



Optimizing the Event-based Method of Localization in Wireless Sensor Networks

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Abstract

A Wireless Sensor Network (WSN) is a wireless decentralized structure network consists of many nodes. Nodes can be fixed or mobile. WSN applications typically observe some physical phenomenon through sampling of the environment so determine the location of events is an important issue in WSN. Wireless Localization used to determine the position of nodes. The precise localization in WSNs is a complex issue that requires consideration of many prominent aspects such as energy consumption at the nodes as well as the algorithm execution time. In this article, we optimize a system called Spotlight. The spotlight is a localization system that delivers high-location estimation accuracy at low cost. We propose several methods to reduce execution time compared with previous methods in Spotlight. We proposed ILS, LAS and PAS methods that improve execution time about 25%, 50% and 75%. Execution time of the proposed scheme is restricted by the size of deployment area. Furthermore, in these methods, there is no need to equip the nodes with any special hardware.

Keywords: Localization, spotlight, linear scan, event base

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1. Introduction

Recently WSNs received significant attention from researchers due to its unlimited potential [20-22]. Determining location of the nodes in WSN is an important issue. Different methods have been proposed to solve this problem, including the use of GPS in nodes that are not economically efficient. It also should be noted that locations of the most sensor nodes are fixed after deployment in the environment, and thus, once localization is sufficient for each node. There are many protocols reported in the literature that increase energy consumption of the nodes due to exhaustive messages exchanges among them.

In Spotlight method [1, 2], there is no need the nodes to be equipped with GPS, only spotlight needs to know its location. The core concept of the spotlight localization system is the generation of controlled events detectable by deployed sensor nodes. Events like light and sound, with well-characterized spatiotemporal properties which are detectable with simple sensing hardware are performed well in this system [1]. In this system, initially, the nodes start to sync up their time. Then the spotlight will start to spread events. Detection time of events is recorded by the nodes, and then system can calculate the location of all nodes.

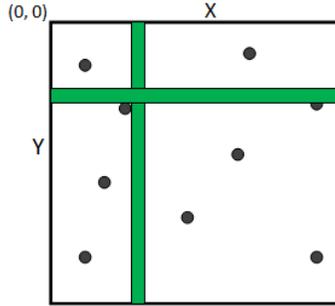


Fig.2.The line scan method, tow spotlights do scan horizontally and vertically

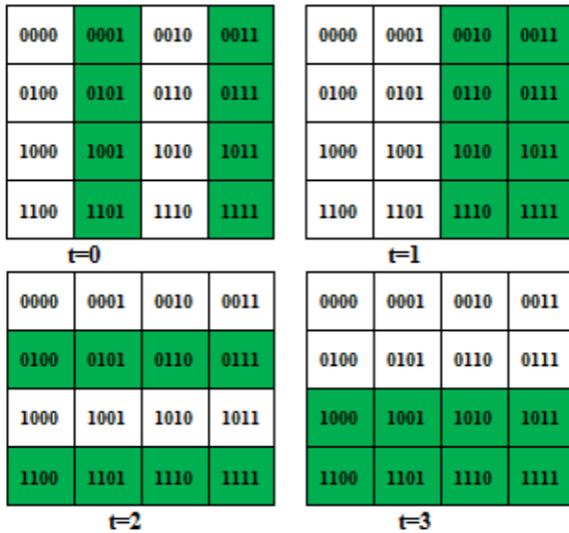


Fig.3.The area scan with events covering the shaded areas.

The rest of this article is organized as follows. In section 2, we review related works. In section 3 we propose improved methods and in section 4 their performance is presented. Section 5 concludes the paper.

2. Related Works

Location information is crucial for many applications in wireless sensor networks. Localization algorithms in WSNs can be classified into two general categories: range-based localization [6, 7, 8, 9, 10 and 17] and range-free localization [11, 12, 13, 14, 15, and 16]. Range-based method uses the measured distance/angle to estimate the location. And the free localization method uses the connectivity or pattern matching method to estimate the location. Measuring the range of wireless signal transmissions is a key for range-based localization techniques. The common methods to estimate the indoor location are time of arrival (TOA),

time difference of arrival (TDOA), angle of arrival (AOA), and received signal strength (RSS). Many algorithms have been proposed based on these methods. Almuzaini and Gulliver propose a range-based algorithm which is based on decision tree classification and the density based spatial clustering of applications with noise (DB SCAN) algorithm in [18]. Lei Zhang and Binwei Deng in [19] proposed a novel range-based distributed localization algorithm based on genetic algorithm uses sampling method to obtain initial location and refines the initial location based on genetic algorithm.

In this article, we extend the idea proposed in [1] that focuses on design paradigms in event-based localization systems.

2.1 Spotlight system architecture

The architecture of the Spotlight system comprises the following three functions:

- Distribution function, or EDF, $E(t)$
- Event detection function, $D(e)$
- Localization function, $L(Ti)$

Since $E(t)$ is computed by the Spotlight device, hardware requirements for the sensor nodes remain minimal. Substantial algorithmic changes can be made without requiring updates on deployed sensor nodes [1].

The EDF $E(t)$ may be tuned to distribute events optimally based on the limitations imposed by sensor capabilities, the platform transporting the spotlight system, terrain, and availability of detailed geographic information. The Point Scan, Line Scan, and Area Cover Event Functions each illustrate basic functionality of the Spotlight localization system.

2.1.1. Point Scan Event Distribution Function

Spotlight device generates point events (e.g., light spots) in an area $A \in R^2$ along the x-axis (Figure. 1). It is assumed that the scanning speed is a constant s , the deployment area is $A=l \cdot l_r$, the radius of the event is r , and finally the EDF is given by:

$$E(t) = \{ P | P(x,y) \in A \text{ and } x = (st) \bmod (l) \text{ and } y = \lfloor st/l \rfloor r \}$$

In this case, the resulting localization function is: $L(Ti) = E(t_{i1}) = \{ (st) \bmod (l) , \lfloor st_{i1} / l \rfloor r \}$ (1)

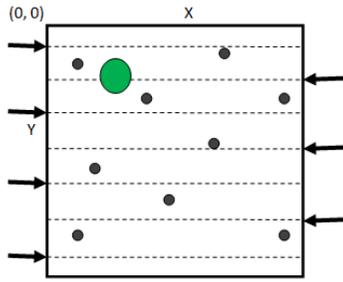


Fig.1.The Point Scan method. Spotlight scan environment by moving on X-axis and distribute events.

2.1.2. Line Scan Distribution Function

In this method, two spotlights do scan horizontally and vertically (Fig.2). Therefore, each node should records two events. $Ti = \{t_{i1}, t_{i2}\}$. Formula 1 is used to calculate the position of each node on X-axis and Formula 2 is used to calculate the position on Y-axis. Based on formula 3, estimated location for any nodes is calculated from Subscribe points that calculated by formula 1 and 2.

$$E(t) = \{P|P \in A \text{ and } P = (ts, k) \text{ where } k \in [0, l]\} \quad (1)$$

$$E(t) = \{P|P \in A \text{ and } P = (k, ts) \text{ where } k \in [0, l]\} \quad (2)$$

$$\text{Where } t_1 \in [0, l/s] \text{ and } t_2 \in [l/s, 2l/s]$$

$$L(Ti) = E(t_{i1}) \cap E(t_{i2}) \quad (3)$$

2.1.3. Area Cover Event Distribution Function

The Point Scan and Line Scan functions require precise tracking of the event generator orientation. Area Cover EDF lessens the precision required by using devices, like light projectors, to generate events that cover an area. It can be illustrated with a simple example. As shown in Figure 3, the plane A is divided in 16 sections and each section S_k is assigned a unique code k . The spotlight device distributes events according to these codes: at time j , a section S_k is covered by an event (illuminated, in the case of a visible light event) if j^{th} bit of k is 1. A node residing anywhere in a section S_k is localized to that section's center. For example, nodes within section "1010" detect the events at time $T = \{1, 3\}$. S_k can be determined at $t = 4$ for any sensor in the area covered by the event generator.

Assume that all sensor nodes are located in a square with edge size D , and that the Spotlight device can generate N events (e.g., Point, Line, and Area Cover events) every second, and that the maximum tolerable localization error is r . Table 1 compares the execution cost of the three techniques [1].

Table1.
Execution Cost Comparison Criterion

Criterion	Point Scan	Line Scan	Area Cover
Localization Time	$(D^2/r^2)/N$	$(2D/r)/N$	$LOG_r^{D/N}$
# Event Detection	1	2	LOG_r^D
Event Overhead	D^2	$2D^2$	$D^2 LOG_r^{D/2}$

3. Improved methods

3.1 Improved Line Scan (ILS)

In this proposed method, the environment is divided into regions. Initially, the spotlight1 is in position $(L/2, 0)$ as it is shown in Fig.5. In this Figure, long arrows depict direction of the movement. Small arrows also show direction of scan. Nodes in the scanned area record detection time of events.

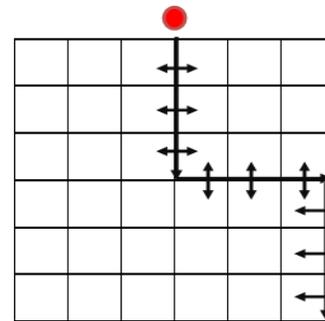


Fig.5. ILS method-initial position of spotlight1

And as it is shown in Figure 6, initial position of spotlight2 is $(L/2, L)$. After step1, the following times were recorded by the nodes in each region (Figure 7).

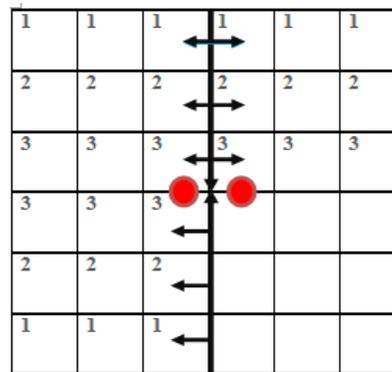


Fig.7. ILS method - detected times after step1

Figure

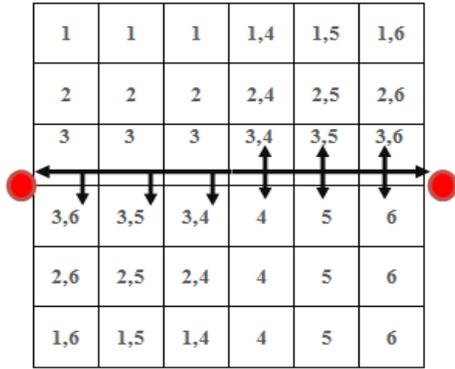


Fig.8. ILS method -detected times after step2

In the second step, spotlight1 moves to the right and spotlight2 moves to the left. After end of this step, times detected by the nodes would be according to Figure 8. Finally, the spotlight1 moves down and spotlight 2 goes back to right (Fig.9).

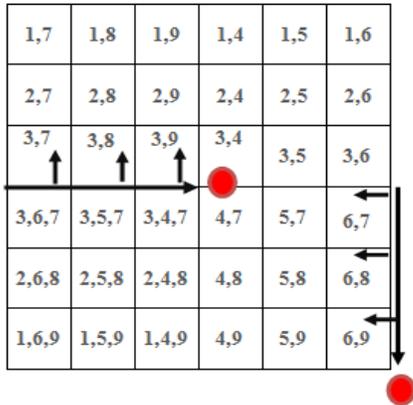


Fig.9. ILS method – detected times after step3

As it can be seen, each area has a unique diagnostic time and by this times, we can determine which nodes are located in one area by following algorithm:

First assume that t_1, t_2, t_3 are:

$$t_1 = \{x|x \in t \text{ and } 0 < x \leq t/3\}$$

$$t_2 = \{x|x \in t \text{ and } t/3 < x \leq 2t/3\}$$

$$t_3 = \{x|x \in t \text{ and } 2t/3 < x \leq t\}$$

To determine the position of nodes we divide the area into four regions.

1	2
3	4

```

if (dt1 ∈ t1 and dt2 ∈ t3 ) //
zone 1
  { // dt1 and dt2 are times detected by sensor
and t is total scan time
    x=( dt2-(2t/3) ) * linewidth
// linewidth is width of the scanning beam
    y= ( |(2t/3)-dt1| +1 *linewidth
  }
else if (dt1 ∈ t1 and dt2 ∈ t2 ) //
zone 2
  {x=dt2 * linewidth
    y= ( |(2t/3)-dt1| +1 *linewidth }
else if ( count(detected times) == 3 ) //
zone 3
  {x= ( | dt2-(2t/3) | +1) * linewidth
    y= dt1 * linewidth }
else if (dt1 ∈ t2 and dt2 ∈ t3 ) //
zone 4
  {x=dt1 * linewidth
    y= ((t-dt2) +1) * linewidth }
    
```

The execution time of ILS method is $(3D/2r) / N$. Compared with the line scan method, execution time reduced. The improved time can be used to improve the location accuracy.

3.2 Hybrid methods

3.2.1 Point scan & Area scan (PAS)

PAS method is a combination of the point scan and area scan. In this method, the environment is divided into four regions as shown in Figure 10.

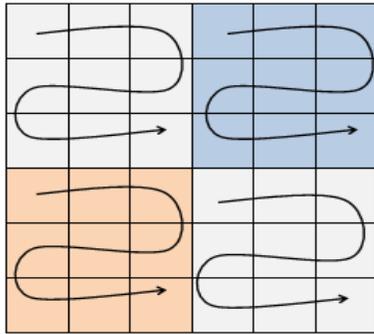


Fig.10. PAS method

Four spotlights simultaneously scan the regions. A binary number can be assigned to each region:

- Region 1: 00
- Region 2: 01
- Region 3: 10
- Region 4: 11

Then, area scan method is used to distinguish between regions. For example, the third region is scanned at the second time and fourth region is scanned at the first and second time. So each node can record 3 times. The second and third times indicates the region and the first time can determine the position of nodes in the area. Method's execution time is equal to $(D^2/4) + 2$.

3.2.2. Line scan & Area scan (LAS)

In this method, the environment is divided into four regions as shown in Fig.11.

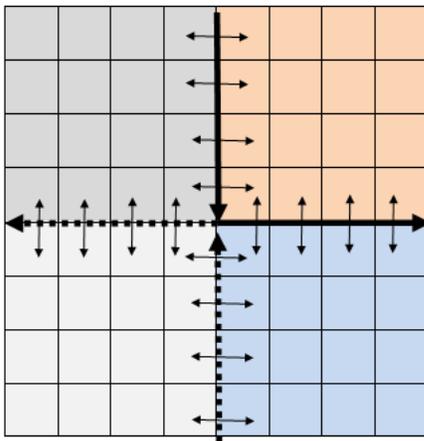


Fig.11. LAS method.

As it is depicted in Figure11, two devices scan the field by moving across pre-specified paths. Recording times are shown in Fig.12.

1-8	1-7	1-6	1-5	1-5	1-6	1-7	1-8
2-8	2-7	2-6	2-5	2-5	2-6	2-7	2-8
3-8	3-7	3-6	3-5	3-5	3-6	3-7	3-8
4-8	4-7	4-6	4-5	4-5	4-6	4-7	4-8
4-8	4-7	4-6	4-5	4-5	4-6	4-7	4-8
3-8	3-7	3-6	3-5	3-5	3-6	3-7	3-8
2-8	2-7	2-6	2-5	2-5	2-6	2-7	2-8
1-8	1-7	1-6	1-5	1-5	1-6	1-7	1-8

Fig.12. Recording times in LAS method

Then, area scan method is used to distinguish between regions as in the PAS method. Method's execution time is equal to $D + 2$.

4. Experimental Results

In this paper, we have presented several methods called ILS, LAS and PAS. In the following we analysis their performance with other similar methods from the perspective of execution time

4.1. experiment 1

In this experiment we compared execution time for ILS method with line scan method for $r=3\text{cm}$, $r=13\text{cm}$, $r=23\text{cm}$ and $r=33\text{cm}$ where r is radius of the events.

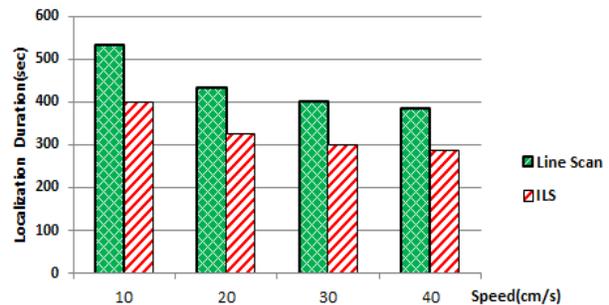


Fig.13.a. execution time for ILS method compared with line scan method where $r=3\text{cm}$

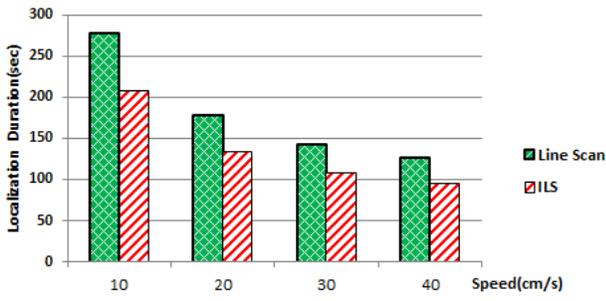


Fig.13.b. Execution time for ILS method compared with line scan method where r=13cm

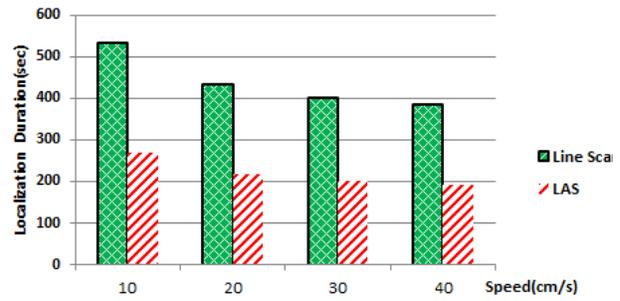


Figure 14.a. Execution time for LAS method compared with line scan method where r=3cm

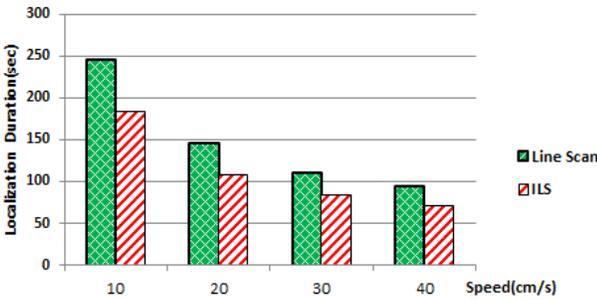


Fig.13.c. Execution time for ILS method compared with line scan method where r=23cm

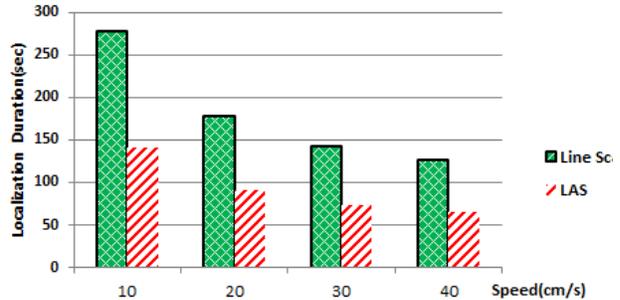


Fig.14.b. Execution time for LAS method compared with line scan method where r=13cm

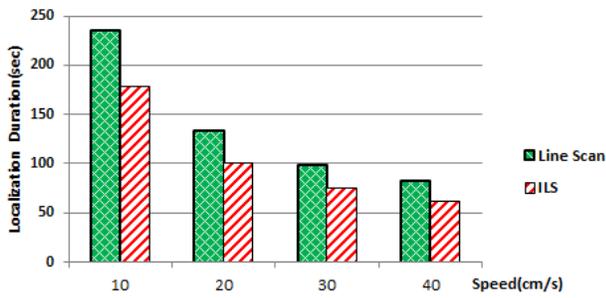


Fig.13.d. execution time for ILS method compared with line scan method where r=33cm

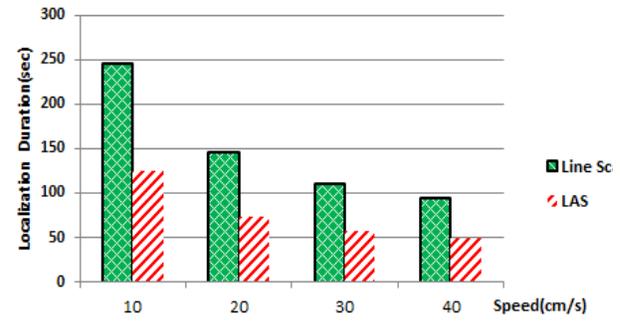


Fig.14.c. Execution time for LAS method compared with line scan method where r=23cm

As can be seen, the execution time of ILS method is reduced by about 25% compared to the line scan method. This reduction in execution time is due to the simultaneously scanning by tow spotlights.

4.2. Experiment 2

In this experiment we compared execution time for LAS method with line scan method for r=3cm, r=13cm, r=23cm and r=33cm (figure14), where r is radius of the events.

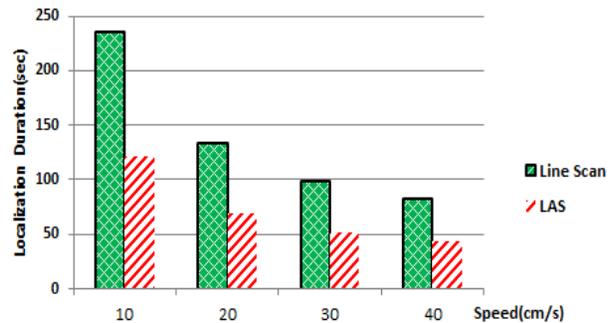


Fig.14.d. Execution time for LAS method compared with line scan method where r=33cm

Execution time of LAS method is less than the line scan method because in this method the two spotlights do scan simultaneously and for distinguish between different regions we use area scan method.

5. Conclusion

This paper improved the event-based localization methods in wireless sensor networks. The proposed method reduces the execution time of line scan method from $2D$ to $3D/2$ where D is the width of environment. It also presents two hybrid methods, PAS and LAS. The former, reduces execution time of the point scan method from D^2 to $(D^2/4) + 2$ and latter, reduces execution time of the line scan method from $2D$ to $D + 2$. As for our future works, we will more concentrate on the hybrid approaches and try to improve their accuracy.

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