Indian Journal of Science and Technology, *Vol 9(26), DOI: 10.17485/ijst/2016/v9i26/92406, July 2016*
ISSN (Print) : 0974-6846
ISSN (Online) : 0974-5645

A Novel Technique to Control Congestion and Energy Aware Routing Scheme for Wireless Mobile Ad hoc Networks

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Abstract

Background/Objectives: With the increase of portable devices as well as progress in wireless communication, Mobile Ad-hoc Networking is gaining importance with the increasing number of widespread applications. Due to the special characteristics of MANET, such as dynamic nature, energy constrains, lack of centralized infrastructure and link capacity make load balancing over these networks a challenging objective. Also a major concern in MANET is energy conservation due to the limited lifetime of mobile devices. Energy is a precious resource in MANET. For many multi-hop scenarios, nodes are battery-operated, thus requiring efficient energy management to ensure connectivity across the network. **Findings**: In MANET, balancing the load can evenly distribute the traffic over the network and to prevent early expiration of overloaded nodes. To achieve this, we combine load balancing and energy aware routing technique and named as Path Efficient and Energy Aware Ad Hoc Multipath Distance Vector (PE-EA-AOMDV) routing protocol. **Improvements**: The proposed scheme is simulated and results show that there are significant improvements in the proposed scheme compared to AOMDV, PE-AOMDV and EA-AOMDV with respect to packet loss, normalized routing overhead, packet delivery fraction, throughput and routing overhead.

Keywords: AOMDV, EA-AOMDV, Load Balancing, Mobile Ad Hoc Network, Multipath Routing

1. Introduction

A Mobile ad hoc network (MANET)[1-3] is described as an infrastructure-less volatile temporary network that consist a set of portable computational devices with a wireless communication interface that communicate with each other within a rapidly dynamic topology. In MANET[4,5], nodes used to discover themselves and maintain routes through the network. Since the transmission range of network interfaces is very limited, intermediate nodes are needed. Thus each node will have two roles at the same time: namely terminal role and router to forward packets of other mobile nodes. Nodes are freely movable and their batteries have limited capacities, which produce frequent changes in network topology. In fact, the restrictions on the bandwidth, memory and energy make MANET a network with complicated topology. Consequently, MANETs must adapt dynamically to be able to maintain on-going communications in spite of the changes.

A major concern in MANET is energy conservation due to the limited lifetime of mobile devices. Energy is a precious resource in MANET. For many multi-hop scenarios, nodes are battery-operated, thus requiring efficient energy management to ensure connectivity across the network. Normally, most of the routing protocol[6-8] that chooses the best route between the source and destination nodes to fulfil the multi-hop transmission is called single path routing. In cases of highly dynamic network topology and strictly limited resources the multipath routing schemes are introduced[8-10]. Multipath routing scheme provides multiple and alternative routes

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to assure successful data packet transmission. So to select energy-aware paths for data transmission that reduces the early power exhaustion of nodes and network portioning problem. Numerous energy aware routing protocols[11,12] have been proposed using various techniques such as transmission power adjustment, adaptive sleeping, topology control. These routing algorithms have not considered the problem like early exhaustion of nodes. Also these routing algorithms don't address node transmission power, remaining battery energy and reliability constraints. So it increases overall energy consumption of the node on the path.

In MANET, balancing the load can evenly distribute the traffic over the network and prevent early expiration of overloaded nodes due to excessive power consumption in forwarding packets. Due to the special characteristics of MANET, such as dynamic nature, energy constrains, lack of centralized infrastructure and link capacity make load balancing over these networks a challenging objectives. Also the presence of mobility implies that link breaks are happened often in an in-deterministic fashion. So this leads to congestion and delay for overall network. To overcome this optimal solution is to select a load balanced path for extending lifetime and aggregate QoS.

Pham P and Perreau S[13] describes that the load balancing is an important principal factor for achieving good throughput in MANET. The objective of load balancing is to distribute workload across multiple paths achieve optimal resource utilization, maximize throughput, minimizes response time, increase network life time, avoid overload and more overheads. Some of the issues related to load balancing in on-demand multipath protocols are uncertainty of RTT values, inhomogeneous load distribution, priority based path selection, unable to switch the route dynamically and improper bandwidth usage.

Wenjing YANG et.al.[14] introduced a Bandwidth Aware Multipath Routing Protocol (BMR) to select multiple paths based on the node's available bandwidth. In BMR, available bandwidth of a node is obtained based on cross-layer mechanism, which can provide a metric for route discovery. Node's available bandwidth is obtained by calculating node's local available bandwidth and neighbourhood available bandwidth. BMR gives better performance in improving end-to-end throughput and packet delivery ratio.

Wang I et.al[15] proposed Multipath Source Routing (MSR) based on DSR and presented a delay model for multipath routing protocol. They show that delay performance of a network can be improved by load balancing. In order to monitor real-time delay information along each path, a special type of packet called probing packet is sent periodically to estimate RTT. This delay information is considered to distribute traffic. If a path with longer delay will dispatch less delay for alleviate congestion. This protocol distributes traffic over different paths to achieve a minimum mean delay in a whole network.

Ducksoo shin et. al.[16] proposed an Adaptive Ad-hoc On-demand Multipath Distance Vector (A2OMDV), which resolves the problem of dynamic route switching when link failure occurs. Based on the delay of multiple paths, a source node selects its route dynamically and checks quality of the alternative routes according to the changes on the network. Path selection is made based on priority mechanism. In A2OMDV each source node prioritizes its routes based on RTT value and transmits data through the route with highest priority as primary route and other routes as alternative routes. This avoids contention and bottleneck.

Peter P. Pham and Sylvie Perreau[17] introduced a Multipath Routing Protocol with Load Balance policy (MRP-LB). The main objective of MRP-LB is to spread the traffic equally into multiple paths that is the total number of congested packets on each route is equal. They introduced analytical model and achieves guaranteed throughput based on congestion and contention. The results reveal that multipath routing provides better performance than reactive single-path route in terms of congestion and connection throughput, provided that the average route length is smaller than certain upper bounds which are derived and depend on the analytical model.

Yahya Tashtoush et.al.[18] proposed Fibonacci Multipath Load Balancing protocol (FMLB) for Mobile Ad Hoc Networks. This protocol distributes transmitted packets over multiple paths by using Fibonacci sequence. It assigns weights for each discovered paths using Fibonacci value and order the transmitted packets in decending order. The hop-count is taken as a main metric for assigning fibonacci value. FMLB packet distribution reduces congestion and increased packet delivery ratio up to 21% as compared to AODV and up to 11% over linear Multiple-path routing protocol.

Yaser Khamayseh et.al.[19] introduced Mobility and

Load aware Routing protocol (MLR) for adhoc networks. MLR uses node load and speed factors for route selection process. MLR is designed to solve broadcast storm problem due to the flooding strategy that is used in the route discovery process. By using Markovian Decision Process the routing overhead are controlled and maximizes overall network performance. Also high speed and heavy loaded-nodes are eliminated during route discovery phase because which causes contention, redundancy and collision problems.

Vishnu kumar Sharma and Sarita Singh Bhadauria[20] proposed Mobile Agent Based Congestion Control using Aodv routing protocol for Mobile ad hoc network. The authors use Mobile Agents (MA) to collect congestion status of each node in the network. Based on the congestion status of node the Mobile Agent can select less-loaded neighbor node as its next hop and update the routing table. This scheme avoids congestion and attains high throughput during communication.

Venkatasubramanian and Gopalan[21] introduced Cluster Based Congestion Control (CBCC) for supporting congestion control in ad hoc networks. Clusters are used to monitor path traffic rate and control it within localized scope. After estimating the traffic rate along a path, the sending rate of the source nodes adjusted accordingly. The clusters are autonomously and proactively adjust the traffic rate while waiting for congestion feedback.

Chai Keong Toh et.al.[22] made a qualitative comparison of the various load metrics and load balanced routing protocols. Among these protocols, only LARA and CSLAR use multiple load metric to balance the load among the discovered paths. Comparing the operations of routing protocols, only LBAR and ABR perform load balancing in effective manner. But it fails while distributing traffic over different wireless links due to link-reliability.

The remaining of the paper organised as follows. Followed by the simple introduction, Section II briefs the proposed scheme. The results obtained from the proposed scheme are discussed in Section III and at last Conclusion follows.

2. Proposed Work

2.1 Path Efficient Load Balanced Routing

In this part, we propose an extension to [23] AOMDV protocol in order to support certain mechanism and technique to improve its performance. The AOMDV protocol selects the route with the lower hop count to forward data. However, the less congestion routes can provide short end to end delay than routes providing lower hop count. To choose the less congestion routes, we need a new metric which allow source node to select the less congestion routes. For this reason, we propose a new metric which achieve load balancing between the selected routes by taking into account the number of active paths through every node.

In general, the number of links passing over a node is not restricted. In the mean time when the number of links increases, it leads to congestion and contention problem. It causes a high delay, more control overheads and performance degradation due to its node mobility, large queue size and deficiency of bandwidth. To overcome this problem, we introduce a threshold value that limit the number of links passing over a node. This new congestion-avoidance routing scheme is called as Path Efficient Ad-hoc on-demand Multipath Distance Vector (PE-AOMDV) routing protocol.

To implement the proposed idea, we introduce a new variable called *AP (Active Path) threshold* which defines the maximum number of paths passing over a node and *AP counter* is used to keep current active number of paths on a node. The AP counter variable is incremented by one for every new communication path establishment. These two variables *AP counter* and *AP threshold* are introduced in the existing structure of AOMDV routing protocol's routing table and RREQ (Route Request) packet as shown in Table 1.

Table 1. **a)** Routing Table of PE-AOMDV

Destination IP Address
Destination Sequence Number
Advertised hop count
Route List (next_hop,last_hop,hop-count)
Expiration Time Out
AP (Active path) counter

Table 1. Structure of Routing Table Entry and Route Request of PE-AOMDV protocol
b) RouteRequest Packet of PE-AOMDV

Type	Reserved	Last hop	Hop count	AP threshold
Request ID				
Destination IP Address				
Destination Sequence Number				
Originator IP address				
Originator Sequence Number				

2.1.1 Network Model

Consider a MANET with *N* nodes, whose topology can be described as the inter connection of links between *N* nodes, as well as a connected graph G(V,E), where V = {*ni*, *i* = 1, . . . , *N*} is the set of nodes and E ⊂ V × V is the set of edges of the graph. Let *Rt*(*ni*) and *Rc*(*ni*) denote the transmission range and carrier sensing range of node *ni*, respectively. For *ni* ∈ V and 1 ≤ *i* ≤ *N* if *ni* is inside the transmission range of *nj* as well as *nj* is also inside the transmission range of *ni*, then the edge *eij* ∈ E.

Definition 1: Path ***Lij*** denotes a sequence of edges from a source node *ni* to a destination node *nj*, and *Lij* includes all successive links from *ni* to *nj*. All nodes but the source and the destination over a path are called intermediate nodes. If there are *M* paths from node *ni* to *nj*, then the multiple paths can be represented as ***Lij*** = **{*Lm ij* , 1 ≤ *m* ≤ *M*}**.

2.1.2 Multipath Evaluation Based on Link Load

Based on the network model mentioned previously, the traffic load at node *ni* can be defined by

$$T\left(n_i\right) = \sum_{k=m}^{M} S_k$$

where *M* is the number of paths and *Sk* is the average number of links passed through at node *ni* over path Lm_{ij} which should not exceed the AP threshold value depending on the application in consideration (network size, network load etc.). Let *Q*(*Lij*) denote the traffic load on the link between nodes *ni* and *nj*. Then, the link load can be defined by

$$Q\left(L_{ij}\right) = \sum_{p=n_i}^{n_j} T\left(p\right)$$

From the above evaluation model load-balancing approach that computes the *path vacant ratio* is proposed for multiple-paths. The *path vacant ratio* can be used to evaluate the load over multiple paths, which is derived from taking account of load balancing, path load, important paths, and importance of nodes over multiple-paths.

2.2 Path Efficient and Energy Aware Routing

In this paper, we propose a new scheme that combines the mechanism of PE-AOMDV and EA-AOMDV schemes[24,25]. The resulting algorithm is **Path Efficient and Energy Aware Ad-hoc on-demand Multipath Distance Vector (PE-EA-AOMDV) Routing Protocol** and works more efficiently. This scheme takes into consideration the factors such as balancing load within the nodes, energy level of a node and energy cost for transmission of packet within the nodes. This scheme prevents the congestion and contention problem by maintaining the number of links passing through the nodes. The number of links that make up a path for transmitting packet will not exceed the threshold value. In case of exceeding the threshold value the request to transmit packet gets discarded. The scheme also maintains the life time of a node by maintaining the energy level of the node. The energy level and energy cost for transmitting packet for both sending and receiving node is checked and the transmission of packet are rejecting the request takes place depending on the energy level.

This scheme implements the maintenance and checking the number of links, energy level and energy cost for packet transmission simultaneously each time when a request comes to a node to transmit packet through it. The implementation of the protocol helps in overcoming the traffic overhead while transmitting packet. Also the life time of the nodes is also prolonging maintained. So that data can be transmitted for long time without any congestion and loss. The Figure 1 details the implementation of the energy simulation factors within the existing algorithm.

2.3 Illustration of Proposed Scheme

To illustrate the proposed scheme, we consider a network model as shown in Figure 2 with 19 wireless nodes. Let us consider that the nodes S, R and B are source nodes and D, Z and Y are their corresponding destinations and they use multipath routing scheme. The possible paths for each pair are:

(i) (S-D) - {(S-A-N-D), (S-P-M-N-D), (S-A-K-X-D),(S-P-Y-Z-D), (S-A-K-L-X-D)}

(ii) (R-Z) - {(R-A-M-Z), (R-A-M-Y-Z),(R-A-K-N-Z),(R-A-P-Y-Z), (R-S-P-Y-Z)}

(iii) (B-Y) - {(B-A-P-Y), (B-A-M-Y), (B-A-S-P-Y),(B-R-S-P-Y)}

Let us consider node A whose energy level at time ti is 78 jules. The node A accepts paths from nodes (S, R, B) respectively. At the same time the node A also transmits the received packets to other nodes through available paths mentioned above. So the energy level of node A gets reduced and AP counter gets incremented gradually based on the proposed scheme. Now AP counter has reached its maximum threshold value and also the energy level also gets below the energy threshold.

Algorithm Route Update Rules of PE-EA-AOMDV Protocol

if $\left(seqnum_i^d < seqnum_j^d\right)$ **then**
  $seqnum_i^d := seqnum_j^d$
  if $(i \neq d)$ **then**
    if $activepath_{threshold\ i} > active_{path_{counter_i}}, energyfactor_{threshold\ i} > rem\ battery_{energy_i})$ **then**
      $active_{path_{counter_i}}^{j} := active_{path_{counter_i}}^{j} + 1$
      $energy_{cost_{trans_i}}^{j} := transmiting_{cost_i}^{j} + receiving_{cost_j}$
      $rem_{battery_{energy_i}} := cur_{battery_{energy_i}} - energy_{cost_{trans_i}}$
      $advertised_{hopcount_i}^{d} := \infty$, $route_{list_i}^{d} := null$
      insert (j, $advertised_{hopcount_i}^{d}$ +1, $activepath_{threshold\ i}$, $rem_{battery_{energgt_j}}^{d}$)
      into $route_{list_i}^{d}$
    end if
  end if
else if $\left(seqnum_i^d = seqnum_j^d\right)$ and
  $\left(\left(advertised_{hopcount}]_i^d, i\right) > [\left(advertised_{hopcount}]_j^d, j\right)\right)$ **then**
  $active_{path_{counter_j}}^{j} := active_{path_{counter_i}}^{j} + 1$
  $rem_{battery_{energgt_j}}^{d} := cur_{battery_{energy_i}}$
  insert (j, $advertised_{hopcount_i}^{d}$ +1, $activepath_{threshold\ i}$, $rem_{battery_{energgt_j}}^{d}$) **into**
  $route_{list_i}^{d}$
end if

Figure 1. Modified Load & energy aware Route update algorithm of PE-EA-AOMDV.

From Figure at time t2 based on the routing information, node P sends its RREQ (P) to node A for transmission of packet. Node A examines its AP counter value to the new RREQ(p) packet AP threshold value and RBE value to EF threshold value. Node A already has AP counter value as 10 and RBE value is 18 jules. By comparing these value, node A drops the RREQ(P) and not involves the new communication at any node. Also sending of packet from node A to node N is rejected because energy level is low and will not be able to withstand till the complete packet transmission. Preventing high load and low energy nodes to be a part of the selected route and distributing the load among the n odes evenly and improve the performance in terms of PDR, Energy, throughput, delay. Moreover, it prolongs the nodes lifetime by preventing the battery power resulted from broadcasting useless control packets for new route re-discovery process.

3. Simulation Results

We consider the AOMDV and EA-AOMDV to compare with the proposed PE-EA-AOMDV and NS2 is used to simulate the results. The performance metrics such as Average End-to-End Delay, Minimum Energy consumption, Packet delivery fraction, Packet loss Ratio, Routing Overheads and Throughput are taken into account. The considered simulation parameters are given in Table 2.

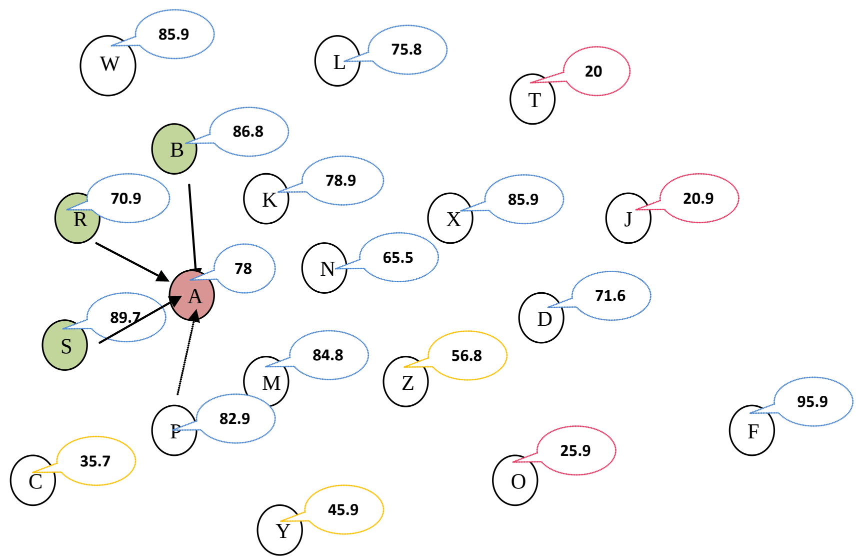

Figure 2. Contention and congestion Problem of node A.

Table 2. Simulation Parameters for PE-EA-AOMDV

Parameter	Value
Simulator	NS-2.34
Simulation time	100 seconds
Simulation Area	1520x1520 m^2
Transmission Range	250 m
Packet Size	512 bytes
Traffic & Mobility model	CBR/TCP
Traffic Rate	10 packets/second
Simulation Model	Random Way Point
Pass Time	5 seconds
Number of nodes	100
MAC Type	802.11 DCF
Channel Type	Wireless Channel
Routing Protocols	AOMDV,EA-AOMDV
Antenna Model	Omni
Network Load	4 packets/sec.
Radio Propagation Model	TwoWayGround
Idle Power	0.0001 W
Transmission Power	1.0 W
Receiving Power	1.0 W
Sleep	Power 0.0001 W
Transition Power	0.002 W
Transition Time	0.005 Sec.
Initial Energy	100 Joules
Interface Queue Type ,length	DropTail/PriQueue,50
Speed	5 m/sec.
Frequency	2.4 GHz
Data Rate	11.4 Mbps

From the simulation parameters of the proposed load energy-aware scheme performs well with respect to number of nodes, various network flow and different pause times. The following table summarized the supported features of AOMDV, PE-AOMDV, EA-AOMDV and PE-EA-AOMDV protocol.

In Table 3 all the six constraints have been evaluated with increasing number of nodes by 20,40,60,80,100. The graph results of the corresponding performance metrics are evaluated as below.

3.1 Packet Delivery Ratio

The packet delivery ratio can be represented as the ratio of an amount of successive received packets of a destination from an amount of transmitted packets by a source node during the simulation time. It can be represented in the following equation,

$$\text{Packet Delivery Ratio} = \frac{\text{Received Packets}}{\text{Sent Packets}} * 100$$

The Figure 4 represents the comparison of packet delivery ratio of the schemes AOMDV, PE-AOMDV, EA-AOMDV and PE-EA-AOMDV. The [Figure 4] represents the packet delivery ratio with the increase in number of nodes. The ratio reaches its maximum with the scheme PE-EA-AOMDV, where the simulation values are given in Table 4.

Table 3. Comparison of PE-AOMDV, EA-AOMDV and PE-EA-AOMDV

Compare with AOMDV		Packet Delivery Ratio	Energy Required for packet transmission	Throughput	Normalized Routing Overhead	Packet Loss Ratio	Routing overheads	Average End-to-End Delay
PE - AOMDV	Nodes (20,40,60,80,100)	✓	✓	✓	✓	✓	✓	✓
EA-AOMDV	Nodes (20,40,60,80,100)	✓	✓	✓	✓	X	X	✓
PE-EA-AOMDV	Nodes (20,40,60,80,100)	✓	✓	✓	✓	✓	✓	✓

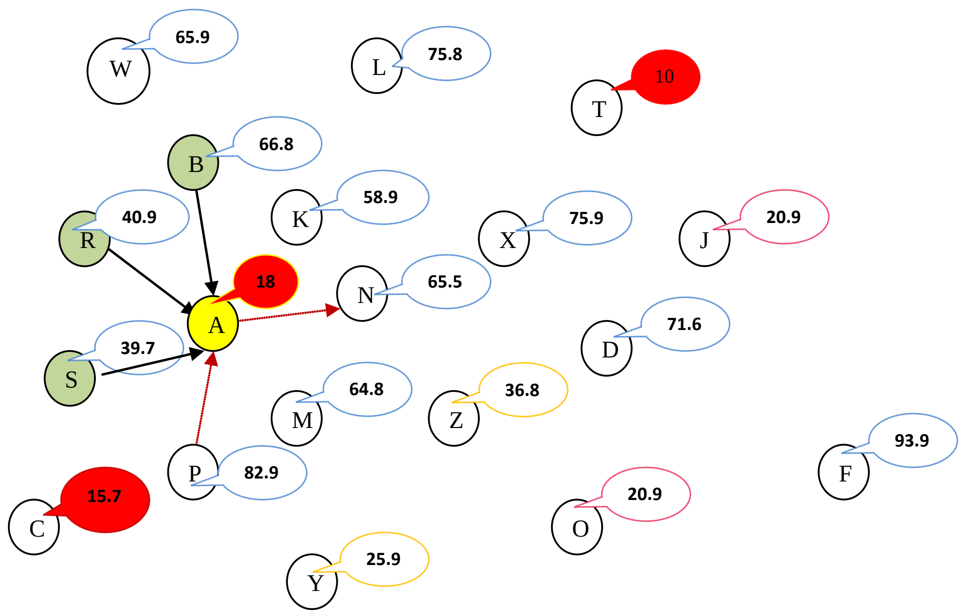

Figure 3. Our proposed scheme to alleviate contention and congestion Problem of node A.

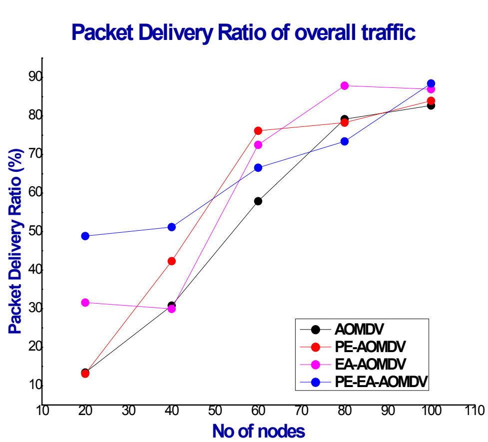

Figure 4. Packet Delivery Ratio with respect to number of nodes.

3.2 Energy Consumption

The energy consumption for packet transmission (transmitting and receiving) is taking into account. PE-EA-AOMDV balances the energy among all the nodes and prolongs the individual node lifetime and hence the entire network lifetime. The above Figure 5 details the maintenance of an energy level of the nodes using the four schemes such as AOMDV, PE-AOMDV, EA-AOMDV and PE-EA-AOMDV for packet transmission. Figure 5 shows the energy level maintenance with the increase in number of nodes. Comparison reveals that PE-EA-AOMDV scheme enables efficient maintenance of the energy level of the nodes.

Table 4. Overall comparison of the experimental results for 4 schemes

Traffic density (no of nodes)	20	40	60	80	100
1. Packet Delivery Ratio (%)					
AOMDV	13.400	30.781	57.867	79.176	82.710
PE-AOMDV	13.084	42.301	76.153	78.293	83.918
EA-AOMDV	31.587	29.915	72.488	81.876	86.937
PE-EA-AOMDV	48.851	51.154	66.559	73.414	88.409
2. Energy Required for packet transmission (Jules)					
AOMDV	16.725	103.343	260.599	543.803	591.433
PE-AOMDV	11.669	261.942	267.764	406.758	438.972
EA-AOMDV	30.129	69.247	406.091	422.842	458.639
PE-EA-AOMDV	75.151	178.081	662.039	306.779	429.171
3.Throughput of overall traffic (kbps)					
AOMDV	18.686	42.849	80.940	111.062	115.029
PE-AOMDV	18.240	58.751	106.895	109.327	116.030
EA-AOMDV	44.220	41.829	101.341	120.233	122.997
PE-EA-AOMDV	68.820	71.731	92.737	101.928	124.047
4.Normalized Routing Overheads (times)					
AOMDV	7.728	8.619	5.388	5.111	5.463
PE-AOMDV	7.222	4.478	3.423	4.229	5.053
EA-AOMDV	2.688	9.587	3.498	3.373	5.427
PE-EA-AOMDV	2.552	4.640	5.085	4.587	4.227
5.Packet Loss Ratio (%)					
AOMDV	86.600	69.219	42.219	20.824	17.290
PE-AOMDV	86.916	57.699	23.847	21.707	19.082
EA-AOMDV	68.413	70.085	27.512	12.124	23.063
PE-EA-AOMDV	51.149	48.846	33.441	26.586	11.591
6. Routing overheads (times)					
AOMDV	507	198	116	96	77
PE-AOMDV	494	211	125	100	76
EA-AOMDV	353	190	140	91	83
PE-EA-AOMDV	260	214	145	83	68
7. Average End-to-End Delay (ms)					
AOMDV	1.996	1.891	3.601	2.601	2.570
PE-AOMDV	0.969	3.353	2.018	2.276	2.264
EA-AOMDV	0.935	1.397	2.517	2.033	2.339
PE-EA-AOMDV	1.227	2.735	4.127	2.162	2.268

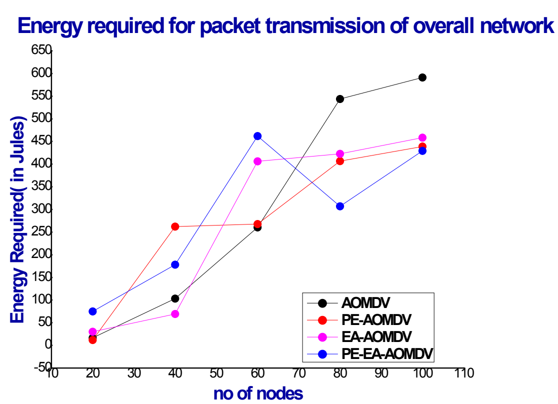

Figure 5. Energy Level with respect to number of nodes.

3.3 Throughput

Throughput is obtained by calculating how many packets are received at the destination from the source at a specified time interval (kbps). It is shown in following equation,

$$\text{Throughput} = \frac{\text{Received Packet Size}}{(\text{Stop Time} - \text{Start Time})} * \frac{8}{1000}$$

Figure 6 details the number of packets received at destination at particular time interval. With increase in number of nodes the throughput is maximum using PE-EA-AOMDV scheme.

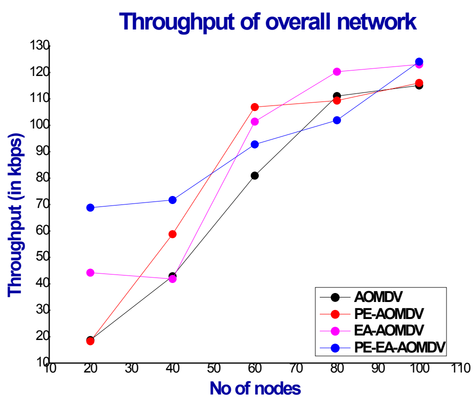

Figure 6. Throughput Ratio with respect to number of nodes.

3.4 Normalized Routing Overheads

Normalized routing load is the number of routing packets transmitted per data packet sent to the destination. Also each forwarded packet is counted as one transmission.

$$\text{Normalized Routing Overheads} = \frac{rt_{packets}}{received_{dtpackets}}$$

This metric is also highly correlated with the number of route changes occurred in the simulation. Normally sum of the routing control messages such as RREQ, RREP, RRER, HELLO etc, counted by k bit/s. The normalized routing overhead is calculated by using the following equation, Normalized Routing Overhead comparison for the schemes AOMDV, PE-AOMDV, EA-AOMDV and PE-EA-AOMDV is depicted in Figure 7. The normalised routing overhead is less in using the scheme PE-EA-AOMDV with increase in number of nodes.

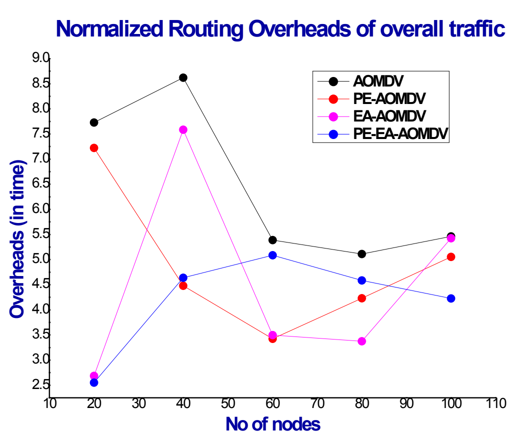

Figure 7. Normalized routing overheads with respect to number of nodes.

3.5 Packet Loss Ratio

The reasons for packet drops can be incorrect routing information, mobility & power management. AOMDV cannot maintain precise routes and drops, when nodes move often. The usage of state routes from its caches is the major reason for AOMDV packet drops. The packet loss ratio can be calculated as follows,

$$\text{Packet Loss} = \text{SentPackets} - \text{Recieved Packets}$$

$$\text{Packet Loss Ratio} = \frac{\text{Packet Loss}}{\text{SentPackets}} * 100$$

Comparison of packet loss ratio for the schemes is shown in the Figure 8. From this PE-EA-AOMDV scheme enables minimum packet loss ratio by efficient transmission of the packets even with the increase in number of nodes.

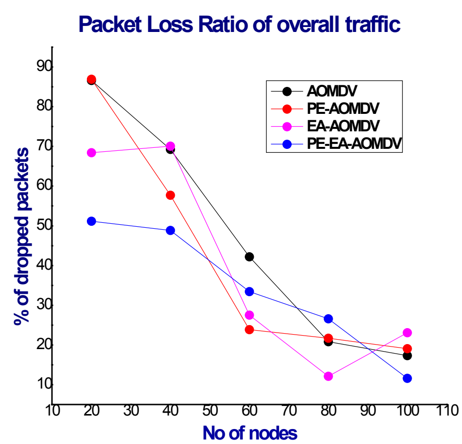

Figure 8. Packet Loss Ratio with respect to number of nodes.

3.6 Routing Overheads

Routing overhead is the ratio of the number of control packets propagated by every node for maintains routing information and time. In AOMDV routing overheads are increased, due to the earliest exhaustion of node and path life time. AOMDV path selection doesn't care of remaining battery energy. So it causes less processing power and links breaks. It is calculated as below,

$$\text{Routing Overhead} = \frac{\text{Router Packets Transmitted}}{\text{Total Time}}$$

Routing Overhead is well maintained by using PE-EA-AOMDV scheme, which has been detailed in Figure 9. Even with increase in number of nodes the routing overhead is efficiently handled with the above said scheme and the overhead is considerably low.

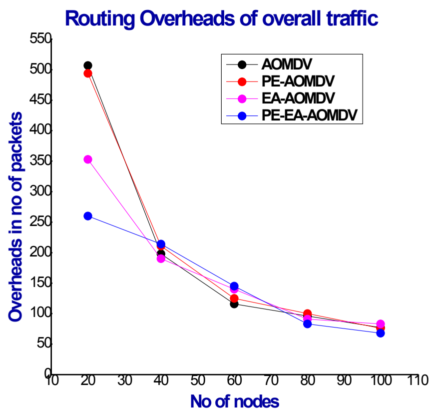

Figure 9. Routing Overheads with respect to number of nodes.

3.7 Average End-to-End Delay

Average End-to-End Delay is represented by how much time it takes for successful packet transmission. The average end-to-end delay for tested AOMDV protocol increases when increasing the network size, but in PE-EA-AOMDV delay is decreases with significant value. The calculation of average end-to-end delay is as follows,

$$\text{Total Delay} = \text{Received Time} - \text{Sent Time}$$

$$\text{Avereage End} - \text{to} - \text{End Delay} = \frac{\text{Total Delay}}{\text{Received Packets}} * 1000$$

The Figure 10 depicts the comparison of average end-to-end delay using the four schemes. The delivery of packets with minimum delay is enabled using the scheme PE-EA-AOMDV. The minimum delay is achieved even increase the number of nodes increases.

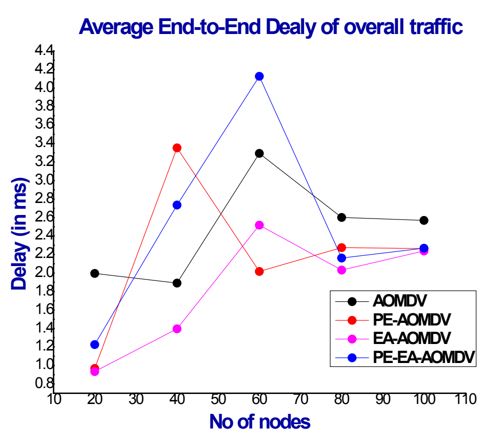

Figure 10. Average End-to-End Delay with respect to number of nodes.

The simulation values for the comparison of the schemes (AOMDV, PE-AOMDV, EA-AOMDV and PE-EA-AOMDV) with increase in number of nodes in the following Table 4 respectively. The tables reveal the scheme that is efficient in handling all the aspects as Packet Delivery Ratio, Energy conception, Throughput, Normalized Routing Overhead, Packet loss Ratio, Routing Overhead and Average end-to-end delay. These enable proper routing of the nodes and exact delivery of packets.

4. Conclusion

The proposed PE-EA-AOMDV scheme optimized load and energy by slightly modifying AOMDV route update rules in order to generate more energy efficient and load balanced routes than AOMDV and PE-EA-AOMDV routing protocol by finding minimal residual energy of each path without taking the destination in account unlike AOMDV. It reduces the energy consumption, average end-to-end delay and normalized routing overhead. It also reduced the routing overhead than AOMDV and increases the routing overhead than PE-EA-AOMDV. It increased packet delivery ratio and throughput. Simulation results showed that the PE-EA-AOMDV routing protocol has performed better than AOMDV routing protocol.

5. Acknowledgement

This work is supported by University Grants Commission (UGC-MRP (F.No:41-614/(2012) SR) under the Major Research Project Scheme.

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