Swarm Intelligence (Ant) Based Route Repair in Ad-Hoc On Demand Distance Vector Routing Protocol

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Abstract
Mobile Ad-Hoc Networks (MANET) constitutes a group of wireless mobile nodes that transmit information without any centralized control. MANETs are infrastructure-less and are dynamic in nature that is why; they require peremptorily new set of networking approach to put through to provide efficacious and successful end-to-end communication. Therefore, an efficient routing approach is needed in MANETs for changing network conditions such as the size of network and partitioning of network. A large number of protocols proposed for MANETs such as DSDV, WRP, CGSR, AODV, CBRP, TORA, ZRP, ZHLS etc. Based on the recent surveys on performance comparisons of all these protocols, it has been seen that the performance of AODV was very good in all network sizes and it performs better in dense mediums and with faster speed. Recent researches on AODV have also figured out that the route repair scheme of AODV needs modifications to make it highly robust protocol for MANETs. This paper gives a modification on local repair of route/link in AODV, if it is broken during communication for MANET and proposes a new route repair scheme namely SI-AODV in order to make up the deficiency of the existing route repair scheme in AODV. The improved route repair scheme concerns about the over head requirement control overhead and end to end delay in transmission. In this improved scheme, nodes are required to keep the next two-hop node address for each route entry in routing table. During route repair, the repairing node use Swarm Intelligence for finding new route for next to next node in the link using ANT based packet forwarding. This ANT based approach will give significant reduction in overhead. The proposed protocol will be highly adaptive, scalable and efficient and mainly reduces end-to-end delay in high mobility cases.

Keywords
MANET, AODV, SI-AODV, FAnt-RREQ, FAnt-RREP

I. Introduction
A Mobile Ad-Hoc Network (MANET) [1] is a collection of wireless mobile nodes forming a temporary/short-lived network without any fixed infrastructure where all nodes are free to move about arbitrarily and where all the nodes configure themselves. Mobile Ad-Hoc Networks (MANETs) represent complex distributed systems that comprise wireless mobile nodes that can freely and dynamically self-organize into arbitrary and temporary, ''ad-hoc'' network topologies, allowing people and devices to seamlessly inter network in areas with no pre-existing communication infrastructure, e.g., disaster recovery environments.

In MANET, each node acts both as a router and as a host & even the topology of network may also change rapidly.

A large number of routing protocols has been proposed for MANETs such as DSDV, WRP, AODV, TORA, CBRP, ZRP, ZHLS etc. Fig. 1 below shows the categorization of routing protocols for MANETs.

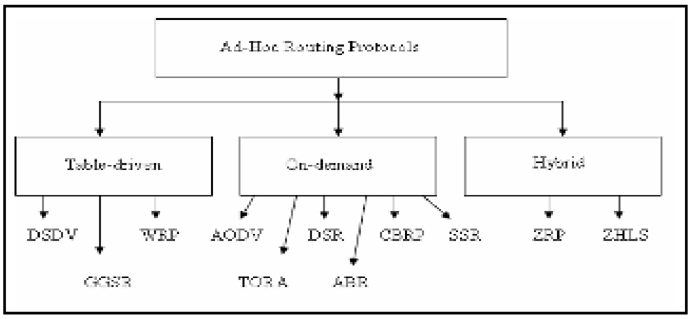
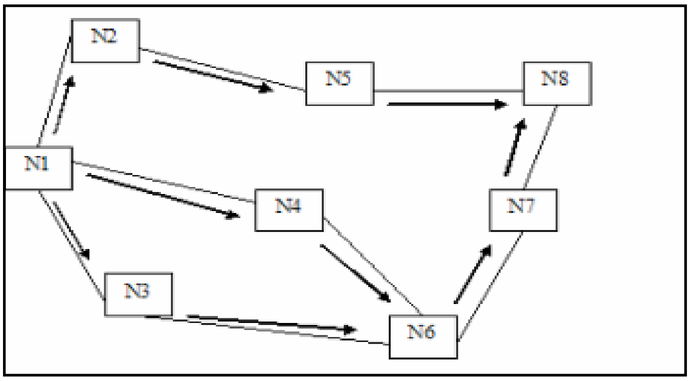


Fig. 1: Categorization of Ad-Hoc Routing Protocols

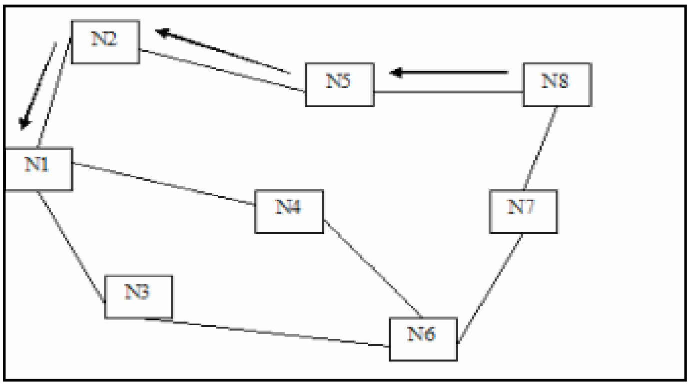
AODV [2] is a well known on-demand routing protocol where a source node initiates route discovery when it needs to communicate to a destination that doesn't have a route to it. Once a route discovered between the two nodes, data transfer occurs through until the route broken due node movement or interference due the erroneous nature of wireless medium. Route maintenance initiated when a route failure happens between two nodes. The upstream node of the failure tries to find a repair to the route and this process called local repair. This paper proposes a new Swarm Intelligence (Ant) based route repair routing protocol for Mobile Ad hoc networks called SI-AODV (Swarm Intelligence (Ant) based Route Repair in Ad Hoc On-Demand Distance Vector Routing Protocol). The SI-AODV modifies the local repair algorithm used in the route maintenance of the AODV routing protocol. Route repair will be performed in case of link failure i.e. when a link between two nodes is broken during the data transfer then route re-discovery will be initiated from the upstream node of the broken link based on Swarm Intelligence using forward and backward Ant routing instead of the source node as in regular AODV. The SI-AODV mainly reduces the routing message overhead resulted from the original AODV local repair algorithm. This enhancement leads to higher throughput and lower latency than AODV and improves the performance of AODV especially in the route maintenance procedure in the realistic mobility model. This protocol reduces the delay experienced in the packet transfer (hop-by-hop). The control packets generated are less; therefore the congestion is less in the route and the overhead in the bandwidth is also less. The packets drop is less in the proposed protocol.

II. Overview of AODV
The Ad Hoc On-Demand Distance Vector (AODV) [2] routing protocol described in builds on the DSDV [3] algorithm previously described. AODV is an improvement on DSDV because it typically minimizes the number of required broadcasts by creating routes on a demand basis, as opposed to maintaining a complete list of routes as in the DSDV algorithm. The authors of AODV classify it as a pure on-demand route acquisition system, since nodes that are not on a selected path do not maintain routing information or participate in routing table exchanges [4]. When the route is required between source and destination, the source sends the RREQ to all its neighbors, which then forward the request to their neighbors, and so on, until either the destination or an intermediate node with a "fresh enough" route to the destination is located and

when the destination is found, then RREP packet is propagated towards the source. This way route gets established between source and destination. Fig. 1 shows the route establishment in AODV. AODV utilizes destination sequence numbers to ensure all routes are loop-free and contain the most recent route information. Each node maintains its own sequence number, as well as a broadcast ID. The broadcast ID is incremented for every RREQ the node initiates, and together with the node's IP address, uniquely identifies an RREQ. Along with its own sequence number and the broadcast ID, the source node includes in the RREQ the most recent sequence number it has for the destination.



(a) Propagation of RREQ



(b) Path of the RREP to the Source
Fig. 2: AODV Route Delivery

A. Route Repair in AODV

When a link between two nodes breaks in AODV, Route error message is generated and propagated towards the source. After receiving the route error message source node re-initiate the route discovery.

III. Swarm Intelligence (Ant) Based Routing Algorithm

Swarm Intelligence (SI) is the local interaction of many simple agents to achieve a global goal [5]. SI is based on social insect metaphor for solving different types of problems. Insects like ants, bees and termites live in colonies. Every single insect in a social insect colony seems to have its own agenda. The integration of all individual activities does not have any supervisor. In a social insect colony, a worker usually does not perform all tasks, but rather specializes in a set of tasks. This division of labor based on specialization is believed to be more efficient than if tasks were performed sequentially by unspecialized individuals. SI is emerged with collective intelligence of groups of simple agents. This approach emphasizes on distributed-ness, flexibility, robustness and direct or indirect communication among relatively simple agents [6].

The agents are autonomous entities, both proactive and reactive and have capability to adapt, co-operate and move intelligently from one location to the other in the communication network. The basic idea of the Ant Colony Optimization (ACO) [7] meta-heuristic is taken from the food searching behavior of real ants. Fig. 3 shows ant food searching. Ant agents can be divided into two sections [8]:

- FANT (Forward Ants)
- BANT (Backward Ants)

The main purpose of this subdivision of these agents is to allow the BANTs to utilize the useful information gathered by FANTs on their trip time from source to destination. Based on this principle, no node routing information updates are performed by FANT, whose only purpose in life is to report n/w delay conditions to BANT [9].

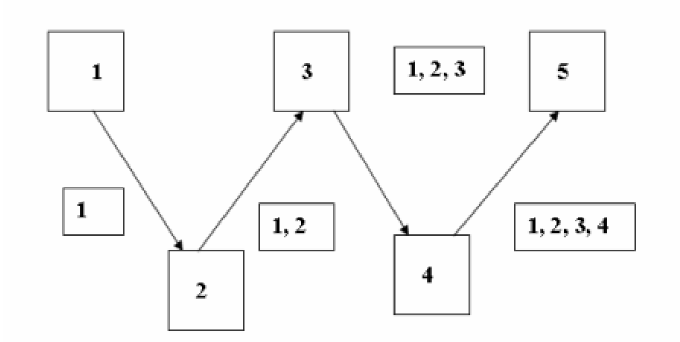


Fig. 3: Figure Shows an Ant Traversing the Network and Providing Routing Information to Nodes

The concentration of pheromone on a certain path is an indication of its usage. With time the concentration of pheromone decreases due to diffusion effects. This property is important because it is integrating dynamic into the path searching process. At the intersection, the first ants randomly select the next branch. Since the below route is shorter than the upper one, the ants which take this path will reach the food place first. On their way back to the nest, the ants again have to select a path. After a short time the pheromone concentration on the shorter path will be higher than on the longer path, because the ants using the shorter path will increase the pheromone concentration faster. The shorter path will thus be identified and eventually all ants will only use this one. A scenario with two routes from the nest to the food place is shown in the fig. 4.

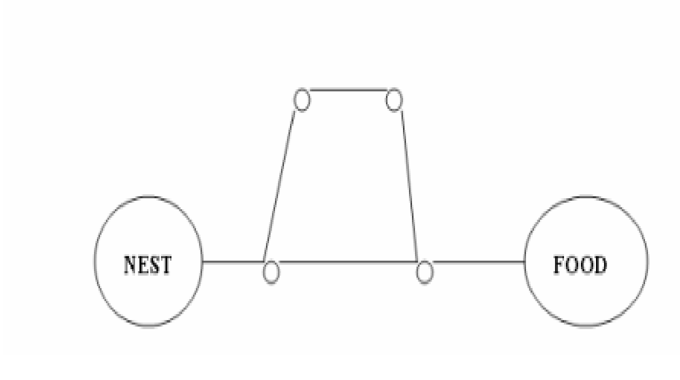


Fig. 4: All Ants Take the Shortest Path After an Initial Searching Time

IV. Proposed Swarm Intelligence (Ant) Based Route Repair in AODV

Methodology and design of proposed SI-AODV is defined in below sections.

A. SI-AODV Message Formats

Following are the different message formats used in the proposed SI-AODV protocol:

1. Format of FAnt-RREQ (Forward Ant Route Request)

Type	Reserved	Hop Count
Source IP Address		
Destination IP Address		
Source IP Address		
Destination Sequence Number		
Route Records (IP List of Traversed Nodes)		

2. Format of BAnt-RREP (Backward Ant Route Reply)

Type	Reserved	Hop Count
Destination IP Address (Add. Of Source)		
Destination Sequence Number		
Source IP Address		
Route Records (IP List of Traversed Nodes)		

3. Format of RREP-ACK (Reply Acknowledgement)

Type	Reserved

4. Format of RERR (Route Error)

Type	Reserved	Dest. Count
Unreachable Destination IP Address		
Unreachable Destination Sequence Number		

B. Algorithm for SI-AODV Route Discovery

1. Source node ‘S’ broadcasts the FAnt-RREQ to all its neighbors.
2. After receiving the FAnt-RREQ the neighbor nodes check the RREQ-ID, to check whether it has been received before and the IP address of that node will be attached to the route record field of FAnt-RREQ.
3. If the RREQ-ID has been already received, then the neighbor node discards the packet.
4. Otherwise, a reverse path is established between the source and the neighbor node.
5. If this node is not the destination or having no path to the destination, then Repeat step 1.
6. When the FAnt-RREQ packet find the destination node or node having path to the destination, the destination node unicast the BAnt-RREP towards the source node.
7. When the BAnt-RREP packet reach to the source node following the path of intermediate nodes, the route is established in the reverse way i.e. from the destination to the source.
8. The route is established, and the data packets can be sent through the established route.

Route discovery process in SI-AODV is described below. Consider the network of 17 nodes below (fig. 5), where:

Source Node- S
Destination Node- D
FAnt-RREQ Broadcasting-
BAnt-RREP Unicasting-

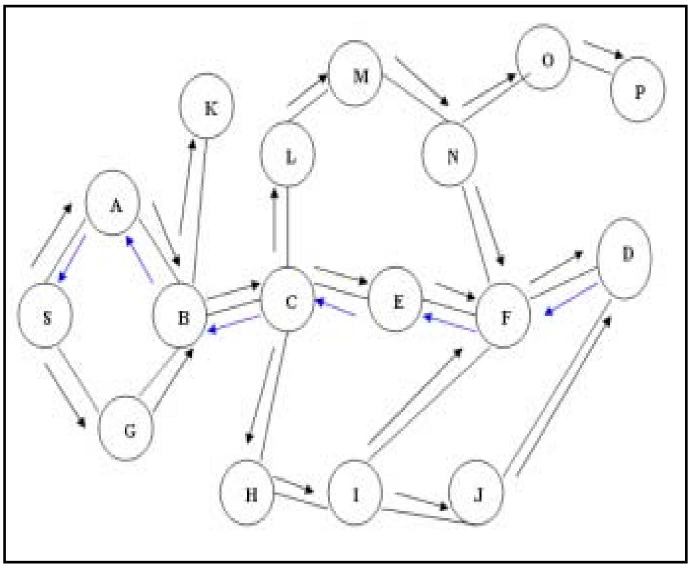


Fig. 5: Route Established Between S and D

Source node S broadcast the FAnt-RREQ towards all of its neighbors and neighbors again broadcast the FAnt-RREQ to their neighbors and so on. Each time a FAnt-RREQ traverse the new node, its address is attached to list of traversed node in FAnt-RREQ packet. Due to this, it is known to each node that the request is arrived from which node and a reverse path is generated. When the destination node D is found, it unicast the BAnt-RREP towards the reverse path generated.

C. Algorithm for SI-AODV Route Repair

1. When the route established, buffer is attached to each node following the route.
2. When the link breaks, transmission of data packets stops at the upstream node of the broken link and packets are stored in the buffer attached to it.
3. Now the upstream node of the broken link will try to repair broken link locally.
4. This node will broadcast the FAnt-RREQ for the search of next to next node in the link as this information is already available in the modified routing table. At this instant it is considered that after the current link failure rest of the route is still active.
5. Forward ant (FAnt-RREQ) search for next to next node, which is not very far away. In one or two hop this forward ant will reach the required node, having information about the rest of the path.
6. When the next to next node is found, it will generate backward ant (BAnt-RREP), as this node is having rest of the required active route and data packets can be transferred to destination via this path.
7. If within the Active_Route_Time, node requesting the path does not get BAnt-RREP from next to next node. It is assumed that link break can not be repaired.
8. Then upstream node of broken link will generated Route error (RERR) message and send it to source node.

Suppose during the data transfer node C sends the data packet to node E and do not get the acknowledgement. This means the link is failed between C and E. This link failure can be due to power failure, hardware/software failure or node mobility. Fig. 6, shows that the link between C and E is failed.

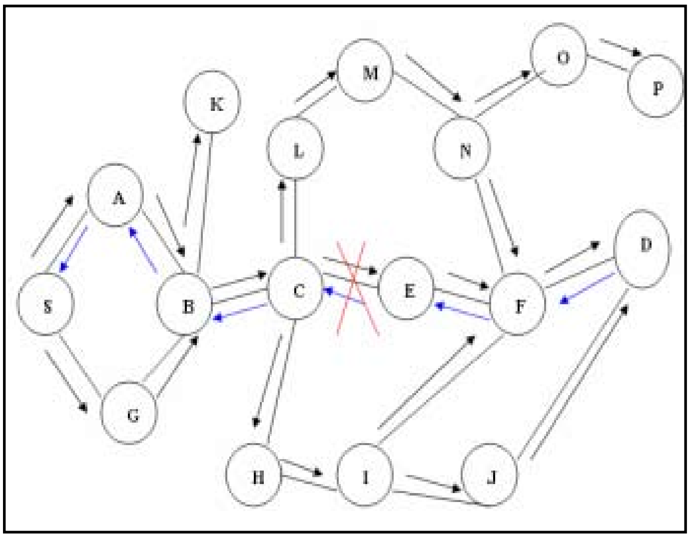


Fig. 6: Link Break Between C and E

Now SI-AODV route repair algorithm can be applied to repair the route as in fig. 6. Route is re-established after the repairing as shown in fig. 7 below.

Source Node- S
Destination Node- D
FAnt-RREQ Broadcasting-
BAnt-RREP Unicasting-
Link Breaks between C and E
Buffer at Node C

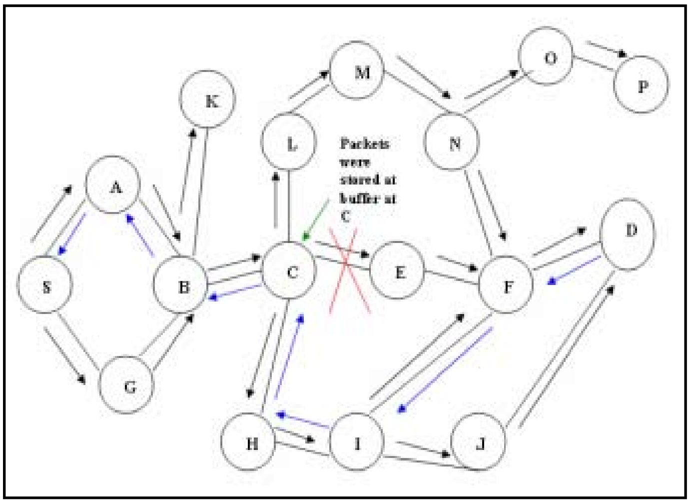


Fig. 7: Route Re-Discovered

V. Simulations

The simulator used to simulate the AODV route repair is the OMNET++ 4.2.1. OMNET++ [10] is a component-based, modular and open-architecture discrete event simulation framework. The most common use of OMNET++ is for simulation of computer networks, but it is also used for queuing network simulations and other areas as well.

OMNET++ is licensed under the its own Academic Public License, which allows GNU Public License-like freedom but only in noncommercial settings.

Simulations of SI-AODV are performed and compared with the traditional AODV protocol. The parameter values of simulation are as shown in Table 5.

Parameter	Value
Number of nodes	17
Max speed	0, 5, 10, 15, 20m/s
Simulation time	200sec
Max connection	20 two way connections

In this simulation, the network of 17 nodes of different network devices for traditional AODV and proposed SI-AODV protocol are designed. AODV is designed with simple modules using two way Input/Output gates connections and SI-AODV is designed with simple modules using two way channel connections as defined in OMNET++. For each route reply of these protocols, a network activity log is generated by the simulation. Vector and scalar files are generated when the run of the simulation is stopped. At this time, objects of simulation can also be inspected such as sent/received messages. All the information about successful run of the simulation is available in the running window and the result folder at project explorer of the project. Route repair process of both of the protocols is compared with respect to routing message overhead, end to end delay, control overhead and throughput.

A. Simulation Analysis

1. Routing Message Overhead

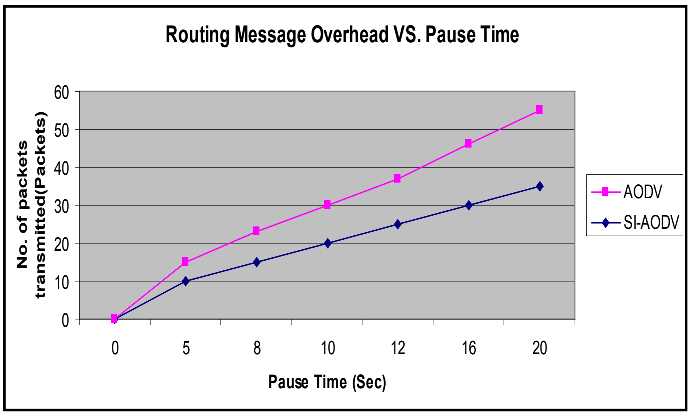


Fig. 8: Routing Message Overhead vs. Pause Time

The routing message overhead resulted from both AODV and SI-AODV routing protocols has been presented in Figure 16. From fig. 8, it could be noticed that SI-AODV has lower routing message overhead less than the AODV routing message overhead. This result demonstrates the effect of route repair trial in SI-AODV on reducing routing message overhead.

2. Average End to End Delay

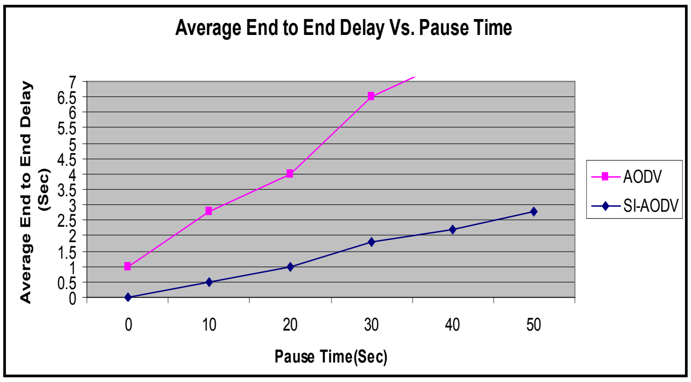


Fig. 9: Average End to End Delay Vs. Pause Time

Fig. 9, demonstrates the average end to end delay of both the AODV and SI-AODV routing protocols. It is clear that SI-AODV gives average end to end delay higher than the AODV. The results demonstrate the high effect of route repair trial in SI-AODV on the delay of the small size networks which resulted from broadcasting FAnt-RREQ. This means that the AODV routing protocol is suitable for small size networks from the end to end delay point of view than the proposed SI-AODV. The increase in the route length led to an increase in the end to end delay of transferring a packet between two nodes.

The increase in the number of broken links will led to increase the delay of transferring packets on a route until finding a repair to the route. The number of broken links affected by the route length as longer routes means the higher chances for broken links.

3. Control Message Overhead

As in traditional AODV, the control overhead is increased when the route error packet is transmitted. But in SI-AODV, route error packet is propagated only when the route can not be repaired and this gives significant less control overhead. The routing message overhead resulted from both AODV and SI-AODV routing protocols has been presented in fig. 10. From the figure, it could be noticed that the SI-AODV routing protocol has lower control overhead than the AODV routing protocol.

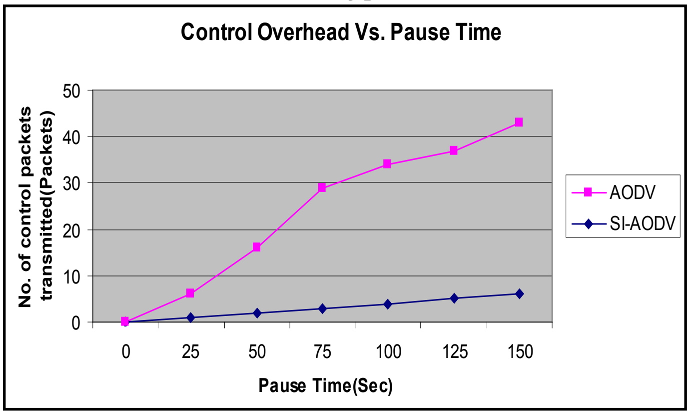


Fig. 10: Control Overhead Vs. Pause Time

4. Throughput

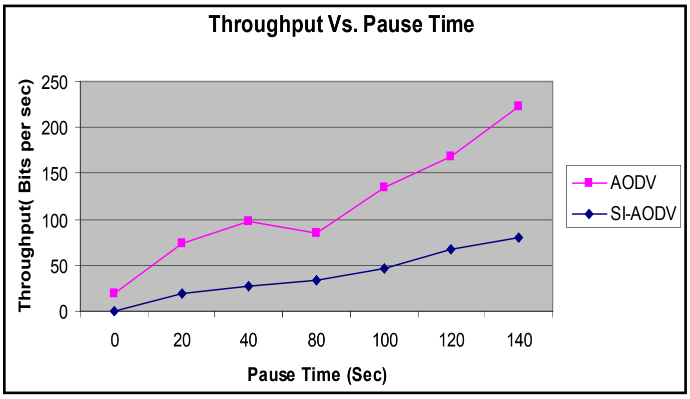


Fig. 11: Throughput Vs. Pause Time

Throughput is the average rate of successful message delivery over a communication channel. The throughput resulted from both AODV and SI-AODV has been presented in Fig. 11. It can be found that SI-AODV has higher throughput than AODV routing protocol.

The number of packets dropped or left wait for a route affect the throughput as the increase in the number of packets dropped or left wait for a route reduce the throughput. The number of packets dropped or left wait for a route affected by the success of local repair in repairing a failed route, where the number of packets dropped or left wait reduced as the percentage of success local repair attempts increased. SI-AODV has number of packets dropped or left waits for a route higher than the AODV routing protocol.

VI. Conclusion

AODV is one of the most popular ad-hoc on demand routing protocols. In the AODV routing protocol, local repair operation is performed by broadcasting RREQ packet from the source again. This process produces high routing message overhead which consumes high portions from the bandwidth of the connected nodes. Whereas the new adaptive SI-AODV routing protocol, route repair will reduce the routing message overhead resulted from local repair operation in the AODV routing protocol.

First from the obtained results it could be concluded that in small ad-hoc networks, SI-AODV is suitable for the applications that need low routing message overhead which means by its turn more free bandwidth for data bytes transfer as SI-AODV routing message overhead is less than AODV routing message overhead.

Second from the obtained results it could be concluded that in large ad-hoc networks, SI-AODV is suitable for applications that need very less control message overhead, where SI-AODV has control message overhead lower than the AODV routing protocol.

SI-AODV is suitable for the applications that need low average end to end delay, where SI-AODV has average end to end delay lower than the AODV routing protocol.

SI-AODV is suitable for applications that needs high throughput, where SI-AODV has throughput higher than the AODV routing protocol.

From the above all comparisons between route repair of AODV and SI-AODV, it can be concluded that SI-AODV gives higher performance than the AODV routing protocol, so it is suitable for most of the larger applications.

VII. Future Work

The scalability of the proposed SI-AODV routing protocol for Mobile Ad hoc Networks can be studied by having large ad hoc network sizes in comparison with the AODV routing protocol. Also the effect of the SI-AODV routing protocol in energy consumption could be studied in comparison with AODV routing protocol.

Finally, the SI-AODV routing protocol can be studied on different types of application layer protocols like http, ftp, telnet, and real time audio/video transmissions.

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