# Ant Based Dynamic Source Routing Protocol to Support Multiple Quality of Service (QoS) Metrics in Mobile Ad Hoc Networks

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**Abstract**

Quality of Service (QoS) support for Mobile Ad hoc Networks (MANETs) is an exigent task due to dynamic topology and limited resource. To support QoS, the link state information such as delay, bandwidth, jitter, cost, error rate and node energy in the network should be available and manageable. The focus of this paper is extending the scope to QoS routing procedure, to inform the source about QoS available to any destination in the wireless network. However, existing QoS routing solutions were dealt with only one or two of the QoS parameters. It is important that MANETs should provide QoS support routing, such as acceptable delay, jitter and energy in the case of multimedia and real time applications. This paper proposes a QoS Dynamic Source Routing (DSR) protocol using Ant Colony Optimization (ACO) called Ant DSR (ADSR).The performance of DSR and ADSR are analyzed using network simulator-2. ADSR produces better results than the existing DSR in terms of delay, energy, jitter and throughput.

**Keywords:** Ad Hoc Networks, Quality of Service, Dynamic Source Routing, ACO and ADSR

## 1. INTRODUCTION

Mobile ad hoc network (MANET) is a collection of mobile devices, which form a communication network with no pre-existing wiring or infrastructure. Routing in mobile ad hoc networks is challenging since there is no central coordinator, such as base station, or fixed routers as in other wireless networks that manage routing decisions. All nodes in MANETs cooperate in a distributed manner to make routing decisions. Multiple routing protocols have been developed for MANETs. In proactive protocols, every node maintains the network topology information in the form of routing tables by periodically exchanging routing information. Routing information is generally flooded in the whole network. Whenever a node requires a path to a destination, it runs an appropriate path-finding algorithm on the topology information it maintains.

The Destination Sequenced Distance Vector (DSDV) routing protocol, Wireless Routing Protocol (WRP), and Cluster-head Gateway Switch Routing (CGSR) protocol are some examples for the protocols that belong to this category. Protocols that fall under reactive protocols category do not maintain the network topology information. They obtain the necessary path when it is required, by using a connection establishment process. Hence, these protocols do not exchange routing information periodically. The Dynamic Source Routing (DSR) protocol, Ad hoc On-demand Distance Vector (AODV) routing protocol, Temporally Ordered Routing Algorithm (TORA) and Associativity Based Routing (ABR) are some examples for the protocols that belong to this category [1].

Quality of Service (QoS) is usually defined as a set of service requirements that need to be met by the network while transporting a packet stream from source to destination. With the increasing needs of QoS provisioning for evolving applications such as real-time audio/video, it is desirable to support these services in ad hoc networking environments. The network is expected to guarantee a set of measurable specified service attributes to the user in terms of end-to-end delay, bandwidth, probability of packet loss, energy and delay variance (jitter).

The QoS metrics can be classified as additive metrics, concave metrics, and multiplicative metrics. Bandwidth and energy are concave metrics, while cost, delay, and jitter are additive metrics. Bandwidth and energy are concave in the sense that end-to-end bandwidth and energy are the minimum among all the links along the path. The end-to-end delay is an additive constraint because it is the accumulation of all delays of the links along the path. The reliability or availability of a link based on some criteria such as link break probability is a multiplicative metric. Finding the best path subject to two or more additive/concave metrics is a complex problem. A possible solution to route dealing with additive and non-additive metrics is to use an optimization technique.

Ant Colony Optimization (ACO) is a subset of Swarm Intelligence. The basic idea of the ant colony optimization is taken from the food searching behavior of real ants [2]. When ants are on the way to search for food, they start from their nest and walk toward the food. When an ant reaches an intersection, it has to decide which branch to take next. While walking, ants deposit a pheromone, which ants are able to smell, which marks the route taken. The concentration of pheromone on a certain path is an indication of its usage. With time, the concentration of pheromone decreases due to diffusion effects. This property is important because it is integrating dynamic into the path searching process.

The rest of the paper is organized as follows. In section two, the previous work related to QoS routing protocols is briefly reviewed. In section three, enhanced version of DSR based on Ant Colony Optimization (ACO) called Ant Dynamic Source Routing (ADSR) is described. In section four, the major simulation results are shown. In section five, the result of the work done is summarized.

## 2. RELATED WORK

QoS support in MANETs includes QoS models, QoS resource reservation signaling, QoS Medium Access Control (MAC), and QoS routing [3]. This paper discusses some key design considerations in providing QoS routing support, and presents a review of previous work addressing the issue of route selection subject to QoS constraints.

Core-Extraction Distributed Ad hoc Routing (CEDAR) algorithm is designed to select routes with sufficient bandwidth resources. CEDAR dynamically manages a core network, on which the state information of those stable high bandwidth links is incrementally propagated. CEDAR selects QoS routes upon request [4].

A number of successful ant-based routing algorithms exist for wired networks, and are based on the pheromone trail laying-following behavior of real ants and the related framework of Ant Colony Optimization (ACO). Ant based routing algorithms exhibit a number of desirable properties for MANET routing: they work in a distributed way, are highly adaptive, robust and provide automatic load balancing. AntNet is an algorithm conceived for wired networks, which derives features from parallel replicated Monte Carlo systems, previous work on artificial ant colonies techniques and telephone network routing [5]. The idea in AntNet is to use two different network exploration agents (forward and backward ants), which collect information about delay, congestion status and the followed path in the network.

Ant based Control (ABC) is another ant based algorithm designed for telephone networks. It shares many similarities with AntNet, but also incorporates certain differences [6]. The basic principle relies on mobile routing agents, which randomly explore the network and update the routing tables according to the current network state. The routing table stores probabilities instead of pheromone concentrations.

Ant Colony Based Routing Algorithm (ARA) works in an on-demand way, with ants setting up multiple paths between source and destination at the start of a data session [7]. Probabilistic Emergent Routing Algorithm (PERA) works in an on-demand way, with ants being broadcast towards the destination at the start of a data session. Multiple paths are set up, but only the one with the highest pheromone value is used by data and the other paths are available for backup [8].

AntHocNet is based on ideas from Ant Colony Optimization [9]. AntHocNet uses end-to-end delay as a metric to calculate congestion at a node, which may not yield accurate results as end-to-end is affected by both congestion as well as the length of the route from source to destination. ANSI (Ad hoc Networking with Swarm Intelligence) is a congestion-aware routing protocol, which, owing to the self-configuring mechanisms of Swarm Intelligence, is able to collect more information about the local network and make more effective routing decisions than traditional MANET protocols. ANSI is thus more responsive to topological fluctuations [10].

A unicast on-demand routing protocol Swarm-based Distance Vector Routing (SDVR) is proposed to optimize three parameters delay, jitter, and energy[11].Ant-like agents are used in this algorithm to discover and maintain paths with the specified QoS requirements in Ad hoc On demand Distance Vector routing (AODV) protocol. SDVR produces better performance than AODV in terms of packet delivery ratio, end-to-end delay, energy, and jitter.

## 3. ANT DYNAMIC SOURCE ROUTING (ADSR)

This paper proposes an enhanced version of DSR based on Ant Colony Optimization (ACO) called Ant Dynamic Source Routing (ADSR) and it takes into consideration of three QoS parameters delay, jitter and energy.

### 3.1 Ant Colony Optimization (ACO)

Two of the most successful swarm intelligence techniques are Ant Colony Optimization (ACO) and Particle Swarm Optimization (PSO). ACO is a meta-heuristic optimization algorithm that can be used to find approximate solutions to difficult combinatorial optimization problems. In ACO artificial ants build solutions by moving on the problem graph and they, mimicking real ants,

deposit artificial pheromone on the graph in such a way that future artificial ants can build better solutions. ACO has been applied successfully to an impressive number of optimization problems. PSO is a global minimization technique for dealing with problems in which a best solution can be represented as a point or surface in an n-dimensional space.
ACO is application of ant's behavior to complex computational optimization problems. ACO is inspired by the foraging behavior of ant colonies, wherein they are able to find shortest path between two points through collective learning. Learning is achieved by deposition of a chemical called pheromone. ACO is based on real ant's behavior in finding a route to food nest. It has been observed that of available routes, ants find shortest route to food nest. To achieve this, ant communicates through deposition of chemical substance called pheromone along the route. Shortest path has highest concentration leading to more and more ants using this route.

**Basic Ant Algorithm**
The basic idea of the ant colony optimization Meta heuristic is taken from the food searching behavior of real ants. Figure 1 shows a scenario with two routes from the nest to the food place. At the intersection, the first ants randomly select the next branch. Since the route below is shorter than the upper one, the ants that take this path will reach the food place first.


**FIGURE 1:** Ants take the shortest path after an initial searching time

On their way back to the nest, the ants again have to select a path. After a short time the pheromone concentration on the shorter path will be higher than on the longer path, because the ants using the shorter path will increase the pheromone concentration faster. The shortest path will thus be identified and eventually all ants will only use this one. This behavior of the ants can be used to find the shortest path in networks. Especially, the dynamic component of this method allows a high adaptation to changes in mobile ad hoc network topology, since in these networks the existence of links are not guaranteed and link changes occur very often.

**3.2 Ant Dynamic Source Routing (ADSR)**
Dynamic Source Routing (DSR) protocol is an on-demand routing protocol that is based on the idea of source routing [12]. Mobile nodes are required to maintain route caches that contain the source routes of which the mobile is aware. Entries in the route cache are continually updated as new routes are learnt. The protocol consists of two major phases: route discovery and route maintenance.

**Route Request**
When a mobile node has a packet to send to the destination, it first consults its route cache to determine whether it previously has a route to the destination. If it has an unexpired route to the destination, it will use this route to send the packet. On the other hand, if the node does not have such a route, it initiates route discovery by broadcasting a route request packet. This route request contains the address of the destination, along with the source node's address and a unique identification number. Each node receiving the packet checks whether it knows of a route to the destination. If it does not, it adds its own address to the route record of the packet and then forwards the packet along its outgoing links. To limit the number of route requests propagated on the outgoing links of a node, a mobile only forwards the route request if the request has not yet been seen by the mobile and if the mobile's address does not already appear in the route record.

**Route Reply**

A route reply is generated when the route request either reaches the destination itself, or reaches an intermediate node which contains in its route cache an unexpired route to the destination. By the time the packet reaches either the destination or such an intermediate node, it contains a route record yielding the sequence of hops taken. If the node generating the route reply is the destination, it places the route record contained in the route request into the route reply. If the responding node is an intermediate node, it will append its cached route to the route record and then generate the route reply. To return the route reply, the responding node must have a route to the initiator. If it has a route to the initiator in its route cache, it may use that route. Otherwise, if symmetric links are supported, the node may reverse the route in the route record. If symmetric links are not supported, the node may initiate its own route discovery and piggyback the route reply on the new route request.

**Route maintenance**

Route maintenance is accomplished through the use of route error packets and acknowledgments. Route error packets are generated at a node when the data link layer encounters a transmission problem. When a route error packet is received, the hop in error is removed from the node's route cache and all routes containing the hop are truncated at that point. In addition to route error messages, acknowledgments are used to verify the correct operation of the route links. Such acknowledgments include passive acknowledgments, where a mobile is able to hear the next hop forwarding the packet along the route.

In Ant DSR (ADSR) the Forward ant (FANT) and backward ant (BANT) packets are added in the route request and route reply of DSR respectively as shown in figure 2 and 3. FANT and BANT packets are used in this route discovery process.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| IP Header | DSR Fixed Header | Source Address | Sequence Number | Destination Number | Delay Energy Jitter | Route Record | Hop Count | Route Address Add1, Add2 -- Addn |

**FIGURE 2:** ADSR Route Request Packet format

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| IP Header | DSR Fixed Header | Source Address | Destination Address | Delay Energy Jitter | Dynamic Route Record | Sequence Number | Reply Address Address source Add1, Add2 --Addr dest |

**FIGURE 3:** ADSR Route Reply Packet format

Forward ants are used to explore new paths in the network. Ants measure the current network state for instance by trip times, hop count or Euclidean distance traveled. Backward ants serve the purpose of informing the originating node about the information collected by the forward ant. The ant routing has two types of feedback: positive feedback increases the pheromone levels on routes actively carrying ant packets and negative feedback periodically decreases pheromone values to limit the effects of stale information. Routing decisions tend to support paths with higher pheromone levels and, when allowed to converge, shortest end-to-end paths are empirically observed to be favored. Modified ant mechanism algorithm that uses energy, delay and jitter metrics to perform updates of pheromone levels is proposed. Assuming a control packet containing energy, delay and jitter metrics, a separate pheromone level will be maintained for each metric [11].

In the algorithm, ant packet headers have fields that:

1. track the minimum residual energy of the nodes that relay them and
2. track the cumulative delay and jitter based on backlog information of queued packets destined to the packet's source.

Thus, energy, delay and jitter pheromone levels will be maintained at each node.

## 4. PERFORMANCE EVALUATION

The performance of DSR and ADSR protocol is evaluated using the ns-2 simulator [13]. Throughput, end-to-end delay, routing overhead, jitter and residual node energy are used as metrics to compare the performance of DSR with ADSR. Table 1 lists the simulation parameters and environments used.

| Simulation Parameters | |
|---|---|
| Simulation area (Grid size) | 500m x 500m |
| Number of nodes | 100 |
| Node communication range | 50 m |
| Protocol | DSR and ADSR |
| Medium access mechanism | IEEE 802.11b |
| Traffic source model | Constant bit rate |
| Packet size | 1024 Bytes |
| Mobility model | Random waypoint |
| Initial Node Energy | 100 J |

**TABLE 1:** Simulation parameters

### 4.1 End-to-end Delay

Figure 4 shows effect of pause time on end-to-end delay of the two protocols. End-to-end delay tends to increase as the pause time increases in both protocols. The end-to-end delay is reduced by applying ADSR. This is mainly due to adding of delay pheromone in the RREQ and RREP packets. The reduction in delay is maximum (15 %) when the pause time reaches 300 seconds. Both protocols have same delay for higher pause time.

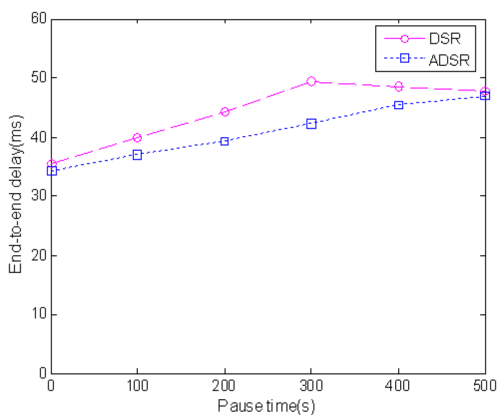


**FIGURE 4:** Effect of pause time on end-to-end delay

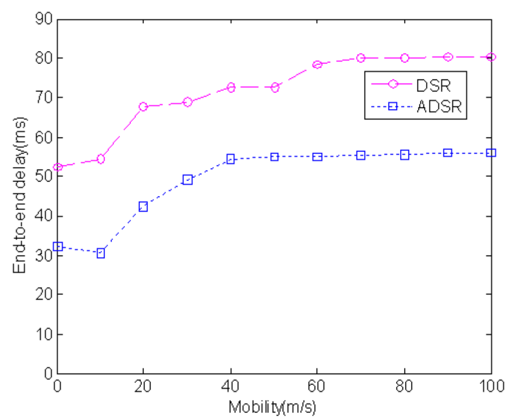


**FIGURE 5:** Effect of mobility on end-to-end delay

Figure 5 shows the effect of mobility on end-to-end delay. The end-to-end delay increases as the mobility increases. Higher mobility causes more link breaks and frequent re-routing, thus causing larger end-to-end delay. ADSR shows better performance in all the mobility conditions and the improvement over DSR is around 44%.

### 4.2 Energy

Figure 6 shows the effect of pause time on energy. The remaining energy of ADSR is 11% higher than DSR, since the energy pheromone is added in the route request and route reply of DSR packets. Figure 7 shows the effect of mobility on residual node energy. Residual node energy decreases with the increase in mobile speed, due to more link failures. The residual energy is high in ADSR than DSR because of energy pheromone is added in the route request and the route reply of DSR. The improvement over DSR is varies from of 6 to 26%.

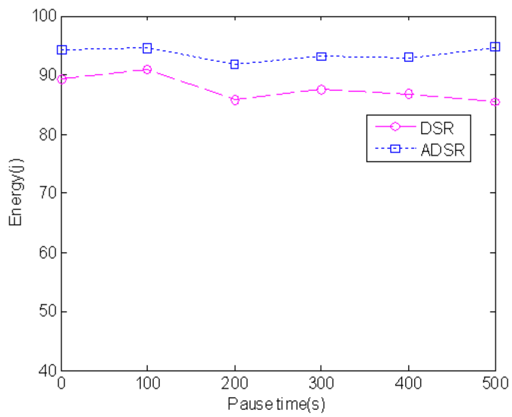


**FIGURE 6**: Effect of pause time on energy

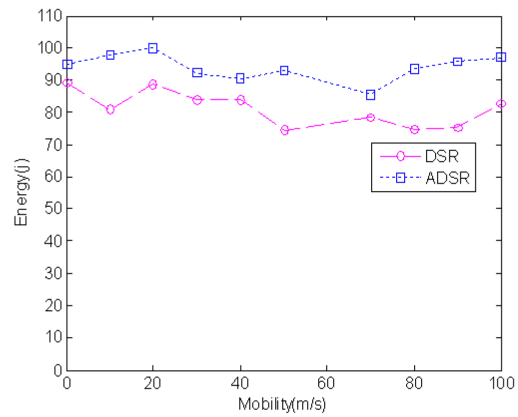


**FIGURE 7:** Effect of mobility on energy

### 4.3 Jitter

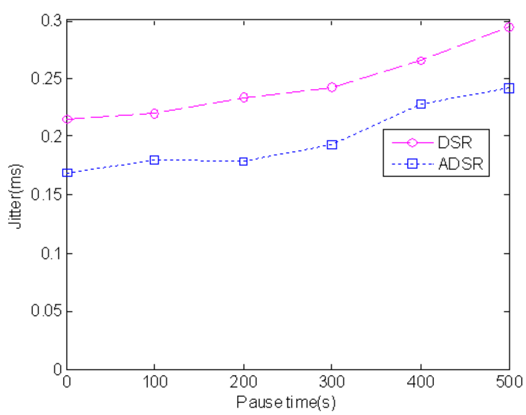


**FIGURE 8**: Effect of pause time on jitter

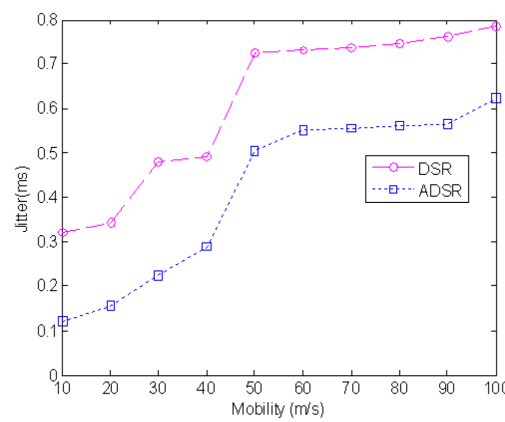


**FIGURE 9:** Effect of mobility on jitter

Figure 8 shows effect of pause time on jitter. The jitter is reduced in ADSR by 14 to 25%. This is due to addition of jitter pheromone in the route request and route reply. The variations in jitter under different mobility conditions are shown in Figure 9. The jitter is increased at higher mobility due to breaking of more links and frequent re-routing. The reduction in jitter varies from 24 to 30%. This is due to jitter pheromone included in the route request and route reply. ADSR gives better performance than DSR in all the mobility conditions.

### 4.4 Throughput

Figure 10 shows the effect of pause time on throughput. Number of packets received in the destination is calculated and taken as throughput. The improvement over DSR is high for low pause time. The throughput under different mobility values is shown in Fig. 11. It can be seen that increase in node speed results in significant decrease in throughput in both the protocols. This is due to more link breaks. ADSR shows around 5% improvement in throughput over DSR.

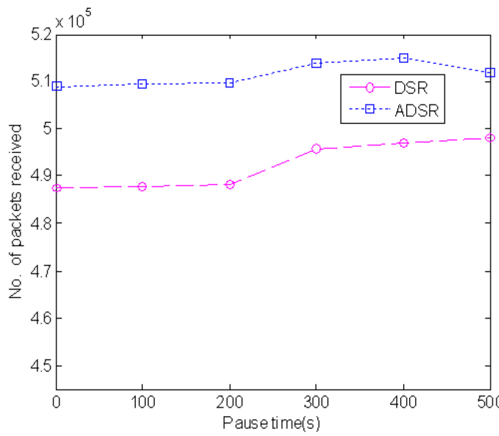


**FIGURE 10:** Effect of pause time on throughput

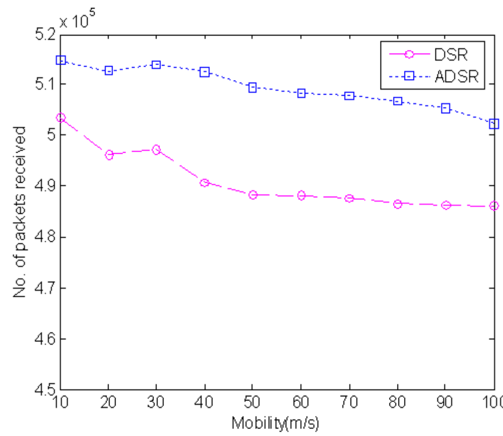


**FIGURE 11:** Effect of mobility on throughput

### 4.5 Routing Overhead

The effect of pause time on routing overhead is shown in Fig.12. Since more control packets are required at the route discovery phase and extra control packets are required periodically to monitor the condition of the paths, the routing overhead of ADSR is slightly higher than that of other protocol. The overhead for path monitoring can be reduced by piggybacking the pheromone information on data packets if appropriate traffic exists in opposite direction.

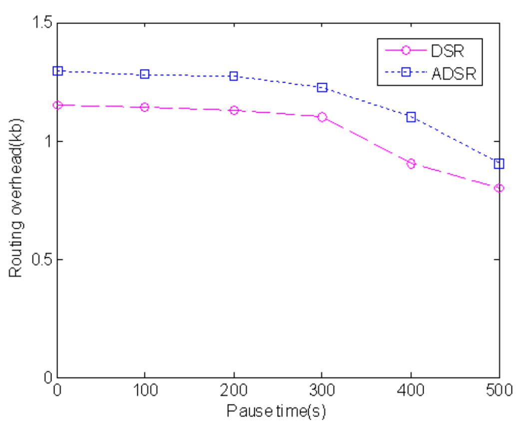


**FIGURE 12:** Effect of Pause Time on Routing Overhead

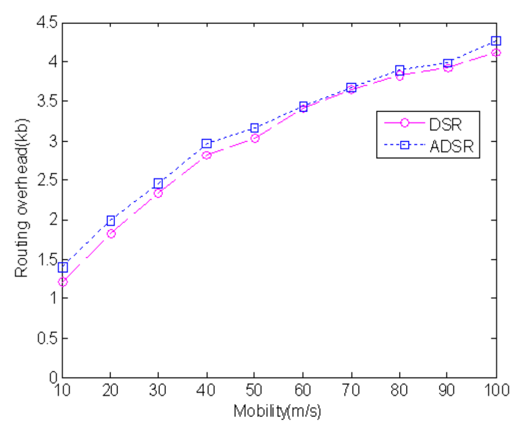


**FIGURE 13:** Effect of Mobility on Routing Overhead

The effect of mobility on routing overhead is shown in Fig.13. Higher mobility causes more links broken and frequent re-routing and thus causes larger routing overhead. Because of the periodic updates, ADSR requires certain amount of routing overhead constantly. The routing overhead due to mobility is slightly higher than that of DSR due to the use of FANTs and BANTs control packets.

## 5. CONCLUSION AND FUTURE WORK

In this paper, DSR based on-demand routing algorithm ADSR is proposed to optimize three QoS parameters delay, jitter and energy using Ant Colony Optimization (ACO). This avoids the overhead of having three independent routing algorithms, one for each QoS metric. The mechanism was based on the Forward ant (FANT) and backward ant (BANT) packets added in the route request and route reply. The proposed protocol selects a minimum delay path with the maximum residual energy at nodes. Furthermore, the selection of QoS routes should also take into consideration the jitter metric in order to keep the minimum and maximum delay values approximate to the average delay. ADSR produced better results than the existing DSR in terms of packet delivery ratio, end-to-end delay and residual energy at node. Even though ADSR results in a slightly high routing overhead than DSR, it performs well in route discovery with dynamic changes in the network topology and produces much better throughput with very low variance in the delay. Further, this can be implemented on the other reactive and hybrid routing protocols.

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