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# Performance Evaluation of DHT based Multipath Routing Protocol for IEEE Standard 802.11 and 802.15.4

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**Abstract— *A Mobile Ad-hoc Network (MANET) is a wireless network that doesn't need any pre-existing infrastructure and in which all the nodes act as host as well as router. There is problem of frequent route breakages and changing topologies. So one such protocol needs to be designed, which can perform well in all these dynamically changing scenarios. A lot of protocols have been developed by modifying pre existing wired or wireless network protocols and they have been extensively simulated and tested in various scenarios. They don't perform well for larger networks or we can say they are not scalable. Some protocols perform well in one environment and not in the other. We need a protocol or paradigm, which is being designed specifically for MANETs. Distributed Hash Tables (DHTs), has been developed keeping in mind the needs of MANET. DHT has been seen as an effective method for designing scalable routing protocols. Now the networks are becoming more complex, which leads to frequent node failures and route breakages. Multipath routing protocols are efficient in solving these problems. M-DART is a recently proposed multipath routing protocol based on DHT, which is multipath version of Dynamic Address Routing (DART). DART is shortest path routing protocol based on DHT. We have considered two different scenarios for evaluating performance of M-DART, one for IEEE 802.11 and other for IEEE 802.15.4. Under both these scenario's, we have taken CBR and FTP traffic with varying network size. The results show that for IEEE 802.11 M-DART gives consistent performance for networks of various sizes and performs relatively better than widely adopted protocol Ad-hoc On-demand Distance Vector (AODV) and it's multipath version Ad-hoc On-demand Multipath Distance Vector (AOMDV) for both CBR and TCP traffic. M-DART gives satisfactory performance in this environment. It decreases the packet loss, routing overhead, delay and increase throughput. For IEEE 802.15.4 results show that AODV performs better in case of CBR traffic and AOMDV performs better in case of FTP traffic. M-DART is not suitable for IEEE 802.15.4, as it doesn't give consistent performance.***

***Keywords— MANET; DHT; M-DART; AODV; AOMDV***

## I. INTRODUCTION

A MANET is a network of mobile nodes, that doesn't have any centralized control or fixed communication infrastructure. For establishing communication channel nodes act as routers. They can act as host as well as router at the same time. While acting as router, each node discovers and maintains route to other nodes. The topology of network changes from time to time as it depends on location and transmission power of the mobile nodes. Due to lack of centralized control and randomly changing topology efficient packet delivery becomes very critical aspect. Routing is a major challenge due to these frequent changes. A lot of research has been done for the development of efficient protocols, which can perform well in all the scenarios. These protocols can be classified in two categories [2]. Proactive Protocols follows a Table Driven approach as they maintain routing table all the time that contains routes to all nodes. They make changes in routing table, whenever there is slight change in topology, it doesn't matter if the traffic is being affected or not, by the change. They send periodic control messages to other nodes for maintaining route to every other node. With increase in node mobility they use more energy and bandwidth to maintain routing tables. Reactive routing protocols also known as on demand protocols doesn't maintain any tables, in fact they establish the route only when some packets needs to be sent. Thus it helps in reducing unnecessary sharing of control messages for routing table maintenance and thus saving bandwidth and battery life, when network is not being used for packet transfer [5]. But most of the proposed protocols are not scalable, since they are the modified versions of the protocols proposed for wired networks or infrastructure based wireless networks. More so because they use static addressing, where node identity is equal to routing address, but it is not yet valid in ad hoc scenarios. In case of centralized infrastructure based networks geographical position is provided by central infrastructure such as GPS, but it is not suitable for MANETs. DHT is proposed for self organizing networks, in which the information stored, is the node address, which gives the node's topological position inside the network. This introduces a logical and mathematical structure on the address space based on connectivity between nodes. Lookup procedure is being used to get the node identifiers in the DHT. The routing is performed using the topological information associated with the node address, resembling the routing procedure performed for wired networks [1]. This scheme is hierarchically organized in the form of a tree for node identifier management as well as routing. The multi-path dynamic address routing (M-DART)[1], is a multipath version of DART, which is shortest-path routing protocol based on DHT. M-DART extends the DART protocol to discover multiple routes between the source and the destination. So M-DART improves the tolerance of a tree-based address space against mobility as well as channel impairments [1]. Multi-path feature also improves the performances in case of static topologies. M-DART has two features that are better than other multi-path routing protocols. First, the multiple routes discovered by M-DART are communication-free and coordination-free, i.e., their discovering and announcing these routers does not require any additional communication or coordination overhead. Second, M-DART discovers all the available paths between source and destination, not just a limited number[1]. However, in the performance comparison the DHT system is replaced by a global lookup table available to all nodes, which neglects the impact of the address discovery, which is a key feature of the M-DART [1].

Lot of research is being done to evaluate the performance of routing protocols using various simulation models. M-DART has been evaluated for limited number of scenarios. In This work we focused on evaluating M-DART performance in two different environments (IEEE 802.11 and IEEE 802.15.4) using NS-2. We studied the impact of network size on performance metrics like PDR, Routing Overhead, Throughput, End to End Delay, and Energy with two different traffic models (CBR and FTP).

This paper is organized as follows. Section II discusses Dynamic Addressing and Dynamic Hash Table (DHT). In Section III we provided design and implementation details of AODV, AOMDV and M-DART routing protocols. In Section IV we compared the performance of M-DART with AODV and AOMDV based on metrics like PDR, Hop Count, Normalized Routing Load(NRL), End to End Delay, Throughput and Residual Energy. Finally, we summarized and concluded our paper with the help of simulation results in Section V.

## II. DYNAMIC ADDRESSING AND DHT

Dynamic Addressing [6] separates the routing address from the node identity. Whenever a node moves it's routing address changes to show, it's location in the network topology. The node identifier is a unique number that remains same during the lifetime of the node. Now we need to look into how the mapping between node identity and routing address is provided. In fixed infrastructure based networks information about the location of the node can easily be stored into node address, which can used to give unique identification to the node in the network. But in case of self-organizing networks, location of the node and node identifier can't have a permanent relation, due to frequent changes in network topology. So, a dynamic association is required between node identification and its location and a mechanism to manage this association [6].

To fulfill all these needs, DHTs [12] have been proposed to provide functionalities like location service, distribution of information and identity, which is location independent, Based on DHT several new systems have been built. By separating node identification from location and providing a mapping mechanism between them has developed researcher's interest in DHT, to incorporate it in routing protocols. The main idea of DHT is to distribute location information among rendezvous points, by using hash function throughout the network. Source also uses this hash function to identify a point to store location information of the destination [12]. DHT based algorithm implements hierarchical routing in an efficient way and it reduces the routing state routing state information being maintained by each node. The mapping from node identities to network addresses is provided by a Distributed Hash Table (DHT) [12].

## III. OVERVIEW OF PROTOCOLS

### *A. Ad-hoc On Demand Distance Vector*

AODV [3] is an on demand protocol and it finds routes as and when required by using route discovery mechanism. It uses routing tables which stores, one entry per destination. It doesn't use source routing and depends on routing table entries to send RREP (Route Reply) to the source. It is also being used to route data packets to the destination. Every destination maintains a sequence number, which is being used by AODV to check freshness of routing information and to avoid routing loops [9]. All routing packets carry these sequence numbers. Timer-based states are used in each node, to remove unused older entities from routing table. Each routing table maintains a predecessor node set, which indicates the neighboring nodes sets, to be used to route packets. RERR (Route Error) packets are sent to neighboring nodes when the next-hop link breaks. Each predecessor forwards these packets to its predecessor node, and thus removing all routes that are using the broken link. Route error propagation in AODV can be visualized conceptually as a tree whose root is the node at the point of failure and all sources using the failed link as the leaves [9]. The AODV requires lesser memory space and has lower overhead as it stores information about active routes only, thus increasing the performance[3], But AODV is not scalable and can't be used in larger networks.

### *B. Ad-hoc On Demand Multipath Distance Vector*

AODV has been modified to eliminate frequent route breaks and link failures in highly changing ad hoc networks, and AOMDV has been developed from. The AOMDV [22] protocol discovers multiple routes. This involves two stages i) Multiple loop-free routes are established and maintained at each node, by route update rule and ii) Link disjoint paths are found by distributed protocol. The AOMDV protocol finds node-disjoint or link-disjoint routes between source and destination [2]. AOMDV was developed, for the networks, where links fail and routes break very frequently. Routing loops are avoided by using sequence number, which determines freshness of the route[2]. Three types of control messages are being used: route request (RREQ), route error (RRER), and route reply (RREP) to discover routes. Whenever a node needs route for sending data, it broadcasts RREQ. When a node receives a RREQ message, it checks the destination address in RREQ [2]. If it is destination itself, it sends RREP packet to the source node. If it does not have a route to destination, it sends RRER message back to the upstream node. AOMDV routing table has 5 fields. It uses hop count field for discovering multiple routes. AOMDV uses next hop lists, to define multiple next hops with relevant hop counts; a node updates its advertised hop count for a destination whenever it sends a route advertisement for the destination [4].

### *C. Multipath Dynamic Address Routing(M-DART)*

 

M-DART [1] uses distance vector concept and hop by hop routing approach. It also uses dynamic addressing paradigm with the help of transient network addresses. The main feature of M-DART is that increase in routing state information being stored by each node doesn't increase communication or coordination overhead, as it relies on the routing information stored by DART protocol. It does not introduce any additional control packet in the routing update entry and the number of entries remains same as in DART. No special coordination action is needed by nodes and the node memory requirements constitute the only additional overhead in M-DART relative to DART [1]. In this way, M-DART improves tolerance against mobility and channel impairments of the address space. The multipath feature improves the performances in case of static topologies as well by using route diversity [1]. Some key features of M-DART are described below:-

**Address Space[1]: -** The network addresses are strings of l bits, thus the address-space [1] 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 (Fig -1). In the tree structure each leaf is associated with a network address, and a 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 Fig -1 the vertex with the label 01x is a level-1 sub tree and represents the leaves 010 and 011. Let us define as 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 Fig. 2, 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 relying on inefficient mechanisms like flooding.

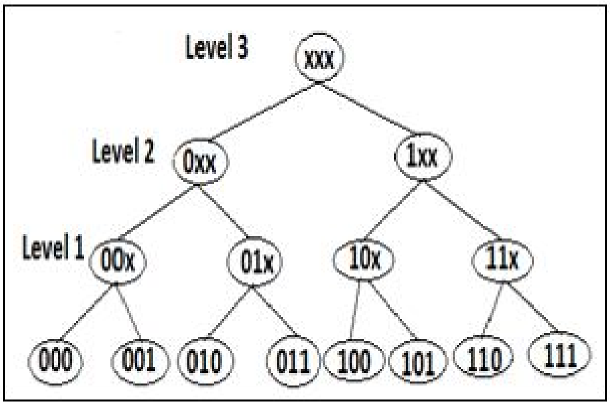


Fig -1: Address Space [1]

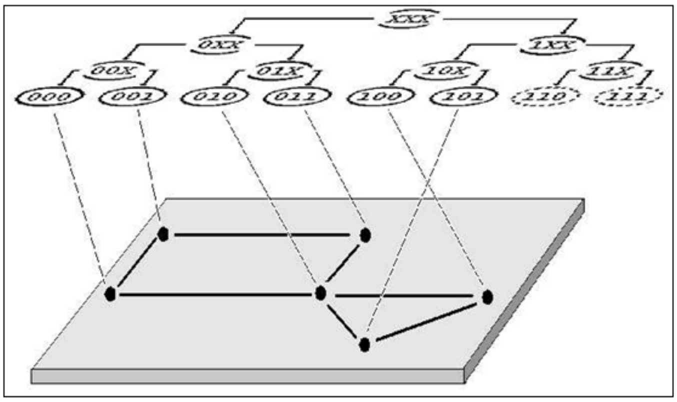


Fig -2: Relationship between address space and physical topology [1]

***Route Discovery and Packet forwarding [1]:-*** Each node maintains a routing table composed by l sections, one for each sibling, and the k-th section stores the path toward a node belonging to the level k sibling. Each section stores five fields: the sibling to whom 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 [1]. Table -1 is the routing table of node 000 for the network depicted in Fig -2. The table has three sections: the first stores all the routes toward the node 000, the second toward a node belonging to the sibling 01x and the last toward nodes belonging to the sibling 1xx[1]. The routing state information maintained by each node is kept consistent through the network by means of periodic routing updates exchanged by neighbour nodes. Each routing update stores l entry and each entry is composed by four fields: the sibling id, the cost, the network id and the route log. The packet forwarding [1] process exploits a hop-by hop routing based on the network addresses [1]. To route a packet, a node compares its network address with the destination one, one bit at 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 [1]. With reference to the previous example, if the node 001 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 (ie. the node 011)[1]

Table -1: Routing Table for Node 000[1]

| Sibling id | Next hop | Route cost | Net_id | Route log |
|---|---|---|---|---|
| 000 | 000 | C(001,000) | MIN_ID(n) n in 001 | 000 |
| 01x | 000 | C(001,000) + MIN_C(000,n) n in 01x | MIN_ID(n) n in 01x | 010 |
| | 011 | C(001, 011) | MIN_ID(n) n in 01x | 010 |
| 1xx | 000 | C(001,000)+ MIN_C(000,n) n in 01xx | MIN_ID(n) n in 1xx | 100 |
| | 011 | C(001,011)+ MIN_C(011,n) n in 1xx | MIN_ID(n) n in 1xx | 100 |

 

## IV. Performance Evaluation

We used network simulator ns-2(Ver-2.35) to compare performance of M-DART with AODV, AOMDV in Two different scenarios In Scenarios-I for IEEE Standard 802.11 and in Scenario-II for 802.15.4. In bothe these scenarios we have taken two traffic types ie. CBR and FTP. First we evaluated the performance for CBR traffic over UDP and then FTP traffic on TCP based on the performance metrics mentioned in next section.

### *A. Performance Metrics*

**Packet Delivery Ratio (PDR):-** It is the ratio of number of packets received at the destination to the number of packets generated by the source.

**Hop Count:-** This is the average of nodes being followed by each packet in reaching from source to destination.

**Normalized Routing Load (NRL):-** This is the ratio of total routing packets sent and the total number of data packets successfully received by the destination.

**End to End Delay:-** This is the average of time delay of all the data packet from source to destination. This delay includes route establishment time, propagation time and queuing time.

**Throughput:-** It is the measurement of data transmitted throughout the network per unit time. This is the measure of how fast data can travel through the network

**Residual Energy:-** This is the average remaining energy per node after simulation.

### *B. Simulation Setup*

We have taken two scenarios. In Scenario-1, we have analysed PDR, Hop Count, NRL, End to End Delay, Throughput and Residual Energy of AODV, AOMDV and M-DART for IEEE 802.11. These metrics are calculated by varying the number of nodes from 50 to 400. Nodes are being randomly distributed in the area. This is being done to evaluate impact of network size on these performance metrics. In Scenario-II, we have analysed these metrics for IEEE 802.15.4. Node number is varied from 5 to 40. Nodes are being uniformly distributed in the area. This is being done to check the suitability of DHT paradigm for IEEE 802.15.4 based networks. First we have considered CBR over UDP and then FTP over TCP in both these scenarios. These traffic types support different application, therefore these have different requirements. Simulation parameters being taken are shown in Table -2.

Table -2: Simulation Parameters

| Parameter | Scenario-I | Scenario-II |
|---|---|---|
| MAC | IEEE 802.11 | IEEE 802.15.4 |
| Density/Area | 4096/$KM^2$ | 80 x 80 |
| Simulation Time | 400 Secs | 500 Secs |
| Propagation Model | Shado | Two Ray Ground |
| Routing Protocols | AODV, AOMDV, M-DART | |
| Traffic Type | CBR/FTP | |
| Transport Layer protocol | UDP/TCP | |

### *C. Simulation Results for Scenario-I (CBR over UDP for IEEE 802.11)*

All the protocols try to achieve the Packet Delivery Ratio of 1. As shown in Fig -3, AODV has better performance as compared to AOMDV and M-DART for smaller networks ( <50nodes ). When we start increasing the network size, PDR of AODV and AOMDV starts to degrade, whereas it remains almost same for M-DART. For a network of 400 nodes PDR of AODV and AOMDV are very low. Distance vector base algorithms follow minimum number of hops. As shown in Fig- 4 AODV and AOMDV have almost same Hop count for all network sizes, as they use shortest path based approach. M-DART uses DHT based approach, so it has highest Hop Count for all network sizes. A protocol can be said efficient if it finds a path from source to destination by using lowest number of routing packets. As shown in Fig -5, M-DART has lesser routing load as compared to AODV and AOMDV. However for network of up to 250 nodes, there is minor different in routing load. But for networks of larger size (more than 250 nodes) routing load for AODV and AOMDV grows exponentially. For M-DART there is uniform increase in routing load, when network size increases. Delay should be minimized for real time or multimedia applications. Protocol should reduce time in finding a route and should also reduce propagation delays. As shown in Fig -6. M-DART has uniform delay for all network sizes and it is very less as compared to AODV and AOMDV. Throughput is the measure of how fast data can be transmitted through the network. To offer different kind of services network should support higher transfer rates. As shown in Fig-7, for network of about 50 nodes throughput is higher for AODV as compared to AOMDV and M-DART. As network size increase it starts to degrade. For AODV and AOMDV it degrades at a much higher rate as compared to M-DART.

And for all network sizes of more than 100 nodes, Throughput is higher for M-DART. Ad-hoc networks operate in energy constrained environment, so protocol should conserve energy. As shown in Fig- 8, M-DART consumes higher energy than AODV and AOMDV for all network sizes. AOMDV is best in conserving energy as it can avoid route and network failures by using multipath based approach. M-DART consumes higher energy because of it’s proactive nature.

 

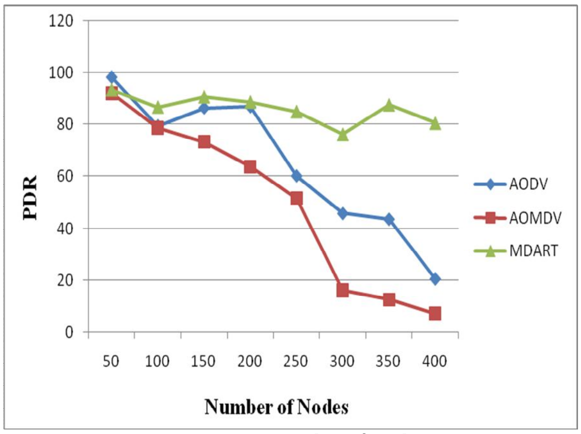


Fig -3: PDR Vs Number of Nodes

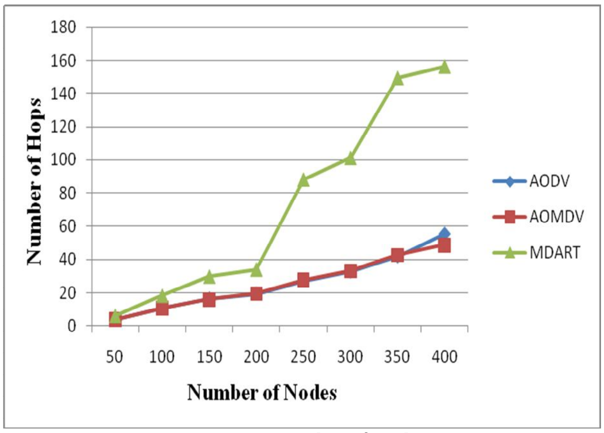


Fig -4: Hop Count Vs Number of Nodes

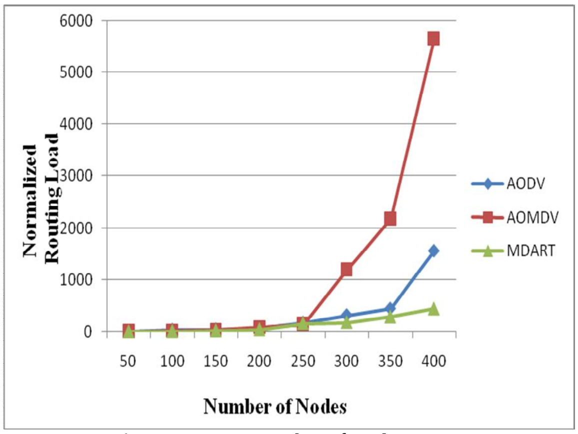


**Fig -5:** NRL Vs Number of Nodes

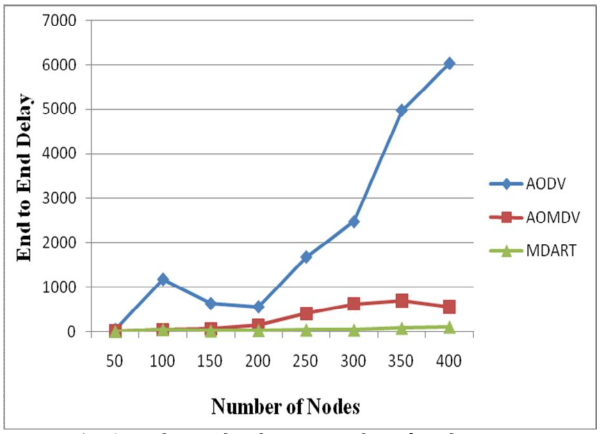


**Fig -6:** End to End Delay Vs Number of Nodes

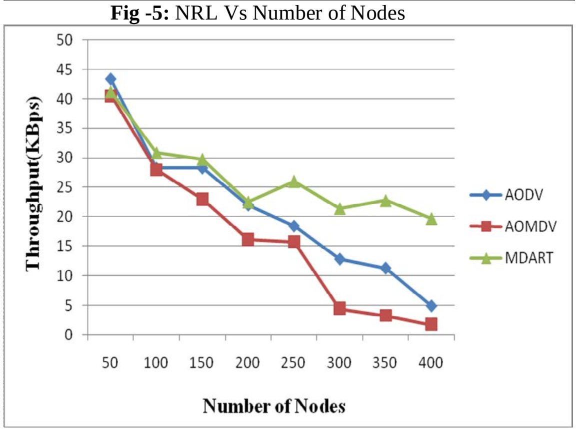


Fig -7: Throughput Vs Number of Nodes

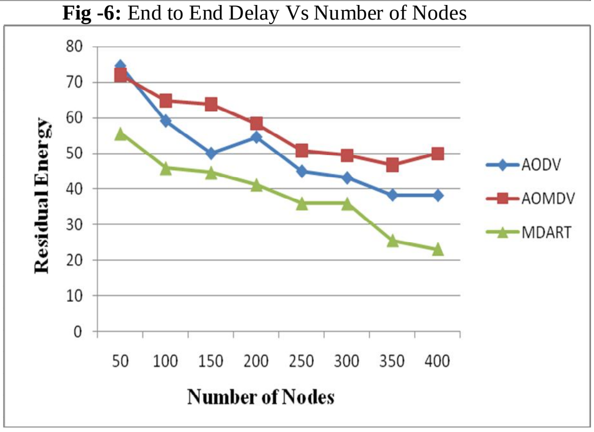


Fig -8: Residual Energy Vs Number of Nodes

*D. Simulation Results for Scenario-I(FTP over TCP for IEEE 802.11)*

For FTP traffic we need a connection oriented protocol. For this purpose we use TCP. This creates a different environment. So results for FTP traffic over TCP differ from CBR over UDP. Results are shown below from Fig- 9 to Fig- 14. All the considered protocols show relatively better performance than in case of CBR traffic. As shown in Fig- 9, AODV and AOMDV shows better PDR for larger size networks also, But M-DART has better PDR as compared to AODV and AOMDV. AODV has better PDR than AOMDV. PDR of AODV and AOMDV decrease with increase in network size, whereas it remains almost same for M-DART. For hop count all these protocols show similar kind of behavior as they have shown in CBR traffic. As shown in Fig- 10, M-DART has very high hop count as compared to AODV and AOMDV, because AODV and AOMDV uses shortest path based approach. AODV has slightly higher hop count than AOMDV for all network sizes. For NRL these protocols show different kind of behavior. As shown in Fig- 11, for networks of up to 250 nodes, Routing overhead is lowest for AODV and highest for M-DART. As network size goes beyond 300 nodes routing overhead remain same for M-DART, but increases at a much higher rate for AODV and AOMDV. For these networks, NRL is lowest for M-DART.

 

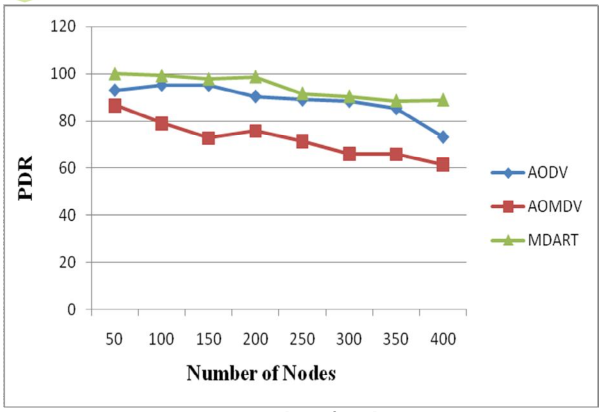


Fig -9: PDR Vs Number of Nodes

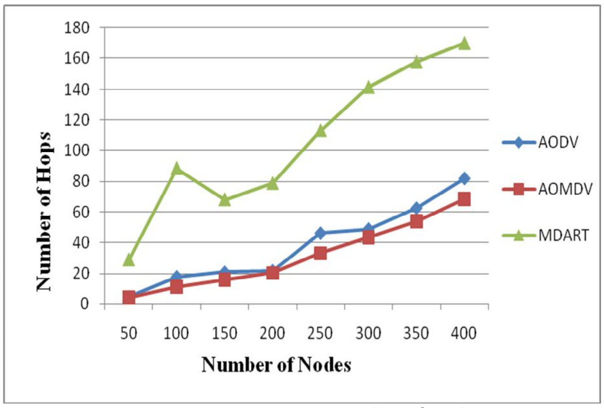


Fig -10: Hop Count Vs Number of Nodes

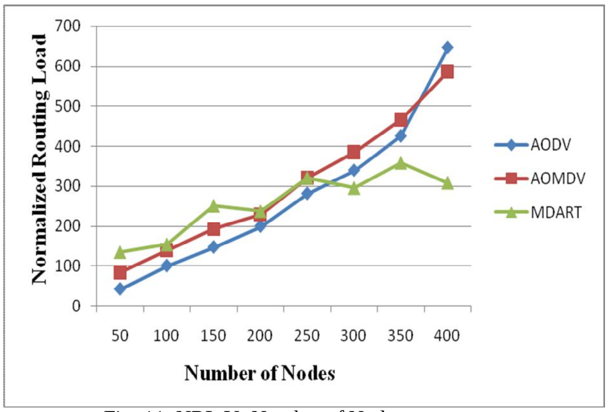


Fig -11: NRL Vs Number of Nodes

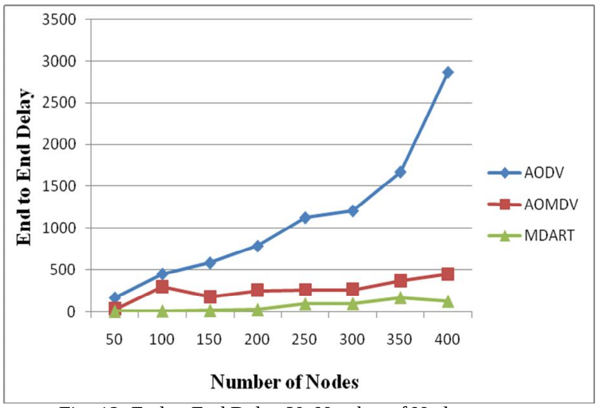


Fig -12: End to End Delay Vs Number of Nodes

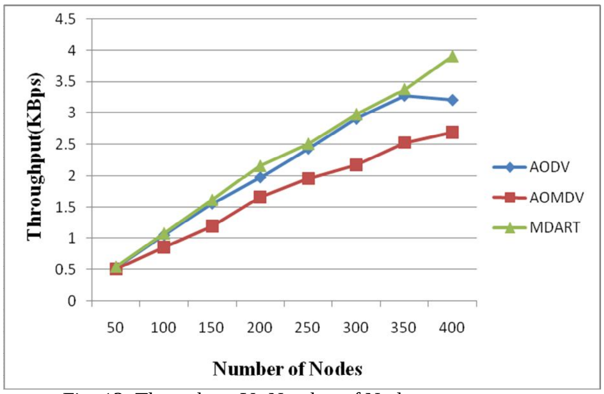


Fig -13: Throughput Vs Number of Nodes

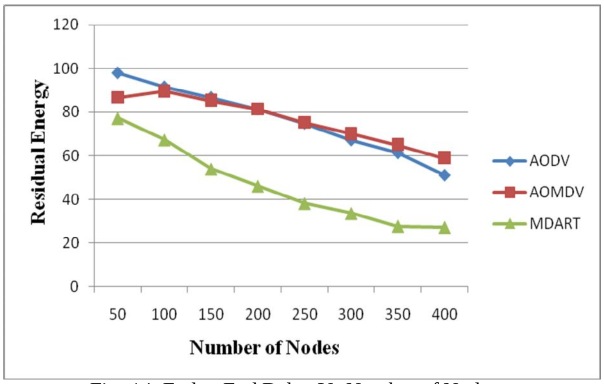


Fig -14: End to End Delay Vs Number of Nodes

For End to End Delay these protocols show similar kind of behavior as they have shown for CBR traffic. As shown in Fig- 12, End to End delay is lowest for M-DART, far lower than AODV and AOMDV. This is due to it's proactive nature and efficient route finding technique. For AODV delay increases at a much higher rate as network size increases. Throughput of all these protocols shows an increasing trend. As shown in Fig-13 throughput is lowest for AOMDV and highest for M-DART for all network sizes. Throughput of AODV is slightly lesser that M-DART. M-DART consumes higher energy as it is more complex and keeps on updating routes. As shown in Fig-14 residual energy is lowest for M-DART. For networks of up to 200 nodes residual energy is higher for AODV and for network of more than 250 nodes residual energy is higher for AOMDV

*E. Simulation Results for Scenario-II (CBR over UDP for IEEE 802.15.4)*

IEEE 802.15.4 is a standard for small networks that operate in personal area space. Devices have low bit rate and low power consumption. We have considered Beacon Enabled peer to peer networks that range form 5 to 40 nodes. As shown in Fig- 15, AODV and AOMDV have similar PDR. They have been able to deliver above 95% packets for all networks. MDART doesn't have consistent PDR. For some networks it shows good results and for other it shows PDR of below 20%. As shown in Fig- 16 AODV has the minimum NRL and it remain almost constant with increasing network size. M-DART has the highest NRL, whereas AOMDV has comparatively less NRL than M-DART, but that increases with network size. As shown in Fig- 17, M-DART has the lowest delay due to it's proactive nature. For AODV delay is highest and AOMDV has higher delay than M-DART but lower than AODV. Throughput as shown in Fig- 18 has similar kind of results as shown in case of PDR in Fig-16.

 

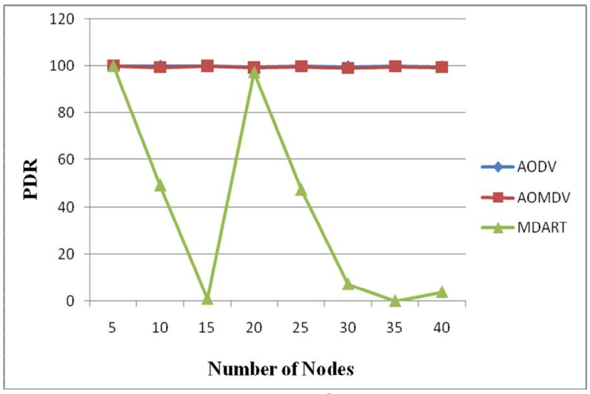

Fig -15: PDR Vs Number of Nodes

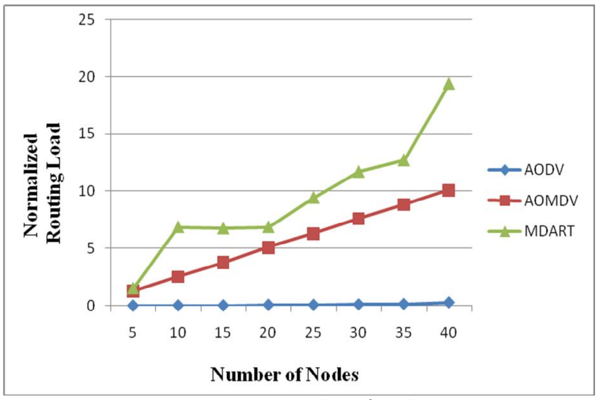

Fig -16: NRL Vs Number of Nodes

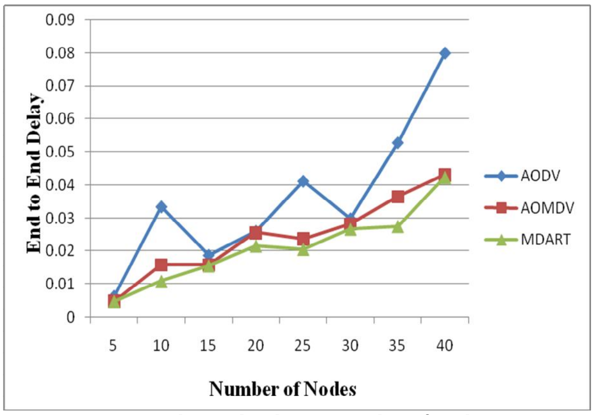

Fig -17: End to End Delay Vs Number of Nodes

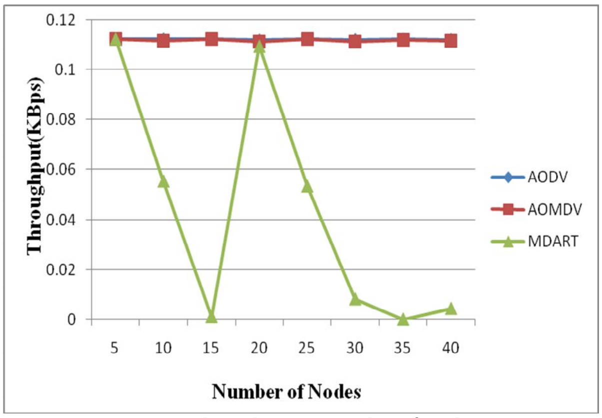

Fig -18: Throughput Vs Number of Nodes

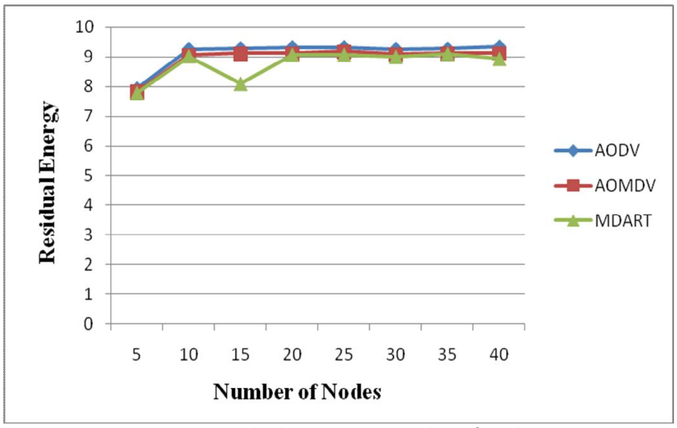

Fig -19: Residual Energy Vs Number of Nodes

AODV and AOMDV has almost constant and same throughput for all network sizes, But M-DART doesn't have consistent throughput. For some networks it is high and for others, it is very low. As shown in Fig- 19 AODV is best in conserving energy, where as M-DART consumes relatively higher energy, as it periodically sends routing messages to keep routing information updated and correct all the times.

*F. Simulation Results for Scenario-II (FTP over TCP for IEEE 802.15.4)*

IEEE 802.15.4 creates different environment. Results for FTP traffic over TCP differ from CBR over UDP. These are shown in Fig- 20 to Fig- 24. Results show that AOMDV performs better for all the metrics being considered. AOMDV shows highest PDR as shown in Fig- 20. AODV has slightly lower PDR and M-DART has the lowest for all network sizes. For AODV and AOMDV NRL increases consistently with increase in network size as shown in Fig- 21. However M-DART doesn't show consistent performance and also have highest NRL. AOMDV has the lowest NRL for all network sizes. E2E delay is also lowest for AOMDV, as it uses multipath feature. And it is highest for AODV as shown in Fig- 22. M-DART has relatively higher delay than AOMDV. Throughput of AOMDV is highest among these protocols as shown in Fig- 23. For network of five nodes AODV and M-DART give good throughput as no hops are being followed. But for networks of 10 or more nodes multiple hops are being followed and AODV and M-DART doesn't give good throughput value. AOMDV consumes highest energy as shown in Fig-24, as more number of data packets travel through AOMDV network because of it's high throughput compared to AODV and M-DART.

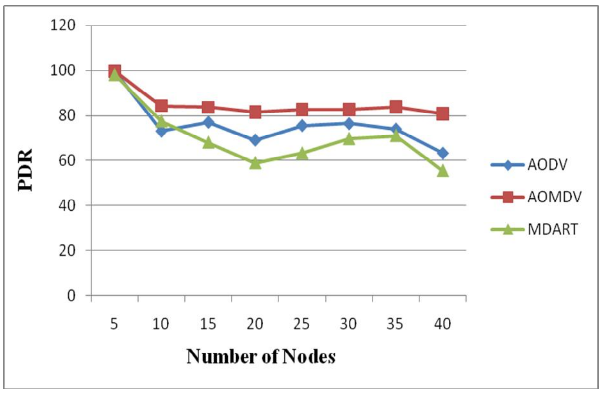


Fig -20: PDR Vs Number of Nodes

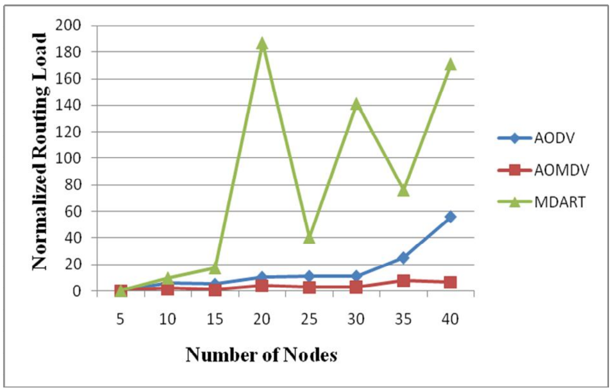


Fig -21: NRL Vs Number of Nodes

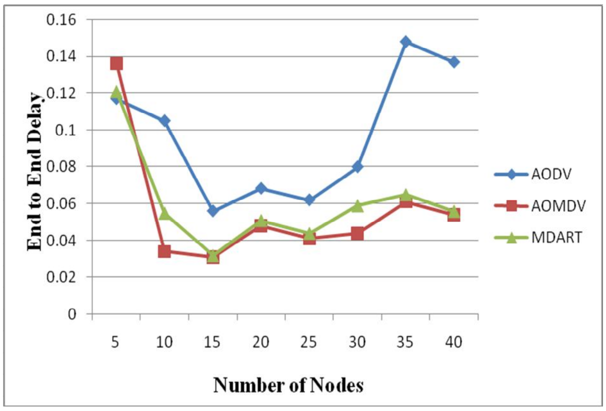


Fig -22: End to End Delay Vs Number of Nodes

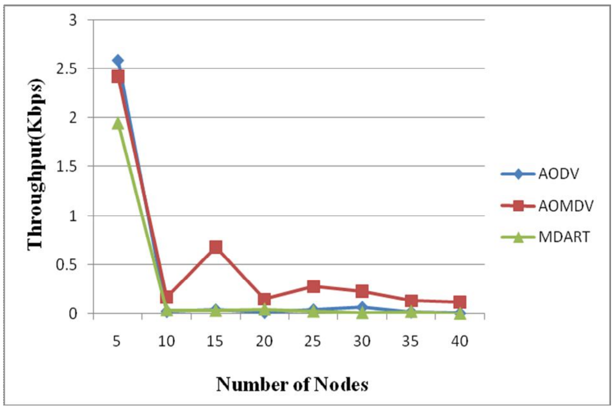


Fig -23: Throughput Vs Number of Nodes

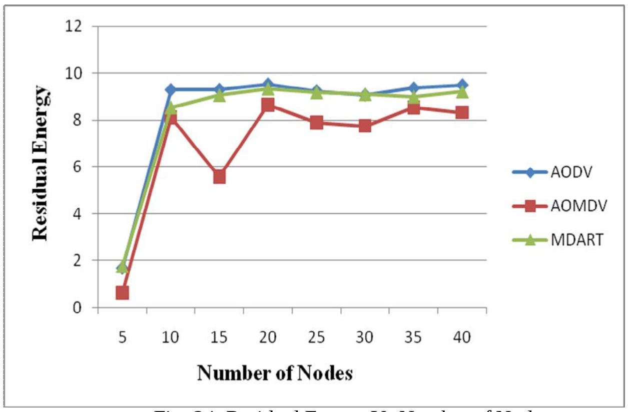


Fig -24: Residual Energy Vs Number of Nodes

## V. CONCLUSIONS

For IEEE 802.11 DHT based multipath routing has better performance as compared to previously well known protocols and it is scalable. M-DART is an efficient protocol which gives improved performance in large networks. We have analysed that for CBR traffic M-DART has better PDR, Average Throughput, End to End delay, Normalized Routing Load and AODV, AOMDV has better hop count and residual energy. For FTP traffic M-Dart has better PDR, Average Throughput, End to End delay and AODV, AOMDV has better hop count, Residual Energy. Normalized Routing Load is better for AODV, AOMDV in smaller networks and for M-DART it is better for larger networks (more than 250 nodes). We have found that AODV and AOMDV performs good for smaller networks, but when number of nodes grows, the performance of these Reactive protocols declines, whereas M-DART shows consistent performance. M-DART is scalable, as it supports large number of nodes. For IEEE 802.15.4 M-DART doesn't show consistent performance. It is not suitable for this environment. AODV shows better performance for CBR traffic, where as AOMDV shows better performance for TCP traffic. In future we can analyse the behaviour of M-DART in different scenarios, considering different MAC versions, propagation properties, and mobility scenarios

 

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