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Energy Aware Adhoc On-demand Multipath Distance Vector Protocol for QoS Routing

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***Abstract*—**Mobile Adhoc Networks (MANETs) are infrastructure-less, dynamic network of collections of wireless mobile nodes communicating with each other without any centralized authority. A MANET is a mobile device of interconnections through wireless links, forming a dynamic topology. Routing protocols have a big role in data transmission across a network. Routing protocols, two major classifications are unipath and multipath. This study evaluates performance of an on-demand multipath routing protocol named Adhoc On-demand Multipath Distance Vector routing (AOMDV). This study proposes Energy Aware AOMDV (EA-AOMDV) an extension of AOMDV which decreases energy consumed on a route.

***Keywords*—**Mobile Adhoc Network (MANET), unipath, multipath, Adhoc On-demand Multipath Distance Vector routing (AOMDV).

I. Introduction

MANET is a collection of wireless nodes with wireless transceivers that communicate and form a network dynamically to exchange information without pre-existing fixed network infrastructure. It is a temporary. Communication is by transmission of data packets over a common wireless channel. Nodes act as host and router resulting in multi-hop routing. Nodes frequently change position. Unlike Wireless LAN (WLAN) which is single hop and infrastructure based network, a MANET is multi-hop. Flat routing protocols are sufficient for comparatively small networks. But, in larger networks either hierarchical or geographic routing protocols are needed, they being chosen according to network characteristics like density, size and node mobility [1].

Adhoc network has many characteristics [2] different from characteristics of wired networks and static wireless networks. Some characteristics of adhoc network are:

- Bandwidth constrained
- Energy constrained
- Variable bandwidth
- Highly unfavorable environmental conditions
- Dynamic nature of the nodes
- Low communication range

Adhoc network nodes are battery operated making energy, a precious resource which a node always try to reduce. They reduce communication range for same reason. Wireless network bandwidth availability is limited compared to wired networks. Also, bandwidth available is not constant and varies due to varied reasons. Nodes move with different pause times and speeds making the network highly dynamic. As the network is called for when existing networks do not function, they operate in highly unfavourable environmental conditions. Due to such adhoc network characteristics, routing in adhoc network is non-trivial and a challenge to be addressed [3]-[5].

Mobile nodes in radio range of each other directly communicate whereas others need intermediate nodes to route packets. Each node has a wireless interface to communicate with others. Such networks are distributed, and work at any place without fixed infrastructure as access points or base stations. Fig. 1 shows an adhoc network with 3 nodes. Node 1 and node 3 are not within range, but node 2 can forward packets between nodes 1and 2. Node 2 acts as a router and the 3 nodes form an adhoc network.

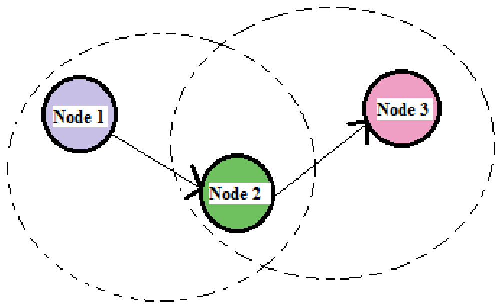

Fig. 1 Example of mobile adhoc network

A routing protocol is used for communication within a network, to discover valid routes between nodes. The goal of such adhoc network routing protocols is establishing correct and efficient routes between a node pair so that messages are delivered on time. Route construction should be with minimum overhead and bandwidth consumption. It must handle high node mobility. Routing protocols classification in MANETs is done in many ways; routing protocols are categorized as Proactive (Table Driven), Reactive (on demand) and Hybrid depending on network structure. The other MANET routing protocols classification are unipath and multipath routing depending on how routes are found.

Proactive protocols perform routing operations between source-destination pairs periodically, irrespective of a need for routes. Proactive protocols with advantage of lower latency in data delivery, support applications with QoS constraints. Their disadvantage is wastage of bandwidth in sending update packets periodically even when unnecessary, so that when

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there are no link break or when only a few routes are needed. Reactive protocols minimize routing overhead. Instead of tracking changes in network topology to continuously maintain shortest path routes to all destinations, they determine routes when necessary. The advantage of this is that it usually has much lower average routing overhead compared to proactive protocols. But, its disadvantage is that route discovery involves flooding an entire network with query packets, required frequently in high mobility or when there are a huge number of active source-destination pairs [6].

Unipath routing protocols [7] discover a route between source and destination. A new route discovery is needed in response to route breaks leading to high overhead and latency. Unipath routing protocols 2 components are: Route Discovery - finding a route between source and destination and Route Maintenance - repairing a broken route or finding a new route due to route failure. Most commonly used unipath routing protocols are Adhoc On-demand Distance Vector (AODV), Dynamic Source Routing (DSR), and Destination Sequenced Distance Vector (DSDV).

Multipath routing protocols [7] discover multiple routes between a source and destination pair to balance load to satisfy QoS requirements. The 3 components of multipath routing protocols are: Route Discovery - finding multiple nodes disjoint, links disjoint, or non-disjoint routes between source and destination, Traffic Allocation – when route discovery is over, source node selects a set of paths to destination and starts sending data to destination on those paths, and Path Maintenance - regenerating paths after initial path discovery to avoid link or node failures that happen over time and node mobility.

Benefits of multipath routing protocols are

i. Fault tolerance: redundant information routed to destination via alternative paths it reduces, in case of link failures, probability of communication disruption
ii. Load Balancing: selecting varied traffic through alternative paths to avoid link congestion,
iii. Bandwidth aggregation: Splitting data into multiple streams and then each being routed through different paths to same destination. Hence, effective bandwidth is aggregated
iv. Reduced delay: In unipath routing protocols, path discovery needs to be initiated to find a new route to avoid a route failure. This leads to high route discovery delay which is minimized in multipath routing protocols through backup routes identified in route discovery.

Most recently used multipath algorithms are Split Multipath Routing (SMR), Temporarily-Ordered Routing Algorithm (TORA), Adhoc On-demand Distance Vector-Backup Routing (AODVBR), Multipath Dynamic Source Routing (MP-DSR), and Adhoc On-demand Multipath Distance Vector routing (AOMDV).

AODV routing protocol builds on DSDV algorithm where every route hop maintains next hop information on its own. Protocol operation is divided into 2 functions, route discovery and route maintenance. At first all nodes send Hello message on its interface and receive Hello messages from neighbours. This is repeated periodically to determine neighbour connectivity. When a route to a destination is needed, the protocol starts route discovery. Source sends Route Request Message to neighbours. If a neighbour has no information on destination, it sends a message to all neighbours and so on. Once a request reaches a node with information about destination (either destination itself or some node with a valid route to the destination), that node sends Route Reply Message to Route Request Message initiator. Route Request Message is saved in intermediate nodes (nodes that forward Route Request Message), which have information about source and destination. The address of the neighbour from whom the Route Request Message originated is also saved [8].

AOMDV is an AODV derived routing protocol. It has characteristics similar to AODV but is a multipath routing protocol, i.e., it determines multiple paths between source and destination and uses them to transmit data packets. Route determination is similar to that of AODV. When a route is required to a specific destination, a route request control packet is generated and broadcast [9].

When a source node gets back route replies from many intermediate nodes and destination, it stores the information on possible routes instead of choosing the best among them. A similar strategy is adopted by intermediate nodes. Presence of multiple routes is an advantage. It reduces route discovery frequency and prevents best path overloading. Multiple routes to same destination are disjoint. There are 2 kinds of disjoint paths; node disjoint and link disjoint. Node disjoint means routes do not have a common node whereas link disjoint means nodes do not have common links [10].

This study proposes an extension to the popular AOMDV, which decreases energy consumed along a route. Section II provides related work in literature; Section III presents the methodology. Section IV provides results and discussion and section V concludes the paper.

II. Related Works

The effect of node mobility on AOMDV performance was analyzed by [11]. This, adhoc network routing protocol was analyzed with random way point mobility model alone. This is insufficient to evaluate a routing protocol's behaviour. So, this paper considered random way point, random direction and probabilistic random walk mobility models for a performance analysis of AOMDV protocol. Result reveals that PDR decreases with increasing node mobility for all mobility models. Also, average end-to-end delay varies with varied node speed.

A MANET environment was simulated and operated with AOMDV routing protocol by [12]. The effects of many nodes, their speeds and pause times were modeled and analyzed. Network simulator NS-2 studied and evaluated effects of such factors. Many performance metrics like packets loss, throughput, packet delivery fraction, normalize routing load, average end-to-end delay, and jitter were used as comparison indicators. Simulation environment was implemented with different nodes, different speeds, and varying pause times. Important effects and relations between all parameters and performance metrics was found and calculated.

A congestion control load balancing scheme, to reduce congestion, with multipath AOMDV protocol was proposed by [13] where the rate of sender is controlled through Acknowledgement (ACK) scheme. But sometimes a sender controls when packets are stored in a node's memory (queue) and assigning a memory management scheme. This scheme handles packets beyond capacity so that packet dropping is reduced. The original AOMDV was incapable of balancing network loads efficiently. Simulation results of the proposed scheme significantly increase packet delivery ratio and decrease average delay. Performance is better than other protocols.

The use of AOMDV which improved MANET security against vulnerabilities was analyzed by [14]. Performance of On-demand routing protocols like AODV and AOMDV was analyzed. AOMDV had better packet delivery ratio and low average end-to-end delay comparatively compared to current AODV protocol. Packets dropped in AOMDV against vulnerabilities are very low. Thus, the new technique which uses AOMDV proved to be better, against attacks.

A method based on AOMDV protocol providing a route recovery mechanism when a link breaks on an active route to reduce lost packets was proposed by [15]. Results show that the new method reduces packet loss ratio and delay time compared to AOMDV.

A multipath routing protocol (EAOMDV) based on node residual energy strategy MMBCR was proposed by [16]. Node residuary energy is used for backup path selection metric in a modified protocol. Simulation software NS2 is used, and EAOMDV and AOMDV performances are compared by changing nodes pause times. NS2 simulation results show that, compared to AOMDV multipath routing protocol, routing overhead and packet loss ratio increased but the network's total energy consumption was reduced and exhausted energy nodes at any moment was also less. This prolongs network life in the new protocol.

A modified AOMDV for multipath routing using ant colony for MANETs was presented by [17]. Ant-AODV is compared with Ant-AOMDV. The idea behind working of Ant-AODV and Ant-AOMDV is that RREQ message packets are sent to one path in Ant-AODV based routing and to multiple paths in Ant-AOMDV based routing. RREQ message packets are termed pheromone regarding standard ACO algorithm used by ants. Selecting transmission path dynamically through regular transmission path pheromone updating is expected to improve routing performance. Simulation shows that Ant-AOMDV algorithm outperforms Ant-AODV effectively regarding packet delivery fraction, normal routing load and packet drop compared to AODV and AOMDV. The goal is to reduce routing overhead, congestion and increase performance.

An AOMDV based protocol providing route recovery mechanism when a link breaks in an active route to reduce lost packets was proposed by [18]. Results show that the new method reduces packet loss ratio and delay time compared to AOMDV.

Fuzzy controllers consider number of hops, packet queue occupancy and remaining energy along paths while picking routes was presented by [19]. The new fuzzy routing method is evaluated and compared with conventional AODV routing regarding PDR, average of end to end delay and average energy consumption per node using OMNeT++ 4.0 simulator.

III. Methodology

Transmission power control ensures a chance to save energy by using intermediate nodes between two distant nodes. But, a resultant path with many short-range links performs worse than a path with fewer long-range links regarding latency and energy consumption. This is because a path with many short-range links causes more link errors than would result in retransmissions [20]. In the new Energy Aware AOMDV (EA-AOMDV), active communication energy is reduced by adjusting a node's radio power to reach a receiving node, but not more and by considering link and transmission overhead. Transmission power control approach is extended to determine optimal routing path that reduces total transmission energy to deliver data packets to destinations.

Consider a path from source node S to destination node D consisting of N-1 intermediate nodes indexed as 2, 3.... , N (index of source is 1, and that of destination is N+1). Transmission energy over a link $p_{i,i+1} = ad_{i,i+1}$, where $d_{i,i+1}$ refers to distance between node i and i+1, a is a constant determined based on physical environment, and $\alpha \geq 2$. Assuming that each of N links ($L_{1,2}$, $L_{2,3}$, ... , $L_{N,D}$) has an independent link- error rate of $e_{i,i+1}$, number of transmissions (including retransmissions) between node i and node i+1 is a geometrically distributed random variable X, so that

$$\text{Prob}\{X = x\} = e_{i,i+1}^{x-1} \times \left(1 - e_{i,i+1}\right), \qquad \forall x \tag{1}$$

Mean number of transmissions for successful transfer of one packet is thus $1/\left(1-e_{i,i+1}\right)$. So, effective transmission energy between nodes i and i + 1 includes effect of transmission link error, is [20]

$$P_{i,i+1} = p_{i,i+1} \times \frac{1}{1-e_{i,i+1}} = \frac{ad_{i,i+1}^{\alpha}}{1-e_{i,i+1}} \tag{2}$$

When packet-error rate ($e_{i,i+1}$) is not negligible, benefit of indirect transmission via intermediate nodes is overshadowed by inflation factor, $1/(1-e_{i,i+1})$.

To deliver packets with minimum energy, transmission power control approach adjusts each node's radio power allowing varied transmission power levels at different nodes. But, for link-level MANET connectivity to work correctly, a pair of communicating nodes must share a bidirectional link [21]. For example, at link level, control packet handshaking is used to enhance link-level reliability in error-prone wireless environments; i.e. when a node receives a packet, it immediately replies to sender with ACK. If no ACK is received by sender, it automatically retransmits the packet. In addition, request to send (RTS) and clear to send (CTS) packets are exchanged to handle hidden terminal problems [22]. So, when 2 nodes have different power levels, data communication in one direction (from node with stronger transmission power to another with weaker transmission power) is possible but not vice versa.

IV. Results and discussion

The proposed EA-AOMDV is simulated to evaluate packet delivery ratio, average end to end delay and number of hops to sink. The performance of EA-AOMDV is compared with AODV and AOMDV. Simulation is conducted using varying number of nodes (25, 50, 75, 100) spread over an area of 1200 sq m. The transmission range of node is 250 m. Tables I-III and Figs. 2-4 in this study explains result value and graph respectively for packet delivery ratio, end to end delay and Average Number of hops to sink.

TABLE I
Packet Delivery Ratio

Number of nodes	AOMDV	AODV	EA-AOMDV
25	0.83	0.7027	0.8648
50	0.8041	0.6634	0.8132
75	0.7924	0.6594	0.8228
100	0.7456	0.6358	0.772

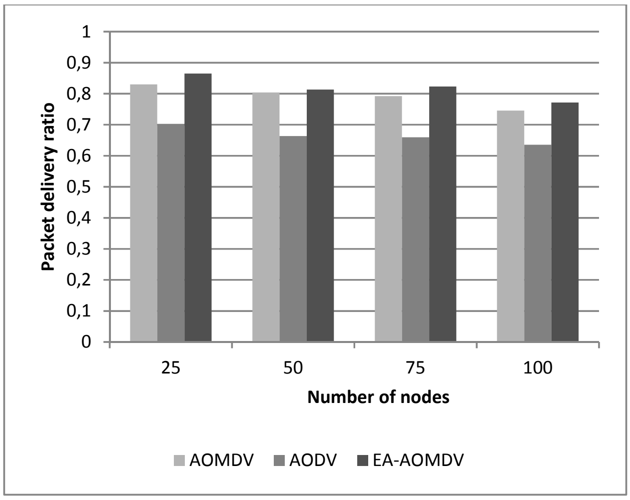

Fig. 2 Packet delivery ratio

From Table I and Fig. 2, it is observed that Packet delivery ratio increases for EA-AOMDV when compared to AOMDV and AODV. When number of nodes is 25, PDR increases for EA-AOMDV by 4.11% than AOMDV and by 20.68% than AODV. When number of nodes is 75, PDR increases for EA-AOMDV by 3.76% than AOMDV and by 22.05% than AODV.

From Table II and Fig. 3, it is observed that average end to end delay decreases for EA-AOMDV when compared to AOMDV and AODV. When number of nodes is 25, average end to end delay decreases for EA-AOMDV by 39.80% than AOMDV and by 40.52% than AODV. When number of nodes is 75, average end to end delay decreases for EA-AOMDV by 28.85% than AOMDV and by 93.88% than AODV.

TABLE II
End to End Delay

Number of nodes	AOMDV	AODV	EA-AOMDV
25	0.001464	0.001475	0.000978
50	0.001714	0.00197	0.001236
75	0.001971	0.004082	0.001474
100	0.002107	0.005979	0.001485

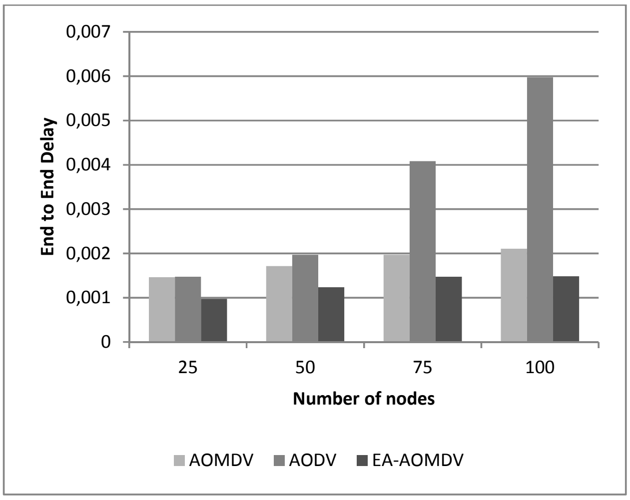

Fig. 3 End to end delay

TABLE III
Number of Hops to Sink

Number of nodes	AOMDV	AODV	EA-AOMDV
25	4.29	4.73	3.92
50	5.89	6.12	4.9
75	6.71	6.64	5.09
100	7.04	7.06	5.44

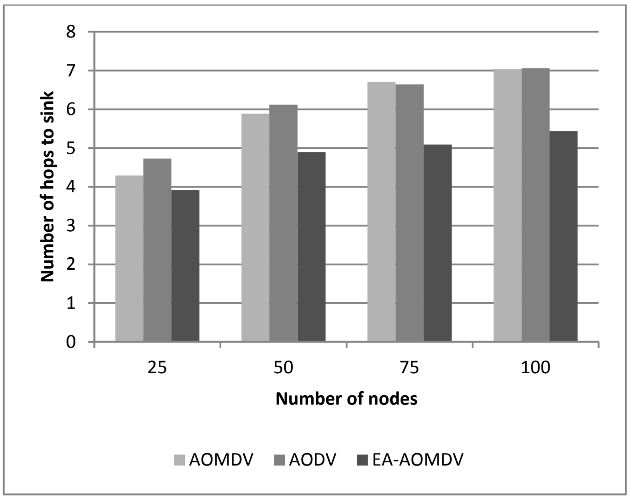

Fig. 4 Number of hops to sink

From Table III and Fig. 4, it is observed that average Number of hops to sink decreases for EA-AOMDV when compared to AOMDV and AODV. When number of nodes is 25, average Number of hops to sink decreases for EA-

AOMDV by 9.01% than AOMDV and by 18.73% than AODV. When number of nodes is 75, average Number of hops to sink decreases for EA-AOMDV by 27.46% than AOMDV and by 26.43% than AODV.

V. CONCLUSION

To facilitate communication in an MANET, a routing protocol must discover routes between mobile nodes. Energy efficiency is a big issue in MANETs, especially when designing a routing protocol. This study proposes Energy Aware AOMDV (EA-AOMDV) where active communication energy is reduced by adjusting a node's radio power just enough to reach a receiving node by considering link and transmission overhead. Simulation is through varied number of nodes, and the new EA-AOMDV's performance is compared with AODV and AOMDV. Results prove that the new EA-AOMDV increases packet delivery ratio and decreases end to end delay.

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