Comparison Between Reactive MANET Routing Protocols: AODV and DSR

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***Abstract*— This project demonstrates a comparative study between the MANET routing protocols AODV and DSR. This was achieved by transferring packets from a wireless source node to a wireless destination node while employing predetermined topologies applied on NS-2. The schemes consist of a basics network of nodes. The protocols will be evaluated and analyzed as per topology scenario while using the same evaluation rubric for each protocol. Overall, DSR was determined to be superior to AODV in practical wireless scenarios.**

Keywords*— *MANET, AODV, DSR, TCP, UDP, Throughput, Total Residual Energy, Packet Delivery Ratio.

I. Introduction

Mobile Ad Hoc Network (MANET) are decentralized mobile nodes that interact with each other without utilizing any infrastructure [1]. Due to the dynamic nature of MANETS, they can function as the host or the router to maintain active communication in the network [2]. MANET nodes can move freely in a random fashion as they are wireless nodes [3][4] furthermore, nodes work together, by rerouting packets to other nodes, to deliver packets from a source to the destination. The motivation of this research is to better understand the functionality of wireless networks to improve and optimize communication techniques. This paper will present results of two reactive MANET routing protocols; AODV and DSR. Transmission Control Protocol (TCP) traffic will first be used to demonstrate the 'ideal' scenario and then User Datagram Protocol (UDP) traffic will be employed to illustrate a more realistic representation of how these protocols function. These simulations will be simulated on NS-2. The NS-2 program will attempt to transfer a file through the wireless network topologies. The results will be compared to identify the best performer in each aspect. The routing protocols will be graded in terms of average throughput, instantaneous throughput, total residual energy, and packet delivery ratio [5]. This area of research has been well explored as routing protocols have been compared in terms of different metrics which include speed of route discovery and packet drop rate [6].

II. Background

Reactive, or on-demand routing protocols, have reduced overhead when compared to Proactive, or table-driven routing protocols [7]. Reactive routing protocols search for a currently requested route by using the concept of Flooding which sends Route Request (RREQ) packets throughout the network [8]. This project aims to simulate how each of the MANET reactive routing protocol function with the different predetermined scenarios. Using the NS-2 software enables ease of design and allows for variations that allow to represent scenarios that are similar to real life ones. The two reactive routing protocols used are:

1. AODV: Ad Hoc On-Demand Distance Vector, is a loop-free reactive routing protocol [9]. AODV maintains active routes moreover, sequence numbers are used for loop prevention and to ensure route freshness [10]. AODV discovers and maintains necessary routes. Route discovery is done by flooding. Every node maintains its monotonically increasing sequence number [11]. AODV employs routing tables one for each unicast and multicast. In terms of route discovery, when a packet is to be sent, the sending node checks whether it has the destination's route. If yes, the packet is forwarded to the next hop else Route Request (RREQ) is sent by the source node [12].
2. DSR: Dynamic Source Routing is a loop-free reactive protocol the aims to reduce bandwidth by deleting frequent table updates [13]. The source packet determines the entire sequence of nodes where the data will be forwarded through. The source routing does not need to maintain the routing information through the intermediate hops. DSR supports unidirectional links [14] and unlike AODV, active routes are maintained on a routing cache rather than a routing table [15].

The properties of the selected reactive MANET protocols are further discussed in Table. 1. The traffic generated for each of MANET protocols will be either from TCP, to show what would happen in an ideal situation, or UDP to demonstrate what really occurs in a simulation that aims to simulate a real-life scenario. TCP is a reliable way transmitting data moreover and it has error checking [16]. TCP ensures packets reach their destination and only disconnects a session either by finishing transmission of the packets or by packets getting lost. UDP on the other hand tolerates loss and aims to provide fast communication [17]. With regard to the aforementioned points, TCP is used for services such as HTTP and SMTP while UDP is used for real-time applications such as video streaming and VoIP.

III. Literature Review

There have been many advancements in this field with different variations in studies for instance, study [18]

TABLE I. REPRESENTS A COMPARISON BETWEENAODVANDDSRREACTIVEMANETROUTING PROTOCOLS

Property	AODV	DSR
Reactive	Yes	Yes
Loop free	Yes	Yes
Multicast routes	No	Yes
Distributed	Yes	Yes
Unidirectional link	No	Yes
Routes maintained in	Routing table	Routing cache
Packet size	Uniform	Non uniform

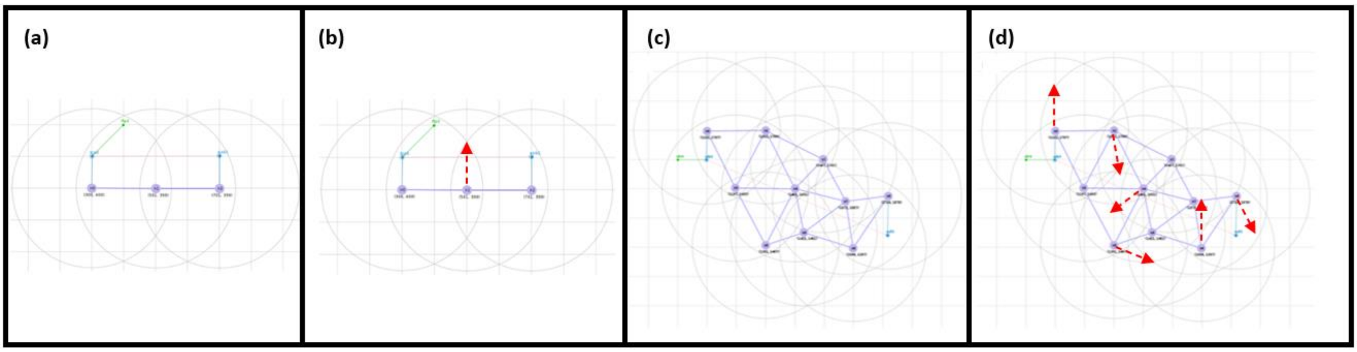

Fig. 1 (a) Depicts the scenario 1 and (b) illustrates how scenario 2 initially appears before n1 moves away causing the session to disconnect. (c) Portrays scenario 3 while (d) displays the initial state of scenario 4 before nodes start moving randomly. Note that the red arrow in (b) and (d) indicate movement.

mainly focused on mobility packet delivery, mobility, and delay. The study gave a comprehensive review of how each of the protocols work along with a clear comparison in terms of theoretical properties. Furthermore, different scenarios of randomly moving nodes was implemented on NS-2 and analysed. The paper only used a packet size of 512 Bytes and claimed that AODV performs better than DSR when nodes are mobile with 92.44% packet delivery rate versus 87.82%.The study suggests using a combination of both protocols for optimal results. In paper [19], reactive routing protocols were claimed to be superior to proactive ones. [19] focused on packet sized versus number of packets received, with randomly moving nodes, while maintaining a fixed network topology. Despite this, no mention of benchmark results was given to compare how results vary when nodes are stagnant versus when they a randomly moving. Despite the claim that performance decreases as mobility increases, both AODV and DSR were said to do better with smaller packet size. Overall, DSR was crowned the winner. A thorough theoretical background was provided in [20] along with claims that DSR is the most energy efficient. Protocols were graded 1 to 3 in terms of predetermined metrics moreover, metrics employed include end-to-end delay and packet delivery ratio. This paper claimed that AODV is the best performer due to the increase in mobility since DSR only performs well when mobility is moderate. The goal of [21] was to target energy consumption of nodes when using either AODV or DSR. Their claims were expected and predictable as they mentioned that as the number of nodes increases, so does the overall energy consumption. The study concluded by mentioning that DSR performed better. The study had no mention of by how much did DSR overall perform better than AODV. The evaluation metrics in [22] appear to be the best so far by having a variety of aspects to evaluate the MANET networks. The evaluation metrics include variation for control overhead, packet delivery ratio, end-to-end delay, and throughput. The claim for choosing these specific metrics is for understanding how the protocols function in order to provide better Quality of Service (QoS).The simulation area in [22] is also the largest with an area of 600x600 meters squared. In conclusion, [22] suggested that DSR would provide the best QoS. Finally, [23] investigates how the performance varies when nodes are moving at different speeds. The setup consisted of a 512 Byte packet being transmitted in a network with fixed number of nodes. Speed was varied between 10, 20, 30, 40 meters per second. As mobility increased, the packet delivery ratio decreased and the end-to-end delay increased. AODV had better packet delivery ratio but more end-to-end delay. While considering the previously mentioned literature re-view, despite the area of reactive MANET routing protocols being comprehensively studied, issues in the result presentation and discussion constantly appear. First, Most of the studies do an excellent job at providing a theoretical background and clearly mentioning their experimental setup but fail to show their respective setups. This raises concerns since studies claim to have nodes moving randomly and for the same metrics, they conclude with different decisions on which protocols perform the best. For instance, if nodes move randomly but eventually end up closer to each other, results will be completely different than nodes that are moving randomly but finally are overall much further away from each other. Second, many papers seem to not be very effective at portraying and quantifying how much a superior protocol performs with in regard to a specific metric. Instead, many studies produce graphs that evidently show that a protocol performs better but without clearly specifying the margin of superiority. Papers tend to conclude with qualitative results or possibly ambiguous statements rather than irrefutable and quantitative results produced from their respective experiments. Finally, many previous works tend to mainly consist of theoretical work with less on the number of evaluation metrics considered. Since theoretical work has been established and clarified, the focus of researchers should shift towards more practical applications and implementations of the protocols.

IV. PROJECT METHODOLOGY

A. *Evaluation metrics*

To fully understand how each of the protocols, AODV and DSR, work, a set of testing criteria has been placed to measure different aspects which include:

1. Average Throughput: The measure data that, on average, was successfully transferred from one end to another in a long amount of time. The unit of the Average Throughput is Kilobits per second (Kbps) [24].
2. Instantaneous Throughput: The measure of data instantly and successfully transferred from one end to another in a short amount of time, in this case 0.1 of a second. The unit of measuring Instantaneous Throughput is Kilobits per second (Kbps) [25].

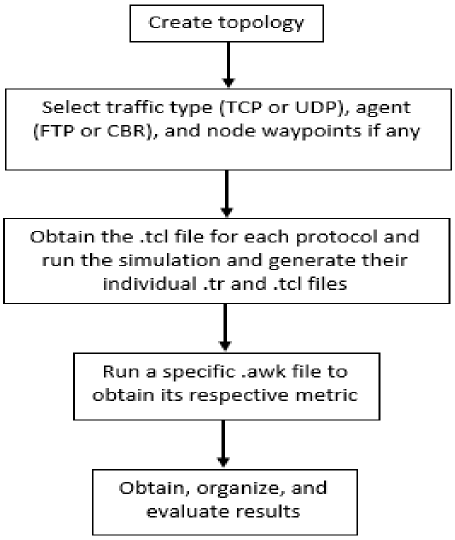

Fig. 2. Steps to obtaining the results for each protocol with every topology.

3. Total Residual Energy of Nodes (TRE): The sum of change of energy in each node, before (at the sender) and after (at the receiver).

$$TRE = \sum_{i=0}^{n} (Energy\ at\ sender_i - Energy\ at\ reciver_i)$$

4. Packets Delivery Ratio (PDR): Is the number of packets received by the receiver divided by the number of packets sent by the sender.

$$PDR = \frac{Packets\ recieved}{Total\ packets\ sent}$$

B. *Experiment setup*

This project has multiple stages to obtain the required results. The designed typologies, they are follows:

1. Scenario 1; 'Ideal' stagnant: This scenario consists of 3 stagnant wireless nodes equidistant and placed alongside one another while utilizing a TCP connection with an FTP agent. This is shown in Fig. 1(a). This topology aims to demonstrate how communication occurs, with node n0 being the source and n2 being the destination, when barely any factors are affecting communication such as distance and packet loss.

2. Scenario 2; 'Ideal' with disconnected session: At time 0, the node placement is similar to the 'ideal' stagnant scenario but node 1, that is shown in Fig. 1(a), moves out of nodes 0 and 2's range to prevent them from communicating. This scheme is meant to show how if packet loss occurs in TCP, the session is terminated. Therefore, TCP is not ideal in terms of loss tolerance.

3. Scenario 3; Stagnant practical scenario: This scheme depicts a more realistic illustration in terms of the number of nodes and the random allocation of the positions of each node. This scheme, shown in Fig. 1(b), utilizes UDP traffic with a CBR agent and has 10 nodes with node n0 being the source and node n9 being the destination. The topology aims to provide a benchmark for the 'Randomly moving nodes in the practical scenario' setup. This scenario will clarify how drastic the effects of mobility are on the determined metrics.

TABLE II. REPRESENTS THE FEATURE OF EACH SCENARIO

Feature	**Scenario Number**			
	1	*2*	*3*	*4*
Number of nodes	3	3	10	10
Moving	No	Yes	No	Yes
Connection	TCP	TCP	UDP	UDP
Agent	FTP	FTP	CBR	CBR
Packet size (Bytes)	1500	1500	1500	1500
Simulation duration (Seconds)	11	11	11	11
Initial energy per node (Joules)	10	10	10	10
Node's energy requirement to send (J)	1.00	1.00	1.00	1.00
Node's energy requirement to receive (J)	0.6	0.6	0.6	0.6
Node's energy requirement to idle (J)	0.3	0.3	0.3	0.3
Node's energy requirement to sleep (J)	0.1	0.1	0.1	0.1

4. Scenario 4; Randomly moving nodes in the practical scenario: This scheme is similar to the one in Fig. 1(b) but has randomly moving nodes to simulate a real-life wireless Ad-hoc network. This specific scenario was designed in a way such that the randomly moving nodes do not intentionally make it easier of more difficult for the source and destination to communicate. This avoids experimental bias.

The experiment's duration for each scenario is between 0 and 10 seconds. Scenarios 1 and 2 use an FTP agent while scenario 3 and 4 use a CBR agent. Moreover, the energy each node starts with in all scenarios is 10J. Furthermore, for all scenarios, Nodes spend 1.00J to transmit and 0.600J to receive data. All nodes spend 0.300J when idle and 0.100J when asleep. The specifications for each scenario are summarized in Table II.

All schemes were implemented using NSG2.1 software; this allowed for the placement of nodes and the construction of the desired network. Furthermore, The NSG2.1 program allows the user to observe the simulated motion of nodes and produces files which allow the user obtain the desired metrics from. To obtain the metric's values, first the Tool Command Language (.tcl) file for each individual topology is run. This produces a trace file (.tr) and a Newsletters And More (.nam) file. The contents of these produced files allow for the grading metric's values to be generated. Each grading criteria has its own Aho, Weinberger, and Kernighan (.awk) file. The names of these files are as follows:

1. avgTp.awk: Generates the average throughput of the topology.
2. instTp.awk: Produces the Instantaneous throughput of the topology.
3. pdr.awk: Gives the packet delivery ratio of the topology.
4. res.awk: Outputs the residual energy of each individual node in the topology and the total energy consumed by all the nodes.

The results produced will be organized and illustrated in an appropriate manner to provide and effective representation of each protocols performance. This will be followed by concluding which reactive MANET routing protocol achieves the best result with regard to each respective evaluation

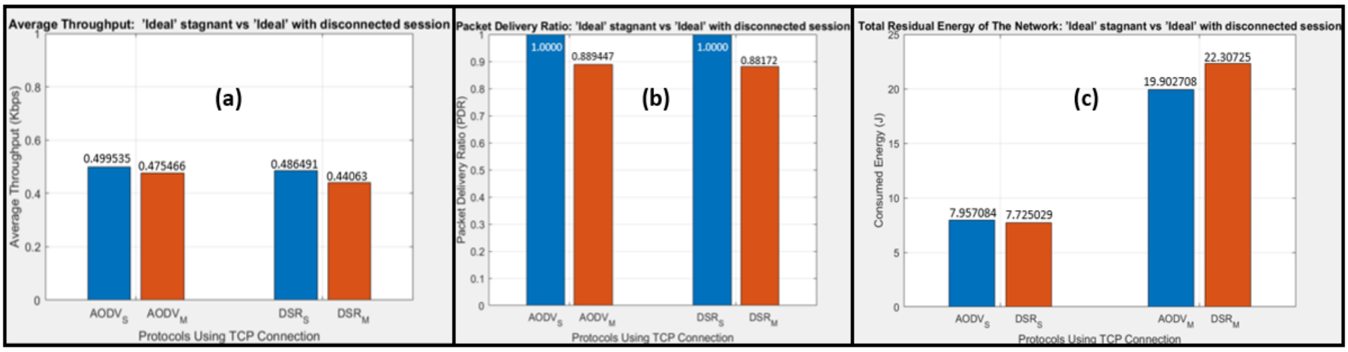

Fig. 3. For scenarios 1 and 2, (a) shows the average throughput, (b) illustrates the Packet Delivery Ratio, and (c) depicts the total residual energy of the network. AODVs and DSRS indicate Stagnant AODV and Stagnant DSR while AODVM and DSRM refer to AODV Moving and DSR Moving, respectively.

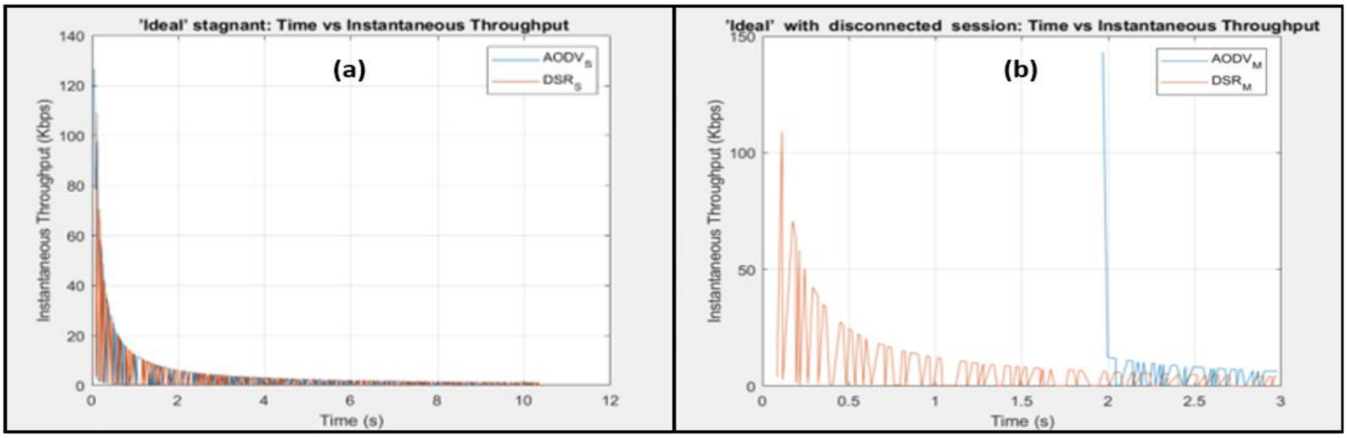

Fig. 4. For scenarios 1 and 2, (a) shows the time vs instantaneous throughput of the 'Ideal' stagnant scenario while (b) illustrates the time vs instantaneous throughput of the 'Ideal' with disconnected session. $AODV_S$ and DSR_S indicate Stagnant AODV and Stagnant DSR while $AODV_M$ and DSR_M refer to AODV Moving and DSR Moving, respectively.

metric. The steps to generating the results for each individual protocol with every scheme is summarized in Fig. 2.

V. Results and Evaluation

This section will display the results obtained in an effective manner and clarify which reactive MANET routing protocol performs the best in which metric. In that regard, finally, a protocol will be announced superior with respect to the experiments conducted and the overall results retrieved. This section will be split into two subsections. The first subsection will highlight scenario 1 and 2 to demonstrate what would ideally occur. This will be followed by the second subsection which will provide the results scenario 3 as a benchmark for scenario 4.

A. Scenario 1 and 2

Scenario 1 demonstrates what occurs in hypothetical situation where nodes of a network are close to each other, are small in number, not moving, and use TCP. TCP ensures packet delivery. To show how TCP reacts when the source, node n0 in Fig.1(a), cannot reach the destination, node n2 in Fig.1(a), node n2 will be moved out of range to cause the session to disconnect. The session being disconnected will be shown in scenario 2. Fig. 3(a) shows how the average throughput compares for AODV when stagnant then when moving followed by DSR when stagnant then when moving. Under ideal conditions and when all nodes are still, AODV has an average throughput of 0.4995 Kbps compared to 0.4755 Kbps when node n1 causes the session to disconnect. The difference is a 4.82% in performance. On the other hand, When the same topology is employed for DSR, the average throughput is 0.4865 Kbps when still versus 0.4406 Kbps when node n1 causes the session to disconnect. This is a 9.43% difference. AODV in both still and moving scenarios performs better than DSR. Once explanation to why the average throughput drops in both moving AODV and moving DSR when compared to their stagnant counterparts is possibly due to the throughput being an average over the same duration of time for the still and moving scenarios therefore, when the node n1 moves out of range, the session disconnects, and the instantaneous throughput is zero. This effect can be seen in figures 4(a) and (b). As expected, when all three nodes are still, the have a packet delivery ratio of 1.00 for both AODV and DSR. The packet delivery ratio changes when node n1 causes the session to disconnect. For AODV, the source node n0 was able to transfer 88.9% of the 1500 Bytes before the session was terminated while DSR was able to send a very close but less 88.2%. The difference in performance of the two protocols is negligible. This is due to no issues with long distances or the packet having to be relayed to multiple nodes. In terms of energy consumption, shown in Fig. 3(c), when nodes were not moving, the energy required is less. More specifically 7.9571 J and 7.973 J for AODV and DSR respectively. This is a negligible 0.200% difference. On the other hand, in the scheme were node n1 moves, AODV recorded 19.90 J out 30 J that were initially given compared to 22.31 J out of 30J for DSR. Therefore, DSR consumes 10.8% more energy than DSR. The instantaneous throughput

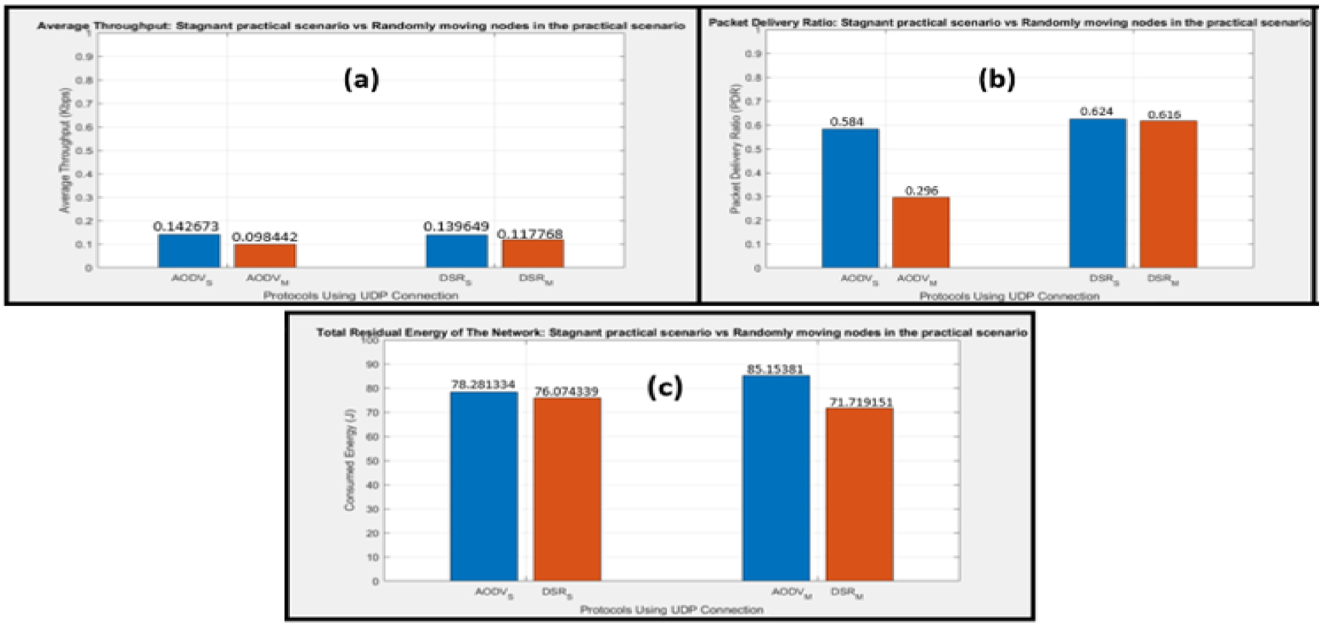

Fig. 5. For scenarios 3 and 4, (a) shows the average throughput, (b) illustrates the Packet Delivery Ratio, and (c) depicts the total residual energy of the network. AODVs and DSRS indicate Stagnant AODV and Stagnant DSR while AODVM and DSRM refer to AODV Moving and DSR Moving, respectively.

for the stagnant network is shown in Fig. 4(a). The instantaneous throughput of both protocols appears very similar as the decay exponentially while heavily fluctuating. Both sessions start 0 seconds and end close to 11 seconds. At time=0.00s, AODV has a larger initial throughput at 141Kbps versus 109 Kbps for DSR. On the other hand, when node n1 is made to move (shown in Fig 4(b)), the instantaneous throughput of AODV starts are time=2.00s rapidly decays till time=3.00s where the TCP session is terminated. Meanwhile, for DSR, the session appears to start at time=0.1 s and exponentially decay to end at time=3.00s. The delay of the AODV session starting may be attributed to DSR's utilization of a routing cache rather than a routing table which in small networks (little packet header overhead) allows the sender to find the destination quicker.

B. *Scenario 3 and 4*

This subsection presents a more realistic network topology consisting of wireless nodes that use UDP. Due to wireless nodes moving, they are more susceptible to packet loss therefore, using UDP provides a better packet loss tolerance than TCP. First the results scenario 3 will be discussed. The benefit of this scenario is to provide a benchmark of what scenario 4 could potentially accomplish Furthermore, studying the benchmark will portray how drastic are the effects of random motion in a network. By referring to Fig. 5(a), it can be deduced the average throughput value of the benchmark scheme is greater for AODV, 0.1427Kbps, than in DSR, 0.1396Kbps. This is a 2.12% difference. On the other hand, when nodes are mobile (during scenario 4), DSR tends to perform better, 0.1178Kbps, than AODV, 0.09844Kbps, in terms of average throughput. This is a significant 16.4% difference. In terms of the packet delivery ratio (shown in Fig. 5(b)), DSR performs better than AODV in both the benchmark test and the randomly moving test. AODV had a 58.4% packet delivery ratio compared to that of DSR which is 62.4% when all nodes are still. Furthermore, AODV had a packet delivery ratio of 29.6% versus that of DSR which is 61.6% when the nodes are randomly moving. This is a 32.0% difference in performance which is very large. This difference can be linked to the fact that DSR has alternative routes available in its routing cache which makes is adapt better than AODV to nodes moving. With each node given 10.0J of energy at time=0.00s, the network has 100.0J of energy to start off with. Fig. 5(c) shows that AODV consumed more energy in both the cases, when nodes are not moving and when nodes are moving, is more than DSR. For the non-moving topology, AODV consumes 78.3J while DSR required 76.1J. The difference is a small 2.81J. Surprisingly, when nodes randomly, AODV needed 85.2J while DSR required 71.7J. Not only DSR is 15.8% more efficient in the randomly moving scheme but it is also 5.72% more efficient than DSR in the stagnant DSR scheme. The results can be explained as follows, first, in the randomly moving nodes scheme, DSR uses less energy than AODV due its use of a routing cache. When a network is not extremely big, routing caches are faster and more efficient. Second, regarding DSR's energy consumption being less in the randomly moving nodes network than in the not moving one, this can be due to the random nature of node's movements. For AODV, this specific movement led to a higher energy consumption than the stagnant scheme but resulted in less energy intake for DSR when utilizing the same random motion of nodes. The instantaneous throughput illustrated in Fig. 6(a) for the stagnant scenario. It can be observed that the overall line for both AODV and DSR is smooth. AODV starts at a high throughput of 63.86 Kbps at time=1.13s and rapidly decreases to its end at time=4.09s with a throughput of 2.638Kbps. On the other hand, DSR starts 6.709 Kbps at time=1.12s and continues to decay very slightly reaching an instantaneous throughput of 1.790 Kbps at time=4.47s. A similar shape to that in Fig. 6(a) is followed in Fig. 6(b). Fig. 6(b) shows the instantaneous throughput of AODV and DSR when nodes are moving randomly. AODV, starts at time=1.10s with a throughput of 76.38 Kbps and ends quickly due to its drastic exponential decrease at time=3.00s with a throughput of 4.066 Kbps. DSR begins transmission at time=1.16s with an initial throughput of 6.908 Kbps and decays at a small rate till its end at time=5.23s and a throughput of 1.529 Kbps. In both the moving and schemes AODV has a quicker initial start due to

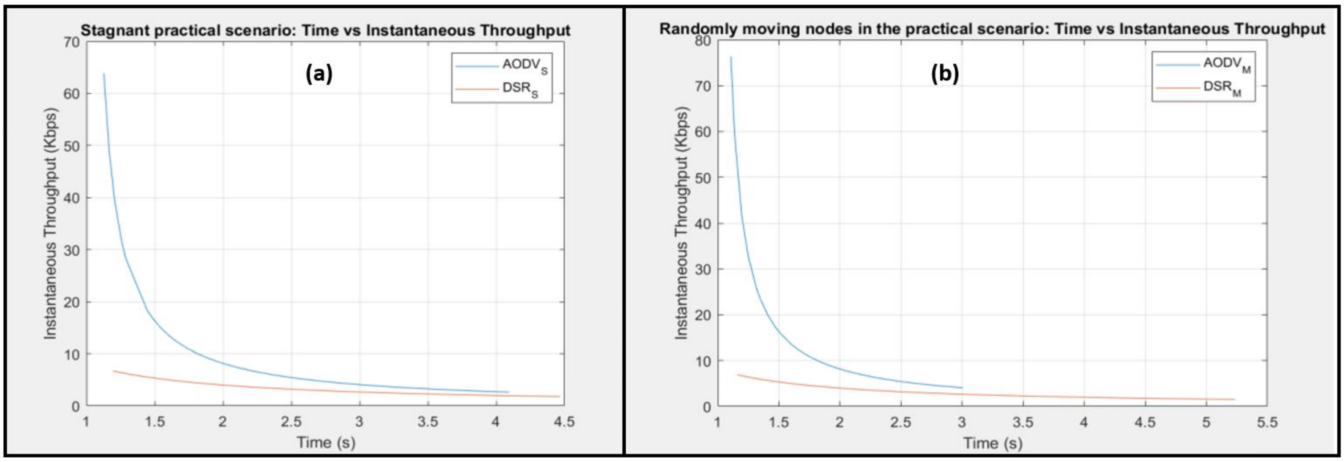

Fig. 6. For scenarios 3 and 4, (a) shows the time vs instantaneous throughput of the Stagnant practical scenario while (b) illustrates the time vs instantaneous throughput of the Randomly moving nodes in the practical scenario scheme. $AODV_S$ and DSR_S indicate Stagnant AODV and Stagnant DSR while $AODV_M$ and DSR_M refer to AODV Moving and DSR Moving, respectively.

it constantly ensuring that routes are fresh are contain no loops.

VI. Conclusion and Future Work

This paper studies the performance of reactive MANET routing protocols. Reactive protocols are on demand therefore they search for a request route when needed. Moreover, MANETs are decentralized mobile networks that do not require any infrastructure. The main goal of this research is to observe, analyze, and asses the behavior of wireless networks to provide a better understanding to what conditions they perform better in and to observe their limitations. This will be done by investigating two reactive MANET routing protocols namely, AODV and DSR. One of many important features of AODV is that it ensures route freshness by using sequence numbers. On the other hand, for DSR, an important feature is that it uses a routing cache rather than a routing table. This project first presents an ideal scenario with three nodes while employing TCP. This is to ensure all packets are received by the destination. This scenario aims to show how ideal communication happens between nodes. Furthermore, a session termination scenario for the ideal scheme was demonstrated to portray what occurs when a node moves out of range. This was followed by a practical scheme with 10 stagnant nodes to provide a benchmark for the next scenario where some of these nodes start moving. Finally, randomly moving nodes were introduced to the practical scenario to provide a realistic idea of how each routing protocol reacts. Both AODV and DSR were implemented with each of the four scenarios to obtain results. As for evaluation criteria, this paper looked into average throughput, packet delivery ratio, total residual energy of nodes, and instantaneous throughput. Both AODV and DSR experienced a slight average throughput drop in the scenario 2 than in scenario 1. Furthermore, both protocols experienced a smaller number of total packets delivered when the session was terminated along with higher energy consumption due to the movement of node n1. The instantaneous throughput for scenario 1 for both protocols was near identical while in scenario 2, DSR started much earlier while exponentially decaying till time=3.00s meanwhile AODV starts at time=2.00s and drastically decays till time=3.00s. AODV saw a better 2.12% lead in terms of average throughput over DSR in scenario 3. On the other hand, DSR tends to perform 16.4% better than AODV with regard to average throughput in scenario 4. DSR also saw a 6.41% and 52.6% improvement over AODV in terms of the packet delivery ratio in scenario 3 and 4, respectively. DSR also has a steadier instantaneous throughput than AODV in scenario 4 and consumes 15.8% less overall energy. With these results in mind, in real-life scenarios, using UDP would lead to better service than TCP in applications that can afford packet loss for instance, video steaming. If nodes are stagnant, AODV performs better in terms of average and instantaneous throughput. When nodes start randomly moving, DSR handles motion better and becomes superior to AODV in that aspect. Despite this, DSR performs better than AODV with respect to packet delivery ratio and total energy consumption in both stagnant and mobile cases. Further development for this project includes increasing the number of scenarios. This includes also increasing the number of nodes to observe whether these conclusions hold up.

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