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# Energy Efficient Approaches towards Proactive Routing in MANET

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***Abstract: Mobile ad-hoc network (i.e. MANETs) is getting popularity in the field of wireless communication due to its distributive and infrastructure-less nature, self configuring nodes, support for mobility and dynamic topology, and multi-hop communication. Energy is one of the most important concerns as the nodes (devices) in MANETs are mobile and have limited battery power. Routing protocol in MANET need to be energy efficient to limit the power consumption for prolong the battery and network lifetime and to enhance throughput of the network. In this paper we have investigated different energy efficient variants of Optimized link state routing (i.e. OLSR) which is a proactive routing protocol. Different aspects of the routing protocols modified for energy efficiency are discussed in this paper and finally we suggest possible extensions to the previous works that may lead to better performance and more energy efficiency.***

***Keyword: MANET; OLSR; MPR; Energy Efficiency; QoS.***

## I. INTRODUCTION

Mobile ad-hoc networks are autonomous system of mobile hosts (nodes) connected by wireless links. Each device in a MANET is free to move independently in any direction and will therefore change its links to other devices frequently. Devices forward traffic on its own and hence also be a router. MANETs have unique characteristics which make them different from other networks [3-7]. These are: multi-hop communication, infrastructure-less, distributive, dynamically changing topology etc. Due to these features, MANETs have wide range of application in different field like-emergency search, disaster management, electronic class rooms, military operations, collaborative and distributed computing, sensor networks, conferences etc. [1].

The routing concept basically involves two activities: firstly, determining optimal routing paths and secondly, transferring the packets through the selected paths. Routing protocols in MANET can be categorized as Pro-active (table- driven) [18-20], Reactive (on-demand) [8-10], and Hybrid protocols [11-14]. The main difference between table-driven and on-demand routing protocols is regarding the routing information stored in the routing tables for every node. A network using an on-demand protocol will not maintain current routing information on all nodes for all times. Instead, such routing information is obtained on demand. Ad hoc On Demand Distance Vector (AODV) is example of on demand routing. Proactive routing protocol maintains correct routing information on all nodes in the network at all times. Destination-Sequenced Distance Vector routing protocol (DSDV) and the Optimized Link State Routing Protocol (OLSR) comes in this category. Hybrid routing protocols combine feature of both proactive and reactive routing. Zone Routing Protocol (ZRP) is a type of hybrid protocol [11].

Routing protocols affect energy consumption behavior of nodes in a network. Mobile nodes often consume their energy due to various actions such as transmitting packets, receiving packets, processing packets. Since mobile nodes in MANETs are supplied by battery with limited energy, energy efficiency is a serious problem that affects the overall system performance of MANETs [16][17].

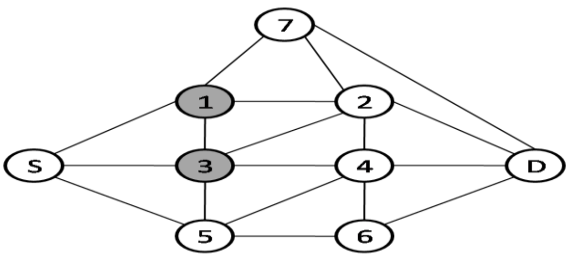
Taking energy into consideration, reactive protocols are more efficient as compare to proactive protocols [17]. Proactive protocols have more control overheads which takes lots of energy. This is because each node has to process control packet to maintain routing information. This routing information exchanged between nodes periodically. In case of reactive protocol, no information is maintained in advance. Packets are sending immediately as they arrive. Due to less control overheads less energy consumed by nodes [10]. In this paper we are dealing with energy consumption in OLSR, which is a kind of table driven i.e. proactive protocol.

OLSR employs an efficient link state packet forwarding mechanism called multipoint relaying (MPR) [2]. This protocol optimizes the pure link state routing protocol by reducing size of control packets and by reducing the number of links that are used for forwarding the link state packets. MPRs selection is a key process in OLSR. MPR nodes consumes large amount of energy in routing process as all the link state messages are broadcasted through them [18]. Various energy efficient techniques have been proposed which takes energy of MPR node into consideration. Here we are dealing with various energy efficient variants of OLSR with their limitation. The rest of paper is organized as follow: In Section II, the mechanisms behind OLSR routing protocol are explained, Section III reviews the related energy-efficient approaches, in Section IV, various energy efficient variants of traditional OLSR are described; Section V gives suggested approach to make OLSR energy efficient. Finally, Section VI concludes the paper with future work.

## II. OPTIMIZED LINK STATE ROUTING

OLSR is a table driven or proactive protocol which is developed for Mobile Ad-hoc Networks. It is a optimization over traditional link state routing [2]. The key concept used in the protocol is multipoint relays (MPR). Each node selects a set of its 1-hop neighbours as MPRs. MPRs are 1-hop neighbour selected such that all the 2-hop neighbours must be reachable through one of the MPRs. This technique substantially reduces the message overhead as compared to a classical flooding mechanism, where every node retransmits each message when it receives the first copy of the message. In OLSR, link state information is generated only by nodes elected as MPRs. Thus, a second optimization is achieved by minimizing the number of control messages flooded in the network. As a third optimization, an MPR node may chose to report only links between itself and its MPR selectors. Hence, as contrary to the classic link state algorithm, partial link state information is distributed in the network. The nodes which select MPRs are called MPR selectors. By selecting MPRs, MPR selector nodes announce reachability to the nodes in the network selected as MPRs [1].

OLSR is well suited to large and dense mobile networks, as the optimization achieved using the MPRs works well in this context. OLSR uses hop-by-hop routing, i.e., each node uses its local information to route packets. It is useful for networks, where the traffic is random and sporadic between a larger set of nodes rather than being almost exclusively between a small specific set of nodes [2]. Fig. (1) Shows the all 1-hop neighbour and 2-hop neighbour with selection of MPR nodes for source node S.




1-hop neighbours 1,3,5
2-hop neighbours 2,4,6,7
MPR node 1,3

Fig. 1 Network topology using OLSR as a routing protocol

*A. Types of Messages*

In OLSR, different control messages are used for maintain topology information and other routing information [2]. These are:

1. *HELLO Messages:* These are the messages sent by nodes to their 1-hop neighbours according to the Hello interval. Basically these messages are used for neighbour detection, link sensing and MPR signalling. These messages are not forwarded to nodes other than 1-hop neighbours. Hello messages contain a list of neighbours with which the node has bidirectional links and the list of neighbours whose transmissions were received in the recent past.
2. *TC (Topology Control) Messages:* Each node broadcasts TC messages for topology declaration. TC packets contain the MPR selector set of every node and are flooded throughout the network using the multipoint relaying mechanism. Each node sends TC messages after a regular interval of time called TC-interval. Based on the information in TC packets each node updates its routing table.
3. *Multiple Interface Declaration (MID) Messages:* For single OLSR interface nodes, the relationship between an OLSR interface address and the corresponding main address is OLSR interface address. For multiple OLSR interface nodes, the relationship between OLSR interface addresses and main addresses is defined through the exchange of Multiple Interface Declaration (MID) messages.
4. *Host and Network Association (HNA) Messages:* In order to provide capability of injecting external routing information into an OLSR MANET, a node with such non-MANET interfaces periodically issues a Host and Network Association (HNA) message, containing sufficient information for the recipients to construct an appropriate routing table.

*B. MPR Selection mechanism*

The objective of MPR selection is for a node to select a subset of 1-hop neighbouring nodes such that the broadcast messages retransmitted by these neighbours are received by all nodes 2-hop away. MPR set should be updated whenever a change in 1-hop neighbourhood or 2-hop neighbourhood is detected. MPRs are selected on the per interface basis and the union of MPRs of all the interfaces gives the MPR set of the corresponding node. Keeping the MPR set small, the overhead of the protocol can be kept minimum. In route calculation, MPRs are used to form route from a given node to any destination node in the network.

*C. OLSR Functionality*

OLSR is modularized into a "core" of functionality, which is always required for the protocol to operate, and a set of auxiliary functions.

- The core functionality of OLSR specifies the behaviour of a node, equipped with OLSR interfaces participating in the MANET and running OLSR as routing protocol. This includes a universal specification of OLSR protocol messages and their transmission through the network, as well as link sensing, topology diffusion, route calculation, neighbour detection, MPR selection and MPR signalling, topology control message diffusion.

- Auxiliary functions include situations where a node has multiple interfaces, some of which participate in another routing domain, where the programming interface to the networking hardware provides additional information in form of link layer notifications. This includes finding non-OLSR interfaces, link-layer notifications, advanced link sensing redundant topology, redundant MPR flooding etc.

## III. RELATED WORK

For energy saving in MANET, many energy efficient protocols have been proposed and discussed in [18-33]. Depending on the routing path selection these energy efficient protocols can be classified as proactive, reactive and hybrid protocols. For the energy saving perspective they can be classified into two categories. Maximum network lifetime routing protocol like described in [25]. Minimum Energy routing and Energy conservation mechanism applied on proactive protocol like OLSR are proposed [18-25]. Energy efficient OLSR protocols are focused on two directions. Selecting energy efficient routing path described in [22] and [24] and selecting energy efficient multipath relay (MPR) node [18-20].

Energy efficient routing path focus on reducing energy cost per packets as well as avoid low energy node from routing path to improve network life time. Selecting energy efficient MPR node is important in OLSR protocol which can prolong the network lifetime. Due to the random deployment, ad hoc environment and different mobility condition of the network, collecting QoS service information has also been a crucial task. QoS information can enhance network performance significantly [32].

Our aim is to explore all the proposed solution of energy efficiency in OLSR and come up with the solution which takes all the limitation into consideration.

## IV. ENERGY EFFICIENT VARIANTS OF OLSR

Energy efficient OLSR protocols are focused on improving two directions of OLSR. First is improving the routing path determination algorithm and second is improving MPR selection process keeping energy consumption and network lifetime in mind. Energy efficient path selection is important to reduce energy cost per packets and to maximize network lifetime. The network lifetime can be defined as-

- The time to the first node failure due to battery outage.
- The time to the unavailability of application functionality.
- The time to the first network partitioning.

Various solutions have been proposed to improve QoS information in order to maximize network lifetime and to make OLSR energy efficient. Here we are classifying them in three category according to different approaches used for getting energy efficiency –

### *A. Energy Efficient Routing Path Determination*

*1) Transmission power Control Approach:* A general routing algorithm find an optimal route based on hop count, delay or bandwidth availability. Energy efficient OLSR protocol find path that minimize energy cost or maximize network lifetime. Transmission power plays an important role in path selection process. Transmission power model are of two types: Constant power model and variable power model [25]. When transmission power is constant the shortest path may be the optimal energy efficient path. But when the transmission power is controllable the shortest path may not be the energy efficient path because the transmission power p required to communicate between two nodes has super-linear dependence on distance. The primary goal is forward packets on path using minimal power.

Minimum Total Transmission Power Routing (MTPR) based energy efficient routing protocol find the best route that minimizes the total transmission power between a source and destination pair [25]. The problem can be represented as a graph optimization problem where each node is a vertex and each link has a cost associated with it. The cost corresponds to required transmission power ***p*|*N1->N2*|** for sending a packet from a node ***N1*** to another node ***N2***. The energy efficient path is the least cost path from a source to destination. MTPR reduces the overall transmission power consumed per packet. Though MTPR minimizes the cost per packets it does not improves the network life time. MTPR has the disadvantage that some nodes will be always selected for routing which would lose their battery very soon.

*2) Residual Energy based Approach:*

- Minimum Battery Cost Routing (MBCR): The MBCR routing tales the battery capacity as the routing cost. The battery cost function $f_i(t)$ of node $n_i$ at time t is defined as- $f_i(t)=1/c_i(t)$ where $c_i$ is the battery capacity of node $n_i$ at time $t$. The less battery capacity of a node, show the more reluctant nature of that node [18]. As the battery capacity decrease the cost function of node increases. Therefore, to find a route with the maximum remaining battery capacity, route $i$ that has the minimum battery cost is selected. The summation of battery cost in a path still selects node with little remaining battery capacity.
- Min-Max Battery Cost Routing (MMBCR): To make sure that no node will be overused, the objective function of the MBCR algorithm is modified. Instead of summing the battery cost function of all nodes of the individual routes, select the battery cost which is maximum among all nodes of route [22]. For each route, select battery cost function which having maximum value among all nodes in the route. Select the route with minimum battery cost among all routes. The power of each node is being used more fairly in this scheme than previous schemes. There is no guarantee of minimum total transmission power path under all circumstances. Hence MMBCR Consume more power to transmit i.e. reduce the lifetime of all nodes.
- Conditional Max-Min Battery Capacity Routing (CMMBCR): Using MMCBR, maximizing the life time of each node and use the battery fairly cannot be achieved simultaneously [25]. CMMBCR uses battery capacity instead of cost function. It chooses route with minimum total transmission power among routes that have nodes with sufficient remaining battery capacity. It uses a battery capacity threshold (Y) for selecting routes. For each route $j$, CMMBCR find the minimum capacity $C_j$ among all nodes in that route. If $C_j >= Y$ is true for some or all routes between a source and destination, it implements Minimum Total Transmission Power Routing (MTPR) scheme to select path among. If the condition is not satisfied the route $i$ with the maximum battery capacity is selected.
- Minimum Drain Rate (MDR): Power saving mechanism using remaining battery power may inject too much traffic to a node having sufficient battery power may cause congestion and sharp reduction of battery power. To overcome this problem a cost function takes into account Drain Rate index $D_R$ and the residua battery power $RBP$ to measure the energy dissipation rate at a given node. $RBP_i / D_{Ri}$ at node $n_i$ indicates how long $n_i$ can keep up routing operation with the current traffic scenario [23]. Maximum life time of a given route is determines by the minimum value of $RBP_i / D_{Ri}$ over the routes. The MDR selects the route having the highest maximum lifetime value from the set of all possible routes. Protocol using Remaining energy drain rate and Transmission power is proposed in [24]. Which include tuning parameters to control remaining energy and drain rate of a node?

### *B. Energy Efficient MPR Selection Methods*

In order to reduce the number of broadcast packets, OLSR uses the idea of multipoint relay (MPR). MPR nodes forward more packets than other nodes. Hence the energy of an MPR node may exhaust rapidly. A good MPR selection process may increase network lifetime of OLSR significantly. MPRs are a subset of the 1-hop neighbors that provide access to all 2-hop neighbors of a node. Reducing the number of MPRs selected by each node, is a key to the OLSR optimization. Determining the minimal MPR set is NP-hard. A heuristic iteratively adds 1-hop neighbors with connectivity to the maximum number of 2-hop neighbors to the MPR set until all 2-hop neighbors are covered.

*1) MPR with Maximal Residual Energy:* The above strategy is modified [20] to iteratively add 1-hop neighbours with maximal residual energy level to the MPR set until all 2-hop neighbours are covered. As routes ultimately are build from MPRs (accept potentially the first and last node), this will avoid nodes with low residual energy levels, unless they are the source or destination. When there are multiple node with same amount of remaining energy node with maximum 2 hop neighbour may be selected.

2) *Willingness Factor:* A variable, "willingness" of a node, representing the availability of that node to act as a MPR for its neighbours is a measure for selecting the node as an MPR [18]. Each node, calculating its own energetic status, can declare an appropriate willingness. Willingness selection is based on two metrics, the battery capacity and the predicted lifetime (based on the energy-drain rate) of a node. The heuristic used to associate a willingness ("default", "low" or "high") to a pair (battery, lifetime). Nodes having high willingness have more chance to select as an MPR. To avoid node with small residual energy another mechanism is proposed in [19] considers degree and reachability of a node for the selection of MPR. Below table shows different values of willingness factor with respect to energy lifetime.

### *C. Accuracy Prediction in OLSR*

Due to bandwidth constraints, communication costs, high loss rate and the dynamic topology of MANETs, collecting and maintaining up-to-date state information is a non-trivial task [20]. Nodes having only inaccurate/imprecise knowledge of the energy levels of other nodes may decrease the network performance as high as 10% for all mobility scenarios, traffic loads, and protocol variations [28]. Residual battery life which we refer here as QoS service information is included in the OLSR protocol messages (Hello and TC messages) to be available to other nodes in the network. Extended Hello and TC messages contains the most recent QoS-related state associated the sender node itself with those neighbors from the sender node's perspective in addition to a list of addresses of neighbors. Moreover, a timestamp of when the data was sent out (created) is collected along with the QoS-related state. Timestamps are used to analyze delays and "knowledge age". As control message get lost, traffic does introduce a considerable level of inaccuracy to the network and the age of the QoS state information at a node becomes obsolete. When control message are lost the energy level of a node can be predicted by knowing the average energy drain rate (r) of that node. Drain rate is calculated as-

$$r = (E_{t1} - E_{t2})/(t_2 - t_1)$$

Where $E_{t1}$ and $E_{t2}$ are energy level at time stamp $t_1$ and $t_2$ respectively, where $t_2$ is the most recent time stamp. Hence Energy level at any time $t_k$ is predicted. The disadvantage of the above prediction is not possible by when one of the energy time stamps is missing. For such a cases average drain rate of the network to be taken into consideration.

## V. SUGGESTED APPROACH

Routing through MPR nodes may not be always energy efficient. Including non-MPR node as an Intermediate node between two MPR nodes may reduce the energy cost per packet. This will result in energy efficiency as energy drain rate of MPR node will reduce with the use of non-MPR node in route establishment. An adaptive protocol which tune the MTPR and residual energy (RE) and consider selecting non MPR node accordingly may improve the OLSR energy performance.

All the discussed protocols have not considered mobility and density of node. Effect of node density on MPR selection is still unnoticed. Because MPR selection and routing path changes with mobility, mobility should be given importance while designing these protocols. Above protocol need modification integrating with mobility and node density.

## VI. CONCLUSION AND FUTURE WORK

Energy efficiency has been an important consideration in design of mobile ad hoc network. As compared to reactive and dynamic protocol, less work has been done to improve OLSR energy performance. EE-OLSR excels OLSR in terms of throughput, average node lifetime, network lifetime and overhead.

We studied about various modifications to OLSR protocol and the effect of these modifications on the node lifetime and performance of network in terms of energy efficiency. Higher number of MPRs selected for routing results in degraded network performance due to increased overhead. By exploring many energy aware metrics, we found MDR mechanism outperforms others for MPR election and route selection between source and destination. Most of the OLSR energy saving protocols has focused on MPR selection and energy consumption as discussed in Section III and Section IV.

Finally, we suggested that considering the mobility and density of node in design considerations is also an important issue. Because MPR selection and routing path changes with mobility. Since the routing path is dominated by MPR nodes, existence of efficient routing path using non MPR node is ignored. Effect of node density on MPR selection is still unnoticed. There is need of integrated approach to considering all of the above constraint.

Future work includes designing of an efficient OLSR protocol which have all the aspects discussed in Section V. Designing of such type of protocol must meet all the requirements of real time routing and should not degrade performance threshold of network.

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