COMPUTER SCIENCE LETTERS

www.csl.issres.net

Vol. 1 (1) – June 2009

A Review of Delay Aware Routing Protocols in MANET

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ABSTRACT

Delay aware routing protocols make path selection between source and destination based on the delay over the discovered links during routing discovery and routing table calculations. Conventional routing protocols such as AODV, DSR and OLSR use minimum hop count or shortest path as the main metric for path selection. However, networks that require high Quality of Service (QoS) needs to consider several criteria's that could affect the quality of the chosen path in packet forwarding process. This study presents a review of existing delay aware routing protocols looking at their proposed solutions features, which could be very useful for future improvement.

Keywords: Mobile Ad-Hoc Network, Delay aware, QoS, Routing protocols.

1. Introduction

A Mobile Ad Hoc Network (MANET) is a network consisting of a set of mobile hosts capable of communicating with each other without the assistance of base stations [1]. MANET represent complex distributed systems that include mobile nodes that can dynamically self organize into arbitrary ad-hoc network topologies, allowing people and devices to seamlessly work in areas with no preexisting communication infrastructure such as, disaster recovery environments. Peoples and vehicles can thus be internetworked in areas without a preexisting communication infrastructure or when the use of such infrastructure requires wireless extensions [2]. In view of the fact that MANET is an autonomous system of functionality equivalent mobile nodes, which have to be able to communicate while moving without any kind of wired infrastructure. To this end, mobile nodes must work together to provide the routing services.

In mobile ad hoc networks there are no dedicated routers. Each node operates as a router and transmits packets between source and destination. The node within the transmission range of the source node and is not the destination node, accepts the packet sent by the source and forwards it along the route to the destination node.

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A number of MANET routing protocols have been proposed in the last decade. These protocols can be classified according to the routing strategy that they follow to discover route to the destination. These protocols perform variously depending on type of traffic, number of nodes, rate of mobility, etc [3]. Routing protocols are classified into 3 categories. Those are Proactive protocols, Reactive protocols and Hybrid protocols. Proactive protocols also known Table-Driven Protocols, maintain routes to all nodes, including nodes to which no packets are sent. They adjust well to topology changes. Reactive protocols also known On Demand protocols, consider the demand for data transmission. Determine the routes between hosts only when they are needed. This can reduce routing overhead. Hybrid protocols combine both proactive and reactive protocol properties to come up with a better routing protocol for well-organized packet routing [4, 5].

Limited resources in MANETs made a very challenging problem that is represented in designing of an efficient and reliable routing strategy [4]. A routing strategy is required to use the limited resources efficiently while at the same time being adaptable to the changing network conditions such as: network size and traffic density. The most well known way of finding the best path from source to destination by routing protocols is the minimum hop count or shortest path, and such a selected path not always the best path to deliver data need high QoS metrics. Thus, the routing protocol may need to offer different way or method to select the path such as on the available QoS metrics on the discovered paths.

As known by definition the Quality of Service (QoS) [6] is a set of service requirements to be met by the network while transporting a packet stream from the source to the destination. Intrinsic of the notion of QoS is an agreement or a guarantee by the network to provide a set of measurable of prespecified service performance constraints for the user in terms of end-to-end delay, delay variance (jitter), available bandwidth, and probability of packet loss. Transferring real-time traffic over MANETs is a big challenge due to the high requirements of bandwidth, time delay, and latency for such traffic. This requires the offering of guaranteed service quality.

Many protocols and enhanced techniques for existing MANET's routing protocols have been proposed by the researchers to enhance the QoS for MANETs, some of them focused on selecting the path depending on the QoS metrics such as delay, bandwidth, and battery power, but few of them focused on delay aware protocols. Delay aware protocol is a kind of protocols that take into account delay metric of the discovered links between source and destination in the route discovery process. This metric will be recorded inside the routing table, and it will be used to select the path that carries the lowest value of delay to use it as an active route between the source and destination instead of minimum hop count or other metrics. Selecting such paths make the stream of data and especially the real-time stream better in terms of less delay for delivered data. And as mentioned above the route with minimum hop is not usually the best route in terms of QoS metrics.

Delay defined as the total latency experienced by a packet to traverse the network from the source to destination. Delay over MANETs has many types such as routing delay, which is the required time to find the path from source to destination. A compression and decompression delay, which is related to transmitting audio files. Processing delay, this occurs while the node processes the packet for transmission. Propagation delay, related to propagating bits through wireless media. End-to-end Delay, which is the total time, requires for one bit traversing from source to destination. Media Access Delay, Acknowledgment and Retransmission delay, And Delay jitter [7].

The problem with current routing protocols is they did not build to support the QoS metrics, so the delay aware protocols are proposed to overcome this problem and take into account the delay metric as the main metric to choose the path from source to target.

The rest of this article is ordered as follows. In section 2, the delay aware proposed protocols on AODV, DSR and OLSR are presented. Metrics for performance comparison of the proposed protocols are presented in section 3. And section 4 concludes this article and gives some future directions.

2. Delay aware techniques on reactive routing protocols

2.1. Delay aware techniques on AODV

To provide quality of service with AODV, Perkins and Belding-Royer [8] proposed QoS-AODV protocol with some extensions that can be added to the used messages during route discovery. These extensions help in selecting the best path from source to destination in terms of delay and bandwidth. When a source broadcasts a Route Request (RREQ) control to search for a route to the destination the message will includes Maximum Delay extension, that indicates the maximum number of seconds acceptable for a transmission from the source (or from an intermediate node forwarding the RREQ) to the destination. While in RREP message delay has different meaning, it indicates the current estimate of cumulative delay from the intermediate node forwarding the RREP to the destination as shown in Figure 1.

For supporting QoS routing in AODV, the routing table has been modified and the (RREQ) and (RREP) messages as well. Four fields added to the routing table entry related to each destination. The fields are: Maximum Delay, Minimum Available Bandwidth, List of Sources Requesting Delay Guarantees, and List of Sources Requesting Bandwidth Guarantees.

In this technique the intermediate node compare its NODE_TRAVERSAL_TIME to the (remaining) delay indicated in the Maximum Delay Extension before forwarding the RREQ. And if it founds the delay is less, the node must discard the RREQ and not process it any further. Otherwise, the node subtracts NODE_TRAVERSAL_TIME from the delay value in the extension and keeps on processing the RREQ as stated in [9].

The delay field in the RREP that originated by the destination in response to RREQ the Maximum delay Extension is initially set to zero, as this RREP going back to the source each intermediate node add its own NODE_TRAVERSAL_TIME to the delay field and then records this delay value in the route table entry for that destination before propagating the RREP.

After establishing a route (i.e., from source to destination), any node along the path notices that the requested Quality of Service parameters such as NODE_TRAVERSAL_TIME or a decrease in link capacity can no longer be retained, that node must originate an ICMP QOS_LOST message back to the node which had originally requested the now unavailable parameters. The QOS_LOST message is forwarded to all sources possibly affected by the change in the QoS parameter. These sources are the same sources to which a RREP with a QoS extension has been forwarded before. As a part of the route table entry, recall that these sources are recorded in a list in this route table.

This study proposes only two QoS metrics delay and bandwidth. Other QoS metrics are added to a newer version of this protocol, including Maximum Jitter that provides information about the cumulative jitter that has been experienced by the nodes along the path from the initiating node to the node currently handing out the RREQ. Details of this work can be found in [10]. And the security considerations not introduced in this study.

A delay aware protocol has been proposed by Boshoff and Helberg [11], called Delay Aware AODV Multi-path (DAAM). It is a combined selective and modified component of QoS-AODV [9] and AODV-Multipath [12] which is a modification to a popular ad hoc routing protocol AODV, to enable the computation of multiple node-disjoint paths without incurring the overhead generated by link-state routing methods. During the discovery for routes from the source to destination the delay of each route is recorded. The type of data contained in the packets that arrives at the routing layer from the application layer is classified according to the Type-of-Service (ToS) field in the IP header and a delay request is assigned accordingly. This will be used to determine whether the new route is appropriate for a certain traffic type or not.

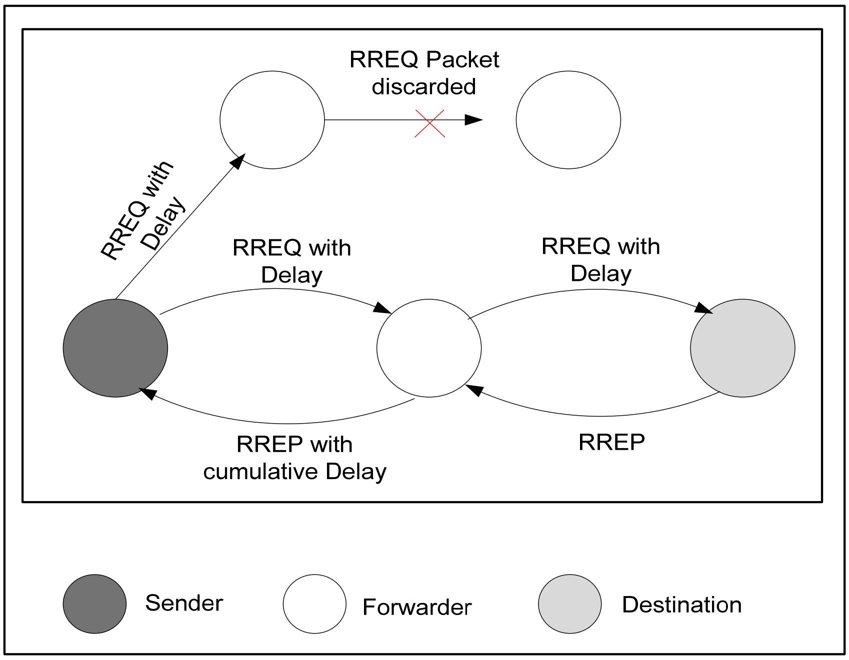

Figure 1 the Illustration of QoS-AODV protocol.

To add the delay field in which the cumulative delay up to the node processing the packet is recorded, the RREQ and RREP messages are modified. And in the route table, each route entry will be stored with delay value that obtained during the route discovery. The route in this protocol is only used if the route delay (i.e., delay offered by the route) is equal or less than the requested delay by each packet.

The nodes on the active route compare the link delay determined from a received Hello message (which is broadcasted locally each HELLO_INTERVAL milliseconds to offer connectivity information) with a delay threshold which is permitted per link, and if it is more than the threshold value, the link is no longer used. It is assumed that such a link can no longer provide the requested QoS.

The work for this protocol has been done using OPNET modeler to perform network simulation where two scenarios are configured. One is configured to be static and the other one mobile. Two kinds of traffics were set VoIP and video conferencing. The performance of DAAM protocol is compared with AODV, DSR, DYMO, and OLSR. This simulation shows that DAAM managing acceptable delay among other protocols including AODV. The problem with DAAM is that route delay information might not always be up to date as mentioned in this study. The efficiency and functionality of DAAM did not compare to other QoS protocols and the authors recommended this as a future work.

In Sánchez-Miquel [13], the authors propose an enhancement on AODV to select the suitable path during route discovery in terms of energy and delay. Two parameters have been maintained by the Energy and Delay-Constrained (EDC) routing algorithm; Residual battery power, that indicates the capabilities of a node to forward more new traffic, and Current size of the queue which is exercised at each node to limit the end-to-end delay of the data packet. Since end-to-end delay composed of many kinds of delays, the congestion of queues on nodes will increase the delay and that will affect the end-to-end delay at the end. So, buffer information has been made as an important metric in the process of finding the path. This technique carried out using ns-2, and a performance comparison between AODV and EDC-AODV has been carried out as well, and shows EDC-AODV performs better than AODV when end-to-end delay is regarded.

Asokan and Natarajan [14] added two fields with AODV routing table for each entry; the minimum energy and maximum delay. A source requiring those two extensions transmits a route request (RREQ) packet with QoS energy and delay extension. The extension of delay gives the maximum delay permitted between the source and destination.

The mechanism for this technique is as follows; before forwarding the RREQ packet an intermediate node compares its available energy to the energy field indicated in the QoS extension. If node energy is less than QoS energy then the packet will discarded, otherwise it will be pass to next assessment. The next assessment represents the delay estimation, if it exceeds the QoS delay, it will discard the packet; otherwise the node subtracts its node traverse time (NTT) from the delay bound provided in the extension. In this protocol the delay value has different meaning in RREQ and RREP. Where in RREQ packet it indicates the delay allowed for a transmission between the source and destination. While in RREP packet it represents the cumulative delay estimation allowed for transmission between the intermediate node which forwards the RREP and destination. The destination responses to the RREQ QoS and reply with estimated delay and energy, this estimation values will be recorded in the routing table for the destination.

In this paper the delay and energy extensions have been added to both AODV and DSR. For the EDAODV which is the modified AODV with delay and energy extensions, each RREQ packet that flooded in the network builds up the cost for the path crossed so far by the packet. Each entry of the routing table maintains energy and delay for that route as well. The use of these new metrics needs

AODV acts on all duplicate of RREQ packets received via alternate routes if they carry lower cost metrics, because in regular AODV they are ignored. If the node who receives the RREQ with lower cost metrics is not the destination node and does not have the route to destination it will forward the packet otherwise it will reply.

The simulation for this protocol carried out using ns-2. Some metrics used to evaluate this protocol like; packet delivery ratio, end-to-end delay, remaining energy. And a comparison with AODV has been done and showed that EDAODV has better performance in terms of end-to-end delay and other measured metrics. As this study shows that EDAODV and EDDSR working on routing layer and exploit only route specific information. The study recommends exploring the use of MAC layer and other layers information for future work.

2.2. Delay aware technique on DSR

The same study [14] proposed almost the same technique that they used with AODV to work on DSR. In such work the delay and energy metrics were added to the route discovery messages and this protocol named EDDSR. Node who receives route request will search within its route cache to this destination with the specified energy and delay. If both metrics values satisfied with the values in node’s route cache the packet will be forwarded else it will be discarded.

A simulation has been carried out to implement this protocol (i.e., EDDSR) and test its performance using ns-2 simulator, and some metrics also have been used to evaluate this protocol like; packet delivery ratio, end-to-end delay, remaining energy. And the comparison for this protocol compared to original protocol DSR has been shown in that paper. EDDSR showed that it has better performance than DSR.

In [20] the authors proposed an on-demand routing scheme called Split Multi-path Routing (SMR), which selects two paths from source to destination. The first path selected with shortest delay, which is determined on the first RREQ packet received by the destination node. The path with shortest delay was used to minimize the route acquisition latency required by reactive routing protocols. The protocol works as follows; the RREP will be send by destination on this path (i.e., with shortest delay) back to the source. Destination will wait for new RREQ and it will learn all possible routes to select the second route to the source that maximally disjoint with the first route that already replied. Selecting the first path with shortest delay makes the data delivery better. Proposing two routes in this paper is to avoid congestion on the network while sending traffic from source to destination and to avoid route recovery when the active route disconnect.

The simulation carried out for this scheme using Global Mobile Simulation (GloMoSim) Library, it shows better performance of SMR compare to DSR in terms of end-to-end delay and packet loss.

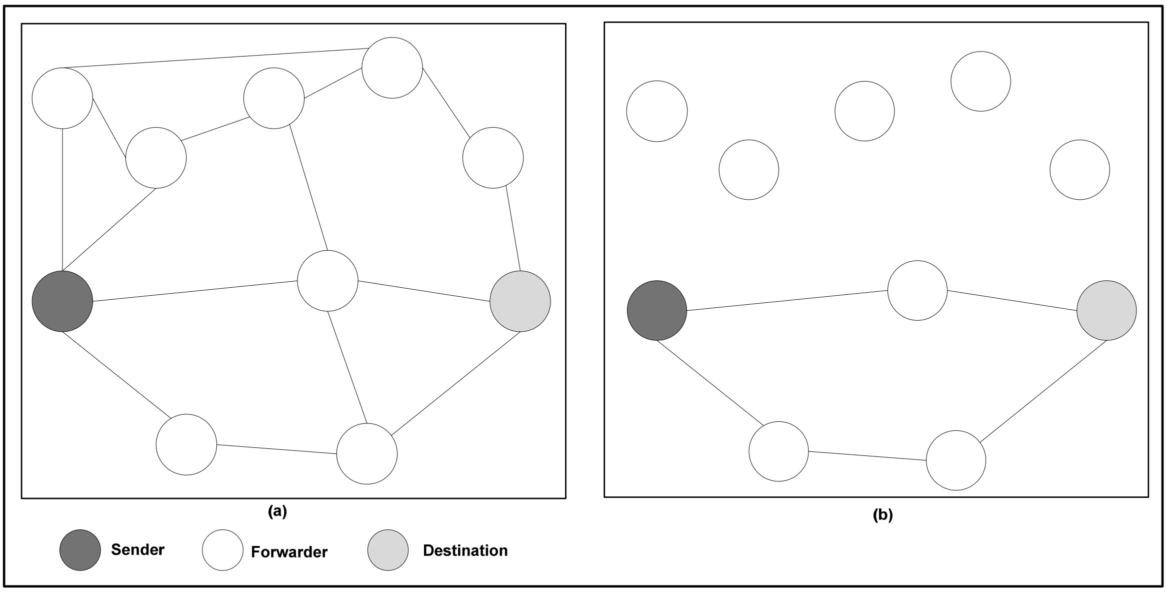

Figure 2 (a) broadcast path query message. (b) Selecting two paths between source and destination.

3. Delay aware technique on proactive routing protocols

3.1. Delay aware technique on OLSR

The basic algorithm underlying routing table calculations in the Optimized Link State Routing (OLSR) protocol selects the minimum hop path between source and destination node without concern for the link quality (e.g. delay). Authors in [15] proposed a method of determining the quality of the path in MANET before building the routing table in OLSR. The protocol enhanced by looking for the min-hop and taking into account the links delay metric. The received delay characteristics will be recorded in routing table to be used in the selection of the suitable path.

This method stated that a node after determining the average Medium Access Delay for each of its links to neighboring nodes will includes this delay in a link-state advertisement. When the nodes receives advertised media access delay that companion the link-state advertisement and it has a value less than the threshold (within the acceptance value) it will appear in the routing table when the protocol will do its routing table computations. The nodes who determined its media access delay for its links, will convert these average delay values into length metrics, and each link consider active by OLSR will include in its link-state advertisements these delay metrics.

In [17] authors designed a QoS routing scheme over OLSR protocol, called QOLSR. Delay and bandwidth measurements are applied in order to improve quality requirements in routing information. Delay and bandwidth metrics are included on each routing table entry corresponding to each destination. The approach of choosing the path with best bandwidth and delay is to treat each metric individually. The strategy in this paper is to find a path with maximum bandwidth (widest path) and if there is more than one path with maximum bandwidth the one with lowest value of delay will be chosen.

During QOLSR neighbor discovery, the creation time of each HELLO message is included by each node in this message. When HELLO message reaches a neighbor node, it calculates the difference between such a time and the current time that represents the measured_delay. The one-way measured_delay consist of the transmission time, the queuing time, the collision avoidance time and the control overhead time. A synchronized network was used in this study due to that the measurement of one way delay avoids the increase of traffic load at adding acknowledgment messages to the QOLSR protocol. Two proposed methods of calculating delay were presented in this paper, the first one Average delay and variance method (AV) during routing calculations which proposed in [18]. The second one is RTT, which is used in [17] to calculate the one way delay.

The performance evaluation of QOLSR carried out with OPNET modeler, and the results showed the high performance of the QOLSR compare to OLSR. Detailed information about QOLSR protocol can be found in [16], which includes the detailed actions of this protocol and proposes to use some other QoS metrics to choose the best path such as jitter and packet loss.

Predicting and evaluating of the mean queuing delay using neural network methods and using the predicted delay as routing metric is presented in [19]. The extended version of OLSR in this paper named OLSR_NN, where NN stands for neural network. For each fix length interval, every node in the network calculates its mean queuing delay and uses them to train the neural network. Retraining the neural network periodically is important in order to be adapted to the network dynamics. The predicted delay will be attached to Topology Control (TC) message and broadcasted. The node that receives this TC message will retrieve the predicted delay and use it in routing table calculations. The algorithm that has been used to calculate node-state routing table calculations is called TierUp, which is derivative of Dijkistr’s algorithm to utilize the predicted delay as a routing metric proactive routing protocol in MANET. This paper shows that the computational complexity for TierUp algorithm is less than Dijkistr.

Overall, the simulation results for this paper were carried out by ns-2 shows that OLSR_NN performs better than OLSR in terms of reducing end-to-end delay and increasing data packed delivery ratio and authors claim that OLSR_NN at the mean time maintain the overall throughput at the same level or even improve it. Several future work directions were proposed by the authors of this study, such as using advanced neural network technologies to predict the mean queuing delay may be predict with sufficient accuracy, so the routing decision maker will have a reliable view of the congestion condition.

Authors in [21] proposed Link Quality aware Optimized Link State Routing (LQOLSR), which is a protocol that makes route selection between source and destination based on transmission delay between nodes. Selecting such routes needs to calculate the delay using a metric that represents the transmission delay and this paper used Mobility Adaptive Transmission time (MATE) as a metric to represent delay and calculated this delay by mobility adaptive delivery rate (MAPDR) with transmission time in IEEE 802.11b. MAPDR is a modified version of PDR method which is used to calculate the throughput of links but the authors claimed it is not suitable for mobile networks due to the number of received probes varies after node moves to new position. The calculations provided by the authors prove the ability of this method to calculate the metrics for the new position of the node.
However, the LQOLSR uses the value of MATE to choose the faster path instead of shortest path as in original OLSR. The test for this proposed protocol have been done with real implementation of

MANET testbed where the throughput and the hop count have been tested and showed that the throughput is almost similar to each other and the authors justify that the links pair in the network might be exist within one hop count. Overall, the average hop count in LQOLSR is larger than OLSR, and that means LQOLSR chooses paths with high quality metrics regardless the hop count. And the tests in this paper show that QOLSR outperforms OLSR.

4. Metrics for performance comparison

Delay aware routing protocols which are presented in this paper, could be evaluated to address following comparisons. And Table 1 summarizes the main characteristics of the presented routing protocols:

a. As mentioned earlier, different protocols have been enhanced by delay aware metric. Most of the work done on reactive routing protocols, in the other hand a few number of proposals has been done on proactive protocols and only OLSR have been modified in this class of protocols.
b. Some of these protocols focused on delay metric only as the main enhancement on the protocol. Some others added energy metric like in references [13, 14] or bandwidth metric like in [8, 17] as the second metric for selecting the best path. In addition, references [11, 20] use multipath as a second metric with the delay.
c. Different simulation software used to simulate most of the proposed protocols. The half of the protocols simulated with ns2 simulator which considered the most well known simulation software used by researchers, while other proposals simulated with OPNET modeler and GloMoSim. These simulated protocols have been compared to the standard protocols and other MANET's routing protocols. However, LQOLSR has been tested in real implementation environment. But no one of these proposals compared to QoS routing protocols to benchmark its efficiency and performance. Some papers used different evaluation metrics to evaluate the functionality of the proposed technique. Such as end-to-end delay, packet delivery ratio, remaining energy, and routing overhead.
d. Delay extension has been added to the routing table calculations and the messages for requesting and replaying the path for some of the proposed protocols. And the type of delay that examined during route discovery differed from study to another. Some of the studies chose end-to-end delay while other focused on medium access delay or queue delay.
e. In reference [8] the Maximum Delay is examined along the path during route discovery process, to determine the best path in term of low cost delay. In reference [11] the ToS field in IP packets examined to determine the required delay according to the type of service and check the delay over the route before doing the path discovery. And this point could affect the delay of selecting best path with lowest delay.

5. Conclusion and Future Directions

In this article, delay aware routing protocols for MANET have been studied. The delay on discovered links during path discovery is considered as the main metric in path selection from source to destination in delay aware routing protocols. Many papers used second metric along with delay to select the best path such as bandwidth or energy. The implemented protocols showed better performance than the modified protocols when tested using simulators.

Using neural network to predict QoS metrics such as delay could give superior results. Apply delay aware when selecting routing path on other MANET's routing protocols such as LORA or DYMO could be a good area for research. Security is a big issue in MANET's environment and Securing the proposed protocols by adding some security features could also give some robustness for this kind of protocols. The fast moving mobile nodes (such in VANET the nodes are moving fast) causes frequently link breakage and that means longer end-to-end delay and packet loss, so applying delay aware protocols could be efficient in such applications to minimize the delay to deliver messages between nodes. And the packet loss could be taking into account as second QoS metric with the delay when developing future versions of this kind of routing protocols.

Table 1 Main features of the delay aware routing protocols.

Protocol	**Added metrics**	**Routing protocol class**	**Simulation**	**Modify messages**	**Kind of delay**
QoS-AODV	Delay and Bandwidth	Reactive	N/A	Yes	End-to-End
DAAM	Delay and multipath	Reactive	OPNET	Yes	End-to-End
EDC-AODV	Delay and energy	Reactive	ns2	Yes	Current size of queues
EDAODV	Delay and energy	Reactive	ns2	Yes	End-to-End
EDDSR	Delay and energy	Reactive	ns2	Yes	End-to-End
SMR	Delay and Multipath	Reactive	GloMoSim	Yes	End-to-End
OLSR	Delay	Proactive	N/A	Yes	Media Access Delay
QOLSR	Delay and Bandwidth	Proactive	OPNET	Yes	Average Delay
OLSR_NN	Delay	Proactive	ns2	Yes	Mean Queuing Delay
LQOLSR	Delay	Proactive	Real Implementation	Yes	Packet Transmission Delay

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