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# Impact of Node Mobility on Routing Protocols for Wireless Sensor Networks

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*Abstract*— **Wireless sensor networks monitor their surrounding environment for the occurrence of some anticipated phenomenon. Most of the research related to sensor networks considers the static deployment of sensor nodes. Mobility of sensor node can be considered as an extra dimension of complexity, which poses interesting and challenging problems. Node mobility is a very important aspect in the design of effective routing algorithm for mobile wireless networks. In this work we intent to present the impact of different mobility models on the performance of the wireless sensor networks. Routing characteristics of various routing protocols for ad-hoc network were studied considering different mobility models. Performance metrics such as end-to-end delay, throughput and routing load were considered and their variations in the case of mobility models like Freeway, RPGM were studied. This work will be useful to figure out the characteristics of routing protocols depending on the mobility patterns of sensors.**

*Index Terms*— **Wireless Sensor Network, Ad-Hoc Network, Mobility Model, Routing Protocol**

## I. INRODUCTION

Wireless sensor networks [1,2] are promising unprecedented levels of access to information about the physical world, in real time. Many areas of human activity are starting to see the benefits of utilizing sensor networks. Some of the real deployments include UC Berkley's Smart Dust, MIT's μ-Adaptive Multi-domain Power aware Sensors and UCLA's Wireless Integrated Sensor Networks. In almost all such cases, sensor networks are statically deployed. In static networks, the mobility of sensors, users and the monitored phenomenon is totally ignored. The next evolutionary step for sensor networks is to handle mobility in all its forms. One motivating example could be a network of environmental monitoring sensors, mounted on vehicles used to monitor current pollution levels in a city. In this example, the sensors are moving, the sensed phenomenon is moving and users of the network moves as well.

The dynamic nature of mobile wireless sensor networks introduces unique challenges in aspects like data management, accuracy and precision, coverage, routing protocols, security, software support. Many of the above mentioned problems related to a static deployment of the sensors are well addressed by the researchers. One of the most important constrains on sensor nodes is the route enabling when the nodes keep moving. It has been reported that the clustering mechanisms and hierarchical routing make huge improvement in sensor networks in terms of energy consumption and efficient data gathering [3,4]. Such improvement is due to the structure of the network, assumed before the deployment of the sensor nodes. Once the network becomes dynamic we do not have the freedom to pre-assume such structures. The conventional routing protocols for static sensor networks are to be optimized once we introduce mobility. To study the performance of routing protocols under such conditions, we have to consider the mobility patterns of the entire network.

This paper attempts to examine the performance issues specially on routing associated with mobility in WSN. The paper is organized as follows, Section II discuss description of routing protocols used in ad-hoc environment. Section III describes various mobility models used in common practice. Section IV details simulation model used for the performance study and the succeeding section V follows the detailed experiments used for the performance comparison of various protocols. Finally Section VI contains the conclusion.

## II. ROUTING PROTOCOLS

Mainly ad-hoc routing protocols are divided into two categories:

a. *Table-driven routing protocols:* In table driven routing protocols, each node maintain the route table, which contains consistent and up-to-date routing information about all nodes in the network.
b. *On-Demand routing protocols:* In on-demand routing protocols, whenever a source wants to send to a destination node, it first finds the path to the destination using route discovery mechanism. Routing overhead is less and it is suitable for networks where frequency of communication is very less.

A number of routing protocols like Destination-Sequenced Distance-Vector (DSDV), Dynamic Source Routing (DSR), Ad Hoc On-Demand Distance Vector

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Routing (AODV), and Temporally Ordered Routing Algorithm (TORA) are normally used in ad hoc networks.

### A. Destination-sequenced distance-vector routing

The Destination-Sequenced Distance-Vector (DSDV) [5] routing algorithm is built on top of Bellman-Ford routing algorithm. The main achievement of the algorithm was to solve the routing loop problem. In DSDV algorithm, every mobile station has to maintain a routing table, which lists all available destinations, the number of hops to reach the destination and the sequence number assigned by the destination node. The sequence number is used to distinguish old routes from new ones and thus avoid the formation of loops. The stations periodically transmit its routing table to its immediate neighbors. Transmission of routing table can be sporadic, if there is a significant change has occurred in its table from the last update sent. So, the update is both time-driven and event-driven. The Routing information is distributed between nodes by sending *full dumps* infrequently and smaller incremental updates more frequently. A full dump sends the complete routing table information to the neighbors whereas in an incremental update, entries which posses the metric change is send across to the neighbor. Thus, the incremental update reduces the routing traffic a lot. But in view of mobility, node dynamics cause incremental packets to grow big so full dumps will be more frequent in use.

### B. Dynamic source routing

The distinguishing features of DSR [6] are low network overhead, requires no extra infrastructure for administration and the use of source routing. By source routing, implies that the sender had full knowledge of the complete hop-by-hop route information to the destination. The protocol is composed of the two main mechanisms of *Route Discovery* and *Route Maintenance*. Normally routes are stored in a route cache of each node. When a node would like to communicate to a destination, first it checks for the route for that particular destination in the route cache. If yes, the packets are sent with *source route* header information to the destination. In the other case, the route is not available at the route cache; initiate the route discovery mechanism to get the route first. Route discovery mechanism, floods the network with *route request* (RREQ) packets. RREQ, packets received by the neighbors, checks for the route to destination in its route cache. If it is not in cache rebroadcasts it, otherwise the node replies to the originator with a *route reply* (RREP) packet. Since RREQ and RREP packets both are source routed, original source can able to obtain the route and add to its route cache. In any case the link on a source route is broken; the source node is notified with a *route error* (RERR) packet. Once the RERR is received, the source removes the route from its cache and route discovery process is reinitiated.

DSR being a *reactive routing protocol* have no need to periodically flood the network for updating the routing tables like table-driven routing protocols do. Intermediate nodes are able to utilize the route cache information efficiently to reduce the control overhead

### C. Ad-hoc on-demand distance vector (AODV) routing

AODV [7] offers quick adaptation to dynamic link conditions, low resource constrain and low network utilization. The protocol adapts the similar route discovery mechanism as in DSR. However, route maintenance in AODV adapts table driven mechanism, keeps only single route for each node irrespective of multiple route in route cache maintained in DSR protocol. AODV relies on sequence number based mechanism to keep track of the freshness of the route entry also to avoid route loops. All the routing packets carry these sequence numbers. Also AODV maintains timer-based state information of various states in each node. Whenever a route entry is not used for long time the entry will be erased from the route table. Nodes keeps monitor the link status of next hope of all the active routes. In case of any link break is identified, RERR packets are sent to notify the other nodes. In contrast to DSR, route error packets in AODV are intended to inform all sources in the subnet using the link when a failure occurs.

## III. Mobility Models

There is much attention currently focused on the development and evaluation of wireless routing protocols for wireless sensor networks. Most of this evaluation has been performed with the aid of various network simulators (such as ns-2 and others) and synthetic models for mobility and data patterns. These models can have a great effect upon the results of the simulation, and thus, the valuation of these protocols. Some of the models, which are in consideration for our work, are listed below.

### A. Random waypoint (RW) model

The Random Waypoint model [8] [9] is most commonly used mobility model in research community. This model is an extension of Random walk. In this model node starts its journey from a point, chooses a velocity between [0, V_Max] towards an intermediate destination, which is chosen in a random manner. It stays at the intermediate location for a specified period called *pause period*. At the end pause period the node propagation proceed to the new random destination with a new chosen velocity. In the current network simulator (ns-2) distribution, the implementation of this mobility model is incorporated.

### *B. Reference point group mobility (RPGM) model*

The main use RPGM [10] is in military battlefield communication. In this mode, each group has a logical center called *group leader*. The group leader's motion determines the behavior of group motion. Initially, each member of the group is uniformly distributed where group leader also is a part of that. Each group will have a reference point. At each instant, nodes in the group are randomly placed at the neighborhood of the reference point of that group. The speed and direction variations of each node are derived by randomly deviating from that of the group leader.

*Important Characteristics:* Each node deviate its speed and direction from that of the leader can be characterized as follows:

1) Velocity {member} (t) = Velocity {leader} (t) + random () * SDR * Max_speed
2) Angle {member} (t) = Angle {leader} (t) + random () * ADR * Max_angle

Where 0 <= SDR, ADR <= 1. SDR is the Speed Deviation Ratio and ADR is the Angle Deviation Ratio. SDR and ADR are used to control the deviation of the velocity (magnitude and direction) of group members from that of the leader. Since the group leader mainly decides the mobility of group members, group mobility pattern is expected to have high spatial dependence for small values of SDR and ADR.

### *C. Freeway mobility (FW) model*

The FW [11] model emulates the motion behavior of mobile nodes on a freeway. It can be very well used in exchanging traffic status or tracking a vehicle on a freeway.

*Important Characteristics:* In this model we use maps. There are several freeways on the map and each freeway has lanes in both directions. The differences between Random Waypoint and Freeway are the following:

1) Each mobile node is restricted to its lane on the freeway.
2) The velocity of mobile node is temporally dependent on its previous velocity. Formally,

   vec{Velocity{i}}(t+1) = vec{Velocity{i}}(t) + random() * vec{a{i}}(t)
3) If two mobile nodes on the same freeway lane are within the Safety Distance (SD), the velocity of the following node cannot exceed the velocity of preceding node. Formally,

   for all {i}, for all {j},for all{t}

   if D{i,j}(t) < Safety_Distance, then vec{Velovity{i}}(t) < vec{Velocity{j}}(t), if j is ahead of i in its lane.

Due to the above relationships, the Freeway mobility pattern is expected to have spatial dependence and high temporal dependence. It also imposes strict geographic restrictions on the node movement by not allowing a node to change its lane.

### *D. Manhattan mobility (MH) model*

The Manhattan model [11] [12], the mobile nodes are allowed to move along the grids of horizontal and vertical streets on the map. It can be useful in modeling movement in an urban area where a pervasive computing service between portable devices is provided.

*Important Characteristics:* Maps are used in this model too. However, the map is composed of a number of horizontal and vertical streets. The mobile node is allowed to move along the grid of horizontal and vertical streets on the map. At an intersection of a horizontal and a vertical street, the mobile node can turn left, right or go straight with certain probability. Except the above difference, the inter-node and intra-node relationships involved in the Manhattan model are very similar to the Freeway model. Thus, the Manhattan mobility model is also expected to have high spatial dependence and high temporal dependence. It too imposes geographic restrictions on node mobility. However, it differs from the Freeway model in giving a node some freedom to change its direction.

The general metric that differentiate one mobility model from one another are

1. Velocity of specified node at a particular instant of time *t*.
2. Speed of specified node at a particular time *t*.
3. Angle made by Velocity vector at time t with the X-axis.
4. Acceleration vector of node at time *t*.
5. X, Y, Z co-ordinate of node at time *t*.
6. Distance between nodes two nodes at time *t*.
7. Transmission range of a mobile node.
8. Number of mobile nodes.
9. Degree of Spatial Dependence: It is extent to which the velocities of two neighboring nodes are similar.
10. Degree of Temporal Dependence: It is the extent of similarity of the velocities of a node at two time slots that are not too far apart. It is a function of the acceleration of the mobile node and the geographic restrictions.

## IV. SIMULATION MODEL

Routing protocols can be evaluated in two ways. First one is to use the real hardware itself for evaluation. Since it requires adequate recourse to be procured to build setup, uses of simulation-based methods are popular in lab environment. In both cases, the performance metrics as well as the network context are equally important. In this paper we use the simulation-based approach in which the network parameters must be stated first.

Simulation model based on NS-2 [13] is used here for evaluation. Support for simulating multi-hop wireless networks complaint with physical, data link, and medium access control (MAC) layer, modeled with NS-2. IEEE

802.11 for wireless LANs is used as the MAC layer protocol. An un-slotted carrier sense multiple access (CSMA) technique with collision avoidance (CSMA/CA) is used to transmit the data packets. The radio model uses characteristics similar to a commercial radio interface, bit rate of 2 Mb/s and a nominal radio range of 150 m. The protocols maintain a send buffer of 50 packets. It contains all data packets waiting for a route, such as packets for which route discovery has started, but no reply has arrived yet. To prevent buffering of packets indefinitely, packets are dropped if they wait in the send buffer for more than 60 s. All packets (both data and routing) sent by the routing layer are queued at the interface queue until the MAC layer can transmit them. The interface queue has a maximum size of 50 packets and is maintained as a priority queue with two priorities each served in FIFO order. Routing packets get higher priority than data packets.

Continuous bit rate (CBR) traffic sources are used. The source-destination pairs are spread randomly over the network. Only 512-byte data packets are used. The number of source-destination pairs and the packet-sending rate in each pair is varied to change the offered load in the network. The mobility models are simulated using the tool IMPORTANT [14], which generates the scenarios that can directly call from NS-2 script. The field configurations used is 1000 m × 1000 m field with a maximum of 40 nodes. Here, each packet starts its journey from a random location to a base station with chosen scenario. Once the destination is reached, another random source is targeted. Simulations are run for 850 simulated seconds. Identical traffic scenarios are used across protocols to gather fair results.

Most of the analysis is done using Trace graph [15], a network trace file analyzer used for network simulator ns-2 trace processing. Because of the use of MATLAB libraries by the Trace Graph, it gives pretty good graphical analysis.

## V. EXPERIMENTS

Our main focus is given to study whether mobility affects protocol performance or not. We have evaluated the performance of DSR, AODV and DSDV across deferent set of mobility models and observed that the mobility models may drastically affect protocol performance.

End-to-end delay, throughput and Normalized routing load are taken as the main metrics for study of performance. End-to-end delay and throughput have the meaning, which is same as in networking scenario. Normalized routing load [16] is the ratio of number of routing packets sends to the number of data packets received at the destination. This ratio evaluates the efficiency of routing in terms of extra load introduces to the network in view of mobility.

The end-to-end delay variations against throughput for various mobility models are studied first. Fig. 1 shows the variations for various routing protocols using mobility model as Freeway. In DSDV, the delay increases almost linearly with throughput increment except for very low and very high throughput. Traces are obtained fixing the parameters as number of nodes to 10 and speed used is 10 m/s. All the nodes are communicating to a base station. In AODV and DSR for low throughput the delay increases steeply. But for medium range of throughput it linearly decreases. Relative ranking of AODV and DSR seems to be comparable in freeway model.

RPGM mobility model the delay variation shown for various rooting protocols is shown in Fig. 2. In DSR for RPGM mobility model, the delay remains almost same for entire throughput range except for low throughput, offering a steady performance irrespective of variations. Also it out performs very well the other protocols AODV and DSR. In AODV, for middle range of throughput the performance is comparable as like in Freeway. In DSR the delay dip rate is negligibly small compared to AODV.

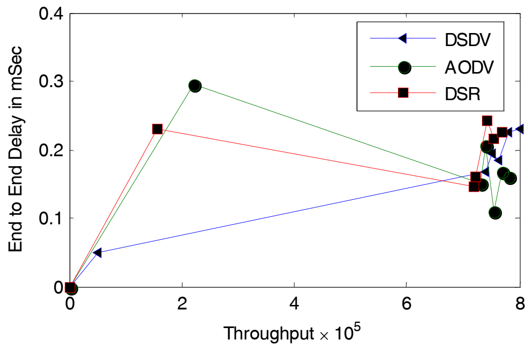


Fig. 1. End-to-End delay variations against throughput in Freeway mobility model

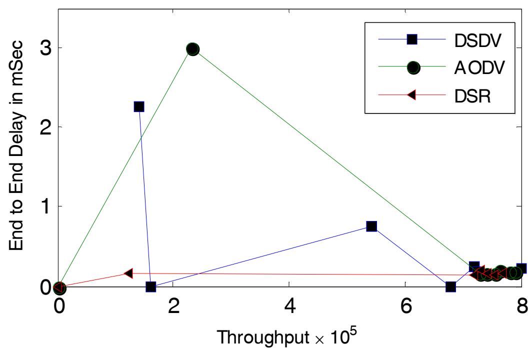


Fig. 2. End-to-End delay variations against throughput in RPGM mobility model

In Manhattan mobility model the delay variation shown for various routing protocols is shown in Fig 3. In this mobility model, DSR performs worst compared to other two mobility models.

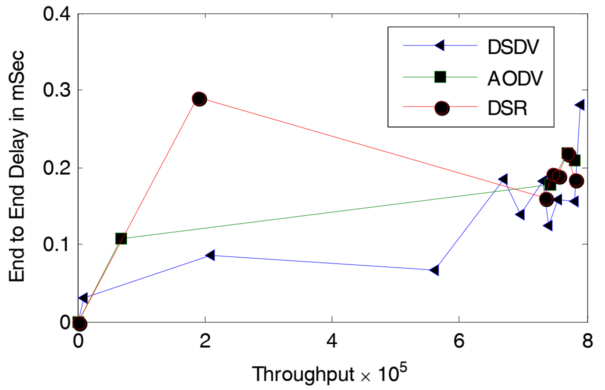


Fig. 3. End-to-End delay variations against throughput in Manhattan mobility model

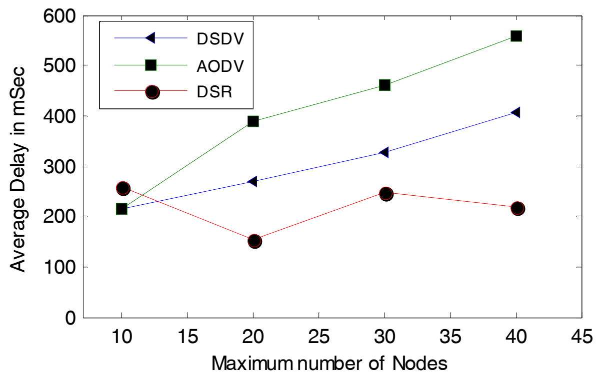


Fig. 4. Delay variation against the number of nodes in Freeway model

In, all the three mobility models, the AODV and DSR routing are seems to be comparable, whereas DSDV protocol is very much dependent on the mobility pattern. Since it is proactive table driven category, mobility variations can easily affect routing performances.

The variation of end-to-end delay against node size for Freeway mobility model is shown in fig. 4. It is observed that as the number of nodes increases the AODV and DSDV performs worst compared to DSR. In DSDV, the node number increment will increase overhead of routing messages. In DSR, since it is on demand, may not cause the any drastic end-to-end delay variations. The speed maintained as 10 m/s for all trace.

In RPGM routing protocol make use of the relative properties of the group action. The delay is almost comparable for medium range of number of nodes per group, whereas the routing suffers for lower range in DSDV. As observed from fig. 5, DSDV make use of multi hoping very well. As the group crowd reduces, node degree affecting the routing. The parameters maintained constant for the plot are speed deviation 0.1, angle deviation 0.2 and the number of group as one.

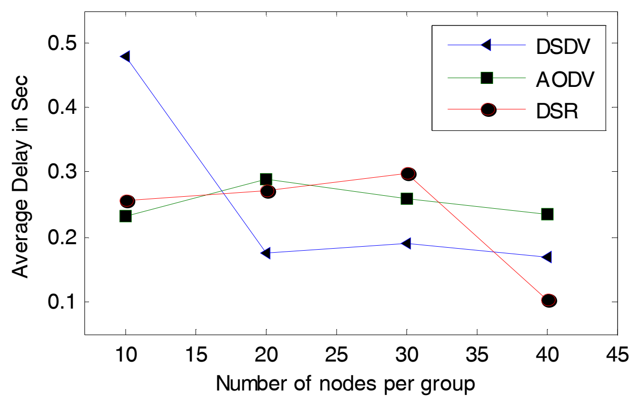


Fig. 5. Delay variation against the number of nodes in RPGM model

Normalized routing load against the speed variation is shown in Fig 6. Routing overhead is less in DSR in comparison with AODV. Since the DSDV offers relatively very high routing loads (30 times more than that of AODV), it is not taken it for consideration. The very high overhead in DSDV is because of flooding of routing packets across the nodes periodically. But in all the cases mobility increases the routing load over head.

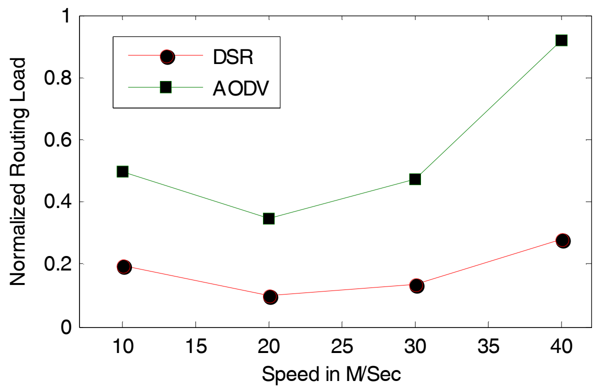


Fig. 6. Normalized routing load against Speed variations for freeway model

Routing load variations with respect to the mobile node size can be another point of interest. As shown in Fig. 7, routing load shoots in DSDV as the node number increases. In DSR offers good performance, than that of AODV. But as the node number increases AODV out performs DSR. Even though all of them make use of multi-hoping, fact that in DSDV doesn't get performance like DSR may be of extra overhead of messaging overrides multi-hoping.

In all cases, DSR demonstrates significantly lower routing load than AODV and DSDV with the factor increasing with growing node number.

The various studies on routing protocol for various mobility models concluded to the following

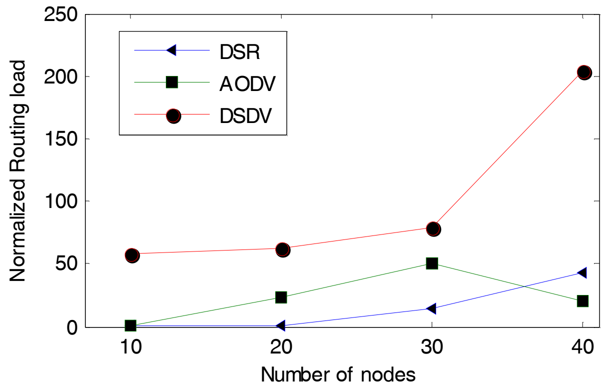


Fig. 7. Normalized routing load against number of mobile nodes for freeway model

a. End-to-End Delay Comparison: DSDV and DSR offers similar fractions for Freeway and Manhattan mobility models, whereas in RPGM, DSR offers a flat performance irrespective of throughput variations at the base station.
b. Average Delay with respect to no. of nodes: In Freeway DSR out performs AODV and DSDV. But all three routing protocols show the trend that delay increases with the factor of increasing node size. In RPGM AODV and DSDV out perform DSR at large node size.
c. Normalized Routing Load in view of speed: Change in speed of mobile node, DSDV is performing worst, beyond the scope, offering very high routing overhead compared to the other two
d. Routing load in view of node size: Once again DSDV performs worst. AODV out performs DSR at higher node size.

## VI. Conclusion

In this paper, we analyzed the impact of mobility pattern on routing performance of mobile sensor network in a systematic manner using simulated environment. In our study, we observe that the mobility pattern does influence the performance of routing protocols. This conclusion is consistent with the similar studies going on in this area. This study that compared different routing protocols, there is no clear winner among the protocols in our case, and since different mobility patterns seem to give different performance rankings of the protocols. Use of test-suite of mobility models incorporated from IMPORTANT helps a lot to simulate the scenarios. We, continuing the work on this area to get the optimized version of ad-hoc routing protocols well suited for mobile WSNs.


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