A Novel Passive Tracking Scheme Exploiting Adaptive Line of Sight Links

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***Abstract*—The wide deployment of wireless access points and smart mobile devices has been recently addressed in the research field of positioning. In traditional positioning schemes, the target is assumed to hold a tag or a transceiver for being tracked and it is regarded as active tracking. However, the target without any tags nor transceivers can be tracked by using radio frequency tomography, and it is known as passive tracking. In this paper, we propose a passive tracking scheme exploiting adaptive line-of-sight links (LOSLs). In the proposed scheme, the LOSL between each of wireless mobile device and wireless access point can be constructed adaptively to enhance the tracking performance in indoor environment. It maintains only least links while waiting for detection of a target with minimum energy consumption. However, when a target is detected with the least links, we can get a more accurate trajectory of the target by adaptively increasing the complexity of the links higher. According to the simulation results, it is shown that the proposed scheme can enhance the positioning performance remarkably.**

Keywords-positioning; active tracking; passive tracking; adaptive links.

I. INTRODUCTION

According to literatures, positioning schemes can be classified into two categories: Active tracking that requires the target to hold actively a device for tracking, such as a tag or a transceiver, and Passive tracking that tracks passively the target without any of devices [1]. However, the active tracking scheme has a limitation that it is not always expected for the tracked persons, such as criminals and intruders, to possess any devices for tracking. Accordingly, this issue has provoked much research about the passive tracking scheme. Zhou et al. had introduced a passive indoor tracking scheme with geometrical formulation [2]. They explored the characteristics of the wireless propagation radio frequency tomography (RFT) [3]-[6], under line-of-sight links (LOSLs), and by formulating the geometrical problem and applying Particle Swarm Algorithm (PSO) [7], the trajectory of the target can be estimated accurately. However, it is not efficient to maintain complex LOSLs under waiting for detection of a target with energy consumption. Moreover, since there are limitations of detecting multi-targets and more complex situations with triggered sequence error or time stamp error. In this paper, we propose a novel passive tracking scheme exploiting adaptive LOSLs to overcome the limitations of the conventional scheme. Therefore, we can get a more accurate trajectory of the target by increasing adaptively the level of the link complexity higher, while the conventional scheme is based on the fixed LOSLs.

The rest of the paper is organized as follows. In Sect. II, the basic concept of the conventional passive tracking scheme based on RFT are briefly discussed. In Sect. III, a passive tracking scheme exploiting adaptive LOSLs is proposed. In Sect. IV, the positioning performance of the proposed scheme is evaluated with computer simulations. Finally, our concluded remarks are summarized in Sect. V.

II. SYSTEM DESCRIPTION

A basic concept of the conventional passive tracking scheme based on RFT is described in Figure 1. As shown in the figure, a RFT operator consists of two access points (APs) (1, 2) and two RSS indicators (a, b), and it estimates a cross point (CP) on the LOSL [2]. Note that the CP indicates the intersecting point by the target on the LOSL. Both the RSS Indicators and the APs are placed on either side of the corridor, forming a LOSL web to monitor the corridor. When an obvious RSS fluctuation on a LOSL is detected, it is defined as this LOSL is triggered by the target. When a pedestrian walks across the RFT operator from position A to B in Figure 1, the triggered sequence of LOSLs is record as L(i), (i = 1, 2, 3, 4), which are L(1, a), L(1, b), L(2, a), and L(2, b), respectively. Note that L(i) is represented as a 1st order straight line, $y = k_i \cdot x + b_i$, where k_i and b_i are foreknown according to the coordinates of the APs and the RSS Indicators.

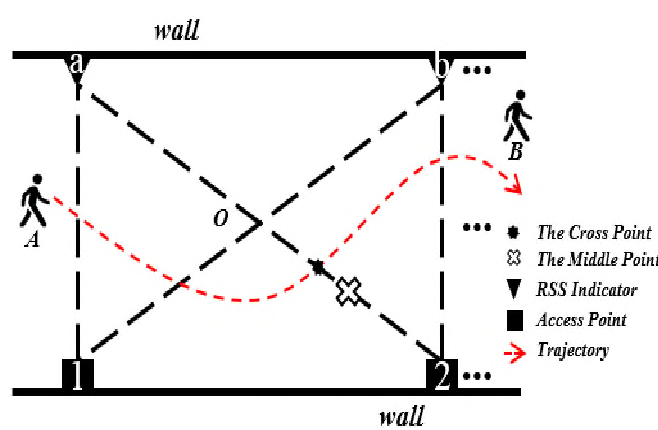

Figure 1 . CP estimation on L(2,a) by a RFT operator

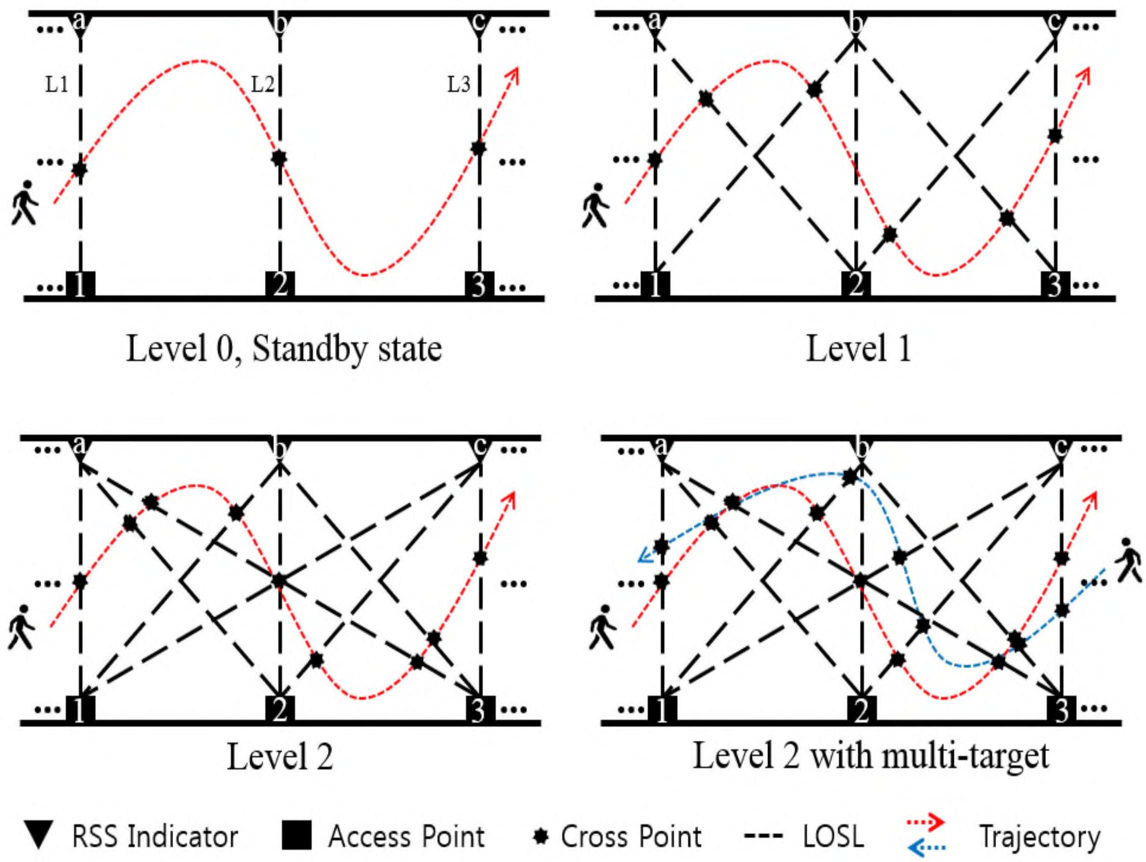

Figure 2. Scenario with proposed scheme

Generally, when L(i) is triggered, the middle point, which is *O* on L(3) in Figure 1, on L(i) is selected as the CP for minimizing the tracking error, and it is called as a central method (CM) scheme. Once the triggered sequence is considered, however, the CP can be set as the middle point of the restricted segment (the cross mark in Figure 1) on the LOSL, which is cut by the previous obstructed LOSL and the subsequent obstructed LOSL, and it is given as follows:

$$x_{cp}^{i}, y_{cp}^{i} \in [the\ segment\ on\ LOSL(i)\ cut\ by\ LOSL(i-1)\ and\ LOSL(i+1)] \quad (1)$$

For example, in Figure 1, the CP on L(2, a), must locate on segment *O*2 in common sense because the previous triggered LOSP is L(1, b) and the later triggered LOSP is L(2, b). However, if the previous triggered LOSP is L(1, a) and the later triggered LOSP is L(2, a), the CP will be located on segment *O*a. With the presented example in Figure 1, therefore, the CP is located at the middle point of segment *O*2, which is cut by L(1, b) and L(2,b) for further minimizing the tracking error.

III. PROPOSED SCHEME

As for the conventional scheme, it is not efficient to maintain complex LOSLs under waiting for detection of a target with energy consumption. We assumed that more transmitting power is used to maintain complex links, because the distance between AP and RSS indicator is increased. Moreover, there are other limitations of detecting multi-targets and performance with fixed structure of LOSL web. In this paper, therefore, we propose a novel passive tracking scheme exploiting adaptive LOSLs.

Figure 2 shows a scenario with the proposed scheme. In the proposed scheme, it remains level 0, as the standby state with minimum number of LOSLs. When the LOSL is triggered, the level is changed to higher level with respect to the situations such as multi-targets or enhanced accuracy of tracking. In this paper, three representative situations are considered; when we want to get higher accuracy of the trajectory of the target, when the multi-targets are detected, when the sequence history of trajectory of the target is not clear.

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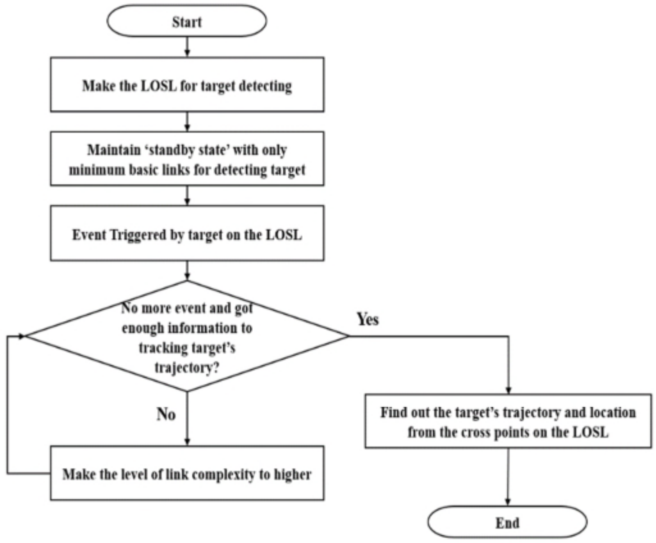


Figure 3. The flow chart of proposed scheme

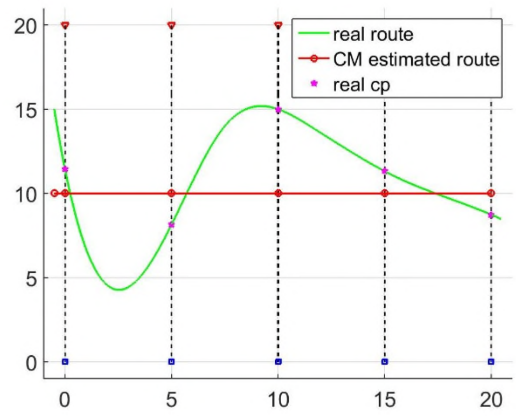
Firstly, when we just want to get higher accuracy, we can make it by increasing the number LOSLs per each of nodes as shown in the Figure 2. By changing level 0 to 2, then, we can get more CPs, and we can track the trajectory of the target more densely.

Secondly, if we get different trigger sequences with different directions, compared with originally tracked trajectory, then we can assume that there are multiple targets. Tracking of the multi-targets cannot be achieved with only the low levels. To make a clear division with original target, we can increase the number of LOSLs and compare the triggered sequence of original target with that of new targets. Moreover, by increasing the number of LOSLs, we can decrease the tracking error when the sequence history of trajectory of the target is not clear.

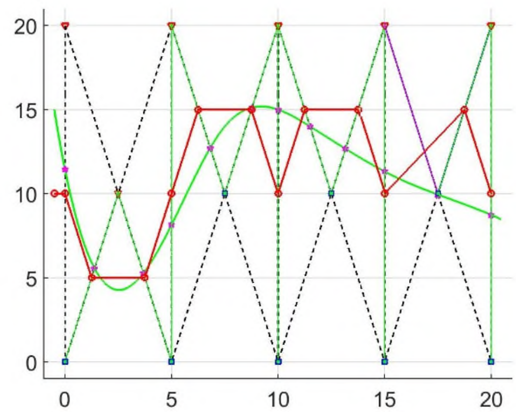
Figure 3 presents the flow chart of the proposed scheme. For the first step, we make the LOSLs for target detection by sending propagation signals from APs to RSS Indicators. Then, it maintains 'standby state' with only minimum basic links for detecting target while saving power consumption. When a target is detected with the basic links, the proposed scheme increases the complexity of LOSL. Meanwhile, if the proposed scheme has enough information of the sequence with time stamp for tracking the target, it moves on to the next step to find out the trajectory of the target. However, if the information of the sequence with time stamp is missed or the sequence history is not reasonable, then it moves on the next step. In the next step, it can bring the level of LOSL to higher level and goes back to former step until the conditions are satisfied.

IV. PERFORMANCE EVALUATION

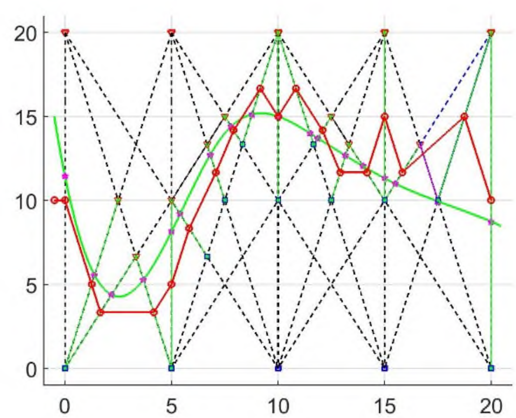
We performed computer simulations with MATLAB. In the simulations, Wi-Fi APs and smart-phones are assumed as APs and RSS indicators, and the characteristics of Wi-Fi signal are measured and modeled with path-loss and fading effects. The simulation also models a 20m x 20m space with 5 APs and 5 RSS indicators to validate the effectiveness of the proposed scheme.



(a) Level 0 (units: meters)



(b) Level 1 (units: meters)



(c) Level 2 (units: meters)

Figure 4. Results of simulations with the proposed scheme (x-axis and y-axis indicate the coordinates in meters)

With the proposed scheme, we used the CM scheme, which sets the central point of each of the LOSLs to the CP for estimating the real CP, which is the intersecting point by the target on the LOSL. Note that purple stars indicate the real CPs on the actual trajectory of target. Figure 4 shows the result of simulations with the proposed scheme. The green solid line indicates the actual trajectory of target, which is made randomly, while the red line with circle marks indicates the estimated trajectory of the target and the dotted lines are the LOSLs. As shown in the figure, the proposed scheme can change the levels of LOSL web from 0 to 2 and even more to enhance the tracking performance. Note that the level 1 is the tracking performance with the conventional scheme. In the simulations, we used only five couples of APs, but we can notice that the performance of tracking is enhanced remarkably, and the errors are reduced as the number of LOSLs is increased. It is reasonable that the power consumption of the proposed scheme is decreased because it can save the transmitting power, while it waits for the target. However, the amount of power saving depends on the scenarios with different ratio of waiting time and active time. Therefore, we are under performing experiments for the proposed scheme to confirm the operation of the algorithm in terms of the power saving as well as the accuracy, and the results will be discussed in future works. Moreover, if there is an error of the triggered sequence or time stamp, which is caused from events of the multi-targets, the proposed scheme can track the multi-targets with independent sequence and time stamp.

V. CONCLUSIONS

In this paper, we proposed a passive tracking scheme exploiting adaptive LOSLs. In the proposed scheme, the LOSL between each of wireless mobile device and wireless APs can be constructed adaptively to enhance the tracking performance in indoor environment. Compared with the conventional scheme, we can get advantages in accuracy, while maintaining the existing number of APs, by increasing the number of LOSLs in each of levels. It is natural that the tracking accuracy becomes higher when the number of APs increases. However, there are several issues left for future works. As the number of LOSLs is increased, the complexity also is proportionally increased. Therefore, one of the future work is to find an optimal number of APs' deployment for tracking a target in usual indoor environment. Also, we need to evaluate the performance of the proposed scheme with various number of multi-targets in future works. Moreover, we will analyse the stability of the algorithm with respect to the accuracy of the inputs in future works.

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