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Multiple Event-Driven Node Localization in Wireless Sensor Networks

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***Abstract*– In the area of wireless sensor networks, localization is the essential issue. Localization - discovering the location of individual sensor nodes leftovers one of the most complex research challenges. Practical solutions involving reasonable power, computation and monetary costs do not exist. Since many rising applications based on networked sensors require location awareness, a node must be able to find its location. So, Spotlight, a localization system that carries high-location estimation accuracy at low cost. The system uses spatiotemporal properties of well-controlled events in the network; light in this case, to obtain locations of sensor nodes. The system is to detect the multiple events in the network and to increase the area of the sensor field by increasing the number of nodes. By handling this kind of detection of multiple events in the network at once, mainly the time is saved. Spotlight offers various techniques that allow users to balance time and accuracy to obtain results tailored to requirements.**

***Index Terms*–Wireless Sensor Networks; Node Localization; Multiple Events.**

I. INTRODUCTION

A wireless sensor network (WSN) consists of spatially scattered independent sensors to examine corporal or environmental circumstances, such as temperature, sound, pressure, etc. and to considerately forward their data through the network. The WSN is formed of nodes - from a very little to many, where every node is linked to one or numerous sensors.

Localization plays an important role. Here, Localization problem means the method of approximating and figuring out the positions of sensor nodes. The significance of this information directed the researchers to find a solution for it. One way is the manual design configuration but this is very unworkable in wide-ranging or when sensors are deployed in remote areas or when sensors are movable. Another way is adding the global positioning system (GPS) to each sensor. Since GPS needs line-of-sight between the receiver and satellites, it has exaggerated heavy trees and big buildings. Due to poor signal reception it has low accuracy.

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II. LOCALIZATION METHOD

Localization is an important issue in the WSN technology. Localization problem refers to the method of estimating and calculating the locations of sensor nodes. The significance of this fact directed researchers to look for a solution for localization problem. One simple way is manual design but this is not viable in large scale or when sensors are deployed in unreachable areas such as volcanoes or when sensors are movable. Another way is to add global positioning system (GPS) to each sensor. GPS has affected by heavy trees and buildings because it requires line-of-sight between the receiver and satellites. So, it has low accuracy due to poor signal reception. As it is mentioned earlier, localization means finding the position of the individual sensor nodes. In general, the localization method can be classified into four different categories:

- Centralized vs Distributed
- Anchor-free vs Anchor-based
- Range-free vs Range-based
- Mobile vs Stationary

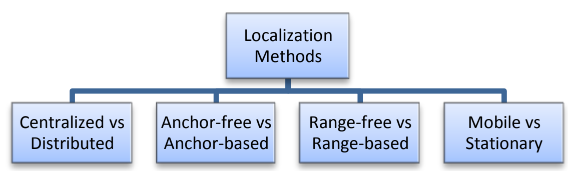

Fig. 1 – Classification of Localization Method

III. EXISTING METHOD

Asymmetric Event-Driven Node Localization in Wireless Sensor Networks proposes Spotlight, a localization system that gives high-location estimation accuracy at low cost. Using an asymmetric design with all complicated hardware and computation in a single device, Spotlight delivers a variety of methods that allow users to balance time and precision to attain outcomes modified to requirements. In all cases, the only limiting aspect is the total size of the sensor field. Any number of sensors may be identified within an enclosed area at no additional cost, making Spotlight suitable for large-scale deployments.

The basic concept of the Spotlight localization system is the generation of controlled events detectable by deployed

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sensor nodes. Events like light and sound, with well characterized spatiotemporal properties and detectable with simple sensing hardware, perform well in this system. By determining a sensor node's recognition time of a generated event, a spatial relationship between the sensor node and the event generator can be inferred. There are three main functions: Event Detection, Event Distribution Function and Localization Function.

The EDF E(t) may be adjusted to disseminate events optimally based on limitations forced by sensor abilities, limitations of the platform transporting the Spotlight system, limitations forced by 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. Each of these designs is evaluated in three scenarios: 1) the terrain is known or assumed to be flat; 2) terrain information is available; and 3) the terrain is unknown.

Point Scan, Line Scan, and Area Cover EDFs all localize sensor nodes. However, they vary in localization time, communication overhead, and energy consumed (defined as Event Overhead). 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.

Table I - 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 Detections	1	2	$\log_r D$
Event Overhead	D^2	$2D^2$	$D^2 \log_r D/2$

IV. PROPOSED METHOD AND ARCHITECTURE

Some of the limitations in the existing concept are as follows:

- The limiting factor here is the total size of the sensor field. Because of this the coverage is minimized. To overcome this, the number of nodes should be increased to increase the total size of the sensor field.
- Here only single event is detected and the multiple events are not worked out.
- High precision of localization is not up to the level with respect to the time and accuracy.

To overcome these limitations, the following concepts are enhanced. In the existing concept, single event is detected and driven, but here, the multiple events detection concept is discussed and implemented. Addition to that, the coverage is maximized by increasing the number of nodes and also the localization concept is précised with respect of time and accuracy.

Any number of sensors may be localized within a covered area at no additional cost, making Spotlight suitable for large-scale deployments. Events like light and sound, with well characterized spatiotemporal properties and detectable with simple sensing hardware, perform well in this system.

In further, there are three main functions which support the above said modules in the implementation and they are as follows: the Event Distribution Function (EDF) E(t), the Event Detection Function D(e), and the Localization Function $L(T_i)$.

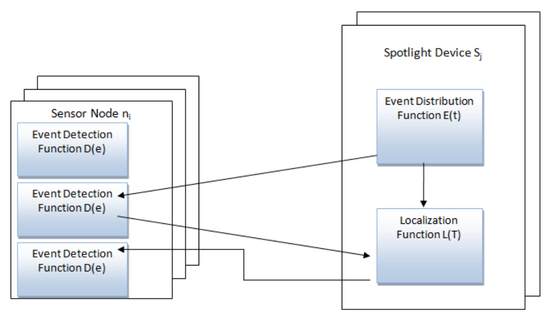

Fig. 2 – Spotlight system architecture, depicting the multiple events

With the support of these three functions, the localization process proceeds as follows:

- A Spotlight device distributes events in the space A.
- During event distribution, sensor nodes record the time sequence $T_i = \{t_{i1}, t_{i2}, \ldots, t_{im}\}$ at which they detect the events.
- After event distribution, each sensor node sends the detection time sequence T_i to the Spotlight device.
- The Spotlight device estimates the location of a sensor node n_i, using T_i and the known E(t) function.

Event Detection D(e) is carried by the sensor nodes. It resolves whether a peripheral event occurs or not. Localization Functions $L(T_i)$ are applied by Spotlight devices Event Distribution E(t) depicts the dispersal of

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events over time and is present on one or more Spotlight devices.

The EDF is given by

$$E(t) = \begin{cases} P \mid P(x,y) \in A \text{ and } x = (st)mod(l) \\ \quad \text{and} \end{cases}$$
$$y = \lfloor st/l \rfloor r\}.$$

The resulting localization function is

$$L(T_i) = E(T_{i1}) = \{(st_{i1})mod(l), \lfloor sti1/l \rfloor r\}$$

There are two terrains: known terrain and unknown terrain. Now, the equation of the line from Spotlight device to the terrain is given by

$$\begin{pmatrix} x \\ y \\ z \end{pmatrix} = \begin{pmatrix} x1 \\ y2 \\ z3 \end{pmatrix} + k \begin{pmatrix} \cos\alpha1 \\ \cos\beta1 \\ \cos\gamma1 \end{pmatrix}$$

where k is given by

$$k = \frac{x-x1}{\cos\alpha1} = \frac{y-y1}{\cos\beta1} = \frac{z-z1}{\cos\gamma1}$$

and

$$\begin{pmatrix} x \\ y \end{pmatrix} = \frac{z-z1}{\cos\gamma1} \begin{pmatrix} \cos\alpha1 \\ \cos\beta1 \end{pmatrix} + \begin{pmatrix} x1 \\ y1 \end{pmatrix}$$

Now, the resulting localization function is

$$L(T_i) = E(T_{i1}) = \max \left\{ \begin{pmatrix} x \\ y \end{pmatrix} = \frac{z-z1}{\cos\gamma1} \begin{pmatrix} \cos\alpha1 \\ \cos\beta1 \end{pmatrix} + \right.$$
$$x1y1 \text{ and } xyz \in HM$$

where α_1, β_1, and γ_1 are functions of time and are calculated using the time stamp t_{i1} received.

V. SYSTEM IMPLEMENTATION

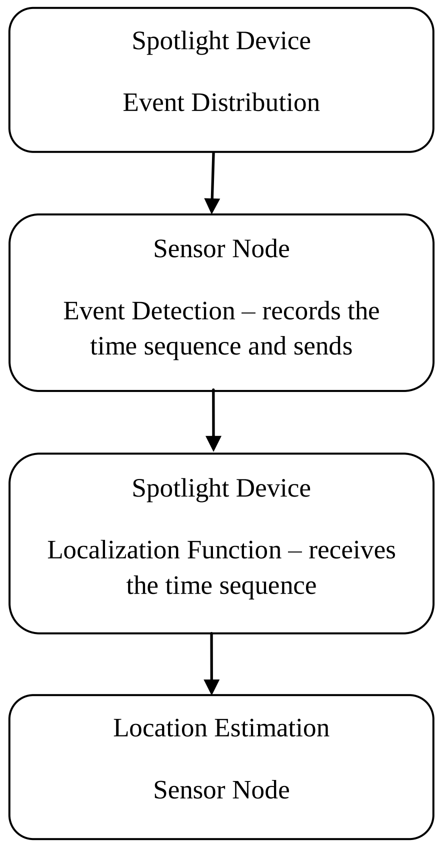
The implementation of this project is planned to be done with following modules. These modules would help in practical implementation of this project. Each module would be made through precise steps towards the successful implementation. The modules are as follows:

- Increasing the total size of the sensor field by maximizing the coverage and increasing the number of nodes.
- Distribution and detection of multiple events.
- High localization precision with respect to the time and accuracy.

A. Algorithm

Start Proc_ Localization (Event_Id, Source Address, Destination Address, Device ID)
Assume a space A $\subset$ R^3 and a spotlight device
Initialize Sensor nodes
For each node n
Do
    Position node at $P_i(x_i, y_i, z_i)$
Compute Event Distribution Func_EDF(Event Id, Node Id, Address)
Record the time Sequence $T_i = \{t_{i1}, t_{i2}, \ldots, t_{im}\}$
End
Compute Event Detection Func_ D(e) (Node Id, Event Id, time T_i)
For each sensor node
Do
    Send detection time sequence $T_i = \{t_{i1}, t_{i2}, \ldots, t_{im}\}$ to spotlight device
End
Compute Localization function_L(t) (sensor node Id, time Sequence)
For each node do
    Estimate location of node n_i,
    Process with T_i and E(t)
End
End Proc_ Localization

B. Flow Chart



VI. PERFORMANCE EVALUATIONS

For discussing the results, there are four parameters used to compare the single event detection with the multiple events detection, they are as follow:

- Nodes vs Packet Delivery Ratio
- Nodes vs Delay
- Nodes vs Overhead
- Nodes vs Throughput

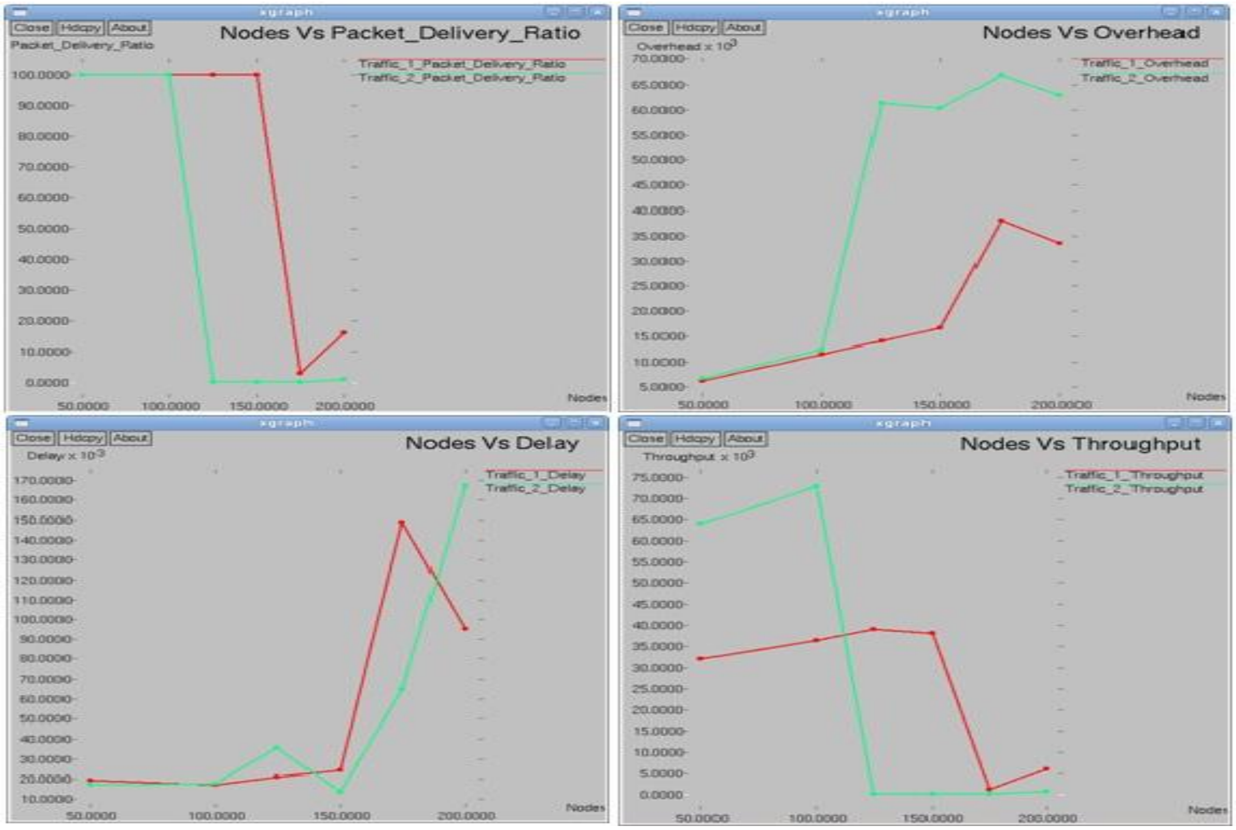


Fig. 3(a) – Nodes vs Packet Delivery Ratio, Fig. 3(b) – Nodes vs Delay, Fig. 3(c) – Nodes vs Overhead, Fig. 3(d) – Nodes vs Throughput

The fig. 3(a) depicts the graph comparison between the single event and multiple events detection with respect of nodes and the packet delivery ratio. Here, the red line shows the single event detection and the green line shows the multiple events detection. The nodes lie through the x-axis and the packet delivery ratio lies through the y-axis.

The fig. 3(b) depicts the graph comparison between the single event and multiple events detection with respect of nodes and the delay. Here, the red line shows the single event detection and the green line shows the multiple events detection. The nodes lie through the x-axis and the delay lies through the y-axis. In this graph, there is a variation occurs in the multiple events detection when compared with the single event detection.

The fig. 3(c) depicts the graph comparison between the single event and multiple events detection with respect of nodes and the overhead. Here, the red line shows the single event detection and the green line shows the multiple events detection. The nodes lie through the x-axis and the overhead lies through the y-axis. In this graph, there is a variation occurs in the multiple events detection when compared with the single event detection.

The fig. 3(d) depicts the graph comparison between the single event and multiple events detection with respect of nodes and the throughput. Here, the red line shows the single event detection and the green line shows the multiple events detection. The nodes lie through the x-axis and the throughput lies through the y-axis. In this graph, there is a variation occurs in the multiple events detection when compared with the single event detection.

VII. CONCLUSION

Based on the limitations of the existing model, it is decided to implement three enhancement ideas: To maximize the coverage by increasing the total size of the sensor field and also by increasing the number of nodes; To distribute and detect the multiple events; High Localization precision with respect to time and accuracy. Localization is finding the position of individual sensor nodes remains one of the most difficult research challenges. Here, this method presents the design, implementation, and evaluation of Spotlight, a localization system for wireless sensor networks. The system is divided into different modules and each module is processed separately and finally implemented together.

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