Target Tracking Algorithms in Wireless Multimedia Sensor Networks

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***Abstract*—In this paper, we propose two tracking algorithms: CTA and PTA. CTA for Collaborative Tracking Algorithm and PTA for Predictive Tracking Algorithm. The main objective of these tracking algorithms is to handle the tradeoff between the tracking accuracy and the energy consumption. By performing simulation, we evaluate the performance of CTA and PTA and compare the results to existing solutions: 1) BASIC solution where all the Camera Sensors are always active, 2) Optimal Camera Node Selection (OCNS) which is a cluster-based solution based on probabilistic node election.**

I. INTRODUCTION

The tremendous advances in wireless technologies have enabled the development of sensors with different sensing and communication capabilities. Wireless Multimedia Sensor Networks (WMSN) are a set of interconnected nodes, deployed in an area of interest to accomplish specific tasks as they can handle multimedia data such as video and audio stream and share them over the wireless links[1]. The emergence of WMSN opened application prospects like industrial surveillance, health care monitoring, etc.

In this work, we focus on target tracking, specially non-communicating targets: humans, animals, etc. Mobile target tracking is defined as a two stage application: detecting the presence of the target in the area and reporting its position along the trajectory. We distinguish three main classes of tracking techniques: cluster-based, structure-less and predictive-based. In cluster-based approach; a cluster of sensors, composed of a cluster head and cluster members, is selected at each step of the tracking process. The clusters can be formed statically at the network deployment stage or dynamically, based on predefined criteria such as position, residual energy, etc. In structure-less approach, no network architecture is defined. The tracking is performed in reactively manner at each stage of target evolution inside the area. In predictive-based class, models are utilized to proactively predict the upcoming mobile target displacement. We propose two tracking algorithms: CTA and PTA. CTA is a structure-less Collaborative Tracking Algorithm that uses Camera Sensor and Motion Sensor. PTA for Predictive Tracking Algorithm is based on Kalman filter to predict the target displacement.

II. SOLUTION OVERVIEW

A. CTA: Collaborative Tracking Algorithm

CTA [2] is a collaborative tracking algorithm. It runs on Heterogeneous WSN (HWSN) composed of two types of sensors, each of them handle a different task: Motion Sensors (MSs) are infrared detectors with circular detection field (FoD) in charge of mobile object detection while Camera Sensors (CSs) equipped with video cameras with sector view field (FoV) handle object localization (See Figure 1).

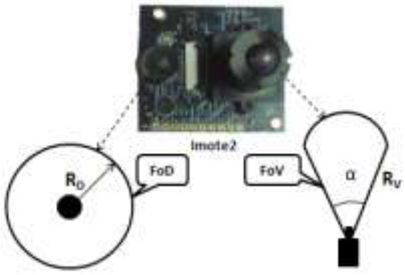

Figure 1: FoD and FoV

CTA starts when a MS detects the target. A target is detected by a MS when it is within its detection field. In this case, the MS broadcasts a DETECTION message to all nodes within its transmission range. DETECTION contains the MS coordinates. When a CS receives DETECTION message, it calculates the probability that the CS detects the target. If this probability exceeds a predefined threshold, this CS turns on its camera to perform localization. The CS sends the obtained results MS via LOCALIZATION message. When a MS receives a LOCALIZATION message from CS, it extracts the object coordinates and sends them to the sink. After receiving all object coordinates, the sink reconstitutes the whole target trajectory. The performance of CTA is closely related to the deployment strategy. For this purpose, we also propose a deployment solution for both types of sensors. We introduce the notion of critical sub-area: in real indoor environment, some areas are more important to cover than other (entrance/exit, corridor, etc.). Our proposed deployment technique begins with MS placement. We divide the AoI in cells grid and place the MSs at the center of each cell. Afterward, we place the CSs, with random orientation, at the corner of every critical sub-area. Finally, every CS calculates its most beneficial orientation using local information such as neighbors and critical sub-areas. The deployment strategy is proposed in order to enhance the video coverage of critical sub-areas and to improve the performances of CTA.

B. PTA: Predictive Tracking Algorithm

PTA is a predictive, collaborative and distributed algorithm. It uses Kalman filter [3] to predict the future displacement of the mobile target. This is an efficient state estimation process which uses current information to predict the future one. It has been successfully used in various applications such as geo-localization or weather forecast. It is usually described as follow:

System state equation: $X_{t+1} = A\,X_t + W_t \ldots$ (1)
Measurement equation: $Z_t = H\,X_t + V_t \ldots$ (2)

X_{t+1} is the mobility state vector at time t+1.We define a mobility state by: $X_{t+1} = [x_{t+1}, v_{xt+1}, y_{t+1}, v_{yt+1}]'$

Where x_{t+1} and y_{t+1} specify the coordinates of the target at time t+1, and v_{xt+1} and v_{yt+1} denote the velocity of the mobile target at time t+1 in 2D ground-plane. Each element of the state matrix plays an important role in prediction. Indeed, the prediction is based on the correlation between the position and the velocity over time. Z_t is the measurement vector. It is defined by: $Z_t = [x_{Zt}, y_{Zt}]'$

Where x_{Zt} and y_{Zt} specify the measured target coordinates. A is the state transition matrix, it defines the relation among the component of mobility state vector between t and t+1. H is the measurement matrix, it relates the mobility state to the measurement. W_t and V_t are white Gaussian noise with zero mean and respectively Q_{wt} and Q_{vt} variance. PTA has five main steps: wake up, detection, localization, prediction and next node selection. Initially, all the CSs are in sleeping mode. Periodically, each of them wakes up to check if the target is within its field of view. When an awaked camera detects the target, it localizes it and computes its upcoming position using Kalman filter. Finally, based on the prediction results, the current sensor selects the succeeding one based on two criteria: position and orientation. If several cameras are candidates, nearest to the target or best directed one is elected.

III. Performance Evaluation

To evaluate CTA and PTA, we have used NS-2 simulator [4]. The simulation parameters are chosen according to Imote features [5]. In our evaluation, we consider tracking accuracy and energy consumption as key metrics to evaluate CTA and PTA. Using these metrics, we compare our algorithms to two existing solutions: 1) Basic scheme where all Camera Sensors deployed are always active; 2) a cluster-based solution named OCNS for Optimal Camera Node Selection [6].

1) Tracking accuracy: It is the most important metric for tracking algorithms evaluation. We define it as the number of target 2D coordinates captured by nodes along target trajectory. We assume that the best tracking accuracy (100%) is defined by one coordinate every five meters, the target being a pedestrian. Figure 2 shows the average tracking accuracy for five different trajectories depending on the number of nodes. Obviously, the tracking accuracy increases with the number of nodes, whatever the solution. PTA has the best tracking results with 75% for 30 CSs. It uses Kalman filter which is an efficient predictive algorithm. PTA is followed by CTA, due to the deployment of MS, only the CSs which are in object trajectory are activated. The case where the target evolves with sudden direction changes, CTA outperform PTA. Indeed, CTA is a reactive algorithm where the MS are always active to monitor the area which allows to detect the target during each step of its evolution whatever its trajectory. Because a lack of space we don't add the correspondent figure. BASIC method has a better tracking

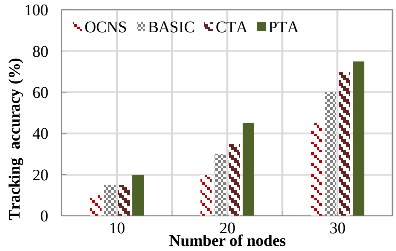

Figure 2: Tracking accuracy vs. number Nodes

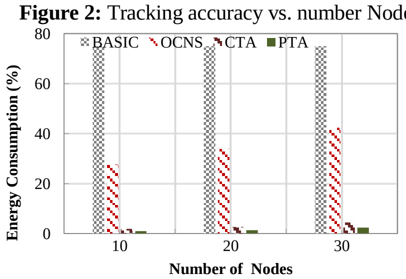

Figure 3: Energy Consumption vs. number of Nodes

accuracy than OCNS. Indeed, while in BASIC solution the CS sensors are always active, in OCNS they wake up periodically.

2) Energy consumption: we evaluate the energy consumed for node activation and communication for five different trajectories. Figure 3 shows the average energy consumption of the whole network. 100% is the network energy available before the simulation begins. BASIC is an inconsiderable solution. Indeed, due to the permanent wake up of CSs, it consumes 75% of network energy. PTA consumes up to 40% less energy compared to OCNS. Thanks to the predictive model, only the CSs which are in target trajectory are activated. Due to the deployment of HWSN and the probabilistic threshold to avoid unnecessary CS activation, CTA consumes just 1.38 % more than PTA. While in PTA the CS wakes up depends only on predicted information. In CTA the MS are always active and the CS wakes up only if the probability to detect the target is higher than a threshold.

IV. Conclusion and Future Works

Handling the compromise between energy consumption and tracking accuracy in WMSN research field is a crucial issue. In this paper, we propose two tracking algorithms: CTA and PTA. CTA runs on HWSN. It is based on a probabilistic study to limit the active period of the camera. PTA is new predictive tracking Algorithm. It uses Kalman filter to predict the future target location based on the current one. Based on the predicted coordinates, it activates only the Camera sensors which are in target trajectory. As next step, we plan to include object identification and multi-target tracking.

References

[1] I.F.Akyldiz, T.Melodia,K.R Chowdhury," A survey on Wireless Multimedia Sensor Networks", in Computer Networks 51 (2007)
[2] I.Boulanouar, S.Lohier A.Rachedi, , G.Roussel ,"CTA : a Collaborative Tracking Algorithm in Wireless Sensor Networks", ICNC'13 (to appear)
[3] G.Welch and G.Bishop."An introduction to Kalman filter", Technocal report. Univ. of North Carolina, 1995
[4] Ns-2, http://www.isi.edu/nsnam/ns
[5] "Imote2_Multimedia_datasheet.pdf",http://www.memsic.com
[6] L.Liu, X,Zhang," Optimal Node Selection for Target Localisation in Wireless Camera Sensor Netwoks", in IEEE Trans. Vehicular Technology Vol. 59, No. 7, September 2010