Enhancing Energy Efficiency of Routing Protocol through Cross Layer Interactions in MANET

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***Abstract*— Energy conservation is important for mobile ad-hoc networks where devices are expected to work for longer periods of time without the need for charging their batteries. High probability of disappointment in Ad-Hoc networks is due to energy-tired nodes, if some nodes expire early due to lack of energy, they cannot transfer the data with each other. Therefore, excessive energy consumption of nodes energy should be prevented. Energy conservation can be done at different layers using many existing energy protocols, to ensure a long-lived network of wireless communicating nodes, there is a need of an intelligent routing protocol that can minimize overhead and ensure the use of minimum energy routes and a MAC protocol that is able to improve energy efficiency by minimizing congestions and reducing loss of packets**

This paper presents a solution to energy conservation by a cross layered approach. This can be achieved by applying congestion control algorithm for the MAC layer and then finding the maximum residual energy route in the network layer for packet transfer. To ensure an efficient cross layer interaction, issues related to efficient channel access, quality-of-service (QoS) support and congestion control are addressed with an energy efficient MAC protocol that adjusts with the enhancements in the performance of the network layer protocol.

Keyword- Energy Conservation, Cross Layer Interactions, AODV, Reno, residual energy, hop count, congestion.

I. INTRODUCTION

Mobile Ad hoc networks (MANETs) allows portable mobile devices to establish communication path without having any central infrastructure. Since there is no central infrastructure and the mobile devices are moving randomly, gives rise to various kinds of issues, such as routing and security. Routing is one of the key issues in MANETs because of highly dynamic and distributed nature of nodes. Especially energy efficient routing is most important due to fact that all the nodes are battery powered. Failure of one node may affect the entire network. If a node runs out of energy the probability of network partitioning will be increased. Since every mobile node has limited power supply, energy has become an important resource for mobile ad-hoc networks and efficient communication between nodes depends on the network lifetime. To support energy-efficient communication, it is necessary to consider energy consumption at multiple layers in the protocol stack. In accordance to this, energy conservation techniques have been applied to different layers individually and the results showed measurable energy consumption at each layer but overall energy consumption was same.

As a better alternative to this, energy conservation with cross layer interactions has been proposed which will apply energy saving model to a layer and the performance of that layer will affect the routing layer thereby reducing the energy consumption at each layer and also at the overall cross layer communication. To achieve the goal, an enhanced energy model is proposed for energy conservation in mobile ad-hoc networks.

Initially, a slow-start, exponential increasing congestion window algorithm is applied to the MAC layer, which will efficiently balance energy consumption and delivery ratio by reducing the packet loss. The residual energy information will be used by the network layer where nodes with maximum residual energy will be discovered for energy efficient route discovery. Then, hop count information from the source node to destination node is received from the network layer, based on the obtained information remaining hop count ratio is calculated. This ratio information will be used by the MAC layer to give the priority to the packets with lesser hop count ratio to reduce packet delay. This model will also affect other performance metrics such as overall energy consumption, packet delivery ratio, average end-to-end delay and overall routing load.

II. RELATED WORKS

Implementation of a cross layer design allows network layer and MAC layer to communicate [1]. Two main ideas of energy saving routing algorithm for Ad hoc routing protocols were proposed, the first one is to send each packet with minimum energy consumption. The second is to maximize the network lifetime as much as possible. A new mechanism of energy-aware named EA_AODV was proposed [2]. Energy Entropy-based Multicast Routing Protocol in MAODV (EEMAODV) protocol was proposed to find the minimal nodal residual energy of each route in the process of selecting path by descending nodal residual energy [3]. PBMR is used for decision of routing forwarding should be based on each node's energy level. The ultimate goal of this approach was to achieve a better energy balance among mobile nodes, which eventually results in a longer lifetime and a stable routing of the topology [4].

Assuming that all nodes start with a finite amount of battery capacity, a new protocol was proposed, a new source-initiated (on demand) routing protocol for mobile Ad Hoc networks with that balances the traffic inside the network in order to increase the battery lifetime of the nodes and hence the overall useful life of the Ad Hoc network(EEAODV) [5]. An accurate analytical model was proposed to track the energy consumptions due to various factors, and a simple energy-efficient routing scheme PEER to improve the performance during path discovery and in mobility scenarios [6]. ED-DSR efficiently utilizes the network resources such as the intermediate node energy and load in order to balance traffic load. It ensures both timeliness and energy efficiency by avoiding low-power and busy intermediate node [7].

Here Slow-sTart Exponential and Linear Algorithm (STELA**)**, a novel battery saving mechanism which saves up to 70% energy compared with the algorithms employed by IEEE 802.11 while preventing the delivery performance from degrading significantly and consequently reducing the negative impact on user Quality of Experience (QoE) [8]. Less remaining hop More Opportunity (LEMO) algorithm was proposed to improve the packet delivery ratio and fairness among flows for multi-hop ad hoc networks through cross-layer interaction between MAC and the routing layer [9].

III. PROPOSED CROSS LAYERED APPROACH

Energy efficiency is a major challenge in Mobile Ad-hoc Networks because of the following reasons. Firstly, due to the absence of an infrastructure, mobile nodes in an ad hoc net-work must act as routers and participate in the process of forwarding packets which will increase traffic loads. Second, energy-efficient design needs to consider the trade-offs between different network performance criteria and finally because there is no centralized control for nodes in MANETs. In cooperation to this, energy efficiency models have been proposed and applied to each layer individually but a strict layered design is not flexible enough to cope with the dynamics of the mobile ad hoc networks because by doing so, performance of each layer is enhanced individually but does not show effective results in overall network performance.

To overcome the problems facing in the existing system, cross layer design is proposed as an emerging solution to support flexible layer approaches in MANETs. In our proposed solution, an energy conservative model based on slow start, exponential increase of congestion window is integrated with the MAC layer where, the congestion increases exponentially for every acknowledgement received and for every Round Trip Time and once the threshold for congestion window is reached, congestion avoidance takes place and if packet loss occurs, fast recovery is done. Then, the residual energy of each node is calculated in the network layer and each node's residual energy is added to other nodes' residual energy, the maximum energy is compared and this goes on until the destination node is reached. This results in energy efficient route discovery with maximum residual energy and then the total hop and remaining hop count from the source node to destination node is received from the network layer, using this information the hop count ratio of remaining hops is calculated and based on the obtained ratio the packets to be forwarded are prioritized. The packets with lesser remaining hop ratio get more priority. Fig 1 shows the architecture of the proposed system with the detailed cross layer interaction between the MAC layer and the network layer.

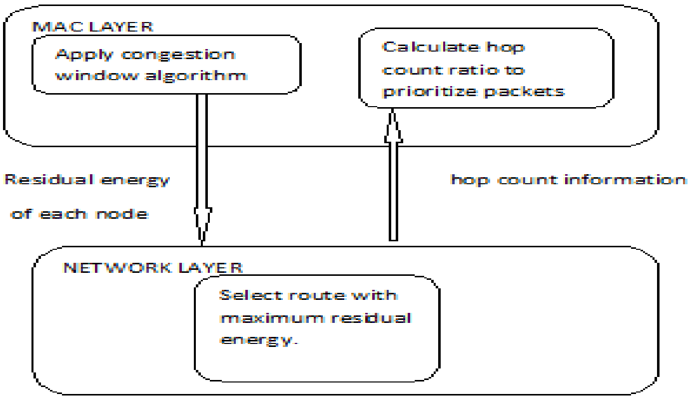

Fig. 1: Proposed Energy Conservation cross layerd approach

A. *Algorithm Steps of the Proposed work*

i. In the MAC layer, the congestion window algorithm is used to reduce congestions in the network.

ii. The congestion window value increases by one for every acknowledgement received and doubles every Round Trip Time

iii. If the threshold value for Congestion window(cwnd) is reached, then congestion avoidance takes place and if packet loss occurs fast recovery is done.

iv. Calculate the residual energy of all the nodes in the network.

v. Network layer identifies the nodes with maximum residual energy by summing the Nodes' residual energy with other nodes' until destination node is reached

$$\mathbf{C_R = \sum_{i=1}^{k-1} E_r^{\,i}(t)}$$

vi. Identify the energy efficient route, considering the route with maximum residual energy.

vii. The total hop count (HopT) and remaining hops to the destination HopRR information is obtained from the network layer.

viii. This information is used by the MAC layer to calculate the remaining hop ratio.

HopRR=HopR/HopT

ix. If the hop ratio is less than 0.5, the packet has traversed more hops and hence gets the priority to be forwarded to the destination.

x. If the hop ratio is more than 0.5, the packet has traversed fewer hops and hence does not get the priority to be forwarded.

IV. SIMULATION

The simulation of the proposed algorithm is done using the NS2 simulator. The proposed algorithm is implemented by applying cross layered approach between AODV protocol at the routing layer and IEEE 802.11 DCF at the MAC layer. In order to achieve this, the congestion window algorithm is applied to the MAC layer and then the residual energy information of each node is carried to the network layer where, the energy efficient route with maximum residual energy is established and then the information about the total number of hops between the source and the destination nodes, and the number of remaining hops from the forwarding node is collected from the routing layer and is sent to the MAC layer to calculate the remaining hop count ratio, based on which the packets are prioritized to be forwarded

V. RESULTS AND DISCUSSIONS

A. *Performance metrics*

The following metrics are compared:

- Energy consumption
  - The total amount of energy consumed in the network.
- Packet delivery ratio
  - The ratio of the data packets delivered at the destination to those generated by the traffic.

The experiment has been performed with different number of traffic scenarios with 11, 30 and 50 nodes respectively.

B. *Network Scenario and Simulation results*

- Fig 2 shows the simulation results of a network scenario with 11, 30 and 50 nodes respectively using the TCP traffic flow. The graph indicates the total energy utilized by the network for the normal AODV protocol-represented by red line, AODV protocol after applying congestion window algorithm-represented by green line and the optimized AODV protocol after energy efficient route discovery and the hop count ratio algorithm-represented by blue line in the graph.

  The results showed that the energy consumed by the optimized protocol has been reduced compared to the normal AODV protocol.

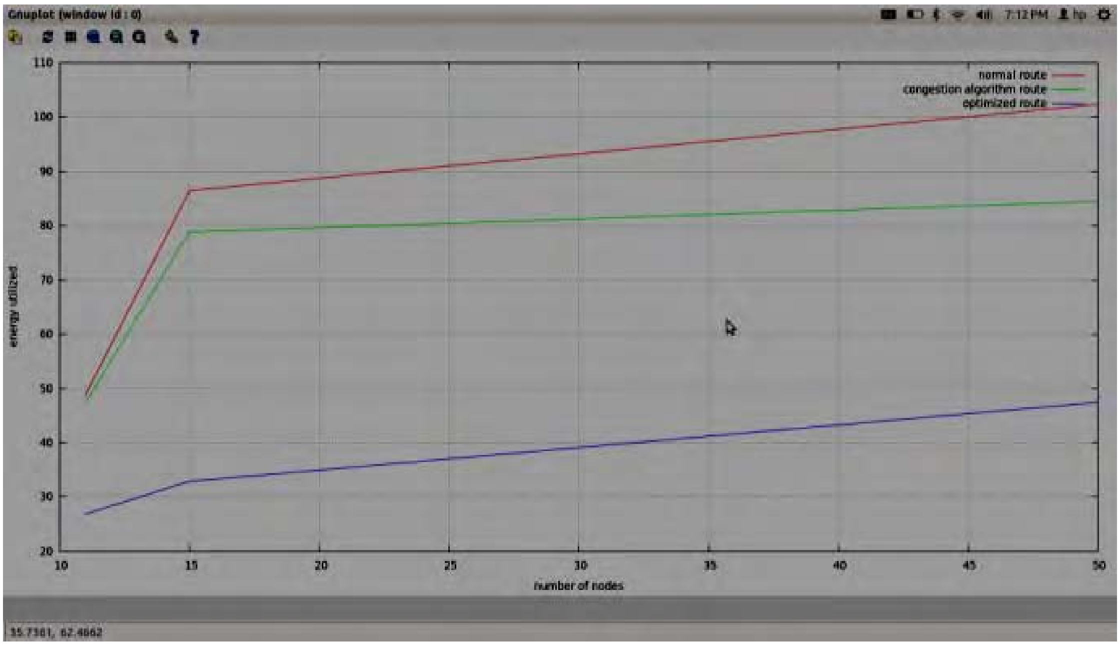

Fig 2: Simulation graph-1

- Fig 3 shows the simulation results of a network scenario with 11, 30 and 50 nodes respectively using the TCP traffic flow. The graph indicates the packet delivery ratio for the normal AODV protocol-represented by red line, AODV protocol after applying congestion window algorithm-represented by green line and the optimized AODV protocol after energy efficient route discovery and the hop count ratio algorithm-represented by blue line in the graph.

  The results showed that the packet delivery ratio obtained by the optimized protocol has increased compared to the normal AODV protocol.

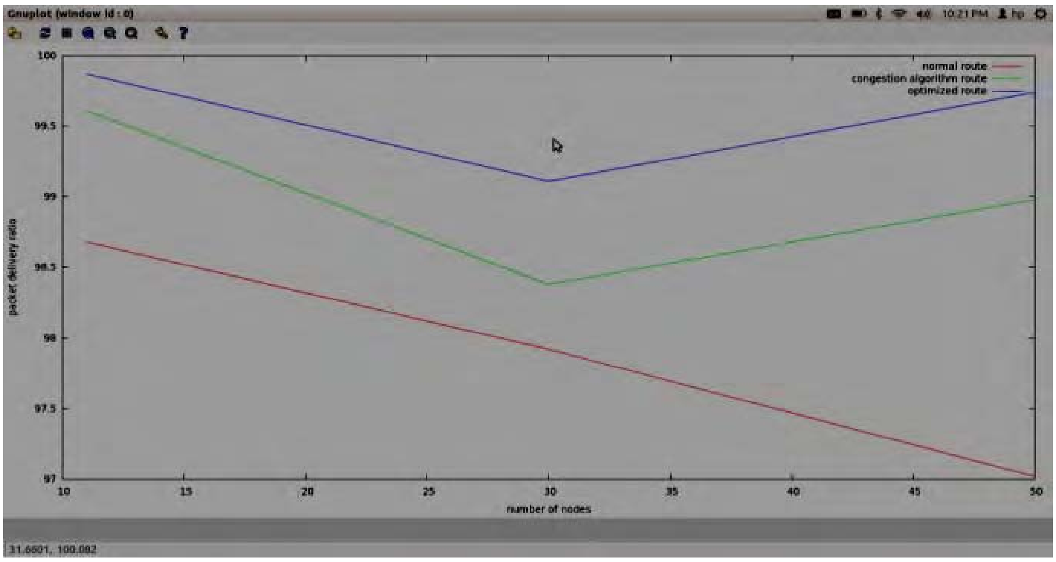

Fig 3: Simulation graph-2

- Fig 4 represents the residual energy in the network for 11 and 30 nodes respectively, the route with maximum residual energy is the optimal route. The green line in the graph indicates the normal route with AODV protocol and the red line indicates the optimal route selected with AODV protocol.

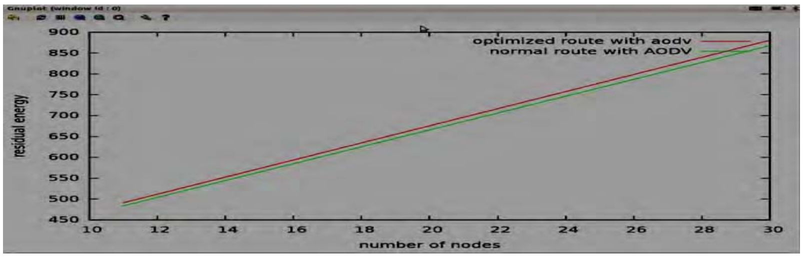

Fig.4: Simulation graph-3

The results show that the route selected with maximum residual energy nodes has maximum residual energy in the route compared to the normal route.

- *Fig 5* represents the packet delivery ratio in the network for 11 and 30 nodes respectively; the route with maximum packet delivery ratio is the optimal route. The green line in the graph indicates the normal route with AODV protocol and the red line indicates the optimal route selected with AODV protocol.

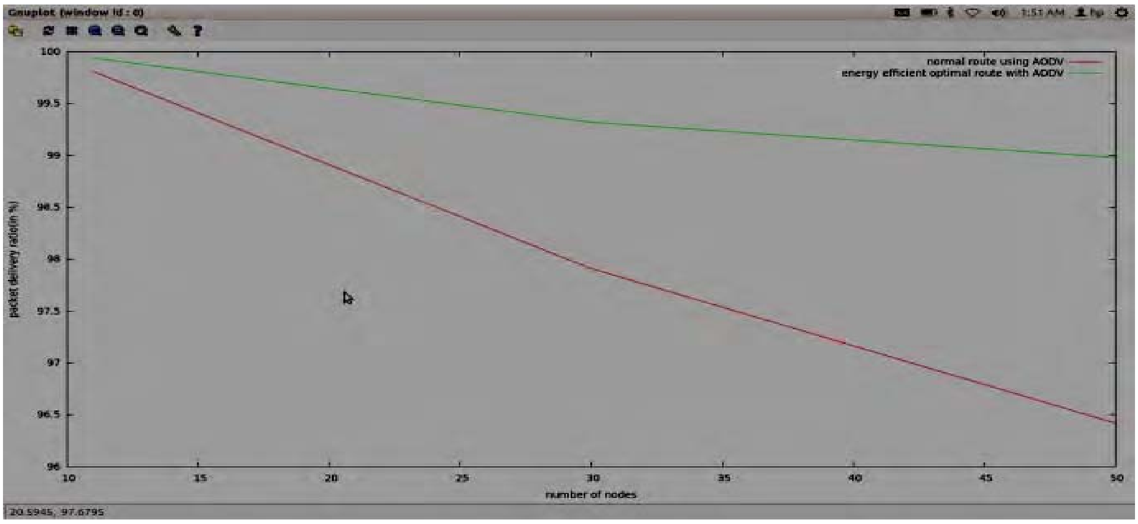

Fig. 5:Simulation graph-4

VI. CONCLUSION AND FUTURE WORK

In this research work, initially a congestion window algorithm is applied to the MAC layer, this algorithm reduces the congestions in the network and recovers the packet loss very efficiently. The algorithm affects the energy consumption, because when congestions are reduced in the network, packet loss is also reduced and hence the retransmission of packets is minimized, thus reducing the energy consumption. Secondly, an optimal path is selected for packet transfer. This is done by identifying the nodes with maximum residual energy and a route is established such that it has maximum energy remaining in all the nodes. The probability of packet loss will be less in such routes than compared to other routes, because if nodes have less residual energy the probability of slow transmission or system breakdown increases. Thus energy efficient route discovery is optimum and reduces packet loss and end-to-end packet delay and thereby reducing the overall network performance. Finally, remaining hop count ratio is used to prioritize the packet flow in the network. This is done in the MAC layer but the hop count information is obtained from the network layer. This reduced the packet delay, because packets have been forwarded priority based and this reduced the congestions and traffic load. These scenarios have been simulated and the results were obtained and compared.

Though energy consumption can be reduced by eliminating congestions in the network and using maximum residual energy routes to transfer a packet, still the energy issues need to be addressed from other views such as, when a node is in idle state i.e., when packet forwarding is not being performed or the node is waiting for an acknowledgement, the node consumes a lot of energy which can be eliminated. In such conditions, the node can be made sleep for a longer duration and wakes up periodically to check for any packets in the network. This reduces the network's energy consumption and thereby improves the overall throughput and increases the packet delivery ratio. Further, the energy conservation techniques should be implemented with cross layer design as the improved performance in a layer should positively affect the other layer and as different layers interact, the probability of improvement in the overall performance of the network will increase. These conservation techniques should be worked with different routing protocols and their performances can be compared which is left for future work.

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