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Enhancement in Accuracy Metrics of Energy Levels in MANETS

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Abstract: The nodes in mobile ad hoc networks are highly power dependent. Therefore, energy consumption serves as an important metric. In this study, researchers proposed technique that includes energy aspects in the routing protocol, Enhanced Optimized Link State Routing (EOLSR). On implementing few modifications to the OLSR, researchers aim at improving the life time of the node and performance of the network under different CBR intervals. In addition, the modified MPR selection plays an important role in making the EOLSR an energy aware and efficient routing protocol. Researchers finally showed that tuning the control message intervals have a greater enhancement on the performance and life time of nodes. For the dynamic network, it is observed that there is a throughput gain of about 20-35% showing better performance than the default OLSR.

Key words: MANET, MPR, OLSR, QoS, dynamic network

INTRODUCTION

Mobile Ad hoc Networks (MANET) consist of wireless nodes that form a communications network among themselves without a fixed infrastructure (Perkins, 2001). MANET is frequently used in special situations such as in emergency operations such as natural or manmade disasters, rescue activities, battle fields or seminar halls particularly in areas where there is no fixed infrastructure or such infrastructure has been destroyed (Latiff and Fisal, 2004). Topology changes in MANET usually occur due to the mobility of a participating node or break down of a node due to loss of energy in that node (Zhao *et al*., 2005). These dynamic conditions disrupt the smooth communication between nodes in the network.

Conceptually, in MANET, a node may either function as an end node or as a router forwarding data packets between end nodes (Shakkeera, 2010). An effective routing mechanism is required to maintain acceptable service quality during communication between nodes (El Gamal *et al*., 2002). Hence, the fitness of the node in terms of available energy in the node becomes an important issue during the selection of an intermediate node in order to maintain stable transfer of data between nodes.

Maintaining an optimized lifetime of a routing path in a network is a very challenging task because the power or energy of the nodes depends on the size, model, property and capacity of the battery (Zhao *et al*., 2005). Energy in batteries continuously deplete due to node activities such as transmission, reception and overhearing. Depletion of energy in nodes especially the intermediate ones disrupt communication results in changes to the network topology. However, disruption can be minimized through an efficient selection of intermediate nodes. Such selection criteria must be the first step in any route selection processing order to maintain a stable routing of data between the end nodes.

The node selection process has been included in many routing algorithms and techniques (Shakkeera, 2010). Hence, these algorithms and techniques have considered the service quality as an important factor. But these algorithms and techniques suffer from certain shortcomings especially during the route discovery process. These techniques do not consider the available energy of a node as a parameter, so they may select a node with low energy level as an intermediate node. Selection of a node with low energy level reduces the stability of the communication path as that node may run out of energy causing the breakdown of the communication channel. In this study, researchers proposed a probability based node selection scheme where the available energy level of a node is an important parameter.

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LITERATURE SURVEY

Optimized Link State Routing (OLSR) is a table driven proactive routing protocol for MANET (Mobile Ad hoc Network). In a Classic Link-State algorithm, the link-state information is flooded throughout the network. The OLSR uses this approach also but since the protocol runs in wireless multi-hop scenarios the message flooding in OLSR is optimized to preserve bandwidth. The optimization is actually based on a technique called multipoint relaying. In this all nodes contain pre-computed routes information about all the other nodes in network. This information is exchanged by protocol messages after periodic time.

OLSR performs hop by hop routing where in each node uses its most recent topology information for routing. Each node selects a set of its neighbor nodes as MPRs (Multi Point Relays). Only nodes selected as MPRs are responsible for forwarding control traffic. MPRs are selected such that the 2-hop neighbors must be reachable through at least one MPR node and OLSR provide shortest path routes to all destinations by providing link-state information for their MPR selectors. The nodes which have been selected as MPRs by some neighbor nodes announce this information periodically in their control messages. MPRs are used to form the routes from starting node to the destination node in MANET. All this information is announces to neigh boring MPRs through control messages. The purpose of selecting MPR is to reduce flooding overhead and provide optimal flooding distance. Figure 1 shows flooding with MPR.

The key messages in OLSR are Hello and TC messages. Hello messages are actually periodically exchanged to inform nodes about their neighbors and their neighbors' neighbors and are 1-hop broadcast messages. The 2-hop neighborhood information is then used locally by each node to determine MPRs. In contrast, TC messages are flooded through the network to inform all nodes about the (partial) network topology. At a minimum, TC messages contain information about MPRs and their MPR selectors.

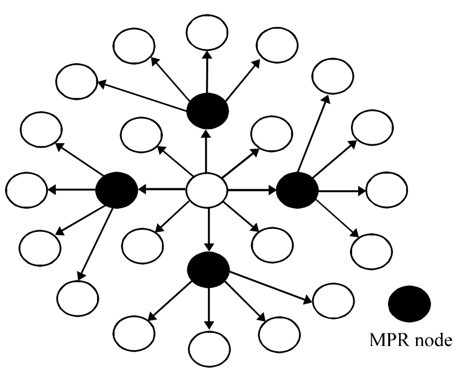

Fig. 1: Flooding with MPR

There are few parameters in OLSR which can control the efficiency of OLSR. The Hello-interval parameters represents the frequency of generating a Hello message. Increasing the frequency of generating Hello messages leads to more frequent updates about the neighborhood and hence a more accurate view of the network and result in overhead. The TC-interval parameter represents the frequency of generating a TC message and is used for topology discovery. If frequency of TC messages is increased then nodes are having more resent information about topology as nodes leaves and enter into the network very frequently. The MPR-coverage parameter allows one node to select redundant MPRs. No. of MPRs should be minimum as it introduce overhead in the network. But more the MPRs more is the reachability. The TC-redundancy parameter specifies, the amount of information that for the local node may be included in the TC message. The TC-redundancy parameters affects the overhead through affecting the amount of links being advertised as well as the amount of the nodes advertising links.

Through, the exchange of OLSR control messages, each node accumulates the information about the network. This information is actually stored according to the OLSR specifications. Time stamp with each data point modifies the control messages and local repositories accordingly. For better efficiency of OLSR state informations such as residual energy level of each node, bandwidth, queue length, etc. must be available while making routing decisions. Incorrect information may lead to degradation in efficiency of OLSR. As state information in OLSR is collected by periodic exchange of above mentioned message. This information may not be up to date as topology changes very fast. Residual energy level of nodes is changes rapidly and the node with less energy level must not be selected in route. Researchers are interested in studying the effect of residual energy levels on protocol efficiency. The point is how nodes can collect accurate energy level information about other nodes by OLSR control messages. Traffic load can be a factor that can affect the inaccuracy of energy level information.

LITERATURE REVIEW

Seung Hwan Lee, projected an energy efficient power control mechanism for base station in mobile communication systems and an efficient sector power control based on distance between base station and mobile node. They also proposed a sleep mode energy control mechanism. In the sleep mode energy saving protocol, each sector monitors the number of users in sector cell. They proposed, if number of mobile node falls down a given threshold in sector cell, base station shuts down power. The key point is to minimize power consumption and maximize lifetime of the entire network.

De Rango *et al*. (2008) in their research EE-OLSR: energy efficient OLSR routing protocol for mobile ad-hoc networks introduced a routing protocol to prolong the network lifetime without losing the performance. It uses the concept of Multi Point Relays (MPRs) which reduces the message overhead. In the EA-Willingness Setting mechanism each node associated with variable used "willingness" where longer the node lifetime-HIGH willingness and vice versa. Overhearing exclusion is another feature where OLSR does not takes any advantage from uni cast network information. It uses energy-aware packet forwarding for route discovery. EE-OLSR outperforms OLSR by providing a better traffic load balancing and throughput. It provides a normalized control overhead, enhanced node lifetime, high packet delivery ratio and also the lower end to end delay.

In the research by Rishiwal *et al*. (2009) QoS based power aware routing in MANETs (Rishiwal *et al*., 2009), the proposed mechanism selects energy stable, QoS constrained end to end path. It performs the routing in two phases where first phase deals with route discovery with bandwidth and energy constraints and the second phase deals with route repair mechanism for finding a new energy stable path. Route Discovery algorithm performs an energy based path selection.

Research also provides a mechanism for route maintenance by considering the cases such as link failure due to energy depletion and topological changes. This protocol yields better packet delivery ratio, better throughput, average end to end delay and efficient route reconstruction. But a prior estimation of bandwidth and admission control is needed to ensure bandwidth availability which is its drawback. In summary, none of the prior researches fully address the problem of inaccurate state information.

MOTIVATING EXAMPLE

Researchers modified the MPR selection and the Path Determination algorithm. MPRs are a subset of the 1-hop neighbors that provide access to all 2-hop neighbors of a node. As most routing is done via MPR, researchers iteratively add 1-hop neighbors with maximal residual energy level to the MPR set until all 2-hop neighbors are covered. More formally, when a node N selects its MPRs:

- N puts in the set uncovered all its strict two-hop neighbors (Fig. 2)
- N sorts its 1-hop neighbors by decreasing residual energy level (Fig. 3)

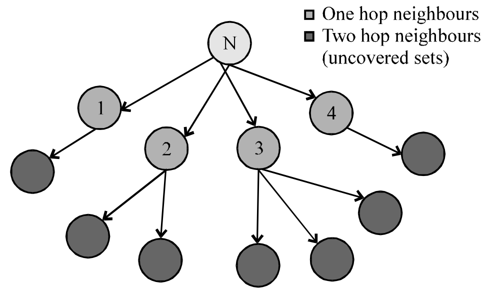

Fig. 2: Modified MPR selection

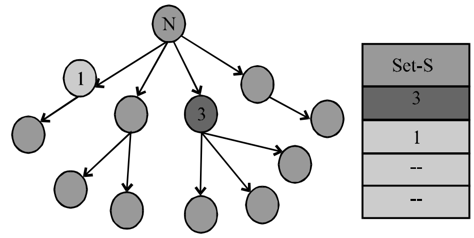

Fig. 3: Ordering the node based on energy levels

Let S be this ordered set:

- Repeat:
  - Node N selects the first node in S (the node with the highest residualenergy level) and removes it from S, let that node be M (Fig. 4)
  - If M covers any nodes in uncovered, M becomes an MPR, remove the nodes covered by M from uncovered
- Until uncovered becomes empty

This algorithm will increase the number of MPRs selected and therefore the protocol overhead to flood TC messages where MPR selection is also modified to take residual energy into account, the increase may be substantial (log(n) where n is the number of neighbors of a node). However, as routes ultimately are built from MPRs (except potentially the first and last node), this will avoid nodes with low residual energy levels unless they are the source or destination.

The modification changes the weight associated with each link. Researchers assign it the reciprocal value of the sending node's residual energy level. Again, this will penalize routes that traverse nodes with low residual energy level (changes weight on each link, Weight = 1/Residual energy of sending node). As a node's energy level depletes, the path determination algorithm will be increasingly less likely to use such nodes as the associated costs are increasing rapidly. So, the results here cover two protocol variants: modified routing refers to the version that uses the original MPR selection criteria

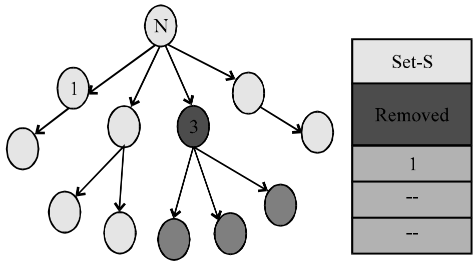

Fig. 4: MPR selection

but uses the new Path Determination algorithm whereas modified MPR/Routing combines both the new MPR selection and the new Path Determination algorithm. Researchers use two different versions of each protocol, the ideal version (where a node has access to the actual, current residual energy level of remaining nodes when selecting MPRs and determining paths) and the realistic version in which one node needs to rely on the residual energy levels it learned through protocol messages as described. Depending on the traffic rate and network mobility, an ideal protocol version having omniscient access to the current, instantaneous energy values when making routing decisions, typically achieves a much superior protocol performance, delivering up to 20% more packets.

ENERGY LEVEL-INACCURACY IMPROVEMENT

Based on the energy level knowledge age inaccuracy level analysis in the previous study, the results show that the main source of inaccuracies is the existence of old data. A first approach to address this problem would be for a node to selectively probe nodes for which it holds old information (above a certain threshold, say), hopefully obtaining more recent (and therefore more accurate) state information. In research reported elsewhere, researchers experimented with such an approach and found that it, in general is, not capable of achieving significant reductions in inaccuracy.

Alternatively, as energy level is a monotonically decreasing metric, a node can adjust "old" information and predict the current value whenever it needs to determine the residual energy level for a visible node (when selecting MPRs or determining a routing path for example). The idea is therefore to have every node locally adjust nodes' old energy levels based on their past energy consumption rate researchers propose a residue forecast mechanism in which each node locally extrapolates an expected energy level based on old energy levels and energy consumption rate pattern for all other nodes.

Every second of the simulation, instead of having every node report its perceived knowledge for every other node in the network as is a node's perceived value is first adjusted based on its past behavior and then the adjusted value is reported. The Residue Forecast Mechanism algorithm is where every node keeps a record of the last perceived values of all the other nodes and the timestamps of when this data is created. Whenever, a node receives a new perceived value for another node, along with the timestamp, it calculates, if possible, its consumption rate. It then adjusts the perceived value based on the consumption rate. Whenever, a node receives a new perceived value, there are 3 cases:

The new perceived value is the same as the old perceived value which mean that no update was received for that node.

The timestamp associated with the new perceived value is smaller than the timestamp of the old perceived value. This might seem wrong at first but there are 2 cases where that might happen as shown Table 1.

Let us say, for example, that node 1 receives knowledge about node 2 from two different sources (say "a" and "b") and that the one from "a" was the one with the most recent information. It might be that the next time node 1 receives a message from "a", the message does not include any info about 2 (2 is no longer heard), so the tuple expires from the information base and researchers are left with the older information (the only available knowledge corresponding to a tuple for node "b"). The second case is that the messages were received out of order, so the message with the later information was received first. If within 15 sec no further info is received, the tuple expires and again the tuple with the older info is used until it expires (expiration time is calculated from the time the knowledge is received).

The timestamp associated with the new perceived value is higher than the timestamp of the old perceived value (actual energy of each node) which is the typical case, since researchers are collecting the most recent information.

Consumption rate refers to the node's energy consumption per second and is calculated in Eq. 1:

$$\text{Consumption rate} = \frac{\text{Old perceived value-New perceived value}}{\text{New timestamp-Old timestamp}} \quad (1)$$

The adjusted value is calculated as the perceived value Eq. 1 minus the amount of energy this node consumed since, it sent out this value until collection time:

Table 1: Overall inaccuracy level (J) under different packet inter arrival times with different OLSR parameters

OLSR parameter	Traffic interval				
	0.2	0.14	0.09	0.04	0.02
Hello-interval					
2	0.17 [0.05, 0.2]	1.49 [0.79, 2.1]	4.88 [3.66, 6.1]	8.48 [6.86, 10.09]	9.39 [7.72, 11.06]
1	0.105 [0.06, 0.014]	1.175 [0.55, 1.79]	3.684 [2.91, 446]	7.16 [5.82, 8.15]	8.84 [7.22, 10.47]
TC-interval					
5	0.17 [0.05, 0.29]	1.49 [0.079, 2.91]	4.88 [3.66, 6.1]	8.48 [6.86, 10.09]	9.39 [7.72, 11.06]
4	0.154 [0.0068, 0.24]	1.5 [0.89, 2.11]	4.81 [3.63, 6]	8.48 [7.09, 9.87]	9.77 [8.34, 11.2]
3	0.17 [0.07, 0.27]	1.74 [1, 2.48]	5.24 [4.05, 6.42]	8.61 [7.03, 10.2]	9.82 [8.127, 11.5]
MPR-coverage					
1	0.17 [0.05, 0.29]	1.49 [0.79, 2.91]	4.88 [3.66, 61]	8.89 [6.86, 10.09]	9.39 [8.73, 11.91]
2	0.22 [0.11, 0.34]	1.94 [0.79, 2.81]	5.44 [4.19, 6.69]	8.48 [7.07, 10.71]	10.32 [7.72, 11.06]
TC-redundancy					
0	0.17 [0.05, 0.29]	1.49 [0.81, 2.24]	4.88 [3.66, 6.1]	8.48 [6.86, 10.09]	9.39 [7.72, 11.57]
1	0.17 [0.086, 0.25]	1.52 [0.81, 2.24]	5.15 [3.9, 6.41]	8.79 [7.17, 10.41]	9.84 [8.11, 11.57]
2	0.17 [0.087, 0.25]	1.73 [0.89, 2.56]	4.9 [3.74, 6.06]	8.46 [6.95, 9.98]	10.15 [8.85, 11.44]

$$\text{Adjusted value} = \text{Perceived value-Consumption rate}\times(\text{Collection time-Perceived value timestamp}) \quad (2)$$

Since, for the calculation of the overall inaccuracy level researchers ignore the first 20 sec and start data collection at time 20, at time 20 no adjustments are made and the adjusted values are the same as perceived values since consumption rates are not known yet. Researchers only use perceived measurements that are at least 1 sec apart to update the consumption rates since researchers are interested in long-term rates not potentially extreme rates that could result from a node continuously sending packets for a short period of time and it happened to be between successive protocol messages for instance. Since, the number of times an adjustment takes place is an indicator of how well the residue forecast algorithm works, Table 2 shows the percentage of times an energy level adjustment takes place under the different traffic rates.

It can be easily noticed from this Table 3 that the adjustments percentage is much lower under higher traffic rates than it is under lower traffic rates. This is due to two main factors. First, for any adjustment to take place researchers need two different perceived value readings so that a consumption rate can be calculated and used to adjust the perceived value. But under high traffic rates and with the high levels of message loss and delay, updates are not received in a timely fashion. And the second factor is that under high traffic rates nodes get disconnected more frequently and consequently they get reset. When a node becomes heard again, it is dealt with as a new node and again two different perceived value readings are needed for the adjustments to start taking place.

The only apparent drawback of the Residue Forecast algorithm is the need to wait for two different perceived values readings, so a consumption rate can be calculated and used to adjust the perceived values. In this study, researchers enhanced Residue Forecast algorithm which is an enhanced version of the Residue Forecast algorithm so that adjustments take place almost all the time.

Table 2: Percentage of number of times adjustment takes place under different traffic rates

Traffic interval	No. of adjustments (%)
0.20	97
0.14	95
0.09	91
0.04	82
0.02	78

Table 3: Overall inaccuracy level under default OLSR parameters and under a combination of hello-interval 1 and TC interval 3

Traffic interval	Overall inaccuracy level default OLSR	Overall inaccuracy level Hello1 TC3
0.2	2.6225 [2.37, 2.8]	1.6887 [1.49, 1.89]
0.14	3.4287 [2.96, 3.9]	2.461 [22. 92]
0.09	5.1793 [4.8, 5.56]	4.6302 [4.05, 5.21]
0.04	6.7602 [5.946, 7.58]	7.231 [6.42, 8.04]
0.02	6.839 [5.86, 7.781]	8.003 [6.6, 9.41]

In the enhanced Residue Forecast algorithm, for every pair of nodes (n1, n2) if n2's consumption rate is not known yet, n1 adjusts the perceived value of n2 based on the average of all known consumption rates for other nodes. If n1 knows not a single consumption rate for other nodes, it adjusts n2's perceived energy level based on its (n1) consumption rate. Using all the known nodes' consumption rates eliminates the domination of outliers and ensures closeness to the actual consumption rate.

According to Fig. 5, the Residue Forecast algorithms improve the overall inaccuracy level under different traffic

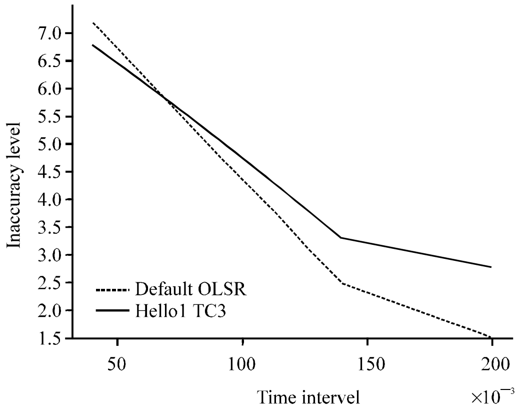

Fig. 5: Overall inaccuracy level of the default OLSR vs. hello1TC3 OLSR

rates. The improvements under higher traffic rates is not as high as it is under lower traffic rates. For an adjustment to take place, a node must have already received two different reported values. But under high traffic rates, due to message loss and delays, the percentage of times the adjustments take place decreases as shown in Table 1.

Since the enhanced Residue Forecast algorithm addresses the problem of not being able to adjust the perceived energy level value all the time, it achieves much better performance in terms of overall inaccuracy level, especially under higher traffic rates. Both, the residue forecast and enhanced algorithms outperform the default OLSR protocol. At the same time, the Smart Residue Forecast algorithm outperforms the Residue Forecast algorithm in improving the overall inaccuracy level.

CONCLUSION

In this research, researchers used the Optimized Link State Routing (OLSR) protocol as the underlying MANET routing protocol. Researchers reported the quantification of state information accuracy for a metrics, energy level. Researchers defined state information accuracy as the average difference between the perceived QoS-related state and its actual state.

For the metrics, researchers determined the inaccuracy level under different traffic rates. It was shown that traffic induces a high overall inaccuracy level to the network. And as traffic rate increases, the overall inaccuracy level increases. Consequently, information available to the nodes in the network becomes out-dated and no longer accurate. Tuning the protocol parameters did not seem to have a noticeable impact on overall inaccuracy level. Number of hops analysis concluded that very little improvement in energy level inaccuracy can be obtained under low traffic rates by using a combination of Hello-interval 1 and TC-interval 3 for OLSR parameters. In addition, knowledge age analysis energy level resulted that inaccuracy levels are highly affected by the age of the data.

Two other techniques were proposed to reduce energy level inaccuracies, residue forecast and smart residue forecast. Under the residue forecast technique, a node's energy level is adjusted based on its past behavior (its own consumption rate). On the other hand, smart residue forecast is a modified version of the residue forecast technique such that if no behavioral pattern was known for a node, its energy level is adjusted based on the average of all known consumption rates for other nodes. The results show that both residue forecast and smart residue forecast outperform the default OLSR (OLSR with QoS-related state propagated and using default parameters). Moreover, smart residue forecast outperforms residue forecast since energy levels adjustments take place all the time. In addition to that the overheads associated with residue forecast and smart residue forecast is exactly the study same as the default OLSR since no extra messages or fields are required.

As part of future research, smart residue forecast could be evaluated when nodes have homogeneous wireless interfaces. In other words, nodes are not required to have similar transmitting, receiving or idle power. Overall inaccuracy levels can be determined under different mobility patterns to get a broader understanding of the different factors that might affect the state information accuracy. Researchers then need to identify additional techniques to increase the collected information.

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