MOBILE TARGET TRACKING USING PREDICTION SCHEME IN WIRELESS SENSOR NETWORKS

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Abstract

In this paper, discussing a target tracking scheme based on prediction method using Mobile Tracker in Wireless Sensor Networks (WSN). Localization is playing a huge role in the field of application of WSN. If the exact location is not known, the interaction seems to be useless, if to whom the interaction should be done or from whom fetching the data or information are not known. So mobile target localization and tracking are needed research issues in WSN. The interaction between sensor nodes are considered in order to fetch the location information of the nodes. Tracking in WSN has wide variety of applications in surveillance of battlefield reconnaissance, intruder detection, habitat monitoring and investigations etc. It is important to save energy during tracking, as the sensor nodes are resource constrained. So proposing a mobile target tracking scheme based on prediction of faces called the PF-Tracking which aims to provide higher quality in tracking with higher energy efficiency. PF-Tracking has mobile node called Tracker which is a sink node responsible for tracking the mobile target. The algorithms are proposed to find like the location of target, face detection, face prediction and the exchange of information between the Tracker and the monitor.

Keywords: *Wireless Sensor Networks, Localization, Surveillance, Energy Efficiency, Quality of Tracking.*

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1. INTRODUCTION

Wireless sensor network (WSN) consist of collections of small, low-power nodes called sensor nodes. These sensor nodes are capable of performing some processing, collecting sensed information from its surrounding environment, communicating with other connected nodes in the network. Wireless sensor networks are used in various safety-critical applications such as critical infrastructure protection and surveillance, health monitoring, monitoring and control of environmental parameters etc. Sensor nodes send data to other nodes through wireless links in the network. Tracking the targets have been gaining much importance in WSN because of the surveillance applications discussed in [1], [2], [3], [4], [8] etc. For example in battlefield reconnaissance, investigation scenario and road patrolling etc. As there is a need for fast tracking operation along with higher quality in tracking as well as more energy efficient there are some concerns need to be addressed.

Sensor nodes are responsible for sensing and storing the information. The information is sent to the sink node. In previous works [4], [5], [7], [9], [10], [11], [12], [13], includes higher frequency of interactions between the nodes while sending the tracked data to the sink, time delay is occurred because of congestion, etc. As the nodes are organized as some local regions, clusters, grids, cells, trees, etc. This division leads to higher energy consumption due to more interaction between the nodes.

The tracking highly requires localization accuracy, so need to compromise among the energy efficiency and the QoT. Practically it's tough to get the exact localization information. A WSN can use the metrics such as received signal strength indication (RSSI), time of arrival (TOA), time difference of arrival (TDOA), or their combinations in [14], [15], [16], [17], [18] to fetch the localization information. In dynamic environment QoT is affected and may lead to biased or unbiased errors.

All these drawbacks motivates to design a tracking scheme called PF-Tracking, in which prediction of face is made to assist the target tracking. The nodes which are located in an area near to target moving path are organized as "face" as shown in Fig -1. And are responsible for target's location detection. The nodes are enabled to compute, store and replay to other node's requests. Target tracking can be more effective by using a mobile node called Tracker, which is the sink node. The main objectives here is to build the tracking scheme with higher tracking quality and higher efficiency in energy.

In this proposed method, "Tracker", a sink node able to traverse through the WSN, is the entity intended to follow the "mobile target", a "target" is the moving object like a vehicle or any intruder node, it may move in any dynamic pattern in the deployed plane. The "faces" are constructed, which are non-overlapping using graph planarization.

The Tracker queries the WSN when it is starts tracking the mobile target. Here the nodes in WSN are synchronized between the three states such as active, awakening and inactive states in order better make use of energy. Once the Tracker starts tracking, it requests for the location of the mobile target to a nodes in face. The node which is very nearer to the target in the face will become the "monitor"node and it will take care of interacting between the target as well as Tracker. One of the immediate neighbour node of monitor is elected as "backup" in order to assist tracking in case of monitor node failure.

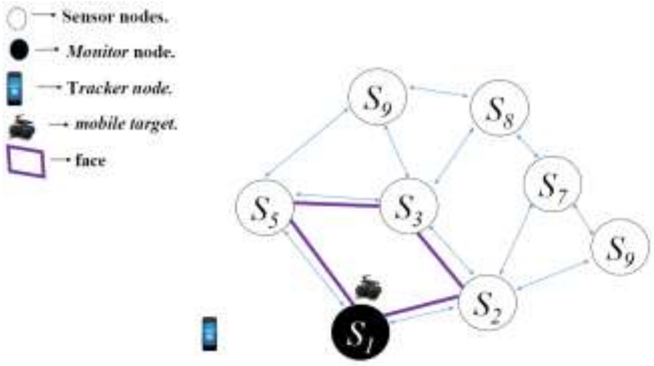


Fig -1: Illustration of PF-Tracking

If the target is still within the face, the monitor keeps tracking the target. When the target moves out of the current face, to detect the next face the prediction method is used. The current monitor selects the new monitor. As the target moves out of the face, the Tracker informed by the monitor about the new monitor selection. Then the Tracker moves towards the new monitor. Old monitor is made inactive to avoid unnecessary energy consumption.

Main objective is to implement the Target Tracking scheme with the following features.

- With high accuracy in localization.
- Fast tracking by considering face detection and prediction method.
- Reducing the active sensor nodes and their involvement in tracking
- Building high quality in tracking.
- Increasing energy efficiency of the WSN.

2. RELATED WORK

Many works are undertaken in the field of localization and target tracking in wireless sensor networks. As the sensor network is resource constrained, distributed tracking schemes are more suitable than centralized tracking techniques. In order to avoid energy depletion of WSN, in the tracking scenarios, at the requested time the sensor nodes nearer to the sensing range of the target are made active andother nodes are placed in inactive state until target moves towards them. The number of nodes need to be active during tracking depends on the moving target's speed. Network resources like energy, bandwidth, etc. should be balanced during tracking.

Distributed schemes overcomes the difficulties found in the centralized tracking schemes [4], [5], [7], [12], [13], [19]. Tracking methods are classified as Tree based, Cluster based, Prediction based etc. The division of network are is often done as cells, grids or some polygon etc. to track in distributed manner [7], [14], [19], [18].

In paper [14] the nodes aregroupedas grid structure, target may enter into any cell. The voting scheme is proposed to determine the position of target. The Kalman or Particle filters are used to estimate position of the target. The signal-emitting mobile targets by using navigated mobile sensors based on signal reception is discussed in [16]. The mobile sensor controller acquires the TOA measurement information from both the mobile target and the mobile sensor. A min-max approximation approach is designed to findthe target location and a weighted tracking algorithm is used. A new tracking framework is proposed in [12], called FaceTrack. Edge detection algorithm is used to generate each face. An optimal selection algorithm is designed to select the sensors to which the queries are need to be sent and to forward the tracking data.

Drawbacks of the existing Tracking schemes.

- Huge interactions during tracking operation.
- Delay is introduced during tracking process because of the multi-hop communication and congestion.
- High energy consumption of the network.
- Tracking needs higher quantity of active nodes.
- High update cost and query cost.
- Loss of tracking or node failure is often possible, since WSNs are prone to fault or failure.
- Sink has no mobility function, energy consumption is much.

3. PROPOSED TRACKING SCHEME

The key design of PF-Tracking is shown in Fig -2. The scheme includes the target detection using the detection probability, face detection by monitor selection, the area where the target remains, predicting the next face, to which the mobile target enters, location information exchange between the target and Tracker through the monitor node. Table 1 gives the notations used in the PF-Tracking.

3.1 Target Detection

Each node in WSN is capable of locally sensing, detecting and processing the target's data independently. If the target t is in the node's radio range then shares the information with the neighbors. Every node calculates the probability of detection P_d and the Euclidian distance between the node to the target $d(l^s_i, l_i)$. If t is in the node's R_s, P_d is "The node's probability which indicates the presence of t".

Fig -2: Key Design of PF-Tracking

P_d and $d(l^s_i, l_i)$ are calculated using the below equations.

$$P_d = D_c + \square\ r L / (2L + r/2).T_p$$

and

$$d(l^s_i, l_i) = \sqrt{(x_i - x_{i-1})^2 + (y_i - y_{i-1})^2}$$

Table -1: Notations Used

Symbol	Description
t	A mobile target
T	A mobile sink(Tracker)
S_i	Sensor nodes i=0,1,…n, where 'n' is the number of nodes
T_p	A common toggle period for waking up
H	A period of tracking
h	A discrete time of a period (h□ H)
s_0	Active state
s_1	Awakening state
s_2	Inactive state
R_s	Sensing range of a node
P_d	Detection probability
r	Radius of sensor node radio range

Algorithm 1. Target Detection
1. Every node S_i in WSN is in the s_1
2. Start listening and sensing the environment
3. if target detected
4. Node is made active
5. P_d is calculated
6. Run face detection algorithm

3.2 Target's Moving Face Detection

The target t's current face, in which the mobile target is present is detected in this phase using P_d and $d(l^s_i, l_i)$ and is shown in Fig -3.

Algorithm 2. Face Detection
1. At some instance of time, t is detected by the sensors S_i, e.g., S_1, using P_d. Similarly, it'sneighbors, e.g., S_5, S_6, S_7, S2, etc. having almost the same P_d may find t. As S_1 is having highest P_d, it is declared as monitor node.
2. To detect the face, S_1 sends request message, which contains P_d and $d(l^s_i, l_i)$ to its immediate neighbors in its radio range. Here the three adjacent neighbors of S_1 are: S_5, S_2, S_3.
3. If the request message is fetched by all the neighbors and node $S_i$compareits P_d with node S_j, $S_i$and S_j should be adjacent nodes.e.g., S_1-S_2, S_1-S_3, S_1-S_5.
4. From Fig - 3, S_5 or S_2 are the nodes with second highest probability of detection and are the adjacent to each other. S_3 is having the lower probability than S_5 or S_2. So t is present in the face F_2 rather than F_1 and F_{18}.

3.3 Face Prediction

Whenever target moves from F_i to F_j, it quits the R_s of the old monitor and it moves to the R_s of other node. Target may move in any direction inside the face as shown in Fig - 4(a). The direction probability (p) is calculated by monitor as illustrated in Fig - 4(b). The neighbors of monitor in the current face are able to predict t's movement from one face to other i.e. from F_2 to F_3 as in Fig - 4(c). So two nodes S_6 and S_7 be the new monitor and backup, they are the two common nodes for the two faces F_2 and F_3.

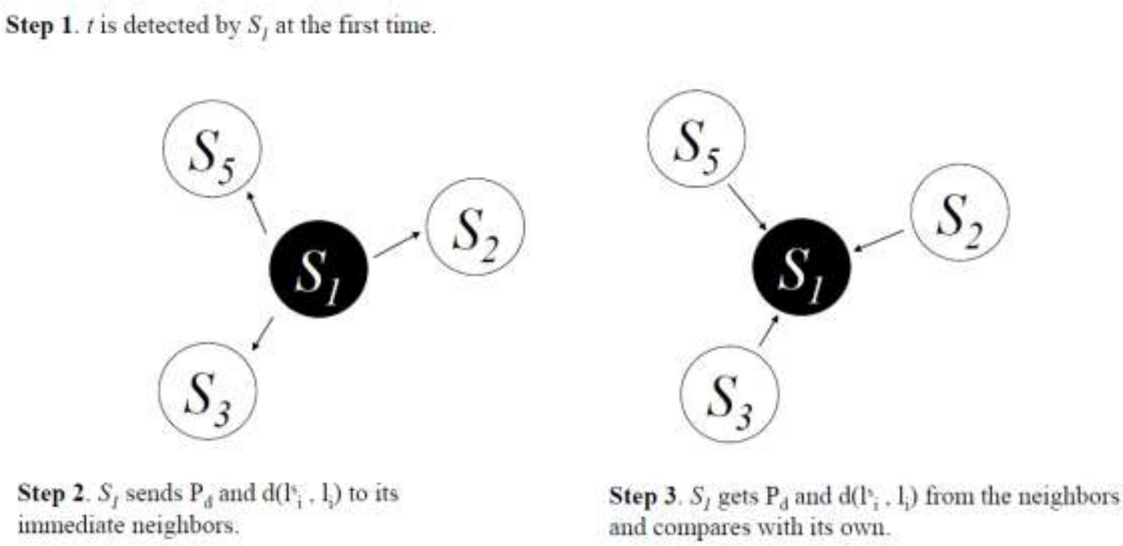
In order to compute the direction probability, the edge between the monitor and backup is considered. θ_p indicates the direction. $\theta_p \in (-\pi, \pi)$, $\theta_p = 0$, is the instant direction at the current time. $d(\theta_p)$ is the radii between the monitor and the neighboring nodes in the and $p(\theta_p)$ is the directional probability. At $d(\theta_p = \pi)$, p decreases linearly.

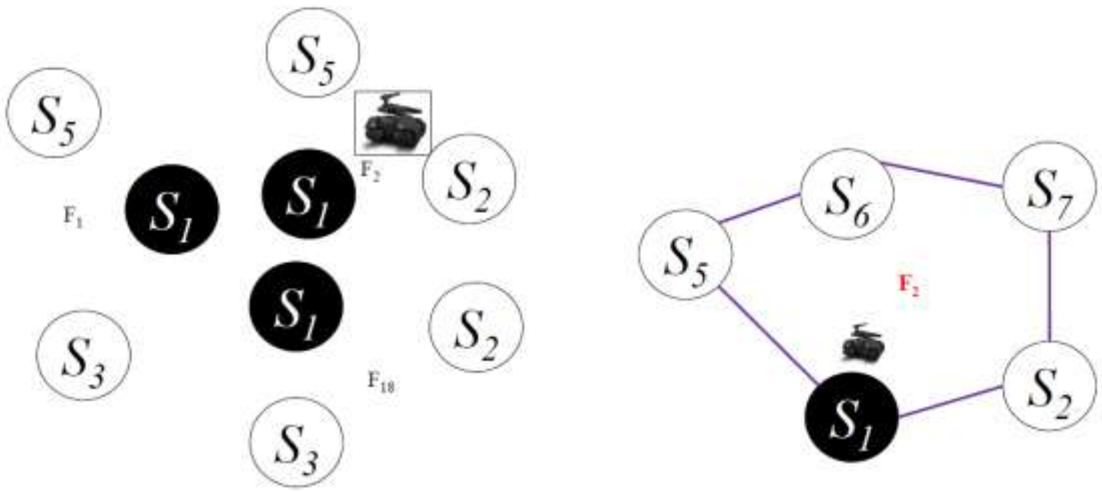
$$\alpha = x_{i+1}\,\theta_p + y_{i+1}$$

$$\alpha^* = -\,x_{i+1}\,\theta_p + y_{i+1}$$

The probability of direction is given by,

$$p = \alpha\,,\ \theta_p \in (-\pi, 0)$$
or
$$\alpha^*,\ \theta_p \in (0, \pi)$$





Step 4. *t* can be detected by anywhere and be closest to an immediate neighbour

Step 5. *t*'s moving face.

Fig -3: t's moving face detection for the first time.

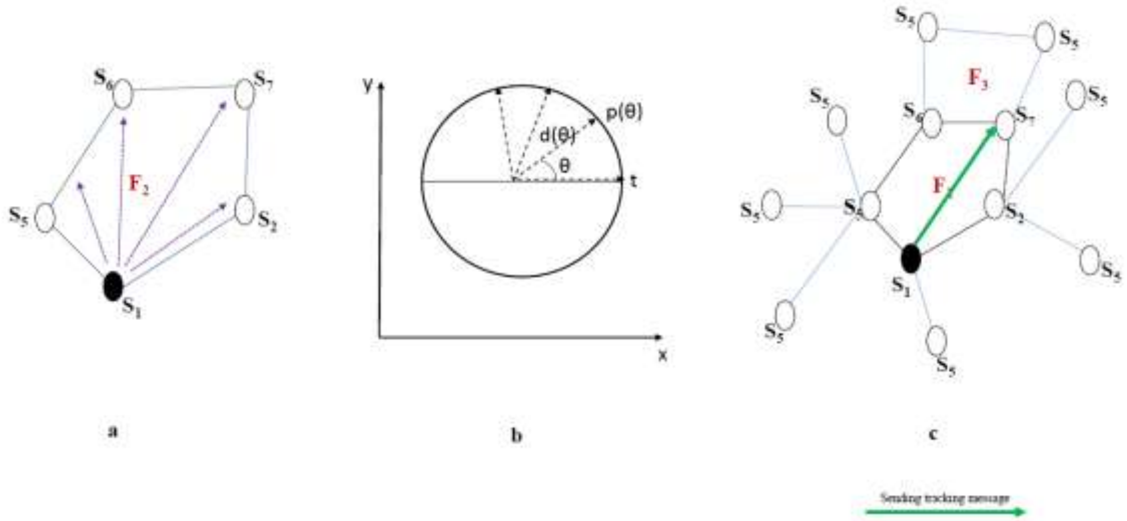


Fig -4. The monitor S_1 in the face F_2 indicating t's moving in the direction from F_2 toward F_3.

Algorithm 3. Face Prediction by the Monitor and Backup
1: θ_p is calculated by recording t's moving direction, α, α*and p are also computed.
2: An alert message is issued to distant neighbors of F_i in t's predicted path, Start the new face F_{i+1} and neighboring faces formation by the nodes, if the alert message is received by the requested node. Else the node stays in awakening state $S_{1.}$ The received node will become the new monitor.
3: if t is detected and reception of the final alert then, find t's location inside newly detected face byusing Algorithm 2. Elseinteract with the previous monitor and all of its neighbors for t's detection
4: if t is present in F_{i+1} then $F_j = F_{i+1}$. The new predicted face.

3.4 Information Exchange Phase

This phase includes 2 algorithms, in which algorithm 5 states how the Mobile Tracker requests the location information from the monitor and algorithm 6 gives how the monitor sends the response to the Tracker's request.

Algorithm 4. Tracker T's Query
1. MT: Queries are sent to monitor with sequence numbers 1, 2, . . k.
2. Monitor: Gets the query request q_k.
3. Detects loss by checking sequence number.
4. If any sequence number is missing then
5. NACK is sent to recover the query loss
6. For each further location measurement do:-
7. MT: Test the sequence number.
8. If the NACK is received,
9. Again send the previous query i.e. q_{k-1}.
10. Monitor: Checks the successfully received requests.
11. If the query received is not the last one,
12. Then, don't receive the next request until timeout,
13. MT resends the lost query until the ACK is received.
14. Else ACK is sent to MT by monitor.

Algorithm 5. Transferring Tracking Information
1. MT: Move to the node S_i's proximity and query for the location update about mt
2. Monitor: to send mt's location information, provided with h_{out} timer, Begin h_{out}
3. Data buffering is made, wait for an ACK is sent by MT,
4. If $d(l^s_i, l_i) < \epsilon$, then // mt is still within R_s
5. Message is sent to MT like mt is closer to it.
6. Else message is sent to the new predicted monitor i.e. mt's is travelling near to it
7. MT is informed about its movement towards new monitor,
8. And is put in awakening state s_1.
9. MT: if MT is at the vicinity of l^s_i and h_{out} is not over
10. Then monitor is informed that the mt is near to it,
11.Tracking process is stopped
12. Else if h_{out} is over or after getting response from monitor.
13. ACK is sent to monitor
14. Direct towards new monitor.
15. Monitor: if the MT is not got any ACK
16. Then retransmission is occurs and resetting of time is made till t_{out}
17. Else if the report is received correctly
18. Then put the monitor in inactive state s_2.
19. Else let it be in the active state s_1.

4. PERFORMANCE ANALYSIS

To analyze the performance of PF-Tracking the power consumption model is used. The energy consumption of PF-Tracking is shown in Table -2 at different values of distances. The total energy consumption by PF- Tracking is shown in Fig -6 graphically.

Table -2: Energy consumption in PF-Tracking.

PF-Tracking(10^2 mj)	Distance(m)
26.45	0
38.024	20
72.64	40
136.4	60
214.49	80
315.2	100

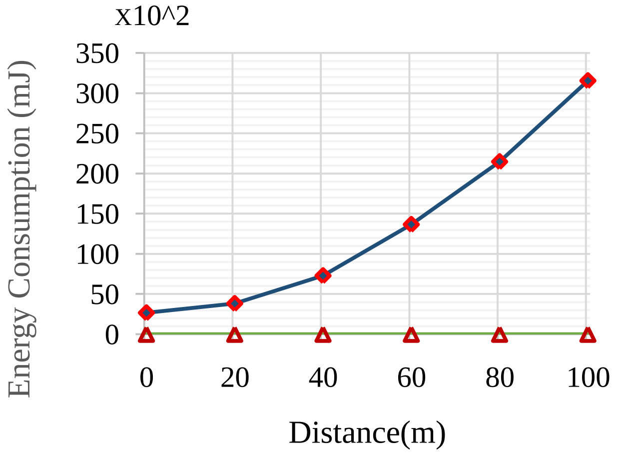


Fig - 6: Energy consumption versus distance

4.1 Snapshots

A wireless sensor network of 30 nodes is deployed as shown in Fig -7. After deploying sensor nodes and TRACKER, TARGET nodes are defined in Fig -8. In Fig -9 the TARGET starts emitting the signals, as the node 20 is nearer to the TARGET in the current face it is declared as MONITOR node based on the Euclidian distance calculation as shown in Fig -10.

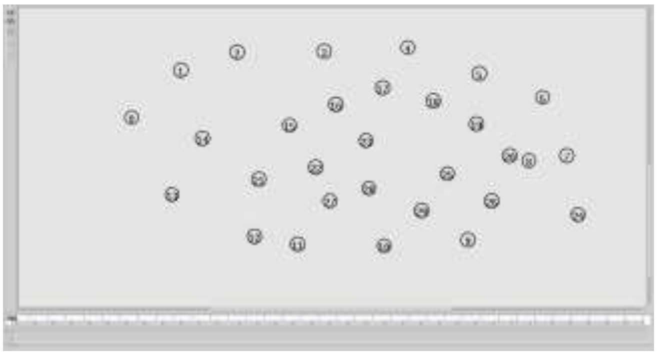


Fig - 7: Node deployment.

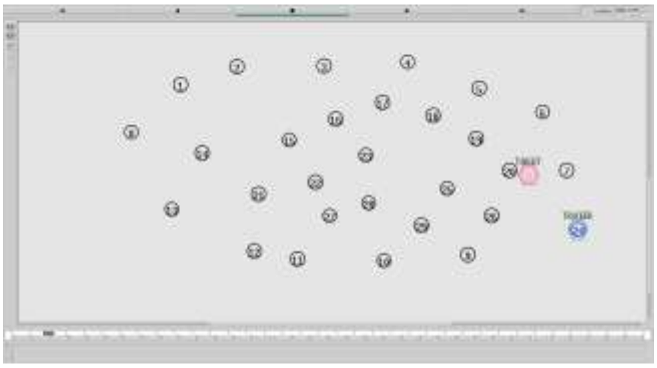


Fig - 8: Defining a TARGET and TRACKER nodes.

After the selection of MONITOR node the TRACKER sends the query to the MONITOR requesting the location of the TARGET as shown in Fig - 11.

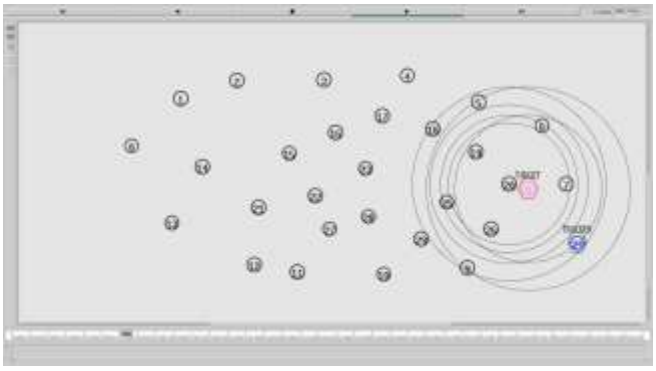


Fig -9: TARGET node starts emitting the signals

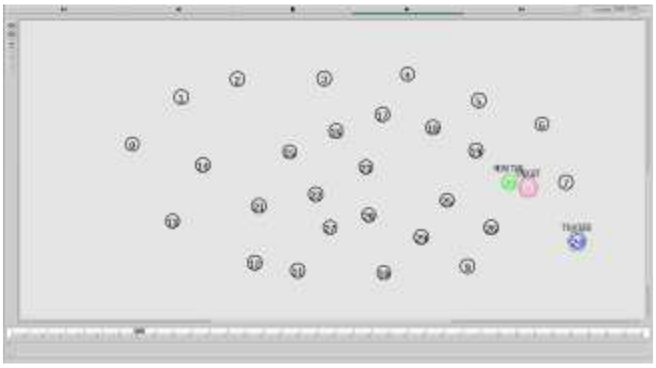


Fig - 10: MONITOR selection

MONITOR sends the response i.e. the location of the TARGET at that instance of time to the TRACKER request as shown in Fig -12. Then the TRACKER starts moving towards the MONITOR node and TARGET also moves randomly to some other face as shown in Fig - 13. To get the new location of the TARGET node by TRACKER node, again the new MONITOR is selected based on the detection probability, Euclidian distance and the old monitor is made inactive to save the energy, this is depicted in Fig - 14. This procedure continues by making the different monitor selection at the requested time until the TARGET node goes out of the sensing range of the nodes in deployed wireless sensor area. If once the target goes out of network's sensing range tracking is stopped.

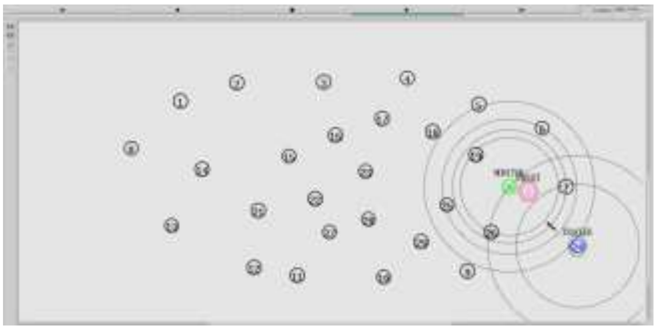


Fig - 11: TRACKER Sending location request to MONITOR

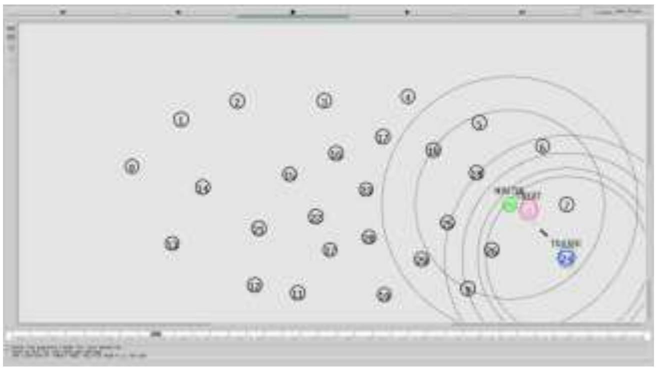


Fig - 12: MONITOR sending location of TARGET to TRACKER.

The location information of target at different requested time is displayed at terminal as shown in Fig -15 along with the random sequence numbers generated for each query request

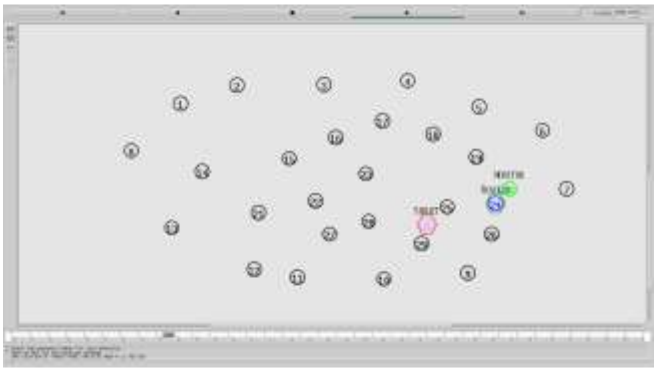


Fig - 13: Mobile TRACKER moving towards MONITOR node.

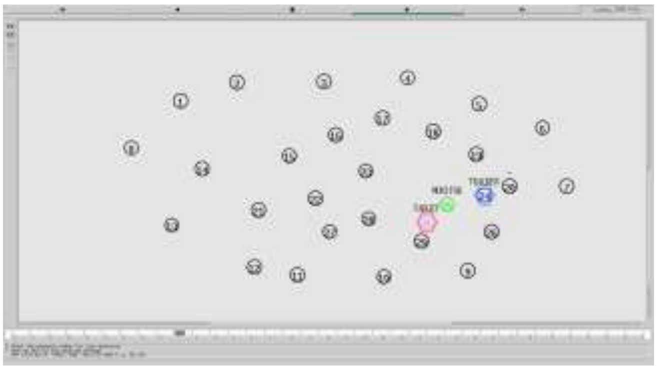


Fig - 14: New MONITOR selection.

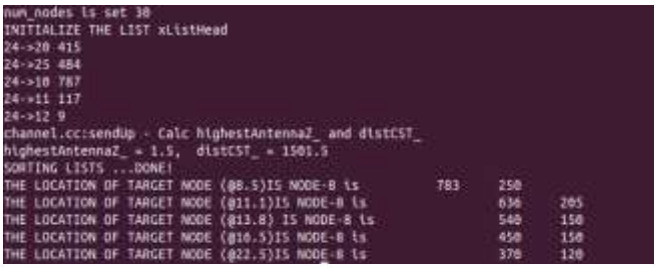


Fig -15: Terminal displaying the location of target at different instant of time.

5. CONCLUSION

There are plenty of tracking schemes in WSN. The paper explains how the target is detected by using monitor node, moving sequence is calculated using different patterns and the information exchange between the monitor and the Mobile Tracker. PF-Tracking leads to fast tracking because of face detection and prediction methods. The interaction between the nodes is reduced. The dependency on requiring high accuracy in localization is eliminated. The energy consumption is less compared to previous works and is also discussed in detail in the performance analysis. So this method is well suited for many surveillance applications.

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