Performance Evaluation and Analysis of MANET Protocols at Varied Speeds

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***Abstract*—A Mobile Ad Hoc Network (MANET) is a decentralized wireless network that does not rely on pre-existing infrastructure. Instead, it is each node's responsibility to forward data according to its specified routing protocol. Although these protocols perform the same task, their performance in a variety of scenarios differ. This paper simulates four different routing protocols in NS-3 at a variety of movement speeds and area sizes, comparing their Packet Delivery Ratio (PDR) and Average End-To-End Delay (AETED). The performance results reflect what would be expected if a system would be implemented in a similar environment. Therefore it is crucial in choosing a protocol to best suit a system.**

Keywords—Reactive, Proactive, Communication Protocol, NS3 Simulation

I. Introduction

Originally designed for military use, over the past decades MANET has made its way into the civilian market [1]. MANET is the mobile implementation of an ad hoc network. Unlike a centralized network where routing is performed by intermediary devices, an ad hoc network does not require infrastructure. Instead, each node is responsible for its peer-to-peer routing to maintain a self-forming, self-healing network [2]. These nodes communicate using wireless technology, including Bluetooth, WiFi, and Zigbee. For nodes not directly connected, routing protocols are utilized to determine how nodes forward packets that require multiple hops to reach their destination [3]. A layout of how a MANET network functions is illustrated in Fig. 1

This paper was inspired by previous work which compared proactive and reactive protocols in NS-3. [4]. The work focused on comparing the performance of systems that contained 5, 10, and 30 nodes, which transmitted 64, 256, and 1024 bit data packets. The simulation area size and speed remained static.

To accurately simulate a real-world application, the parameters of the simulation must match the application. It was predicted that the speed and density of the nodes would best reflect real-world applications. The question was then asked, would MANET protocols perform differently when nodes moved at lower speeds comparatively to higher speeds? Lower speeds could reflect a scenario where individuals are walking about, whereas nodes moving at higher speeds could reflect individuals driving.

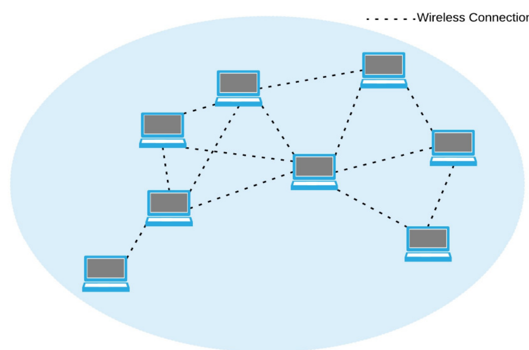

Fig. 1. A MANET network.

This paper is broken down into five sections. In the next section, the three different types of MANET protocols are discussed. Section III discusses the simulation setup as well as the performance metrics being evaluated. Section IV breaks up the gathered results from the simulation between the two metrics and evaluates the results. The last section summarizes what was covered, and discusses how this paper will support future work.

II. Protocols

MANET protocols can be classified into one of three different categories: proactive, reactive, and hybrid. Proactive routing protocols maintain a routing table consisting of each node by periodically propagating update information. Comparatively, reactive protocols establish a route on-demand and maintain it until it is no longer used, or no longer accessible. Lastly, hybrid protocols try to merge the advantages found in both proactive and reactive protocols [3]. For the focus of this paper all three will be discussed, though only proactive and reactive protocols are being evaluated and analyzed. A diagram of the three categories is shown in Fig.2.

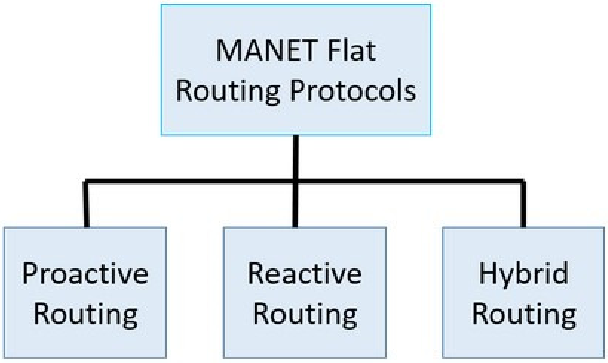

Fig. 2. MANET routing protocols [4].

A. Proactive Protocols

The first proactive protocol is Destination-Sequenced Distance-Vector Routing (DSDV). This is a table-driven routing protocol, based off of the Bellman-Ford algorithm. The routing table consists of each known destination node, as well as which node the packet should be forwarded to. This assesses how many hops the packet will need to travel to achieve efficient delivery. DSDV also utilizes sequence numbers to ensure the fastest route [5].

Optimized Link State Routing Protocol (OLSR) is the other proactive protocol being tested. This protocol focuses on sending out “Hello” messages to its neighbors and topology control to discover and compute its next hop destination. Once determined, it uses the shortest hop path to deliver packets [6].

B. Reactive Protocols

The first reactive protocol being tested is Ad Hoc On Demand Distance Vector Routing (AODV). Like DSDV, AODV uses sequence numbers to indicate how fresh a route is, and to avoid loop formation. AODV utilizes three types of routing messages: Route Request (RREQ), Route Reply (RREP), and Route Error (RERR). In order to acquire a route to a destination, AODV floods the network with RREQ. If the RREQ reaches its destination, then the destination responds by sending a RREP, otherwise the RREQ would time out and the last node would respond by sending a RERR [7].

The second protocol is the Dynamic Source Routing (DSR). DSR is similar to AODV in which it floods route requests to acquire paths to a destination. However, DSR is different because it relies on source routing over each node’s routing table. In source routing, each address between the source and destination is collected and processed. Once the best route is processed, the address of each hop is included with the packet and sent along its designated path [8] [9].

C. Hybrid Protocols

Hybrid protocols are created by merging the advantages of proactive and reactive protocols. Specific characteristics can be combined here to tailor a protocol to best suit an application. Zone Routing Protocol (ZRP) is an example of a hybrid protocol [10]. In ZRP, zones are formed around each node, which encases its neighboring nodes. Intra-zone Routing Protocol (IARP) is used when communicating with neighbors that are within the zone. At this time a proactive protocol would be used. Otherwise, when communicating with nodes outside of the zone, Inter-zone Routing Protocol (IERP) is used which would consist of a reactive protocol.

D. Modified Protocols

Protocols can also be modified beyond their initial configuration to improve performance. Mai et al. [11] implemented a congestion control scheme to AODV to lower the performance degradation caused by packet congestion. Jhajj et al. [12] is another example of where AODV was modified. In this case, the time to live (TTL) factor was used to assist in route discovery to avoid flooding the network. In both of these cases AODV was modified to outperform its original protocol.

III. Simulation

The simulation software that was used is NS-3, a robust network simulator. NS-3 was chosen since it supports mobility and WiFi models as well as MANET routing protocols. It has excellent documentation and allows for simple network analysis. NS-3 can also utilize other tools like NetAnim. NetAnim visualizes the simulation, allowing for the movement and communication of the nodes to be observed. An example of a simulation being run through NetAnim is shown in Fig. 3.

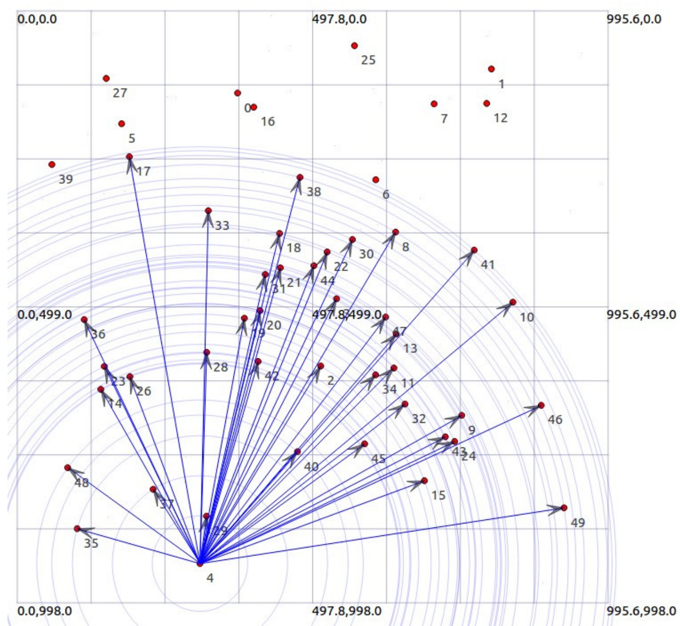

Fig. 3. NetAnim visualizing a simulation with a 1000 m^2 area.

A. Simulation Setup

There are a total of 50 nodes with 10 of them acting as sinks and 10 sending application data. The data is sent at a constant rate of 256 bytes per second in the form of four 64 byte UDP packets. Each simulation runs over a period of 200 seconds and the application packets start being sent between the 100 and 101 second marks. The nodes use WiFi 802.11b in ad hoc mode and the transmit power is fixed at 7.5 dBm.

Simulations were run for each protocol (AODV, DSDV, DSR, OLSR) across several nodes speeds: 0, 5, 10, 15, 20, 25, and 30. Each set of simulations were run for areas of 500 m^2, 750 m², and 1000 m². The complete configuration of the simulation is tabulated below in Table I.

TABLE I SYSTEM AND SIMULATION CONFIGURATION

Parameter	**Value**
Simulator	Network Simulator v3.29
Operating System	Ubuntu 16.04 LTS
Protocols	AODV, DSDV, DSR, OLSR
Simulation Area (m^2)	500, 750, 1000
Total amount of nodes	50
Amount of sink nodes	10
Node Speed (*m/s*)	0, 5, 10, 15, 20, 25, 30
Simulation Time	200 seconds
Channel Type	Wireless Channel
Mac Protocol	802.11b
Data Packet Size	64 bit
Data Packet Type	UDP
Transmit Power	7.5 dBm

B. Metrics

The two metrics that was evaluated during these simulations were PDR and AETED. Equation (1) was used to determine PDR for all of the simulations.

$$PDR = \frac{Packets\ Received}{Packets\ Sent} \quad (1)$$

Equation (2) was used to determine AETED for all of the simulations. The variable n represents the total number of packets received by the sink nodes. Time Receivedi represents the simulation time at the moment when a sink node receives a Packeti and Time Senti represents the time when that packet was sent.

$$AETED = \frac{1}{n}\sum_{i=1}^{n} Time\ Received_i - Time\ Sent_i \quad (2)$$

IV. SIMULATION RESULTS AND JUSTIFICATION

A. Packet Delivery Ratio Results and Justification

The first set of simulations shown in Fig. 4 compares the protocols' PDR across different node speeds in a 500 m² area. AODV has a higher PDR at higher node speeds, but has a lower PDR than OLSR and DSR at 5 and 10 m/s. DSDV has the lowest PDR at each simulated speed.

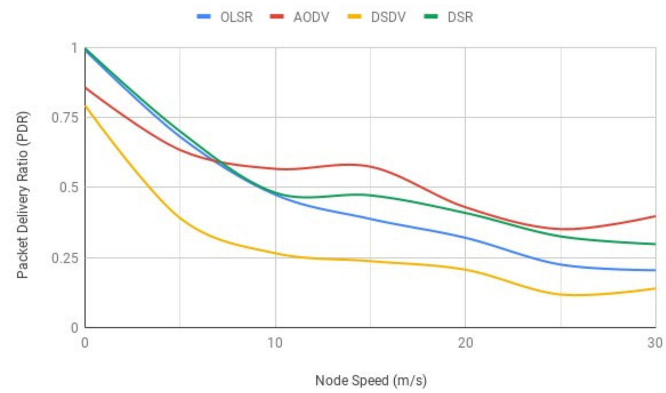

Fig. 4. PDR vs node speed in a 500 m² area.

In the 750 m² area simulations, shown in Fig. 5, OLSR has the highest PDR at 0 m/s and AODV being a close second. AODV has the highest PDR for each other node speed. DSDV has the lowest PDR for each speed value.

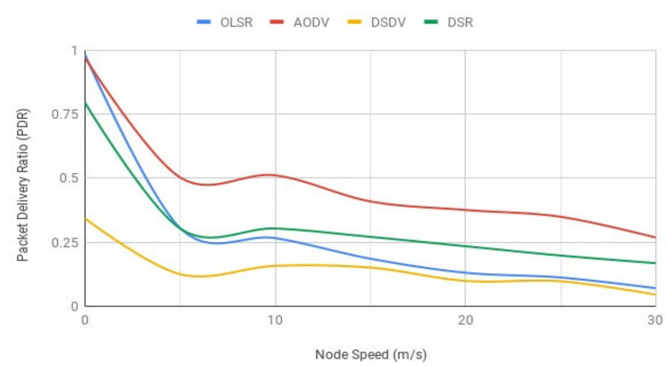

Fig. 5. PDR vs node speed in a 750m2 area.

The last set of simulations have an area of 1000 m² and are shown in Fig. 6. DSR, OLSR, and AODV have similar PDR at speed 0 m/s, but AODV tends to have a higher PDR than the others at higher node speeds.

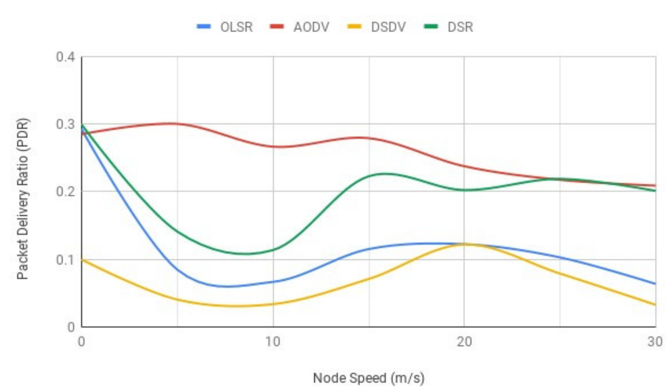

Fig. 6. PDR vs node speed in a 1000 m² area.

The data collected during the simulations and used for the PDR line charts is tabulated in Table II.

TABLE II PDR RESULTS

Area Size (m^2)	**Protocols**	**Speeds (*m/s*)**						
		0	*5*	*10*	*15*	*20*	*25*	*30*
500	AODV	.86	.63	.57	.58	.43	.35	.40
	DSDV	.79	.39	.27	.24	.27	.12	.14
	DSR	.99	.70	.48	.47	.41	.33	.30
	OLSR	.99	.68	.48	.39	.32	.23	.21
750	AODV	.97	.50	.51	.41	.38	.35	.27
	DSDV	.34	.13	.16	.15	.10	.10	.05
	DSR	.80	.30	.3	.27	.23	.20	.17
	OLSR	.98	.31	.27	.19	.13	.11	.07
1000	AODV	.29	.30	.27	.28	.24	.22	.21
	DSDV	.10	.05	.03	.07	.12	.08	.03
	DSR	.30	.14	.11	.22	.20	.22	.20
	OLSR	.29	.08	.07	.12	.12	.10	.06

B. Average End-to-End Delay Results and Justification

The set of simulations for the 500 m² area in Fig. 7 shows that DSR has much higher AETED than the other protocols for speeds greater than 0 m/s with the exception of the 20 m/s simulation. OLSR has the lowest AETED for speeds below 30 m/s.

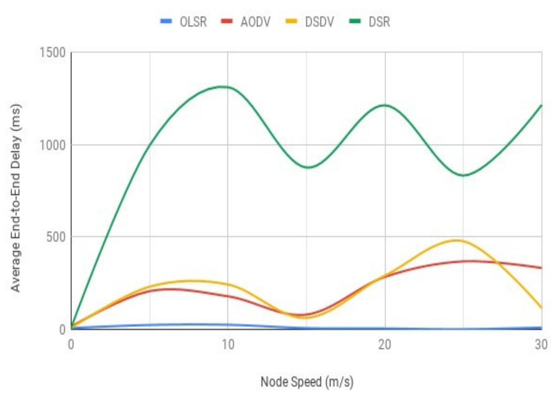

Fig. 7. AETED vs node speed in a $500m^2$ area.

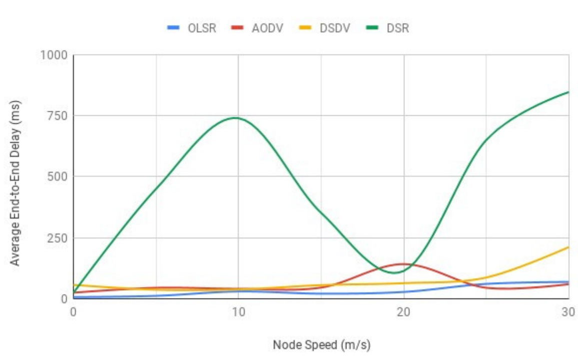

Fig. 8. AETED vs node speed in a $750m^2$ area

For the 750 m² area in Fig. 8 and the 1000 m² area in Fig. 9, DSR has a much higher AETED after 0 m/s and OLSR has the lowest AETED for each node speed.

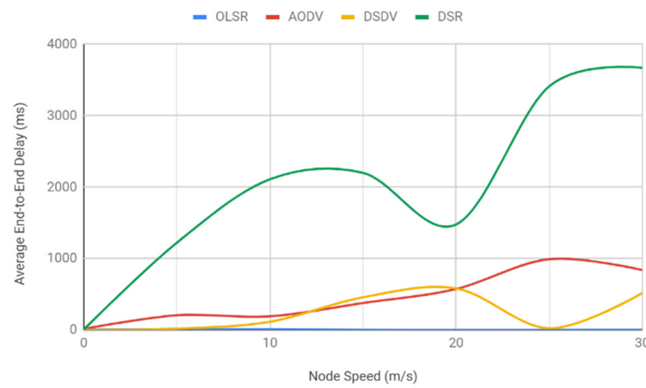

Fig 9. PDR vs node speed in a $1000m^2$ area.

The data collected during the simulations and used for the AETED line charts is tabulated in Table III.

TABLE III AETED RESULTS

Area Size (m^2)	Protocols	Speeds (m/s)						
		0	*5*	*10*	*15*	*20*	*25*	*30*
500	AODV	25	45	41	46	142	45	60
	DSDV	57	37	38	56	64	87	212
	DSR	24	450	740	352	114	651	847
	OLSR	7	12	30	21	28	61	69
750	AODV	15	207	179	80	284	368	332
	DSDV	8	231	243	62	291	447	115
	DSR	9	995	1310	875	1212	832	1215
	OLSR	7	24	25	7	5	1	10
1000	AODV	13	204	189	376	572	990	838
	DSDV	0	17	113	456	580	22	516
	DSR	5	1221	2109	2199	1476	3411	3670
	OLSR	5	9	9	1	0	0	1

V. CONCLUSION

In this experiment, the PDR and AETED performance metrics were applied to four different routing protocols. Each protocol was simulated with nodes traveling at speeds ranging from 0-30 m/s, and area sizes ranging from 500–1000 m². The data analyzed will be applied to improve the efficiency of real-world systems, improvement of protocols, and creation of hybrid protocols.

ACKNOWLEDGMENT

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REFERENCES

[1] Bang, Ankur O. and Prabhakar L. Ramteke. “MANET : History , Challenges And Applications.”.

[2] AnushkaKhattri, “Introduction of Mobile Ad hoc Network (MANET),” GeeksforGeeks, 09-Aug-2019. [Online]. Available: https://www.geeksforgeeks.org/introduction-of-mobile-ad-hoc-networkmanet/. [Accessed: 17-Nov-2019].

[3] Conti, M. and Giordano, S. (2007). Multihop Ad Hoc Networking: The Theory. IEEE Communications Magazine, 45(4), pp.78-86.

[4] Y. Bai, Y. Mai and N. Wang, ”Performance comparison and evaluation of the proactive and reactive routing protocols for MANETs,” 2017 Wireless Telecommunications Symposium (WTS), Chicago, IL, 2017, pp. 1-5. doi: 10.1109/WTS.2017.7943538

[5] Perkins, Charles and Bhagwat, Pravin. (1999). Highly Dynamic Destination-Sequenced Distance-Vector Routing (DSDV) for Mobile Computers. ACM SIGCOMM Computer Communication Review. 24. 10.1145/190314.190336.

[6] En.wikipedia.org. (2019). Optimized Link State Routing Protocol. [online] Available at: https://en.wikipedia.org/wiki/Optimized Link State Routing Protocol [Accessed 17 Nov. 2019].

[7] Jhaveri, Rutvij. (2015). Mobile ad-hoc networking with AODV: A review. International Journal of Next-Generation Computing. 6. 165191.

[8] Tools.ietf.org. (2019). RFC 4728 - The Dynamic Source Routing Protocol (DSR) for Mobile Ad Hoc Networks for IPv4. [online] Available at: https://tools.ietf.org/html/rfc4728 [Accessed 17 Nov. 2019].

[9] En.wikipedia.org. (2019). Dynamic Source Routing. [online] Available at: https://en.wikipedia.org/wiki/Dynamic Source Routing [Accessed 17 Nov. 2019].

[10] A. Khatkar and Y. Singh, ”Performance Evaluation of Hybrid Routing Protocols in Mobile Ad Hoc Networks,” 2012 Second International Conference on Advanced Computing & Communication Technologies, Rohtak, Haryana, 2012, pp. 542-545. doi: 10.1109/ACCT.2012.86

[11] Y. Mai, F. M. Rodriguez and N. Wang, ”CC-ADOV: An effective multiple paths congestion control AODV,” 2018 IEEE 8th Annual Computing and Communication Workshop and Conference (CCWC), Las Vegas, NV, 2018, pp. 1000-1004. doi: 10.1109/CCWC.2018.8301758

[12] H. Jhajj, R. Datla and N. Wang, ”Design and Implementation of An Efficient Multipath AODV Routing Algorithm for MANETs,” 2019 IEEE 9th Annual Computing and Communication Workshop and Conference (CCWC), Las Vegas, NV, USA, 2019, pp. 0527-0531. doi: 10.1109/CCWC.2019.8666607