A Multi-Agent Ad Hoc On-Demand Distance Vector for Improving the Quality of Service in MANETs

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***Abstract*— The field of mobile communication has experienced great changes and growth since the advancement of computing devices and wireless technology. The need for mobile networks with minimal infrastructure that can be easily used, has been aroused by the mobility advancement of people around the world. Such kind of networks is known as Mobile Ad-hoc Networks (MANETs). The Ad Hoc On-Demand Distance Vector (AODV) is a popular routing protocol in the MANETs. Nevertheless, one issue of the AODV is the selection of routes based on minimum delay alone. Even though the delay is a significant parameter that has a direct effect on the performance of the network, other parameters such as energy consumption are necessary to establish efficiency routes. Therefore, this paper proposes employing a Multi-Agent System (MAS) for the establishment of efficient routes from the source to destination nodes in AODV, namely MAAODV protocol. The agents utilize the parameters of energy consumption, number of hops and delay to optimize the selection of the routes. The paper presents a simulation scenario to show the applicability of the proposed MAAODV routing protocol.**

Keywords*— Mobile ad hoc network (MANET), Ad Hoc On-Demand Distance Vector (AODV), Multi-Agent System (MAS), Quality of Service (QoS).

I. INTRODUCTION

The emergence of portable computing devices and wireless communication technology in recent times has resulted in the rapid growth in the number of mobile terminal users. A MANET is a multi-hop wireless network in which the network components such as personal computers, personal digital assistants and wireless phones are mobile [1],[2]. In general, the nodes within the MANET serve as routers. While communicating with other nodes, these nodes roam freely. The use of the MANET is more suitable in cases of unavailability of infrastructure and/or expensive deployment of node mobility. The MANET can be used in the construction of an affordable network anywhere, as it is effective and requires no specialized access points or nodes. It is regarded as a good option for application in networks in situations of emergency or disasters. More so, the nodes in the MANET are able to communicate with each other without a supervisor, because of the presence of a distributed control system [3],[4].

Despite the advantages possessed by the MANET, it also has some limitations which are absent in fixed networks. For instance, the mobility of nodes which results in a regular change in network topology, thereby causing the huge flow of information to the network [5],[6]. Some other limitations of the MANET include the small capacity of batteries and limited bandwidth for wireless channels. Again, communication may become impossible and the quality of services may depreciate as a result of data access that is focused on a single point [7]. Efforts have been made by many researchers to provide solutions to these problems through the use of various optimization algorithms. Various algorithms such as Genetic Algorithm [8], Ant Colony Optimization [9], Particle Swarm Optimization [10], Simulated Annealing [11], Invasive Weed Optimization [12], Tabu Search [13] and MAS [14], have recently been used to solve the problem of the routing protocol. Even though these algorithms are implemented with the aim of solving a common problem, they are all implemented using various kinds of routing protocols. However, the MANET has several routing protocols with the common ones being, hybrid, reactive and proactive protocols.

Routing information, in proactive routing like OLSR, is stored in a table which is constantly updated when any change in the topology occurs. Through the periodic exchange of information between nodes, the routing table is established in advance [15]. In doing this, a considerable amount of battery power and bandwidth is consumed. However, at the time packets are being sent, no overhead is incurred. The level of effectiveness is higher with less mobility of nodes and a larger number of packets.

The best route in reactive routings such as AODV is ascertained anytime the request of sending a packet occurs. Since a route is determined based on demand, the routing overhead is less than that of proactive routing [16]. Nonetheless, the absence of route, results in the flow of a large number of messages, because a request is announced by the source node. The effectiveness of this protocol is high when

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there is less number of packets and high nodes mobility. ZRP is a hybrid model of proactive and reactive models [17].

There are five sections contained in this paper. In the first section, the introduction is presented. The second section contains the problem analysis. The third section presents the review of the literature. The fourth section contains the MAAODV framework. Then in the fifth section, presents the conclusion and future work.

II. Problem Analysis

Most of the routing protocols establish a route based on the minimum delay, without paying attention to other parameters like energy. This is done by ignoring the fact that one of the most significant purposes of designing MANETs is the efficiency of energy, as the operation of mobile nodes requires batteries with limited abilities. The capability of nodes to transmit packets on behalf of others is disturbed by power failures, which in turn has an indirect effect on the entire lifespan of the network.

Thus, the introduction of effective and accurate routes among node pairs, where the most crucial objective of the standard of routing is to maintain the functionality of the network for as long as possible, becomes paramount. There is a need for the energy-efficient routing and optimization in MANETs to handle the negotiation-based scheme without negotiating either the energy or other related parameters like information rate, distance and delays. Therefore, the designing of techniques must be done in such a way that attention is paid to the reduction of compromises that enhance the increase in network population. In this paper, efforts are made to improve the AODV protocol route selection, through the integration of MAS and the MANET.

III. Literature Review

A. The QoS in the MANET

Various heuristic and artificial Quality of Service (QoS) routing algorithms for MANETs have been proposed by many researchers [4]. When designing mobile wireless networks, especially, the MANETs, the power usage is an important factor to be considered. A decrease in the energy consumption of the nodes can occur if there is an increase in the battery life of nodes. A multicast routing algorithm, which is delay-constrained and energy-efficient has been suggested in one study; the algorithm is source-based and puts into consideration end-to-end delay as well as energy consumption while routes are being selected. In this algorithm, there is a direct application of the mutation and operations on the trees, thereby resulting in the simplification of coding operations through the omission of the coding/decoding process. The entire consumption of power of the multicast tree is improved through the heuristic mutation procedure.

The fuzzy genetic algorithm is employed by [18] for QoS routing, because when the nodes belong to a dynamic network, obtaining accurate information about the protection status of the global network becomes impossible. The QoS parameters are regarded as fuzzy sets, hence the application of genetic algorithm with fuzzy logic during the optimization of the fitness function. In another work, the multiple QoS routing algorithm based on only the genetic algorithm is used [19]. The Evolutionary Optimization (EO) strategy is another meta-heuristic method which has been used in the processes of QoS multiple routing [20].

An evolutionary multi-purpose quick process known as the Multi-Objective for the purpose of determining the optimized QoS route is proposed by some researchers. In comparison to the conventional technique, this process improved the convergence results alongside providing a higher diversity. This algorithm is regarded as an algorithm that outperforms the widely known Genetic Algorithm (GA)-based algorithm [20], which is generally used for solving problems that are related to search and optimization [21]. A comparison of the QoS routing problem with several other techniques has been carried out by some researchers [22]. The Swarm intelligence technique, which is a modern technique based on the swarming behaviour of different animals, is among these techniques [23]. It is noteworthy that the natural evolution can be stimulated by the cellular model based on the perspective of an individual, which has the ability to encode a possible problem solution (search, learning and optimization).

There are diverse analyses performed with energy efficiency for which schemes are designed for infrastructure less network of wireless smart insignias for obtaining data from the confined administrator. The aim of this is to perform an analysis of energy effective routing issues that are created in the network and use smart insignias with very limited energy supplies and minimal information rates that are inadequate for cases of disaster. The issue is designed as an anycast routing scheme with the intention to exploit the time till the initial power supply trench outs. The main aim of designing routing schemes that are energy-conscious for MANETs, is to reduce the energetic transmission of energy which is required for the broadcast or acquisition of information packets, or to reduce the sedentary energy which is used during the idle state snooping the wireless channel for any probable transmission demands from rest of the nodes [24].

The fuzzy based logic altered AODV routing protocol for multicast routing in the MANET is also employed. A linkage is established between the independent devices based on the demand of the device that carries out transmission over a wireless channel with all the available energy in the MANET. The lifespan of the node determines the transmissions that occur within these networks, and the nodes lifespan is dependent on battery power of the node. Therefore, in order to increase the lifespan and transmission time, optimization must be performed. The purpose of this is to design a hybrid ant colony optimization, which is based on the fitness, distance proportion and particle swarm optimization for the optimization of energy.

Through the use of ant colony optimization, a route which is energy-effective is located within the network. Based on the high energy and FDR particle, the consumption of energy within the network is reduced using Swarm Optimization. When the energy consumption is reduced, the lifespan of nodes is improved, thereby providing effective routing. Nodes are exchanged among the dynamic and sleep rate by the duty cycle scheme together with the ant colony optimization based on

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their usage. This entirely hinders the node from being dynamic, despite not handling any transmission at that time. More than 100 node network conditions are used in examining the designed hybrid scheme. The use of network simulator is employed in examining the effect of changing the number of nodes and their displacements on behaviour parameters such as the ratio of packet delivery, throughput, drops and remaining energy [25].

MANETs are independent networks, that have self-regulating and semi-supervised architectures. These characteristics result in the frequent use of the MANET in many applications. Thus, so many limitations are related to this kind of networks, especially the energy consumption. From all these limitations the immense dispute is the energy utilization. The traditional routing standards, which are designed using the internet engineering task force, are based on the designed route, finding the shortest route in terms of a number of hops within the source and target. These routing standards do not partake based on energy level concerns of the lifespan of in-between nodes.

This paper focuses on providing the solution to this energy problem by designing the improved energy AODV. This serves as an enhancement of the ad hoc on demand distance vector routing standard. The goal here is to obtain appropriate results in terms of improving the lifespan of the different routes within the network, through the amalgamation of the energy utilization based on the selected conditions of the AODV routing standards. Based on the various results of analyses, the performance of the designed scheme is better than that of the fundamental AODV, as it reduces the distributions of energy while improving some precise metrics which are affected by energy-related problems like the ratio of packet delivery and standard routing weights [24].

MANETs are found in wireless nodes that independently initiate a temporary network without planning or supervision. The mobile network's ability to connect wired or wireless is determined by the quality of service. A detailed analysis can be performed in order to identify a route which is able to authenticate the QoS application and parameters such as topology which are quite crucial issues related to the MANETs.

Quality of service is also important an important factor to consider in practical application of an impartial multi-hop mobile network. The purpose of the QoS conscious protocol is to identify a constant route between the source and target nodes; this route must meet the requirements of the QoS. The designed scheme is a novel energy and delay conscious routing standard which combines the cell-based automata, hybrid genetic algorithm and African buffalo optimization in order to optimize the different routes in an ad hoc in demand distance vector routing standard. The results consist of two QoS metrics used for routing; delays and energy. The routing schemes are based on cell-based automata that are used in identifying a set of routes that overcome the delay limitations, followed by an improved route using the hybrid algorithm. The results show that, in comparison to the AODV with cell-based automata and hybrid genetic algorithm, the performance of the designed scheme is better [2].

The main purpose of using fuzzy logic in the MANET is to approximate the energetic routes. One of the setbacks associated with this designed scheme is that it does not assess the values according to the rating of all possible routes, but it selects accurate routes. More so, regulating routes that are very valuable is a bit complex. The energy-conscious protocol aims at selecting a steady route from the autonomous host based on the fuzzy-based interpretation system, using battery back-up, speed and position parameters [11].

In the energy-conscious phase, an appropriate energy-conscious administrator is selected to manage the intra-cells and inter-cells. The energy-conscious mobile mediator stage is segmented and managed by the designed protocol, which employs a multi mobile mediator. More so, the independent agents are divided into two parts, which are, energy-conscious inter-mobile mediator and energy-conscious mobile mediator. The schemes are responsible for enhancing the supervising capability of the intra-cell and energy-conscious inter-mobile mediators. It is accountable for the inter-cell and it is limited by the fact that the hop counts are not considered for handling the energy of the MANETs [1].

B. Multi-Agent System

A Multi-agent system is described as a set of intelligent agents that have an interaction with each other within an environment [26],[27]. These agents function jointly to solve problems which they cannot solve independently [28],[29].

Agents have so many characteristics which include adaptation, autonomy, scalability, responsiveness, distribution and local view [30]. In order to achieve a certain goal, the agents need to interact with each other [27]. MAS has different application domains, and some of them include aircraft maintenance [31], internet agent [32], surveillance [29], environmental monitoring [33], health care [28], military demining [34], spacecraft control [35] and industrial monitoring [36]. The reason why these agents are used in the aforementioned kind of systems is to improve: (1) the speed performance and efficiency, (2) the flexibility and scalability of the operations, and (3) the reusability of the system modules [37].

C. The MAS in the MANET

The multi-agents have been used by many researchers to propose different systems based on dynamic routing. Generally, an agent is an independent entity that carries out single or multiple tasks so as to accomplish some goals. In the networking domain, an agent never stops working even if users disconnect from the network. While some agents run on standard platforms, some others run on dedicated servers. There are many examples of existing agent systems. Figure 1 illustrates the local and global views of a MAS.

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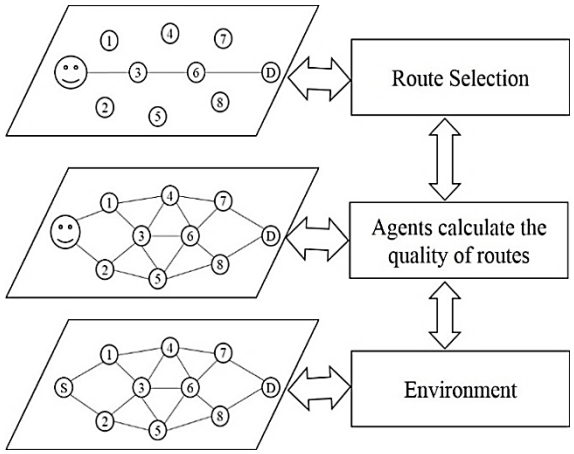

Fig. 1. A simple MAS based routing in the MANET

Through the establishment of trust among nodes, a mechanism for providing Agent-Based Trust Estimation for Mobile Ad Hoc Network is developed by [38]. In order to estimate the trust of the node, two agents are used in the proposed node. While the first one keeps a record of the failure in network link and packet dropping, the other one a keeps a record of any malicious behaviour or attack that occurs within the network. Through the use of this two-agent based scheme, the nodes are able to interconnect with the trusted nodes, thereby increasing the QoS of the MANET environment.

The work of [39] introduce agents in Ad-hoc On-Demand Distance Vector Routing Protocol (AODV), as a way of providing a better version of the existing AODV routing protocol. This group of researchers decreased the routing overhead and network delay by using the idea of the mobile agent in conventional AODV. Again [40] proposed a reliable routing protocol, which is mobile agent-based and energy efficient for the MANET. This routing protocol is proposed to enhance the reliability and energy efficiency of the protocol. The Network Load in terms of the level of node burden, Minimum Drain Rate (MDR) for energy consumption, link availability and bandwidth usable degree are used in evaluating the link cost metric. An estimation of cost metric is provided using the obtained information. Lastly, several routes are established subsequent to the collection of information, and then the route cost metric is used by the source to select the optimal route.

Bisen & Sharma [41] propose an agent-based secure enhanced performance approach (AB-SEP) for mobile ad hoc network. Here, the optimal node is used as a reliability factor in the selection of agent nodes. The calculation of this factor is carried out based on the characteristics of node performance like energy level, the value of normalized distance, degree difference, the optimal hello interval of node and mobility.

Cognitive agents-based security scheme (CAs) is recently presented by [6] for the purpose of identifying counterfeit adversaries within MANETs. This proposed scheme effectively identifies counterfeit camouflaging adversary nodes using CAs along with observations belief model. Subsequently, the identified counterfeit nodes will be cut off from the network. This isolation of counterfeit adversaries, improves the performance of the network, in terms of performance metrics such as throughput, the ratio of packet drop, bandwidth and reliability.

IV. Overview of MAAODV

In this study, the multi-agent system is combined with the AODV's protocol so as to implement the MAAODV routing protocol. In a standard AODV, when a source node announces a Route Request (RREQ), more than one route to the destination will be identified and forwarding of data packets will occur through the route that has first RREP which comes from destination rather than knowing the routes' quality. The selection of route becomes different once the integration of the MAS and AODV is established. After the broadcast of an RREQ, an RREP is received and then the source node will first have information about each network's route, delay rate, number of hops and energy level. The lifespan of the network is increased as long as possible through the use of this technique. The overall performance of the network is improved in turn.

A. The MAAODV

Three types of parameters for the selection of an ideal route are calculated using the proposed MAAODV. The three types of parameters include; (1) number of hops (node) for each possible route between the source and destination nodes, (2) average of delay of each possible routes, and (3) the average of the energy level of each route. Figure 2 is a representation of the overall MAAODV routing protocol.

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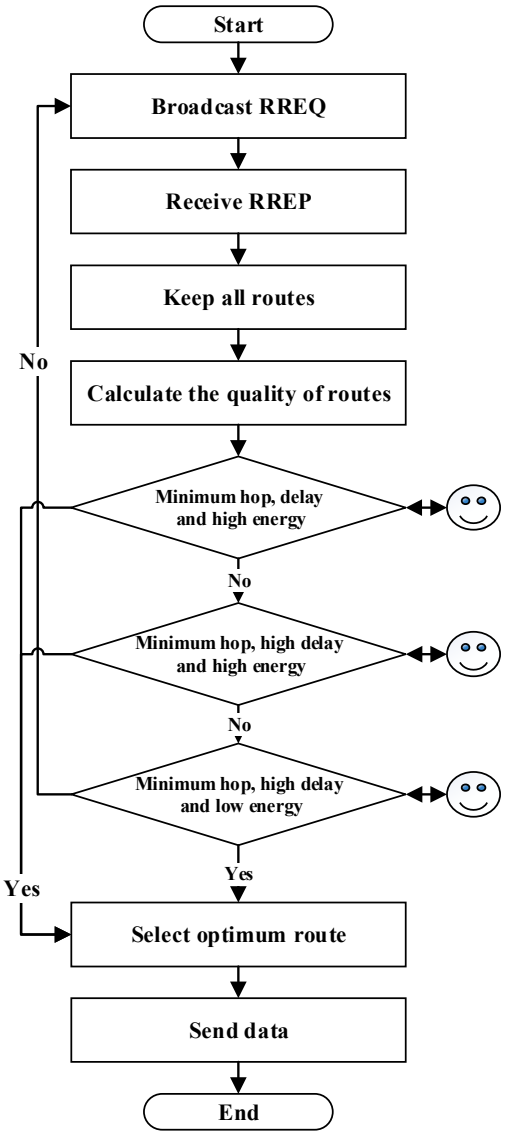

Fig. 2. The MAAODV routing protocol

Figure 2 illustrates the steps of a route selection in the MAAODV protocol. Firstly, the source node broadcast an RREQ to find a specific destination, secondly, the destination node sends an RREP to the source, this mechanism discovers all possible routes between the source and destination nodes. Next, the MAAODV keeps all routes and evaluate the quality of them based on three parameters (i.e., the number of hops, delay, and energy), furthermore, it sorts these routes based on high quality. Finally, select the optimal route to forwarding data to the destination.

In calculating these parameters, equations 1, 2 and 3 are used respectively. The routes are sorted according to their quality so as to enable the selection of routes; starting with the route that achieves (1), secondly (2), and finally (3), example scenario that shows the procedure of the MAAODV. Data packets are sent by the source node through the route having minimum hops, delay and highest energy level. Just as with any reactive protocol, the process of new route discovery when existing routes fail to reach the destination routes. When this route fails, an alternative route is selected by the source node from its routing table. The following equation is used in calculating optimum routes:

$$\text{No. of Hops} = \sum_{S=0}^{D} m \tag{1}$$

$$Average\ Delay = \frac{\sum_{i=1}^{n} T_{receive} - T_{sent}}{m} * 100\% \tag{2}$$

$$Average\ Energy = \frac{\sum_{j=1}^{m} energy\ level_m}{m} * 100\% \tag{3}$$

where S , D denote the source and destination nodes respectively, T denotes the time and the number of nodes in the route is denoted by m.

B. Example Scenario

Assume a MANET that has 13 nodes. The selection of route in MAAODV is based on certain parameters. Several routes might exist between the source node, S and the destination node, D . Table 1 presents an example scenario of the information about possible routes.

TABLE 1. THE ROUTES DETAILS

No.	Possible Route	No. of hop	Delay	Energy
1	S-1-3-6-11-D	4	16 ms	88.0%
2	S-1-4-7-11-D	4	21 ms	86.4 %
3	S-1-4-8-10-D	4	25 ms	86.6 %
4	S-1-2-5-9-10-D	5	26 ms	82.7 %
5	S-2-5-9-10-D	4	25 ms	81.2 %
6	S-2-4-8-10-D	4	31 ms	82.6%
7	S-2-4-7-11-D	4	27 ms	84.4%
8	S-2-1-3-6-11-D	5	25 ms	83.4%

At the initial stage, an RREQ is broadcasted by the source node so as to obtain information about the available routes that lead to the destination. In the MAAODV routing protocol presented above in Figure 2, the route with the highest energy level, fewer hops and delay is given more attention as presented in table 1. Figure 3. Depicts the working of MAAODV routing protocol based on the example scenario. As we can see, in the absence of a route with the highest energy, fewer hops and delay, priority will be given to the route that has the highest energy because it reduces the possibility of link failure, expands the lifespan of the network. Thereby, resulting in an increase in the data packets that will be received by the destination node [42].

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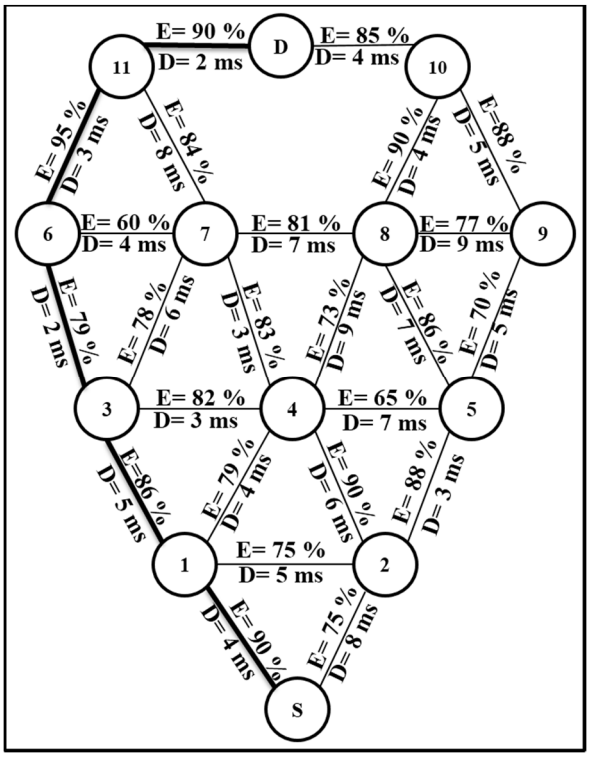

Fig. 3. An example scenario of the MAAODV

V. CONCLUSION

The promising features possessed by the MANET has made an attractive research field. These features which have made the use of the MANET common in several applications and as a wireless network including, ease of use, simplicity and cost-effectiveness. Several types of research which have been carried out with MANET environments. They aim at improving the MANET's QoS like performance, resources, security, and energy. The development of the MANET implies the development of novel applications that are unachievable in the conventional networks. In this paper, a MAS is employed to address the problem associated with the AODV protocol as stated in section II. The proposed routing protocol is called Multi-agent Ad Hoc On-Demand Distance Vector (MAAODV) uses three parameters (delay, number of hops and energy level) to select a route. This protocol has a potential to improve the performance of AODV protocol as well as increase the lifespan of the network to be as long as possible, reduce the possibility of links failure, increase the data packet that is received by the destination and reduce the loss of packets. These, in return, help in meeting the requirements of the QoS.

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