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AN IMPROVED MULTIPATH DHT BASED ROUTING PROTOCOL FOR MOBILE AD-HOC NETWORKS

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ABSTRACT

Mobile Ad-hoc networking is a concept in computer communications, which means that users wanting to communicate with each other form a temporary network, without any form of centralized administration. Each node participating in the network acts both as host and a router and must therefore is willing to forward packets for other nodes. For this purpose, a routing protocol is needed.

Forwarding packets through MANET's dynamic changing network is a challenging issue. Most existing MANET protocols are suggested by considering different scenarios of mobile nodes of MANET which function properly in an optimistic manner. We investigated the single and multipath routing protocols based on QoS. The Single Path Reactive Routing Protocol AODV and Multipath reactive routing protocols AOMDV were analyzed the QoS performance of MANETs. Then DHT based routing protocol called MDART was implemented in ns-2. Performance of proposed protocol was analyzed and compared with multipath routing protocol AOMDV and table driven routing protocol DSDV.

KEYWORDS: MANET, AODV, AOMDV, DHT, MDART, QoS and DSDV.

1. INTRODUCTION

Wireless communication between mobile users is becoming more popular than ever before. This is due to recent technological advances in laptop computers and wireless data communication devices, such as wireless modems and wireless LANs. This has lead to lower prices and higher data rates, which are the two main reasons why mobile computing continues to enjoy rapid growth.

There are two distinct approaches for enabling wireless communication between two hosts. The first approach is to let the existing cellular network infrastructure carry data as well as voice. The major problems include the problem of handoff, which tries to handle the situation when a connection should be smoothly handed over from one base station to another base station without noticeable delay or packet loss. Another problem is that networks based on the cellular infrastructure are limited to places where there exists such a cellular network infrastructure.

The second approach is to form an ad-hoc network among all users wanting to communicate with each other. This means that all users participating in the ad-hoc network must be willing to forward data packets to make sure that the packets are delivered from source to destination. This form of networking is limited in range by the individual nodes transmission ranges and is typically smaller compared to the range of cellular systems. This does not mean that the cellular approach is better than the ad-hoc approach. Ad-hoc networks have several advantages compared to traditional cellular systems. These advantages include:

i. On demand setup
ii. Fault tolerance
iii. Unconstrained connectivity

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Ad-hoc networks do not rely on any pre-established infrastructure and can therefore be deployed in places with no infrastructure. This is useful in disaster recovery situations and places with non-existing or damaged communication infrastructure where rapid deployment of a communication network is needed. Ad-hoc networks can also be useful on conferences where people participating in the conference can form a temporary network without engaging the services of any pre-existing network.

Figure 1: Working of Mobile Ad-hoc network

A routing protocol plays very important part in implementation of mobile ad-hoc networks. Because of the nature of mobile ad hoc networks it is non-trivial problem to find path from source to the destination and perform the communication between nodes for a long period of time. Figure 1 shows the working of Mobile Ad-hoc network.

Because nodes are forwarding packets for each other, some sort of routing protocol is necessary to make the routing decisions. Currently there does not exist any standard for a routing protocol for ad-hoc networks, instead this is work in progress. Many problems remain to be solved before any standard can be determined.

2. RELATED WORK

Because of the importance of routing protocols in dynamic multi hop networks, a lot of MANET routing protocols have been proposed in the last few years.

Khan et. al., (2018) presented how forward and reverse paths are created by the AOMDV routing protocol. Loop free paths formulation is described, together with node and link disjoint paths. The performance of the AOMDV routing protocol was investigated along link and node disjoint paths. They showed that WSN with the AOMDV routing protocol using link disjoint paths is better than the WSN with the AOMDV routing protocol using node disjoint paths for energy consumption.

Amish et. al., (2016) surveyed the techniques dealing with wormhole attack in WSN and a method is proposed for detection and prevention of wormhole attack. AOMDV (Ad hoc On demand Multipath Distance Vector) routing protocol is incorporated into these method which is based on RTT (Round Trip Time) mechanism and other characteristics of wormhole attack. As compared to other solution shown in literature, proposed approach looks very promising. NS2 simulator is used to perform all simulation.

Al-Sultan S., et. al., (2014) presented aspects related to ad hoc network to help researchers and developers to understand and distinguish the main features surrounding VANET in one solid document, without the need to go through other relevant papers and articles starting from VANET architecture and ending up with the most appropriate simulation tools to simulate VANET protocols and applications.

Khan et. al., (2014) analyzed the behavior of a new multi-path routing protocol named Multipath Dynamic Addressing routing with other protocols under five different mobility models (Random Waypoint mobility, Random Walk mobility, Reference Point Group mobility, Gauss Markov, Manhattan Grid mobility model). The RPGM model outperform for both AOMDV and MDART regarding Throughput, End-to-End Delay, Average Packet loss, and Packet Delivery Fraction (PDF). The output of selected performance matrices under selected mobility models has an inverse relation with node density for both multi-path protocols.

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Araghi et. al., (2013) evaluated the performance of reactive routing protocols in order to find the best routing protocol. They observed that in a network with increased number of nodes to maximum 20 nodes, packet delivery ratio and throughput in DSR and AOMDV routing protocols are better than AODV while in checking end to end delay, AOMDV shows less delay than DSR and AODV.

Bindra et. al., (2012) presented a lifetime prediction routing protocol related to node and link lifetime for MANETs that maximizes the network lifetime by utilizing the dynamic nature, such as the energy drain rate and the relative mobility estimation rate of nodes. Utilizing these two performance parameter the algorithm selects the least dynamic route with the longest lifetime for maintaining the uninterrupted data flow.

Jain and Gupta (2012) summarized that MANET is a self-organized, decentralized wireless network with mobility as core functionality. Routing is key in to enhance MANET performance. Routing in mobile ad hoc networks and some fixed wireless networks use multiple-hop routing. Routing protocols for this kind of wireless network should be able to maintain paths to other nodes and in most cases, must handle changes in paths due to mobility. AODV is most popular routing protocol among others. It is On-demand type routing protocol and its performance is better than other routing protocols in MANET environment. This paper focus on AODV routing protocol to enhanced the break avoidance mechanism using multipath extension in core AODV to avoid route break problem in existing AODV method.

Singh, G. et. al., (2012) has shown that Distributed Hash Tables (DHTs) has recently proven to be a novel and efficient way for developing scalable routing protocols in MANETs. Moreover multipath protocols provide fault tolerance against node and link failures. They have analyzed the performance of M-DART, which is DHT based Multipath protocol against Ad hoc On-Demand Multipath Distance Vector Routing Protocol (AOMDV), which is a reactive Multipath protocol. They have conducted various simulation experiments to evaluate its performance in terms of throughput, packet delivery ratio, end to end delay and energy consumption.

Caleffi and Paura (2011) has proposed a Distributed Hash Table (DHT)-based multi-path routing protocol for scalable ad hoc networks. They proposed a multipath-based improvement to a recently proposed DHT-based shortest-path routing protocol, namely the Dynamic Address RouTing (DART). The resulting protocol, referred to as multi-path DART (M-DART), guarantees multi-path forwarding without introducing any additional communication or coordination overhead with respect to DART.

Zhang and Shao (2011) have proposed four mobility models for simulating different scenarios of mobile ad hoc networks and to know which protocol is better than another in different mobile network scenarios. Also a byte-based energy consumption evaluation methodology is introduced for the protocol assessment. The experiment built upon mobility models, shows that TORA can cause too much energy consumption on large-sized network and is more fit for the mobile adhoc network with low node mobility, while AODV, DSR, and especially DSDV performs well on energy consumption for the mobile ad hoc network with high node mobility.

Kumar et. al., (2010) evaluated the current research work being done on MANET routing protocols. Because nodes in a MANET normally have limited transmission ranges, some nodes cannot communicate directly with each other. Hence, routing paths in mobile ad hoc networks potentially contain multiple hops, and every node in mobile ad hoc networks has the responsibility to act as a router. In this paper they have surveyed the active research work on routing protocols for MANET.

Zhao et. al., (2009) have proposed Kademlia-based Dynamic Source Routing (KDSR), which integrates the functionality of a DHT and Dynamic Source Routing (DSR) at the network layer to provide an efficient indirect routing primitive in MANETs. KDSR organizes mobile nodes into a XOR-based metric topology. This topology has the property that every message exchanged conveys useful routing information, which facilitates route discovery and route maintenance. Simulation results show that KDSR achieves better packet delivery ratios at significantly lower overhead than DSR.

Jiazi et. al., (2007) discussed that routing is a critical issue in designing of MANETs. They examines the main protocols and issues in routing in MANETs, especially multipath protocol. The conventional routing algorithms for wired networks are not efficient for dynamic changes. In recent years people have developed lot of routing protocols and they have summarized some typical protocols.

Kong et. al., (2006) presented the reachable component method (RCM) for analyzing the performance of different DHT routing systems subject to random failures. They applied RCM to five DHT systems and obtained analytical expressions that characterize their routability as a continuous function of system size and node failure probability. An important consequence is that in the large-network limit, the routability of certain DHT systems go to zero for any non-zero probability of node failure. These DHT routing algorithms are therefore unscalable, while some others, including Kademlia, which powers the popular eDonkey P2P system, are found to be scalable.
Das and Marina (2006) developed an on-demand, multipath distance vector routing protocol for mobile ad hoc networks. They propose multipath extensions to a well-studied single path routing protocol known as ad hoc on-demand distance vector (AODV).

Basaran and Molle (2005) discussed that in order to achieve better throughput, load balancing and congestion avoidance multipath routing has been widely studied and used in wired networks. The good results inspired the researchers in mobile Ad Hoc area and many multipath routing protocols have been proposed. Each of these protocols has a different approach to problem and a different objective to achieve. There is not a comprehensive comparative study among these protocols. In their study, they have examined 11 multipath routing protocols and compared them with respect to our framework. There is no winner of the comparison, but there are important inferences for researchers who will design new routing protocols.

3. PROPOSED METHODOLOGY

It comprises the analysis of methods and principles associated with a specific area of study. Performance outcomes of routing protocols of MANETs are analyzed using network simulator NS-2 and performance evaluation of these algorithms are performed using two scenarios' namely Scenario I and Scenario II

❖ Steps Followed

To accomplish above mentioned objectives following methodology is opted.

i. Perform extensive literature survey to obtain ample knowledge of our research area.

ii. Study single path and multipath routing protocols for MANETs. Main routing protocol under consideration for MANETs is MDART. It is proactive in nature. MDART discovers and stores multiple paths to the destination in the routing table. With dynamic addressing paradigm network addresses are assigned to nodes on the base of the node position inside the network topology. Other protocols selected for analysis are AODV, DSDV and AOMDV.

iii. Configure the simulation setup and Implement routing protocols for MANETs in network simulator (ns-2).

iv. Run several simulation experiments to analyze the behavior of chosen protocols.

iv. Compare the proposed routing protocol with the traditional routing protocols. Energy consumption, packet delivery and throughput are used as parameters for analysis.

❖ Multipath Routing Protocol Followed

A routing protocol specifies how routers communicate with each other, distributing information that enables them to select routes between any two nodes on a computer network. Routing algorithms determine the specific choice of route. Following described the DHT based multipath routing protocol which is used to provide better performance to proposed work.

a) DHT based Routing

Most of the proposed protocols, regardless of the belonging class (reactive, proactive, and hybrid), do not scale efficiently when the number of nodes grows mainly since they have been proposed for wired networks and modified to cope with ad hoc scenarios. More specifically, they are based on the assumption that node identity equals routing address, that is they exploit static addressing which of course is not yet valid in ad hoc scenarios. Recently, some routing protocols have exploited the idea of decoupling identification from location by resorting to Distributed Hash Table (DHT) services, which are used to distribute the node's location information throughout the network. Several proposals based on this approach have been recently presented, and they can be classified according to the lookup model in two main groups. The former group requires the knowledge of the geographical node's position which can be provided by a central infrastructure such as the GPS and clearly this solution is not suitable in the case of self-organizing networks **(Caleffi and Paura (2011))**.

The information stored in the DHT is the node address, which reflects the node topological position inside the network. The proposals belonging to this group introduce a logical and mathematical structure on the address space based on connectivity between nodes. After that the node identifiers has been retrieved by the lookup procedure in the DHT, the routing is performed using the topological information associated with the node address, resembling the routing procedure performed for wired networks.

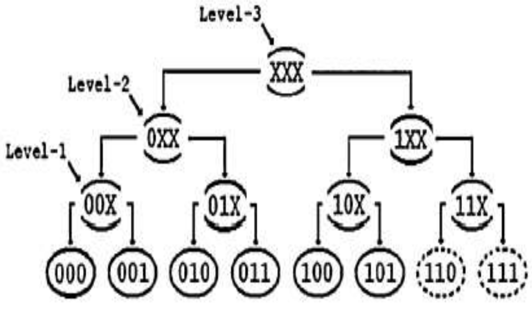
All the above-cited schemes are hierarchically organized and exploit a tree structure for both the node identifier management and routing. Although this structure offers a simple and manageable procedure, it lacks for robustness against mobility and/or link failure and exhibits unsatisfactory route selection flexibility. In order to improve the performances, more complex structures can be used, like ring ones. However, in such a case the increased complexity in the identifier allocation mechanism could discourage their use in presence of channel hostility and very large networks.

b) Dynamic Address Routing (DART)

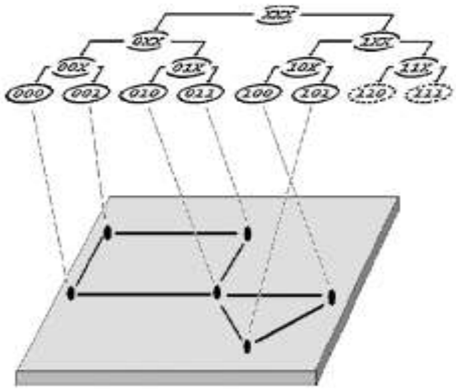
DART is a proactive distance vector routing protocol based on the dynamic addressing paradigm. According to such an approach network addresses are assigned to nodes on the base of the node position inside the network topology. By means of dynamic addressing, DART is able to implement hierarchical routing in a feasible way, reducing so considerably the routing state information maintained by each node. Since the whole routing process is based on the transient network addresses, they have to be efficiently distributed across the network. The mapping between node identities and network addresses is provided by a DHT. In the following sections, we give an overview of some key features of the DART protocol required for the understanding of the M-DART design.

Address Space

The network addresses are strings of l bits, thus the address space structure can be represented as a complete binary tree of l + 1 levels, that is a binary tree in which every vertex has zero or two children and all leaves are at the same level (Figure 2(a)). In the tree structure, each leaf is associated with a network address, and an inner vertex of level k, namely a level-k sub tree, represents a set of leaves (that is a set of network addresses) sharing an address prefix of l - k bits. For example, with reference to Figure 2(a), the vertex with the label 01X is a level-1 sub tree and represents the leaves 010 and 011. Let us define level-k sibling of a leaf as the level-k sub tree which shares the same parent with the level k sub tree the leaf belongs to. Therefore, each address has l siblings at all and each other address belongs to one and only one of these siblings. Referring to the previous example, the vertex with the label 1XX is the level-2 sibling of the address 000, and the address 100 belongs only to this sibling. In Figure 2(b), the address space is alternatively represented as an overlay network built upon the underlying physical topology. Its tree-based structure offers simple and manageable procedures for address allocation, avoiding inefficient mechanisms like flooding.



(a)



(b)

Figure 2: (a) Address space overlay (b) The physical topology

Route discovery and packet forwarding

Each node maintains a routing table composed by l sections, one for each sibling, and the kth section stores the path toward a node belonging to the level-k sibling. Each section stores five fields: the sibling to which the entry refers to, the next hop, the cost needed to reach a node belonging to that sibling using the next hop as forwarder, the network id used for address validation, and the route log used by the loop avoidance mechanism.

Figure 3 shows the routing table of node 000 for the network depicted in Figure 2. The table has three sections: the first stores the best route, according to a certain metric, toward the node 001, the second toward a node belonging to the sibling 01X, and the last toward nodes belonging to the sibling 1XX.

The routing state information maintained by each node is kept consistent through the network by means of periodic routing updates exchanged by neighbor nodes. Each routing update stores l entries, and each entry is composed by four fields: the sibling id, the cost, the network id, and the route log. The packet forwarding process exploits a hop-by-hop routing based on the network addresses and it is summarized by

Algorithm 1. To route a packet, a node compares its network address with the destination one, one bit at a time starting with the most significant (left-side) bit, say the *l*th. If the *i*th bit is different, the node forwards the packet towards one the route stored in the *i*th section. With reference to the previous example, if the node 000 has to send a packet to the node with the address 101, then it will forward the packet to the next hop stored in the third section (i.e., the node 010)

Sibling ID	Next Hop	Route Cost	Network ID	Route Log
001	001	C(000,001)	$\min_{N \in 000} ID(N)$	001
01X	010	C(000,010)	$\min_{N \in 01X} ID(N)$	010
1XX	010	$C(000,010)+\min_{N \in 1XX} C(010,N)$	$\min_{N \in 1XX} ID(N)$	100

Figure 3: DART routing table for node 000.

The hierarchical feature of DART is based on the concept of sibling and it allows nodes to reduce both the routing state information and the routing update size, with respect to a traditional approach, from Θ(n) to Θ(log(n)), where *n* is the overall number of nodes in the network.

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Table 1: Algorithm-1 DART forwarding rule

A node *i* applies the rule whenever it receives a packet directed to node *j*. *k* denotes the most significant bit that differs between *i* and *j* addresses.

```
k = levelSibling(i.add, j.add)
if routingTable[k].nextHop is valid then
        nextHop = routingTable[k].nextHop
end if
```

Moreover, it assures that routes toward far nodes remain valid despite local topology changes occurring in the vicinity of these nodes.

False route breakage avoidance

A DART routing table is composed by l sections, one for each sibling, and each section stores one route towards the set of nodes belonging to the sibling to which the section refers to. In such a way, the routing state information is considerably reduced. This attractive property is obtained at the price of low fault-tolerance as well as traffic congestion vulnerability since there exists only one path between any pair of nodes.

Moreover, the address overlay embeds only a partial knowledge about the physical network topology, since only a subset of the available communication links is used for the routing. Therefore, a major issue is raised for DART protocol: a data flow may also experience a false route breakage if are liable path in the network exists. Such issue is particularly harmful since the breakage affects a whole set of nodes due to its hierarchical nature. Let us take an example by considering the simple network depicted in Figure 2 and by assuming that node 000, whose routing table is illustrated in Figure 3, has to communicate with node 100.

According to the considered example, the node 000 routes the packets basing on the entry stored in the third section, i.e., toward node 010. If we suppose that the link between nodes 000 and 010 fails due to mobility and/or wireless propagation instability, a false route breakage happens. Unlike flat routing, such a breakage affects all the nodes belonging to the third sibling and, therefore, all the communications toward such nodes have to be interrupted until the completion of the next route discovery process, which involves the exchange of several routing update packets. Otherwise, M-DART solves the false route breakage issue by exploiting multi-path routing.

With reference to the same previous example, in case of link failure the node 000 can use all the available neighbors (Figure 4), avoiding, therefore, to stop the communications until at least one path is still available. In other words, M-DART exploits the route diversity avoiding, therefore, to waste the resources already spent for route discovery and packet forwarding.

Sibling ID	Next Hop	Route Cost	Network ID	Route Log
001	001	$C(000,001)$	$\min_{N \in 001} ID(N)$	001
01X	010	$C(000,010)$	$\min_{N \in 01X} ID(N)$	010
	001	$C(000,001)+\min_{N \in 01X} C(001,N)$	$\min_{N \in 01X} ID(N)$	010
1XX	010	$C(000,010)+\min_{N \in 1XX} C(010,N)$	$\min_{N \in 1XX} ID(N)$	100
	001	$C(000,001)+\min_{N \in 1XX} C(001,N)$	$\min_{N \in 1XX} ID(N)$	100

Figure 4 DART routing table for node 000

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MDART

The M-DART extends the DART protocol to proactively discover all the available routes between a source and a destination. In this section, we first present an example of how the MDART's multi-path approach improves the tolerance of the address space overlay against mobility as well as channel impairments. Then we give an overview of how M-DART is capable to implement a multi-path routing strategy without introducing any communication or coordination overhead. Finally, we provide a detailed description of the multi-path data forwarding strategy and a polynomial bound on the on the routing table size.

M-DART shares several characteristics with DART. It is based on the distance vector concept and it uses the hop by hop routing approach. Moreover, M-DART also resorts to the dynamic addressing paradigm by using transient network addresses. The main difference between DART and M-DART lies in the number of routes stored in the routing table: the former stores no more than l entries, one for each sibling, while the latter stores all the available routes toward each sibling. The core of M-DART protocol lies in ensuring that such an increase in the routing state information stored by each node does not introduce any further communication or coordination overhead by relying on the routing information already available in the DART protocol. In particular, it does not employ any special control packet or extra field in the routing update entry (Figure 5) and, moreover, the number of entries in the routing update packet is the same as DART: l. No special coordination action is needed by nodes and the node memory requirements constitute the only additional overhead in M-DART relative to DART.

Figure 5: DART and M-DART routing update entry

These valuable characteristics are obtained by means of blind route notification that is by notifying neighbors only about the presence of routes towards a sibling without detailing the paths that the packets will be forwarded through. Although such a strategy allows us to avoid introducing any communication or coordination overhead, a major issue arises when a blind route notification is used in multi-path hierarchical routing. In fact, in such a case the cost associated with a path is not enough to single out the best route among multiple ones.

Table 2: Routing table for node 100

101	101	1	ID(101)	001
11X 0XX	101 000	2 2	$\min_{N\in 11X}$ ID(N) $\min_{N\in 0XX}$ ID(N)	010 100

Table 3: Routing update sent by node 100

101	1	ID(101)	001
11X 0XX	2 2	$\min_{N\in 11X}$ ID(N) $\min_{N\in 0XX}$ ID(N)	010 100

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Table 4: Routing table for node 010

011	-	-	-	-
00X 1XX	000 110	1 1	$\min_{N\in 01X}$ ID(N) $\min_{N\in 1XX}$ ID(N)	010 100

Figure 5 illustrates this problem using a simple network where the hops represent the cost associated with a path. Suppose that node 000 is the source and node 101 is the destination. There are two paths toward 101: a good path via node 100 and a bad one via node 010.

Table 2 and Table 4 summarize the routing tables of node 100 and 010 respectively, while Table 3 and Table 5 show the respective routing updates. By listening the neighbors' route updates, the node 000 is unable to discover which one is the best suitable to communicate with the destination. In fact, both nodes 100 and 010 announce a route with cost 1 respectively toward the sibling 101 and 1XX and the destination address belongs to both the siblings.

Table 5: Routing update sent by node 010

011	-	-	-
00X 11X	1 1	$\min_{N\in 01X}$ ID(N) $\min_{N\in 1XX}$ ID(N)	010 100

In fact, the cost c_k announced by the node *i* in the k-entry of a routing update refers to the minimum cost to reach one of the nodes belonging to the sibling related with that entry:

$$c_k = \min_{j \in kth\ sibling} C(i, j)$$

Where C(*i*, *j*) is the minimum cost associated with the path (*i*, *j*). In other words, the more the destination node is far from the announcing node in the address space, the larger is the set of nodes to which the route update entry refers to. This simple and straightforward observation is the basis for our mechanism to select the best path among multiple ones. In the following subsection, we detail the M-DART forwarding rule that allows us to implement the above idea.

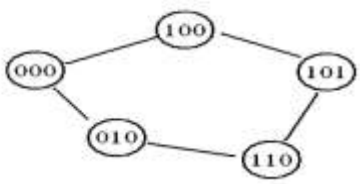

Figure 6: Path cost information is insufficient to guarantee best route selection

As example, let us consider again the network illustrated by Figure 6. We assume that the node 000 has to forward a packet towards the node 101. Since the destination belongs to the level-3 sibling, namely the 1XX, the node looks for routes in the third section of its routing table.

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4. WORK FLOW

A schematic flow chart for flow of proposed work is shown below in figure 7. It represents how the proposed work is carried out in various phases.

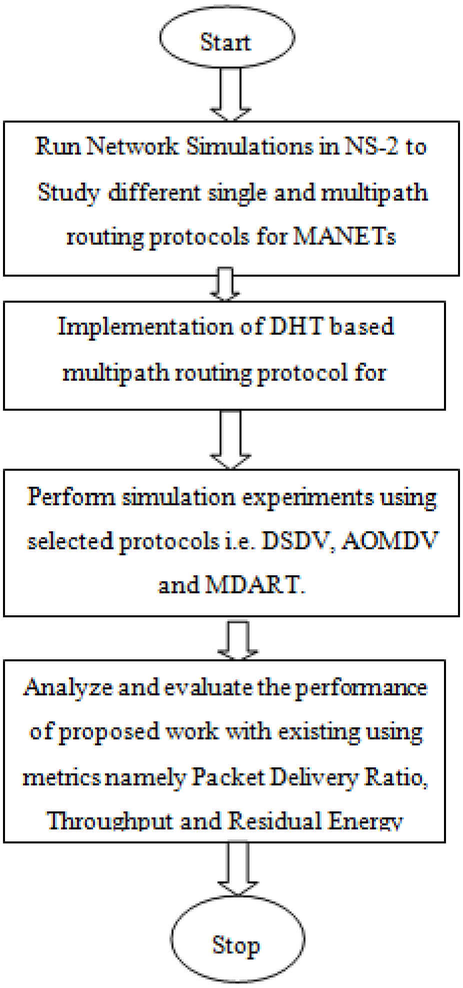

Figure 7: Work Flow of proposed work.

5. METRICS USED FOR EVALUATION OF PROPOSED WORK

To analyze the performance of routing protocols, various contexts are created by varying the number of nodes and node mobility. The metrics used to evaluate the performance of the protocols. The performance metrics are purposely chosen to show the difference in performance among the different routing methods. These metrics are the most crucial and common yardstick to measure the overall performance of the network routing algorithms. Similar types of metrics were also used in many other comparison related work. The performance metrics are defined as the followings.

Packet Delivery Ratio (PDR): Packet Delivery Ratio (PDR) is the ratio between the number of packets transmitted by a traffic source and the number of packets received by a traffic sink. It measures the loss rate as seen by transport protocols and as such, it characterizes both the correctness and efficiency of ad hoc routing protocols. It represents the maximum throughput that the network can achieve. A high packet delivery ratio is desired in a network.

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$$\text{PDR} = \frac{\text{Total Data Packets Received}}{\text{Total Data Packets Sent}}$$

Average Throughput: This is the average number of bits arrived per second at destination node. The metric is used as a measure of the reliability of the protocol under different conditions; hence the average throughput in the network needs to be higher as much as possible. Factors that affect throughput in MANETs include frequent topology changes, unreliable communication, limited bandwidth and limited energy. A high throughput network is desirable.

$$\text{Average Throughput} = \frac{\text{Number of Data Packets Successfully Received x Packet Size}}{\text{Simulation Time}}$$

Residual Energy: It is amount of energy left out after communication is over. In another words it is equal to total energy minus energy consumed during network communication.
Residual Energy = Total Initial Energy – Energy Consumed

6. SIMULATION SETUP

A detailed simulation model based on NS-2 is used in the evaluation. The IEEE 802.11 for wireless LANs is used as the MAC layer protocol. In Scenario-I, single path routing protocol AODV and multipath routing protocol AOMDV are analyzed as per simulation setup given in Table 6. Scenario is conside density of 4096/KM^2 and simulation time of 200 secs. Shadowing Propagation model is being u ....3.10 metrics have been evaluated by considering node numbers 20, 50,100, 200 and 300.

Table 6: Simulation Configuration-I

Configuration parameter	**Detail**
MAC	IEEE 802.11
Simulator	ns-2.35
Density/Area	4096/KM^2
No of Nodes	20, 50, 100, 200, 300
Routing Protocols	AODV, AOMDV
Simulation Time	200 Secs
Propagation Model	Shado

In Scenario-II, AOMDV (multipath), DSDV (table driven) and proposed protocol MDART (multipath + table driven) are analyzed as per simulation setup given in Table 7. Scenario is considered with a node density of 4096/KM^2 and simulation time of 200 Secs. Shadowing Propagation model is being usedand different metrics have been evaluated by considering node numbers 20, 50,100, 200 and 300.

Table 7: Simulation Configuration-II

Configuration parameter	**Detail**
MAC	IEEE 802.11
Simulator	ns-2.35
Density/Area	4096/KM^2
No of Nodes	20, 50, 100, 200, 300
Routing Protocols	DSDV, AOMDV, M-DART
Simulation Time	200 Secs
Propagation Model	Shado

Performance is analyzed in terms of average packet delivery ratio (PDR), average throughput and residual energy.

7. SIMULATION RESULTS

In Scenario-1 average PDR, average Throughput and Residual Energy of AOMDV and AODV are analysed in simulated environment of ns-2. These metrics are calculated by varying the number of nodes from 20 to 300 as mentioned in Table 6. Nodes are randomly distributed in the area. This is done to evaluate impact of network size on these performance metrics.

In Scenario-II, we have analysed these metrics for AOMDV, DSDV and proposed protocol MDART. Node number is varied from 20 to 300. Simulation configuration is mentioned in Table 5.2. Nodes are uniformly distributed in the area. This is being done to check the suitability of DHT paradigm for Mobile Ad-hoc networks.

Scenario I

Performance of Single path and Multipath routing protocol are analyzed in ns-2 and their outcomes are observed and listed in table below.

Table 8: Average PDR for AOMDV and AODV.

Average PDR		
Nodes	**AOMDV**	**AODV**
20	0.9913	0.9999
50	0.9832	0.9984
100	0.968	0.9911
200	0.9219	0.9569
300	0.8287	0.9314

Figure 8 shows the comparison of the two routing protocols in terms of packet delivery ratio. Figure shows that although AOMDV is meant for environments where direct or single communication is not reliable yet it is achieving high vlaue of PDR at par with AODV for IEEE802.11. AODV because of its single path nature transmits appropriate number of packets and that to within coverage area of nodes and is showing high PDR.

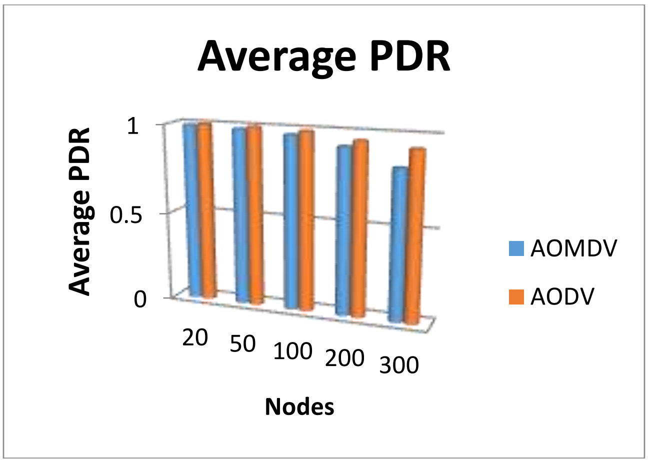

Figure 8: PDR comparison for AOMDV and AODV

Average throughput is out next pararmeter for performance analysis for these protocols. Simulations results are listed in Table 9 below.

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Table 9: Average Throughput of AOMDV andAODV

Average Throughput (kbps)		
Nodes	**AOMDV**	**AODV**
20	213.86	215.71
50	130.27	132.3
100	86.36	88.42
200	60.65	62.95
300	45.28	50.89

Graph for comparison of Average throughput is shown below in Figure 9. Throughput for AOMDV is similar to AODV for less number of nodes but it is less when number of nodes in network increases because of high traffic in multipath environment.

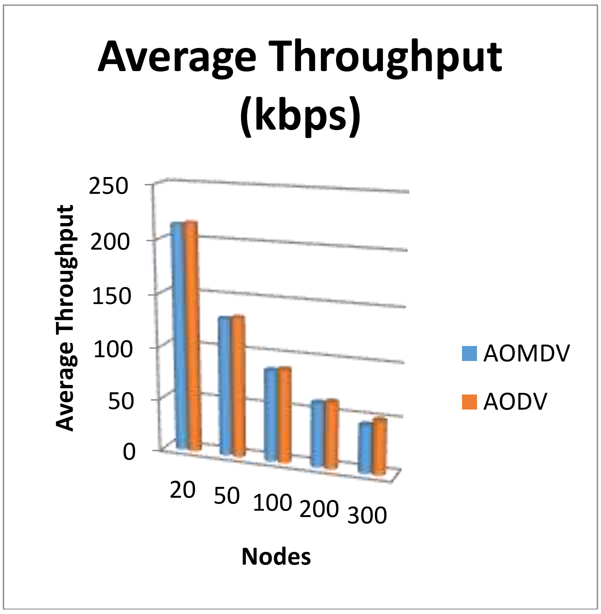

Figure 9: Comparison of average Throughput for AODMV and AODV.

These two protocols were observed for energy efficiency and followin observations were made as shown in Table 10.

Table 10: Residual Energy for AOMDV and AODV.

Residual Energy (J)		
Nodes	**AOMDV**	**AODV**
20	93.96488	94.815831
50	95.818737	96.671779
100	93.509861	94.864355
200	90.592009	92.581437
300	90.334282	92.46023

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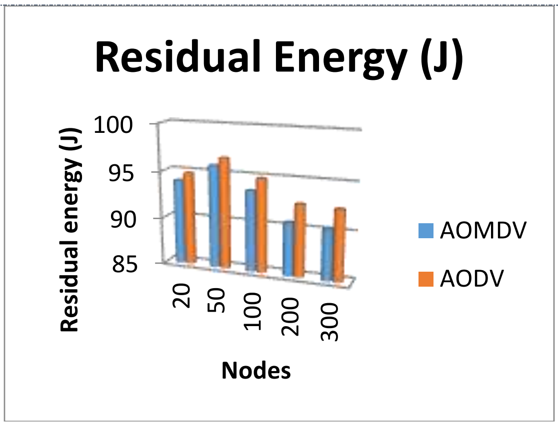

Figure 10: Comparison of Residual energy for AOMDV and AODV.

As obvious from Figure 10 it is clear that because of multipath nature AOMDV consumes more power than single path routing protcol but it is significant for networks where energy efficiency is not an issue.

Scenario II

In this scenario three routing protocols are considered namely AOMDV, DSDV and MDART as they have some common features. AOMDV and MDART are multipath in nature whereas DSDV and MDART protocols are table driven. Simulation setup is already mentioned in Table 7. Observations were made after performing simulation experiments and are listed in table below.

Table 11: Average PDR for MDART, AOMDV and DSDV.

Average PDR			
Nodes	**MDART**	**AOMDV**	**DSDV**
20	1	0.9913	0.9642
50	0.9998	0.9832	0.9479
100	0.889	0.968	0.9072
200	0.9152	0.9219	0.8012
300	0.8363	0.8287	0.6715

Comparison graph shown in Figure 11 made it clear that for a network of size 20-300 nodes MDART is giving more promising PDR results as compare to AODMV and DSDV because of DHT paradigm. Difference is more significant for bigger network.

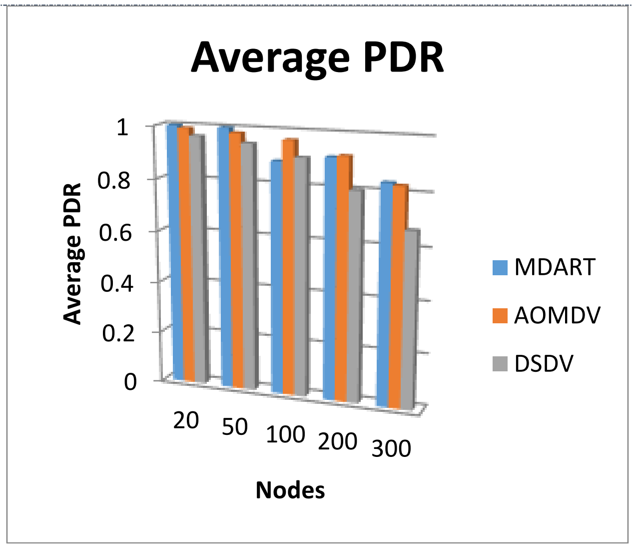

Figure 11: Comparison of average PDR for MDART, AOMDV and DSDV.

Simulation experiments were also performed for next evaluation parameter i.e. throughput. Outcomes are listed in table below for the same.

Table 12: Average Throughput for MDART, AOMDV and DSDV

Average Throughput (kbps)			
Nodes	**MDART**	**AOMDV**	**DSDV**
20	215.74	213.86	208.05
50	132.47	130.27	125.6
100	79.32	86.36	81.05
200	60.21	60.65	53.86
300	45.69	45.28	39.39

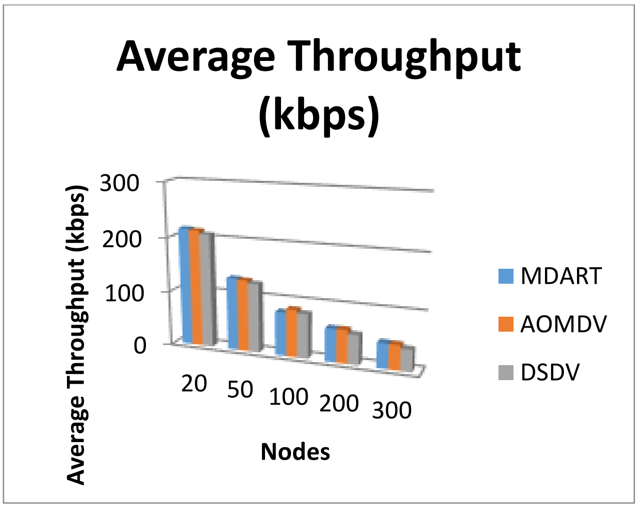

Figure 12: Comparison of Average throughput for MDART, AOMDV and DSDV.

Energy efficiency is another performance parameter for which following observations were made (See Table 13). Residual energy decides network life time.

Table 13: Residual Energy of MDART, AOMDV and DSDV

Residual Energy (J)			
Nodes	**MDART**	**AOMDV**	**DSDV**
20	91.12465	93.96488	94.28841
50	86.00766	95.818737	95.98094
100	83.853	93.509861	95.70938
200	79.51831	90.592009	94.75724
300	66.12044	90.334282	87.91289

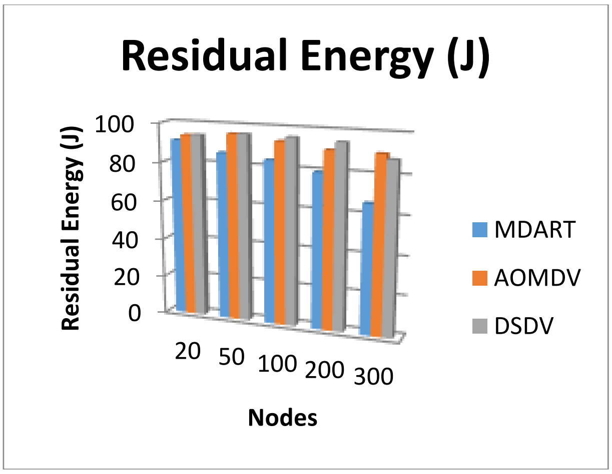

Figure 13: Comparison of Resudual Energy for MDART, AODMV and DSDV.

As shown in Figure 13 below AOMDV and DSDV are consuming comparatively less energy while MDART because of its approach meant for achieving high Quality of Service for bigger networks is consuming more energy comparatively.

8. CONCLUSIONS AND FUTURE SCOPE

Conclusions: In this paper we evaluated and compared the performance of routing protocols for MANETs. In Scenario-1 single path and multipath routing protocols were considered i.e. AODV and AODMV respectively, and in Scenario-II three routing protocols AOMDV, DSDV and MDART were analyzed. Simulation of these protocol has been carried out using NS-2 and performance has been evaluated based on Packet Delivery Ratio(PDR), Average Throughput and Residual Energy.

In Scenario-I we have observed that when number of nodes grows, the performance of AOMDV declines, whereas AODV shows consistent performance. In Scenario-II we have observed that M-DART has higher Average PDR, Average Throughput and Residual Energy. We can conclude that M-DART is suitable for WLAN (IEEE 802.11) as it forms a bigger packet. M-DART is proposed for scalable networks. AOMDV shows better performance as compare to DSDV in terms of Average PDR and Average Throughput. But DSDV due to its simple proactive approach consumes less energy and shows higher residual energy results as compare to MDART and AOMDV. MDART can be applied to scalable large networks with stumpy energy efficiency requirements.

Future Scope: In future, the work can be extended to include other proactive and reactive protocols to find how M-DART performs in comparison to other protocols. More scenarios with different mobility models, different network and traffic load, the topology area, choice of the traffic type between the mobile nodes, can be created for simulation and to carry out detailed analysis of scenarios in which M-DART is more suitable as compared to other protocols. We can also investigate performance in highly mobile scenarios as there are growing numbers of applications, which demand high mobility. Impact on QoS can be analyzed, using different mobility patterns, because increase in mobility has different kind of impact on different protocols. Another work that can be carried out is to analyze the security of routing protocols in an Ad hoc network.

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