On using Multiple Routing Metrics with Destination Sequenced Distance Vector Protocol for MultiHop Wireless Ad Hoc Networks

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ABSTRACT

A mobile ad hoc network is a collection ofmobile nodes which communicate without a fixed backbone or centralized infrastructure. Due to the frequent mobility of nodes, routes connecting two distant nodes may change. Therefore, it is not possible to establish a priori fixed paths for message delivery through the network. Because of its importance, routing is the most studied problem in mobile ad hoc networks. In addition, if the Quality of Service (QoS) is demanded, one must guarantee the QoS not only over a single hop but over an entire wireless multi-hop path which may not be a trivial task. In turns, this requires the propagation of QoS information within the network. The key to the support of QoS reporting is QoS routing, which provides path QoS information at each source.To support QoS for real-time traffic one needs to know not only minimum delay on the path to the destination but also the bandwidth available on it. Therefore, throughput, end-to-end delay, and routing overhead are traditional performance metrics used to evaluate the performance of routing protocol. To obtain additional information about the link, most of quality-link metrics are based on calculation of the lost probabilities of links by broadcasting probe packets. In this paper, we address the problem of includingmultiplerouting metrics in existing routing packages that are broadcasted through the network. We evaluate the efficiency of such approach with modified version of DSDV routing protocolsin ns-3 simulator.

Keywords: Mobile Ad Hoc Networks, Quality of Service, ns-3, Routing Metrics, DSDV, routing overhead

INTRODUCTION

The rapid development of the automotive industry and unmanned aerial vehicles has led to great interest in ad hoc network technologies. An ad hoc network differs from conventional networks in the dynamic topology of interconnections and self-organizing manner. The communication is performed on a hop-by-hop basis with limited range wireless links with no existing pre-established infrastructure. However, the main characteristic of these networks is a decentralized organization and the unpredictable mobility of nodes, which can often lead to unstable routing paths[1,2]. Because of this, routing in such a dynamic environment is one of the most discussed and debated questions.

Due to the dynamic nature of the ad hoc network, routing protocols from the wired network cannot be directly applied, which has led to the development of new solutionsthat are broadly divided into proactive and reactive routing protocols. A proactive routing protocol is also called a “table-driven” protocol where nodes continuously evaluate routes to all reachable nodes and attempt to maintain consistent, up-to-date routing informationwhich allows the rapid establishment of communication when necessary.Examples include the Destination-Sequenced DistanceVector (DSDV) protocol[3], Wireless Routing Protocol (WRP)[4], Temporally-Ordered Routing Algorithm (TORA)[5], and Lightweight Mobile Routing (LMR) protocol[6].Each node maintains a routing table which contains a set of distance/cost value and the address of next hop to reach the destination. To keep these values up to date, periodic exchange of values between all nodes is required. Butin the case of sudden changes of network topology,nodes have toinstantly exchange triggered routing update in order to maintain updated information.However, the periodic exchange of routing data is performed even in the case when no changes in the network occur.

To reduce the amount of information stored in nodes with limited power, reactive “on-demand” routing protocols are used. In these protocols, routing paths are searched only when needed, mainly by flooding the network. The discovery procedure terminates when either a route has been found, or no route is available after all route permutations have been checked. However, this process can take time, which may cause delays in establishing of routing paths and, therefore, reactive routing protocols may not be applicable to time sensitive communication. Examples include the Ad hoc On-Demand Distance Vector (AODV) protocol[7] and Dynamic Source Routing (DSR) protocol[8].

In practice, all of these protocols typically find routes with the minimum hop-count which is the most popular metric widely used due to its simplicity. However, it was shown that minimum hop-count routing typically finds routes with

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significantly lower throughput than the best available[9]. Therefore, in ad hoc network, different Quality-Link Metrics (QLM) were introduced, such as Expected Transmission Count (ETX)[9], Expected Transmission Time (ETT)[10], Interference and Bandwidth Adjusted ETX (IBETX)[11], Expected Link Performance (ELP)[12], Minimum Loss (ML)[13], Minimum Delay (MD) [14] and Inverse ETX (InvETX)[15]. Most of these metrics are based on calculation of the loss probabilities of links by broadcasting probe packets. Following this approach, each node is supposed to periodically broadcast probe packets only to the neighbors without any retransmission. It was shown that such approach incurs more overhead than minimum hop-count, due to its loss ratio probes, but this overhead is small compared to the gains in throughput that these techniques provide. In contrast to this popular approach,Randomized Destination-Sequenced Distance Vector (R-DSDV) routing protocol[16,17], showed that the reduction of the amount of traffic which is routed through a temporarily congested node can improve the performances of the network.
In this paper, we combined these two approaches by including additional parameters in existing routing packetswhich use is unavoidable. In simple words, instead of transferring of additional probe packets within the network, the payload of these probe packets is included in already existing routing packets. We have conducted extensive simulation experiments to study and analyze the effectiveness of such approach by modifying DSDV routing protocolin ns-3 network simulator.Our results demonstrated that this approach is justified in the network with increased mobility of nodes.
The remainder of the paper is organized as follows. Section 2 gives an overview of the DSDV protocol. Section 3 presents the details of our simulation experiments, while section 4 discusses the results obtained. Section 5 concludes the paper.

DESTINATION SEQUENCED DISTANCE VECTOR ROUTING PROTOCOL

Destination Sequenced Distance Vector (DSDV) is the most popular proactive routing protocol based on the distributed Bellman-Ford algorithm[3]. In DSDV, each node maintains two tables. One of them is the permanent routing table in which all of the possible destinations within the network, the address of next hop and the total number of hops to reach the destination are listed. Each node is in charge to periodically broadcast its routing table to its neighbor nodes by using periodic update packets. After receiving the update packet, the neighbor node updates its routing table by incrementing the number of hops by one and forwards the packet further in the network. The process is repeated until all the nodes in the network receive a copy of the update packet with a corresponding value. To avoid the formation of routing loops, entries in the routing table are marked with a sequence number. Routes with higher sequence number are preferred since it is likely that they provide most accurate information. The sequence number from each node is independently chosen and it is incremented each time when update is performed:the sequence number of the regular periodic update is an even number while an urgent update for an expired route to its neighbors is marked with an odd sequence number.

In addition to regular periodic updates, DSDV uses triggered updates when the network topology suddenly changes. The main purpose of these updates is to advertise the information that has changed since the last periodic update. However, if a periodic and triggered update occurs in a short period of time, the values may be merged and only periodic update will be performed. To limit the propagation of unstable information, the transmission of triggered updates is delayed using settling time which is recorded in the second DSDV tablefor each destination node.

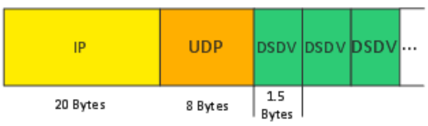

Figure 1. DSDV header encapsulation

DSDV headers are carried by User Datagram Protocol (UDP) packets which are further encapsulated in IP packets as shown in Figure 1.It is worth noting that probe packets from previously mentioned quality-link metrics are usually broadcast packets and they are also carried within UDP and IP packet. Therefore, each probe packet consumes at least 20 Bytes of IP header and 8 Bytes of UDP header. The probe packets have fixed size and they should be sent at a constant rate in order to probe link parameters accurately[14].

However, since the transmission of routing packets is inevitable, in this paper, we analyzed the idea of extending the routing packets to carry additional probe values. Following this approach, the transmission of additional probe packets will be avoidedwhich would reduce the consumption of network resources.

SIMULATION SETUP AND RESULTS

We evaluated our proposed method by using the ns-3.22network simulator[18].The parameters of thesimulation are presented in the Table 1 whilethe parameters not given here are the default parameters of the ns-3 simulator.

Table 1. Parameter values of the simulation

Parameter	Value
The dimensions of the simulation area	1000*1000 m^2
Total number of nodes	30
The number of sink nodes that are receiving traffic	10
Type of connections among nodes in the network	Wireless Mesh
WifiPhy mode	DsssRate11Mbps
Packet Traffic Type	Constant Bit Rate (CBR)
Packet Traffic Rate	8kbps
Mobility Model	RandomWayPoint
Routing Protocol Used	DSDV
Time interval between the exchange of periodic update of routing tables (Periodic route update interval)	15 seconds
Settling Time before sending out an update for changed metric (Route advertisement aggregation time)	5
Node speed in mobility model	10,15,20,30,40,50 m/s
Total Simulation time	300 seconds

The DSDV message headerhas the total header size of 12bytes containing the node's IP address, the number of hops required to reach that node, and its last known sequence number[18]. For the purposes of the simulation, theDSDV message header has been extended to include additional random values of 4 bytes as shown on Figure 2. In the following text, the default DSDV message header without additional values is referred to a "pure" DSDV header and a package that carries pure DSDVheaders is referred as pure DSDV routing packet.

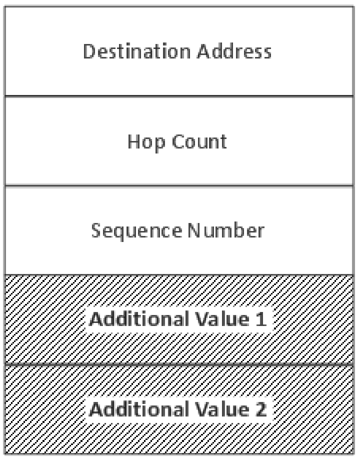

Figure 2. Extended DSDV message header

SIMULATION ANALYSIS

First of all, we analyzed the number of DSDV pure routing packets in relation to the mobility of nodes and their distribution in time. As Figure 3 shows, the number of periodic DSDV pure routingpackets which are exchanged each 15 secondsslightly increasedwith the mobility of nodes. However, the number of triggered DSDV pure routing packets clearly increased with the mobility of nodes. This is probably due more likely to increased interaction of nodes and sudden changes in network status which indirectly increasethe advertisement rates. Nevertheless, this result is quite encouraging and promising since it states that the additional routing packets are present in the networkwith increased mobility of nodes.

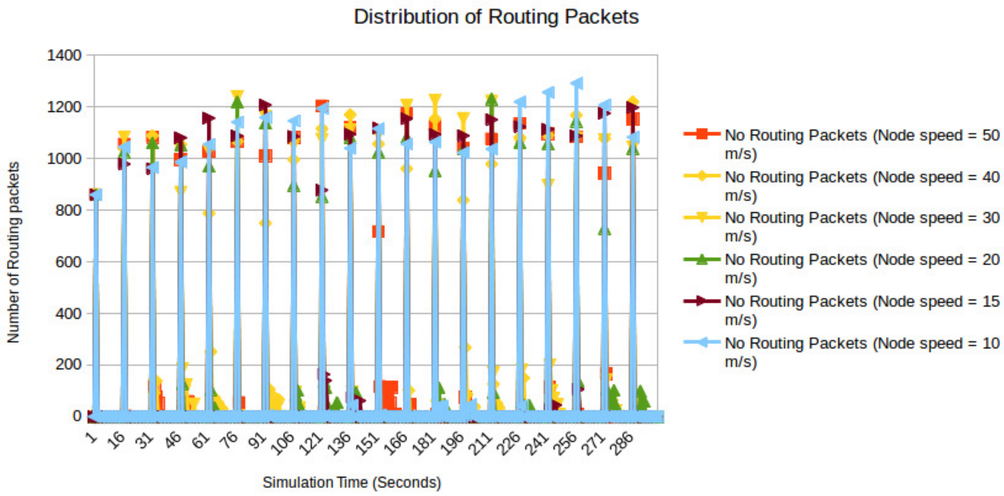

Figure 3. Distribution of Routing Packetsin relation to the mobility of nodes

Next, we analyzed the traffic generated by the DSDV routing protocol when the additional parametersare included in the DSDV message header.As Figure 4 shows, the inclusion of additional parameters in the DSDV headers did not cause the generation of a larger number of additional packages.Also, based on the comparison from results from Figures 4 and 5 it is easy to see that the additional routing packets were generated mostly due toincreased number of information resulting from the increased mobility of nodes.

In addition, from Figures 4 and 5 it is evident that the triggered DSDV packets occur in the first few seconds after the periodic exchange of routing information. This is very likely due to the route advertisement aggregation mechanism which is tuned with the *settling time* parameter.

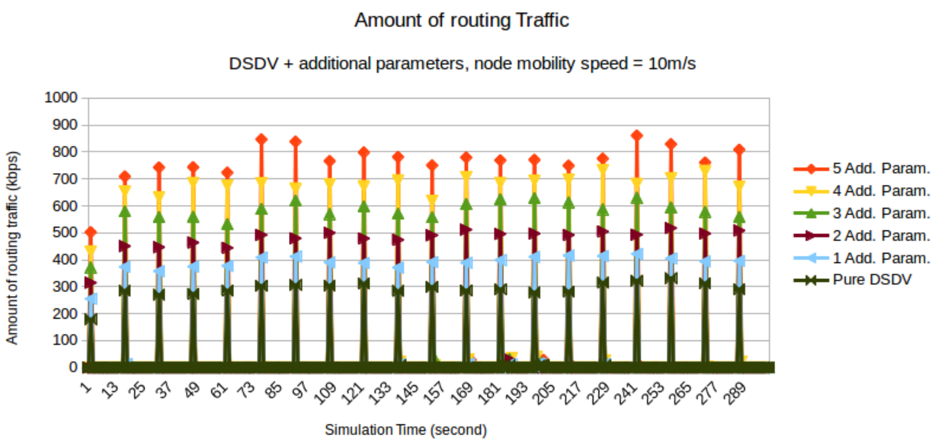

Figure 4.Amount of routing traffic when DSDV message header contains additional parameters (node mobility speed is 10 m/s)

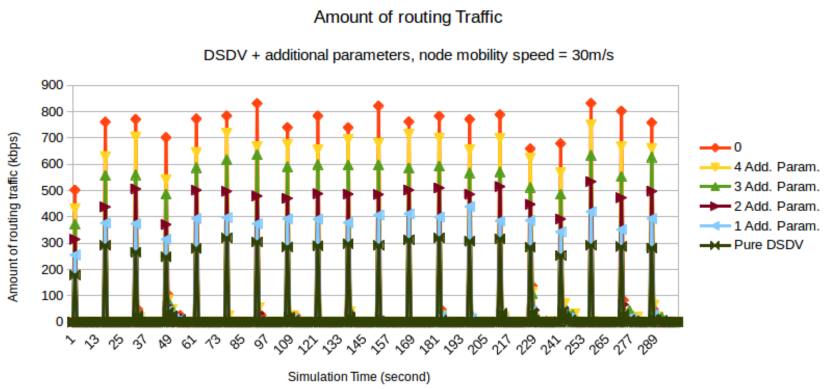

Figure 5.Amount of routing traffic when DSDV message header contains additional parameters (node mobility speed is 30 m/s)

EXAMPLE OF USE

To show the applicability of our results, in the DSDV message header the generation timestamp has been included. Therefore, DSDV message header contained following fields:

- the node’s IP address (4 Bytes),
- the number of hops required to reach that node (4 Bytes),
- the last known sequence number(4 Bytes),
- thegeneration timestamp of the header (8 Bytes).

The DSDV routing algorithm is modified to calculate the one-way delay by comparing the current timestamp with the generation timestamp of the header. Since single DSDV header propagates only one route, the calculation of the delay is performed for all DSDV headers received. After calculations, DSDV updates its routing table by including calculated delay into route selection when the received sequence number of the route is greater than the previously stored sequence number in the following way:

- if the number of hops is different from the previously recorded number of hops or the number of hops is equal but the calculated delay is lower than the previously stored value of delay toward the destination, DSDV will update its routing table with incoming route details.

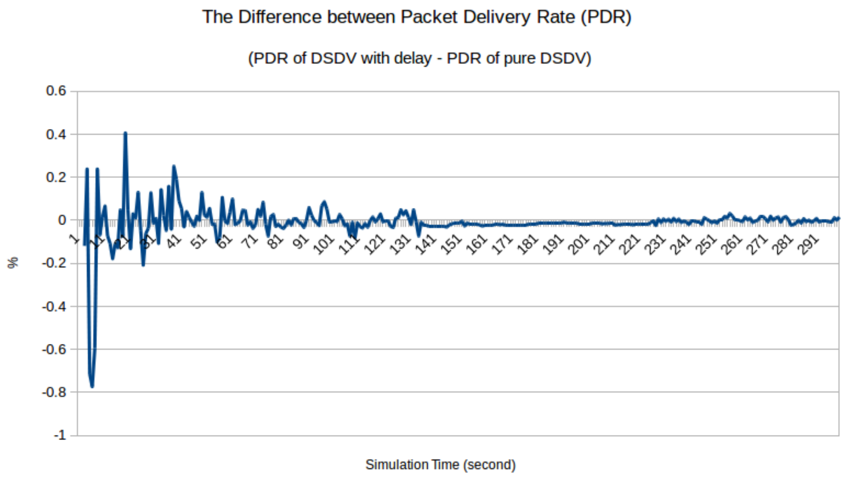

Figure 6. The difference between Packet Delivrey Ratio (PDR) whenpure DSDV message header and DSDV which contains information about the delay (QoS) are used

In simple words, this modification of DSDV routing protocol uses the delay to compare only the routes with an equal hop count. The route with lower delay is preferred when the hop count values are equal.

However, as shown in Figure 6. this simple modification of DSDV protocol improved the Packet Delivery Ratio (PDR) of the traffic in the first part of the simulation in which the initial routing information about the network are exchanged. In the second part of the simulation, the nodes move away out of range of wireless links and routing protocoldo not have a significant impact on the performance of communication.

CONCLUSION

The area of ad hoc networking has been receiving increasing attention among researchers in recent years. Because of its great use in the automotive industry, more and more attention is paid to these technologies in particular with regard to quality of service. In order to estimate the performances of the links, the solutions that are based on sending additional probe packets are proposed. However, the main disadvantage of this approach is additional consumption of network recourses.

In order to reduce the consumption of network resources, in this work, we estimated usage of periodic and triggered updates of DSDV routing protocol to include additional values. Our implementation uses both periodic and triggered updates asrequired by the DSDV protocol’s description.We have conducted extensive simulation experiments to study and analyze the effectiveness of such approach by modifying DSDV routing protocol in the ns-3 network simulator. Our results showed the presence of additional routing packets which can be used to carry additional values. Also, the results demonstrated that this approach is justified in the network with increased mobility of nodes.Our future work will include consideration of different QoSmetrics within a rotating packet in order to effectively assess the status of the network.

ACKNOWLEDGMENTS

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