IMPROVING AODV ROUTING PROTOCOL USING TTL-BASED SCHEME IN MOBILE AD HOC NETWORKS (MANET)

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ABSTRACT
One of the challenges in Mobile Ad hoc Network (MANET) routing is the mobility and rapid change in network topology which poses a number of problems. The protocols must be able to adapt to the unpredictable dynamic topology. The paper is aimed to improve the conventional AODV routing protocol using TTL-based scheme by proposing AODV-TTL mechanism. NS2.34 was used to conduct the experiment. The preliminary investigation showed that DSDV outperformed AODV most especially when the nodes moved at high speed, which was due to inability of the AODV to repair a broken link locally and lack of any mechanism to control the freshness of routes when there are multiple options. However, to support the proposed mechanism, experiments were conducted using some set of Time to Live (TTL) values based on the performance metrics; throughput, end to end delay and packet loss. The analysis was based on the small network size with constant and variable speed. The results of the study indicated that TTL = 3 revealed a high performance for the metrics used for the study. Therefore, with all default parameters unchanged as in conventional AODV protocol, the new TTL value was set for the proposed scheme. From the results it was found that at high speed when the nodes move and topology changed, which caused link failure, the new mechanism outperformed the conventional AODV in terms of data delivery with about 15%. It is also found that there were fewer tendencies for dropping of packets due to a small value of TTL in the new scheme at high speed compared to both AODV and DSDV that used the larger value for TTL. However, this proposed protocol generally improved the network throughput and reduced the total overhead.

1. INTRODUCTION

Mobile Ad hoc Network (MANET) is a multi-hop of self-organized wireless mobile nodes forming a decentralized network without using any communication infrastructure. In MANET, each node acts as a router and direct data to or from other nodes in the network [1]. Routing generally comprises two activities which include; determining the optimal routing paths between source to destination and packet transmission in a highly dynamic environment [2]. Routing in MANETs is very challenging due to the unpredictable dynamic changing topology cause by nodes random movement without central coordination [3]. In MANET, nodes can move within and outside the range of transmission of other nodes and still communicates with the help of intermediate nodes as shown in the Figure 1 below. The nodes A and B and nodes B and C are in communication range with each other. If node A wants to communicates with node C, then node B will acts as an intermediate node, which will forward the packet of data to node C.

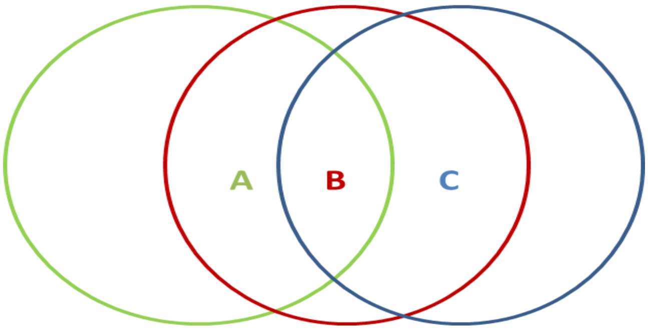


Figure 1: Simple mobile ad hoc network architecture

MANETs can be used for various applications due to their flexible nature, which may include military battlefield operations, emergency rescue operations in remote areas, commercial projects, remote construction sites, monitoring different environmental changes and effects etc. [4].This technology is characterized by some features, which imposes new demands on the routing protocols such as node mobility, dynamic topology, bandwidth limitation, low power and decentralized network control [5]. Routing in MANETs has certain challenges some of which requires available resources according to the service required. Nodes can move around in and out of wireless connectivity range while communicating with other nodes. One of the major challenges in Quality of Service (QoS) provisioning in MANET routing protocol is the mobility and rapid change in network topology, which poses a number of problems. The routing protocols must be able to adapt themselves with the high degree of node mobility and converge the network without disrupt in communication. Similarly, a dynamic routing protocol should also find routes between source and destination nodes efficiently and reliably [6]. Despite the fact that a lot of MANETs routing protocols have been implemented [7], such as Ad hoc On Demand Distance Vector (AODV), Dynamic Source Routing (DSR), Destination Sequence distance Vector (DSDV), Temporally Ordered Routing Algorithm (TORA) and Optimize Link State Routing protocol (OLSR), etc. The main focus of this paper is to improve the conventional AODV routing protocol using TTL-based scheme. Compare this new proposed scheme with conventional AODV and evaluate the performance using the metrics such as throughput, end-to-end delay and packet loss. The remaining part of this paper is organized as follows; in section II, related works are discussed. In section III, we present the proposed system model, while in section IV, the results are presented and discuss. Finally, we conclude the paper in section V.

2. Related Work

Routing protocols in MANETs are categorized into two main groups based on the mechanisms they used to relay data within the network, which include reactive and proactive approaches. The reactive routing protocol is called source initiated or on demand routing protocol. In this approach, routes are created when they are needed only for transmission. On the other hand, proactive approach, which is a table driven, uses periodic updates. This means that all nodes have tables with routing information which are updated at intervals. Many different protocols in MANETs are designed by using these two approaches. The DSR, AODV and TORA [8] are source initiated or reactive routing protocols while DSDV [9] is a table driven or proactive routing protocols. A brief description of AODV and DSDV routing protocols is given below. Figure 2below shows the classification of Mobile Ad hoc Network routing protocols.

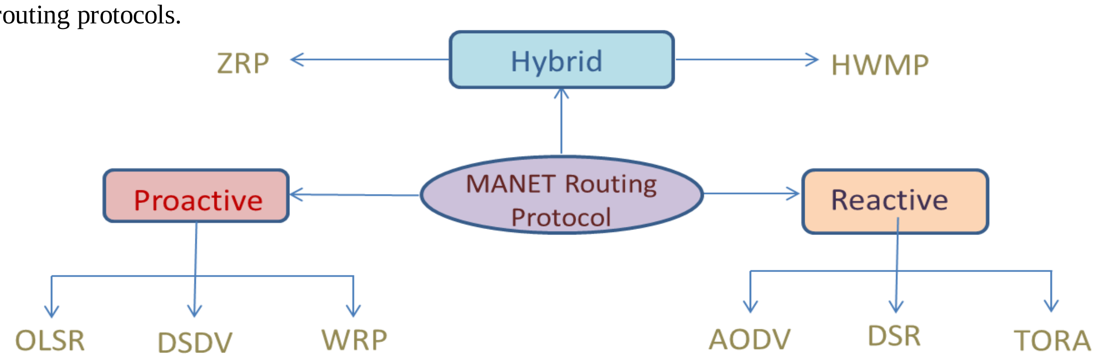
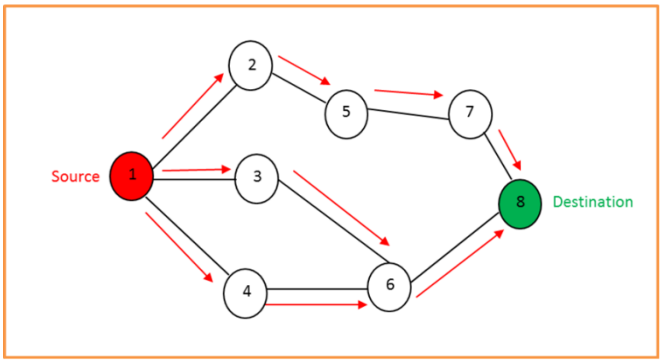


Figure 2: Classification of MANET Routing Protocols

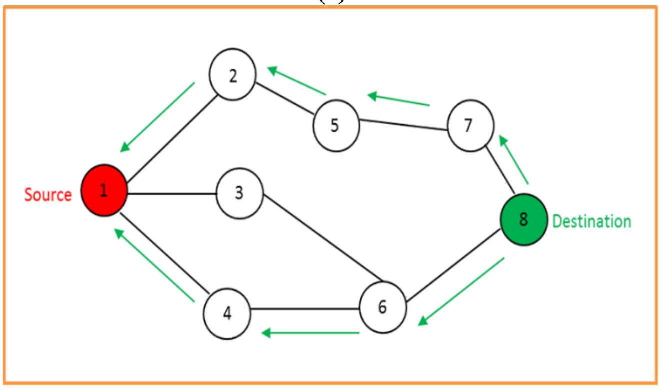
2.1 Ad hoc On Demand Distance Vector (AODV) Protocol

Ad hoc On Demand Distance Vector (AODV) is one of the reactive routing protocols that discover the routes from the source to the destination only when needed. This means it builds routes between nodes only as desired by the source nodes and maintains these routes as long as they are needed by the source [10]. To ensure the freshness of routes, AODV routing protocol uses sequence numbers and time to live TTL.

In this scheme, a source node that wants to send data initiates the route discovery process if there is no information of the requested destination in the routing table. It will broadcast a route request message RREQ to the neighbour nodes in order to discover a path to the destination. The intermediate node, which lies between the source node and destination node, will check its routing table to see if there is a valid route to the destination. A route reply message RREP will be send back if a valid route is found otherwise the intermediate node will rebroadcast the same RREQ to its neighbour nodes. The process will continue until a valid route is found. Once the source node receives the RREP message, it will start transmitting the data packets to the destination as long as the path remains active. Also, the link will be deleted from the intermediate node routing table if the source node stops sending the data packets. However, in a situation where the path is active and the link breaks a route error message RERR will be propagated to the source node to inform it about unreachable destination [11, 12]. The propagation of RREQ and RREP packets in AODV is shown in Fig. 3a and 3b below.



(a)



(b)

Figure 3: Propagation of (a) RREQ and (b) RREP Packets in AODV

2.2 Destination Sequence Distance vector (DSDV) Protocol

The Destination Sequence Distance Vector (DSDV) proactive routing protocol is based on the Bellman-Ford routing algorithm [13]. The main goal of this protocol is to solve the routing loop problem. Every node within the network maintains a routing table and contains a list of all known destination within the network along with number of hops required to reach to a particular node. Each node entry has a sequence number assigned by the destination node. These sequence numbers are used to identify routes thus avoiding formation of loops.

To maintain consistency of routing tables in a dynamically topology, each node periodically sends broadcasts with the routing table updated to its neighbours adds its sequence number when it sends its routing table and updates its routing table when the other nodes receive this information [14].The routing tables also can be sent if there are topology changes such as link creation or breakage. The nodes use the sequence numbers to distinguish between broken link and new routes to a destination. A node increases its sequence number when there is a topology change.

The route to a destination with the most current sequence number is the valid one. If there are two routes with the same sequence number, then the one with the smaller number of hops will be chosen. Broken link entries are those entries that have not been updated for a while. Such entries as well as the routes using those nodes as next hops are deleted.

2.3 Review on the Existing Literature

Several research works have been conducted to improve, compare and evaluate the performance of MANETs routing protocols. This study looked at the previous work done on the efforts made to compare the performance of reactive and proactive routing protocols. Further, it highlights on the improvement of conventional AODV routing protocol. AODV and DSR were compared with DSDV in UDP and TCP environments [15]. Some problems were highlighted such as routing overhead, dynamic topology, interference and asymmetric links, which make routing mechanism in MANETs to be a challenge. The authors used some metrics to measure the performance and determine the type of application that can be supported in a particular environment (UDP or TCP). Simulation result showed that depending on the environment and the values of the parameters used, routing algorithms performed differently, in terms of packets delivery, end-to-end delay and packet loss. In [16] DSR and AODV also were compared and analysed by looking at the mechanisms they used to select paths using different parameters. The result showed that DSR outperforms AODV when the network is less dense for application oriented metrics such as end-to-end delay packet delivery.

Research also was conducted using OLSR, DRS and AODV routing protocols [14]. Analysis was made on how these protocols differ during periods of link outages. Simulation results showed that in OLSR there was a reduction in end-to-end delay compared to AODV and DSR due to consistent lower hop count, which improves the global network performance. Some authors focused on the impact of mobility models using variable number of nodes and constant pause times [17].

The paper highlighted the effect of various mobility models on the performance of DSDV and DSR routing protocols. The metric used for the performance comparison were varying node density and hop count. This is because the mobility affects the number of connected paths, which in turn affect the performance of the routing algorithm. The performance was studied and compared for different mobility models in terms of data rate, and for different number of nodes. The results of the study showed that performance of routing protocols varies in different mobility models, which has effect on the choice of a model for a particular application.

Performance of two reactive routing protocols DSR and AODV were compared in [18] with proactive routing protocol DSDV also using some metrics such as packet delivery function, normalized routing load and average end-to-end delay. They used mobility model with different pause time and maximum speed. A network where the knowledge of the target destination is not known in priori, broadcasting of route request (RREQ) packets is commonly used. This usually incurs high overhead in terms of bandwidth across the network. Some techniques were used as an optimization strategy to reduce this overhead. Expanding ring search (ERS) is one of the schemes used to reduce the effect of flooding; though it has some problems since locating time was not considered. Performance analysis showed that for any given topology, selection of the threshold value (TTL) can determine the route cost, which conversely affects the expected broadcast cost, by reducing the high overhead across the network.

The authors in [19] also considered the problem of searching a destination node in a large network area. However, they specifically focus on the search strategy where the time to live (TTL) value in the route request RREQ packet expires. Whenever a search fails, a time to live (TTL) value increases, which increases the search area. This relatively showed that the performance of a search strategy is determined by the sequence of TTL values used. Moreover, some authors consider the use of predefined TTL value in order to enhance the performance of conventional DSR routing protocol. It was proposed in [20] that the use of appropriate TTL value in the query packet, where the source node can control the search radius. The search begins with a small TTL value, each time a query is forwarded by a source node, and the TTL value is decremented by 1. When it reaches zero, the query packet is dropped. Some authors [21] proposed the impact of using the optimal TTL sequence-based route discovery in order to improve conventional DSR routing performance. The simulation result showed that using this scheme enhanced route discovery with similar overhead than the basic route discovery mechanism, but incurs higher delay.

Regardless of many efforts to improve MANETs routing protocols, attention have not been focused much in evaluating the performance of AODV and DSDV in particular when applied to variable speed. Similarly, no comparison was made using a constant and variable mobility to determine their performance. However, in this study the performance of conventional AODV and DSDV routing protocols with constant and variable speed will be investigated. The proposed mechanism will be evaluated and analysed using simulation tool. In the propose AODV_TTL, a number of TTL values will be tested and the TTL value that gave a better result in terms of performance metrics will be selected.

3. SYSTEM MODEL

In MANET, most of the time route discovery is challenged with great delay, which may leads to unusual performance of the routing protocols. Generally every routing protocol has its own time to live (TTL) value, which is defined in the IP header. This value defines the maximum radium of a searching area by flooding. Whenever the value runs out, the source node restarts the flooding again in order to increase the search area by rebroadcasting the RREQ packet across the network. The architecture of a TTL in a node is shown in Figure 4 below.

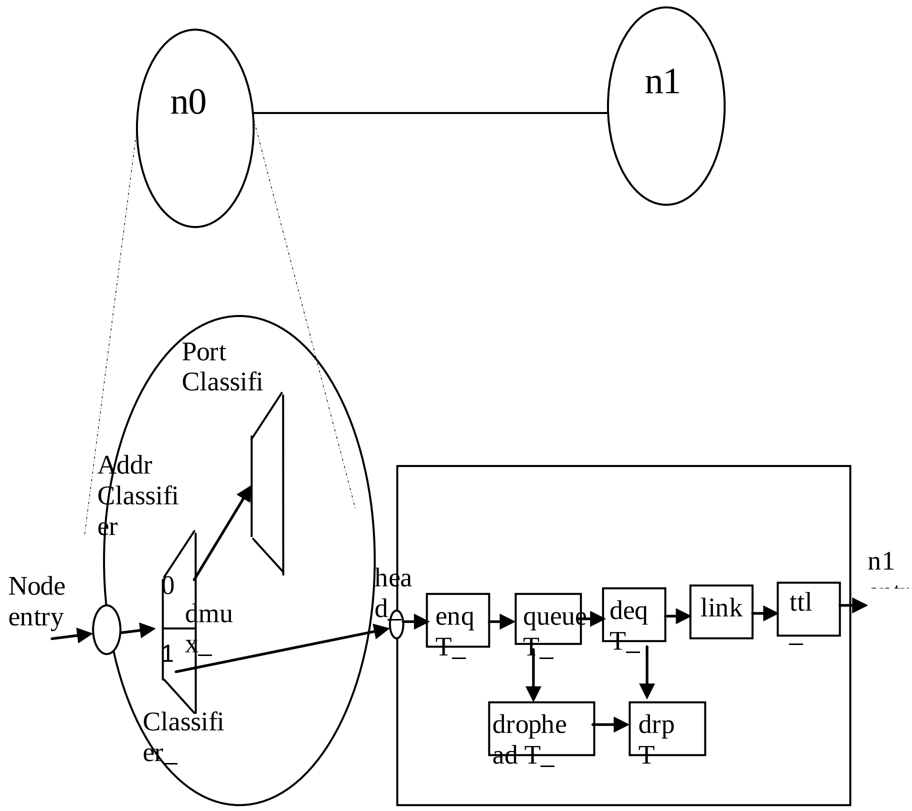


Figure 4: Architecture of a Node Simple Link [22]

*head_* is the entry point *ttl_* This is a time to live checker object, which decrements the time to live field of an incoming packet. If the time to live value is greater than zero after the decrement, then the packet will be forwarded to node 2 (n1). Otherwise the packet will be dropped.

4.1 TTL Sequence-based Expanding Ring Search

The main idea behind using sequence-based ERS is to find the nodes with required route information to the destination by propagating RREQ packet. This technique is one of the efficient ways of route discovery in MANETs routing protocols. TTL sequence-based Expanding Ring Search is used to control the flooding in MANETs. A predefined number for the TTL is used, which defines the radius of the search area. Each time it fails to find a node with a route to the destination, the source node rebroadcast the RREQ packet. So, whenever the source node rebroadcasts a RREQ packet for the next time, the TTL value will increases, which will allow the route request packet to reach nodes at a further distance. The increment for the TTL value is done linearly with a specified value. Figure 3.7 shows how TTL controls the RREQ packet using a predefined value [23]

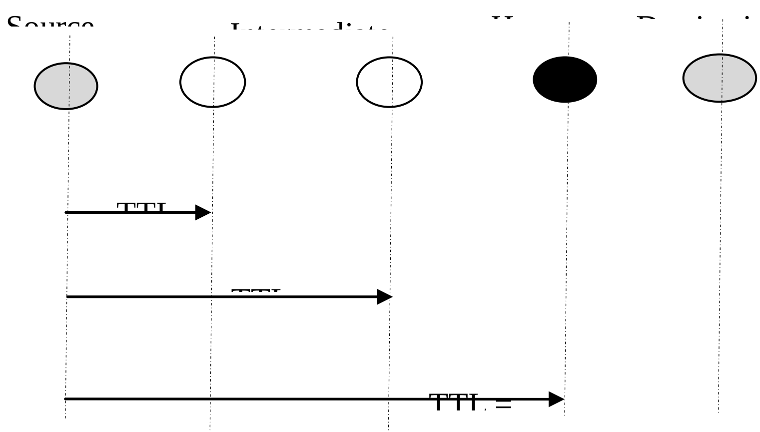


Figure 5: TTL Sequence-based ERS [23]

This scheme was initially adopted in order to ensure successful route discovery by flooding the network in one round. However, a new scheme called optimal TTL sequenced-based route discovery was later proposed, which consequently enhanced the route discovery. This technique allows a chosen set of TTL value to be used for the discovery of routes.

Optimal TTL Sequence Search Strategy
Theoretical results showed that using an optimal TTL sequence values can enhance and increase the efficiency of discovery of routes by minimizing the cost in finding these routes [21]. However, using this scheme sometimes incurs a high delay than basic route discovery mechanism. Two dynamic programming formulations were generated using the scheme where the probability of the destination is known in priori and randomized search strategy if the probability is not known, which is usually adopted by MANETs. A randomized search strategy uses a TTL sequence that consists of random TTL variables instead of deterministic TTL values. For any non-random TTL sequence *g*, a new randomized sequence can be find $\hat{g}$ to achieve a lower worst-case cost. For two dimensional networks, a quadratic cost function is of the form $C_k = a.k^2$, where the optimal search strategy $\hat{g} = [\hat{g}_1, \hat{g}_2, \ldots]$ can be created by the non-random sequence $g = \{g_k\}$, $g_k = [r^{k-1}]$, for $r = \sqrt{2} + 1$, by assigning the probability distribution, each strategy creates a sequence of sets of TTL, just instead of single sequence. Whenever a query failed, a new value for TTL will be chosen at random within the next set of values. Furthermore, using the optimal search strategy under the quadratic cost function, the following sets of TTL values were generated, which are shown in table 1 [21].

Sequence	Possible TTL values	Corresponding Probabilities
1	1	1
2	2, 3, 4	5/21, 7/21, 9/21
3	5, 6, 7, … 13	11/171, 13/171, …, 27/171
4	14, 15, 16, … 32	29/893, 31/893, …, 65/893

Table 1: The First Four Set of TTL Values used in Optimal Search Strategy under Quadratic Cost Function

4.2 AODV_TTL Using Optimal TTL value

The procedure that is involved in the discovery of route for the proposed aodv_ttl is described below. Among the set of TTL values selected, the one with the best performance were chosen in order to reduce high overhead and increase the efficiency in discovery of route. Figure 6describes the flow of the route request (RREQ) packet across the network in a proposed scheme. The route request packet usually contains a time to live value (TTL) which specifies the hop limit that the packet could be used for re-broadcast within the network. To discover a route from source to destination, a route request packet (RREQ) is flooded across the network and will be replied back by a unicast route reply message (RREP).

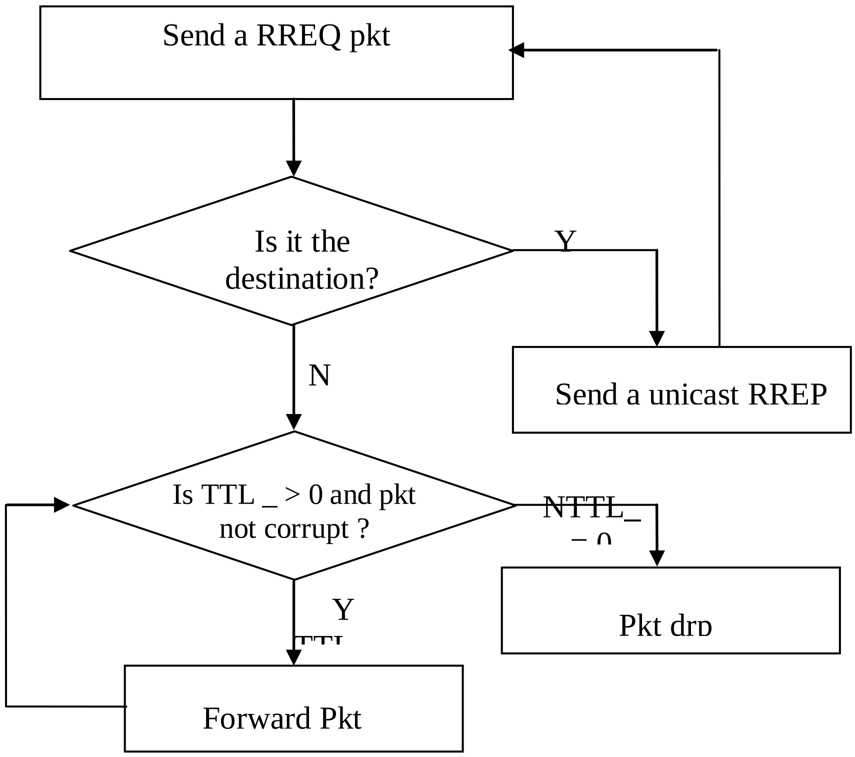


Figure 6: aodv_ttl Optimize TTL Flow Diagrams

The main goal of this study was to improve the conventional AODV routing protocol by determining the optimal TTL value among the set of TTL values, and then compare the performance of conventional AODV and DSDV with the new improved mechanism based on the stated metrics earlier. The study looked at the route discovery mechanism for conventional AODV and DSDV with the new optimal TTL value considering a smaller network. In this case, we choose network size less than ten (10) (i.e. n <10) was chosen where n is the number of nodes in the network under consideration. Set of time to live values (TTL values) 1, 2, 3, 5 and 9 were chosen as against the value (32) in the conventional AODV and DSDV protocols.

General case: to find the optimal TTL value for a smaller network, it involves a) searching for a destination node using a route request packet RREQ and b) returning the route reply packet RREP. Among the predefined set of TTL values that were chosen for the experiment, the performance metrics; throughput, end to end delay and packet loss were investigated and analysed. This gave the idea on which particular TTL value was much better for AODV routing protocol in a smaller network.

5. EVALUATION

An attempt was made to compare the performance of conventional AODV, DSDV and AODV_TTL routing protocol for MANETs under the same simulation environment maintaining all the default parameters such as time to live (TTL) value, which is set to 32. Moreover, the simulations were run with the same data rate of 1Mbps and a packet size of 512 bytes. In order to evaluate these protocols the behaviour of the routing protocol based on the fixed and variable speed (where 0 m/s, 5 m/s, 10 m/s, 15 m/s and 20 m/s) for the nodes movements were considered. This wide range of speed is chosen in order to correspond to the real life situation, which moves at a low speed. The comparative analysis of the performance metrics used for the evaluation is as follows:

- **Throughput:** This is the sum of the data packets delivered from source to the destination. This consists of the number of bits forwarded to the destination. It is measured in bits per second (bps). Throughput can also be defined as the total amount of data a receiver actually receives from sender divided by the time taken by the receiver to obtain the last packet of that particular data.

  Throughput = $\sum_{i}^{n} \frac{CBRtdrecvd}{pro\_time}$

  Where, CBRtdrecv is the total data packets received from source to destination
  Pro_time is the propagation time in seconds

- **Packet loss:** This is the number of packets dropped that are not successfully sent to the destination. This might be due to poor network quality, network congestion or too much variable delay in the network.
  Pkt_Loss = npkts_sent – npkts_recv
  Where, npkts_sent is the total number of packets sent by the source
  Npkts recv is the total number of packets received by the receiver

- **Average end-to-end delay:** End-to-end delay is the time that it takes the source node to send the packet to the destination node. That is how long it will take a packet to travel from source to destination. It is measured in seconds. This performance metric includes all the possible delays caused by buffering during route the discovery latency, queuing at the interface, retransmission delays at the MAC, propagation and transfer times of data packets. Only successfully delivered packets will be counted. Lower delay means better performance.
  Average end-to-end delay =
  $$\frac{\sum_{1}^{n}(CBRstime - CBRrtime)}{\sum_{1}^{n} CBRr}$$
  Where, CBRstime is the time data packets sent from the source node
  CBRrtime is the time data packets received at the destination node

Simulation Environment

In the simulations a number of different scenarios for the experiments were selected in order to evaluate the performance of conventional AODV, DSDV and new proposed AODV_TTL. A smaller network size with 8 numbers of mobile nodes in the network topology at stationary and variable speeds was considered. All nodes transmitted within the transmission range of 250 M, and can move around the simulation area using random way point mobility model. The simulation was run under NS-2 with configuration of IEEE 802.11 MAC, standard two ray ground propagation model and Omni directional antenna model. The simulation period for each scenario was conducted in 120 seconds.

Before the actual simulation the following activities were performed; defining the type of network topology to be used for the experiment, determine the connection patterns among the mobile nodes (agents and sinks) and traffic generators in particular UDP and lastly the schedule of the processes or events. Having defined the topology, nodes were configured for traffic flow through them. Thereafter, the routing information that is from source to destination, the agent protocols and their applications (UDP/CBR) was defined. The agents represent end points where the network layer packets are constructed and they are used for the implementation of protocols at various layers. In this study, the protocol agents used were the basic UDP agent and the loss monitor, a packet sink, which checks for losses. The transmission rate and packet size were also defined.

5.1 Throughput for AODV_TTL Vs Conventional AODV and DSDV

Figure 7 clearly shows a bit of improvement in terms of packet delivery. When the nodes were at stationary, the performance for the new scheme is less of all the three protocols, but there was sharp increase when the nodes started moving at 5 m/s with DSDV given more packets. As the nodes continue moving, the topology changes, which caused the routes or link failure due to changing position of the nodes, the AODV slow down. Due to reduction for the search area across the network, since the network size is small, the AODV_TTL outperformed the conventional AODV protocol with about 15%. The DSDV protocol outperformed both DSR_TTL and AODV when the nodes moved at 10 m/s, but AODV_TTL outperformed both the conventional AODV and DSDV at 20 m/s.

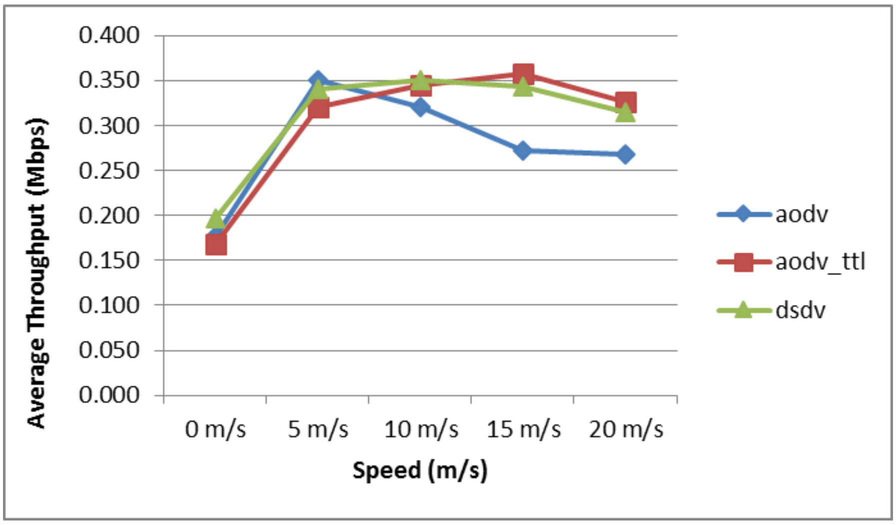


Figure 7: Average Throughput for AODV_TTL Vs Conventional AODV and DSDV

5.2 Packet Loss for AODV_TTL Vs Conventional AODV and DSDV

The packet loss measured among the three protocols across the network is shown in Figure 8 below. It is observed that when the nodes were at high rate even across a small network area, the AODV performed poorly, though the transmission was better when the nodes were at stationary for all of them. At 20 m/s AODV_TTL outperformed both AODV and DSDV and this is because there were fewer tendencies for dropping of packets due to small value of TTL, which consequently determined the search area for the destination node. At low speed for example 5 m/s to 10 m/s the dropping was almost the same percentage around 25% of the packet dropped for both DSDV and AODV_TTL.

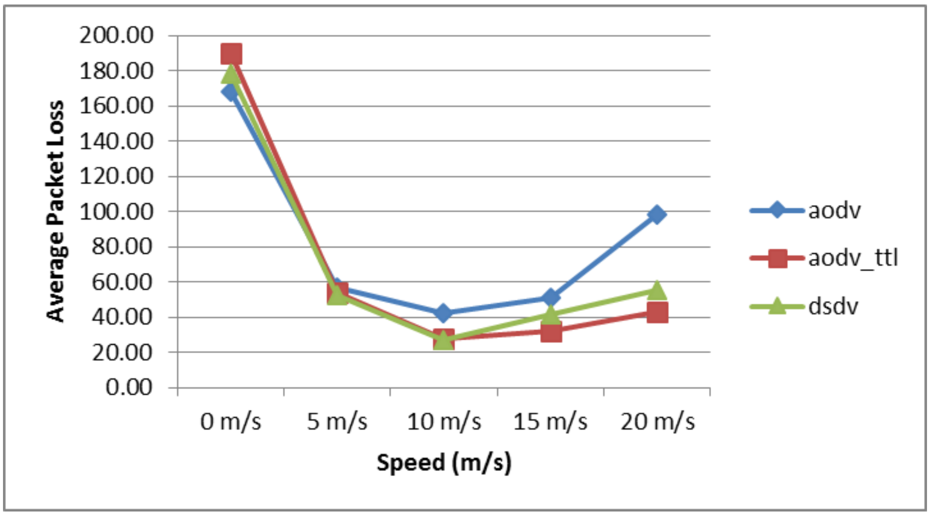


Figure 8: Average Packet Loss for Conventional AODV_TTL Vs AODV and DSDV

5.3 Packet Delay for AODV_TTL Vs Conventional AODV and DSDV

Figure 9 shows the result of the experiment to determine the average packet delay at static and dynamic topology across a small network size. This result showed that AODV generated less delay because it does not initiates more flooding when compared to AODV_TTL, which always initiates flooding. The conventional AODV always use the maximum TTL value to send the route request packet across the whole network. However, unlike AODV, the new scheme is not the same way, where it involves multiple flooding for a single route discovery. The flooding starts with a value larger than one and then continuously decrementing until it reaches the value zero. From this result, it was observed that when the nodes were not moving, there was a minimal delay for AODV_TTL of just 0.025 seconds. Moreover, when the nodes started to move at 5 m/s, it showed that, it relatively affect the performance as delay reaches 0.03 seconds, and as the speed increases the level of delay reduces tremendously to 0.062 seconds. This means the speed affect the performance of AODV_TTL when compared to AODV

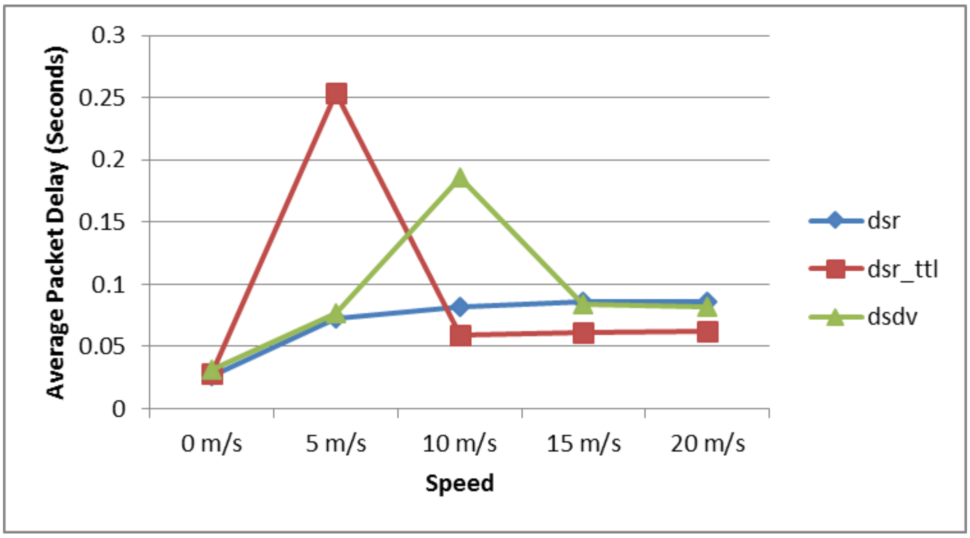


Figure 9: Average Packet Delay for Conventional DSR_TTL Vs DSR and DSDV

6. CONCLUSION

One of the challenges in Quality of Service (QoS) provisioning in MANETs routing protocol is the mobility and rapid change in network topology, which poses a number of problems. The routing protocols must be able to adapt themselves with the high degree of node mobility and converge the network without disrupt in communication. The main focus of this research project was to improve the conventional AODV using TTL-based scheme. Compare this new proposed scheme with conventional AODV and DSDV routing protocol and evaluate the performance using the metrics; throughput, end-to-end-delay and packet loss. A mechanism was proposed to improve the conventional AODV called AODV_TTL using TTL-based scheme.

To achieve the desired objectives, some set of TTL values were selected and experiment with them based on the performance metrics that provide a better quality of service; throughput, packet loss and end to end delay. The analysis was made based on small network size with stationary and mobile nodes around the network topology. Finally, the new proposed AODV_TTL preserving all default parameters except the TTL value. It was shown that generally AODV_TTL outperformed AODV in terms of packet delivery for about 15%. This is because high mobility causes the link failure due to changing position of nodes, hence for large TTL value (used by AODV) invalid routes are likely to be used which might cause lower transmission throughput.

Also, it was shown that use of small TTL value improved the total network throughput for small scale network and reduced the dropping of packets. However, the proposed protocol generally improved the network throughput, reduced the total overhead but, still created congestion near the source which leads to high delay than the conventional AODV. In the future, it is suggested that extensive simulations could be carried out for a larger network in order to gain more in depth performance analysis. The study conducted considered only a small size network under fixed and variable mobility rate; it will be of great benefit if similar study is conducted on a larger network in order to increase the general performance across the network. Likewise, the problem of congestion due to multiple flooding using TTL-based should be studied for all categories of the network size

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