Introducing Energy Efficient QoS Enabled OLSR Protocol using Connectivity Index and Delay in MANET

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Abstract*— The Optimized Link State Routing Protocol (OLSR)is an IP routing protocol optimized for mobile ad hoc networks, which can also be used on other wireless ad hoc networks. OLSR is a proactive link-state routing protocol which uses *hello* and *topology control* (TC) messages to discover and then disseminate link state information throughout the mobile ad hoc network. The original definition of OLSR does not include any provisions for sensing of link quality; it simply assumes that a link is up if a number of hello packets have been received recently OLSR is based on the MPR (Multipoint Relay) concept to offer an efficient flooding technique and to build shortest routes. The MPR selection according to native OLSR is unable to build routes satisfying a given QoS request because it only allows shortest routes that do not take into consideration any other route metrics (bandwidth, delay …). So our approach is to find a mechanism to improve the QoS of the OLSR protocol in terms of weighted CI and delay. Weighted CI is the combined QoS metric of link capacity and connectivity. Thus, these optimized paths refer to the paths which have enough link capacity and are robust to link failures. We construct the simulation to demonstrate that the proposed algorithm can improve performances over OLSR protocol, and are also flexible enough to deliver services in highly mobility networks.

Keywords*— *MANET, OLSR, QoS, Weighted Connectivity Index, Delay, Energy

I. Introduction

Many routing protocols have been developed for ad hoc networks [1]. They can be classified according to different criteria. The most important is by the type of route discovery. It enables to separate the routing protocols into two categories: proactive and reactive. In reactive protocols, e.g. Dynamic Source Routing (DSR [2]) and Ad hoc on demand Distance Vector routing (AODV [3]), the routing request is sent on-demand: if a node wants to communicate with another, then it broadcasts a route request and expects a response from the destination. Conversely, proactive protocols update their routing information continuously in order to have a permanent overview of the network topology (e.g. DSDV [4], TBRPF [5] OLSR [6],[7]).

The Optimized Link State Routing Protocol (OLSR) is developed for mobile ad hoc networks which can also be used on other wireless ad-hoc networks. It is a proactive link state protocol, the nodes are maintains the route information in the route table, so routes are available immediately when it is required.

The source node will be alerted by the topology whenever the node mobility in the route or changes in the bandwidth then the new route should be identified. Instead of pure flooding to identify the route OLSR uses MPR [5] to reduce the number of the host which broadcasts the information throughout the network. The MPR is a node which is selected such that it covers all nodes that are two hops away. The nodes which are selected as a MPR by some neighbor nodes announce this information periodically in their control messages. In route calculation, the MPRs are used to form the route from a given node to any destination in the network.

Quality of Service Routing is at present an active and remarkable research area, since most emerging network services require specialized Quality of Service (QoS) [6], [8], [9], [10],[11] [12], [13] functionalities that cannot be provided by the current QoS-unaware routing protocols. The provisioning of QoS based network services is in general terms an extremely complex problem, and a significant part of this complexity lies in the routing layer. It is very difficult to offer QoS guarantee in ad hoc networks because of their characteristics like dynamic topologies and bandwidth-constrained [14],[15],[16],[17]. In this work, we propose an effective algorithm to compute the feasible path by using Connectivity Index (CI) and delay to provide hop-by-hop QoS routing in ad hoc networks in OLSR since it doesn't have any quality for sensing the link quality . CI is routing metric which indicates connectivity of each node in ad hoc networks; large value of CI indicates more branch node which makes a node more robust to link failure.

II. RELATED WORKS

A. Overview of OLSR

OLSR protocol [6],[18] inherits the stability of link state algorithms. Due to its proactive nature, it has an advantage of having the routes immediately available when needed. In a pure link state protocol, all the links with neighbor nodes are declared and are flooded in the entire network. OLSR protocol is and optimization of a pure link state protocol for mobile ad hoc networks. First, it reduces the size of the control packets: instead all links, it declares only a subset of links with its neighbors who are its multipoint relay selectors. Secondly it minimizes flooding of this control traffic by using only the selected nodes, called multipoint relays, to diffuse its messages on the network. The idea of multipoint relays is [1] is to minimize the flooding of broadcast packets in the network by reducing duplicate retransmissions in the same region. Hence, OLSR itself does not support QoS. Many research works were proposed in a decade to offer QoS in OLSR by enabling hop-by-hop QoS routing. In hop-by-hop QoS routings, each node applying these algorithms calculates its own local state information and distributes them to other nodes for using in path computation process to find global state information of the networks. These research works are described below.[2] Consider "bandwidth" as the QoS routing constraint. That is because bandwidth guarantee is one of the most critical requirements of real time applications. Their goal is to find an optimal bandwidth path – the one has the highest bottleneck bandwidth among all the paths from source to destination. However, bandwidth computation is a complex issue.

Many papers such as [3] discuss how to compute bandwidth in ad-hoc networks. In research work [19] proposes to perform at each node an estimation of the bandwidth share between all adjacent nodes and tends to ensure the selection of a path with all MPRs that provide a higher bandwidth along the path. The bandwidth share estimation on each link is based on the study of conflict graphs to derive the set of maximal cliques. Once the bandwidth share estimation is done, instead of choosing the shortest path following the usual heuristic in OLSR, they try to find the path that ensures the highest bandwidth among all possible paths between the source node and the destination node. General Electronics Company and colleagues [20], create a model of OLSR protocol based on bandwidth of the status link in terms of service quality criteria. This protocol tries to find routes that have the highest bandwidths in bottlenecks. To provide a better service quality (i.e. to provide the route with optimum bandwidth), it is necessary to broadcast the bandwidth changes to calculate the best route with bandwidth correctly.[21] research in order to improve quality requirements in routing information, delay and bandwidth measurements are applied. The implications of routing metrics on path computation are examined and the rationales behind the selection of bandwidth and delay metrics are discussed [22].

III. METHODOLOGY

A. Heuristic for Optimized Path Selection

According to native MPR computation process used in OLSR, each MPR selector will mainly select nodes to be MPR nodes if they provide the maximum number of reachability to its 2-hop neighbors. The purpose of this native MPR algorithm is to optimize number of control overhead by minimizing the number of MPR nodes. Thus, better paths may be hidden since only MPR nodes are allow to forward routing information (only partial graph of network are known to each node) [23].

Thus, this section describes about the proposed heuristic for MPR selection process to allow nodes as MPR selectors to find the MPR nodes based on weighted CI and delay (see Fig. 1). The following terminology will be used in describing the algorithms:

- $MPR(x)$: A set of neighbors of node x which are selected as MPR.
- $N1$: A set of 1-hop neighbors.
- $N2$: A set of 2-hop neighbors.
- $D(y)$: The degree of a 1-hop neighbor of node y (where y is a member of $N1$).

The proposed MPR heuristic applied to each node x in network G is shown in Fig.1. In this algorithm, MPR selector will select nodes to be MPR nodes if they are the only node which provides the reachability to its 2-hop neighbor in step 3. In step 4, MPR selector selects nodes which have the highest value of weighted CI link from itself to its neighbors as MPR nodes. If there is a tie (two or more nodes with the same value of weighted CI are found), nodes which provide the shortest delay link to its neighbors will be chosen. In addition, if there is another tie, a node which provides the maximum number of uncovered nodes of 2-hop neighbors will be selected as MPR nodes [24].

Heuristic MPR($G = (V, E)$; $N1, N2, MPR(x) \subset V$)
Step 1) Initially, **set** $MPR(x) = \{\}$
Step 2) **For** all nodes in $N1$, **calculate** $D(y)$, $\forall y \in N1$
Step 3) **Add** 1-hop neighbor nodes in $N1$ to $MPR(x)$ which provide the only path to reach some nodes in $N2$
Step 4) **While** there exist nodes in $N2$ which are not covered by at least one node in the $MPR(x)$:
  Step 4a) **For** each node in $N1$, **calculate** numbers of nodes in $N2$ which are not yet covered by at least one node in MPR set
  Step 4b) **Add** node in $N1$ that provide the highest weighted CI and shortest delay link to $MPR(x)$
  Step 4c) **If** tie case occurs in above step **then** **Add** node with maximum number of uncovered nodes in $N2$ to $MPR(x)$

Fig.1 : Heuristic for MPR Selection Process

B. *Weighted Connectivity Index*

In this work, we propose to use CI of node, defined as the CI of sub-graph originating at each node, to illustrate the link characteristic of every node in the network. It is shown in [25] that the higher value of CI means the better link connectivity of mobile node in ad hoc network. This implies that nodes with lower link connectivity have higher probability to cause link break in the connecting paths since they may move out of the coverage area of their neighbors. Of course, this leads to increasing dropped packets caused by disconnected links which also affects throughput. Thus, it can be anticipated that the network performances such as throughput and packet delivery ratio can be improved if link connectivity is put into account in path selection process.

In wireless networks, link capacity (available channel bandwidth) indicates transmission capacity of data. This implies somewhat that the higher the link capacity is, the stronger the link connectivity becomes. Therefore, by considering the connectivity index of node, the combined merit of degree of nodes and link capacity can be achieved. In [26], we proposed new QoS routing metric called weighted CI of node which is defined as the Randi´c [27] Index of sub-graph modified to accommodate the link capacity. We verified that weighted CI can be effectively used as the QoS routing metric to improve the network performances.

However, this CI does not specify anything related to link capacity. Thus, weighted Connectivity Index is introduced in [28] to combine both link connectivity and link capacity into mixed QoS metric as defined in equation (1).

The weighted CI of any nodes i in graph G can be computed by partitioning the network graph G into sub-graph $G_n{-}hop\ i$ covering only nodes and links within n-hop from node i. Let u and v represent nodes in a set of $V_{n}{-}hopi$ and each link (u, v) is in a set of $E_n{-}hopi$. The n-hop weighted CI of node i or $X_w(G_n{-}hopi)$ can be defined as

$$\chi_w(G_i^{n-hop}) = \sum_{(u,v)\in E_i^{n-hop}} \frac{q_{(u,v)}}{\sqrt{d(u)d(v)}} \qquad \textbf{(1)}$$

where $q(u,v)$ $(0 \le q(u,v) \le 1)$ is normalized link capacity and when $q(u,v) = 0$ refers to " unavailable link". In this research work, ratio of local available bandwidth to total bandwidth is used as the link capacity. Thus, $(i,)$ =0 means *disconnected* or *unavailable link* in congested network, and weighted CI in above equation can be replaced by

$$\chi_w = \chi_w(G) = \sum_{(i,j)\in E} \frac{minBW_{(i,j)}}{\sqrt{d(i)d(j)}} \qquad \textbf{(2)}$$

Where $min(i,j)$ is minimum or bottleneck available bandwidth between node i and j [29].

C. *Delay Metric*

In our proposal extension, a delay parameter will be calculated to improve the selection of the best path by the proposed routing algorithm. Each node includes in the Hello message, during the neighbor discovery performed by the OLSR, the creation time of this message. As mentioned before, we suppose a synchronized network. When the Hello message arrives in a neighbor node, the delay between the sender node and received node is calculated. The information about the neighborhood will be stored in the neighbor table, as proceeded in the OLSR standard, but in our proposal, we include the necessary delay to the sender node reaches the received node. Such procedure will be execute for all Hello messages without include any additional message to the routing protocol. Some other proposed Delay enhancement is shown in [10],[30],[31],[32].

IV. SIMULATION RESULTS

In this section, we provide and compare the simulation results , illustrated with 95 % confident interval, of our proposed WCID-OLSR protocol with the standard OLSR protocol by using NS-2 simulator [33].

A. *Simulation Parameters and Network Models*

TABLE I. Simulation Parameters

Parameters	Effect on node density	Effect on node mobility
Area (m^2)	1050 x 600	
Channel Capacity (Mbps)	2	
No. of Nodes (connections)	5(2), 10(4), 15(8),20(14), 25(19),30(26),42(30).	42(30)
Movement Speed (m/s)	2	1 - 30
Pause Time (s)	0	
Traffic Type	CBR	
Packet Size (bytes)	512	
Traffic Rate per Connection (kbps)	100	
Total Simulation Time (s)	20	
Mobility Model	Random Way Point	
No. of Executions/ Scenarios	15	

TABLE II. Parameters of Energy Module of NS2

Parameters	Values (J)
Initiating Energy	100
Idle Power	1.0
Tx Power	1.0
Rx Power	1.0
Sleep Power	0.01

B. Performance Evaluation Metrics

The following four metrics are used to evaluate the performance of all algorithms:

- **Throughput**: the amount of data bit successfully transmitted over the network in a unit time.
- **Packet Delivery Ratio (PDR)** : the ratio between the total number of data packets received by destinations to total number of packet sent by sources.

Average End-to-End Delay: the average amount of time taken by all packets to reached the destination.

C. Effect of Node Density

The effect of node density with performance evaluation metrics are shown below.

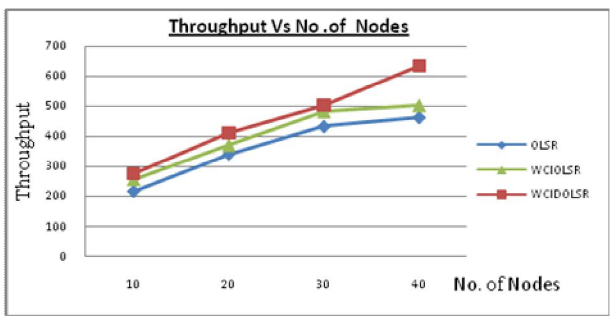

Fig.2 : Throughput Vs No. of Nodes

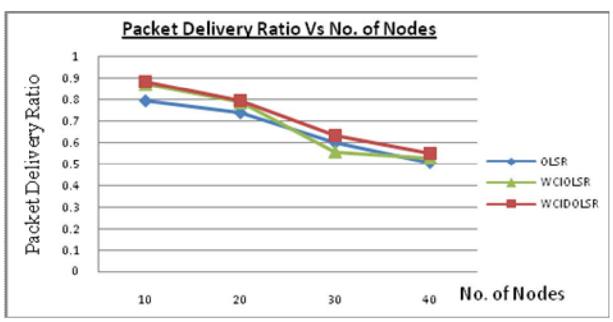

Fig.3 : Packet Delivery Ratio Vs No. of Nodes

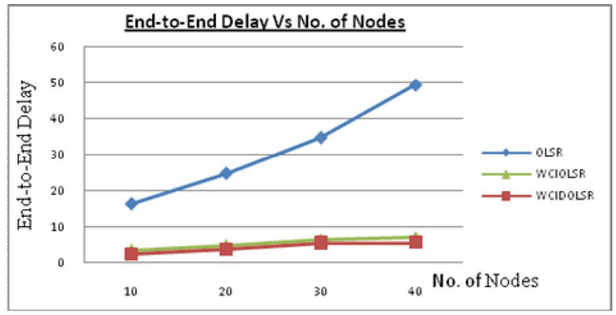

Fig.4 : End-to-End Delay Vs No. of Nodes

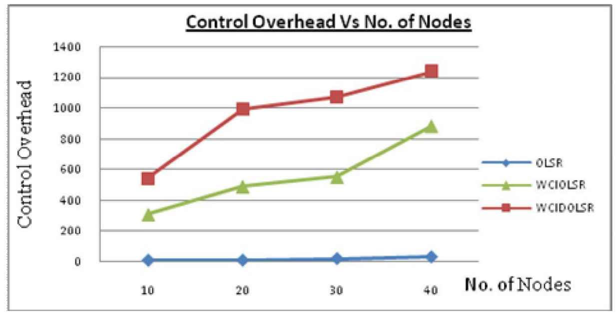

Fig.5 : Control Overhead Vs No. of Nodes

As shown in Fig.2, the proposed WCID-OLSR performs better than standard OLSR and OLSR with only weighted CI, when the node density is high. The proposed method selects the MPR nodes and identifies the best route based on low Delay and high weighted CI. Therefore, when the number of nodes increases, the node's degree also increases and the distance between the nodes decreases. This result in low Delay and increases the degree of neighbors around a node which reduces the link loss. Therefore, the proposed WCID-OLSR provide high Throughput at a high node density. When number of nodes are small in the network, the transmission range is increasing and that leads to data loss. That results in low Throughout. OLSR with only weighted CI (WCI-OLSR) performs a little bit better than standard OLSR, because it is based on QoS metrics of weighted CI and it select most feasible path to transmit route information. However it performs lower than WCID-OLSR, since WCI-OLSR find most feasible path using weighted CI.

Fig.3, shows Packet Delivery Ratio of proposed WCID-OLSR and it is performs better than standard OLSR. When more CBR packets are generated into the network, since the congestion occurs and some packets are discarded when there is no more space for buffering the incoming packets. Proposed heuristic consider highest weighted CI and lowest Delay in path finding process. Therefore, weighted CI and Delay are guaranteed which results in higher packet deliver ratio comparing to OLSR. However, the WCID-OLSR has higher PDR than the WCI-OLSR and the Standard OLSR protocol since more feasible paths is selected in terms of weighted CI and lowest Delay. Thus, each node implementing this heuristic can select the paths to any reachable nodes which have stronger connectivity and results in higher packet delivery ratio.

Fig.4, highlights the improvement of proposed WCID-OLSR in terms of end-to-end delay over OLSR and WCI-OLSR. The delay increases when the node density is high which causes the congestion due to the processing of large number of control packets. Both WCI-OLSR and WCID-OLSR protocols is improved the end-to-end delay by considering Weighted Connectivity Index as one of QoS routing metric. However, WCID-OLSR has slightly lower delay than WCI-OLSR (up to 8.56 % at heavy load situation) since delay parameter which is another additive QoS metric, is also considered in path finding process. Thus, WCID-OLSR has the ability to avoid the congesting path and experiences to the lowest end-to-end delay.

Fig.5, depicts the control overhead of proposed WCID-OLSR, WCI-OLSR and the standard OLSR. It is obvious that control overhead generated by our proposed algorithm (WCID-OLSR) is the highest when offered load increases due to the increasing number of Hello and TC messages flooded to collect the node's degree. The Control Overhead of OLSR with weighted CI is higher than standard OLSR but lower than WCID-OLSR since, similarly, the number of Hello and TC messages needed to collect the nodes' degree is smaller than WCID-OLSR but higher than standard OLSR.

D. Effect on Node Mobility

The effect of node density with performance evaluation metrics are shown below.

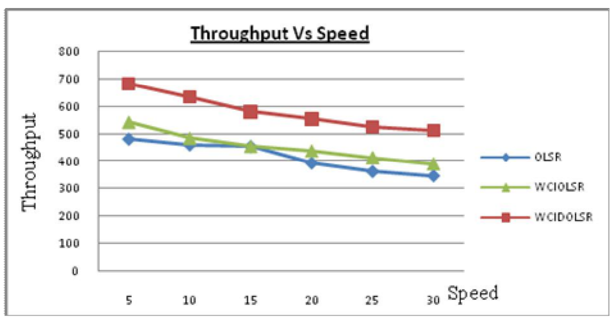

Fig.6 : Through Vs Speed

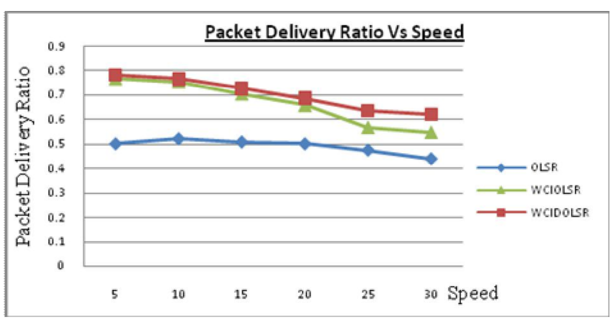

Fig.7 : Packet Delivery Ratio Vs Speed

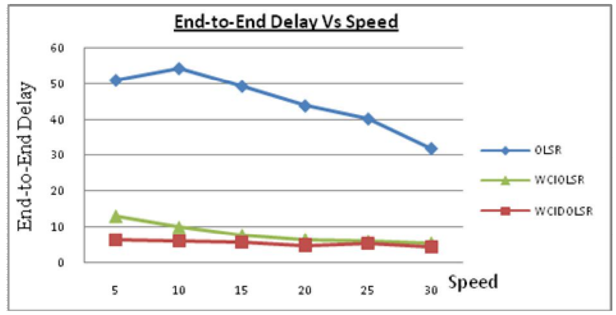

Fig.8 : End-to-End Delay Vs Speed

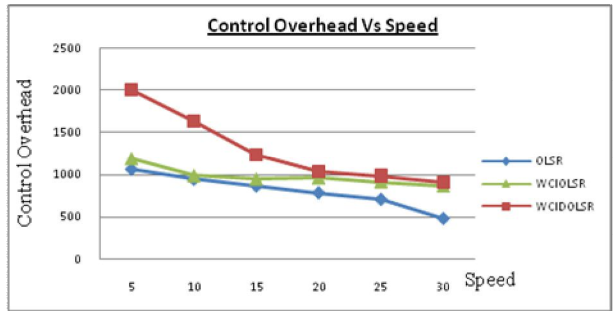

Fig.9 : Control Overhead Vs Speed

Fig.6, demonstrated Throughput of proposed WCID-OLSR and standard OLSR protocols. Our proposed WCID-OLSR protocol is perform better than standard OLSR protocol. When the speed increases throughput of all algorithms decreases, when movement speed increases since the links between nodes are usually broken. However, the OLSR with weighted CI and delay (WCID-OLSR) has highest throughput than the OLSR with only weighted CI (WCI-OLSR) it consider weighted CI and lowest Delay. But, WCI-OLSR is perform better than the standard OLSR since it consider Weighted CI.

Fig.7, demonstrated Packet Delivery Ratio of proposed WCID-OLSR and it is perform better than standard OLSR protocol. It also due to the links between nodes are broken. However, the WCID-OLSR has higher PDR than the WCI-OLSR and the Standard OLSR protocol since more feasible paths is selected in terms of weighted CI and lowest Delay. Thus, each node implementing this heuristic can select the paths to any reachable nodes which have stronger connectivity and results in higher packet delivery ratio.

Fig.8, Average End-to-End delay of proposed WCID-OLSR and it is perform better than standard OLSR protocol. Delays of both WCID-OLSR and WCI-OLSR are less than OLSR since the links are more stable by effect of the Weighted CI. It implies that how strong the link connections of the nodes are. Thus, the paths with highest Weighted CI obtains highest stability which results in lower end-to-end delay.

Fig.9, shows control overhead of WCID-OLSR and it decrease when the speed is increases. Obviously the links can be broken due to the mobility. It causes dropping of the number of routing packets and delivered packets. The proposed WCID-OLSR has higher control overhead since it has more MPR nodes which generate more packets. Thus, it provide more traffic to the network, resulting higher control overhead.

E. Energy Consumption

Energy efficient routing is most important due to fact that all the nodes are battery powered. Failure of one node may affect the entire network. If a node runs out of energy the probability of network partitioning will be increased. Since every mobile node has limited power supply, energy has become an important resources for mobile ad-hoc networks and efficient communication between nodes depends on the network lifetime. Some proposed methods for energy efficient protocol are listed in [34], [35], [36], [37], [38],[39],[40]

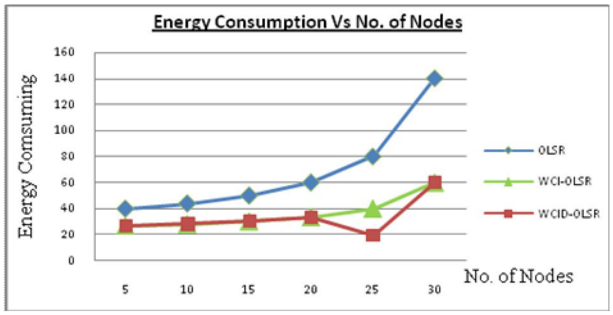

Fig. 10 : Energy consumption Vs No. of Nodes

In Fig.10, shows that proposed WCID-OLSR performs better than standard OLSR protocol. When number of nodes increases the more packets are send by a particular node also increases. In order to sent more TC and Hello messages more energy is required. Therefore, when node density is increasing energy consumption also increasing. But compared to standard OLSR our proposed heuristic consume low energy. However, WCID-OLSR is consume less energy than WCI-OLSR which is only with weighted CI. Both WCID-OLSR and WCI-OLSR are seem to be same on the Fig. 10, but there is a slight improvement in WCID-OLSR since it using highest weighted CI and lowest Delay.

V. CONCLUTION

In this paper, WCID-OLSR is proposed to incorporate QoS routing with OLSR into mobile ad hoc network by considering both additive and non-additive QoS parameters in path computation process. The weighted Connectivity Index (combined parameter of link connectivity and capacity) and delay are proposed as non-additive and additive QoS metrics to be used in this type of network, respectively.

In WCI-OLSR, multiple QoS parameters are effectively combined and considered in path finding process. It can find the feasible paths satisfying multiple QoS constraints which are differently required by various applications. Since link connectivity is one of QoS parameters that is taken into account in selecting paths, therefore, ad hoc networks implementing WCI-OLSR are more robust to link failures and are capable to operate in highly mobility network.

In simulations, we compared performances of the proposed WCID-OLSR with some routing algorithms namely, OLSR and WCI-OLSR using CBR traffic. We can conclude that WCID-OLSR performs better than OLSR in terms of throughput, Packet Delivery Ratio, end-to-end delay and Control Overhead regardless of the node density and node speed. It also gains lots of advantages over Standard OLSR in terms of energy of finding the feasible paths efficiently.

In this research, when weighted CI of both highest value links are different then the delay part is not taken into account and packets are send though highest Weighted CI path. When Weighted CI of both highest value links are same, then the Delay part is taken into account and the Algorithm select lowest Delay path and packets are send through that path. In this research we did not considered about the situation, when both links have same Weighted CI and same Delay. That part reserved for the future works.

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