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RESEARCH ARTICLE

TARGET TRACKING AND MOBILE SENSOR NAVIGATION IN WIRELESS SENSOR NETWORKS

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ABSTRACT:- Tracking moving targets is one of the important problems of wireless sensor networks. In recent years, mobility has become an important area of research for the WSN community. Although WSN deployments were never envisioned to be fully static, mobility was initially regarded as having several challenges that needed to be overcome, including connectivity, coverage, and energy consumption, among others. However, recent studies have been showing mobility in a more favorable light [1]. Target Tracking dictates how accurate a targets position can be measured. This problem becomes particularly challenging given the mobility of both sensors and targets, in which the trajectories of sensors and targets need to be captured. We derive the inherent relationship between the tracking resolution and a set of crucial system parameters including sensor density, sensing range, sensor and target mobility. We investigate the correlations and sensitivity from a set of system parameters and we derive the minimum number of mobile sensors that are required to maintain the resolution for target tracking in an MSN. The simulation results demonstrate that the tracking performance can be improved by an order of magnitude with the same number of sensors when compared with that of the static sensor environment.

INTRODUCTION:-

The development of sensor network technology has enabled the possibility of target detection and tracking in a large-scale environment. There has been an increased interest in the deployment of mobile sensors for target tracking, partly motivated by the demand of habitat monitoring and illegal hunting tracking for rare wild animals [1]. In this paper, we are primarily interested in target tracking by considering both moving targets and mobile sensors as shown in Figure 1. Specifically, we are interested in the spatial resolution for localizing a target's trajectory. The spatial resolution refers to how accurate a target's position can be measured by sensors, and defined as the worst-case deviation between the estimated and the actual paths in wireless sensor networks [2]. Our main objectives are to establish the theoretical framework for target tracking in mobile sensor networks, and quantitatively demonstrate how the mobility can be exploited to improve the tracking performance. Given an initial sensor deployment over a region and a sensor mobility pattern, targets are assumed to cross from one boundary of the region to another. We define the spatial resolution as the deviation between the estimated and the actual target traveling path, which can also be explained as the distance that a target is not covered by any mobile sensors.

Given the mobility of both targets and sensors mobility, it is particularly challenging to model such a stochastic problem for multiple moving objects. Furthermore, we are also interested in determining the minimum number of mobile sensors that needs to be deployed in order to provide the spatial resolution in mobile sensor networks. It turns out that our problem is very similar to the collision problem in classical kinetic theory of gas molecules in physics, which allows us to establish and derive the inherently dynamic relationship between moving targets and mobile sensors. The binary sensing model of tracking for wireless sensor networks has been studied in several prior works. The work in [3] showed that a network of binary sensors has geometric properties that can be used to develop a solution for tracking with binary sensors. Another work [4] also considered a binary sensing model. It employed piecewise linear path approximations computed using variants of a weighted centroid algorithm, and obtained good tracking performance if the trajectory is smooth enough. A follow-up work explored fundamental performance limits of tracking a target in a two-dimensional field of binary proximity sensors, and designed algorithms that attained those limits in [5]. Prior works in stationary wireless sensor networks have studied the fundamental limits of tracking performance in term of spatial resolution. Our focus in this paper is completely different from all prior works. There are two distinctive features of our work:

1) We try to identify and characterize the dynamic aspects of the target tracking that depend on both sensor and target mobility;

2) We consider tracking performance metrics: spatial resolution in a mobile sensor network. By leveraging the kinetic theory from physics, we model the dynamic problem, and examine its sensitivity under different network parameters and configurations. To the best of our knowledge, we believe this is a completely new study of target tracking in mobile sensor networks.

The rest of this paper is organized as follows. Section II describes the network and mobility model, as well as defining the target tracking problem in a mobile sensor network. Section III formulates the target tracking problem. Section IV examines the tracking performance sensitivity under different network parameters and configurations, and finally Section V concludes the paper.

Proposed System:

We are primarily interested in target tracking by considering both moving targets and mobile sensors as shown in Figure 1. Specifically, we are interested in the spatial resolution for localizing a target's trajectory. The spatial resolution refers to how accurate a target's position can be measured by sensors, and defined as the worst-case deviation between the estimated and the actual paths in wireless sensor networks [2]. Our main objectives are to establish the theoretical framework for target tracking in mobile sensor networks, and quantitatively demonstrate how the mobility can be exploited to improve the tracking performance. Given an initial sensor deployment over a region and a sensor mobility pattern, targets are assumed to cross from one boundary of the region to another. We define the spatial resolution as the deviation between the estimated and the actual target traveling path, which can also be explained as the distance that a target is not covered by any mobile sensors.

PROPOSED ALGORITHM

Tracking algorithm

The first step of tracking is to estimate positions of both target and mobile sensor. Since the measurement in the form of TOA information collected at the data fusion center is the same for both the target and the mobile sensor, we, therefore, focus our discussion on how to estimate the location vector $\mathbf{y}_j$ of the target at a given time instant T_j. We can modify the TOA model by rewriting into

$$t_{ji} - t_{j0} = \frac{1}{c}\|\mathbf{x}_i - \mathbf{y}_j\| + \frac{1}{c}\|\mathbf{x}_i - \mathbf{y}_j\| n_{ji} + \delta_j.$$

Squaring both sides, we get

$$(t_{ji} - t_{j0})^2 - \frac{1}{c^2}\|\mathbf{x}_i - \mathbf{y}_j\|^2 = \underbrace{\left(\frac{1}{c}\|\mathbf{x}_i - \mathbf{y}_j\| n_{ji} + \delta_j\right)\left(\frac{1}{c}\|\mathbf{x}_i - \mathbf{y}_j\|(2 + n_{ji}) + \delta_j\right)}_{\omega_{ji}},$$

For i=1……N

The right-hand side of is a noise term ω_{ji} that is independent for different indices i.If n_{ij} and δ_j are zero, then the right-hand side of would be zero. Therefore, one way to estimate the optimum $\mathbf{y}_j$ without assuming any particular characteristics on ω_{ji} is to minimize the ' ℓ_∞ norm of . This approach makes no assumption on the noise distribution or on the noise dependency. It simply tries to minimize the peak error. Therefore, its performance is expected to be less sensitive to the noise distribution or correlation. Thus, we propose to adopt the min-max criterion for location estimation via

$$\hat{\mathbf{y}}_j = \arg\min_{\mathbf{y}_j} \max_{i=1,\ldots,N} \left|(t_{ji} - t_{j0})^2 - \frac{1}{c^2}\|\mathbf{x}_i - \mathbf{y}_j\|^2\right|.$$

The min-max formulation is non-convex, but is quite amenable to semi definite relaxations as shown below. We first introduce two auxiliary variables $y_{js} = \mathbf{y}_j^T \mathbf{y}_j$,: $t_{js} = t_{j0} \cdot t_{j0}$, and define the following function.

$$\psi(t_{js}, t_{ji}, t_{j0}, y_{js}, \mathbf{x}_i, \mathbf{y}_j)$$
$$= t_{js} - 2t_{ji}^2 + t_{ji}^2 - \frac{1}{c^2}\left(y_{js} - 2\mathbf{x}_i^T\mathbf{y}_j + \mathbf{x}_i^T\mathbf{x}_i\right).$$

Then, can be rewritten as

$$\hat{\mathbf{y}}_j = \arg \min_{\mathbf{y},\, y_{js},\, t_{j0},\, t_{js}} \max_{i=1,\ldots,N} |\psi(t_{js}, t_{ji}, t_{j0}, y_{js}, \mathbf{x}_i, \mathbf{y}_j)|,$$

which is a convex function of $\mathbf{y}_j, y_{js}, t_{j0},$ AND t_{js}. However, the two equalities $y_{js} = \mathbf{y}_j^T\mathbf{y}_j$ and $t_{js} = t_{j0} \cdot t_{j0}$ are not affine. In order to make the whole formulation convex, we relax the two equalities $y_{js} = \mathbf{y}_j^T\mathbf{y}_j$ and $t_{js} = t_{j0} \cdot t_{j0}$ to inequalities $y_{js} = \mathbf{y}_j^T\mathbf{y}_j$ and $t_{js} \geq t_{j0} \cdot t_{j0},$, respectively. These inequalities can also be expressed in linear matrix inequalities, i.e.,

$$\begin{bmatrix} \mathbf{I} & \mathbf{y}_j \\ \mathbf{y}_j^T & y_s \end{bmatrix} \succeq 0, \quad \begin{bmatrix} 1 & t_{j0} \\ t_{j0} & t_{js} \end{bmatrix} \succeq 0.$$

In addition, based on the location estimate at time instant T_{j-1}, we can obtain an approximate location vector for the target at time instant T_j. Let $\Delta T_j = T_j - T_{j-1}$ and μ_{j-1} be the estimated velocity vector of the target at time instant T_{j-1}. Then the location change can be approximated as $\Delta\mathbf{y}_j = \mathbf{y}_j - \mathbf{y}_{j-1} \approx \Delta T_j \mu_{j-1}$. This can be used as additional constraints for the target location estimation at time instant T_j. Considering in 2D, the location change vector $\Delta\mathbf{y}_j$ is restricted to a box, then the corresponding $\mathbf{y}_j$ will also be constrained to a box, i.e.,

$$y_{jl} \leq y_{j1} \leq y_{jr}, \quad y_{jd} \leq y_{j2} \leq y_{ju}.$$

Define $\mathbf{a}_j = [y_{jl}\; y_{jd}]^T, \mathbf{b}_j = [y_{jr}\; y_{ju}]^T,$ and y $y_{js} = \mathbf{y}_j^T\mathbf{y}_j$. We can apply the Reformulation-Linearization-Technique (RLT) to in order to obtain some extra constraints.

In fact, based on RLT, (can be relaxed as

$$\mathbf{a}_j^T\mathbf{a}_j - \mathbf{a}_j^T\mathbf{y}_j - \mathbf{a}_j^T\mathbf{y}_j + y_{js} \geq 0,$$
$$\mathbf{b}_j^T\mathbf{b}_j - \mathbf{b}_j^T\mathbf{y}_j - \mathbf{b}_j^T\mathbf{y}_j + y_{js} \geq 0,$$
$$-\mathbf{a}_j^T\mathbf{b}_j + \mathbf{a}_j^T\mathbf{y}_j + \mathbf{b}_j^T\mathbf{y}_j - y_{js} \geq 0,$$

Which can be rewritten in the following matrix form

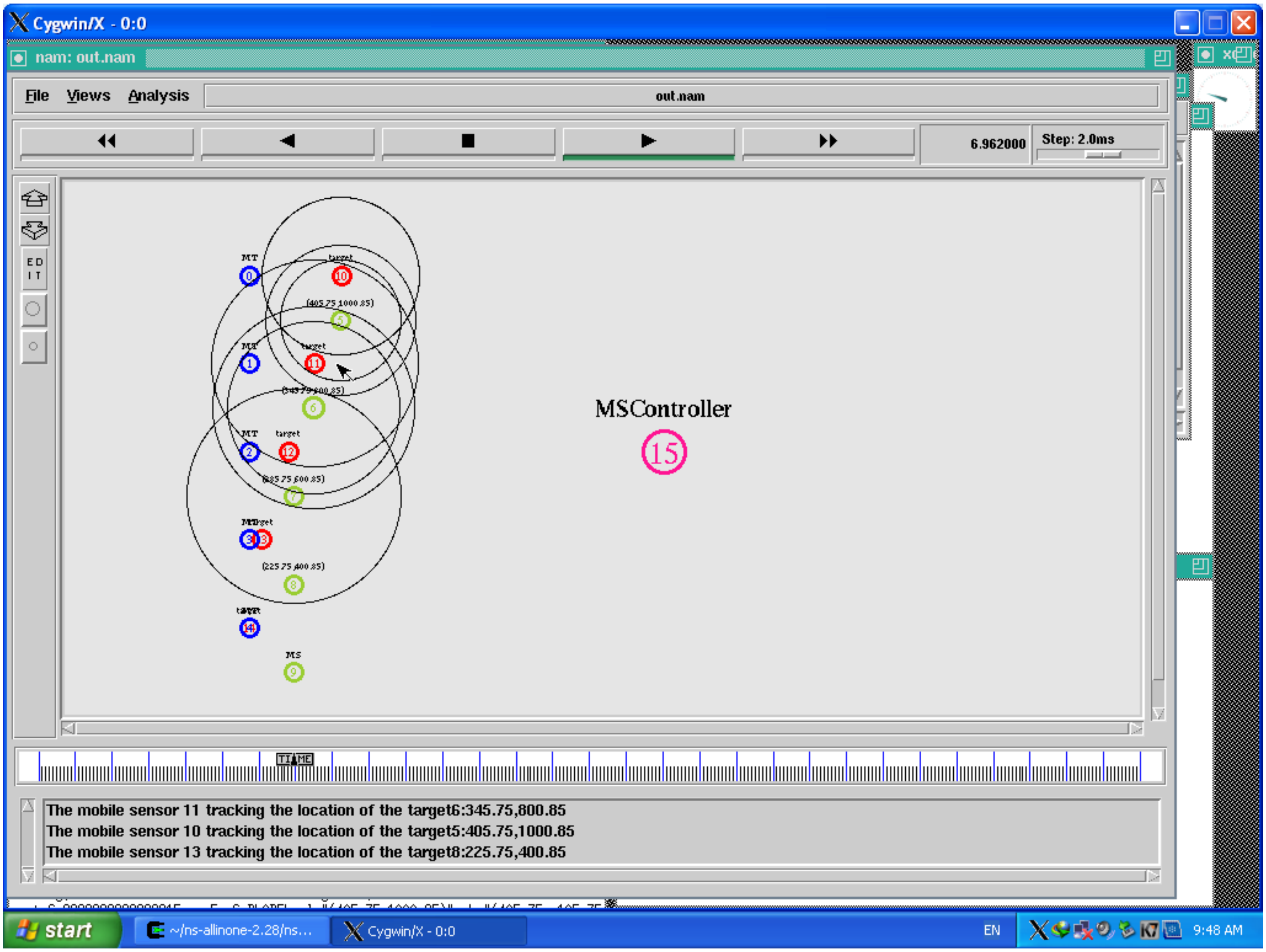
$$\begin{bmatrix} \|\mathbf{a}_j\|^2 & -2\mathbf{a}_j^T & 1 \\ \|\mathbf{b}_j\|^2 & -2\mathbf{b}_j^T & 1 \\ -\mathbf{a}_j^T\mathbf{b}_j & \mathbf{a}_j^T + \mathbf{b}_j^T & -1 \end{bmatrix} \begin{bmatrix} 1 \\ \mathbf{y}_j \\ y_{js} \end{bmatrix} \geq 0.$$

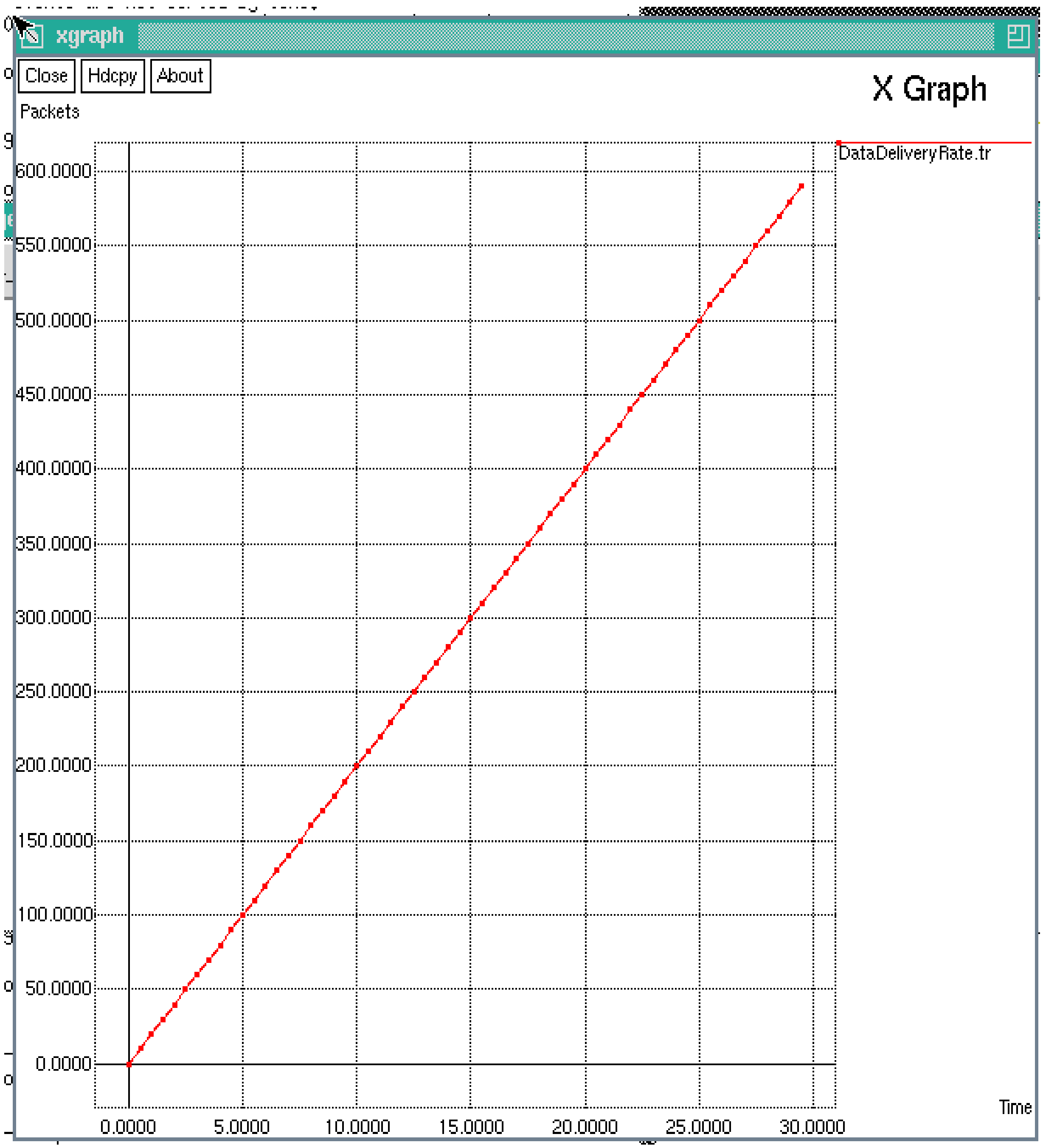
Here “>0”’ denotes that each element in the vector is nonnegative. Combining the above constraints, we obtain the following SDP optimization formulation:

$$\min_{\mathbf{y}_j, y_{js}, t_{j0}, t_{js}} \theta_j$$
$$\text{s.t. } -\theta_j < \psi(t_{js}, t_{ji}, t_{j0}, y_{js}, \mathbf{x}_i, \mathbf{y}_j) < \theta_j,$$
$$\begin{bmatrix} \mathbf{I} & \mathbf{y}_j \\ \mathbf{y}_j^T & y_{js} \end{bmatrix} \succeq 0, \quad \begin{bmatrix} 1 & t_{j0} \\ t_{j0} & t_{js} \end{bmatrix} \succeq 0,$$
$$\begin{bmatrix} \|\mathbf{a}_j\|^2 & -2\mathbf{a}_j^T & 1 \\ \|\mathbf{b}_j\|^2 & -2\mathbf{b}_j^T & 1 \\ -\mathbf{a}_j^T\mathbf{b}_j & \mathbf{a}_j^T + \mathbf{b}_j^T & -1 \end{bmatrix} \begin{bmatrix} 1 \\ \mathbf{y}_j \\ y_{js} \end{bmatrix} \geq 0.$$

The SDP problem of can be solved using some common tools such as SeDuMi.

Results


Cygwin/X - 0:0
nam: out.nam
File
Views
Analysis
out.nam
6.962000
Step: 2.0ms
MSController
15
The mobile sensor 11 tracking the location of the target6:345.75,800.85
The mobile sensor 10 tracking the location of the target5:405.75,1000.85
The mobile sensor 13 tracking the location of the target8:225.75,400.85
start
Cygwin/X - 0:0
EN
9:48 AM


xgraph
Close
Hdcpy
About
X Graph
Packets
DataDeliveryRate.tr
600.0000
550.0000
500.0000
450.0000
400.0000
350.0000
300.0000
250.0000
200.0000
150.0000
100.0000
50.0000
0.0000
0.0000
5.0000
10.0000
15.0000
20.0000
25.0000
30.0000
Time

CONCLUSION

In this paper, we have studied the target tracking problem in mobile sensor networks. Specifically, we introduce performance metrics: spatial resolution and we investigate the resolution against moving targets. By modeling the dynamic aspects of the target tracking that depend on both sensor and target mobility, we derive the inherent relationship between the spatial resolution and a set of crucial system parameters including sensor density, sensing range, sensor and target mobility. The results demonstrated that mobility can be exploited to obtain better spatial resolution. There are several avenues for further research on this problem: (1) to consider the detection error of mobile sensors under varying sensor speeds. This can be formulated into an optimization problem for target tracking; (2) to refine the sensor mobility model, the network model, and the communication model among sensors in order to enable effective detection and tracking. For example, a practical distributed target tracking and sensing information exchange protocol becomes an interesting future research topic when sensors are required to trace the target paths.

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