Measurement 55 (2014) 423–433

Contents lists available at ScienceDirect

Measurement

journal homepage: www.elsevier.com/locate/measurement

DDEUDSC: A Dynamic Distance Estimation using Uncertain Data Stream Clustering in mobile wireless sensor networks

Qinghua Luo [a,c], Xiaozhen Yan [a,*], Junbao Li [b], Yu Peng [b]

[a] Automatic Test and Control Institute, School of Information and Electrical Engineering, Harbin Institute of Technology at WeiHai, WeiHai, China
[b] Automatic Test and Control Institute, School of Electrical Engineering and Automation, Harbin Institute of Technology, Harbin, China
[c] Guangxi Key Laboratory of Automatic Detecting Technology and Instruments, School of Electronic Engineering and Automation, Guilin University of Electronic Technology, Guilin, China

ARTICLE INFO

Article history:
Received 8 March 2014
Received in revised form 16 May 2014
Accepted 30 May 2014
Available online 12 June 2014

Keywords:
Uncertain data stream
Clustering algorithm
Interval data
Dynamic distance estimation
RSSI

ABSTRACT

In RSSI (Received Signal Strength Indicator)-based communication distance estimation of mobile wireless sensor network localization, RSSI is assumed to exponential attenuation with increment of communication distance in ideal radio propagation models, which is invalid due to the uncertainty of RSSI data in real communication environment, resulting in considerable error of communication distance estimation. Moreover, dynamic distance estimation demands a high efficiency of computation for the continual generation of RSSI data stream in the mobile node. This paper develops a new dynamic communication distance estimation method using uncertain interval data stream clustering, named as DDEUDSC (Dynamic Distance Estimation method using Uncertain Data Stream Clustering). First, statistical information of RSSI data is used to represent the RSSI-D mapping relationship in terms of interval data. Then we consider the data pattern composed of some consecutive cluster centers, and apply it in our uncertain RSSI data stream clustering algorithm to estimate the dynamic communication distance. Finally, RSSI data streams in three typical communication environments are conducted for experiments. The experimental results show the proposed method is an effective way to improve RSSI-D estimation precision in RSSI data stream with uncertainty and dynamics characteristic.

1. Introduction

Recently, wireless sensor network (WSN) attracts numerous scholars' concern and reaped rich fruits [1–3]. Dynamic localization in wireless sensor networks has received considerable interest and wide application in recent years, e.g. the traction of mobile target and location-based service. In mobile wireless sensor networks (MWSN), dynamic localization can be achieved by performing periodic static localization and filling in the gaps through an appropriate distance estimation technique [4,5].

During the process of dynamic range-based localization, communication distance is needed to be estimated for localization. Communication distance could be estimated by using RSSI (Received Signal Strength Indicator), TOA (Time of Arrival), TDOA (Time Difference of Arrival), and AOA (Angle of Arrival) techniques, among which RSSI-based distance estimation methods are widely used in range-based WSN localization in terms of the advantages of low cost, low power, no extra hardware and accessibility.

In dynamic localization system, the unknown node is assumed to be mobile, and its location information is

* Corresponding author. Tel.: +86 6315678234.
E-mail addresses: luoqinghua081519@163.com (Q. Luo), yxz_heu@163.com (X. Yan), junbaolihit@126.com (J. Li), Pony911@163.com (Y. Peng).

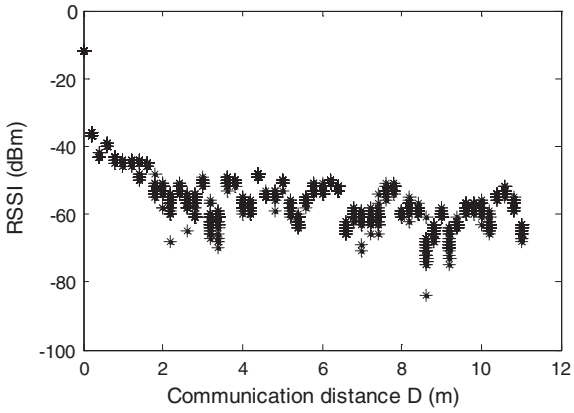
http://dx.doi.org/10.1016/j.measurement.2014.05.040
0263-2241/

changed continually, so the WSN localization should be taken at a regular interval accordingly. The unknown node will measure continually the RSSI of the radio signal from the surrounding anchor nodes, so as to estimation the communication distance, and the sequential RSSI data form a data stream [6]. A data stream is a real-time, continuous, ordered sequence of data [6]. So we should take high efficient and On-line process strategy for RSSI data stream.

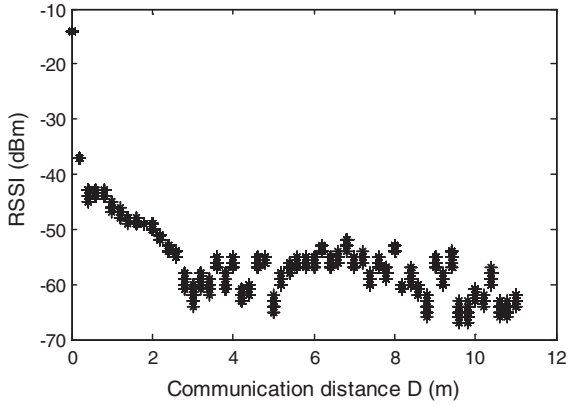
In range-based localization algorithms, localization precision greatly depends on the estimation accuracy of the communication distance between the anchor nodes and unknown nodes (to locate the node) [7]. In this paper, we focus on how to estimate communication distance based on RSSI data stream in dynamic WSN localization, which is a very challenge work because in addition to uncertainty caused by negative impact of many environmental factors, there is also a challenge of RSSI data dynamic change produced by continually changes of communication distance [4]. As a result, the RSSI data stream has the characteristics of a high level of uncertainty and dynamic change, which presents challenges to communication distance estimation in dynamic environments.

1. Dynamic refreshment requirement [4]. As the location of unknown node changes continually, the RSSI data also dynamic changes accordingly, leading to higher request of distance estimation.
2. Uncertain data processing requirement [8]. In real systems, there are uncertainties in arriving signal strength due to the influence of environmental factors such as reflection, refraction, multi-path transmission, antenna gain, and many other obstacle blocks [9]. In three typical environments which are corridor, indoor hall and open air, we measure the RSSI data of radio signal of different communication distances using two CC2530 sensor nodes, as shown in Fig. 1. From Fig. 1, we can see that there is considerable uncertainty in the RSSI data: (1) the RSSI data attenuate generally as the distance increases, but there exists oscillation in the RSSI-D relation curve. (2) On the same communication distance point, the distribution of RSSI data is not concentrated, or even scattered.
3. Computation efficiency of distance estimation requirement [4]. As the localization of wireless sensor dynamic changes, the computation and update of localization should be done efficiently. In the process of dynamic localization, the dynamic distance estimation should be done efficiently accordingly.

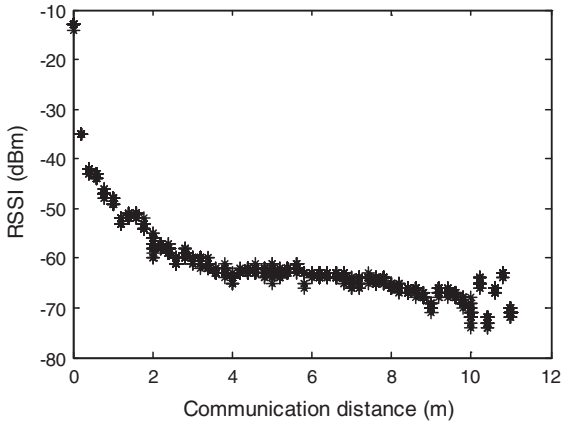
It will lead to 50% distance estimation error or even worse without an effective method to meet the challenges mentioned above [10]. The dynamic communication distance estimation methods of mobile WSN node can be divided into two groups [6]: (1) one is based on ideal propagation model of radio signal [11,12] which does not need extra hardware and computation, however, due to the uncertainty and dynamic of RSSI data, the relationship between RSSI data and communication distance can hardly meet the ideal propagation, which leads to considerable distance estimation error. In this case, the measurement of RSSI data in the specific communication environment and RSSI-D modeling should be done in advance. (2) The other one is based on mapping relation between RSSI data and communication distance [9,10,13–15]. The RSSI measurement and RSSI-D mapping training should be done in advance to obtain the RSSI-D mapping relation, and then



(a) Indoor corridor



(b) Indoor hall



(c) Open air

Fig. 1. The relation between RSSI and communication distance.