08  else
09      Gathering all possible paths with sound ("maaa");
10  end-if
11      Analyse the possible path based on the values of the parameters (energy, delay, No. of hops);
12      Select an optimal path among all possible path based on equations (3-5);
13  end-while
14      Post results and visualization;
15  end;
```

V. SIMULATION ENVIRONMENT

In this study, the simulation was carried out using different scenarios and performance metrics with the aim of demonstrating the efficiency of the proposed technique. The performance metrics and scenarios used in the current study are represented in Figure 3.

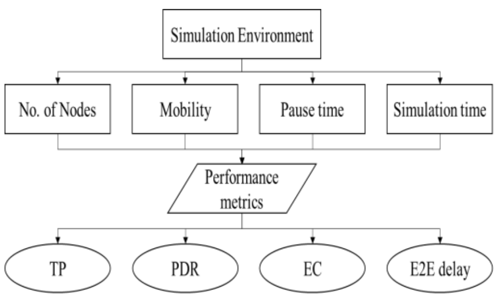

Figure 3.The performance metrics and scenarios

A. Simulation Scenario

a) The Effects of the Node Mobility

In this scenario, the performances of the routing protocols were evaluated using diverse nodes mobility including 5, 10, 15, 20, 25 (m/s) as well as other standard parameters such as number of nodes (325 node), pause time (50 seconds) and simulation time (300 seconds).

b) The Effects of the Number of Nodes

Through the use of this scenario, the performances of the routing protocols were evaluated using different number of nodes including, 25, 125, 225, 325, 425, 525, 625 (node) alongside other specified parameters such as pause time (50 seconds), nodes mobility (15 m/s) and simulation time (300 second).

c) The Effect of Pause Time

In this scenario, the routing protocols' performances were assessed through the use of a variety of pause time which include, 10, 30, 50, 70, 90 (second) alongside other defined parameters such as nodes mobility (15 m/s), number of nodes (325 node) and simulation time (300 second).

d) The Effect of Simulation Time

The use of this scenario was employed in order to assess the routing protocols' performance using different simulation time which include, 50, 100, 150, 200, 250, 300 (second) as well as other fixed parameters which include, mobility of nodes (15 m/s), number of nodes (325 nodes) and pause time (50 second). The parameters which were used for simulation in this study are given in Table 1 below.

Table 1. Simulation Parameters [26]

Parameter	**Value**	**Unit**
Area	3000	m^2
No. of nodes	25, 125, 225, 325, 425, 525, 625	Node
Simulation time	50, 100, 150, 200, 250, 300	Second
Mobility	5, 10, 15, 20, 25	m/s
Traffic type	CBR	
Packet size	64	Byte

Pause time	10, 30, 50, 70, 90	Second
Transmit power	1.4	Joule
Reception power	1.0	Joule
Idle power	0.05	Joule

B. Performance metrics

The behaviors of the protocols were evaluated by converting the speed of the nodes to the following: (5, 10, 15, 20 and 25), alongside a node density of 625 nodes. The nodes were distributed in Random Way Point (RWP) within 3000m2, packet size 512; the traffic is controlled by CPR and pauses time is 5ms. The following are the various performance indicators used in the evaluation of the protocols' performance:

a) *Packet delivery ratio (PDR)*
The ratio of the Data Delivered (DD) to the destination node to the Data Transmitted (DT) by the source.

$$PDR = \frac{DD}{DT} * 100 \quad (6)$$

b) *End-to-end (E2E) delay*
This metric indicates the time duration for the transmission of a data packet from source to destination.

$$E2E\ delay = \frac{\sum_{i=1}^{n} \Delta\, \mathrm{T}}{n} \quad (7)$$

c) *Throughput (TP)*

This metric is equal to the number of bytes which the destination has received successfully.

$$\mathrm{TP} = \left(\frac{(\sum bytes\ received) * 8}{simulation\ time}\right) * 1000\ kbps \quad (8)$$

d) *Energy Consumption (EC)*

Defined as the amount of energy which the nodes in the network have consumed within a given period of simulation.

$$EC = \sum_{i=1}^{n} (ini(i) - ene(i)) \quad (9)$$

VI. Result and Discussion

The results obtained from the different mobility of nodes for two routing protocols (original AODV and B-AODV are presented in figure 4. Based on the results, both routing protocols are negatively affected by the mobility of nodes because as the nodes mobility increases, the possibility of link failure becomes higher. However, the performance of the B-AODV is better than that of the standard AODV. This is as a result of the robust route which is built by B-AODV based on varying parameters such as a minimum number of hops, thereby reducing the possibility of link failure.

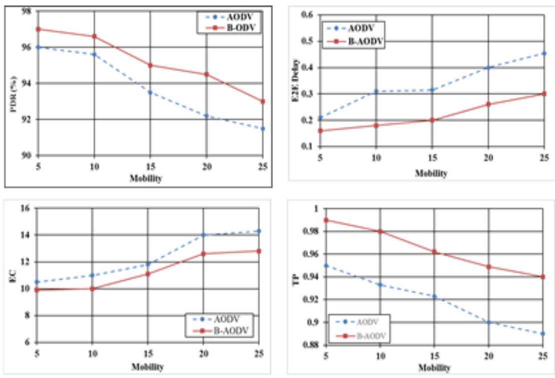

Figure 4.The Mobility of Nodes

Figure 5 shows the results obtained by using a varying number of nodes for two routing protocols which are the proposed B-AODV and the standard AODV. From the result, it is obvious that the proposed approach outperforms the standard one in terms of TP, PDR, EC, and E2E delay. The reason for this is that the moment a path is discovered by the B-AODV, then all the packets are transmitted using the same path. This path utilizes the highest level of energy. Thus, there is no need for wastage of battery power, since the task of route discovery is not performed by intermediate nodes. In addition, the results indicate that an increase in the number of nodes leads to an increase in the protocols' performance. This also results in a more stable and easier connection between the source nodes and destination nodes.

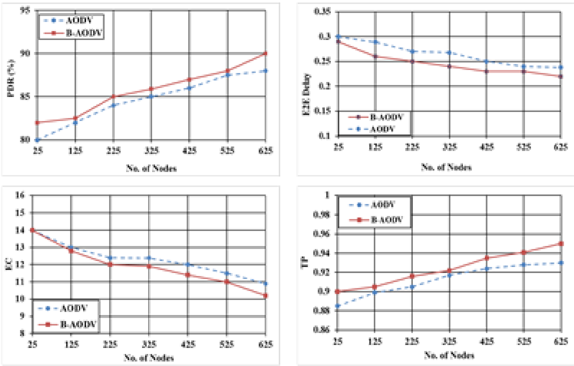

Figure 5.The Number of Nodes

Figure 6 shows the results for the different pause time of nodes for the two routing protocols. Based on the results, the proposed B-AODV outperforms the original AODV in terms of all the performance metrics used for the evaluation. This is attributed to the fact that the route with the least delay, the highest level of energy, the fewer number of hops and fast transmission of the packet over the network is selected by the B-AODV. In addition, the probability of ink failure reduces as the pause time increases, thereby increasing the overall network stability and data which the destination node receives.

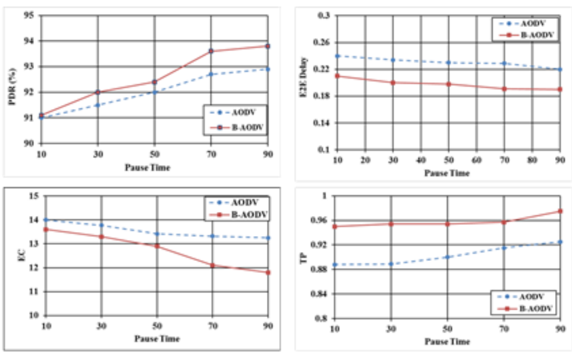

Figure 6.The Pause Time of Nodes

The effect of a change in simulation time on TP, E2E delay, PDR and EC on the two protocols is shown in Figure 7. Based on the results, the proposed protocol outperforms the standard AODV, due to the ability of the B-AODV to choose path using various criteria such as the path with a fewer number of hops, highest level of energy and less delay. It was also found that the stability of the network is positively affected by all these parameters, and they also enable the attainments of QoS goals. Conversely, the time used in the establishment of a connection between the source and destination nodes increases as the simulation time increases, thereby, prolonging the lifetime of the route and reducing the packets drop. Future attempts will consider the application of new intelligent techniques such as [26], [27], [28], [29] in the MANET routing optimization protocols.

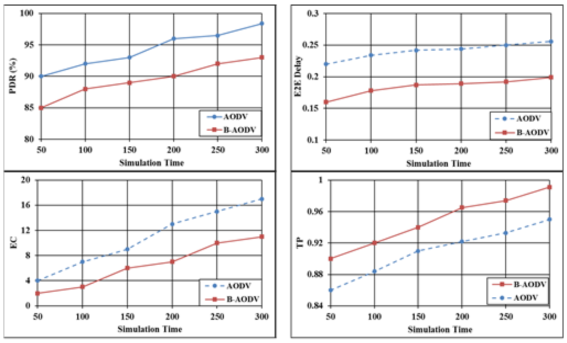

Figure 7.The Simulation Time

VII. CONCLUSION

The need for digital data exchange outside the abstract office environment has been on the increase. For instance, the exchange of relief data subsequent to an earthquake or a flood may be required by a disaster recovery team or even business delegates that meet at an airport by coincidence and need to exchange data. In MANET, each device that is used by these producers and consumers of data is known as a node. One of the technologies that have promising benefits is the wireless ad hoc networking because it enables the retrieval of services and information electronically, regardless of their geographical location. In ad hoc networks, communication occurs over wireless media between stations in a peer to peer manner without requiring a wired, base station or access points. Due to it has several advantages, MANET has been an attractive area for study. Straightforwardness reduced cost, and effortless utilization process has been increased the popularity of MANET in numerous applications. It has been different studies that intended at improving the MANET resources like energy, QoS, and bandwidth. The improvement of MANETs leads to building a new application that not applicable in a traditional network. In this paper, one of the popular routing protocols in MANET is improved by integrating with the newest optimization algorithm. The AODV protocol integrated with ABO algorithm to produce a new protocol called B-AODV. This protocol employs different criteria to build a robust path from source to destination nodes as well as overcome the problems that appeared in traditional AODV protocol. The result showed that B-AODV is superior in all performance metrics when compared with standard AODV routing protocol. MANET is considering an attractive topic in research field due to it has several advantages such as easy installation, less cost and time. However, MANET is still having several problems that require to be tackled. For this reason, this paper attempt to tackle one of these problems via integrating a new algorithm that focuses on improving the path selection process by using several quality parameters (like; energy, delay, and number of hops). On the other hand, the door is still open to propose a new model or implement a new algorithm to increase the percentage of enhancement in different aspects such as path selection, security, and bandwidth.

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