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An Efficient Multipath Dynamic Routing Protocol for Mobile WSNs

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Abstract

In mobile wireless sensor networks, Distributed Hash Tables (DHTs) based multipath routing protocols performs good in terms of energy consumption, delay, throughput etc. This paper strives to analyze and compare the experimental evaluation of M-DART, proactive multipath protocol, and AOMDV, reactive multipath protocol using Network Simulator. Different simulation experiments were performed to check the behavior of both of these multipath routing protocols for Mobile WSN scenario and we observed that MDART outperforms AOMDV in terms of energy consumption, end to end delay, throughput and packet loss percentage.

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Keywords: Mobile WSN, Multipath Routing protocols, MDART, AOMDV, DHT

1. Introduction

Due to their wide range of application, WSNs have always been the topic of research. In wireless sensor networks an enormous number of tiny sensor nodes are deployed. Each sensor node can collect, store, process and communicate observations over wireless channels. Because of their small physical size, these nodes have a limited processing power which further confines the processor's capacity and battery size. Working conjointly, these sensor

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nodes collect and process the information about the physical environment and send it to the base station or sink[1, 2] Various routing protocols proposed so far assume sensor nodes and sinks to be immobile in the WSN implementation. However, there are applications that require a mobile node to gather information from inaccessible areas. In mobile WSNs, sensor nodes are mobile in order to collect data from inaccessible areas. This movement of sensor nodes leads to frequent topology changes, thereby requiring efficient routing protocols to deal with this node mobility. In this paper, based on network structure, routing protocols are classified into two categories: - Flat protocols and Hierarchical protocols as shown in Fig.1[7]. The flat routing protocols are split into two different categories i.e. reactive and proactive routing protocols. A proactive protocol creates routing paths by checking the requirement of routing traffic. It maintains and periodically refreshes the list of destinations and their routes even if there is no traffic flow. In reactive routing protocol, routing process is initiated on demand, i.e. paths are found only when data is present to be sent to other nodes.

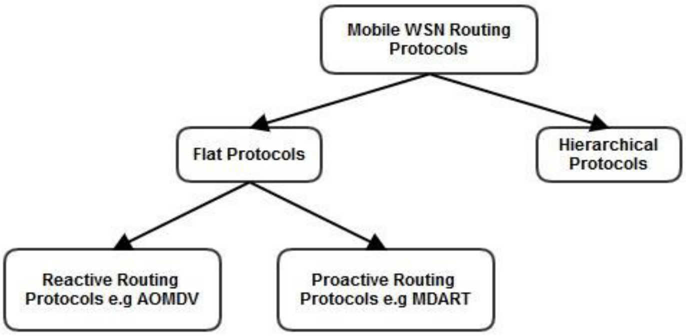

Fig.1 : Classification of Routing Protocols

Behaviour of a routing protocol depends on various factors such as size of network, capacity of link and mobility of nodes. Frequent changes in the network topology results into disconnected routes. Multipath routing protocols provide endurance against unstable wireless links and node mobility[7]. AOMDV protocol, an augmentation of AODV protocol, is an example of multipath on-demand routing protocol. AOMDV explore numerous paths that exist between two given nodes. By using these multiple paths we can achieve proficient fault tolerance against route breakages in a dynamic network. Most of the protocols, (reactive/proactive, single-path/multi-path) are based on static addressing in which each node is identified by using its routing address and hence are improficient for scalable networks. In recent years routing protocols based on DHT paradigm have been purposed to deal with the issue of scalability and channel impairments. In this paper, a protocol is implemented which performs better for scalable mobile WSN as compared to other traditional routing protocol. The remainder of this manuscript is structured as follows. Section II introduces Distributed Hash Table (DHT) and Dynamic Addressing. The brief description of the routing protocols considered in this work is described in Section III. Simulation analysis and experimental results with different performance metrics of both routing protocols are presented in Section IV. Finally we conclude our research work in Section V.

2. Dynamic Addressing and Distributed Hash Tables(DHT)

In Mobile WSN, as node moves from one location to another, its routing address changes and to designate node's current position within the network dynamic addressing[4] is used which provides mapping between node's dynamic address and its identity. Each node in network is identified by its globally unique identifier that remains the same for its lifetime[5]. In order to know the dynamic address of node from its identity, DHT (Distributed Hash table) paradigm is used which helps to provide a mapping between node identification and current location of node in Mobile WSN. In DHT (Distributed Hash Table) lookup service, similar to hash table, is provided where pairs of (key, value) are arranged and by providing the key a **node** can efficiently fetch the corresponding value. By using DHT we can escalate a mobile network and can efficiently handle continuous nodes movement (i.e. node arrivals and departures). DHTs has proven to be an important concept to be integrated in routing protocols as it provides services based upon which self-organizing networks works[7].

3. MDART and AOMDV Routing Protocols Description

3.1 MDART (Multipath Dynamic Address Routing Protocol)

MDART stands for multi-path dynamic address routing protocol based on DHT paradigm, which is used for escalating mobile networks. This protocol originates from DART, a routing protocol. It extends the DART protocol (Single path) by discovering various routing paths from one node to another thereby increasing the forbearance against node's mobility as well as route breakage. M-DART has two important points that need to be considered, which makes it different from existing multi-path protocols. Firstly, the repetitious route located by M-DART does not need any additional overhead [5] and they are assured to be communication-free and coordination-free. Secondly, M-DART detects each possible superfluous routes that can exist among two different nodes. The key concepts of the DART protocol [6, 7] are discussed below which are essential to understand the M-DART.

3.1.1 Address Space

The address of each node in MDART consist of string of *k bits* and is expressed as a binary tree having *k+1 levels* i.e. a tree in which each level, except possibly the last, is completely filled. A network address is assigned to each leaf node and all the internal nodes in the tree structure. *An internal node at level l, namely level-l subtree, consists of leaves that have same k-l bits of address prefix.* To understand this concept take Fig.2 as reference, the internal node acquiring address 11X is level 1 subtree and it consists of leaf nodes that are sharing same address prefix i.e. 111 and 110. Hence, each address has only *k* sibling and every other address is linked to exactly one of these *k* siblings. Referring Fig.2, node having network address 1XX is the level-2 sibling of the node acquiring address 011, and the address 111 refers only to this sibling. An overlay network is designed to represent address space overlay upon the basic physical topology, shown in Fig.3. For allocation of addresses, an easy and convenient procedure based on tree based structure is used, thereby preventing dependency on improficient techniques like flooding [5].

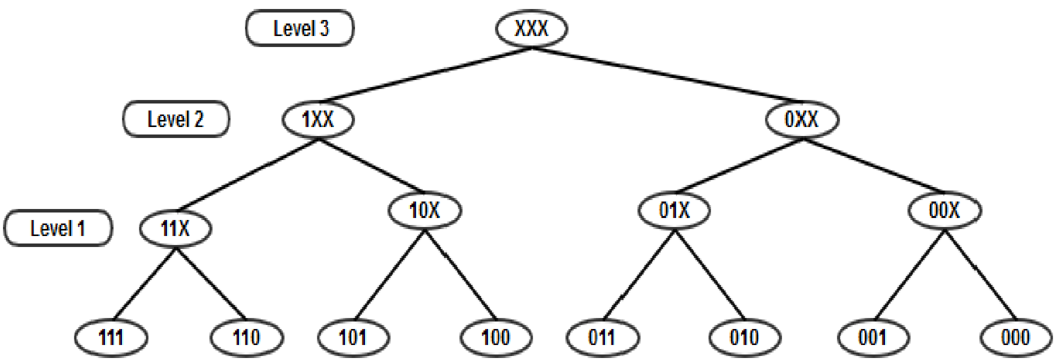

Fig.2 : Address Space Overlay

3.1.2 Route Discovery and Packet Forwarding Mechanism

Route discovery mechanism is scheduled whenever a source node wants to send data to a new destination node or the previously existing route expired. A routing table is maintained by each node in the network that consist of *k* routing entries, one for individual sibling, and the l^{th} entry in table maintains the route for a node that belongs to the level-*l* sibling. MDART routing table entry maintains five different fields: address of sibling to whom the entry belongs to, the next hop, the route cost needed to reach a node belonging to that sibling using the next hop, for address recognition id of network is maintained, and the route log information used by the loop avoidance mechanism. The routing table for node 111 for the network designed above is shown in Table 1[5]. It consist of Three fields: the first field saves all the routing paths for the node 111, the second field stores routes for a node that belongs to the sibling 10X and the third field saves routing paths for nodes belonging to the sibling 0XX. The routing state report managed by each node is kept consistent through the network by means of recurring routing updates shared by neighbour nodes. Every routing update store k entries, each of which comprises of four fields: sibling id, cost of route, network id and route log. To transfer a data packet, a sensor node compares its network address with the destination network address, one bit at a time initiating with the left most bit, say the k^{th}. If the j^{th} bit is a variant, the node forwards the packet towards the route stored in the j^{th} section. Relating with the previous example, if the node 111 has to transfer a packet to another node having address 011, then it will forward the packet to the next hop stored in the third section (i.e. the node 101).

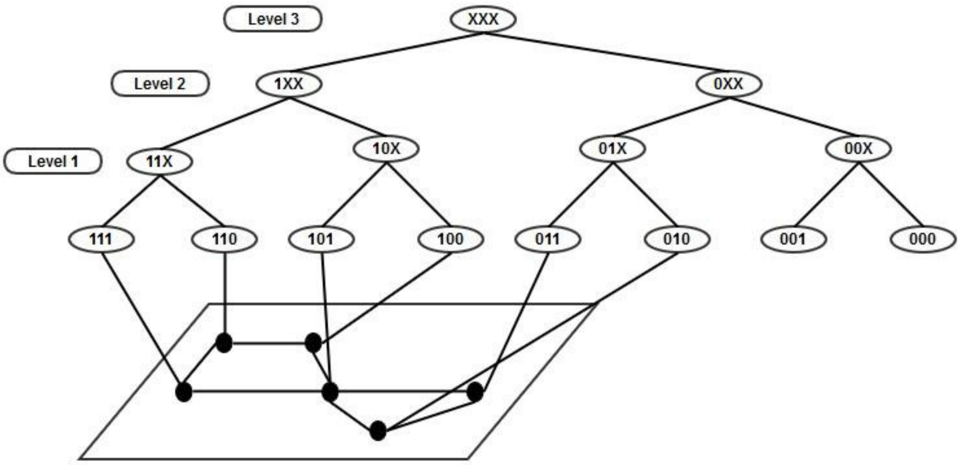

Fig.3: Representation of Address space overlay upon the basic physical topology of network

Table 1 Routing table entries for node 111 in MDART

Sibling ID	Next Hop	Route Cost	Network ID``	Route log
110	110	RC(111,110)	min ID(N) N in 111	110
	101	RC(111,101)	min ID(N) N in 10X	101
10X	110	RC(111,110)+min RC(110,N) N in 10X	min ID(N) N in 10X	101
	101	RC(111,101)+min RC(101,N) N in 0XX	min ID(N) N in 0XX	011
0XX	110	RC(111,110)+min RC(110,N) N in 0XX	min ID(N) N in 0XX	011

3.2 AOMDV (Adhoc On Demand Distance Vector Routing Protocol)

AOMDV originates from an ad hoc on-demand distance vector routing protocol (AODV), a prominent on-demand single path routing protocol. AOMDV, extension of AODV[11] routing protocol is used to locate various routing paths between two given nodes in each route discovery. Different paths discovered are assured to be loopfree and disjoint. For self-organizing or mobile networks where the problem of route breakage and link failures occurs frequently, AOMDV was primarily originated. AOMDV devise different routing paths to the given destination node in active communication. AOMDV provides loop avoidance mechanism by keeping track of recent routing updates using sequence numbers [8]. For mobile networks AOMDV is very helpful as it can react quickly to the link breaches and changes in network topology. Communication between nodes using AOMDV protocol requires Route Request (RREQ) message, Route Reply (RREP) message and Route Error (RERR) message to locate routes. Whenever a sensor node requires transferring data packet to any other sensor node within the network topology, then it simply sends RREQ message to all the nodes that exist in that network. A sensor node that hear a RREQ message, verifies the address of destination node in RREQ message. If it has knowledge related to the target node or it is target in itself, then it utilizes RREP message to send to the originating node. Else if no route or alternative path to the destination is reachable, it conveys RERR message backward to the upstream sensor node. AOMDV routing table entry consists of 5 fields, which are, Destination address, sequence number, advertised hop count, to store multiple route entries [8], next hop field, to define multiple next hops with relevant hop counts and expiration time out.

4. Simulation Results

The implementation and comparative analysis of MDART and AOMDV routing protocols for scalable mobile wireless sensor networks was performed using the network simulation tool NS2. Table 2 shows the simulation scenario with the typical parameters and their values. Sensor nodes in the network are varying between 20 to 500 to check the performance for scalability. In this scenario, the node-UDP type of data pattern was used and the maximum simulation time taken was 200 seconds and. Mac/IEEE 802.11 standard was used for the wireless environment and the speed of mobile nodes was varied from 0.5 ms to 1.5 ms. For all types of simulations performed, omni-directional antennas were used. The simulation results of average throughput, delay, energy consumption and packet loss percentage versus number of nodes obtained are described below.

Table 2. Simulation Scenario

S. No	Parameter	Value
1.	Number of Nodes	20 to 500
2.	Simulation Time	200 Seconds
3.	Data Pattern	Node-UDP
4.	Routing Protocols	MDART,AOMDV
5.	MAC Type	Mac/802.11
6.	Simulator	NS-2.35
7.	Speed	0.5 ms to 1.5 ms
8.	Antenna Type	Omni Directional

4.1 Average throughput comparison between MDART and AOMDV

Els-b

as compared to AOMDV. This is because AOMDV is based on On-Demand paradigm and M-DART uses DHT based mechanism. By increasing number of nodes, the changes in results of throughput become considerable, thereby proving that M-DART performs well with higher number of nodes. By escalating nodes in the network, the throughput of AOMDV decreases because of the longer route followed by every packet from originating node to the target node and time latency incurred for making routing decisions at the intermediate hops. In AOMDV every node finds path to destination whenever it has a packet to be forwarded. This route finding is a time consuming process. In M-DART, each node has a path to all the other nodes stored in its routing table.

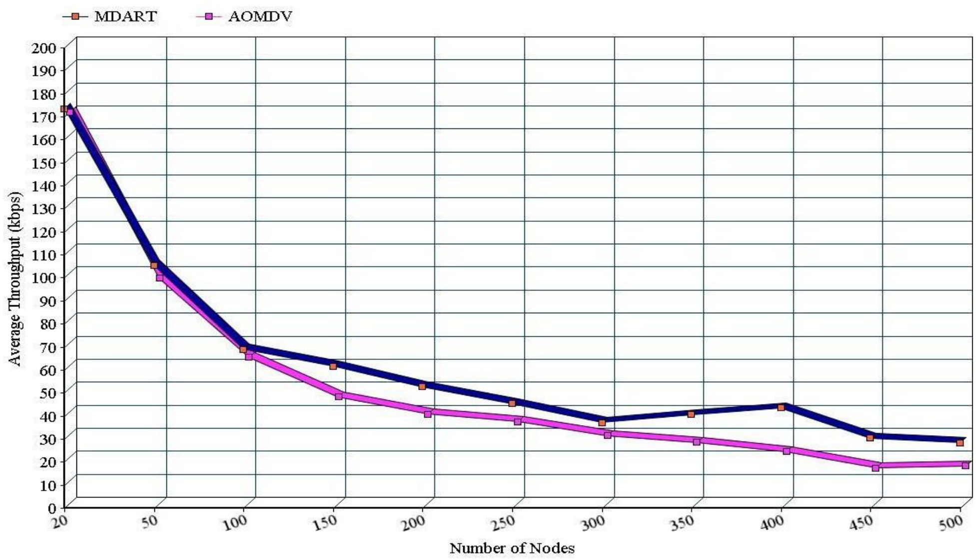

Fig.4: Average Throughput Comparison of MDART and AOMDV

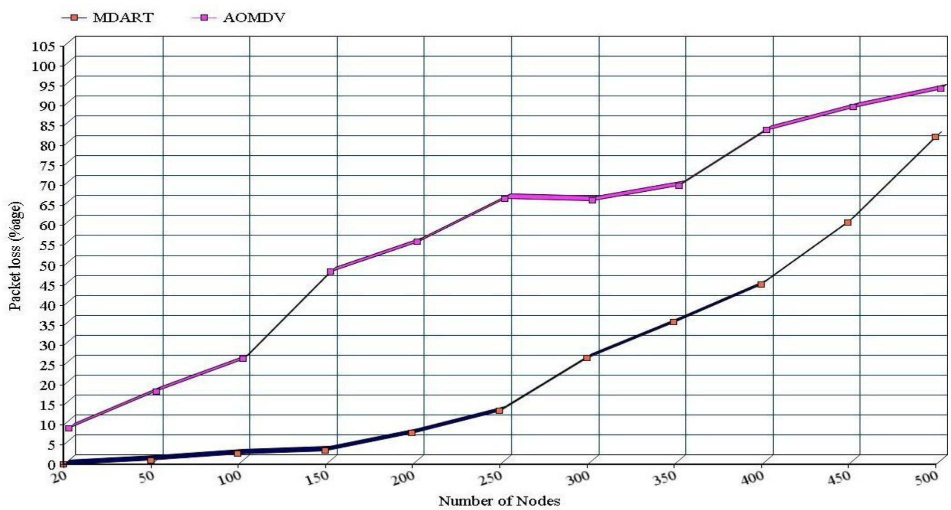

Fig.5: Average Packet Loss Percentage Comparison of MDART and AOMDV

4.2 Packet loss comparison between MDART and AOMDV

When data packets fail to reach their destination while travelling across a network then packet loss occurs. As the nodes in the network escalate then there will be rise in losses of packets, because of packet drops due to the congestion in network. Fig.5 illustrates the packet loss percentage for MDART and AOMDV with increasing number of nodes. When number of nodes are greater than 50, M-DART have less Packet loss percentage than AOMDV. In a reactive routing protocol like AOMDV, the nodes neither maintain routing information nor use the network resources when there is no data to be sent; thus, they are ideal for small networks. However, with larger networks having more traffic, if routes to destination breaks, a different route discovery mechanism must be proposed. As far as the updated fresh path is found, packets are either discarded or deferred. But in DHT based

Multipath approach whenever a route fails, the new topological information is shared among all the nodes and the routing tables are modified accordingly with current topological information.

4.3 Average end to end delay comparison between MDART and AOMDV

The average end-to-end delay means the delay encountered in the transmission of the data packets that are delivered successfully. This delay includes propagation delay, queuing delay, retransmission delays, buffering delay etc. Fig.6 shows, in small network (having less nodes), end to end delay is relatively same for both MDART and AOMDV. But when the number of nodes escalates, end to end delay of M-DART is less as compared to AOMDV because for being a reactive protocol AOMDV first determine the route, which result in considerable delay if the information is not available at that instant.

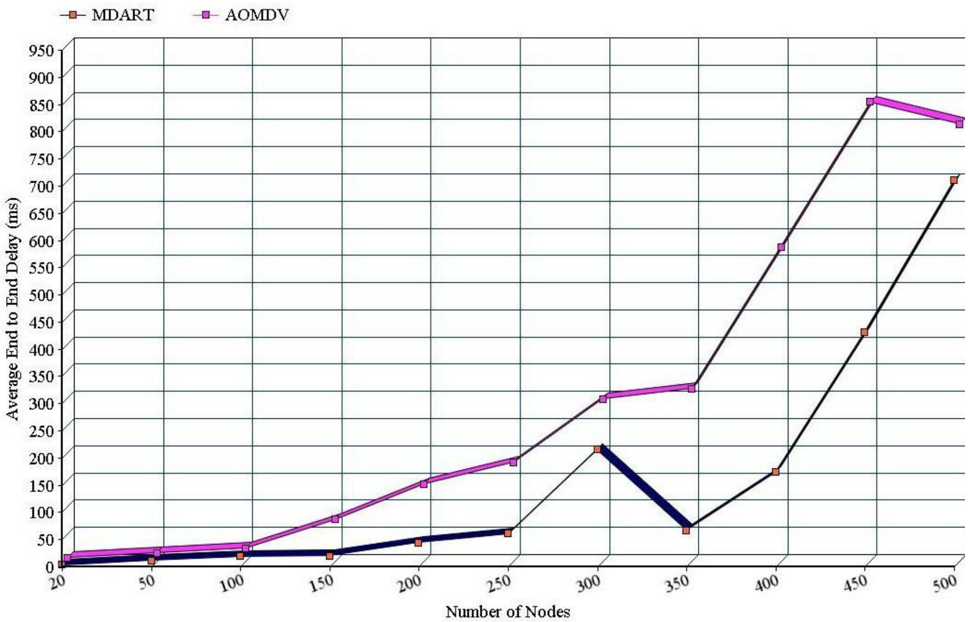

Fig.6: Average End to End Delay comparison of MDART and AOMDV

4.4 Energy consumption comparison between MDART and AOMDV

Energy consumption by M-DART is lesser in correlation to AOMDV, as M-DART is based on DHT paradigm and AOMDV is based on On-Demand paradigm. Fig.7 shows, as node density is less in network, energy consumption of M-DART is comparable to AOMDV because at start up M-DART needs to build its routing table, whereas, no routing table is created in AOMDV initially**.**

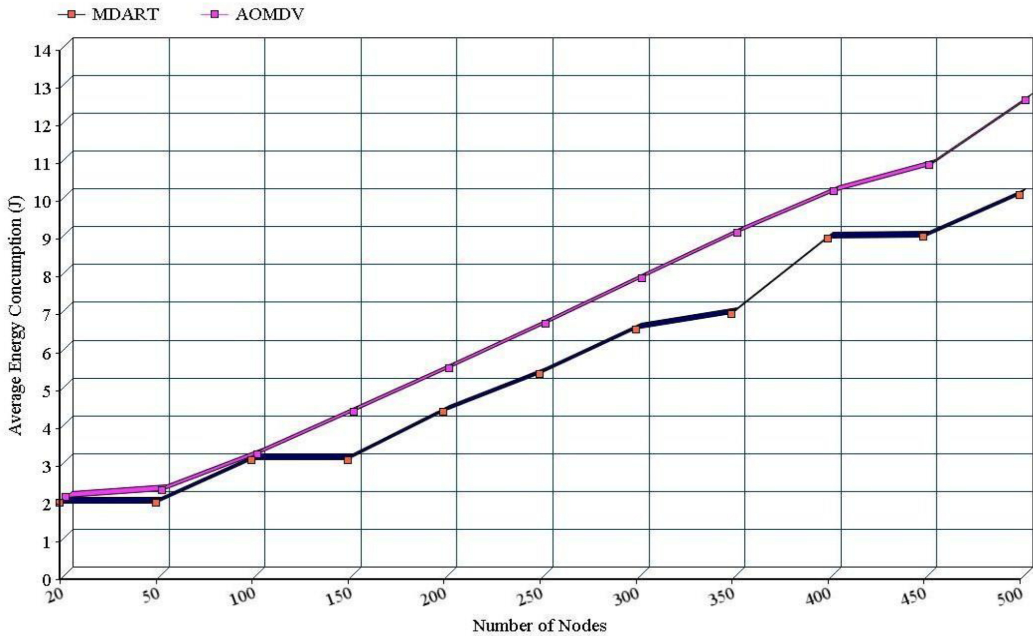

Fig.7: Average energy consumption comparison of MDART and AOMDV

5. Conclusion

In this work, analysis of recent multipath protocol, MDART, for Mobile WSN and its comparison has been performed with another multipath protocol i.e. AOMDV. Various results are obtained by simulating these protocols for different scenarios. Through simulation, it is observed that the energy consumed, delay introduced and packet loss percentage of MDART is lower in view of AOMDV whereas average throughput is also higher. The reason behind this conclusion is that MDART is a proactive multi-path protocol that uses the concept of dynamic addressing and Distributed hash tables for escalating networks. Moreover in M-DART every node maintains a routing table that, having a routing path to the other nodes, contains only log(n) entries for n nodes, so the routing decisions are quick to made.

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