Routing Protocol using Group and Random Based Mobility Models in Wireless Sensor Networks

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Abstract—**Wireless Sensor Network is Multihop Self configuring Wireless Network consisting of sensor nodes. The patterns of movement of nodes can be classified into different mobility models and each is characterized by their own distinctive features. The significance of this study is that there has been a very limited investigation of the effect of mobility models on routing protocol performance such as Packet Delivery Ratio, Throughput and Latency in Wireless Sensor Network. In this paper, we have considered the influence of pursue group and random based entity mobility models on the performance of Ad Hoc On-Demand Distance Vector Routing Protocol (AODV) routing protocol. The simulation results show that Pursue Group Mobility model is better than Random Based Entity model.**

Index Terms—**AODV, Mobility Models, Latency, Packet Delivery Ratio, Throughput, Wireless Sensor Network.**

I. INTRODUCTION

A Wireless Sensor Network (WSN) is multihop self configuring, dynamic routing, and distributed autonomous wireless network. It is used for gathering information, performing data-intensive tasks such as habitat monitoring, seismic monitoring, terrain, surveillance etc. It consist of many small, light weight sensor nodes (SNs) called *motes,* deployed on the fly in large numbers to monitor the environment or a system by the measurement of physical parameters such as temperature, pressure or relative humidity. The important characteristics of a WSN are: (i) Mobility of nodes (ii) Node failures (iii) Scalability (iv) Dynamic network topology (v) Communication failures (vi) Heterogeneity of nodes (vii) Large scale of deployment and Unattended operation.

Mobility of sensor nodes specifies the dynamic characteristics of node movement and is one of the characteristic of wireless sensor network. Its potential use found in variety of applications ranging from vehicular networks and military missions to reconnaissance. The relative movement between nodes creates or breaks wireless connections and changing the network topology. This affects the performance of the network and plays a vital role in the evaluation of sensor networking protocol. The patterns of movement of nodes can be classified

into different mobility models and each is characterized by their own distinctive features. The traditional mobility models include (i) Random Walk Model (ii) Random Waypoint Model (iii) Random Direction Model which attempt to mimic the movements of mobile objects. Such models are simple to implement and analyze. On the other hand, in all these randomized models, nodes choose their velocity and direction independently, with no restrictions. Hence, these models do not capture correlation between node movements. Recent work on mobility models attempts to identify common mobility movements. For example, group mobility may exist in battle fields, disaster relief, or crowd migration. In the case of group mobility, little information is available on how real group mobility patterns look like and sometimes patterns are caused by physical process. The drawbacks of mobility are: it relies on homogeneous velocity and acceleration bounds, which is not at all realistic. The implications for wireless networks are rather weak, for that, the performance of the network depends very much on the density of the nodes in the underlying mobility pattern.

Motivation: The hosts in a Wireless Sensor Network move according to various patterns. Realistic models for the motion patterns are needed in simulation in order to evaluate system and protocol performance. Most of the earlier research on mobility patterns was based on cellular networks. Mobility patterns have been used to derive traffic and mobility prediction models in the study of various problems in cellular systems, such as hand-off, location management, paging, registration, calling time, traffic load. While in cellular networks, mobility models are mainly focused on individual movements since communications are point-to-point rather than among groups.

Contribution: The main objective of this paper is to design an experimental method for explaining the most significant impacts of random based entity and group mobility model in WSN that use reactive AODV routing protocol. This work evaluates existing entity mobility model namely Random Walk, Random Waypoint, Random Direction and Pursue group mobility models. Existing reactive AODV routing protocol is used to verify the result.

Organization: The rest of the paper is organized as follows. Section II presents the Related Work. An overview of AODV Routing Protocol, Communication Model and Mobility Model

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is presented in Section III. Algorithm and Performance Evaluation is discussed in Section IV. In Section V, we present Conclusions.

II. RELATED WORK

A brief survey of performance metrics, mobility metrics and routing in WSNs is presented in this section. Ian et al., [1] present a comprehensive survey of design issues and techniques for sensor networks describing the physical constraints on sensor nodes and the protocols proposed in all layers of network stack. Tilak et al., [2] developed the taxonomy of different architectural attributes of sensor networks. This work gives a high-level description of typical sensor network architecture along with components. Sensor network are classified by considering several architectural factors such as network dynamics and the data delivery model.

Sohrabi et al., [3] have proposed Sequential Assignment Routing algorithm which performs organization and mobility management in sensor networks. An enhanced version to identify the nodes using Global Positioning System is proposed in order to locate the position of nodes. He et al., [4] described the QoS routing protocol for sensor networks that provides soft-real time end-to-end guarantee. The protocol requires each node to maintain information about its neighbors and uses geographic forwarding to find paths. Ali et al., [5] proposed a Mobility adaptive, collision-free Medium Access Control for sensor networks. It assumes that the sensor nodes are aware of their location. This location information is used to predict the mobility pattern of the nodes.

Royer et al., [6] proposed Random direction model to address the non-uniform node distribution problem in the random waypoint model. This model suffers from the same vanishing average speed problem, the reason behind speed decay also applies random direction model and it is observed that the average nodes speed under this model decayed in much the same way as in the Random Waypoint model. Guolong Lin et al., [7] analyzed the steady state distribution function of the random way point model. In addition to confirming the drawbacks of the random waypoint model and theoretical solution for the speed decay problem was determined and provides a general framework for analyzing other mobility models.

Bai et al., [8] used the metrics of relative motion and average degree of spatial dependence to characterize the different mobility models used in their study. They also proposed the connectivity graph metrics as a *bridge* relating the mobility metrics to the protocol performance. They found that average link duration at the graph level could explain this relationship. Broch et al., [9] evaluates that on-demand protocol such as Dynamic Source Routing and AODV perform better than table-driven ones such as Destination Sequenced Distance Vector (DSDV) routing protocol at high mobility rates, while DSDV perform quite well at low mobility rates. C. Perkins [10] evaluated Ad Hoc On-Demand Distance Vector Routing

Protocol is based on the metrics like packet delivery ratio and routing overhead.

III. BACKGROUND

A.. AODV

Ad Hoc On-Demand Distance Vector Routing Protocol is one of the most famous reactive routing protocols. In AODV, a source that intends to reach destination floods the whole network with a *route request* (RREQ) packet to search for all possible routes leading to the destination. Upon receiving the RREQ, each intermediate node creates a reverse routing entry for the source if it does not have a fresh one. The intermediate node also checks whether it has an existing entry for the destination. If it has, a *route reply* (RREP) packet is generated and unicast back to the source along the reverse route request route. Otherwise, it rebroadcasts the first received route request and suppresses the duplicated ones. When the destination receives the first route request or a route request coming from a shorter route, it sends a route reply back to the source. The nodes along the newly discovered routes create forward routing entries for the destination when receiving the RREPs. Source and destination sequence numbers are included in the control packets and routing entries to prevent loop problems. When a route entry is not used for a long time, it is deleted from the routing table to leave space to active entries. This protocol requires all nodes to reserve big enough memory spaces to store possible routing entries for active sources and destinations. As most routes are formed on demand, network latency is quite high.

B. Communication Model

The wireless protocol stack used by all sensor nodes and sink is explained in this section. This protocol stack combines power and routing awareness, integrates data with networking protocols, communicates power efficiently through the wireless medium and promotes cooperative efforts of sensor nodes. The protocol stack consists of the *application layer, transport layer, network layer, data link layer, physical layer, power management plane, mobility management plane,* and *task management plane*. Depending on the sensing tasks, different types of application software can be built and used on the application layer. The transport layer helps to maintain the flow of data if the sensor networks application requires it. The network layer takes care of routing the data supplied by the transport layer. Since the environment is noisy and sensor nodes can be mobile, the MAC protocol must be power aware and able to minimize collision with neighbors broadcast. The physical layer addresses the needs of a simple but robust modulation, transmission and receiving techniques. In addition, the power, mobility, and task management planes monitor the power, movement, and task distribution among the sensor nodes. These planes help the sensor nodes coordinate the sensing task and lower the overall power consumption.

The power management plane manages how a sensor node uses its power. For example, the sensor node may turn off its

receiver after receiving a message from one of its neighbors. This is to avoid getting duplicated messages. Also, when the power level of the sensor node is low, the sensor node broadcasts to its neighbors that it is low in power and cannot participate in routing messages. The remaining power is reserved for sensing. The mobility management plane detects and registers the movement of sensor nodes, so a route back to the user is always maintained, and sensor nodes can keep track of their neighbor sensor nodes. By knowing the neighboring sensor nodes, they can balance their power and task usage. The task management plane balances and schedules the sensing tasks given to a specific region. Not all sensor nodes in that region are required to perform the sensing task at the same time. As a result, some sensor nodes perform the task more than the others depending on their power level. These management planes are needed, so that sensor nodes can work together in a power efficient way, route data in a mobile sensor network, and share resources between sensor nodes.

C. Mobility Model

Mobility models play a key role during the simulation of Wireless Sensor Networks. We discuss (i) Random based Entity mobility model (ii) Group mobility model, and (iii) Movement model below:

(i) *Random based Mobility Models*: In random based mobility models, the mobile nodes move randomly and freely without restrictions. To be more specific, the destination, speed and direction are all chosen randomly and independently of other nodes. This kind of model has been used in many simulation studies. The different types are discussed below:

(a) *Random Walk Mobility Model:* In nature, many entities move in extremely unpredictable ways, the Random Walk model was developed to mimic this erratic movement. This model was originally proposed to emulate the unpredictable movement of particles in physics. The Random Walk mobility model is a widely used mobility model and it is sometimes referred to as the *Brownian Motion*. A mobility node (MN) moves from its current location to a new location by randomly choosing a direction and speed to travel. The new speed and direction are both chosen from pre-defined ranges [speedmin, speedmax] and [2, π] respectively. Each movement in the Random Walk mobility model occurs in either a constant time interval *t* or a constant distance traveled *d*, at the end of which a new direction and speed are calculated. If an MN moving according to this model reaches a boundary area, it bounces off the boundary border with an angle determined by the incoming direction. The MN then continues along this new path. The Random Walk mobility model is a memory-less mobility pattern because it does not retain knowledge concerning its past locations and speed values.

(b) *Random Way Point Mobility Model*: The Random Waypoint mobility model includes pause times between changes in direction and/or speed. An MN begins by staying in one location for a certain period of time (i.e., a pause time).

Once this time expires, the MN chooses a random destination in the simulation area and a speed that is uniformly distributed between [minspeed, maxspeed]. The MN then travels toward the newly chosen destination at the selected speed. Upon arrival, the MN pauses for a specified time period before starting the process again. The movement pattern of an MN using the Random Waypoint mobility model is similar to Random Walk mobility model if pause time is zero.

(c) *Random Direction Mobility Model*: This mobility model was created to overcome density waves in the average number of neighbors produced by the Random Way Point mobility model. A density wave is the clustering of nodes in one part of the simulation area. In this model, MNs choose a random direction to travel similar to the Random Walk mobility model. A MN then travels to the border of the simulation area in that direction. Once the simulation boundary is reached, the MN pauses for a specified time, and chooses another angular direction [0, 2π] and continues the process.

(ii) *Group Mobility Model*: Group mobility model represents multiple MNs whose actions are completely independent of each other. Sanchez et al., [11] proposes a set of mobility models in which mobile nodes travel in cooperative manner and exhibit strong spatial dependency between near by nodes. For example, a group of soldiers in a military scenario may be assigned the task of searching a particular plot of land in order to destroy land mines. In order to model such situations, a group mobility model is needed to simulate this kind of characteristic. The group mobility models include Column mobility model, Pursue mobility model and Nomadic mobility model. Here we consider Pursue mobility model for our simulation that is explained in next section.

(iii) *Movement Model*: This model defines a mobility metric referred to as *mobility*. The mobility metric which is geometric in the sense that the speed of a node in relation to other nodes is measured, while it is independent of any links formed between nodes in the network. The mobility metric describes the mobility of a scenario with a single value M which is a function of the relative motion of the nodes taking part in a scenario. If *l(n, t)* is the position of node *n* at time *t*, the relative velocity *v(x, y, t)* between nodes *x* and *y* at time *t* is

$$v(x, y, t) = \frac{d}{dt}(l(x, t) - l(y, t)) \qquad (1)$$

The mobility measure M_{xy}, between any pair *(x,y)* of nodes is defined as their absolute relative speed taken as an average over the time, *T*, the mobility is measured. The formula for obtaining M_{xy} is given below.

$$M_{xy} = \frac{1}{T} \int_{t_0 \le t \le t_0 + T} |v(x, y, t)| \, dt \qquad (2)$$

In order to arrive total mobility metric, *M*, for a scenario, the mobility measure in Equation 2 is averaged over all node pairs, resulting in the following definition

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$$M = \frac{1}{|x, y|} \sum_{x,y} M_{xy} = \frac{2}{n(n-1)} \sum_{x=1}^{l} \sum_{y=x+1}^{n} M_{xy} \qquad (3)$$

where $|x, y|$ is the number of distinct node pairs (x, y) and n is the number of nodes in the scenario. (Note that the second relation in Equation 3 assumes nodes being numbered from 1 to n). The mobility expresses the average relative speed between all nodes in the network. Consequently, the mobility for a group of nodes standing still, or moving in parallel at the same speed, is zero.

IV. ALGORITHM

Pursue mobility model and its algorithm is presented in this section. The pursue mobility model attempts to represent MNs tracking a particular target. For example, this model could represent the scenario where police officers attempt to catch an escaped criminal. The Pursue mobility model consists of an update equation for the new position of each mobile node: *new_position = old_position + acceleration (target_old position) + random_vector*. The current position of a MN, a random vector, and an acceleration function are combined to calculate the next position of the MN. Where *acceleration (target_ old_position)* is information on the movement of the MN being pursued and *random_vector* is a random offset for each MN. The random vector value is obtained via an entity mobility model. The amount of randomness for each MN is limited in order to maintain effective tracking of the MN being pursued. Fig. 1 illustrates the movements of mobility nodes using the pursue mobility model. The white nodes represent the node being pursued and the black nodes represent the pursuing nodes.

The main objective of this algorithm is target tracking, that is collection of nodes $P (x_i, y_i)$, trying to chase a single target node $T (t_x, t_y)$ as developed and is shown in Table I. Initially, register the location of the target node and individual pursuing node. If the distance between target node and pursuing node is more, then new position of the pursuing node $P (x_i, y_i)$ is updated by acceleration and direction of previous target node position and random offset value until it traces the target node.
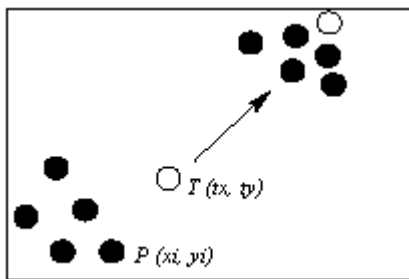

Fig. 1. Pursue Mobility Model

TABLE I
ALGORITHM FOR PURSUE MOBILITY MODEL

1) Take the location of target node $T (t_x, t_y)$.

2) Repeat for $i=1, 2...., n$ nodes.

3) Take location of pursuing _node $P (x_i, y_i)$.

4) Is distance $P (x_i, y_i) <$ distance $T (t_x, t_y)$.

5) Set new position of P (x_i, y_i) by updating current pursuing_node $P (x_i, y_i)$ by acceleration and direction of previous target position and random offset value.

6) Until $P (x_i, y_i)$ catches the target node $T (t_x, t_y)$.

A.. Performance Evaluation

This section describes the simulation and experimental results of impact of mobility models on the performance of Ad Hoc On-Demand Distance Vector routing protocol. We have selected packet delivery ratio, latency, throughput as metrics during the simulation in order to evaluate the performance of AODV routing protocol. *Packet Delivery* is the number of packets received by the destinations to those sent by the CBR sources. *Latency* is the delay between the time at which the data packet was originated at the source and the time it reaches the destination. *Throughput* is the total number of bits successfully delivered at the destination in a given period of time.

TABLE II
SUMMARY OF THE COMMUNICATION PARAMETER VALUES FOR SIMULATION SCENARIOS

Map Size	700m * 700m
Channel Bandwidth	11Mbps
Channel Delay	10μsec
Simulation Time	900s
No. of Enabled Nodes	5
Number of Hosts	25
Packet Rate	3packets/sec
Burst Length	64packets
Message Packet Size	512Byte
Input Buffer Size	1MB

B. Simulation Setup

We carry out the simulation in the customized event driven simulator, OMNET++ [12], which is an object modular network test-bed in C++. The mobility scenarios are obtained through mobility framework which is a part of OMNET++ distribution. The scenario generator produces the different mobility patterns such as Pursue group mobility model and Random Walk, Random Direction, Random Waypoint entity mobility models. In all these patterns 25 hosts with 5 enabled nodes deployed in a simulation area of 700m * 700m rectangular region for 900s simulation time. For our study, we

considered a scenario with three random based (i.e., Random Walk, Random Waypoint, Random Direction) entity mobility model, Pursue group mobility model and AODV routing protocol.

The scenario is chosen in such a way that, in each mobility model the average speed of the nodes remains the same with a pause time of 30 seconds. In all random scenarios, the mobility value is difficult to set exactly, so we have set an interval of 0.5 seconds for each node. From this scenario we compare the performance of AODV routing protocol using entity and group mobility models. The MAC layer protocol IEEE 802.11 is used in simulation with the data rate 11Mbps. The data traffic source to be a Constant Bit Rate (CBR) source. The sending rate is set to three packets per second, the network contains one source and one destination, each message packet size of 512 bytes is defined. The Table II provides all the simulation parameter values.

C. Results and Analysis

From the simulation results, we compare random based entity models and pursue group model which significantly influences the performance metrics such as Packet Delivery Ratio, Latency, and Throughput of AODV reactive routing protocol. The results obtained from the scenario are discussed below.

Fig. 2 illustrates the variation of Packet Delivery Ratio with Number of nodes. From this figure, we investigate that, the number of nodes, $n=1$, Random Walk, Random Waypoint, Random Direction and Pursue group mobility models exhibit similar behavior. All models show 10% improvement in data load as we increased number of nodes to two. At $n=3$, pursue mobility model achieves 6% improvement and 10% decline in Random Direction model because of loss in data load. At $n=4$, all models experience improvement in delivery of packets. At $n=5$, Pursue mobility model has consistent increase of 10% compared to random based entity mobility models. From this, we observed Pursue group mobility model has good packet delivery ratio compared to random based mobility model, while the random based entity mobility model has low packet delivery ratio as it incurs heavy traffic leads to network congestion resulting in more packet loss.

Fig. 3 describes the variation of Latency with the number of nodes. At $n=1$, time taken to generate packets for transmission is different for different mobility models with the least transmission time taken by pursue mobility model. The Random Walk and Random Waypoint mobility model experiences more time for transmission as compared to pursue group mobility model, due to traffic, route discovery at $n=2$. By increasing number of nodes n to three, we obtain better results by all the mobility models. Random waypoint model and pursue group model transmit packets without delay when the number of nodes equal to four. At $n=5$, in Pursue mobility model, packets reach the destination 30% faster than the Random Direction model, which experiences the least delay

among random based entity mobility models. Therefore, Pursue group mobility model performs better than random based mobility model.

Fig. 4 shows the variation of Throughput with the number of nodes. At $n=1$, all models shows different data throughput with highest data throughput by pursue group mobility model. When the number of nodes are three, all the models shows improvement in throughput, with the highest data throughput by Random Direction mobility model among random based mobility models and declines gradually in successive nodes. By increasing the number of nodes to four and five, pursue mobility model shows consistent increase in data throughput and judged as the better mobility model.

V. CONCLUSIONS

WSN is gaining importance in the real world because of its applications. In this paper, the simulation result demonstrates the evaluation of performance of AODV routing protocol with random based entity mobility model and pursue group mobility model. The performance metrics are Packet Delivery Ratio, Latency, and Throughput. We intend to show that the choice of mobility models makes the difference with respect to network performance. We have considered a scenario by keeping average node speed constant in all mobility models. The pursue group mobility model performs better than random based entity mobility models. Other mobility patterns such as Freeway, Manhattan, Column group mobility model, City Section models will be used to illustrate realistic situations, in the future works.
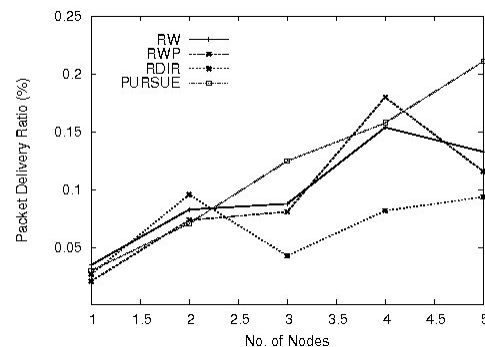

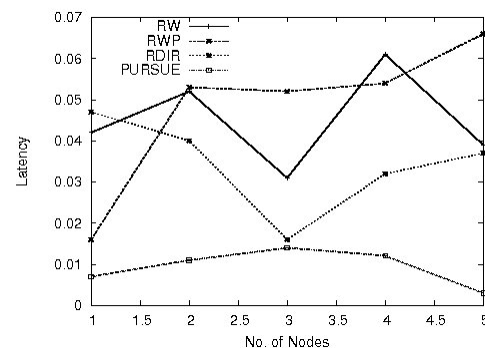Fig. 2. Packet Delivery Ratio and Number of Nodes (n)
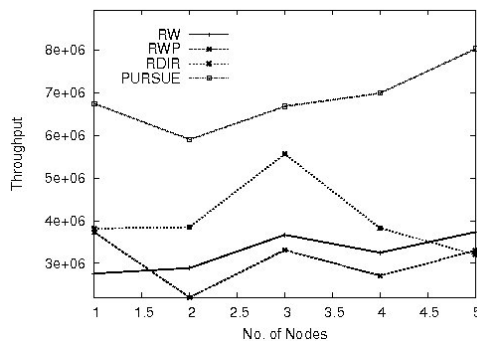

Fig. 3. Latency and Number of Nodes (n)

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Fig. 4. Throughput and Number of Nodes (n)

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