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Adaptive Load-balancing AODV Routing Protocol for MANETs

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Abstract— There are number of challenges in Mobile Ad hoc Networks (MANETs) for providing quality of services, routing with energy efficiency and load balancing. Many existing routing protocols do not consider the problem of load balance with energy efficient transmission. Routing in MANETs is difficult due to the absence of central coordinator and frequent topology changes. Power drainage is a serious issue which causes failure of nodes and network partition. A routing protocol called Adaptive Load-balancing Ad hoc On-demand Distance Vector (ALAODV) is proposed to address the quality of services' issues such as Throughput, End to End delay and Energy Consumption. This paper presents a scheme to balance the load with energy efficiency considering both congestions and nodes' energy usages. A threshold value is used to check if intermediate nodes are overloaded and it is variable with respect to the node's interface queue length along the backward path. The proposed protocol ALAODV routing is intended to provide a secure reliable transmission in terms of Throughput, End to End delay and Energy consumption increasing the life time of nodes than the existing Ad hoc On-demand Distance Vector (AODV) protocol.

Keywords— MANETs, quality of service, load balancing, congestion, threshold, queue length

I. INTRODUCTION

MANET is a temporary wireless network which is composed of wireless mobile nodes with no fixed infrastructure. There are no dedicated routers, servers, access points, base stations and cables. Two mobile nodes within transmission range communicate directly with each other. If they are far apart, intermediate nodes forward the packets from source to destination. Thus, every mobile nodes function as a router to forward the packets. In MANETs, there are various techniques for recovering changes in the network topology such as discovering new routes when older ones break. Routing protocols should be more dynamic so that they quickly respond to the topological changes [1]. In MANETs, a route consists of an ordered set of intermediate nodes that forward packets across a network from source to destination. Intermediate node hands over the packet to the next node of one hop count distance. Efficient routing requires collective cooperation of all nodes [2].The mobile nodes results a highly dynamic network with frequent topological changes causing route failures. The wireless channel acts as a shared medium and provides a much lower bandwidth to communicate among nodes than in wired networks. In MANETs, routing protocol should be effective to adapt to the dynamic network topology and should be designed to be bandwidth efficient by reducing the routing control overhead. The routing protocols can be classified into three main categories: proactive (or table driven), reactive (or on-demand driven) and hybrid [3]. MANETs have a number of applications that rely on multi-hop wireless infrastructures and can be deployed quickly. There are various applications which include emergency situations, battlefield, disaster relief, rescue operation, remote data acquisition and health monitoring. The main aim is to allocate more loads on under-utilized paths and less load to over committed paths so that uniform resource utilization of all available paths can be ensured. Load balancing approach is useful in energy constrained networks so that network life can be enhanced. On distributing load to all the available nodes in the network path, energy consumption in a node can be reduced. Most used on-demand routing protocols are Ad hoc On-demand Distance Vector (AODV) [4] and Dynamic Source Routing (DSR) [5].

This paper presents energy efficient adaptive load balancing in MANETs considering traffic balance and energy consumption by nodes. The proposed ALAODV protocol provides multiple routes to a destination so that a single route with least hop count is chosen and routes with the higher hop counts are discarded. A route request (RREQ) message is flooded in the network for route discovery. A node broadcasts RREQ message based on its interface queue length and residual energy. Threshold value is used to check queue length and energy usage of a node and the surrounding nodes of one hop count apart. The threshold value is a variable which is used as a criterion for broadcasting RREQ message depending on the queue length of nodes along backward path. The path which consumes minimum energy is selected to forward packets from all the possible paths so that node's life time is enhanced. Thus, ALAODV routing protocol selects secure and efficient path with minimum path load.

II. LITERATURE SURVEY

Broadcasting at physical layer is based on two transmission models; one-to-all model and one-to-one model. In one-to-all model, transmission by each node reaches all the nodes that are within transmission radius, while in one-to-one model, each transmission is directed only towards neighbour. Broadcasting at the network layer has many important uses and several MANET protocols assume the availability of an underlying broadcast service. Network routing protocols should be more dynamic to respond to the topological changes. [6] have proposed an approach to constrain RREQ packets based on node caching.

Several load balanced routing protocols for MANETs have been proposed till date which focuses on various parameters like energy consumption, time delay, packet delivery ratio, accuracy etc. Most of the approaches are on-demand based protocols; that is, they combine load balancing strategies with path discovery. A path with the least load among multiple possible paths from source to destination is usually chosen [7]. A great challenge in the design of ad hoc network is the development of efficient routing protocols that can provide high quality communication between two mobile nodes. The load balancing routing protocols for ad hoc wireless networks can be classified into two types. One is based on "Traffic-Size" and the other is "Delay" [8].

Traffic-Size based protocols are Dynamic Load Aware Routing Protocol (DLAR) [6], Load Balanced Ad hoc Routing Protocol (LBAR) [9] and Load Sensitive Routing Protocol (LSR) [10]. Among all these protocols, the load in a node is the number of packets stored in the node's queue length (qol) and the path load is sum of loads of all the nodes along that path. The drawback of these protocols is that they cannot provide the actual load due to varying size of packets stored in a queue. But the proposed protocol SEAODV compares queue length with threshold (Thr) and hence energy efficient path can be determined. Delay based protocols are Delay Oriented Shortest Path Routing Protocol (DOSPR) [11] and Load Aware On- Demand Routing Protocol (LAOR) (Song and Wong).These two protocols uses the total path delay to select a path. Total path delay is the sum of time taken to generate route request packets (RREQ), route reply packets (RREP) and propagation delay along the path. The disadvantage of these existing protocols is that there is more delay in transmitting packets from source to destination. But the proposed protocol overcomes delay through efficient path.

[12] have proposed an energy constraint routing protocol in which routing packets are transmitted based on energy. [13] proposed an algorithm which is an improvement of energy efficient routing by selecting high energy paths, taking into account of energy conservation and other performance metrics. [14] suggested an approach to improve the performance of routing protocols with respect to traffic balance and balance energy consumption. [15] suggested an Error - aware and energy efficient routing approach in MANET. They proposed two novel protocols one is Multi Threshold Routing Protocol (MTRP) and the other is Enhanced Multi Threshold Routing Protocol (EMTRP).

The adaptive load balancing scheme was proposed by [16] to balance the load in the network. A simple load balancing approach in cheat proof ad hoc networks was proposed by [17] Here each node independently determines whether traffic concentrates on itself or not. It calculates the ratio of its own traffic load to the whole average, and checks if the ratio is over two thresholds values. Path selection is based on queue length. The path is created by two ways. The first is Finding Path, where a node uses a flooding technique to determine the path to the destination and there may be various paths to route packets to the destination [18].The second is Initializing Path among all the intermediate nodes based on adaptive threshold. In case of any node failure due to power drainage or by any other means, the path will be broken changing network topology due to partition, and then the protocol removes the existing path from all the available nodes. All these problems are overcome by the proposed method.

III. PROPOSED PROTOCOL

The proposed protocol ALAODV is meant for computing multiple stable paths. The protocol computes multiple paths to avoid congestion. To ensure multiple paths, the node only accepts an alternative path to the destination if it has lower hop count and energy consumption than the advertised path for that destination. The proposed ALAODV load balancing approach is carried out in route request procedure. When source wants to communicate with destination and has no available routing information about the destination, it will flood a route request to find a route by broadcasting a route request message (RREQ) but not every intermediate node that receives the message will respond to the route request. Before broadcasting the RREQ, the intermediate node itself first makes a decision whether it is qualified or not. If its queue length (qol) is below the threshold value (Thr), then the node is qualified and able to broadcast.

Figure 1 illustrates that the threshold value plays the key role in selecting nodes whether or not to forward the RREQ. Every time an intermediate node receives a RREQ, it will recalculate the threshold according to the node's queue length (qol) around the backward path. Therefore the threshold is variable and changing adaptively with load status of the network.

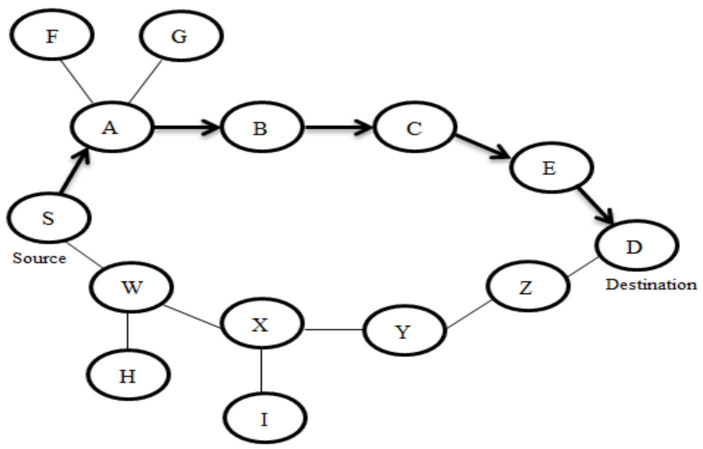

Fig. 1 Route request with adaptive load balancing

Figure 1 depicts the path established from source to destination by broadcasting RREQ message that compares the current 'qol' with its threshold (Thr). If 'qol'> 'Thr' , RREQ will be dropped in nodes such as F, G, H, I, X, Y and Z. Otherwise nodes will deal with RREQ normally, such as nodes S, A, B, C,E and D.

IV. FLOWCHART

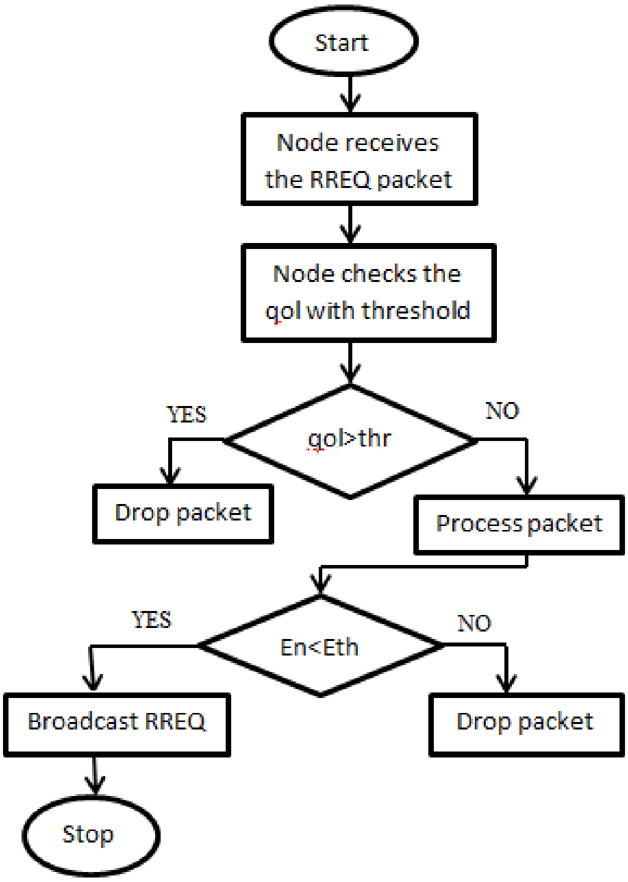

Fig. 2 Flowchart to broadcast RREQ based on threshold

Figure 2 illustrates flowchart to broadcast RREQ based on 'qol' compared with threshold 'Thr' value. RREQ are forwarded or discarded based on 'qol'. Based on the 'Thr' value, RREQ packets are forwarded. Further the node's energy (En) is compared with the threshold energy (Eth). If En <Eth then the packets are transmitted or else the packets are discarded.

V. ALGORITHM

An algorithm to calculate threshold (Thr) for queue length (qol) and energy (En) of each node is as follows:

Step1: the node calculates the average queue length (avgqol) using the nodes current queue length (qol).

Step2: the nodes threshold (Thr) is calculated with the avgqol of all the nodes along the path. With the nodes own 'avgqol' and the received RREQ 'sumqol'which records the sum of avgqolof the nodes along the backward path. The node compares its current queue length (qol) with the threshold (Thr). If 'Thr'> 'qol', it will respond the RREQ otherwise it will simply drop it.

$$avg_{qol} = \frac{qol + \sum_{i=1}^{n} nb_{qoli}}{n+1} \tag{1}$$

$$sum_{qol} = \sum_{i=1}^{k} avg_{qoli} \tag{2}$$

$$Thr = \frac{avg_{qol} + sum_{qol}}{k+1} \tag{3}$$

Threshold can also be written as,

$$Thr = \alpha . avg_{qol} + \beta . \frac{sum_{qol}}{k} \tag{4}$$

where,
'qol' is the node's own queue length.
'avg_{qol}' is the average queue length of a particular node.
'$nbqol_i$'is the node's neighbour's queue length.
'n' is the number of node's neighbours.
'K' is the number of nodes along the backward path excluding itself.
'Thr' is the adaptive threshold of a node.
'α' and 'β' are the parameters to maximize Throughput, minimize End to End delay and Energy consumption such that α+ β=1 and always β≥α.

The node on receiving the RREP from its neighbours calculates the energy levels. The node's threshold energy (Eth) is calculated with the average energy (avgEn) of all the nodes along the path. The node compares its current energy level (En) with the threshold (Eth). If 'Eth' is greater than 'En', it will respond the RREQ otherwise it will simply drop it. When 'α' = 'β', the performance is optimal. For 'α' less than 'β', the Throughput increases due to lower control overheads with higher End to End Delay. The neighbouring nodes on receiving RREQ message, they reply with RREP message, based on residual energy level of nodes.

$$avgE_n = \frac{E_n + \sum_{i=1}^{n} nE_{ni}}{n+1} \tag{5}$$

$$sumE_n = \sum_{i=1}^{k} avgE_n \tag{6}$$

$$E_{th} = \alpha .avgE_n + \beta .\frac{sumE_n}{k} \tag{7}$$

The proposed protocol ALAODV provides routing with minimum energy among all the possible paths. The total energy consumed in forwarding packets from source to destination through any path 'P' is given as,

$$E_p = \sum_{i=1}^{n} E_i \tag{8}$$

where 'E_i' is the energy consumption in any node 'i' and 'n' is the total number of nodes in the path '*P*'. The minimum energy (E_m) path is the path having least energy consumption among all the possible paths which is obtained as,

$$E_m = \min_{\forall P}(E_p) \tag{9}$$

The proposed SEAODV will make the following changes to the existing AODV protocol:

- Paths are selected based on the hop count and queue length
- Load is balanced via alternate paths if queue length processes a certain threshold value.
- RREQ packets are forwarded or discarded depending on the queue length
- Based on the threshold value the route request packets will be forwarded
- Minimum energy path is selected among all the available paths
- Packets with transmission time less than threshold time value are only accepted

Table 1: Tabulation to calculate threshold

Nodes	qol	avgqol	sumqol	Threshold	Condition
S	1	1.67	0.00	1.67	Yes
A	2	3.00	1.67	2.33	Yes
F	5	3.50	4.67	2.72	No
G	4	3.00	4.67	2.56	No
B	3	2.00	4.67	3.32	yes
C	1	2.00	6.67	2.16	yes
E	2	1.60	8.67	2.05	Yes
D	2	3.00	10.27	2.21	Yes
W	2	2.67	1.67	2.17	Yes
H	5	3.50	4.34	2.61	No
X	3	2.50	4.34	2.28	No
I	2	2.50	6.84	2.33	No
Y	4	4.00	6.84	2.71	No
Z	5	3.67	10.84	2.90	No

Table 1 illustrates the calculation of adaptive threshold for various nodes for the RREQ to flood in the network as shown in figure 1. For instance the average queue length (avg_{qol}) of node 'A' can be calculated by queue length (qol) of node 'A' and the neighbouring nodes 'B', 'G', 'F', and 'S'. The node's threshold is calculated with the 'avg_{qol}' of all the nodes along the path. Thus, the threshold of node 'C' can be calculated by its own 'avg_{qol}' and the sum queue length (sum_{qol}) of received RREQ which is the sum of 'avg_{qol}' of nodes 'B', 'A', and 'S'.

VI. SIMULATION RESULTS

The load balancing approach for AODV and the proposed protocol ALAODV is compared, hence evaluated the performance of AODV and ALAODV in terms of Throughput, End to End delay and Energy consumption per packet with different mobility of nodes through simulation. NS-2 is used to perform the simulation for 100 mobile hosts with transmission range of 250 m. The parameters that are involved in simulations are tabulated below:

Table 2: Simulation Parameters

Parameters	**Values**
Number of nodes	100
Transmission range	250m
Topology size	100mx100m
Number of destination	1
Traffic size	Constant Bit Rate(CBR)
Packet size	512 bytes
Packet rate	5 packets per second
MAC layer	802.11
Bandwidth	2Mbps
Node placement	Uniform
Initial Energy for all nodes	0.5J
Transmit power	0.660W
Receive power	0.395

A. Throughput

Throughput is calculated by dividing the number of packets received by the destination to the number of packets originated from the source. The higher throughput specifies maximum packets received at the destination. Throughput Versus Mobility for 100 nodes with different values of α and β is given below. The mobility of 100 nodes is varied from 3 m/s to 25 m/s for existing AODV and the proposed ALAODV protocols. Two conditions are considered to observe the performance of Throughput in the proposed ALAODV protocol. One is when β≥α, the performance of Throughput for the proposed protocol ALAODV is better than AODV protocol. The other is when α≥β the performance of Throughput is less than β≥α for ALAODV but higher than the existing protocol AODV which signifies that the proposed protocol ALAODV has higher Throughput at β≥α.

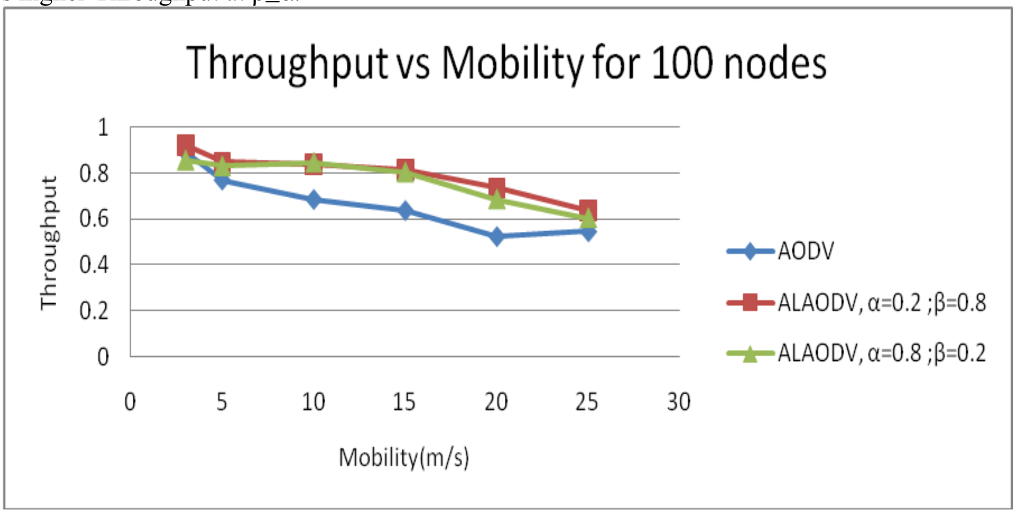

Fig. 3 Throughput Vs Mobility for 100 nodes for α=0.2, β=0.8 and α=0.8, β=0.2

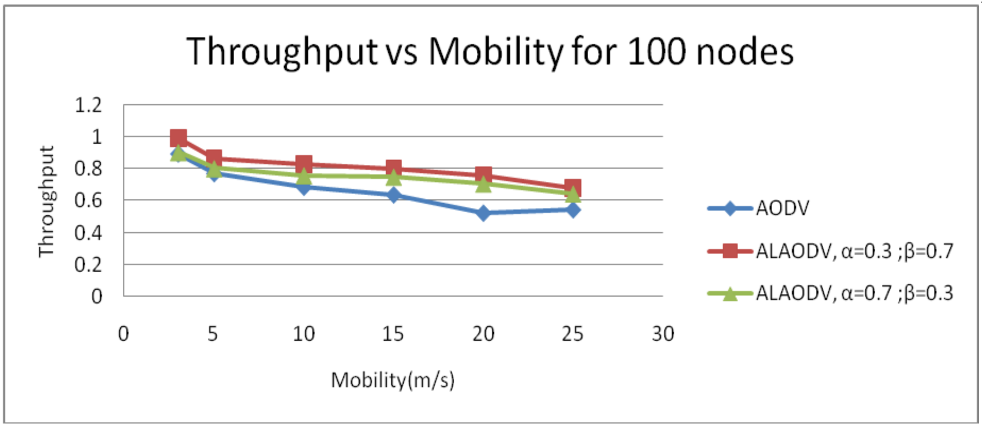

Fig. 4 Throughput Vs Mobility for 100 nodes for α=0.3, β=0.7 and α=0.7, β=0.3

B. End to End delay

It is the time (second) taken to reach the destination. This is calculated by subtracting time at which first packet was transmitted by source node from time at which the first data packet reached to destination. End to End Delay versus Mobility for 100 nodes with different values of α and β is given below. The mobility of 100 nodes is varied from 3 m/s to 25 m/s (3, 5, 10, 15, 20, 25)for existing AODV protocol and the proposed protocol ALAODV protocol. Two conditions are considered to observe the performance of End to End delay in the proposed ALAODV protocol. One is when β≥α the performance of End to End delay for the proposed protocol ALAODV is better than AODV protocol. The other is when α≥β the performance of End to End delay is less than β≥α for ALAODV but higher than the existing protocol AODV which signifies that the proposed protocol ALAODV has lower End to End delay at β≥α.

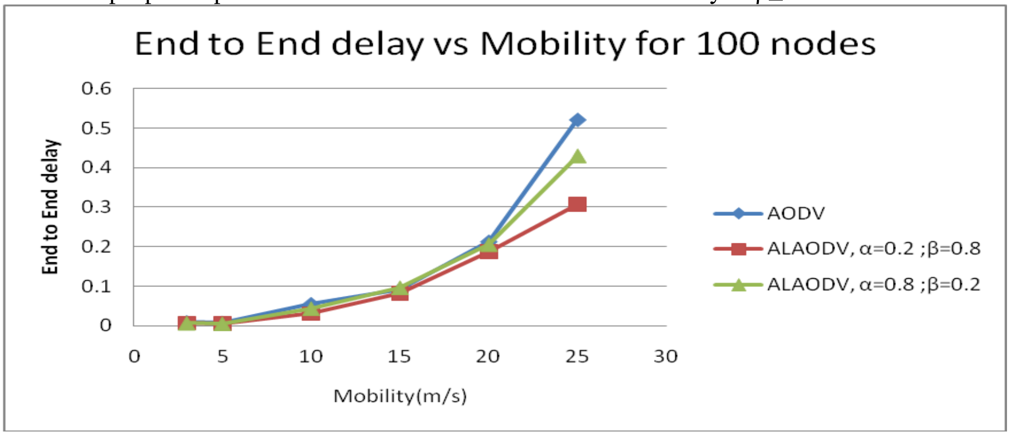

Fig. 5 End to End delay Vs Mobility for 100 nodes for α=0.2, β=0.8 and α=0.8, β=0.2

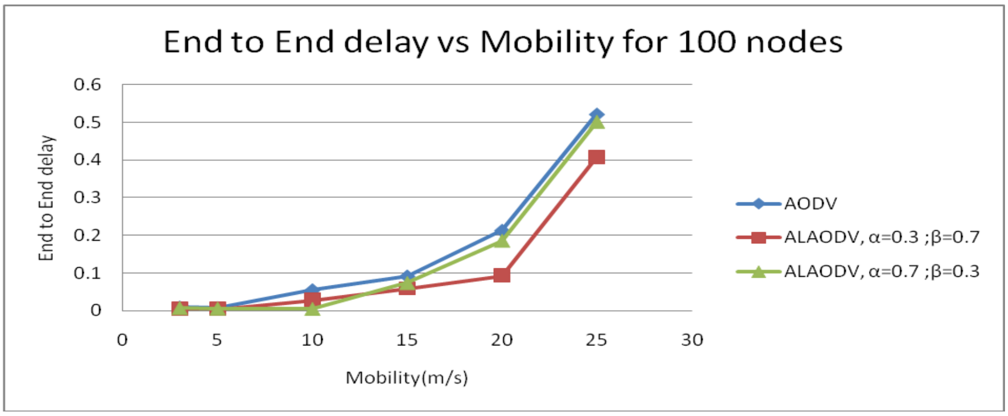

Fig. 6 End to End delay Vs Mobility for 100 nodes for α=0.3, β=0.7 and α=0.7, β=0.3

Figure 5 and 6 depicts that the proposed protocol ALAODV has better performance when β≥α.

C. Energy Consumption

Energy consumption is obtained by the ratio of the total energy consumed to the total number of nodes present in the deployed network. The Energy per Packet is calculated in Joules (J). Energy Consumption / Packet Versus Mobility for 100 nodes with different values of α and β are given below. The mobility of 100 nodes is varied from 3 m/s to 25 m/s (3, 5, 10, 15, 20, and 25) for existing AODV protocol and the proposed protocol ALAODV. Two conditions are considered to observe the performance of Energy in the proposed ALAODV protocol. One is when β≥α the performance of Energy for the proposed protocol ALAODV is better than AODV protocol. The other is when α≥β the performance of Energy is less than β≥α for ALAODV but higher than the existing protocol AODV which signifies that the proposed protocol ALAODV has lower Energy consumption at β≥α. Energy consumption model for lucent IEEE 802.11i WLAN pc card with 2 Mbps Energy Consumption with Transmit and Receive Power of 0.660W and 0.395W respectively.

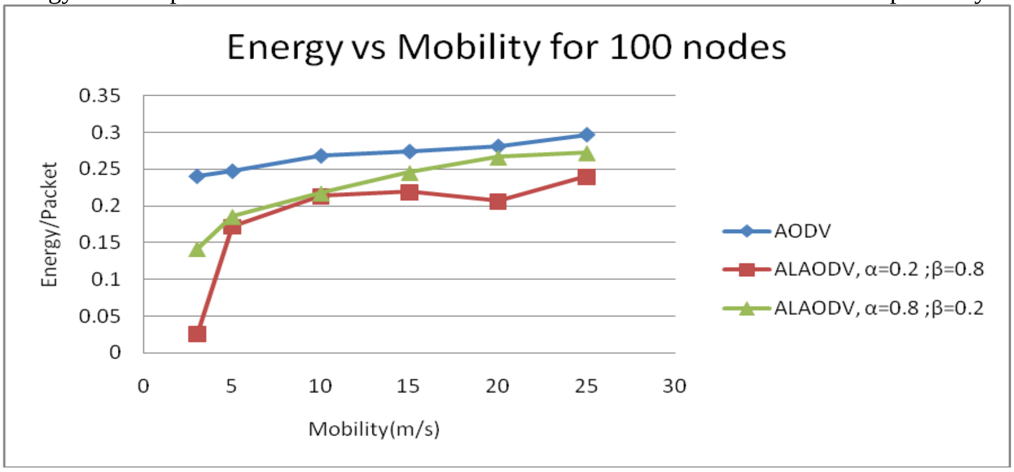

Fig. 7 Energy/packet Vs Mobility for 100 nodes for α=0.2, β=0.8 and α=0.8, β=0.2

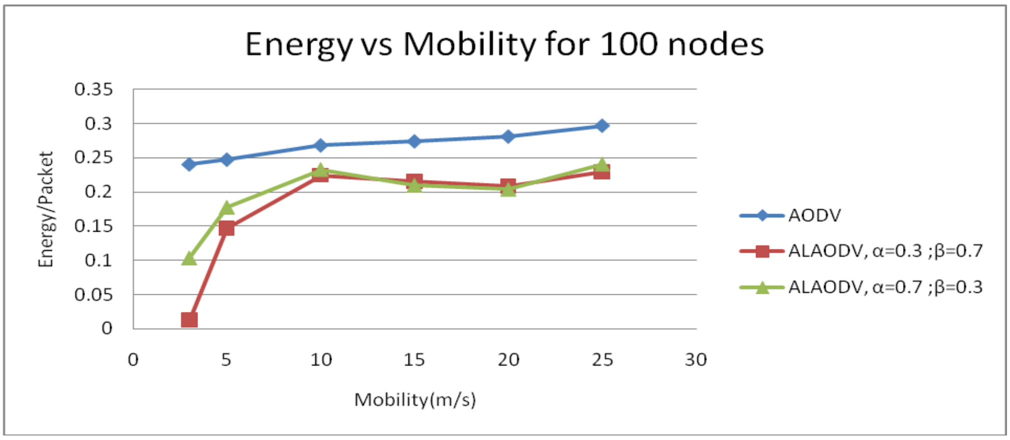

Fig. 8 Energy/Packet Vs Mobility for 100 nodes for α=0.3, β=0.7 and α=0.7, β=0.3

From figure 7 and 8 the proposed protocol ALAODV has good response in terms of Energy when β≥α.

VII. CONCLUSION

This paper presents an efficient way of routing packets in ad hoc wireless networks. The proposed routing protocol ALAODV gives an ideal way of computing due to which reliable transmission is achieved in terms of Packet Delivery Ratio, End to End delay and Energy consumption. Thus, ALAODV provides the shortest path routing than the existing AODV protocol. The future work can be extended by comparing with other existing routing protocols varying more number of nodes to provide reliable transmission in MANETs.

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