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Energy Efficient Load Balanced Multipath Routing in MANET

Simranjeet Kaur[1], Suveg Moudgil[2], Tarunpreet Bhatia[3]

[1]Haryana Engineering College, Jagadhri,
Kurukshetra University, India
ksimran702@gmail.com

[2]Haryana Engineering College, Jagadhri,
Kurukshetra University, India
Suvegmodgil1@gmail.com

[3]Thapar University, Patiala, India
tarunpreetbhatia@gmail.com

Abstract: ***A mobile ad hoc network is defined as a collection of mobile nodes where each node is free to move arbitrarily. As wireless network expands in size, complexity and demand, effective and uniform distribution of the traffic load in the entire network is a matter of utmost importance. In situations, when an intermediate node is used for longer duration for forwarding packets, it may cause traffic concentration on it resulting in higher latency and depletion of battery power of nodes. In this paper, we have studied the problem of load balancing in multi-hop ad-hoc networks and an algorithm ELB-AOMDV is devised to incorporate load balancing mechanism into a multi hop multi path routing protocol (AOMDV) for achieving better load distribution over nodes in a network.***

Keywords: MANET, Load Balancing, Congestion

1. Introduction

Ad hoc network is a collection of wireless mobile nodes without any fixed base station infrastructure and centralized management that moves arbitrarily and communicates via multiple wireless links. Each node is capable of acting as a host and a router. Due to unorganized connectivity, low capacity and error prone wireless links, absence of centralized authority, dynamic changing topology, routing in MANET has become a challenging task and there is a need to manage whole network without causing frequent disconnections [1]. Sometimes, an intermediate node is used for longer duration resulting in traffic congestion causing higher latency and depletion of battery power of nodes. Load balancing can maximize lifetime of mobile nodes, minimize traffic congestions, energy consumption of mobile nodes and end to end packet delays [2].
In real scenarios, shortest path routing has proven to be more useful and efficient than multi path routing which employs multiple optimal paths from source to destination. But, multi path routing is still appreciated because of its fault tolerance nature in providing alternative paths during failures.

2. Load Balancing in MANET

Load balancing turns out to be an effective solution to avoid traffic congestion problem in the network. The basic idea in load balancing is to simultaneously use all available resources. The majority of routing protocols in multi-hop networks use the shortest path or the minimum hop routing, where each source node transmits information via the shortest path to its corresponding destination [3]. This routing policy concentrates the traffic load along certain paths leading to an imbalanced load distribution. As a result, intermediate nodes located on these paths have to deal with heavier traffic loads compared to their peers. These overloaded nodes may form routing bottlenecks which will reduce the networking performance through congestion, while rapidly consuming energy resources at node level causing connectivity losses in network.
As defined in [4], the term load is generally defined as the quantity of traffic received and transmitted by a node per unit of time on behalf of other nodes in the network. Load balancing is defined as the uniform distribution of communication and processing operations among different entities of network to avoid overloading any one element.

3. Literature Review

This section represents the done in the field of load balancing by the researchers. The Predictive Energy-efficient Multicast Algorithm (PEMA) [5] takes the advantage of the network statistical properties in resolving scalability and overhead issues caused by large scale MANETs as opposed to relying on network topology. The running time of PEMA depends on the multicast group size, hence, this resulted in PEMA to be fast enough for MANETs with 1000 or more nodes. The results of simulation shows that PEMA post appreciable power savings as compared to other existing algorithms, it also attains good packet delivery ratio in mobile environments.
A Triangular energy-saving cache-based routing protocol by sieving (TESCES) was proposed by Tuan et al. [6], which is a kind of energy aware and location-aware grid based protocols in MANETs. It was based on two protocols: a fully energy aware and location aware protocol (FPALA) [7, 8] and an energy saving cache based routing protocol (ESCR) [9]. In this

protocol the network is divided into grids depending on GPS. TESCES has three procedures: GLEES to elect leader node with maximum energy for each grid in the network, while some nodes join a grid leader election, other nodes will be in sleeping mode, CGLM for maintain grid leader and new grid leader is candidate from cache table directly and TESRD for saving routing discovery and chose path with minimum nodes.

Rajib Mall et al. [10] proposed a novel power and battery aware routing protocol, which not only incorporates the effect of power consumption in routing a packet and recent traffic density at each node but also exploits the charge recovery effect phenomenon observed in batteries. Route selection is based on a cost metric, which captures the residual battery capacity and drain rate of mobile nodes in the network.

Maleki et al. [11] introduced RTLB-DSR, Load Balancing Real-Time Dynamic Source Routing QoS Routing Protocol, which is a differentiated-service routing based on DSR. It applies various routing policies based on graph-based method. The network is divided into real-time and best-effort flows with the help of a classifier component. The best effort flows do not have any specific requirements whereas real-time packets need to reach their destination before a specific deadline. It addresses best-effort flows through the network edge using a proposed node centrality metric defined as the number of its neighbors in the network for load-balancing. RTLB-DSR tries to route real-time flows through a network center, which contained a smaller load as a result of load-balancing policy.

Maheshwari et al. [12] proposed Load Balancing Congestion Control Scheme which improves the routing process in AOMDV [13] protocol. In this scheme, the rate of sender is controlled through Acknowledgement (ACK) of intermediate nodes that are unable to handle the extra load in network. The sender takes some time to control it so the packets are stored in the memory (queue) of nodes for that duration and memory management scheme is assigned. This scheme can handle the packets beyond the capacity, thus minimizing packet dropping.

Tashtoush et al. [14] proposed FMLB which distributes data packets over multiple paths through the mobile nodes using Fibonacci sequence. Fibonacci distribution increases the packet delivery ratio by reducing the network congestion. The FMLB protocol's responsibility is balancing the packets transmission over the selected paths and ordering them according to hops count.

Geng et al. [15] proposed a LCM protocol which used a new route metric called Expected Transmission Time with Coding and Load Balancing (ETTCL). This protocol selects the path that has possible coding opportunity and where overflow due to network overload can be prevented effectively.

4. Ad hoc On-demand Multipath Distance-Vector Routing (AOMDV)

AOMDV, an extension of AODV, computes multiple loop-free paths per route discovery as contrast to single path computed in AODV. With multiple redundant paths available, the protocol switches routes to a different path when an earlier path fails [13]. Thus, a new route discovery is avoided. Route discovery is initiated only when all paths to a specific destination fail. For efficiency, only link disjoint paths are computed so that the paths fail independently of each other.

Unlike the single path case, different routes for the same destination will now have different hop counts. Nodes must be consistent regarding which of these multiple routes it advertises to others. (An advertisement occurs when an intermediate node replies to a RREQ, or propagates a RREQ to its neighbors, for example). If two nodes on a route advertise routes such that the advertisement from the upstream node has a smaller hop count, it presents a sure recipe for loops.

The basic structure of a routing table entry in the AOMDV in comparison with AODV is shown in Fig 1 and 2 [16]. There are two main differences: (i) the hop count is replaced by advertised hop count in the AOMDV and (ii) the next hop is replaced by the route list. The route list is simply the list of next hops and hop counts corresponding to different paths to the destination. The advertised hop count represents the maximum of the hop counts of each of those multiple paths so long as a strict route update rule is followed. As in AODV, routes corresponding to only the highest known sequence number for the destination are maintained. However, AOMDV allows for multiple routes for the same destination sequence number. Multiple routes can form via any neighbor upon receiving a RREQ or RREP from that neighbor.

Destination ID	Sequence Number	Advertised Hop count	Route List			
			Next hop 1	Last hop 1	Hop count 1	Lifetime 1
			Next hop n	Last hop n	Hop count n	Lifetime n

Fig 1 AOMDV Routing Table Entry

Destination ID	Sequence Number	Hop count	Lifetime of a route	Next hop

Fig 2 Routing Table Entry in AODV

5. Proposed Algorithm

The primary objective of ELB-AOMDV (Energy efficient Load Balanced AOMDV) is to avoid formation of new routes and forwarding of data packets through a congested node. Each node obtains its current congestion status from the interface queue size. The proposed algorithm as shown in Fig 3 will make the following changes to the existing AOMDV protocol:

- Load is balanced via alternate paths based on the interface queue length and channel busy time if load exceeds a certain threshold value
- Residual Energy is further used to distribute load along multiple paths.

1. Initialize the network with mobile nodes. All nodes use AOMDV as default routing protocol.
2. Initialize energy level of all nodes.
3. A source node wishes to communicate to destination node broadcasts RREQ packets.
4. Source node stores the multiple paths in its routing table.
5. Load value of each node 'i' at time 't' is calculated as:

$$L_i(t) = a * Q_{len_i}(t) + (1 - a) * T_{busy}(t)$$

   Where a is weighted factor chosen between [0, 1]. Q_{len} is interface queue length and T_{busy} is channel busy time
6. Load (L) is computed for all the paths and paths are sorted on the basis of load values first. If $L < L_{threshold}$ data packets are sent through same link otherwise residual energy for the different paths is calculated by aggregating energy values of all the nodes along that path.
   Residual energy of each node 'i' at time 't' is calculated as:

$$E_{res_i}(t) = E_{int_i} - E_{con_i}(t)$$

   where $E_{res_i}(t)$ is residual energy of node i at time t, E_{int_i} is initial energy of node i, $E_{con_i}(t)$ is energy consumed by node i at time t in routing packets.
7. The paths are sorted on the basis of E_{res} and data packets are distributed over multiple paths.

Fig 3 Pseudo code of proposed algorithm

Load is computed for every path and compared with threshold value. Route request packets are forwarded or discarded based on the interface queue length and channel busy time. If load value is within the threshold range, packets are sent on that link otherwise residual energy is calculated. The paths are sorted on the basis of residual energy and load is distributed over these multiple paths accordingly. For distributing load, maximum number of paths are assumed to be 3 but that can be varied also. In our simulations, $L_{threshold}$ is taken as half of the maximum channel capacity and residual energy E_{res} is taken as half of the mobile node's initial energy. ELBAOMDV ensures that multiple paths are added in routing tables of respective nodes only if new path does not differ too much in length than already existing and it does not exceeds maximum alternate path count.

6. Simulation Results

NS-2 is used to simulate proposed algorithm. This section presents the topology and different parameters used in the simulation process as shown in table 1. This simulation process considered a wireless network of 40 nodes which are placed within a 1200m x 1200m area. CBR (constant bit rate) traffic is generated among the nodes. The simulation runs for 200 Seconds. The simulation was done for varying speed of nodes, data rate and number of connections. In our experiment we assumed initial amount of energy 100J which is enough to maintain whole 200 sec simulation. We set the TX power to 1.0 W, RX power to 0.5W. Nodes in simulation move according to "random waypoint" model. Data packet size is 512 bytes and control packet size is 48 bytes.

Table 1. Different Parameters and their values

Parameters	Values
Routing Protocol	AOMDV
MAC Type	802.11
Number of nodes	40
Pause Time (sec)	2
Mobility of nodes (m/s)	10, 20, 30, 40
Packet Size (Kb)	512
Queue Length	50
Interface Type	Queue/Drop Tail
Maximum number of connections	10, 50, 100, 150
Data Rate (Number of packets/sec)	5, 10, 20, 50, 100

The following metrics are considered in order to compare the performance of ELB-AOMDV with AOMDV.

- **Packet delivery fraction (PDF):** PDF can be measured as the ratio of the data packets delivered to the destinations to those generated by the CBR sources.

- **Average end-to-end delay:** Average End-to-End delay is the average time of the data packet to be successfully transmitted across a MANET from source to destination.

In the first set of simulation, number of nodes considered are 40, packet sending rate was 10 packet/sec and number of connections are 60. Speed of the node is varied as 10 m/s, 20 m/s, 30 m/s and 40 m/s. It is observed from Fig 4 that in general, PDF increases as speed of node increases from 20 to 40 m/s. Initially, PDF for AOMDV is 76.61 and ELB-AOMDV is 84.22. ELB-AOMDV increases PDF by 29% with speed as 20 m/s.
The proposed algorithm does not increase average end to end delay as shown in Fig 5. As speed of node increases, ELB-AOMDV shows better performance in terms of E2E Delay with 83.72 ms as compared to 218.44 ms in AOMDV with 30 m/s speed and 70.27 ms as compared to 73.18 ms with 40 m/s. Therefore, our proposed algorithm suits well for high mobility. In low mobility also there is slight increase in E2E delay which is negligible as compared to increase in PDF.

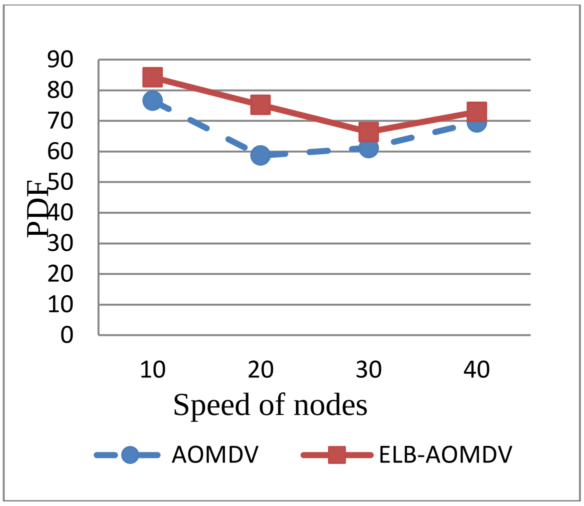

Fig 4 PDF Vs Speed of nodes

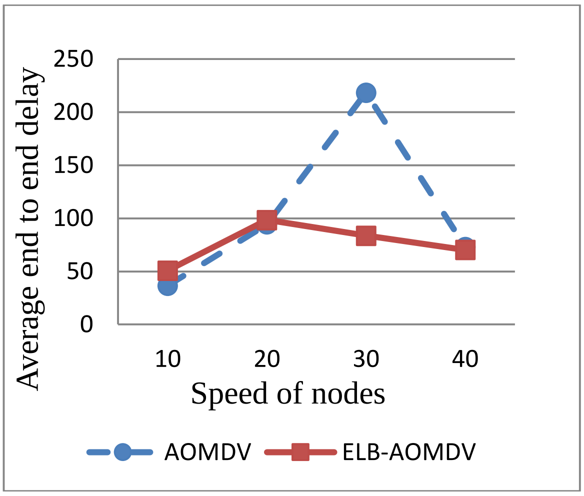

Fig 5 Average E2E delay Vs Speed of nodes

In the second set of simulation, number of nodes considered are 40, packet sending rate as10 packets/sec, speed as 10m/s and number of connections are varied in multiples of 50 as 10, 50, 100 and 150. Fig 6 depicts that change in number of connections has no considerable effect on PDF. On the whole, ELB-AOMDV has higher PDF (12% more on an average) as compared to AOMDV.

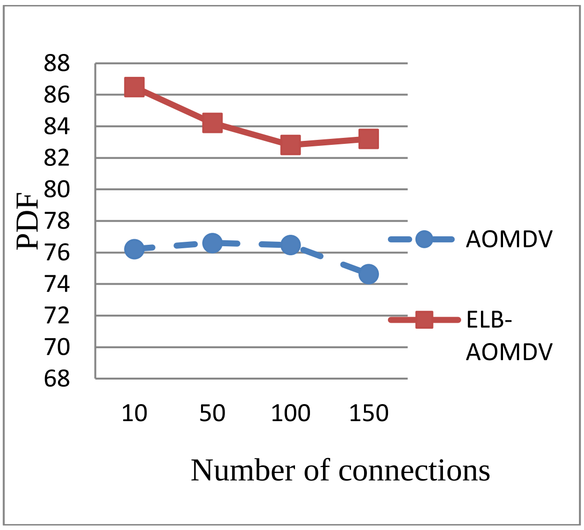

Fig 6 PDF Vs Number of connections

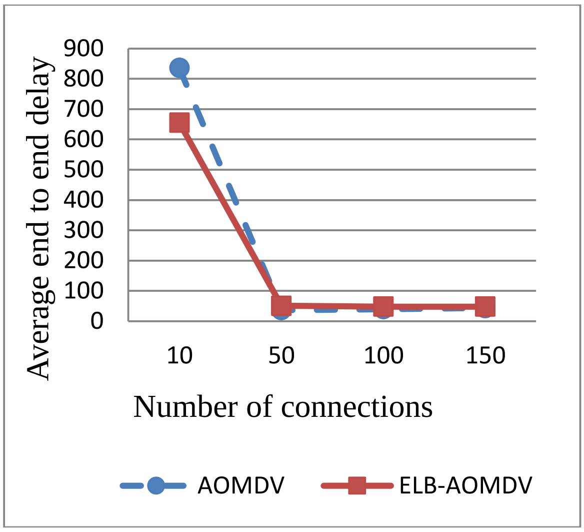

Fig 7 Average E2E delay Vs Number of connections

Average E2E delay is initially high for 10 connections in both AOMDV (836.17 ms) and ELB-AOMDV (655.42 ms), as shown in Fig 7. Thereafter, E2E delay decreases as number of connection increases from 10 to 50 and then again it tends to a constant value. Both the graphs are very close to each other signifying that our scheme doesn't cause much overhead and delay.

In third set of simulations, 20 m/s is the speed of node taken and 60 number of connections with 40 nodes. Data rate is varied from 5 packets/sec to 50 packets/sec ELB-AOMDV works better for high workload and requires less number of control packets therefore it is energy efficient in high workload scenario. ELB-AOMDV is better than AOMDV when packets were sent at a high rate (10 or 20 packets/sec). For instance, when the packet rate was 5, PDF deviation is 11% which increases to 14% with 20 packets/sec as shown in Fig 8.
The average delay of ELB-AOMDV is 37.51 ms as compared to 29.41 ms with 5 packets/sec. As data rate increases from 10 to 50 packet/sec, E2E delay for ELB-AOMDV starts decreasing from 50.82 ms to 45.99 ms whereas for AOMDV E2E delay starts increasing from 36.69 ms to 53.23 ms, as depicted in Fig 9.

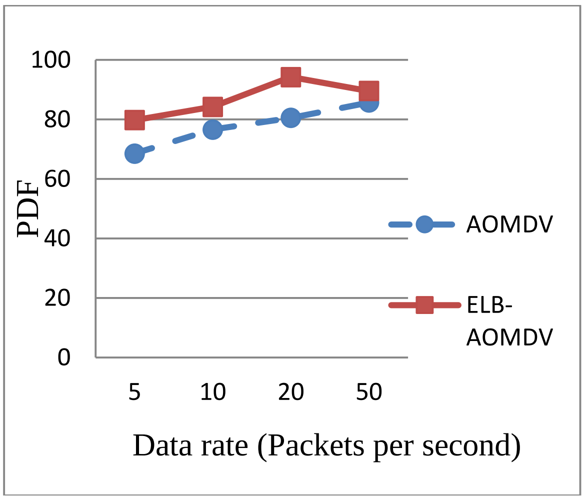

Fig 8 PDF Vs Data rate

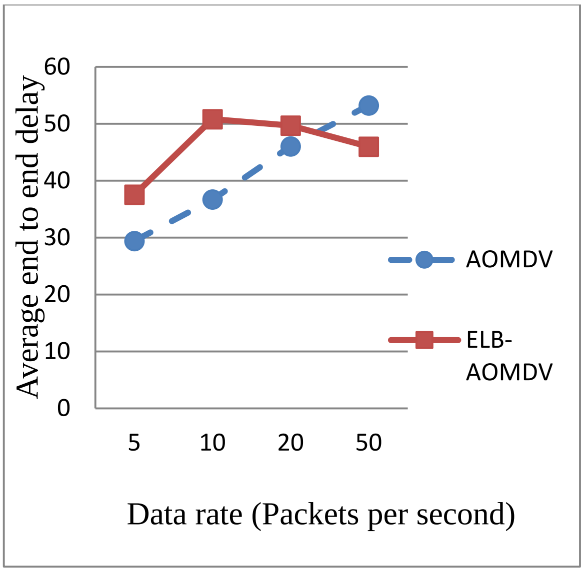

Fig 9 Average E2E delay Vs Data rate

7. Conclusion and Future Scope

In this paper, ELB-AOMDV algorithm has been proposed that provides Quality of Service in the network and results are evaluated on NS-2 in different scenarios by varying nodes' speed, number of connections and traffic load. It has been observed that ELB-AOMDV increases PDF and lowers E2E delay making it suitable for highly mobile nodes and networks with high traffic load.

We are considering the possibility of making the proposed algorithm independent from routing protocol, so that it could be a framework for obtaining QoS. In this paper, we have assumed a homogeneous traffic so in the future we would like to see how it addresses both real-time and best effort traffic.

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