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Performance Evaluation and Enhancement on the AODV Ad hoc Network Routing Protocol

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ABSTRACT

Wireless ad-hoc networks allow the construction of flexible and adaptive networks with no fixed infrastructure or any base station. The core challenge is to develop efficient routing protocols for the dynamic nodes to commune with each other without any hazard or latency. A number of routing protocols such as Dynamic Source Routing (DSR), Ad Hoc on Demand Distance Vector Routing (AODV), Destination–Sequenced Distance Vector (DSDV) and Temporally Ordered Routing Algorithm (TORA) have already been presented for the communication purpose while AODV outperforms the others in terms of the efficiency. Considering several performance factors such as the packet delivery fraction (PDF), end to end delivery, normalized routing overload and the normalized MAC, this paper has proposed an improvement over the existing AODV protocol and termed it as I-AODV (improved AODV). Effectiveness of the proposed I-AODV algorithm under different level of nodal mobility is confirmed through *Cygwin* simulation.

1. Introduction

An Ad Hoc network is a collection of wireless digital data terminals forming a temporary network without aid of any established networking infrastructure or any centralized administration [1, 2]. A communication session is achieved either through a single-hop radio transmission if the communication parties are close to each other, or through transmitting by intermediate nodes on the contrary. Hence, all mobile nodes seem to serve as routers to the limited range, responsible for finding out and maintaining paths to other nodes dynamically in the network. This self-configurable nature of ad hoc network makes them different from wireless infrastructure networks that include base stations. Consequently, it has been flexibly and quickly deployed for many applications such as automated battlefield, search and rescue, and disaster relief. From the beginning, attention has been given to the development of efficient protocols, as successful routing protocols provide means to deliver packets to destination nodes given these dynamic topologies. Although, there are various established protocols proposed by a number of research groups such as Dynamic Source Routing (DSR), Ad Hoc On-Demand Distance Vector (AODV), Zone Routing Protocol (ZRP), and Location Aided Routing (LAR) etc, the individual routing protocol is being personalized for the specific network due to the limitations of the every approach. Authors classify and evaluate all broadcast protocols (which they are aware) that are distributed in nature and designed for wireless ad hoc networks and were motivated to establish a protocol which would be used in all platform without any customization. This paper privileges to modify the AODV protocol as it outperforms all other basic approaches. With the background study in the Section 2, authors' modifications are presented in the Section 3 and 4. The accuracy of the amendment is shown in Section 5 with the Cygwin simulation results. Section 6 presents a description of the results and the proposed future work along with the conclusions in Section 7.

2. Background study

Various routing protocols have been developed for ad hoc networking which can be broadly classified into the following three categories: *Table-driven or proactive* protocols, *On-demand or reactive* protocols and *Hybrid* protocols [3]. DSDV and WRP are the two popular examples of Table-driven proactive protocols where each nodes need to maintain a routing table having all of the possible destinations within the network. AODV, DSR, ABR and TORA are the most common source-initiated on-demand reactive routing protocols i.e. network node finds routing paths on demand independent of the usage of the paths. ZRP [4] is an established Hybrid approach. Table1 shows the performance comparison of these protocols in the tabular form:

The *Destination–Sequenced Distance–Vector Routing (DSDV)* is a table driven protocol based on the classical Bellman-Ford algorithm which includes freedom from loops in routing tables [5]. Each mobile node in the network retains a routing table to indicate each destination i.e. next hop and the number of hops to reach that destination. This protocol requires each node to periodically broadcast routing updates. The periodic update messages are defined into two types: full and incremental. All of the routing information is carried by the full broadcast whereas incremental broadcast carries only the information that has distorted since the last broadcast. The advantage of this routing protocol is that it is loop free while it is reliant on periodic broadcasts and requires some time to

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converge before a route can be used. This convergence time has an adverse impact in mobile network. The *Ad hoc On Demand Distance Vector (AODV)* is an improvement of DSDV algorithm. It reduces the amount of broadcasts as compared to DSDV by generating routes on demand. It does not require maintaining information of routes to destination rather employ RREQ (route request), RREP (route reply) and RERR (route error) messages via UDP (update packet). The source broadcasts a RREQ packet in order to discover a path to destination [6]. The adjacent neighbors one by one broadcast the packet to their neighbors in anticipation of it reaches to an intermediate node or the node to the destination. A node rejects the identical copy of RREQ packet it receives. Like DSDV, to guarantee route freshness and loop freedom, destination sequence number for each active route is being maintained for any route request from neighbor nodes. It also periodically broadcasts intermediate neighbors HELLO messages, the limited announcement for continued presence of the node to its neighbors. The neighbor can consider that a particular node has moved away if HELLO messages end coming from that node. The node informs the affected set of nodes by sending them a failure notification.

AODV outperforms the other protocols as it can manage the handling of the increased load, even in situation of more packet drop ratio and with more routing packets. It has the advantage of lower connection setup delay and reduced number of routing messages. AODV is capable of both unicast and multicast routing and can avoid the counting-to-infinity problem [7] of other distance-vector protocols. Nevertheless, AODV has some limitations too, as it supports only one route for each destination. Whenever a route is out of order, this causes a node to retransmit a RREQ query. This does not scale well as the number of RREQs raises as mobility increases. Intermediate nodes can also lead to inconsistent routes if the source sequence number is very old and the intermediate nodes have a higher but not the latest destination sequence number, thereby having stale entries. Also, multiple RREP packets in response to a single RREQ packet can lead to heavy control overhead. Another disadvantage of AODV is unnecessary bandwidth consumption due to periodic beckoning.

3. Authors' Contribution

Considering the confinements of the proven AODV protocol, authors were motivated to amend the existing protocol (termed as O-AODV in this study) to make it more efficient. To do so, modification was needed in almost every stages of the given algorithm. In terms of the key parameters packet delivery fraction (PDF), end to end delivery, normalized routing overload, and normalized MAC overload, a few improvements are proposed in this study. The new version of the AODV is named as improved AODV (I-AODV) here. Cygwin simulator is also engaged in this approach to analyze the parameter statistics and the effectiveness of this algorithm in different environments.

4. Proposed I-AODV (Improved AODV) Protocol

➢ ***Improvement 1: Local repair***

The process of forwarding packets to the destination from an intermediate node in case of link failure is known as "local repair", in which an intermediate node upstream of the link failure sends out a RREQ (route request), also a TTL (time to live) value added with an increment value. Data packets are buffered at this node during route rediscovery and sent as soon as the route is repaired. Previously, in O-AODV (old AODV), the local repair occurred when the packet passed at least half of the path. Authors have implemented the local repair concept after one third path, one fourth path and one fifth path and found that the local repair considered after the one third path is feasible for packet delivery fraction (PDF) and the normalized mac load. The algorithm for the local repair concept is given below:

Algorithm 1: Local repair

```
AODV failed (packet *p)     // This routine is invoked when
                               link-layer reports a route failure
begin
HDR_IP(p), HDR_CMN(p) ; // Header and control information
                            of packet
aodv _rt_entry*rt ;              //AODV routing table entry
if AODV_LINK_LAYER_ FAILURE_DETECTION
ROUTE_BUFFER (p, intermediate_ node i, path length =1/3
path)                    // Buffer the packets at intermediate node
If TTL>0
        RREQ (p, DESTINATION _P, path length=1/3 path)
else
Drop (p, DROP_RTR_MAC_CALLBACK) //drop packet from
                                        routing table
RREQ (p, DESTINATION_P, source) // Initiate RREQ
                                         from source
end
```

➢ ***Improvement 2: Expanding ring search***

Expanding ring search is a technique that searches in increasingly larger number of neighborhoods, i.e. by sending successive RREQ each with a larger "time to live" value that limits how far a RREQ can traverse from the source. In this technique, several attempts for route discovery are conducted initially by the source. It searches only the region within some limited hops from itself. If the destination cannot be found after timeout, the source attempts another route discovery with greater search scope than preceding attempt by increasing the TTL of RREQ. This process continues until TTL reaches a maximum threshold, after which the RREQ is flooded throughout the network. In the modification of the method, the TTL value is not used for the concept of threshold, rather when the time expires; it specifies in TTL for any packet that has been dropped and retransmit the request.

Algorithm 2: Expanding ring search

```
AODV sendRequest (Destination)// This routine is invoked
when a send request message is sent to destination
begin
HDR_IP(p),HDR_CMN(p),     // Header and control information
                             of packet
aodv _rt_entry*rt,               // AODV routing table entry
if (rt->rt_flags==RTF_UP)     // If the routing table has the route
                                 flag up
assert (rt->rt_hops!=INFINITY)  // the packet will go
                the next hops as long as the total number of
                hops  will not reach ∞
else
Drop (p, rt)                  // drop packet from routing table
RREQ (p, DESTINATION_P, source) //Initiate RREQ from
                                  source to destination end
```

➢ *Improvement 3: Route Retry*

In case the link of the network is broken, a new element in the routing table is proposed to add named as “rt_retry_times_r” which would be used to check whether the packet is send at least two times in order to see whether the broken route is repaired. This phenomenon is used in order to enhance the packet delivery fraction.

Algorithm 3: Route handling functions

AODV Route_Purge (Destination)

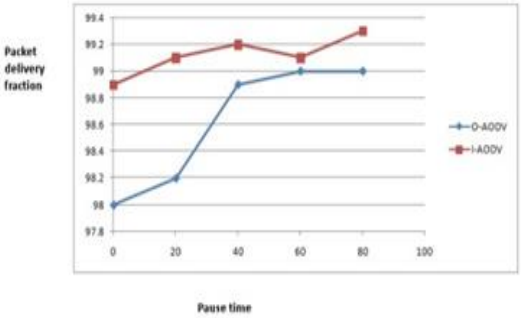
```
begin
now = CURRENT_TIME,
delay =0,
for each rt entry in route table
rtn=rt->rt_link.le_next,     // route next goes to the link of the next route
if  (rt->rt_flags==RTF_UP)&&(  rt->rt_expire<now)  &&(  rt->rt_retry_times_t==0)
    rt-> rt_retry_times_t=1,  // increment route retry entry
    rt-> rt_ expire+=now      // calculate route expire time
    sendRequest (rt->rt_dst) // send request to destination once again
else if
     if (rt->rt_flags==RTF_UP)&&( rt->rt_expire<now) &&( rt->rt_retry_times_t!=0)
assert (rt->rt_hops!=INFINITY)  // if a valid route expired ,
         purge all packets from send  buffer & invalidate  the route.
else if
drop (p,DROP_RTR_NO_ROUTE)      // drop the packet from the route with no  route to  destination.
end
```

5. Simulation Results

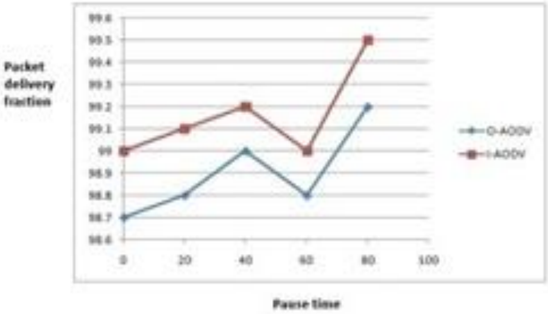
The proposed algorithm is simulated using Cygwin Simulator [8]. The simulation results and the comparison with the old versions of AODV are presented below with the account of key parameters: pause time, PDF, end to end delay time, normalized routing load and normalized MAC load.

Comparison 1: Pause time vs PDF

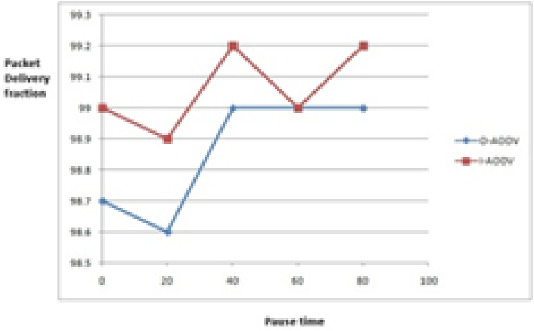
The ratio of the data packets delivered to the destinations to the data packets originated by the source is known as the packet delivery fraction (PDF) [9]. This number presents the routing effectiveness of a protocol. Pause time [10] indicates how much time a mobile host keeps stagnant at a particular place. Figure 1 shows pause time (in seconds) vs packet delivery fraction for O-AODV and I-AODV for 10, 20 and 30 nodes. The proposed algorithm confirms better results than the previous.



(a)



(b)

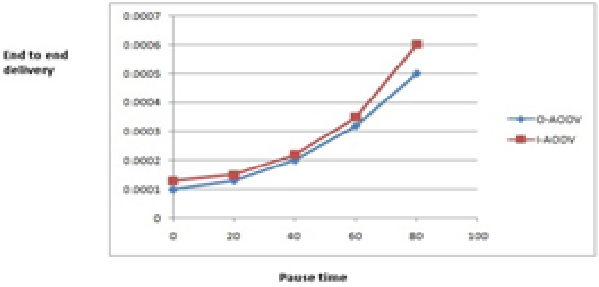


(c)

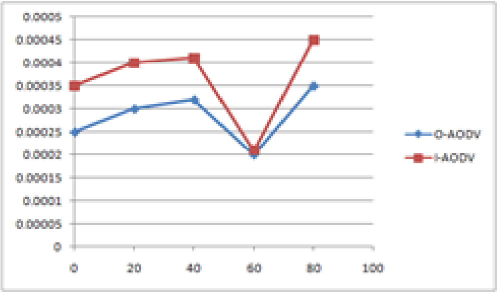
Figure 1 (a,b,c): Performance comparison of Pause time (in seconds) vs PDF of two algorithms for 10, 20, 30 nodes respectively

Comparison 2: Pause time vs end to end delay

End to end delays [11] are always possible which are associated with the route discovery; and the queuing delays associated with the node. As the re-transmitting is always done many times by the nodes after the packets are being stored.



(a)



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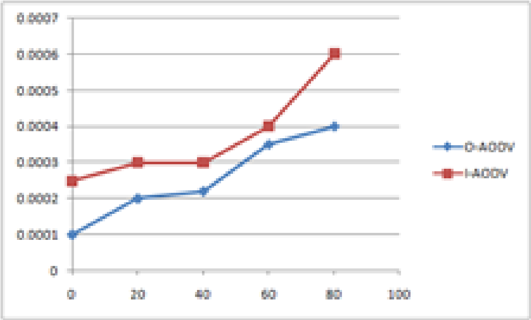


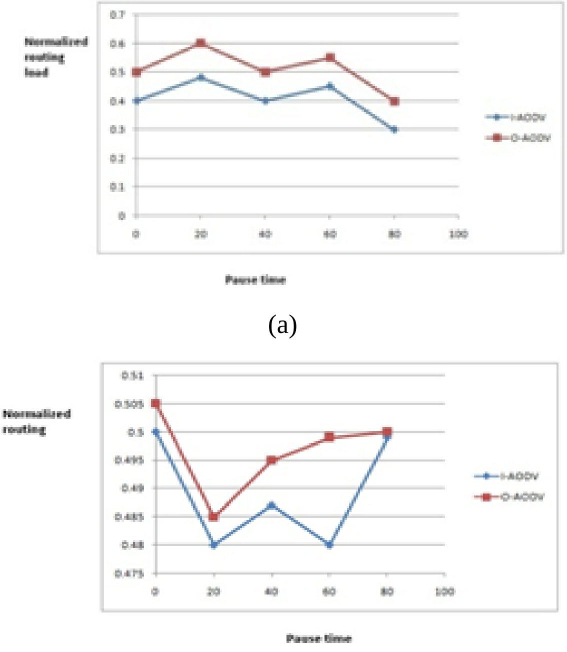
(c)

Figure 2 (a,b,c): Performance comparison of Pause time (in seconds) vs end to end delay for 10, 20, 30 nodes respectively

As the local repair concept is of more concerning, the node is proposed to store the packets and a delay is associated with them. Hence, in all the cases, the end to end delay increases with respect to pause time for 10, 20 and 30 sources in the proposed I-AODV algorithm. Figure 2 shows the contrast of the pause time (in seconds) vs end to end delay for O-AODV and I-AODV for 10, 20 and 30 nodes.

Comparison 3: Pause time vs Normalized routing load

The number of routing packets transmitted per data packet delivered at the destination is known as normalized routing load [12]. In the proposed I-AODV routing method, the normalized routing load is far lesser than the O-AODV. The main reason behind this is the concept of local repair. Here the data packets are sending using local repair, not using the routing packet as it would have been used if it was to be sent with the half of the route. So, by using one third of the path for checking, the routing load is being decreased. It is also found that one–third of the routing path for checking was feasible for most of the parameters such as packet delivery fraction for the transmission of data packets. Figure 3 shows pause time (in seconds) vs normalized routing load for O-AODV and I-AODV for 10, 20 and 30 nodes.



(a)

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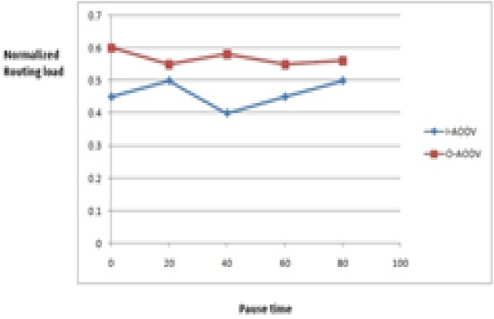
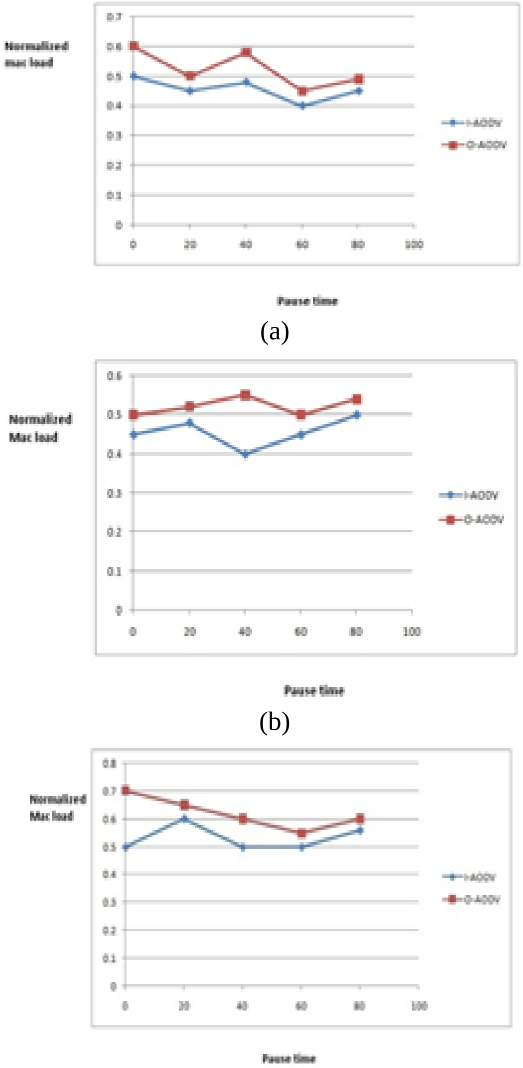


(c)

Figure 3 (a,b,c): Performance comparison of Pause time (in seconds) vs normalized routing load for 10, 20, 30 nodes respectively

Comparison 4: Pause time vs Normalized Mac load

Normalized mac load [13] is computed by the number of control packets and data packets sent to the number of packets delivered at the destination. In almost all the cases, the routing mac load is less than O-AODV protocol.



(a)

(b)

(c)

Figure 4 (a,b,c): Performance contrast of Pause time (in seconds) vs normalized MAC load of two algorithms for 10, 20, 30 nodes respectively

The control packet information are reduced by sending the packets within the one third path of the total path, thus as a result, the normalized routing load is being decreased. The figures below depict the pause time versus the normalized mac load for 10, 20 and 30 sources. Figure 2 shows the comparison of pause time (in seconds) vs normalized MAC load for AODV and I-AODV for 10, 20 and 30 nodes.

6. Discussion and Future Work

In the proposed I-AODV protocol, the condition for checking of local repair at the one third paths has contributed to the increment of packet delivery ratio or fraction more than the traditional O-AODV method. Moreover, the implementation of local repair causes the normalized and mac load to decrease because the route discovery is not initiated once again. But due to the storage of the packets in the queue causes the end to end delivery to increase. Same applies to the case of improvement in expired route and TTL–thread. So, it is observed that the PDF and mac load has decreased whereas the end to end delivery has increased. In future, authors' goal would be to find out a tradeoff between the PDF and the end to end delivery. It would be also interesting to provide modification to decrease the end to end delivery and increase the packet delivery fraction. Further investigation would be devoted to assess the algorithm performance in more realistic conditions. This work is left open for future.

7. Conclusion

In this work, an improvement of the AODV routing protocol is proposed and re-investigate for three different scenarios. The key feature of this algorithm is that it takes advantages of distributing and efficient using of network resources, reducing network congestion and increasing overall performance. When the underlying network is large and the topology is dense, the proposed version outperforms the deficiencies of the original protocol.

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