Comparative MANET Protocol Analysis

Joshua Barksdale, Nhu Duong, and Zack Pelster

***Abstract*—This survey paper introduces the unique set of challenges associated with packet routing in mobile ad-hoc networks (MANETs). Ad-hoc routing protocols must be decentralized and must account for a constantly changing network topology. We discuss three main approaches to solving this problem: proactive routing, reactive routing, and hybrid routing. For each approach we explore a specific protocol which implements that approach. Finally, we simulate a mobile networking scenario in ns3 to compare the performance of 3 common MANET protocols.**

I. Introduction

STARTING in the days of the telegraph line, networking has been largely based on static physical infrastructure. However, many modern applications such as smart vehicles, search and rescue communication, and distributed sensor arrays require a communication infrastructure that is wireless and allows nodes to move around. This sort of network structure is called a Mobile Ad-hoc network (MANET). The ”Ad-hoc” term refers to the ability of a MANET to set up operation on the fly in an area with no existing infrastructure.

Mobile Ad-hoc routing poses a set of unique challenges. First, an ad-hoc infrastructure means that routing and network organization must be fully distributed. No one node is in charge but rather all nodes cooperate to get information from source to destination. Second, the mobility of nodes in the network means that the network topology is constantly changing. Thus a route which is currently valid (or even optimal) may be useless five minutes later in a MANET.

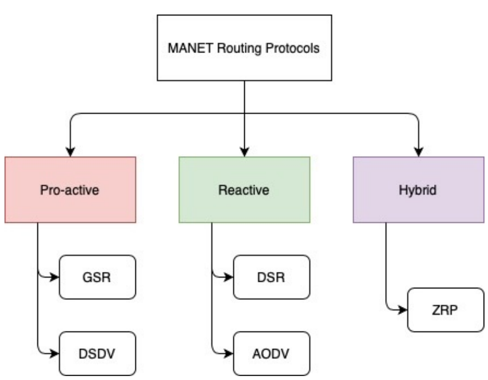

Fig. 1: MANET Routing Protocol Categories

MANET routing protocols solve these challenges with three main approaches: pro-active, reactive, and hybrid, as seen in Figure 1. Pro-active protocols are table-driven and attempt to set up routes before the packets need to be sent by having each node keep track of routes to every other node within the network. Reactive protocols discovery the each packet right before the packet is to be sent, it does so by flooding the system with route request queries. Hybrid protocols attempt to maximize the advantages of pro-active protocols and reactive protocols while minimizing the disadvantages, the relation between the protocols can be seen in Figure 2. In the following sections these types will be gone over in further detail.

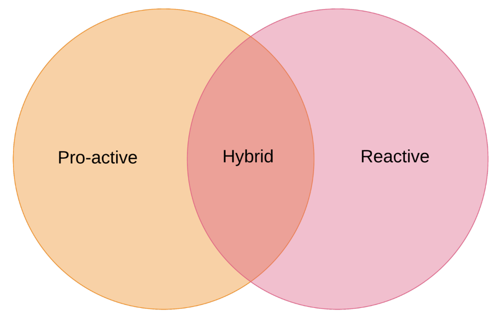

Fig. 2: The intersection of pro-active, reactive, and hybrid protocols.

II. Problem Statement

A. Motivation

Understanding and comparing different MANET protocols is important because it informs design decisions and helps to determine which protocol is best for a given project or scenario. A protocol which works very well for a few mostly static nodes like weather stations may not work as well for autonomous vehicles or coordinated wearable technology. Thus there isn't one ”best” MANET protocol, but knowledge of the different kinds of protocols enables engineers to select one that best fits their use case.
We chose to simulate a use case which involves a medium number of highly mobile nodes, most of whom don't currently have data to transmit.

B. System/Network Setup

The system/network setup will consist of 50 simulated nodes uniformly randomly distributed in a 300m x 1500m rectangular space. The nodes will be mobile, moving around pseudo-randomly according to the Random Waypoint Mobility Model. While the nodes are mobile the Friis Loss Model will be used to simulate wireless communication links that use IEEE 802.11b WiFi protocol paired with IPv4.

1) Random Waypoint Mobility Model (RWP): The RWP Model provides a stochastic model that aims to simulate the behavior of real ”mobile entities” [1]. The model uniformly at random chooses a waypoint for each node within the rectangular space. Each node is then provided a velocity that is uniformly at random chosen from a minimum and maximum velocity interval. Upon each node reaching their destination they will wait a predefined pause time before repeating the process described previously. The RWP Model must be noted for its lack of accuracy after the initialization phase because as the performance of the protocol converges toward the ”steady-state performance” the mobile system will converge to an almost static one [1]. This will be considered when deciding on the length of network simulated time.

2) Friis Loss Model: The Friss Loss Model consists of a simple transmission for a radio circuit [2]. The model calculates quadratic path loss as it occurs in free space [3]. The disadvantage of the formula is that it does not account for the effect of the ”ground” and for absorption in the transmission medium [2]. Although the advantage of the formula is in its simplicity, it does not require any numerical coefficients to be tuned before its usage.

III. Solution Approach

A. Reactive Protocol Approach

Reactive routing, also known as on-demand routing, uses two phases to transmit packets from a source to a destination. The first phase floods the network to discover a route to the destination on the fly. The second phase maintains that route while sending the packets. Reactive routing scales well in large networks, but requires a lot of set-up time to send a single packet since it doesn’t maintain unused routes.

1) Ad hoc On-Demand Distance Vector (AODV) Routing: AODV is an early reactive routing protocol proposed in 2003 which sets up routes on demand via route request (RREQ) and route reply (RREP) packets. It uses TCP/IP for node ID and traffic control and is commonly implemented using WiFi or ZigBee. When an AODV node has information to send to a destination and doesn’t have an up-to-date route to that destination, it sends out a RREQ. RREQs contain the IP address of the destination, the sequence number (SN) of the node’s most recent information about the destination, and a time to live (TTL) value. Figure 3 shows the decision tree for a node which receives a RREQ from another node.

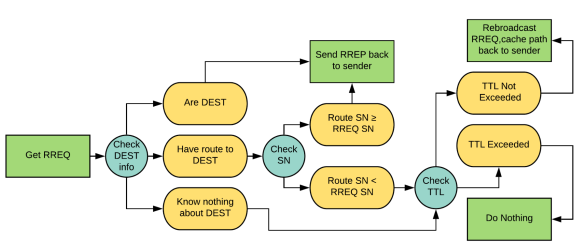

Fig. 3: AODV RREQ Forwarding Flowchart

TTL is the number of hops a route request is allowed to make before it dies. TTL prevents a RREQ from bouncing around the network forever in the case that the destination node is offline. Sequence Numbers are how AODV keeps track of route freshness. Each node has a sequence number which it increments when it gives out new information about itself. It then attaches that sequence number to the information. Thus higher sequence numbers indicate more up-to-date routing information. A node which sends out a RREQ may get several RREPs back. In this case, it selects the RREP with the highest sequence number and thus uses the freshest route.

B. Pro-active Protocol Approach

Proactive routing, also known as table-driven routing, consists of periodically updating the routing table stored in each node as the network topology changes. The disadvantage of using a routing table is that the table grows exponentially as the network size increases.

1) Global State Routing (GSR): GSR was proposed in 1998 at IEEE International Conference on Communication. The goal of this protocol is to make MAC efficient for MANET. With GSR, MAC throughput will be optimized by controllable packet size. [4] Every nodes in the network maintain their own tables: neighbor list which containing the list of adjacent nodes, topology table, next hop table which containing the shortest distance from source node to all other nodes in the network.

The disadvantage of GSR is the large size of network. As topology change, each node need to re-update their tables which can cause a large amount of bandwidth being used. The latency of communication between nodes can be high due to the table update frequency.

C. Hybrid Protocol Approach

Hybrid routing combines routing methods of proactive routing and reactive routing allowing the protocol to be adaptive in nature through the use of initially established routes and reactive flooding. The disadvantage of the protocol is its reaction to traffic depending on the traffic volume.

1) Zone Routing Protocol (ZRP): ZRP was designed to speed up delivery and reduce processing overhead by selecting the most efficient type of protocol to use throughout the route. This is achieved through the combination of a pro-active protocol, a reactive protocol, and a zone radius parameter as depicted in Figure 4 [5].

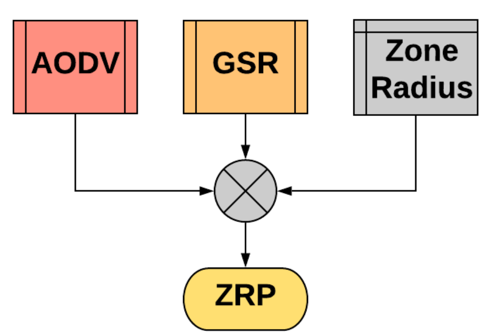

Fig. 4: Flowchart of the parts of the ZRP protocol.

By creating routing zones the overhead for route creation becomes very low due to nodes knowing the topology of the network in their routing zone. Within the routing zone an intrazone routing protocol (IARP), a pro-active protocol, is used to maintain the routes [6].

The flow when the destination node is not in the same routing zone as the source node consists of a query being broadcast to their peripheral nodes [5]. The flow of the query will follow the interzone routing protocol (IERP), a reactive protocol [6].

The zone radius controls the effectiveness of the chosen IARP and IERP [5]. With a large zone radius ZRP reflects the traditional proactive protocol that is implemented for as the IARP. While a small radius results in a highly reactive protocol in accordance with the chosen IERP. When the zone radius is the minimum of one ZRP is pure flooding, or entirely reactive.

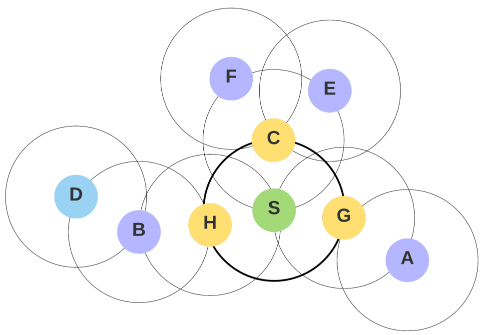

Fig. 5: Example of the ZRP protocol with transmission from node S to node D.

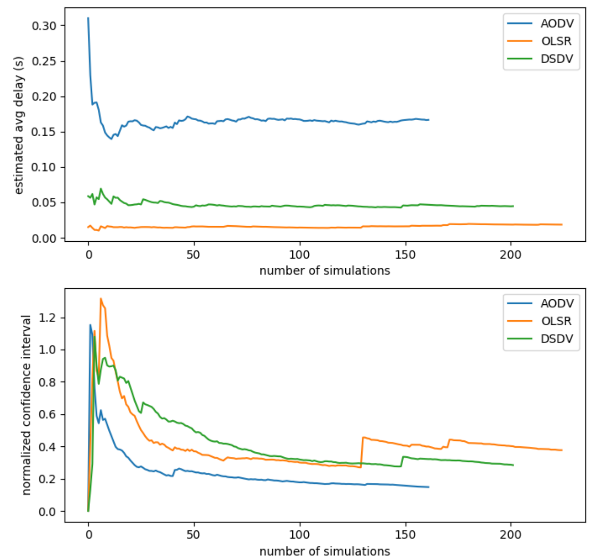

Fig. 6: Simulated Delay

Figure 5 depicts a scenario in which the user would like to send a packet from node S to node D and the zone radius of each routing zone is 2. Node S will begin by checking its routing zone for node D. Upon not finding node D in its routing zone node S will query its peripheral nodes H, C, and G. These nodes will check their own routing zones and upon not finding node D they will check their peripheral nodes. This process will iterate outwards until node D is found and the path to node D will be returned to node S so the packet can be sent.

ZRP has a number of advantages over its pro-active and reactive counterparts. The protocol is extremely robust due to a zone radius greater than 1 resulting in routing zones heavily overlapping, which has the additionally affect of allowing the quick discovery of multiple routes to the destination [5]. Then due to the use of routing zones the query messages remain relatively small, depending on the zone size, because the messages only go to the peripheral nodes [5].

In practice ZRP's disadvantages consist of the protocol being most applicable to large flat-routed networks, as opposed to hierarchical network architectures [5]. In addition to the trade off between resource efficiency and the latency of route discovery. For instance, the protocol can be made more resource efficient through sequential querying of ”peripheral” nodes, but this comes at the cost of a larger route discovery delays [5].

IV. Performance Evaluation

A. Methods and Tools

The team used 3 main simulation tools: BASH, Python, and ns3. ns3 performed individual simulations, BASH automated performing many simulations in a row and storing their results in a csv file, and Python analysed and plotted the results. We based our analysis on ns3's *manet-routing-compare* example simulation. It sets up the scenario and supports implementation of 4 different protocols. We selected three to evaluate: AODV, OLSR, and DSDV. AODV is reactive while OLSR and DSDV are proactive.

We decided that one ”test” was 200 simulated seconds of network activity. After the test was complete, ns3 reported various stats about what happened during the simulation by printing text to the screen and by outputting files. We wrote a Python script to analyse these outputs and extract 3 parameters: average packet delay, network goodput, and total packet loss. Our BASH script supervised the whole process: first running the simulation, then analyzing the outputs and storing the results, and finally cleaning up the directory and preparing for a new simulation.

We called 3 such BASH scripts in parallel - one for each protocol - and let them all run for 6 hours. The 3 protocols had different levels of computational difficulty to simulate so even though each protocol got the same amount of cpu time, different numbers of tests were completed for the different protocols.

Once we had all of our results in csv format, we wrote another Python script to estimate θ for our our different protocols and parameters using a simple mean estimator. This script also computed the confidence interval with confidence level at 90%.

B. Results

Figure 6 shows our estimated average packet delay after each simulation as well as our normalized confidence interval. Around run 150, the OLSR simulation experienced unusually high delay which significantly expanded the confidence interval. Our results at the end of simulation are located in Table I.

	delay (ms)	error (ms)
AODV	166	±25
OLSR	18.5	±7.0
DSDV	45.6	±13

TABLE I: Simulated Delay

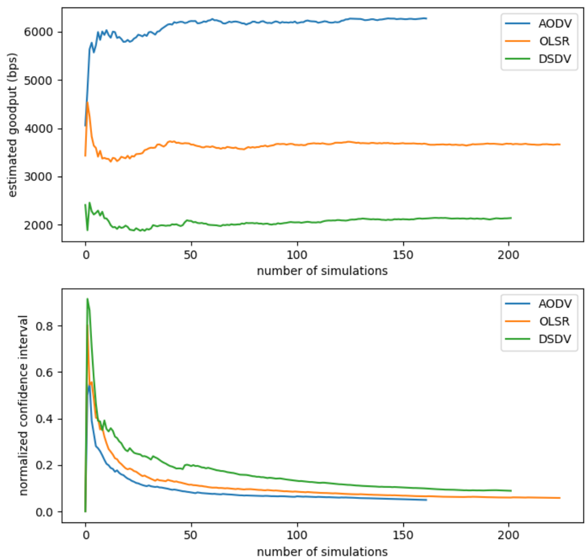

Fig. 7: Simulated goodput

Figure 7 shows our estimated goodput after each simulation as well as our normalized confidence interval. Goodput is the average number of bits of meaningful data which are successfully transmitted per second in the network. AODV outperforms the other protocols even though it has the most end-to-end delay. Our results at the end of simulation are located in Table II.

Figure 8 shows our estimated total packet loss after each simulation as well as our normalized confidence interval. These estimations converged fairly quickly with DSDV dropping packets left and right, while OLSR avoided dropped packets. Our results at the end of simulation are located in Table III.

	goodput (bps)	error (bps)
AODV	6270.4	±309.5
OLSR	3661.2	±212.3
DSDV	2137.3	±189.6

TABLE II: Simulated goodput

	packet loss (pkts)	error (pkts)
AODV	1953	±85
OLSR	1200	±56
DSDV	3048	±53

TABLE III: Simulated packet loss

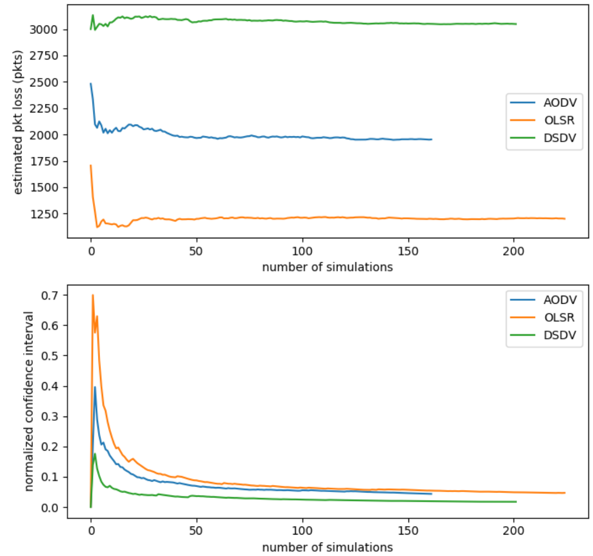

Fig. 8: Simulated packet loss

C. Analysis

From Figure 6 from page 3 we can see that AODV has the highest average delay compared to OLSR and DSDV. High delay time occurs due to AODV having to discover the route while going through the network. Meanwhile, OLSR and DSDV already has the knowledge of the route, transmitter node use the table to find shortest path to receiver. This explains average delay time are very low for OLSR and DSDV.

Figure 7 from page 4 shows AODV has the highest goodput compare to other because of AODV check for destination valid with HELLO before sending the message. This guarantee that AODV has the information of the receiver before transmit the data.

From Figure 8 from page 4 we can see that DSDV have the highest packet loss. This explains the disadvantage of table-driven routing protocol in a environment of dynamic changing topology. As topology change, routing table get re-updated, new sequence number needs to be issued before transmission [7]. Meanwhile for OLSR, the packet loss is the lowest due to it concept of Multipoints Relay (MPR). MPR nodes minimized the redundant control packets [8]. Thus, not every node get flooded with unnecessary information and QoS get improved.

V. Conclusion

In this paper, we conduct performance evaluation on average delays, goodput and packet loss of AODV, OLSR, DSDV routing protocols using ns-3 simulator.

From the simulation results, we can conclude as follows. Under the same conditions with random generated topology with condidence levels greater than 90%, AODV has the highest estimated average delay time and the highest estimated goodput. OLSR has the best performance with the lowest packet loss and lowest estimated average delay.

In this work, we evaluated AODV, OLSR, DSDV with 50 nodes uniformly random distributed in a rectangular of 300m x 1500m. In the futures, we would like to investigate the performance of AODV, OLSR, DSDV in a larger space with more nodes.

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