Range-based Localization implanting Packet Reception Derived Range for Sparse Distributed Wireless Sensor Networks

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Abstract

In centralized range-based localization techniques, sufficiency of inter-node range information received by the base station is strongly affects nodes position estimation accuracy. In real flooded wireless sensor networks (WSNs), the density of network will be varying from part to part. Nodes spared in low density part will potentially have insufficient or even none range information. This research proposed a range-based localization method for sparse distributed WSNs which combined measured range and non-confidential range derived from the packet reception rate (PRR) for cases of insufficiency range information.

Keywords: Wireless sensor networks, sparse distributed, range-based localization

1. Introduction

In many WSNs applications, nodes positional information is needed for data monitoring, reporting and analysis. Some WSNs have solid information of nodes location, so it is easy to plot the information. Other cases, nodes are flooded without knowing their land position, so a localization process is required[1-2].

In centralized range-based localization, adequate inter-node range information is needed. Depend on network condition, ununiformed nodes deployment will leads to a sparse condition, where some nodes will have insufficient or even none inter-node range information. This research proposes the use of packet reception rate as complementary range information to overcome the problem incomplete inter-node range.

2. Problem state of art

Fig. 1 describes insufficiency of inter-node range information which causing non-uniqueness estimated position of node k. An iterative localization program (ILP), for instance, a steepest descent (ILP/SD) protocol principally works by finding minimum error between measured ranges and ranges calculated from estimated position.

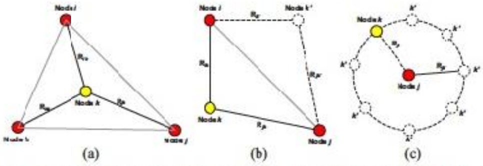

Fig. 1 Two dimensional example of minimum sufficient range data (a) and non-uniqueness caused by range insufficiency (b and c)

Presences of spared node with insufficient inter-node range information will diverse possibility of estimated location. The calculated range will close to the actual range for every of local minimum. In case of fig. 1(b), for each presence of such node, probability to get the right local minimum solution will be decreased by half. Worst condition described by fig 1(c), where there are unlimited possibilities of local minimums.

A solution for fig. 1(b) cases utilizing presence and non-presence of connections has proposed in [1]. However, it is still difficult to solve such fig. 1(c) cases. To overcome such uncertainty, range derived from non-range parameter has used somehow to assist the ILP/SD approximate location of node k.

3. Proposed solution

A. PRR derived range

Fig. 2 left shows a coarse measurement of PRR in an infrared based WSNs [3]. Similar characteristic example of PRR for radio frequency (RF) based WSN found in [4], as shown in fig. 2 right.

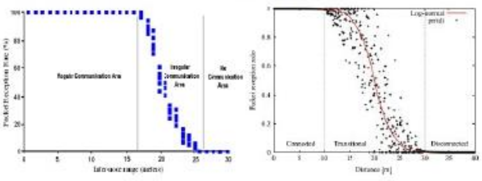

Fig. 2 PRR vs. distance example for IR (left) and RF (right)

Suppose, R_k is range between two nodes, R_b is the maximum range of regular communication and R_m is the maximum communication range. From several models have been created and tested, eq. 1 has been used as the general model of PRR between R_b and R_m.

$$PRR_k = \frac{e^{-(A-\frac{B}{2})}}{1+e^{-(A-\frac{B}{2})}} - rand(irreg) \cdot log\left(\frac{9A+B}{B}\right) \quad (1)$$

Where $A = R_k - R_b$ and $B = R_m - R_b$. PRR is one below R_b and zero above the R_m. Non-confidential range, PRRR, can be estimated from PRR by inversing the non-irregular part of eq. 1 function, as shown by eq. 2

$$PRRR_k \cong Rm + log\left(-\frac{(PRR(R_k)-1)e^{-\frac{(R_m-R_b)}{2}}}{PRR(R_k)}\right) \quad (2)$$

B. Modified ILP/SD embedding PRR derived range

Fig. 3 shows a modified ILP/SD protocol for sparse WSNs. Inner box is the standard ILP/SD protocol. Degree of sparsity (DoS) evaluated from range matrix by eq. (3) right hand side, with n is node numbers and k_i is edge of node-i. If DoS is less than a DoS_limit, l, the PRR ranges (PRRR) matrix will be inserted.

$$\mathrm{R} = \mathrm{R} + \mathrm{PRRR} \leftarrow DoS = \frac{1}{n(n-1)} \sum_{i=1}^{n} k_i \leq l \quad (3)$$

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-   For i=1 to N (node numbers)
      o  Range data sufficiency test
      o  If DoS ≤ DoS_limit insert PRRR
-   End

    - Set initial position
    - For k=1 to max iteration
        o Update position
        o Errors(k)=R(k)-R'(k)
        o If max(Error)< threshold
          (local minimum)→ Stop
    - End
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Fig. 3 Introducing PRR derived range in ILP/SD protocol

3. Simulation result and discussion

Table 1 shows a real test node properties adopted in the simulation. Square network field had been assumed with four anchor nodes on four corners of the field and 16 non-anchor nodes. Field size is the subject of change according to degree of sparsity observed.

Tabel 1. Test node properties

Node parameter	Value
Irregular communication boundary (R_m)	27.5 m
Regular communication boundary (R_b)	16.5 m
Maximum measurable range	16.5 m
Maximum range error	0.3 m
Irregularity factor	0.2

A. PRR derived range simulation

Fig. 4 shows the absolute error of maximum PRR derived range compared to fig. 2 measurement data. Error deviation of PRRR is $\underline{+}0.94$ meter or 1.88 meter which is three times compared to measured range error which is 0.3 meter.

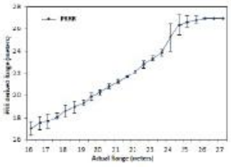

Fig. 4 PRRR and its errors deviation for the test node

B. Localization performance simulation

Fig. 5 shows localization error comparison of normal ILP/SD and ILP/SD with PRRR according to the degree of sparsity (DoS) values.

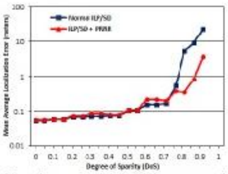

Fig. 5 Localization accuracy for normal and PRRR

At low DoS both method has a very close error performance, however, over DoS=0.7, where average node range is less than five, the ILP/SD+PRRR has successfully suppress location error to around 29 to 93 percent lower than the normal ILP/SD.

5. Conclusion

A new approach for increasing robustness of range based localization in sparse distributed WSNs has been introduced. PRR derived range data have been used as complementary information to the real range measured data, which successfully help the iteration localization program as steepest descent (ILP/SD) to complete iteration with better accuracy in very sparse condition.

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