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ENERGY AWARE ROUTING FOR MANETS BASED ON CURRENT PROCESSING STATE OF NODES

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ABSTRACT

Wireless mobile ad hoc network composed of mobile nodes (MNs) without any Pre-established Infrastructure. MNs are free to move and organized themselves to form a network over radio Communication area. In this environment establishing optimistic route between source to destination is challenging due to limited battery powered heterogeneous mobile nodes. Thus MANETs needs an efficient dynamic routing protocol with respect to energy in order to extend the network lifetime. In this work, we design a new energy aware reactive routing protocol for MANETs to avoid the node to become bottleneck. This Mechanism addresses the two important network performance attributes i.e., network lifetime & link stability. Performance analysis has been evaluated with the help of NS2. Simulation results indicate that our developed mechanism is better than the existing energy aware AODV routing protocols.

Keywords: *Energy, AODV, MANETs, Route Discovery Time, Throughput, Packet Loss.*

1. INTRODUCTION

Mobile Ad Hoc networks [1] consist of set of mobile nodes to form multi-hop communication without any pre established infrastructure. Mobile Nodes in a network are self-organized, autonomous to form a network over wireless links & act as hosts as well as routers to forward the packets. Due to its characteristics MANETs are very suitable for a situation where network is difficult to setup and cost/time effective. When mobile nodes are not in the radio range of each other communicate by relaying on intermediate nodes. Nodes in MANETs are equipped with battery power and these batteries are limited lifetime and most important constraint issue is availability of power during MANETs applications.

Considering energy management is a vital design factor in MANETs due to its constrained energy characteristic as mobile nodes are equipped with limited batteries and during the mission it is not possible to recharge/replace the batteries. Energy of the node is consumed in the form of data reception, data transmission and processing the data. Exhausting energy of any node greatly impact on overall communication performance & network lifetime as MANETs is peer to peer network. In order to improve the network life time & communication performance, packets must be communicated such a way that minimum energy is consumed & nodes energy state is considered. Thus routing is a one of the best way to manage the energy in MANETs. The aim of MANETs routing is not only to establish correct, efficient & effective path but also need to consider the energy efficiency but it is most challenging task due to its characteristics. In literature many routing protocols has been proposed to solve the problem of energy management, these protocols majorly sub divided into three categories [2].

1. Energy efficient routing path
2. Reliable routing path
3. Routing path with higher energy nodes

In energy efficient routing path, protocol focus is to reduce the energy cost during the communication so as to minimize the energy consumption of all nodes present in a network. They achieve the goal by either reducing the active energy required to communicate packet reception/transmission or minimize the inactive energy waste during idle state of nodes. In Reliable routing path, Protocol focus to find the route based on expected transmission count, in which routing link needs minimum number of retransmission to recover from loss of packets. In routing path with higher energy nodes, protocols find the routes with maximum energy nodes path. Every protocol has its own advantage and

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limitations but it is not an easy task to judge which protocol is best for a given network condition. Hence, motivation is to divide the divide the network condition into categories and then compare the routing protocols performance with different performance metrics. Results presented in our work can be used by the researchers for their research. Although there is a lot of review work carried out by researchers to compare the energy management routing protocols, this work includes a new technical performance metric such as node to become ***bottleneck intermediate node*** to forward the packets from multiple sources, which is the one of the most suitable issue to evaluate the energy management routing protocols for multi hop MANETs environment. This performance calculation metric is a novel aspect of this work.

First part of our work gives the state-of-the-art analysis of reactive & proactive routing protocols performance such as AODV [3] and DSDV [4] . It is very difficult to judge which mechanism is best for a given network condition. Hence, motivation is to divide the network condition into categories and then compare the performance metrics. Thus we analyze the routing protocols performance with different network conditions such as variable hop count, variable radio area, and variable packet size with mobility consideration. Results presented in our work can be used by the researchers for their research. Finally we conclude that AODV is best suited to develop an energy efficient routing protocol in MANETs.

Energy efficiency is an important considerable design issue for MANETs, since heterogeneous mobile nodes are equipped with limited power batteries. If the routing protocol is based on shortest path and do not consider the power issue of node, then power failure of node cause the impact on network lifetime. Thus it is important to reduce the energy cost during data communication. The aim of the routing protocol is not just to find the energy consumption during end to end packet travelling, but also to enable reliable routing through the links and make residual energy of nodes. It not only improves the Quality of Service but also improves the network life time. Hence there is still a requirement of a routing protocol which should address the MANET challenges.

Second part of our work design an "Energy aware routing for MANETs based on Current Processing state of Node". This Protocol is based on enhancement of AODV protocol and it initiates the routing activity reactive basis, where its key motivation is to reduce the routing load on mobile node and improve the network lifetime.

Although there is a lot of work carried out by researchers to develop of energy efficiency routing protocols with different performance metrics. Our work includes a new technical performance metric to check the possibility of node to become "*bottle neck node*" when it become the intermediary node to forward the packets. This performance calculation metric is a novel aspect of our work. Thus we develop a routing process that removes the condition of node to become "*bottle neck node*", which in turns improve the network performance and network lifetime.

The remaining paper is organized as follows: Section 1.1 discusses about routing in MANETs, Section 1.2 gives the related work. Section 2 analyses the performance metrics. Section 3 shows our results and the work ends with the conclusion.

1.1 Routing In MANETs

Routing in MANETs faces an extra overhead and challenges when compared to infra-structured networks. There are lot of routing protocols presented in the literature, which have been developed with extra efforts in order to cope with characteristics of MANETs environment. The routing in MANETS is challenging task by limiting factors such as dynamic network topology, heterogeneity and mobility. Most of the existing routing protocols in MANETS follow different design patterns so as to confront the inherent characteristics of MANETs, based on proactive and reactive approaches. Proactive routing protocol initiate the route ahead of time, and maintain the routing information at all time regarding connectivity of every node to all other nodes present in a network with the help of periodic update. Proactive routing protocols allow the nodes to have clear view of the network topology. Thus all nodes are able to make a quick decision about routing. On the other hand periodic messages make an extra overhead. Examples of proactive routing protocols are DSDV & OLSR.

An alternative to proactive approach is followed by on demand protocols is the reactive source initiative routing. Route is

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established only when source wants to communicate with destination. Initiation of route is started by request function of the source node followed by route reply function of destination. Established route is maintained by route maintain function until it is required. Examples of reactive routing protocols are DSR & AODV.

The AODV protocol uses RREQ (route request) packets which are flooded throughout the network to discover the route between sources and destination. When an intermediate node gets RREQ packets, it replies to it by generating a RREP (route reply) packet only if it has routing information to destination with maximum sequence number. The sequence number is useful to determine freshness of the route. Otherwise an intermediate node broadcasts the RREQ packet to its neighbour nodes till RREQ packets reach the destination node. The destination uni-casts a RREP packet to the source node via intermediate nodes, where all the intermediate nodes set up route in their routing tables. AODV uses a route maintenance process for link layer notification. The DSDV protocol is based on table driven & maintains the table at every node at any point of time. Based on table entries, routing path is decided between source to destination. It uses an update mechanism to update the table entries, irrespective of need.

First part of our work proposes a performance evaluation of AODV and DSDV with respect to hop count, Traffic, Mobility and Radio area with respect to variable packet size. The objective of our work is to evaluate the performance of two routing protocols based on proactive &reactive behaviour. Network Simulator 2 is used to calculate the performance of "AODV" and "DSDV" routing protocols. We have designed two different types of simulation scenarios to check the performance of DSDV and AODV in terms of packet loss, throughput & end to end delay.

1. With different hop count between source and destination ranging from one to ten with variable packet size
2. With different communication radio area of each node (100m, 200m, 300m) with variable packet size

Throughput: In our throughput calculation simulation, we finally created the simulation based on different number of hops starting from one to ten with intermediary nodes busy with different communication, with variable packet size and different radio area

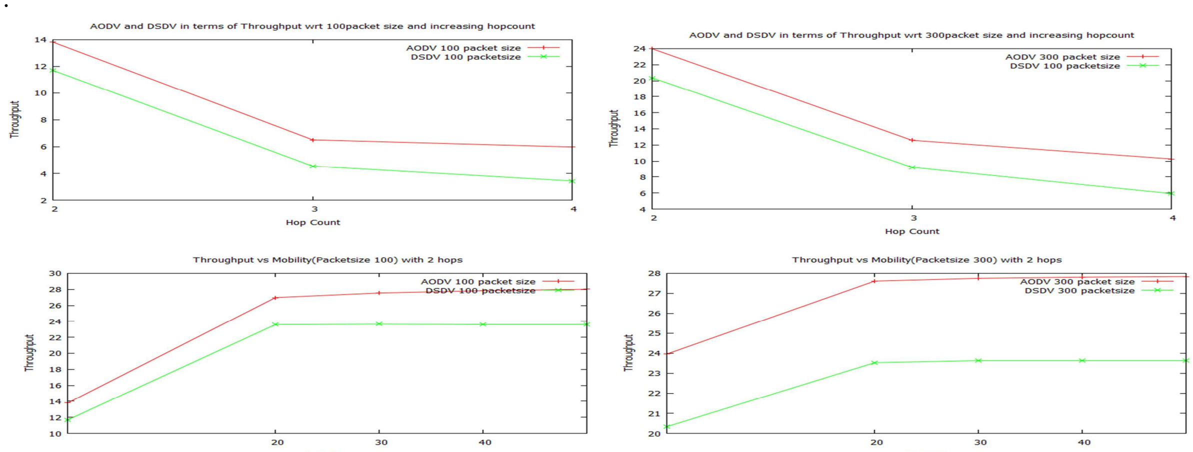

Figure 1. Average Throughput Vs Hop Count And Mobility

The Simulation results show that for all packet size AODV performs well compared to DSDV shown in figure 1. However taking mobility into consideration, we have plotted a graph against increasing Mobility and Throughput with growing hop count and packet size which shows that as the mobility increases among the nodes AODV works well and is very suitable for the high mobile scenario.

End To End Delay: It is generally calculated by summation of all possible delays through the path from source to destination which includes transmission delay, queuing delay, processing delay and propagation delay, where end to end delay is the half of round trip time. We calculated end to end delay for different hop counts ranging from one to ten

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hops, different radio areas and different traffic conditions with increasing packet size. Finally we had plotted the average graph of combination of all mentioned metrics of AODV and DSDV

The figure 1, 2 depict that AODV is effective for high packet size and large hop count in the mobile scenario.

Packet Loss: In an infrastructure less wireless environment, multi-path fading and interference can affect the successful transmission and reception as well. In MANETs route from source to destination contain multiple links and heterogeneous radio, so packet loss performance will be an important issue. In our work we calculated packet loss for different hop counts ranging from one to ten hops, different radio areas and different traffic conditions with increasing packet size. Finally we had plotted the average graph of combination of all mentioned metrics of DSDV&AODV

The figure 3 clearly show that when packet loss is calculated with respect to increasing packet size, hop count and different traffic conditions with less and high mobility there is no such visible difference between performance of AODV and DSDV

Thus most of the researchers used AODV is as a base routing protocol to implement energy efficiency because it is reactive less over head routing protocol and also it avoids the routing loops by introducing destination sequence number. Moreover it quickly responds to link break by RRER and local update mechanism by HELLO message.

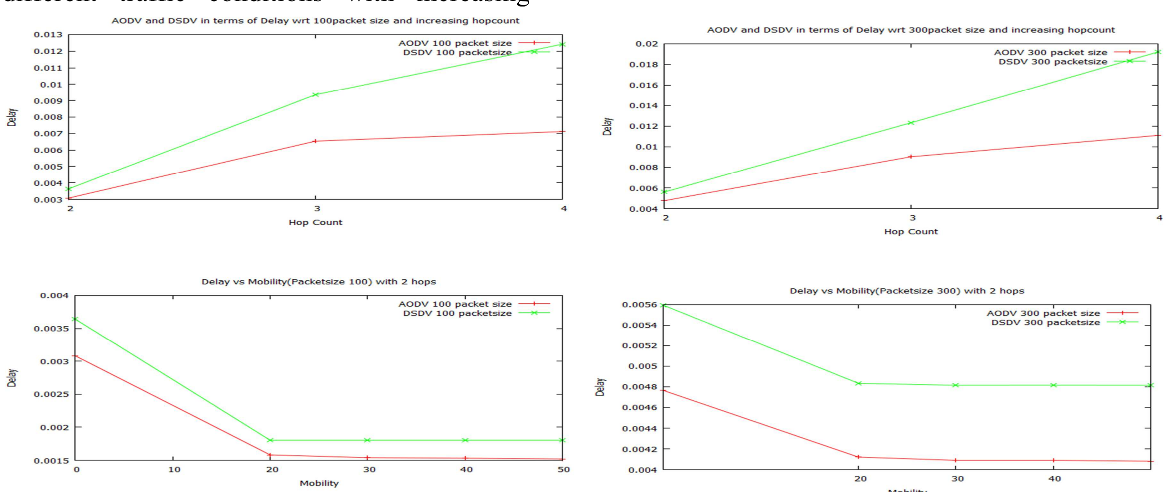

Figure 2. Average Delay Vs Hop Count And Mobility

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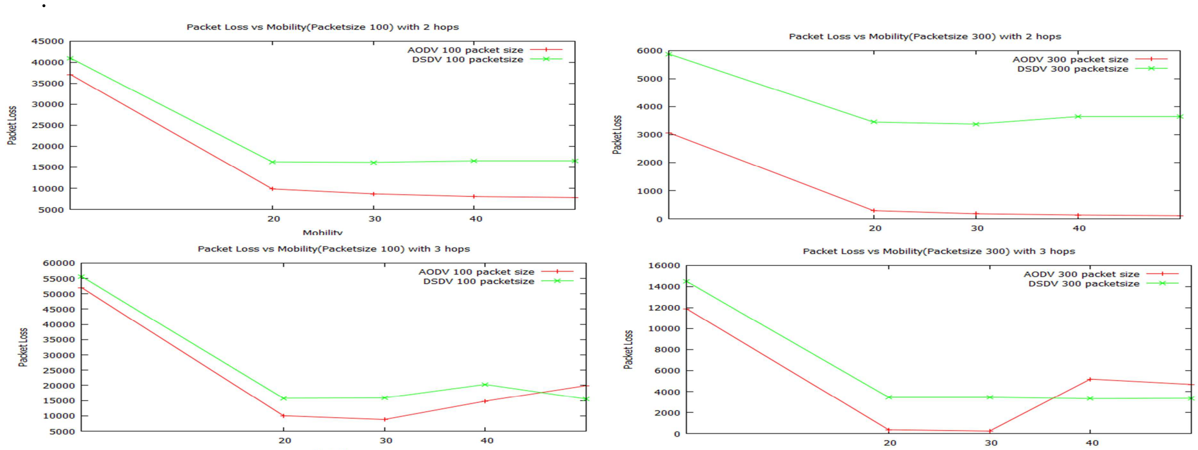

Figure 3. Packet loss vs Mobility

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1.2 Need of Energy Management in MANETs

Mobile nodes in a MANETs are equipped with limited battery power & Due to its characteristics MANETs is very suitable for application such as battle field and disaster recovery. In such applications it is very difficult to replace or recharge batteries. Nodes which loss its total energy cant not be used in communication & thus removed from network. Energy management in MANETs is essential due to limited energy storage capacity and difficult battery replacement problem, lack of central coordination and peer to peer network characteristic. In MANETs, active energy consumption happen through packet communication such as packet transmission and packet reception and inactive energy consumption happen through idle state of node but they are listening medium to any possible communication requests from other nodes and also energy consumed during the node is sleeping. Thus, many researchers developed routing protocols not only simply based on efficient & correct path between source to destination but also considered the energy management so as to provide network functions long as possible. Table 1 shows the energy management protocols taxonomy. Basically Energy efficient Routing finds the route based on transmission power of nodes, Reliable routing path is based on expected transmission count and Routing path with higher energy nodes is based on energy awareness of nodes.

The Algorithms [5-7] goal is to construct the routes to provide energy efficiency based on energy cost for transmission of packet, but not considering the energy state of nodes. Work [8], find the reliable route between source and destination based on transmission count expectation, and routing paths need less number of control messages to recover the loss of packets, which decrease the energy utilization of routes but not end to end packet transmission. The protocols[9-11] goals is o establish route based on energy state of nodes to extend the life time of network but not guarantee the energy efficiency

Table 1 Energy Management Protocols Taxonomy

	Protocols	Aim
Energy efficient routing path	1. Expected Energy Consumption [12] 2. Energy Drain Rate Routing [13] 3. Distributed Energy efficient Routing [14] 4. Minimum Energy Routing[25]	Minimize Energy consumption
Reliable routing path	1. Load Aware Routing[15] 2. Expected Transmission Count Routing [8] 3. Retransmission Energy Aware Routing	Provide Reliability of Link
Routing path with higher energy nodes[16]	1. Local Energy Aware Routing 2. Life Time Prediction routing 3. Battery Sensitive Routing 4. Integrated Energy Aware Routing 5. Energy Based QoS Routing 6. Dynamic Energy Aware Routing	Extend Network Life Time

1.3 AODV based Energy Efficient Routing

Routing protocol based on energy efficiency for MANETs [1] is challenging due to its constraint energy characteristic. Energy metric is powerful Considerable factor in routing so as to achieve energy efficiency in system. In routing, just finding the route with energy awareness or energy cost of the routing path is not sufficient but also need to consider about link reliability and node's residual energy to improve the lifetime of network. In literature number of routing protocols based on energy proposed. As we discussed in previous section AODV is used to propose energy efficient routing by extending its functionality. In literature number of routing

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protocols has been proposed to extend AODV to achieve network lifetime, reliability & energy efficiency network. e.g.[17-26]. Majorly these protocols divided into three sub categories

1. Protocols based on reliable route achieve reliability of link
2. Protocols based on energy-efficient routes
3. Protocols based on routes with higher energy nodes to improve network lifetime

Table 2 shows the comparison of AODV base energy Efficient Routing protocols. AODV based Energy aware Routing for MANETs[17]: - Energy efficiency in network is achieved by integrating battery capacity and propagation power loss, cot function is deduced based on this. AODV RREQ packet destination sequence number field is replaced by cost function. Low battery of node is indicated with alert mechanism to improve the routing updates. Optimized cost function is used to combines local optimization of neighbouring nodes and global optimization of end-to-end routing nodes. This work improves the network lifetime with not effecting network throughput. MELAODV [18]:-This work improves the network life time by calculating a route with maximum remaining energy node path. It selects the path of highest energy route. It calculates the energy consumption during the packet transmission by multiplying transmit Power with transmit time. EE-AODV [19]: - It improves the control messages handling process of AODV routing protocol to save the energy of nodes. It define a threshold level of energy if the node satisfy that level only consider an intermediary node in order to improve the network lifetime. If nodes in a network not satisfied the threshold level must not be considered in routing path, until no another path is exist. MECB-AODV [20]: - In this work network connectivity is maintained by remaining energy of intermediate nodes. Same as EE-AODV, this work is depends on local decisions about intermediary nodes to provide the prolong network connectivity. In route discovery process all nodes uses local information of its own battery to declare whether to participate or not in routing process. Hence, a node with battery is less can preserve its remaining energy by not giving replay packets to route request. This is local approach mechanism, in which node take the self decision based on its own energy state. Small changes to AODV mechanism can greatly balance the energy consumption in routing and also increases the network lifetime. AODV based Energy Efficient Routing [21]: - Work integrates the two metrics remaining energy & transmission power capacity into route selection process so as to extend the network lifetime & energy consumption across the node is reduced.

Table 2 Comparison Of Routing Protocol Based On Energy Aware In Manet

Routing Protocol	Characteristic	Objective	Overhead	Possibility of nodes to become bottle neck
AODV based Energy aware Routing	Optimized cost function, alert mechanism	Network Lifetime	May be possibility of node depletion	**Yes**
MELAODV	maximum remaining energy node path	Network Lifetime	Not a least cost energy path	**Yes**
EE-AODV	threshold level of energy	Network Lifetime	Not a least cost energy path	**Yes**
EE-AODV [23]	local decisions based on threshold level of energy	Network Lifetime	Not a least cost energy path	**Yes**
AODV based Energy Efficient Routing	Remaining energy& transmission power	Minimize consumption of energy	May be possibility of node depletion	**Yes**
Routing based on energy drain rate [24]	Energy Drain rate	Energy efficiency	Not a least cost energy path	**No**

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None of the above protocols consider the possibility of intermediate node to become bottlenecks in the network. When the residual energy or node satisfy threshold level of energy is the metric to calculate the routing path from source to destination, one cannot assure the reliable route for the heavy traffic, then the rout become congested and the intermediate nodes present in that roué become bottleneck. If a node is accepting the heavy traffic because of its current energy, in that case node will drop the packets due to its buffer size and processing capacity and also node will lose its energy instantly. As depicted in figure .4, if the choice of the routing path is based only on the minimum hop number or residual energy or threshold level of energy then intermediary node 4 becomes a bottleneck node and the whole network may be congested.

In this work we develop a routing mechanism aims to enhance the network life time with link stability. In order to avoid the node to become bottleneck and it to die due to its energy, we are considering a network topology with the impact of multiple transmissions through the energy constrained intermediate node. Our work is based on prior work [27] and we use the novel metric ***current processing state*** with respect to energy and its input buffer traffic to decide the routing path between source to destination. **Energy aware reactive routing mechanism for MANETs**

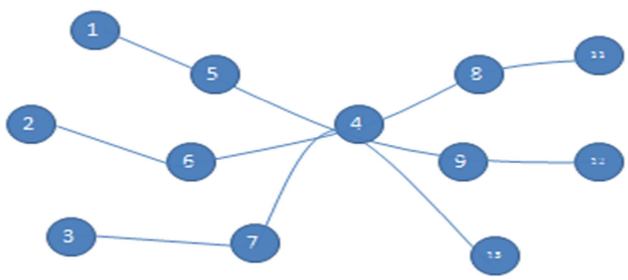

Figure 4. Scenario Of Node To Become Bottleneck

2 ***Current processing state" of node* 'CPS'**

We proposed a novel mechanism to find the energy efficient route from source to destination for MANETs known as "*Energy Aware Proactive Routing for MANEts Based on Knapsack Algorithm*", In which route is selected based on metric "*current processing state" of node* in terms of energy and its input buffer traffic to achieve lifetime of network and link reliability. Major contributions of proposed work as fallows

1. Requirement of energy to process Kbit of packets
2. *Current processing state" of node* in terms of energy & its input buffer traffic say 'CPS'
3. Node's Priority by defining threshold values
4. Selection of routing path depending on node's priority

Node participates in routing only when it satisfied the threshold condition. The metric Node's optimized of information processing capacity with respect to residual energy and current traffic is used to avoid the node to become bottleneck. And model is extension of AODV routing protocol and it reactively select the route ,instead of hop count as it will use node's priority as metric to find optimistic route.

In order to calculate the ***current processing state" of node*** with respect to energy and its input buffer traffic say 'CPS'. Let assume a node 'N_i' with energy 'E_i' Joules, 'B' Kbytes buffer and it need to process the 'n' Kbytes of packets from it in present state. Consider a packet 'K_i' requires a '$E(K_i)$' energy & $B(K_i)$ buffer space of node to process through it. In order to calculate 'CPS' need to compute subset of packets such a way that below condition should be satisfied

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1. All Communicating packets have combined with size (bytes) at most of 'E_i' Joules.
2. Intermediate node must process as much as packets through it in a current condition
3. Part of the packet should not be process.

The energy require by node to process the packet 'K_i' requires a '$E(K_i)$' within Multi-hop wireless ad hoc network is computed by below equation

$$E(K_i) = T(K_i) + R(K_i) + D(K_i)$$

Where, $T(K_i)$, $R(K_i)$, $D(K_i)$ are sending energy, receiving energy & processing energies of node to send, receive, process $K_i$kbps packets. To compute the *current processing state" of node* with respect to energy and its input buffer traffic say 'CPS'. The communication packets need to process through node 'N_i' is K_iKbytes {i=1,2,3,…}, we are considering the condition that the packets must completely processed , & it is not possible to process partial packets (either nothing or complete). We consider n- Topples with positive values as given below,

1. Number of communication packets need to process from given node 'N_i' is K_i Kbytes {i=1,2,3,…},
2. The energy require by node to process the packet 'K_i' requires a '$E(K_i)$'

In order to process as many as packets from node in an current condition is to try all 2n possible subsets of $T(K_i)$ {i=1,2,3,…}. Now we apply Knapsack algorithm to obtain optimal output. Knapsack design two dimensional array as fallows

$$S\,[0\ldots..n,\ 0\ldots.E_i] \quad 1 \le i \le n \quad \forall \& 0 \le E(K_i) \le E_i$$

Such that $S[T(K_i), E_i]$ will process maximum packets of any subset of flows with K_i kbits of data {I = 1,2,3…} of energy required to process at most '$E(K_i)$'.

Where entries of array $S[n, E_i]$ will consist of maximum packets process from given number of packets through a given node. Array should not fallow two conditions

$S[0, E(K_i)]=0 \qquad 0 \le E(K_i) \le E_i$
no packet process through the node

$S[i, E(K_i)]= \forall -\infty E(K_i)< 0$,illegal condition.

Optimization as below

$S[i,E(K_i)]=\max(S[i-1,E(K_i)], Si+S[i-1,E(K)-E(K_i)]) \ \forall \quad 1\le I \le n$ and $0 \le E(K_i) \le E_i$

The algorithm to compute, ***current processing state" of node*** is given in figure 5. Our protocol is based on AODV but instead of hop count as route selection metric we are using 'CPS' of node as a metric to select a route. Every node in a network needs to compute the value of 'CPS'. Rest of the mechanism is fallows the AODV protocol.

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Step 1 (Loop, initialization)

for $E(K_i) \leftarrow o$ to E_i till total energy of node

Set $S[0, E(K_i)] \leftarrow 0$

Step 2 (Loop)

for i $\leftarrow 1$ to n (set the number of packets)

Set $S[i, 0] \leftarrow 0$

Step 3 (Loop checking the packet to process or not)

for i $\leftarrow 1$ to n

for $E(K_i) \leftarrow o$ to E_i

if $(E(K_i) \leq E_i)$ **(then the packet can be process by node)**

if $(K_i + S[i-1, E(K_i) - E_i] > S[i-1, E_i])$ then

set $S[i, E_i] \leftarrow K_i + S[i-1, E(K_i) - E_i$

else

set $S[i, E_i] \leftarrow S[i-1, E_i]$

else set $S[i, E_i] \leftarrow S[i-1, E_i]$ ■ $(E(K_i) > E_i)$

Step 4(Finished)

Exit

Fig5 Algorithm For Calculating

3 PERFORMANCE EVALUATION

NS 2 is used to calculate the performance of “proposed model” and compare it with other AODV based energy efficient routing protocols in same network environment in terms of network lifetime and throughput. The first aim of our simulation study is to evaluate and check the ability of DSDV and AODV routing protocols to react on different traffic conditions of ad-hoc network like changes in network topology with IEEE 802.11 standard, and second aim is to compare the performance metric based on different network conditions like number of hop count, movement and pause time and variable radio communication area of nodes. Life time of network considered as the time that the first node failure occurs due to exhausting of battery. We considered a fixed radio transmission range for every node is 250m. Total 100 mobile nodes are randomly distributed across 1000 × 1000 m. All the nodes containing IEEE 802.11 NIC & channel capacity of 2 Mbps & random waypoint mobility model with speed of 0 to 20 m/s & 30s pastime. The energy of node is set to 10j with transmission power is 0.65 W & receiving power is 0.35 W. Simulation time duration is 600 seconds. Source node generates CBR traffic with data packet size of 512 bytes. Table 3 shows the Simulation Parameters used in our performance evaluation

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Table 3. Simulation Parameters

Network Parameters	Values
Simulation Time	300 Seconds
Number of Nodes	10 to 100
Link Layer (LL)Type	Logical Link (LL)
Medium access control layer Type	802.11
Radio Propagation Type	Two-Ray Ground
Queue Type	Drop-Tail
initial energy of node	15J
transmission range	250 meters
Antenna	Omni Antenna
Transmission and receiving power	650mW & 350mW
Routing	AODV, DSR
Traffic	CBR, FTP
Area of Network	500m x 500m
Mobility Type	Random Way Propagation

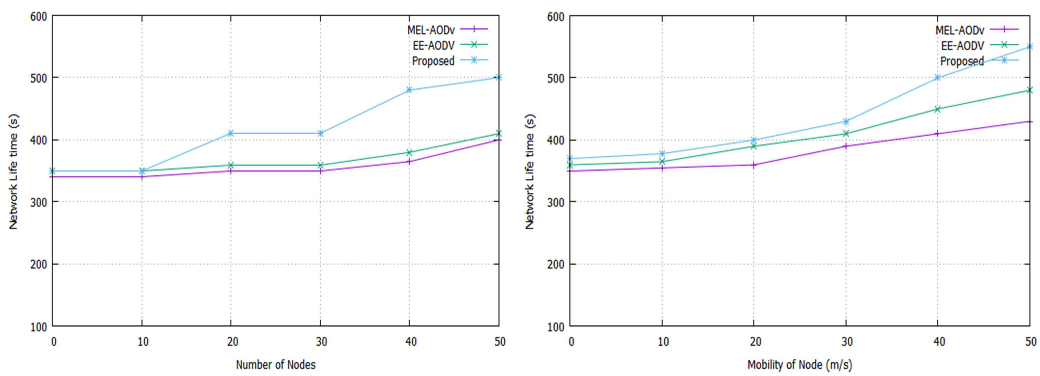

Figure 6. Lifetime Of Network Vs Number Of Nodes & Mobility

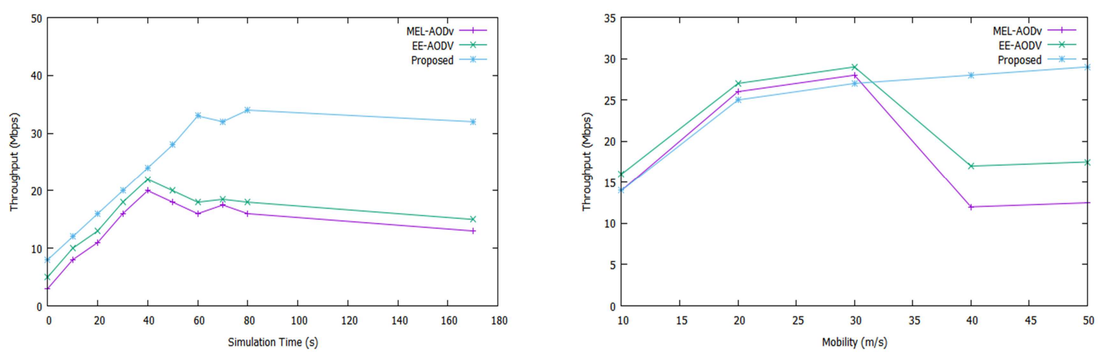

Figure 7. Throughput Vs Simulation Time & Mobility

In Existing work, network topology can become intermediate bottleneck node, which need to forwards the information from multiple sources, as they are considering the routing path which having high energy or it contains high energy nodes. Performance is degrades at this situation due to insufficient capacity to handle the traffic by intermediate bottleneck node. Thus in our approach we are considering the routing path which does not has intermediate bottleneck node by calculating the

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current capacity of node in terms of traffic and energy. Thus results shown in figure 6 and 7 clearly show the better performance of our proposed work with respect to network life time and throughput. In Figure 7, at simulation time 40 seconds intermediate bottleneck node occurs and performance of existing protocols degrades.

4 CONCLUSION & FUTURE WORK

In our work, we firstly discussed about performance comparison of reactive & pro-active routing protocols designed for MANETs, We evaluate the performance by considering various scenarios and compare the results with static, dynamic, multi hop, varying traffic and scalable networks. We conclude that AODV is best suited protocol to improve the energy efficiency in dynamic network environment. Thus we developed a reactive energy aware routing protocol to solve the problem of "intermediate bottleneck node" by considering node's current capacity in terms of current energy & traffic. Simulation results shows outperform of proposed work with respect to network life time & throughput in comparison with energy aware AODV routing protocols.

However our work is useful in multi hop network MANETs with dense traffic environment. In our future work we intend to implement proposed routing protocol in sensor networks, as energy is very vital characteristic in this environment

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