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ENERGY AWARE ROUTING PROTOCOLS IN MANET A REVIEW

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Abstract: Mobile Ad Hoc Networks (MANETs) is a collection of multi-hop wireless mobile nodes that communicate with each other without centralized control or established infrastructure. The energy efficient routing may be the most important design criteria for MANETs, since mobile nodes are powered by batteries with limited capacity and the nodes in MANET are mobile. Energyefficiencydoesn'tmean only the less power consumption, it means increasing the time duration in which any network maintains certain performance level. So, power management becomes critical issue. The paper focuses on such energy efficient protocols especially Ad hoc On-Demand Distance Vector (AODV) Routing protocol and its energy efficient counterparts.

Ad hoc On-Demand Distance Vector (AODV) Routing protocol has been accepted itself as one of the distinguished and dominant routing protocol for Mobile Ad Hoc Networks (MANETs). From various performance analysis and results, it is shown that AODV has been an outstanding routing protocol that outperforms consistently than any other routing protocols. But it could not pervade the same place when the performance was considered in term of energy consumption at each node, energy consumption of the networks, energy consumption per successful packet transmission, and energy consumption of node due to different overhead. Because, AODV protocol does not take energy as a parameter into account at all. And as MANET is highly sensible towards the power related issues and energy consumption, as it is operated by the battery with the limited sources, needed to be used efficiently, so that the life time of the network can be prolonged and the performance can be enhanced. This paper presents a comprehensive summery of different energy efficient protocols that are based on the basic Mechanism of AODV.

Index Terms: Mobile Ad hoc networks, Routing protocols, Power management, AODV, DYMO, MANET, routing protocols, TORA, On Demand Routing.

I. INTRODUCTION

Power failure of a mobile node not only affects the node itself but also its ability to forward packets on behalf of others and thus the overall network lifetime. A mobile node consumes its battery energy not only when it actively sends or receives packets, but also when it stays idle listening to the wireless medium foranypossiblecommunication requests from other nodes. Thus, energy-efficient routing protocols minimize either the active communication energy required to transmit and receive data packets or the energy during inactive periods [1]. The transmission power control approach can be extended to determine the optimal routing path that minimizes the total transmission energy required to deliver data packets to the destination [2]. For protocols that belong to the latter category, each node can save the inactivity energy by switching its mode of operation into sleep/power-down mode or simply turns it off when there is no data to transmit or receive. This leads to considerable energy savings, especially when the network environment is characterized with low duty cycle of communication activities. However, it requires a well-designed routing protocol to guarantee data delivery even if most of the nodes sleep and do not forward packets for other nodes. Another important approach to optimizing active communication energy is load distribution approach [3]. While the primary focus of the above two approaches is to minimize energy consumption of individual nodes, the main goal of the load distribution method is to balance the energy usage among the nodes and to maximize the network lifetime by avoiding over-utilized nodes when selecting a routing path. The paper classifies numerous energy efficient routing mechanisms proposed for MANETs. The main focus is on motivation, research challenges, recent development and modifications in this widely used field and also see how conventional routing protocols are modified to make them as energy efficient. While it is not clear whether any particular algorithm or a class of algorithms is the best for all scenarios, each protocol has definite advantages/disadvantages and is well-suited for certain situations. However, it is possible to combine and integrate the existing solutions to offer a more energy-efficient routing mechanism.

Mobile ad-hoc networks (MANETs) are wireless networks with no fixed infrastructure [Royer and Toh 1999]. MANET nodes can either be hosts or can act as routers when the two end-points are not directly within their radio range. A critical issue for MANETs is that nodes are normally power constrained [Djenouri and Badache 2006]. Available battery technology is not growing fast enough to meet this constraint. It is via routing and routing protocols that we can possibly alleviate this constraint. Extensive research in routing protocols for MANETs has been carried out, with particular emphasis being placed on reactive routing protocols as opposed to proactive ones at saving energy [Gikaru 2004].

Among the energy-efficient routing protocols, AODV has been found to be very useful especially in developing new power-aware routing protocols.

II. CLASSIFICATIONOF ROUTING PROTOCOLS

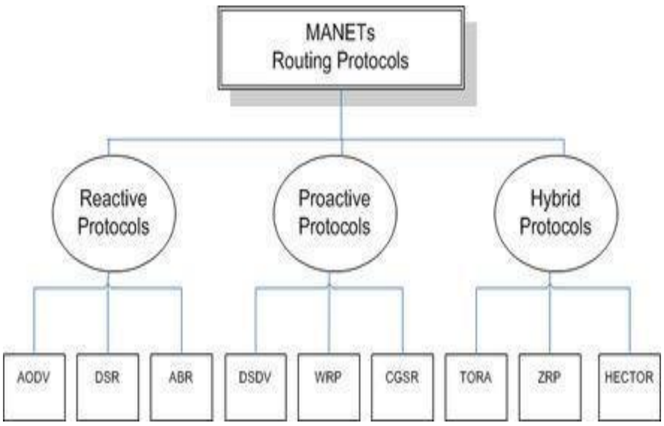

Fig.1: Routing protocols in MANET

A. Proactive/Table Driven routing protocols

These types of protocols are called table driven protocols in which, the route to all the nodes is maintained in routing table. Packets are transferred over the predefined route specified in the routing table. In this scheme, the packet forwarding is done faster but the routing overhead is greater because all the routes have to be defined before transferring the packets. Proactive protocols have lower latency because all the routes are maintained at all the times. E.g. are DSDV, Wireless Routing Protocol and OptimizedLinkStateRouting,TBRPF[4].Thisarticledoes notcoverallthesetabledrivenprotocolsasitisfocusedonDSRanddifferent modifications made on DSRprotocols.

B. Reactive/On Demand routing protocols

It is also called on demand routing. It is more efficient than proactive routing and most of the current work and modifications have been done in this type of routing for making it more and more better. The main idea behind this type of routing is to find a route between a source and destination whenever that route is needed whereas in proactive protocols we were maintaining all routes without regarding its state of use. So in reactive protocols we don’t need to bother about the routes which are not being used currently. This type of routing is on demand.

E.g. are Ad-hoc On Demand Distance Vector (AODV), Dynamic Source Routing(DSR) [5].

C. Hybrid Routing

Hybrid protocols are the combinations of reactive and proactive protocols and takes advantages of these two protocols and as a result, routes are found quickly in the routing zone. E.g. ZRP (Zone Routing Protocol), Hazy Sighted Link State.

III. ENERGY EFFICIENT ROUTING PROTOCOLS

The energy efficient routing protocols [6, 11] play a significant role in mobile ad hoc networks as the nodes are dynamic in nature and each node can participate in routing the data packets. In such scenario, efficient routing protocols are needed for Ad Hoc networks, especially when there are no routers, no base stations and no fixed infrastructure. So establishing the correct and efficient routes between the a source and destination is not the ultimate aim of any routing protocols, rather to keep the networks functioning as much as possible with less battery consumption at each node, should also be the objective of any routing protocols.

These goals can be accomplished by minimizing mobile node’s energy during both the active as well as inactive communications. Active communication is when all the nodes of the route are participating in receiving and forwarding of data. Minimizing the energy during active communication is possible through two different approaches:

a) Transmission power Control
b) Load distribution

In an inactive communication the nodes are idle i.e. neither forwarding any data packets nor receiving any data packets. In such situation, to minimize the energy consumption Sleep/Power-down approach is used. We will not discuss about the power consumption during inactive communication in the network. There are many energy matrices used for calculating the power consumption caused by different reasons. The energy few energy related metrics are used. These metrics are helpful while determining energy efficient routing path instead of considering shortest path like in the traditional DSR protocol use. These metrics are:

a) Energy consumed per packet
b) Time to network partition
c) Variation in node power level
d) Cost per packet
e) Maximum node cost

By using these metrics we can determine the overall energy consumption for delivering a packet, which is known as Link cost. In other word, link cost is the transmission energy over the link. Basically the efficient energy protocol selects the minimal power path depends which minimizes the sum of the link cost along the path.

A. Transmission Power Control Approach

We assume that a node’s radio transmission power [13, 14] is controllable, if its direct communication range as well as the number of its intermediate neighbors is also adjustable. As the transmission power increases, the transmission range also increases and it reduces the number of hop count to the destination. Weaker transmission makes topology sparse and it may result more network partition and high end to end delay.

So it is desirable to have perfect transmission range between any pairs of nodes, so that less power consumption will occur.

And it is possible when the transmission power can be adjustable according to the requirement of the receiver. So, instead of having high or low transmission power between the pair of nodes let the transmission power be set in such a way that any pair of nodes just reachable to each other. It will not only save the energy of battery but also reduces the interference and congestion in the networks.

B. Load Distribution Approach

The main objective of load distribution approach [16] is to select a route in such a way that the underutilized nodes will come in play rather than the shortest route. Due to the proper load distribution among the node, there is high balance in energy usage of all nodes. This approach certainly do not provide lowest energy route but surely prevent certain nodes from being overloaded and contributes towards longer network life time of the node.

C. Sleep/Power-down Approach

This approach is used during inactive communication. When any node is not receiving or transmitting any packets to other node, then it is desirable to put the subsystem/hardware into the sleep state or simply turn it off to save energy.

IV. AD HOC ON-DEMAND DISTANCE VECTOR PROTOCOLOVERVIEW

Wireless mobile ad hoc networksare characterized as networks without any physical connections. In these networks there is no fixed topology due to the mobility of nodes, interference, multipath propagation and path loss. Hence a dynamic routing protocol is needed for these networks to function properly [6]. Many routing protocols have been developed for accomplishing this task. The widely used routing protocols for MANETs are DSDV (Destination Sequenced Distance Vector), DSR (Dynamic Source Routing) and AODV [7].

In 1994, Charles Perkins [8] presented DSDV, which is a proactive routing protocol. It is a modification of Bellman Ford mechanism. In this protocol, source node always has a path to destination in the form of route table at all times i.e. paths are available the moment they are needed. DSDV advertises periodic and event triggered advertisements throughout the network whenever there is a change in topology. Each node changes its sequence number after receiving updates. The node having greatest sequence number is chosen. Each node is having IP address of source and destination, current sequence number and hop count in its route table. The node removes stale entries from route table to guarantee loop problem. System wide updates consume some amount of battery and bandwidth, even if the network is idle. So, DSDV is not suitable for highly dynamic networks.

In 1996, David Johnson and David Maltz [9] proposed DSR which is a reactive routing protocol. Unlike DSDV, DSR starts path finding process only when there is a demand. Source routes are carried out in each data packet. Two mechanisms are involved i.e. route discovery and maintenance.

In the early 2000s, researchers focused on the development of basic functions or services of the AODV protocol, such as shared channel, route discovery, and dynamic nodes. The purpose of their studies was to manage an ad hoc network topology that always change and answer the problem of disconnected route (route error) caused by the level of mobility [10].

In 2001, C. E. Perkins, E. M. Royer and S. Das [11] proposed Ad hoc On-Demand Distance Vector (AODV) routing protocol which functions similar to DSR protocol. But, instead of carrying out source routes in each packet as in DSR, AODV maintains route table entries at intermediate nodes. AODV also maintains destination sequence number to avoid loop problem. AODV works efficiently for large number of nodes which is not the case for DSDV.

This paper tells that, reducing power consumption and efficient battery life of nodes in an ad hoc network requires an integrated power control and routing strategy. The power control is achieved by new route selection mechanisms for MANET routing protocols. In 2005, K. Murugan and S. Shanmugavel [12] proposed Energy Based Time Delay Routing (EBTDR) and Highest Energy Routing (HER).

These algorithms try to increase the operational lifetime of an ad hoc network by implementing a couple of modifications to the basic DSR protocol and making it energy efficient in routing packets. The modification in EBTDR is such that if the nodes' remaining energy is less, then packets are forwarded after some time i.e. delay is introduced. If nodes' remaining energy is high then packets are forwarded immediately i.e. there is no concern of delay. In HER, the route selection is based on the energy drain rate information in the route request packet. It is observed from the simulation results that the proposed algorithms increase the lifetime of mobile ad hoc networks, at the expense of system complexity and realization.

In 2008, Thriveni and et al. [13] proposed an algorithm to improve the flooding performance of an Ad Hoc on Demand Distance Vector (AODV) routing protocol called, Probabilistic Mean Energy Flooding (PMEF) which periodically performs an averaging. As the word Mean Energy is there, algorithm calculates average energy say Eavg. Remaining energy is also calculated called Er. Route selection depends on the probability which is drawn on the basis of difference between residual energy Er and mean energy Eavg. This algorithm is used in route discovery process to make a rebroadcast decision by the node. If, nodes does not have sufficient energy, then rebroadcasting of packet is not done. As compared to the existing AODV, proposed schemes in forwarding a route request are more effective in reducing the flooding overhead and increase the network lifetime and throughput thereby decreasing the network latency.

In 2009, Zhang Jianwu, Zou Jingyuan and Zhao Qi [14], proposed modifications to improve the broadcasting mechanism of AODV protocol. They presented an improved mobile ad hoc network on demand routing protocol which is based on AODV. It controls the broadcasting of RREQ information. This protocol analyzes the lifetime of node, when implementing routing discovery, and avoiding the unnecessary information sending efficiently. By comparing AODV with OAODV in the same scenario, the new protocol is much better than AODV in terms of packet delivery ratio as well as routing load.

In 2011, Sunil Taneja and et al. [15] proposed a scheme that takes into consideration power status of each and every node in the topology and further ensures the fast selection of routes with minimal efforts and faster recovery. Battery strength of nodes is divided into three states namely danger state, critical state and active state. The nodes which are in active state participate in route selection. The results have been derived by carrying out experiments over network simulator NS-2. The performance evaluation of new AODV and existing AODV has been done on the basis of packet delivery ratio and exhausted nodes. The proposed scheme in new AODV works on a reactive approach and utilizes alternate paths by satisfying a set of energy based criteria. This scheme can be incorporated into any ad hoc on demand routing protocol to reduce frequent route discoveries. Alternate routes are utilized only when data cannot be delivered through the primary route. Simulation results indicate that the proposed scheme provides robustness to mobility and enhances protocol performance. Average increases in terms of packet delivery ratio for different network scenarios.

V. AODV OPERATION

This section describes the scenarios under which nodes generate Route Request (RREQ), Route Reply (RREP) and Route Error (RERR) messages.

A. AODV Route Discovery

When source node wants to communicate with destination and if path is not available to destination then source floods or broadcasts RREQ i.e. request packet to all its neighbours in the network. This RREQ message contains source and destination node's IP address, sequence number of destination, its current sequence number, hop count and RREQ ID. RREQ ID is monotonically increasing number. It gets incremented after each node initiates new RREQ. Figure 1 illustrates this flooding procedure [16].

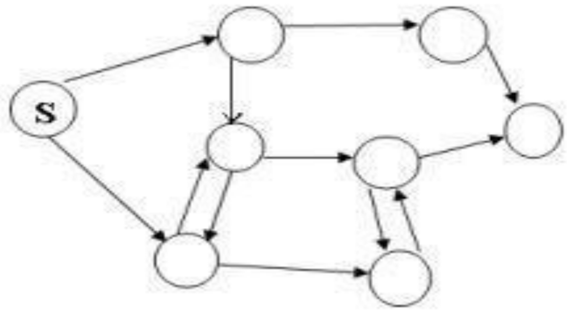

Fig. 2: RREQ Broadcast

When intermediate node receives RREQ, they create reverse link to previous node. They first of all check whether, valid route to destination is present or not. If, valid route is present then another condition must hold i.e intermediate node's sequence number should be at least as great as destination sequence number in RREQ packet. If both conditions hold, then that node generates RREP i.e. reply packet. If valid route is not present then RREQ is further forwarded. As RREQ is forwarded, hop count is incremented. While sending RREQ, intermediate nodes start a timer. If reply doesn't come within that time means, there is no more active route or link failure has occurred [11].

RREP contains IP address of source as well as destination, and destination sequence number. Once the node creates the forward route entry, it forwards the RREP to the destination node. The RREP is thus forwarded hop by hop to the source node, as indicated in Figure 2. Once the source receives the RREP, it can utilize the path for the transmission of data packets [4].

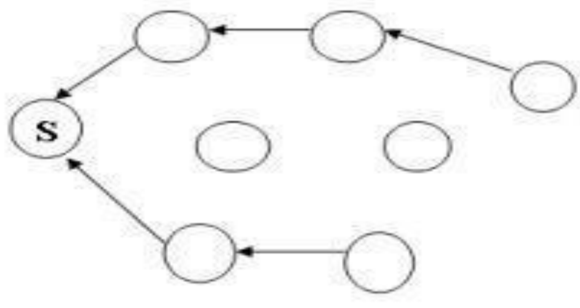

Fig. 3: RREP Propagation

B. AODV Route Maintenance

As MANET is dynamic i.e. mobility and topology of nodes always change, link break occurs. When path breaks, both the nodes inform their end nodes about link failure, who were using that path by sending RERR i.e. error message as illustrated in Figure 3. End nodes delete their entries from route table, as path is no longer useful. If source node still wants to communicate with destination, it reinitiates RREQ broadcasting or path finding process or repair broken link [11].

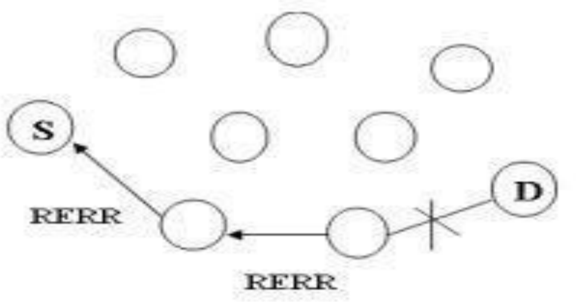

Fig. 4: RERR Message

VI. CHARACTERISTICS OF AODV

1) Unicast, Broadcast, and Multicast communication.
2) On-demand route establishment with small delay.
3) Multicast trees connecting group members maintained for lifetime of multicast group.
4) Link breakages in active routes efficiently repaired.
5) All routes are loop-free through use of sequence numbers.
6) Use of Sequence numbers to track accuracy of information.
7) Only keeps track of next hop for a route instead of the entire route.
8) Use of periodic HELLO messages to track neighbors [21].

VII. ADVANTAGES AND DISADVANTAGES OF AODV

The main advantage of AODV protocol is that routes are established on demand and destination sequence numbers are used to find the latest route to the destination. The connection setup delay is less. The HELLO messages supporting the routes maintenance are range limited, so they do not cause unnecessary overhead in the network.

One of the disadvantages of this protocol is that intermediate nodes can lead to inconsistent routes if the source sequence number is very old and the intermediate nodes have a higher but not the latest destination sequence number, thereby having stale entries. Also multiple RouteReply packets in response to a single RouteRequest packet can lead to heavy control overhead [21]. Another disadvantage of AODV is that the periodic beaconing leads to unnecessary bandwidth consumption.

VIII. LOCAL ENERGY-AWARE ROUTING BASED ON AODV (LEAR-AODV)

The main objective of LEARAODV (Local Energy-Aware Routing based on AODV) [2] is to balance energy consumption among all participating nodes. In their approach, each mobile node relies on local information about the remaining battery level to decide whether to participate in the selection process of a routing path or not. An energy-hungry node can conserve its battery power by not forwarding data packets on behalf of others. The decision-making process in LEAR-AODV is distributed to all relevant nodes.

In route discovery, each node determines whether or notto accept and forward the RREQ message depending on its remaining battery power (Er). When it is lower than a threshold value θ (Er≤θ), the RREQ is dropped; otherwise, the message is forwarded. The destination will receive a route request message only when all intermediate nodes along the route have enough battery levels.

Route maintenance is needed in two cases:

(i) When connect ion between some nodes are lost on the path due to mobility of nodes.

(ii) When the energy of some nodes on the path depleting quickly.

In first case, a new RREQ is sent out and entry in the route table corresponding to the node that has moved out of range is done. In second case node sends a route error RERR message back to the source node to initiate route discovery again.

IX. AN ENERGY EFFICIENT AD-HOC ON DEMAND ROUTING PROTOCOL FOR MOBILE AD-HOC NETWORK (EEAODR)

Energy Efficient Ad-hoc on demand Routing Protocol for Mobile Ad-hoc Network (EEAODR) [3]is an improvement over Ad hoc on-demand destination vector protocol that considers power level of each node in the network while calculating the route in order to increase lifetime of the network. The optimization function is used to select the energy efficient path among the all discovered by considering different factors such as nature of packets, their size and distance between nodes.

Cost = ı × time + μ × 1/minimum battery power of node in route + IJ× 1/ number of hops

The path that has minimum of the communication cost among all the possible paths between a source and destination node pair is chosen as the best path. In this case, every time we uses different path for sending packet which is not possible in the case of AODV which uses same path every time.

X. PAAOMDV

PAAODV protocol is an enhancement of AODV routing protocol, which implements power control information during route discovery. In PAAOMDV [5][6], each node should maintain an Energy Reservation Table (ERT) instead of the route cache in the common on-demand protocols. Each item in ERT is mapped to a route passing this node, and records the corresponding energy reserved. The entries of an item in ERT are Request ID, Source ID, Destination ID, Amount of Energy Reserved, Last Operation Time, Route, and their functions will be presented in detail below. PAAODV incorporates two mechanisms:

(i) Multiple power level route discovery

(ii) Link-by-link power control.

During route discovery, route request packets are used to find a route that is power efficient and route reply packets are used for link-by-link power transmit control. PAAODV employs several power levels during route discovery. The nodes attempt to find a route to the destination initially with low power levels. If it does not succeed, then the power level is increased. It continues until route discovery succeeds. Two power levels are used, i.e. one low and one high, are used.

XI. DYNAMIC SOURCE ROUTING (DSR)

Dynamic Source Routing (DSR) is a routing protocol for wireless mesh networks and is based on a method known as source routing. It is similar to AODV in that it forms a route on-demand when a transmitting computer requests one. Except that each intermediate node that broadcasts a route request packet adds its own address identifier to a list carried in the packet. The destination node generates a route reply message that includes the list of addresses received in the route request and transmits it back along this path to the source. Route maintenance in DSR is accomplished through the confirmations that nodes generate when they can verify that the next node successfully received a packet. These confirmations can be link-layer acknowledgements, passive acknowledgements or network-layer acknowledgements specified by the DSR protocol. However, it uses sourcerouting instead of relying on the routing table at each intermediate device. When a node is not able to verify the successful reception of a packet it tries to retransmit it. When a finite number of retransmissions fail, the node generates a route error message that specifies the problematic link, transmitting it to the source node. When a node requires a route to a destination, which it doesn't have in its route cache, it broadcasts a Route Request (RREQ) message, which is flooded throughout the network. The first RREQ message is a broadcast query on neighbors without flooding.

Each RREQ packet is uniquely identified by the initiator's address and the request id. A node processes a route request packet only if it has not already seen the packet and its address is not present in the route record of the packet. This minimizes the number of route requests propagated in the network. RREQ is replied by the destination node or an intermediate node, which knows the route, using the Route Reply (RREP) message. The return route for the RREP message may be one of the routes that exist in the route cache (if it exists) or a list reversal of the nodes in the RREQ packet if symmetrical routing is supported. In other cases the node may initiate it owns route discovery mechanism and piggyback the RREP packet onto it. Thus the route may be considered unidirectional or bidirectional. DSR doesn't enforce any use of periodic messages from the mobile hosts for maintenance of routes. Instead it uses two types of packets for route maintenance: Route Error (RERR) packets and ACKs. Whenever a node encounters fatal transmission errors so that the route becomes invalid, the source receives a RERR message. ACK packets are used to verify the correct operation of the route links. This also serves as a passive acknowledgement for the mobile node. DSR enables multiple routes to be learnt for a particular destination. DSR does not require any periodic update messages, thus avoiding wastage of bandwidth [1].

XII. DESTINATION-SEQUENCED DISTANCE-VECTOR ROUTING (DSDV)

Destination-Sequenced Distance-Vector Routing (DSDV) is a table-driven routing scheme for ad hoc mobile networks based on the Bellman-Ford algorithm. It eliminates route looping, increases convergence speed, and reduces control message overhead. I

n DSDV, each node maintains a next-hop table, which it exchanges with its neighbors. There are two types of next-hop table exchanges: periodic full-table broadcast and event-driven incremental updating. The relative frequency of the full-table broadcast and the incremental updating is determined by the node mobility. In each data packet sent during a next-hop table broadcast or incremental updating, the source node appends a sequence number. This sequence number is propagated by all nodes receiving the corresponding distance-vector updates, and is stored in the next-hop table entry of these nodes [6]. A node, after receiving a new next-hop table from its neighbor, updates its route to a destination only if the new sequence number is larger than the recorded one, or if the new sequence number is the same as the recorded one, but the new route is shorter. In order to further reduce the control message overhead, a settling time is estimated for each route. A node updates to its neighbors with a new route only if the settling time of the route has expired and the route remains optimal [3] [1].

XIII. CONCLUSION AND FUTURE WORK

This paper concludes that there is not a single protocol which can give the best performance in ad-hoc network. Performance of the protocol varies according to the variation in the network parameters, as we know that in ad-hoc network properties continuously vary. Sometimes the mobility of the node of the network is high while sometimes energy of the node is our prime concern. So, we will choose the protocol in such a way that which perform best for that particular type of network. That's why we have surveyed many types of conventional protocols and their modification which includes energy efficiency.

Energy efficiency is one of the main problems in a MANET, especially in designing a routing protocol. In this paper surveyed and classified conventional and energy efficient routing protocols. In many cases, it is complicated to compare them directly since each technique has a different objective with different assumptions and employs different means to achieve the objective. Our prime concern is energy efficiency and we have tried to discuss almost all possible approaches of energy efficient protocols.

In future work, we will introduce enhancement of energy efficient routing algorithm based on AODV by updating different parameters according to the workload and the node requirements in the network.

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