Investigating quality routing link metrics in Wireless Multi-hop Networks

N. Javaid · A. Bibi · A. Javaid · Z. A. Khan · K. Latif · M. Ishfaq

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Abstract In this paper, we propose a new Quality Link Metric (QLM), “Inverse Expected Transmission Count (InvETX),” in Optimized Link State Routing (OLSR) protocol. Then, we compare performance of three existing QLMs which are based on loss probability measurements: Expected Transmission Count (ETX), Minimum Delay (MD), and Minimum Loss (ML) in Static Wireless Multi-hop Networks (SWMhNs). A novel contribution of this paper is enhancement in conventional OLSR to achieve high efficiency in terms of optimized routing load and routing latency. For this purpose, first we present a mathematical framework, and then to validate this framework, we select three performance parameters to simulate default and enhanced versions of OLSR. The three chosen performance parameters are throughput, Normalized Routing Load, and End-to-End Delay. From the simulation results, we conclude that adjusting the frequencies of topological information exchange results in high efficiency.

Keywords Routing link metric · ETX · Inverse ETX · Minimum Delay · Minimum Loss · Wireless Multi-hop Networks

1 Introduction

Communication at any time without any disruption for mobile users is provided by Wireless Multi-hop Networks (WMhNs). These networks have some distinguished features due to dynamic topologies, various number of nodes, and communication demand at random times, in random directions and for different sessions. Underlying network demands a routing protocol to dynamically cope with changing topologies. Mobile nodes in WMhNs are very often limited in resources such as processing capabilities, storage capacity, battery power, bandwidth, etc. This implies that the routing protocol must be able to minimize the control traffic (as trigger/periodic update messages), delays (due to retransmissions or computation of metrics), and so on. The performance of a wireless network depends upon the efficiency of the routing protocol operating it. The most important component of the routing protocol is “routing link metric,” because a link metric first considers the quality routes and then selects the best one for data transmission. A Quality Link Metric (QLM) plays a key role to achieve the desired performance from an underlying network by making the routing protocol: fast enough to adopt topological changes, lightweight to minimally use the resources of nodes, intelligent to select the fastest path from source to destination among available paths, and capable to enable the nodes to have a comprehensive idea about the topology.

Considering demands of the underlying network from its operating protocol and factors influencing its performance, a QLM is supposed to fulfill certain requirements.
An efficiently designed QLM better helps a routing protocol to achieve appreciable performance by dealing with these issues. In our previous work [1], design requirements of QLM are discussed in detail. Moreover, a new QLM, Inverse Expected Transmission Count (InvETX), is also compared with Expected Transmission Count (ETX) [2], Minimum Loss (ML) [3], and Minimum Delay (MD) [4] in Optimized Link State Routing (OLSR) [5] protocol. As we discuss earlier that a routing protocol and link metric collectively are responsible for efficient performance, therefore, we address improvement in routing protocols as well. For this purpose, in this paper, we enhance OLSR to reduce routing overhead. To validate our enhancements, we evaluate and compare the performance of selected metrics in default and enhanced OLSR.

2 Related work and motivation

After analyzing reactive and proactive protocols, Yang et al. [6] propose that proactive protocols that implement the hop-by-hop routing technique, as Destination-Sequence Distance Vector (DSDV) [7] and OLSR protocols, are the best choice for Static Wireless Mesh Networks (SWMNs). They also inspect design requirements for routing link metrics for the mesh networks and related them to the routing techniques and routing protocols. Das et al. in [8] discuss the dynamics of the following well-known metrics: ETX [9], Expected Transmission Time (ETT) [10], and Link Bandwidth [11] in real test beds. Across various hardware platforms and changing network environments, they test two requirements: stability and sensitivity for some existing routing link metrics. Authors also discuss the dynamics of the above-mentioned metrics and tested their performance on the test beds for the above-stated requirements.

In [12], Yang et al. systematically analyze impact of working of wireless routing link metrics on the performance of routing protocols. Three operational requirements, optimality, consistency, and loop-freeness, are also discussed. However, these properties do not consider all design requirements. For example, computational overhead; a metric can produce, performance trade-offs; a metric has to make among different network performance parameters (e.g. achieving high packet delivery ratio on the cost of increased end-to-end delay). Therefore, we analyze almost all possible design requirements in [1]. Further, in our previous work, we implement three existing link metrics, ETX, MD, and ML, and one newly proposed metric, InvETX OLSR, using NS-2.34. The simulation results show that how computational burden of a metric degrades performance of the respective protocol and how a metric has to trade off between different performance parameters.

In this paper, we present a mathematical framework to analyze the requirements of a routing protocol as well as a link metric to achieve efficient performance in underlying wireless network. To improve overall efficiency in Static Wireless Multi-hop Networks (SWMNs), we enhance OLSR (enhanced OLSR, EOLSR) and then evaluate the performance of default OLSR with EOLSR. To check the effect of enhancement over link metrics, we compare OLSR and EOLSR with ETX, MD, and InvETX. To check the efficiency of enhancement in terms of successfully delivered data, routing load, and routing latencies, we select three performance parameters for analytical comparison: throughput, End-to-End Delay (E2ED), and Normalized Routing Load (NRL), respectively.

3 Mathematical framework

The factors affecting the wireless networks help to have an idea about the problems they have to face. Along with other protocols that operate a network, routing protocols play a significant role in the performance of WMhNs. In WMhNs, especially in SWMhNs, generally the link quality considerably varies in different periods of time. The reasons may be that some mobile nodes are moving randomly, some go out of range, some intentionally cut off the ongoing communication, some die out due to battery, and so on. The respective routing protocols must be able to dynamically cope with the situation.

As this work is devoted for routing protocol and link metric behavior in SWMhNS, therefore, a linear programming model is first constructed to analyze performance efficiency. In this model, the effect of the capacity of a link along with nonzero constraints is listed for path selection requirement in a link metric. Routing load and routing latency of proactive protocols, pro, are modeled in [13]. To address link metric efficiency in routing protocols, we first construct an integer linear programming model to list the possible constraints against routing overhead. Let e denotes efficiency and is considered as an objective function:

$$\text{max } e \quad (1)$$

Subject to:

$$\sum_{j \in (i,j) \in E} x_{ij} - \sum_{j \in (j,i) \in E} x_{ji} = \begin{cases} e & i = s, \\ 0 & i \in N \backslash \{s, t\}, \\ -e & i = t. \end{cases} \quad (1a)$$

$$0 \leq x_{ij} \leq \text{Cap}_{ij}, \; (i, j) \in E \quad (1b)$$

$$\sum_{j \in (i,j) \in E} Z_{ij}, \; (i, j) \in E \quad (1c)$$
\[
\sum_{j \in \langle u \rangle} \left( C_{E-per}^{\text{pro}} + C_{E-tri}^{\text{pro}} + C_{E-metric}^{\text{QLM}} \right) = \beta_{\text{cri}} e = 0, < \beta_{\text{cri}} e \neq 0. \tag{1d}
\]
\[
\sum_{j \in \langle u \rangle} \left( C_{T-per}^{\text{pro}} + C_{T-tri}^{\text{pro}} + C_{T-metric}^{\text{QLM}} \right) = \tau_{\text{cri}} e = 0, < \tau_{\text{cri}} e \neq 0. \tag{1e}
\]

where \( \text{Cap}_{ij} \) specifies the maximum achievable link rate over link \( L_{ij} \) and \( z_{ij} = 1 \) in such a way that \( L_{ij} \) may have a nonzero flow. Equation 1c denotes that there is at most one outgoing link from each node with a nonzero flow. Equations 1a, 1b, and 1c are subjective constraints for a single route in [13]. The links along that path have the same flow, and all other links have zero flow. As we address the issues regarding routing protocol along with routing link metric, therefore, in Eqs. 1d and 1e, we model routing overhead of a routing protocol in terms of routing load and routing latency. \( C_{E-per}^{\text{pro}} \) and \( C_{E-tri}^{\text{pro}} \) denote cost of energy consumed per packet by a pro for periodic and trigger updates, respectively, whereas \( C_{T-per}^{\text{pro}} \) and \( C_{T-tri}^{\text{pro}} \) in Eq. 1e are routing latencies of periodic and trigger periods, respectively. For a QLM, \( C_{E-metric}^{\text{QLM}} \) and \( C_{T-metric}^{\text{QLM}} \) are routing load and routing latencies, respectively. \( \beta_{\text{cri}} \) and \( \tau_{\text{cri}} \) denote critical bandwidth and critical value of time, respectively.

Usually, the behavior of the channels varies in links and then in complete paths from source to destination. Thus, effecting capacity of link in a network as obvious constraint in Eq. 1a, along with nonzero flow constraints (Eqs. 1b and 1c). In the case of Quality of Service (QoS) routing, the link creating bottleneck for performance must be given attention. Similarly, a change in the quality of one link affects the others. Design requirements for routing algorithm and link metric are summarized in Table 1.

### 3.1 Framework of routing overhead in OLSR

In this work, we are dealing with SWMhNs which are bandwidth sensitive because of limited bandwidth. One of the reasons for bandwidth consumption is routing overhead generated by a routing protocol. For efficient utilization of resources in SWMhNs, we select OLSR because it reduces redundant retransmissions more efficiently in static networks due to Multi-Point Relay (MPR) scheme (Fig. 1). OLSR functionality with MPR selection scheme is presented in the next subsection. In our work, we have studied OLSR by a degree-based routing approach. OLSR uses HELLO and Topology Control (TC) messages during route computation. Let \( C_{E-total}^{\text{OLSR}} \) denotes total cost of energy consumed per packet by OLSR and is the sum of \( C_{E-HELLO}^{\text{OLSR}} \) and \( C_{E-TC}^{\text{OLSR}} \).

\[
C_{E-total}^{\text{OLSR}} = C_{E-HELLO}^{\text{OLSR}} + C_{E-TC}^{\text{OLSR}} \tag{2}
\]

OLSR disseminates only trigger updates for maintaining fresh routes. The interval for transmission of routing updates varies with respect to the status of MPR. TC messages are transmitted through default interval, if MPR status remains the same. OLSR triggers routing updates whenever change in the status of MPR nodes occurs.

Let the trigger cost of TC messages due to MPR redundancy be \( C_{E-TC-trig} \) and the default cost of TC messages due to stable MPRs be \( C_{E-TC-def} \), whereas \( \tau_{\text{HELLO}} \) specifies HELLO interval and \( \tau_{\text{NL}} \) is the total network lifetime. Moreover, we have defined three sets of nodes: (1) connected neighbor nodes \( N_{br} \); (2) selected MPRs; and (3) all nodes in the network \( N \). So, \( C_{E-total}^{\text{OLSR}} \) in Eq. 2 can be written as follows:

\[
C_{E-total}^{\text{OLSR}} = C_{E-HELLO} + C_{E-TC-trig} + C_{E-TC-def} \tag{3}
\]

where,

\[
C_{E-HELLO} = \frac{\tau_{\text{HELLO}}}{\tau_{\text{HELLO}}} \sum_{\forall i \in N} \sum_{j \in N_{br}} j \tag{4}
\]

\[
C_{E-TC-trig} = \int_{\tau_{\text{NL}}}^{\tau_{\text{NL}}} \sum_{\forall i \in N} \sum_{j \in \text{MPRs}} |\text{sgn}(\text{\text{change}MPR})| j \tag{5}
\]

\[
C_{E-TC-def} = \int_{\tau_{\text{NL}}}^{\tau_{\text{NL}}} \sum_{\forall i \in N} \sum_{j \in \text{MPRs}} |\text{sgn}(\text{\text{change}MPR})| j. \tag{6}
\]

The trigger updates of OLSR depend upon \( \text{\text{change}MPR} \). MPR selection is based on maximum degree selection to solve NP-complete problem. A framework for MPR selection is presented as follows:

#### 3.1.1 Framework of MPR selection

Using graph theory, a wireless network can be defined as a bidirectional undirected graph \( G(V, E) \), such that \( V \) = vertices. Nodes \( m \) and \( n \) share a bidirectional link \((m, n)\) [22]. For bidirectional links, if and only if nodes \( m \) and \( n \) hear each other, they can communicate. Let \( H_1(u) \) be the one-hop neighbors of node \( u \). Let \( H_2(u) \) denotes two-hop neighbors of \( u \) (neighbors of one-hop neighbors of \( u \) but not one-hop neighbors of \( u \)).

Let \( d_{\text{max}} \) denote the maximum degree of a node in the graph.

\[
d_{\text{max}} = \max_{u, v} H_1(u) \tag{7}
\]

MPR selection is based on willingness in one-hop neighborhood \( H_1(u) \). The reachability of a node with the second hop \( H_2(u) = v \) neighbors \( d_2^+ \) is defined as follows:

\[
d_2^+(v) = |w \in H_1(v) | v \in H_1(u) \text{ and } w \in H_2^+(u) \tag{8}
\]

The maximum reachability of a node belonging to \( H_1(u) \), \( d_2^+ \), is presented as follows:

\[
d_2^+ = \max_{u \in N(u)} d_2^+ \tag{9}
\]
| Design requirement                  | Issue                                                                 | Possible solution                                                                 | Metric or algorithm |
|------------------------------------|----------------------------------------------------------------------|----------------------------------------------------------------------------------|---------------------|
| Minimizing path length             | Longer path increases routing latency and reduces throughput of a path | (1) By minimizing the number of transmissions and (2) path selection with minimum loss rates or higher probabilities of successful transmissions, etc. | Hop count [14]      |
| Balancing traffic load             | Overloaded traffic causes drop rate due to congestion                 | Divert traffic from congested path or overloaded nodes to underloaded or idle ones | Transmission reduction [15] |
| Minimizing delay                   | Delay results time-out buffer                                        | Delay can be reduced with selection of a path having minimum intraflow and interflow interferences along with queuing delays and maximum link capacity | ETX [15], [14], per hop RTT, [11] per hop PktPair [11] ML [3] |
| Maximizing aggregating bandwidth   | Networks capacity directly effects throughput                        | (1) Minimize interferences or retransmissions, and (2) allow the multiple rates to coexist in a network where a higher channel rate is used over each link | MIC [14] |
| Minimizing energy consumption      | A path with an unreliable link produces longer delay due to higher retransmission rates and ultimately results in an increase in energy consumption | Reduction in retransmissions during routing to optimize communication delay | MTPR [17], MBCR [18] |
| Minimizing channel/interface switching | Data flow switching on different channels results in delay       | Interface assignment strategy keeps one interface fixed on a specific channel, while other interfaces can be switched among the remaining channels; when necessary, | MIC [14], WCETT [14] |
| Minimizing computational overhead  | Computational overhead consumes memory, processing capability, and battery power | Computations should be considered that must not consume memory, processing capability, and, most importantly, battery power | InvETX [1] |
| Minimizing interference            | Intraflow and interflow interferences result in bandwidth starvation | During path calculation, capture diversity of channel assignments and link capacity | MCR protocol [14] and [14] |
| Maximizing route stability          | Instability in path weight results in drop rates                    | Load sensitivity or topology-dependent metrics solve instability issues             | Link affinity metric [19] with MCMR [20] wireless ad hoc network [21] |
| Maximizing fault tolerance/ minimizing route sensitivity | Faulty routes cause drop rates in high network flows | This problem can be solved through providing redundant information of alternative paths |                       |
| Avoiding short- and long-lived loops | Redundant links due to short- and long-lived loops resulted in more path lengths and consequently increased E2ED | (1) Minimum TTL value that eliminates mini-loops [16]; (2) fresh sequence number, etc. | OLSR in sparse WMNs [16] |
| Considering performance trade-offs  | E2ED in static networks cause drop rate                             | A suitable trade-off helps to increase efficiency                                  | ML [3] |

| **Table 1** Design requirements of routing link metric |
Also, the \( MPR(u) \) set of a node \( (u) \), a subset of \( H_1(u) \), can be defined as follows:

\[ \forall w \in H_2(u), \exists v \in MPR(u) \text{ such that } w \in H_1(v) \quad (10) \]

### 3.2 Framework of selected link metrics

While designing a routing metric, necessary computations should be considered that must not consume memory, processing capability, and, most importantly, battery power. For example, we discuss the case of three widely used QLMs for wireless routing protocols: ETX; its inverse, say, InvETX; and ML (Fig. 2).

For an end-to-end path, \( P \), these metrics are expressed by the following equations:

\[
\text{ETX}_P = \sum_{l \in P} \frac{1}{fd(l) \times rd(l)}
\]

\[
\text{InvETX}_P = \sum_{l \in P} fd(l) \times rd(l)
\]

\[
\text{ML}_P = \prod_{l \in P} fd(l) \times rd(l)
\]

where \( fd(l) \times rd(l) \) is the probability of success for delivery of probe packets (134 bytes each) on the link \( l \) on \( P \) from source to destination (forward direction) and from destination to source (reverse direction).

Regarding computational complexity, all of the three metrics have to calculate the equal number of products \( fd(l) \times rd(l) \) for the same number of links. But ETX has to suffer from more computational overhead (inverse and sum of \( n \) products) than ML (multiplication of \( n \) products only). Similarly, ML generates more computational overhead than InvETX. As a result, InvETX achieves higher throughputs than ML and ETX. Similarly, ML performs better than ETX (Fig. 3).

From [1], we analyze that routing load is a critical issue in SWMhNs when network load increases either with an increase in the number of nodes or with an increase in the

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**Fig. 1** MPR mechanism in OLSR

**Fig. 2** Computational overhead of ETX, ML, and InvETX
number of packets. As OLSR uses the shortest interval for exchanging topological information as compared to DSDV and Fishye State Routing (FSR) [23], i.e., “full-dump-period” in DSDV and IntraScopeInterval in FSR are equal to 15 s, whereas in OLSR TC_INTERVAL = 5 s; therefore, it causes more routing overhead. In OLSR, after detecting any change in MPR status, TC messages are triggered; thus, an increase in TC_INTERVAL = 15 s value does not affect the stability of route. By increasing TC_INTERVAL, routing load is reduced. Trigger updates in OLSR depend on HELLO_INTERVAL; therefore, to achieve stability in routing table, we decrease HELLO_INTERVAL: 2 s in OLSR, whereas set to 1 s in EOLS, another enhancement in EOLS is that we set window \( w = 10 \) instead of 20 [11].

4 Simulation results

We use implementation of ETX, MD, and ML with default and enhanced version of OLSR in NS2-2.34. Then, we implement the fourth metric, InvETX, as expressed by Eq. 2. In an area of 1,000 m \( \times \) 1,000, 50 nodes are placed randomly to form a static network. Constant Bit Rate (CBR) traffic is randomly generated by 20 source-destination pairs with a packet size of 64 bytes. Each simulation is run for five different topologies for 900 s each. Then, the average of five different values of each performance parameter is used to plot the graphs. To observe performance of OLSR with four metrics, we randomly generated the data traffic with the number of packets from 2 to 16 per second.

To better understand the performance trade-offs, we take an example of the SWMhNs that have two major issues: NRL and E2ED. In this type of networks, the proactive protocols are preferred due to the periodical update of network topology, like OLSR, instead of the reactive ones. Moreover, the hop-by-hop routing technique along with link state information helps OLSR to handle aggressive routing overhead, as compared to source routing. Using MPR selection along with proactive nature, OLSR reduces the number of retransmissions and thus achieves minimum delay. In the following subsections, we discuss simulation results for conventional and EOLS with respect to three performance parameters: throughput, E2ED, and NRL.

4.1 Throughput

In static networks, with varying data traffic rates, MD produces the lowest throughput, as compared to ETX/InvETX and ML. Moreover, in medium and high network loads, there are more drop rates as compared to small load in the case of MD metric. This is due to the one-way delays that are used to compute the MD routing metric with small probe packets before setting up the routing topology and not considering the traffic characteristics. It may thus happen that if no other traffic is present in the network, the probes sent on a link experience very small delays, but larger data packets may experience the higher delay or retransmission due to congestion. Thus, MD is not suitable for the static networks with high traffic load, as it degrades the network performance by achieving less throughput values. The ML in medium and high network loads produces higher throughput values because ML attains the less drop ratios, as compared to ETX. Moreover, in ML, the paths with minimum loss rates or higher probabilities of successful (re)transmissions lead to high data delivery rates, with an additional advantage of more stable end-to-end paths and less drop rates.

MD uses the ad hoc packet technique to measure the one-way delay. Then, proactive delay assurance approach is used to measure MD metric. The minimum delay metric
Fig. 4  Computational overhead, throughput, delay, and routing load by metrics
performs best in terms of average packet loss probability. In Fig. 4c, MD delay shows the lowest values among other metrics. This is due to the route selection decision based on the delay of ad hoc probes, while ETX and ML produce an increasing value of delay, when traffic increases. The very first reason is that both metrics have no mechanism to calculate the round trip, unlike MD metric. Meanwhile, in ML, selection of longer routes with high probability of successful transmission augments the delay, as compared to ETX. In default OLSR, in high traffic rates, more drop rates are noticed, as compared to low traffic rates. This is because of an increase in routing overhead due to frequent generation of TC messages. In EOLSR, we change frequency of TC message generation by increasing value of TC_INTERVAL = 15 s. This enhancement reduce congestion in the network and results in high throughput which is shown in Fig. 4b as compared to Fig. 4a.

4.2 E2ED

The ad hoc probe packets are sent by MD to accurately measure the one-way delay. Thus, low latency is achieved by selecting the path with less Round Trip Time (RTT). On the other hand, these ad hoc probes cause routing overhead in a network and decrease the throughput when the data load is high in a static network. In static networks, to measure an accurate link with less routing load is a necessary condition. The delay cost due to an increase in the number of intermediate hops is paid to achieve throughput by ML. As ML selects those paths which possess less loss rates, therefore, a longer path with high successful delivery is preferred. Thus, the product of the link probabilities selection decreases the drop rates and increases the RTT.

ETX uses the same mechanism to measure the link quality as that of ML, i.e., modified HELLO messages. However, summing up the individual probabilities and preference of the shortest path reduces the delay of ETX as compared to ML. Thus, a slow link preference results in more drop rates of ETX, as compared to ML. This sort of trade-off is common in routing protocols. While designing a link metric, if demands of the underlying network are taken into consideration, then it becomes easy to decide that among performance parameters, trade-off(s) should be made. For example, ML and ETX achieve higher throughput values than MD, as shown in Fig. 1b, whereas MD remarkably achieves less E2ED than ML and ETX which is depicted in Fig. 4c. In EOLSR, E2ED of the metrics becomes less as compared to default OLSR. In OLSR, HELLO messages are used to detect link status information. After detecting link failure, OLSR triggers TC message to update a routing table. In default OLSR, HELLO_INTERVAL = 2 s is not enough to calculate recent information, and thus, E2ED value is increased. On the other hand, HELLO_INTERVAL = 1 s results in quick update of routing table entries which consequently prevents path instabilities (Fig. 4c, as compared to Fig. 4d).

4.3 NRL

OLSR-MD suffered from the highest routing loads. Ad hoc probes are used to measure the metric values and are sent periodically along with TC and HELLO messages. On the other hand, ETX and ML calculate the probabilities for the metric from the values obtained from the enhanced HELLO messages. OLSR uses HELLO and TC messages to calculate the routing table, and these messages are sent periodically. The delivery ratios are measured using modified OLSR HELLO packets that are sent every HELLO_INTERVAL.

Each node calculates the number of HELLO messages received in a w second period (w = 20, by default) and divides it by the number of HELLO messages that should have been received in the same period (10, by default). Each modified HELLO packet notifies the number of HELLO messages received by the neighbor during the last w seconds, in order to allow each neighbor to calculate the reverse delivery ratio. The worse the link quality, the higher is the ETX link value. A link is perfect if the ETX value is 1 and its packet delivery fraction is also 1, i.e., no packet loss. On the other hand, if in a period of w seconds a node has not received any HELLO message, then ETX is set to 0 and the link is not considered for routing due to 100% loss ratio. Thus, due to no extra overhead to measure the metric, ETX/InvETX and ML have to suffer from low routing load as compared to MD. In EOLSR, for path stabilities, we have changed HELLO_INTERVAL = 1 s and value of w = 10. This enhancement results in quick update; however, we also reduce the frequency of TC_INTERVAL to reduce routing overhead which is produced by frequent emission of HELLO messages. Thus, overall path stabilities result to low routing overhead which can be seen in Fig. 1e as compared to Fig. 1f.

5 Conclusion

In this work, we select four quality link metrics: ETX, MD, ML, and our proposed metric, InvETX with OLSR. We discuss several possible issues regarding wireless networks that can better help in designing a link metric. The ambition of a high-throughput network can only be achieved by targeting a concrete compatibility of the underlying wireless network, the routing protocol operating it, and the routing metric, the heart of a routing protocol. Depending upon the most demanding features of the networks, different routing protocols impose different costs of “message overhead”
and “management complexity.” These costs help to understand as to which type of routing protocol is well suitable for which kind of underlying wireless network and then which routing link metric is appropriate for which routing protocol. A novel contribution of this paper is the enhancement in original OLSR, EOLSR, to achieve high efficiency in terms of optimum routing load and routing latency. For this purpose, first, we present a mathematical framework, and then to validate this framework, selected metrics are simulated with OLSR and EOLSR. For comparison, three important performance parameters are selected: throughput, NRL, and E2ED. From our simulation results, we conclude that by adjusting the frequencies of exchanging topological information, high efficiency can be achieved.

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