Chapter 5

Effects of Different Mobility Models on Target Tracking in Directional WSNs

5.1 Introduction

Tracking of a target in the FoI finds the utilities in various domains. For example, tracking a vehicle moving in the wrong direction or identify a high-speed vehicle, help to maintain the traffic rules. Mobility models of targets represent the movement pattern of moving targets in the FoI. It also signifies, how their location, velocity, direction, and acceleration change over time. Mobility models help to improve the quality of the service of the WSNs. For example, if the velocity of moving targets is very slow than the energy consumption of the network can be reduced by increasing the duration of the broadcasting of the network control messages. The mobility models also help to analysis the human movement patterns. It will also help in crowd monitoring and control in an area like world famous bank of Ganga river in India, on auspicious occasions like *Dev Deepawali*.

The movements of different targets have some similarity that could be used to represent the mobility pattern of the target. The literature in this field consider the following characteristics of movement of the targets: pause time, velocity, direction angle, return time, and velocity change Bocca et al. (2014). The exiting work classifies the mobility models into the following three categories: random walk mobility model, random waypoint mobility model, and random direction mobility model. In Lee et al. (2009), Kyunghan *et al.* proposed a new mobility model known as self-similar least action walk, which produces synthetic walk traces containing all the characteristics of the movement of the targets.

In Chapter 3 of this thesis, analysed the deployment of directional sensor nodes for the desired level of target tracking and connectivity of the WSNs. It estimates the number of sensor nodes, their tracking direction, and tracking angle for tracking the targets in the given FoI. In Chapter 4, we used this analysis and presented an energy efficient routing algorithm which reduces the power consumption for relying on the tracking information from the source sensor node to the destination. In both chapters, we used indoor and outdoor scenarios to illustrate the application of our work. The proposed routing algorithm considers the transmission energy, neighbour energy consumption, hop count, tracking time, tracking distance, and residual energy of the sensor nodes. In this chapter, we illustrate the effects of the different mobility models on proposed Target Tracking System (TTS) using directional WSNs. We consider random walk mobility model, random waypoint mobility model, and random direction mobility model.

The rest of the chapter is organised as follows. The next section illustrates characteristics of the target mobility models. In Section 5.3, we discuss the mobility models in WSNs. Section 5.4 shows the implementation of the routing algorithm on a network simulation and discuss the simulation results. Finally, we conclude the chapter in Section 5.5.

5.2 Characteristics of Mobility of Targets

This section will give a brief discussion of the characteristics of mobility of moving targets. We first consider time-related aspects such as pause time and return time. Next, we will discuss target trajectory related characteristics such as velocity, direction angle changes, arrive at the destination, and moving region inside the FoI. Finally, we consider some aspects about the FoI.

5.2.1 Pause Time

Pause time of a moving target is the total time duration when the target does not move inside the FoI. During the pause time, a target stays at a fixed location inside the FoI. In a directional WSNs, a target is tracked by a sensor node only it lies inside the tracking region of the sensor node. The pause time affects directly the quality of TTS. It is because, if a target is paused inside the tracking region of a sensor node, the sensor node continuously receives the tracker information and performs further processing on it. However, it is not a good scenario, when a target presents inside the FoI but it is not inside the tracking region of any sensor node. So, wrong or incomplete information about the target would result and hence tracking system reliability suffers.

5.2.2 Repeated Time

The moving targets such as human, tend returns to some particular location in a given time interval. The repeated time of a moving target tracked by a TTS is the time duration after which the moving target again tracked by the deployed target TTS. Similar to pause time, the repeated time indicates the temporal performance of the moving targets.

5.2.3 Velocity

The velocity of a moving target indicates how fast the target is moving from one location to the other location inside the FoI. The average velocity of the target is the ratio of the sum of the velocities to the number of times the moving target change the velocity. Similarly, low and high velocity indicate the minimum and maximum distance travel by a moving target in a given time period, respectively. During pause time, the velocity of the moving target is equal to zero. The velocity of a moving target helps to correlate the temporal performance of the target to the spatial performance. A moving target with high velocity moves longer distance in a particular time interval to that of target with low velocity in FoI.

5.2.4 Direction Angle Change

Changes in moving direction of the targets inside the FoI plays a vital role in tracking the targets. Such changes affect, the selection of the tracking device and source of the tracking information. It affects accuracy of the TTS. The direction angle change evaluates spatial performance of the mobility of targets. We continue the scenarios as discuss in previous two chapters, *i.e.*, laboratory, corridor, and road inside the institute.

5.2.5 Shape of the FoI

The shape of the FoI can be classified in various ways. For example, indoor and outdoor, with obstacles and without obstacle, and closed loop and cross region. Chapter 3 and Chapter 4 illustrated that the shape of the FoI plays an important role on the tracking quality of targets.

5.3 Mobility Models

In this work, we consider the following three mobility models: Random Walk Mobility Model, Random Waypoint Mobility Model, and Random Directional Mobility Model Lee et al. (2009). We use the same analysis for deployment of directional WSNs as proposed in Chapter 3. We also used the proposed energy efficient algorithm for finding an energy-efficient routing path from source node to destination node.

5.3.1 Random Walk Mobility Model

When a target moves from one location (*i.e.,* current location of the target) to other random location after selecting a random direction and speed in a **random walk model**. There is a predefined range of speed and direction from which we choose these quantities. The range of speed is denoted as $[speed_{min}, speed_{max}]$ whereas, the range of direction is $[0,\ 2\pi]$. Thus, from the given range we can easily calculate the average speed denoted by $speed_{avg}$ and it is lying in the range $speed_{min} \leq speed_{avg} \leq speed_{max}$. The movement in the random walk model occurs either for a constant distance or for a constant time interval. Both the direction and speed of the target movement may be different, or either of direction or speed may be different. The difference is due to randomness in the occurrence of the value of direction and speed. Let C_t and C_d are the constant time interval and constant distance travelled respectively.

5.3.2 Random Waypoint Mobility Model

Random waypoint mobility model has a characteristic of pause time, which is denoted by P_t. The pause time is defined as the event that signifies the change in direction and/or changes in the speed of the target. It indicates the time for which a target stays in the same location and after that, select a new random location in FoI. The speed at which the target further move is a uniform distribution in the range $[speed_{min},\ speed_{max}]$. Let us assume the average speed for a constant time C_t is $speed_{avg}$. Let T denotes the total time when a target step in FoI which is further divided in $T^{'}$ time slots. The value of $T^{'}$ can be calculated as:

$$T^{'} = \frac{T}{(C_t + P_t)}.$$

Figure 5.1 shows an example traveling pattern of a target using the random waypoint mobility model starting at a randomly chosen point or position (133, 180); the speed of the target in the figure is uniformly chosen between 0 and 10 m/s. We note that the movement pattern of the target using the random waypoint mobility model is similar to the random walk mobility model if pause time is zero and $[speed_{min}, speed_{max}]_{randomwalk}$ $=[speed_{min}, speed_{max}]_{randomwaypoint}$.

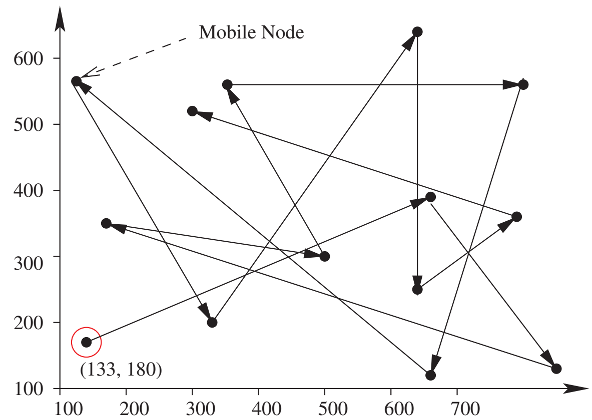


Figure 5.1 Illustration of random way point starting from coordinate (133,180).

5.3.3 Random Direction Mobility Model

In random mobility model, the moving target chooses any random direction for travelling towards the boundary until its edge is reached. The density waves produced by the random waypoint model are overcome by random direction mobility model. A small change in the random direction mobility model is called the modified random direction mobility model. In the modified random direction model the mobility targets continue to select the random directions but cannot compel to travel to the simulation boundary before ending to change direction. Rather a moving target chooses a random direction and chooses a goal anyplace along that direction for travelling.

5.4 Simulation Results

This section will present simulation results to illustrate the effects of mobility models on the TTS. We use Network Simulator 2.35 (NS 2.35) for simulating the results as given in Henderson et al. (2008) . Most of the simulation parameters are similar as shown in Chapter 4. In the proposed system, we also consider the three deployment scenarios as discussed in previous chapters. Here, all the experiment are considered $k = 1$ and $m = 1$, *i.e.*, 1-target tracking and 1-connectivity.

• **Network Model:** Wireless scenarios do not have direct support in the NS 2.35 simulator. Therefore we used the CMU wireless extension CMU (2014). We modified the radio propagation model (wirelessphy.cc file in NS2.35) for creating the application layer. As shown in Chapter 3, the sensor nodes in WSNs have various parameters such as tracking range, tracking direction, tracking angle, etc. Table 5.1 shows the various parameters created for the development of the networking model Bai et al. (2010); Kumar and Sivalingam (2012). In the simulation, it is quite easy to get the exact target location with zero error. However, it does not meet the requirement of practical target tracking. So, a uniform error was added to the tracking information, which is reported by the sensor node. The uniform error was depending on the tracking direction selected for the directional node for the computation of target location.

Table 5.1 Network Parameters.

Parameter	**Value**
Tracking Angle	30°, 45°, 60°
Tracking Range	$5m$, $7m$, $10m$
Communication Range	$10m$, $15m$
Uniform Error	1.0 for 60°, 0.75 for 45°, 0.05 for 30°
Speed$_{avg}$ (in m/sec)	$1.0, 2.0, \ldots, 6.0, 7.0$
Random Waypoint P_t	120 seconds
Random walk C_t	180 seconds
Random walk C_d	130 meters
Area of FoI $\|\Psi\|$ (in m^2)	$200^2, 220^2, \ldots, 300^2$

5.4.1 Impact of Pause Time on Energy Consumption of the Network

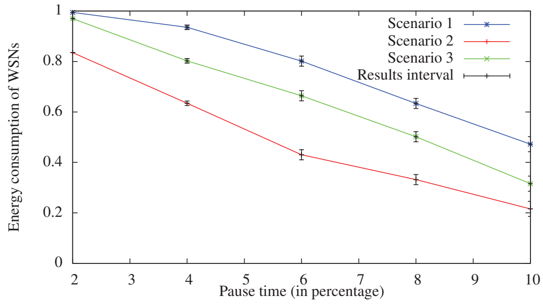
In this results, we study the impact of the pause time on energy consumption using random waypoint mobility model. We consider the three deployment scenarios as discuss in Section 5.2. The energy consumption at a given time instant of the WSN is the difference between the initial energy and the residual energy of the all deployed devices at the given time instant. Let n targets are moving inside the FoI. Let t_i^s and t_i^m are the total time duration of a target is not moving and moving inside the FoI, respectively. The pause time ratio is define as the ratio of the time duration when mobile targets are static and total stay time duration of targets inside the FoI. The pause time ratio of a moving target i is given by

$$\sum_{i=1}^{n} \frac{t_i^s}{(t_i^m + t_i^s)}.$$

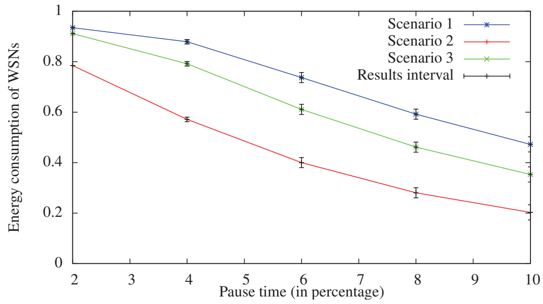
In this simulation experiment, we consider five moving targets and the duration of the experiment is 10 minutes. Therefore $n = 5$ and $t_i^m + t_i^s = 10$, where $1 \leq i \leq n$. Fig. 5.2 shows the total energy consumption for different pause time. It is true that when we increase the percentage of the pause time, the path-finding requirement is reduced and therefore total residual energy of the devices goes down. Fig. 5.2 illustrates that the Scenario 1 consumes minimum energy in all the experiments. It is because, the velocity of the targets inside the Scenario 1 is very low and therefore the routing path does not change very frequently and hence its updates are also slow which will conserve the network lifetime. Such low route discovery in Scenario 1 reduces the control packet overhead and reduces the energy consumption.

5.4.2 Impact of Velocity on Accuracy of Target Tracking System

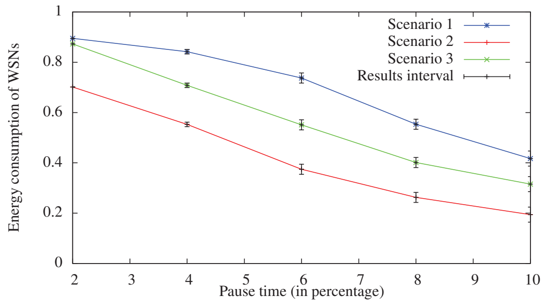
In the next set of experiments, the tracking velocity of the mobile targets is increased from 1 meter/sec to 3 meters/sec to observe the effect of the radius on the proposed work for target tracking. By increasing the tracking velocity, tracking of a moving target per



Part (a) Triangle deployment pattern.



Part (b) Square deployment pattern.



Part (c) Hexagon deployment pattern.

Figure 5.2 Relationship between the pause time (in percentage) and ratio of energy consumption (residual energy/initial energy).

directional sensor node is reduced. Random walk and waypoint mobility models with time interval 20 minutes, 30 minutes, and 40 minutes with 45° tracking angle in the directional sensor node was considered to observe the effect of velocity on target tracking error. Table 5.2 shows that the high velocity of moving targets increases the frequent changes of the tracking sensor node and therefore increases the error.

Table 5.2 Impact of tracking range on average tracking error (in meter).

	Random walk			**Random waypoint**		
	Velocity (m/s)			**Velocity (m/s)**		
	1	**2**	**3**	**1**	**2**	**3**
20m	0.38	0.38	0.40	0.40	0.42	0.44
30m	0.44	0.47	0.49	0.46	0.50	0.52
40m	0.51	0.53	0.55	0.53	0.56	0.58

(a) Triangle pattern.

	Random walk			**Random waypoint**		
	Velocity (m/s)			**Velocity (m/s)**		
	1	**2**	**3**	**1**	**2**	**3**
20m	0.42	0.43	0.45	0.44	0.46	0.48
30m	0.49	0.52	0.54	0.51	0.55	0.58
40m	0.56	0.58	0.61	0.59	0.62	0.64

(b) Square pattern.

	Random walk			**Random waypoint**		
	Velocity (m/s)			**Velocity (m/s)**		
	1	**2**	**3**	**1**	**2**	**3**
20m	0.46	0.47	0.49	0.49	0.51	0.53
30m	0.54	0.57	0.60	0.57	0.61	0.63
40m	0.62	0.64	0.67	0.65	0.68	0.70

(c) Hexagon pattern.

5.4.3 Impact of Direction Angle Change on Accuracy of Target Tracking System

Finally, we illustrate the impact of the changes of direction angle on the accuracy of target tracking system. We consider random walk and random direction mobility model. We consider the three deployment scenarios as discuss in Section 5.2.

Let n targets are moving inside the FoI. Let a moving target i change the m_i times moving direction and t_i duration spends inside the FoI. The direction angle change ratio is the ratio the number of times changes in the direction and total duration spends inside the FoI by a target. The direction change ratio is given by $\sum_{i=1}^{n} \frac{m_i}{t_i}$.

Table 5.3 Impact of direction angle change on average tracking error (missing the targets).

	Random walk			**Random direction mobility**		
	Direction change ratio			**Direction change ratio**		
	0.05	**0.10**	**0.15**	**0.05**	**0.10**	**0.15**
$20m$	0.342	0.3496	0.36	0.36	0.378	0.4048
$30m$	0.396	0.4324	0.36	0.414	0.45	0.4784
$40m$	0.459	0.4876	0.36	0.477	0.504	0.5336

(a) Triangle pattern.

	Random walk			**Random direction mobility**		
	Direction change ratio			**Direction change ratio**		
	0.05	**0.10**	**0.15**	**0.05**	**0.10**	**0.15**
$20m$	0.378	0.3956	0.36	0.396	0.414	0.4416
$30m$	0.441	0.4784	0.36	0.459	0.495	0.5336
$40m$	0.504	0.5336	0.36	0.531	0.558	0.5888

(b) Square pattern.

	Random walk			**Random direction mobility**		
	Direction change ratio			**Direction change ratio**		
	0.05	**0.10**	**0.15**	**0.05**	**0.10**	**0.15**
$20m$	0.414	0.4324	0.36	0.441	0.459	0.4876
$30m$	0.486	0.5244	0.36	0.513	0.549	0.5796
$40m$	0.558	0.5888	0.36	0.585	0.612	0.644

(c) Hexagon pattern.

In this simulation experiment, we consider five moving targets. Table 5.3 shows that the more time direction changes increase the frequent changes of tracking sensor node and therefore increases the error.

5.5 Conclusion

In this chapter, we illustrate the effects of different mobility models on TTS in directional WSNs. The mobility model of the target signifies, how their location, velocity, direction, and acceleration changes over time. We have first considered the time-related aspects such as pause time and return time. Next, we have discussed target trajectory related characteristics such as velocity, the directional angle change, arrival at the destination and moving region inside the FoI. In this chapter, we also consider some aspects of the FoI *i.e.,* shape or boundary of the FoI. Through simulation analysis, we try to find out the impact of pause time on energy consumption of the network, the impact of velocity on the accuracy of the target tracking system, and impact of direction angle change on the accuracy of target tracking system.