



Analysis and Performance Evaluation of Mobile Ad-hoc Network (MANET) Protocols Based on Selected Criteria

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Abstract

Mobile ad-hoc network is a collection of wireless mobile nodes dynamically forming a temporary network without the aid of any established infrastructure or centralized administration. Routing protocols in mobile ad-hoc network helps node to send and receive packets. Mobile ad-hoc networks (MANET), also known as short-lived networks, are autonomous systems of mobile nodes forming network in the absence of any centralized support. This paper carries out a vivid study of the concepts and principles of mobile routing protocols in order to determine which of these protocols is best in a given situation. This is followed by analysis and evaluation of the selected mobile routing protocols based on some criteria carried out by coding their algorithms using java programming language. The resultant developed applications of the selected mobile routing protocols are executed, and the generated results recorded in tables according to the criteria adopted. The execution is based on selected criteria such as packet delivery ratio (PDR), end to end delay, and throughput. The data used in the execution of the mobile routing applications was various size or number of mobile devices ranging from 10 to 50. A further interpretation of the results generated was carried out to depict pictorially the characteristics performance behaviour of the selected mobile routing protocols. The pictorial representation was done with the technical computing language, MATLAB.

1. Introduction

The mobile ad hoc network, also known as MANET, is a network without any available infrastructure [1]. Nodes are mobile and can move whenever and wherever they want and because there is no centralized control, no other infrastructure is needed in MANET as each node in a MANET must be capable of functioning as a router to relay the traffic of other nodes. The mobile nodes act as both hosts and routers as it can route and accept the traffic from the neighbor nodes [2]. The challenges of self-configuration are announced when the network grows and also there are frequent re-associations and connection tearing. In order to cope with the MANET dynamic nature, a number of dedicated protocols have been developed to support and accomplish this task, and this group of protocols are known as mobile protocols. Mobile protocols adopt dynamic routing strategy whereby network routes are being learnt based on the state of the network. That is the information in the routing table is affected by the activeness of the destination of the node [3]. In this routing

strategy, protocols are used to find networks and update routing tables on routers, and routing usually cost more in terms of router CPU processes and bandwidth on the network links [4].

Mobile Ad-hoc networks are self-organizing and self-configuring multi-hop wireless networks where, the structure of the network changes dynamically. This is mainly due to the mobility of the nodes [5]. Nodes in these networks utilize the same random access wireless channel, cooperating in a friendly manner to engaging themselves in multi-hop forwarding. The nodes in the network not only act as hosts but also as routers that route data to/from other nodes in network [6]. In mobile ad-hoc networks where a destination node might be out of range of a source node transmitting packets, routing procedure is always needed to find a path so as to forward the packets appropriately between the source and the destination.

For nodes in a MANET to act as a router as well as the capability to forward data packets to a specific destination, they must implement routing protocol algorithms. These algorithms are used to build the entries of the routing table. The router uses the table entries to decide the best path to deliver data packets to a given destination in a network [7].

2. Methodology

A study of the concepts and principles of mobile routing protocols was vividly elucidated. This was followed by analysis and evaluation of the selected mobile routing protocols based on some criteria were carried out by coding their algorithms using java programming Language. Java was selected or chosen because of the readily available application programming interfaces (APIs), and also the advantage of reuse of code.

The coding of the algorithms was done on Windows 7 operating system platform, HP duo core processor with 10 gigabytes (GB) random access memory (RAM). The resultant developed applications of the selected mobile routing protocols were executed or ran, and the generated results or information were recorded in tables according to the criteria adopted. The data used in the execution of the mobile routing applications was various size or number of mobile devices ranging from 10 to 50.

A further interpretation of the information or results generated was carried out to depict pictorially the characteristics performance behaviour of the selected mobile routing protocols. The pictorial representation was done with the technical computing language, MATLAB.

3. Classification of MANET Routing Protocols

Classification of routing protocols in MANET can be done mainly on two criteria, and these are routing strategy and network structure [8]. Based on network structure, routing protocols are classified as flat, hierarchical and geographic position assisted routing. Table-driven and source initiated protocols are members of the flat routing protocol, and this is the focus of the paper, and the classification based on network structure is shown in Figure 1.

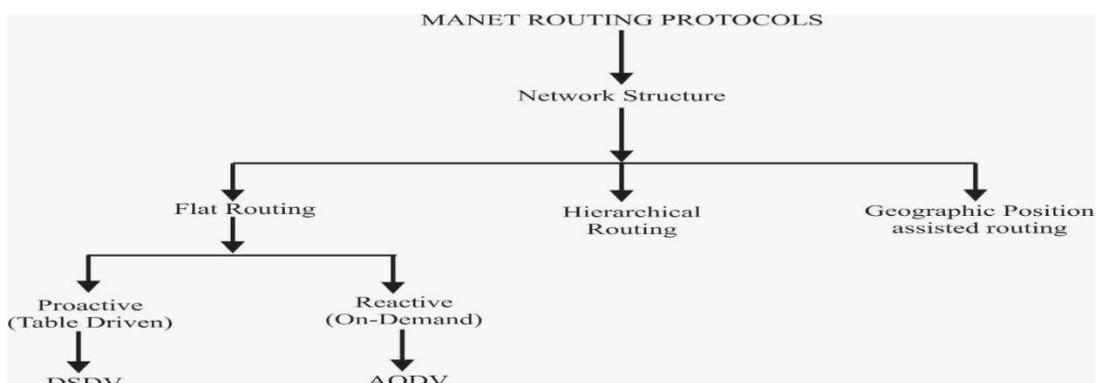


Figure 1: Classification of Routing Protocols in MANET based on Network Structure

3.1. Table-driven Routing Protocols

These proactive protocols maintain the required routing information even before it is needed. Each and every node in the network maintains routing information to every other node in the network. Routes information kept in the routing tables are periodically updated as the network topology changes. These routing protocols come from the link-state routing. The proactive protocols are not suitable for larger networks, as they need to maintain node entries for each and every node in the routing table of every node. This causes more overhead in the routing table leading to consumption of more bandwidth [9]. A major example of a MANET routing protocol that uses this strategy is the Destination Sequenced Distance Vector (DSDV) protocol.

3.1.1 DSDV Routing Mechanism

The destination sequenced distance vector routing protocol is a proactive routing protocol based on Bellman-Ford Routing Algorithm. This protocol adds a new attribute known as sequence number, to each route table entry at each node [10]. Routing table is maintained at each node and with this table, node transmits the packets to other nodes in the network. This protocol was motivated for the use of data exchange along changing and arbitrary paths of interconnection which may not be close to any base station [11].

A routing table is maintained by each node for the transmission of the packets and also for the connectivity to different stations in the network. These stations list for all the available destinations, and the number of hops required to reach each destination in the routing table. The routing entry is associated with a sequence number which is originated by the destination station. In order to maintain the routing consistency, each station transmits and updates its routing table periodically. The packets being broadcasted between stations indicate which stations are accessible and how many hops are required to reach that particular station. The packets may be transmitted containing the layer 2 or layer 3 address [12].

Routing information is advertised by broadcasting packets which are transmitted periodically as when the nodes move within the network. The DSDV protocol requires that each mobile station in the network must constantly advertise its own routing table to each of its neighbors. Since the entries in the table may change very quickly, the advertisement is carried out frequently to ensure that every node can locate its neighbors in the network. This ensures that the exchange of data is done among nodes through a path (or route) with the shortest number of hops to a destination even if there is no direct communication link. The data broadcast by each node contains following items of information:

- i. Sequence number
- ii. Destination address
- iii. Number of hops required to reach destination
- iv. Hardware address
- v. Network address of the mobile host

The time interval between broadcasting the routing information packets is another important factor of consideration. When the new information is received by the mobile host it will be retransmitted, effecting the most rapid possible dissemination of routing information among all the cooperating mobile hosts. The mobile host cause broken links as they move from place to place within the network. The broken link may be detected by the layer 2 protocol, which may be described as infinity. When the route is broken in a network, an infinity metric is assigned immediately by determining that there is no hop and the sequence number is updated. Sequence numbers originating from the mobile hosts are defined to be even number and the sequence numbers generated to indicate infinity metrics are odd numbers [13].

DSDV protocol information broadcast is either full or incremental dump, and it is done in network protocol data units (NPDU). Full dump broadcasting will carry all the routing information using multiple NPDU while the incremental dump will carry only information that has changed since last full dump and requires only one. When information packet is received from another node, the sequence number is compared with the available sequence number for that entry. If the comparison results in larger sequence number, then routing information is updated. During this process, metric is increased by 1 and sequence number by 2. During the process of broadcast, the mobile hosts will transmit their routing tables periodically but due to the frequent movements by the hosts in the networks, this will lead to continuous burst of new routes transmissions upon every new sequence number from that destination. The solution for this is to delay the advertisement of such routes until there is a better metric.

Address stored in the routing table at the mobile hosts will correspond to the layer at which the DSDV protocol is operated. Layer3 will use network layer addresses for the next hop and destination addresses and layer 2 will use the MAC address for its operation, and each mobile node would advertise reachability information about the layer3 protocols at that destination [14]. Figure 2 shows a scenario of a mobile network of eight (8) nodes with a movement of node 1 (X₁) to a new location.

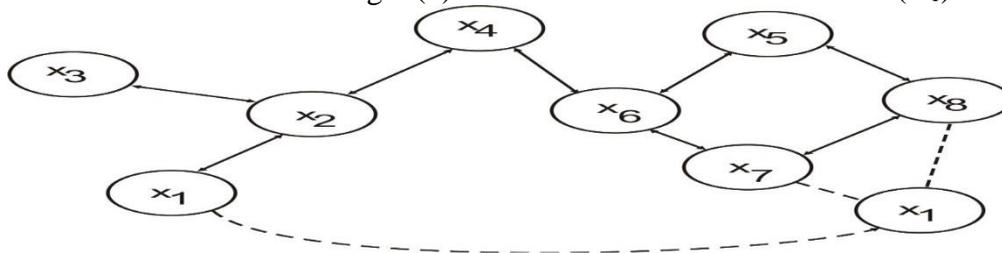


Figure 2: Movement of Mobile host in Ad-hoc Network

Initially, all the nodes advertise their routing information to all the nodes in the network and hence, the routing table at mobile node 4 (X₄) is given Table 1. The forwarding table in the mobile node 4 (X₄) is shown in Table 2.

Table 1: Routing Table of Mobile node X₄

Destination	Next Hop	Metric	Sequence Number	Install	Stable Data
X ₁	X ₂	2	S406 X ₁	T001 X ₄	Ptr1 X ₁
X ₂	X ₂	1	S128 X ₂	T001 X ₄	Ptr1 X ₂
X ₃	X ₂	2	S564 X ₃	T001 X ₄	Ptr1 X ₃
X ₄	X ₄	0	S710 X ₄	T001 X ₄	Ptr1 X ₄
X ₅	X ₆	2	S392 X ₅	T002 X ₄	Ptr1 X ₅
X ₆	X ₆	1	S076 X ₆	T001 X ₄	Ptr1 X ₆
X ₇	X ₆	2	S128 X ₇	T002 X ₄	Ptr1 X ₇
X ₈	X ₆	3	S050 X ₈	T002 X ₄	Ptr1 X ₈

Table 2: Forwarding Table at Mobile node X₄

Destination	Metric	Sequence Number
X ₁	2	S406 X ₁
X ₂	1	S128 X ₂
X ₃	2	S564 X ₃
X ₄	0	S710 X ₄
X ₅	2	S392 X ₅

X ₆	1	S076 X ₆
X ₇	2	S128 X ₇
X ₈	3	S050 X ₈

When the mobile node 1 (X₁) moves its location as shown in the Figure 2 nearer to mobile node 7 and mobile node 8, the link between mobile node 2 and mobile node 1 will be broken resulting in the assignment of infinity metric at mobile node 2 (X₂) for mobile node 1 and the sequence number will be changed to odd number in the routing table at mobile node 2 (X₂) [15]. Mobile node 2 (X₂) will update this information to its neighbor hosts. Since, there is a new neighbor host for mobile node 7 (X₇) and mobile node 8 (X₈), their routing tables' information is updated and they perform broadcast operation. At this point, mobile node 4 (X₄) will receive its updated information from mobile node 6 (X₆). Mobile node 6 (X₆) will receive two information packets from different neighbors to reach mobile node 1 (X₁) with the same sequence number but different metric. The selection of the route will depend on smallest value of hop count when the sequence number is the same, and the resulting routing table shown in Table 3.

Table 3: Routing Table after Mobile node X₁ Movement

Destination	Next Hop	Metric	Sequence Number	Install	Stable Data
X ₁	X ₆	3	S516 X ₁	T001 X ₄	Ptr1 X ₁
X ₂	X ₂	1	S238 X ₂	T001 X ₄	Ptr1 X ₂
X ₃	X ₂	2	S674 X ₃	T001 X ₄	Ptr1 X ₃
X ₄	X ₄	0	S820 X ₄	T001X ₄	Ptr1 X ₄
X ₅	X ₆	2	S502 X ₅	T002 X ₄	Ptr1 X ₅
X ₆	X ₆	1	S186 X ₆	T001 X ₄	Ptr1 X ₆
X ₇	X ₆	2	S238 X ₇	T002 X ₄	Ptr1 X ₇
X ₈	X ₆	3	S160 X ₈	T002 X ₄	Ptr1 X ₈

DSDV protocol guarantees loop free paths as well as a drastic reduction in count to infinity problem. There is an avoidance of extra traffic as the protocol adopts the method of incremental update of its' routing Table [16]. DSDV maintains only the best path among alternative paths to every destination, and this feature reduces the amount of space in its' routing table. However, unnecessary advertising of routing information by DSDV protocol even if there is no change in the network topology causes wastage of bandwidth, especially in large mobile networks. This is a major weakness of the protocol. Another limitation of DSDV protocol is that it supports only single-path routing [17].

3.1.2 On Demand Routing Protocols (Reactive)

These are reactive protocols that does not maintain routing information or routing activity at the network nodes if there is no communication. Whenever a node wants to send a packet to another node, this protocol searches for the route in an on-demand manner and establishes the connection in order to transmit and receive the packet [18]. The route discovery usually occurs by flooding the route request packets throughout the network. The reactive routing protocols uses a distance vector algorithm with a destination sequence number for route updating. A good example of a MANET routing protocol that uses this strategy is the Ad-hoc On Demand Distance Vector (AODV) protocol.

AODV is a very simple, efficient, and effective routing protocol for Mobile Ad-hoc Networks (MANET). This algorithm has the ability to use limited bandwidth that is available in the media that are used for wireless communications [19]. The on-demand route discovery and route maintenance by means of hop-by-hop routing, usage of node sequence numbers make the algorithm cope up with topology and routing information. This mobile routing protocol is considered to be a pure on-

demand routing protocol since nodes that are not in the selected path to a destination do not participate in routing decisions [20].

In this protocol, each mobile host in the network acts as a specialized router and routes are obtained as needed, thus making the network self-starting [21]. Each node in the network maintains a routing table with the routing information entries to its neighboring nodes using two separate counters known as the node sequence number and broadcast-id. When a node communicates with another, the node broadcast-id is incremented triggering path discovery process by broadcasting a route request packet (RREQ) to its neighbors, and the dynamic route table entry establishment begins at all the nodes in the network that are on the path from the source node to the destination node [22]. The route request packet (RREQ) contains the following fields:

Source Address	Source Sequence No.	Destination Address	Destination Sequence No.	Hop Count
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The pair of (source address and broadcast identification) is used to uniquely identify the route request packet (RREQ) from a given node [23]. The pseudocode of AODV algorithm is shown in Appendix 1

4.0 Performance Analysis

Relevant criteria are chosen in order to compare the performance characteristics behaviour of the two selected categories of mobile routing protocols. The criteria used are as follows:

i. Packet Delivery Ratio

This is the ratio of total number of data packets received at destination to the total number of data packet sent from source.

ii. End-to-End Delay

This is the average time taken by the packet to reach destination from source. This metric is calculated by subtracting time at which first packet was transmitted by source from time at which first data packet arrived to destination. This metric is significant in understanding the delay introduced by path discovery.

iii. Throughput

This refers to how much data can be transferred from one location to another in a given amount of time. It can also be defined as the average number of bits transmitted per unit time.

The evaluation of the two selected mobile routing protocol algorithms based on the stated performance criteria are as follows:

The performance behavior of the mobile protocols using packet Delivery Delay as a criterion is shown in Table 4. The graph shown in Figure 3 was plotted using values in Table 4:

Table 4: Performance Behaviour based on Packet Delivery Delay with varying number of Nodes.

S/N	Number of Nodes	AODV Packet Delivery Delay (s)	DSDV Packet Delivery Delay (s)
1.	10	73.14	53.26
2.	20	99.71	70.00
3.	30	100.00	69.66
4.	40	100.00	70.03
5.	50	100.00	69.01

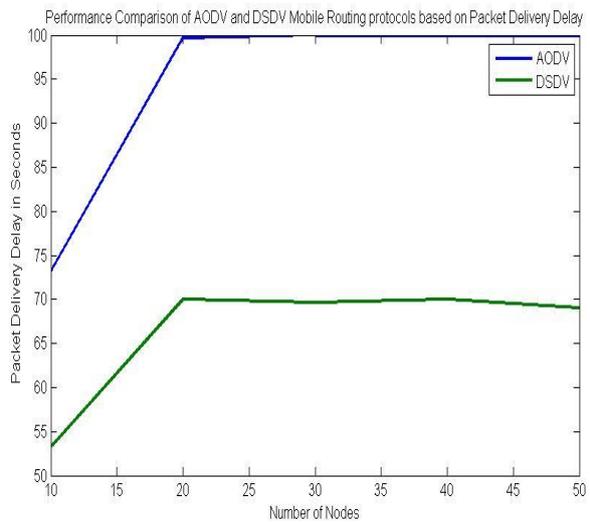


Figure 3: Packet Delivery Delay of AODV and DSDV Mobile Routing Protocols

From the graph in Figure 3, it shows that the AODV mobile protocol performance increased as the number of nodes increases and becomes stable for higher number of nodes. The DSDV mobile protocol increases in performance as the number of nodes increases and also at some points, decreases in performance at higher nodes. This means that AODV has a better performance in terms of packet delivery ratio than the DSDV protocol.

Table 5 shows the performance behavior based on End-to-End Delay with varying number of nodes in seconds while Figure 4 is the corresponding graph.

Table 5: Performance Behaviour based on End-to-End Delay with varying number of Nodes.

S/N	Number of Nodes	AODV End-to-End Delay (s)	DSDV End-to-End Delay (s)
1.	10	1.07	0.01
2.	20	0.01	0.01
3.	30	0.06	0.01
4.	40	0.05	0.01
5.	50	0.02	0.01

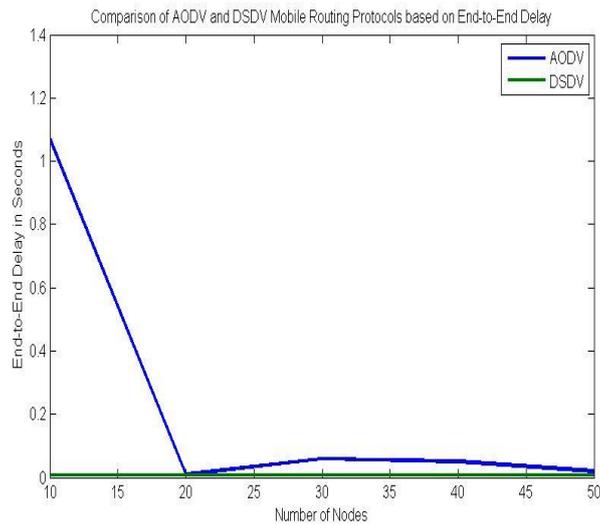


Figure 4: End-to-End Delay of AODV and DSDV Mobile Routing Protocols

From the graph in Figure 4, the performance in terms of End-to-End delay of the DSDV mobile protocol is slightly better than the AODV protocol especially when the number of nodes is more than 20.

Table 6 shows the performance behaviour based on throughput in kilobits per second with varying number of nodes in seconds while Figure 6 is the corresponding graph.

Table 6: Performance Behaviour based on Throughput with varying number of Nodes.

S/N	Number of Nodes	AODV throughput (kb/s)	DSDV throughput (kb/s)
1.	10	15.57	11.46
2.	20	21.18	14.92
3.	30	21.60	15.10
4.	40	21.53	14.83
5.	50	21.81	14.91

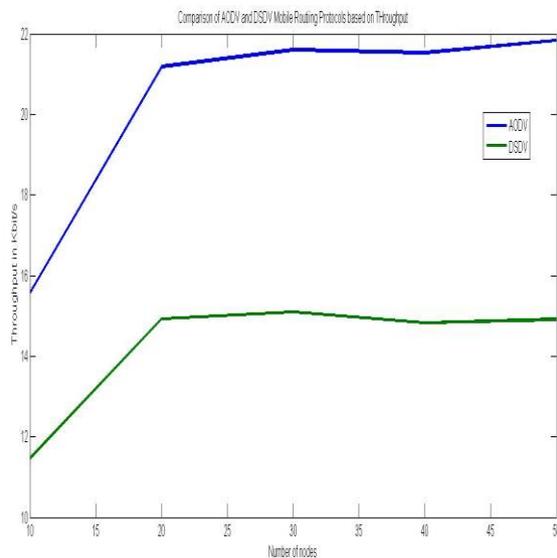


Figure 5; Throughput of AODV and DSDV Mobile Routing Protocols.

From the graph in Figure 5, it is observed that the DSDV mobile protocol is less prone to route stability compared to AODV when the number of nodes increase.

5.0 Findings

- i. DSDV wastes bandwidth as a result of the periodic updates being broadcasted while AODV propagates only hello messages to its neighbours. In terms of bandwidth utilization, AODV is a better mobile routing protocol.
- ii. There is a minimal time delay in routing data from a given node to a specific destination as location routes are maintained in the routing table in DSDV. AODV spent a considerable amount of time to find a location route before sending data to specified locations.
- iii. There is much more overhead in DSDV mobile routing protocol in maintaining routing table especially when the network becomes so large. AODV has less overhead as it maintains small tables for local connectivity.
- iv. DSDV cannot handle mobility at high speeds due to lack of alternative routes. AODV effectively support high speed mobility, since nodes that are not in the selected path to a destination do not participate in routing decisions.
- v. AODV has stable throughput as it doesn't advertise any routing updates. DSDV throughput decreases comparatively as it requires to advertise both periodic updates and event-driven updates.

6.0 Conclusion

The performance of all the routing protocol is measured with respect to the criteria namely, Packet Delivery Ration, End-to-End Delay, and Throughput. The observation results indicate that the performance is improved, especially when the number of nodes in the network is increased. When the number of nodes is increased beyond 30 and above, the performance of the two mobile protocols varies very much. It is due to the fact that, lot of control packets are generated in the network. It is also observed that DSDV is better than AODV protocol in PDR. It is concluded that AODV has lower performance compared to DSDV in most of the criteria.

References

- [1] Gao, C., Zhao, G., R., Lu, J. H., and Pan, S. A. (2015). Drid-based cooperative QoS routing protocol with fading memory optimization for navigation carrier ad hoc networks. *Computer Networks*. Vol. 76, pp. 294–316.
- [2] Palanisamy, C. and Renuka, B. D. (2012). *MANET Routing Protocols Performance Evaluation in Mobility*. Digital Communication, Prof. C Palanisamy (Ed.), ISBN: 978-953-51-0215-1.
- [3] Liu, C. and Chang, S. (2009). The study of effectiveness for ad-hoc wireless network. In *Proc. of ICIS 2nd International Conference on Interaction Sciences: Information Technology, Culture and Human*, Seoul, Korea, pp. 412 - 417.
- [4] Ramesh, V., Subbaiah, P., Koteswar, R. and Janardhana, M. (2010). Performance comparison and analysis of DSDV and AODV for MANET. *International Journal on Computer Science and Engineering (JJCSE)*, vol. 2, pp. 183-188.
- [5] Lu, J. H., Gao, C., Zhao, G. R., and Liu, T. (2015). Decentralized state estimation for networked navigation systems with communication delay and packet loss: the receding horizon case. In *17th IFAC Symposium on System Identification*, Beijing, pp. 1094–1099.
- [6] Matrouk, K. and Landfeldt, B. (2013). KETT-gen: a globally efficient routing protocol for wireless sensor networks by equalizing sensor energy and avoiding energy holes. *Ad Hoc Networks*, vol. 87, pp. 514–536.
- [7] Wahab, O. A., Otrok, H., and Mourad, A. (2013). VANET QoS-OLSR: QoS-based clustering protocol for vehicular ad hoc networks. *Computer Communications*, vo. 36, pp. 1422–1435.
- [8] Zhu, X., Shen, L., and Yum, T. P. (2009). Hausdorff clustering and minimum energy routing for wireless sensor networks. *IEEE Transactions on Vehicular Technology*, vol.58. no. 2, pp.
- [9] Le, T., Hu, W., and Corke, P. (2009). ERTP: energy-efficient and reliable transport protocol for data streaming in wireless sensor networks. *Computer Communications*. Vol. 21, pp. 3235–3251.
- [10] Goswami, S., Joardar, S., and Das, C. B. (2015). Reactive and proactive routing protocol performance metric comparison in mobile ad hoc networks using NS 2. *International Journal of Advanced Research in Computer and Communication Engineering*, vol. 3, no. 1, pp. 4908–4914.

- [11] Gao, C., Zhao G. R., Lu, J. H., and Liu, T. (2016). Dynamic cooperative MAC protocol for navigation carrier ad hoc networks: a diffserv-based approach. *International Journal of Antennas and Propagation*, vol. 4, pp. 30 – 39.
- [12] Gao C., Zhao G. R., and Pan S. (2009). DMDG: a distributed data-aggregation and routing protocol for fleet wireless sensor networks. In: *The 2th International Conference on Intelligent Networks and Intelligent Systems*, Tianjin, pp. 150–155.
- [13] Maan, F. and Mazhar, N. (2011). MANET Routing Protocols versus Mobility Models: A Performance Evaluation. In *Proceeding of Third International Conference on Ubiquitous and Future Networks IEEE*, Dalian, China, pp. 179 - 184.
- [14] Ang, C. and Tham, C. (2008). iMST: a bandwidth-guaranteed topology control algorithm for TDMA-based ad hoc networks with sectorized antennas. *Computer Networks*, vol. 52, pp. 675–1692.
- [15] Zhang, M. and Chong, P. H. J. (2009). Performance Comparison of Flat and Cluster-Based Hierarchical Ad Hoc Routing with Entity and Group Mobility. In *Proceeding of IEEE Communications Society conference on Wireless Communications and Networking*, Budapest, Hungary, pp. 2450 - 2455.
- [16] Gao, C., Zhao, G. R., Lu, J. H., and Pan, S. A. (2015). Decentralized moving-horizon state estimation for a class of networked spatial-navigation systems with random parametric uncertainties and communication link failures. *IET Control Theory and Applications*, vol. 9, no.18, pp. 666–2677.
- [17] Rachid, E. and Mohammed, B. (2009). Routing in wireless sensor networks. *International conference on multimedia computing and systems (ICMCS)*, pp. 4-10. 990–996.
- [18] Awan, I., and Al-Begain, K. (2006). Performance evaluation of wireless networks. *International Journal of Wireless Information Networks*, vol. 13, no. 2, pp. 95–97.
- [19] Goswami, S., Joardar, S., and Das C. B. (2014). *Performance Comparison of Routing Protocols of MANET Using NS-2*. 1st ed. Germany, LAP LAMBERT Academic Publishing, pp. 141.
- [20] Barman, S., Ghosh, A., and Biswas, S. (2015). A transparent tree root identification scheme to support route-optimization and network mobility in PMIPv6 Domain. *IEEE 2nd International Conference on Recent Trends in Information Systems (ReTIS)*, Kolkata. pp. 532–537.
- [21] Alotaibi, E. and Mukherjee, B. (2011). A survey on routing algorithms for wireless Ad-Hoc and mesh networks. *Computer Networks: The International Journal of Computer and Telecommunications Networking*, vol. 56, no. 2, pp. 940–965.
- [22] Goswami, S., Joardar S., and Das, C. B. (2014). A simulation based performance comparison of AODV and DSDV mobile ad hoc networks. *Information Technology and Computer Science*, vol. 6, no. 10, pp. 11–18.
- [23] Morshed, M., Rahman, H., Mazumder, R. and Lutfullah, K. A. M. (2009). Simulation and Analysis of Ad-hoc On-demand Distance Vector Routing Protocol. In *Proceeding. of ICIS*, Seoul, Korea, pp. 610 - 614.

Appendix 1: A Pseudocode of AODV Algorithm

Algorithm AODV-route-discovery (source, N-nodes)

```
begin
    while (node[i].exists())
begin
    source-send (RREG, node[i])           // send route request packet to node i
        max (destination-sequence-numbers[i]) // find maximum
        if max (destination-node[i])
        select (route-path[i])
        record (route-info[i]) // enter route information in routing table
    establish-path (source-node, node[i]) // route path to node[i] selected
        if (no-route-found)
        begin
            route-found = false
            set-reverse-path ( )
            propagate-RREQ (node[i].neighbours)
        end
    end while
    source-send (RREQ, node[i])
begin
    establish (destination-route)
    if (no-route-found)
    begin
        route-found = false
        set-reverse-path ( )
        propagate-RREQ (neighbour-nodes)
    end
    else
    begin
        route-found = true
    end
end
```

```
        send-RREP (source, loop-count, route, destination-sequence-number)
    end
end if
end
propagate-RREQ (node[i])
begin
    if (route[i] not-found)
        route-found = false
    else
        begin
            route-found = true
            send-RREP (node[i], route[i], destination-sequence-number[i])
            end
        end if
    end
end
end
```