Decreasing the Localization Error in Border Areas of Sensor Networks

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The centroid localization scheme is a very efficient and resource aware algorithm to estimate a position. On a sensor node, the precision of the position depends on the number of different beacons positions the node receives. In networks with a small transmission range, the localization error behaves very balanced over the whole network. But in very large sensor networks with high transmission ranges, the localization error behaves very unsteady and is increased in most border regions of the network. This paper presents a new algorithm Centroid Localization with Edge Correction (CLwEC) to decrease the localization error in border regions of a network significantly.

***Index Terms*—Resource Aware Localization, Sensor Networks, Correction of Positions, Localization Error**

I. Introduction

The Localization of resource aware sensor nodes is one of the largest challenges in sensor networks. To avoid equipping every sensor node with the costly and energy-consuming Global Positioning System (GPS), only a few nodes are provided with a positioning system. We call these nodes further on beacons. The positions of the beacons are assumed to be exact. All other sensor nodes localize itself related to their known beacon environment.

II. Centroid Localization

Centroid Localization (CL) was first published by Bulusu [1]. The algorithm completely avoids explicit distance measurements, but assumes a grid based beacon placement

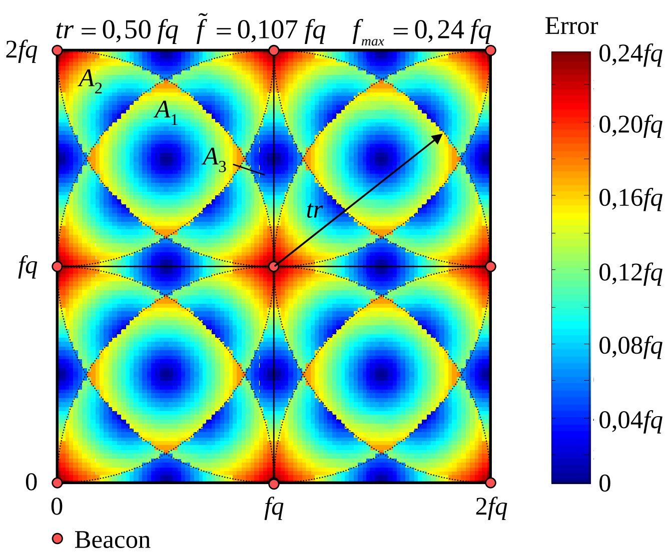

Fig. 1. Localization error of centroid localization

with constant distances fq between each other as demonstrated in Fig. 1. The transmission range tr of all b beacons $B_1(x;y)..B_b(x;y)$ is assumed to be circularly.

The localization starts in phase 1. Each beacon transmits a signal containing its own position. All sensor nodes in range receiving this signal save the position. In phase 2, each sensor node estimates its own position by simply calculating the centroid of the known beacon positions.

$$\underline{P}_{CL} = \begin{pmatrix} x \\ y \end{pmatrix} = \frac{1}{n} \begin{pmatrix} \sum_{i=1}^{n} B_{i,x} \\ \sum_{i=1}^{n} B_{i,y} \end{pmatrix} \quad (1)$$

In sensor networks using small transmission ranges ($tr<fq$), characteristical overlapping regions (e.g. $A_1..A_3$) are formed. All sensor nodes within this region receive the same beacons positions and determine therefore the same position in the centroid of the region. The localization error depends on the distance between the real position and the estimated centroid position. Hence, overlapping regions should be as small as possible to prevent high localization errors.

In huge beacon networks, these overlapping regions emerge in each square of beacons ($fq \times fq$) and are similar to each other. Thus, the behavior of the localization error is constant in each square (Fig. 1).

In case of high transmission ranges ($tr>fq$), different overlapping regions emerge depending on the location within the beacon network. In the center of the network, there are very small overlapping regions. **Fig. 2**a shows the resulting region A_1, if 9 beacon positions were received by P_1.

At the borderline of a beacon network, a similar configuration of beacons and sensor node P_2 results in a significantly greater overlapping region A_2 (**Fig. 2**b). In contrast to P_1 and its overlapping region A_1, P_2 received only 4 beacons.

This paper presents a new approach to decrease the before mentioned localization error in border areas of the network. Therefore, a node tries to detect whether it is at a border region or not. If it is in a border region, it must determine the direction to the border. In case of a grid aligned beacon network, this direction may be left, right, top, or bottom. To detect a border node, all beacons have to send besides their own position additional pre-acquired information about their surrounding especially their neighboring

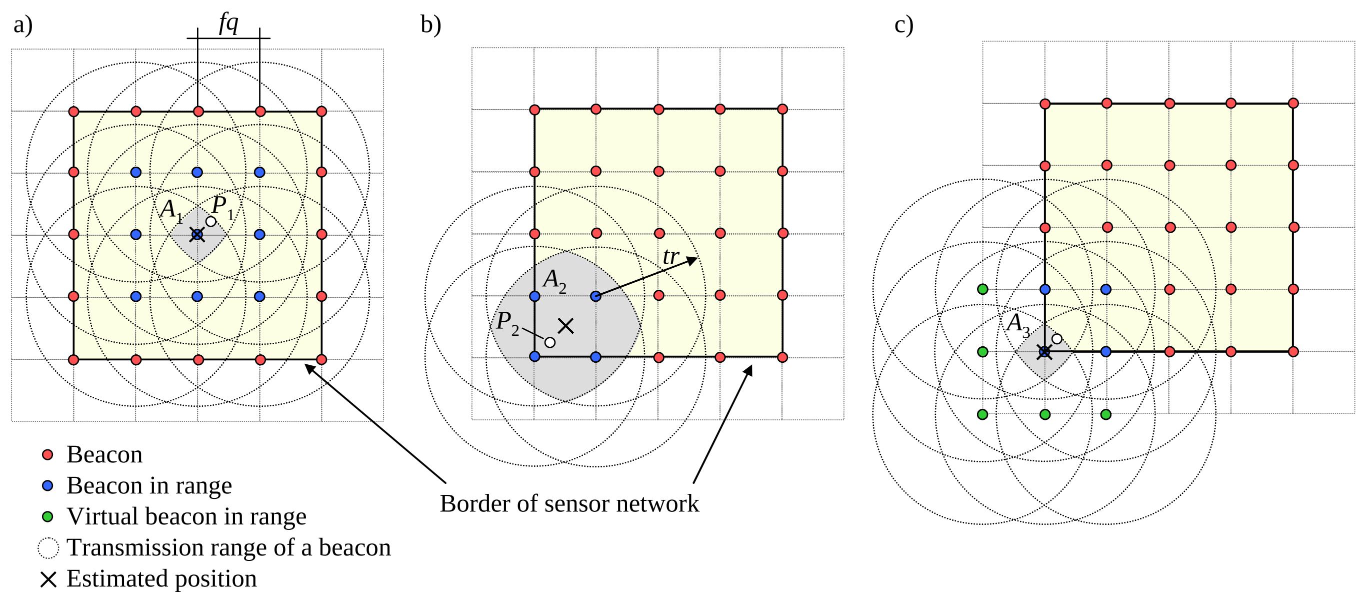

Fig. 2. Centroid localization in a grid based network of beacons a) in the center b) at an edge c) at an edge with virtual beacons

nodes and their direction to the borders of the network.

After determining the direction to the border, it is necessary to calculate the maximal beacon distance d_B a node can detect by down-scaling the doubled transmission range to a multiple of fq [3]

$$d_B = \left\lfloor \frac{2tr}{fq} \right\rfloor fq \tag{1}$$

Assume, a node P_1 lies at the left border of a network as visualized in **Fig. 3**. Then, it can receive only beacon positions from 7 blue marked beacons. If there were additional grid-aligned beacons at x = -25, the node would receive 10 signals. But there are not, that's why the estimated coordinate is x=(3·0+3·25+50)/7=17 instead of x=12.5 in the ideal case.

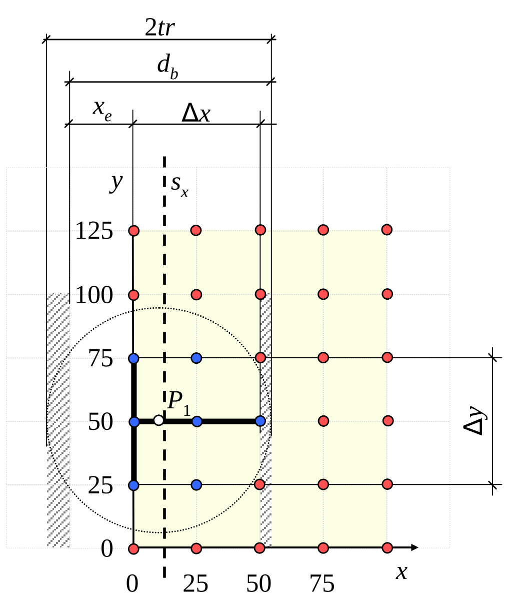

Fig. 3. Localization error of centroid localization

To correct this increased localization error, the algorithm determines the largest coordinate x_{max}=50 and simply reduces it by the half of the maximal beacon distance d_B/2. The resulting value s_x represents the best approximated solution in this case and is concurrently one axis of reflection.

If a node is at another edge or at a corner, then the presented calculation instructions must be applied contrary respectively twice. **Fig. 2**c visualizes an adequate solution for the localization of P_2 at a corner. There, all known beacons positions are reflected at s_x=0 and s_y=0. Therefore, 5 new virtual and non-existing beacons are generated. The overlapping of all transmission areas of all 9 beacons results in A_3 which is much smaller than A_2 and is similar to A_1 located in the center of the network. The centroid localization of all 9 beacons estimates the node at P_2(0;0) and reduces the localization error significantly.

To sum up, ClwEC is a very easy and resource aware algorithm to correct positions near the borderline. In most cases, the averaged localization error reduces to the half depending on the transmission range and the network's width.

Acknowledgment

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