Virtual WiFi Network Database Construction for Positioning Services

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ABSTRACT

WiFi-based location based services (LBSs) are expected to be more and more pervasive in future Internet. In WiFi networks, a virtual network database (VNDB), which maintains the estimated locations of access points (APs), should be constructed for the localization. Since the quality of the LBS is mainly determined by the location accuracy, it is essential to maintain accurate VNDBs for the LBS. In this paper, we propose two novel filtering methods to construct accurate VNDBs for the WiFi-based localization: RSS filtering and grid-based filtering. Experimental results on a real testbed show that the proposed methods construct a VNDB accurately and localization results with the accurate VNDB are comparable to those with a real network database (RNDB).

Categories and Subject Descriptors

C.2.8 [**Communication/Networking and Information Technology**]: Mobile Computing Support Service

Keywords

Received Signal Strength, Localization, WiFi, Access Point, War-Driving

1. INTRODUCTION

Location based services (LBSs) are expected to be more and more pervasive in future Internet. Google's Latitude services [1] and iPhone's Loopt services [2] are good examples of LBSs. Since the quality of the LBS is mainly determined by the location accuracy, precise localization is viable for LBS.

Localization techniques can be classified into two main categories: GPS-based and network-based approaches. Even though the GPS-based approach locates a terminal accurately, it has some limitations such as indoor coverage problems and additional hardware costs. On the other hand, the network-based approach does not need any additional hardware since it exploits the existing network infrastructure.

Due to these advantages, several network-based localization technologies have been developed in cellular, WiFi, and sensor networks [11, 13]. Among them, the WiFi based localization is currently gaining much attention since it provides high accuracy in urban areas due to dense deployments of inexpensive WiFi access points (APs). Consequently, many hand-held devices such as iPhone and iPod touch start LBSs based on WiFi-based localization [3].

In general, network-based localization systems normally employ network databases (NDBs) which maintain the location information of reference points (e.g. WiFi APs, Cellular BSs) to estimate users' locations. In planned networks such as cellular networks, a network provider can manage an NDB which keeps the actual location of BSs. We call it a real NDB (*RNDB*). In WiFi networks, however, an RNDB cannot be maintained since many private users may install their own APs personally. Therefore, a virtual NDB (*VNDB*), which maintains the estimated locations of APs, should be constructed for localization in WiFi networks.

Since the accuracy of a VNDB highly affects the performance of localization, it is an important issue to construct a VNDB accurately for LBSs in WiFi networks. In this paper, we propose a novel method to construct the VNDB accurately for WiFi-based localization. Our contributions are summarized as follows: (i) we construct a VNDB for WiFi-based localization on a real testbed, (ii) we propose two filtering strategies (i.e., Received Signal Strength (RSS) filtering and Grid-based filtering) to improve the accuracy of the VNDB, (iii) we show that a VNDB-based localization achieves comparable performance to an RNDB-based one.

This paper is organized as follows. First, we describe novel methods to construct an accurate VNDB in Section 2. Section 3 shows results of an VNDB-based localization scheme on a real testbed. Section 4 outlines related work, and then we conclude this paper with future work in Section 5.

2. VIRTUAL NETWORK DATABASE (VNDB) CONSTRUCTION

This section describes how to estimate AP positions for a virtual network database (VNDB). A VNDB maintains APs' estimated positions, which will be used as the basis for user location determination. We estimate an AP's position by the weighted average of positions where its signals are

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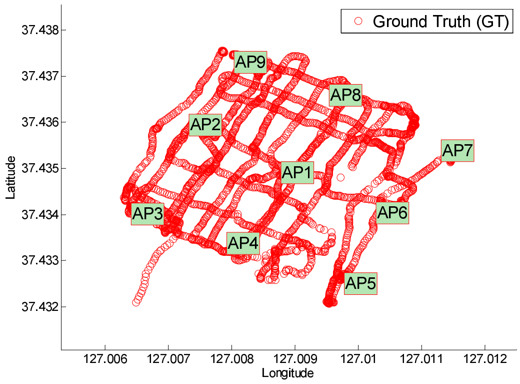

Figure 1: A trajectory through war-driving for constructing a VNDB in a parking place

captured. So, the weight w_i is a function of the distance d_i between the AP and position i where the signal is captured. w_i can be calculated using the following equation.

$$w_i = \frac{1}{{d_i}^2}$$

Here, d_i can be obtained from the Received Signal Strength (RSS) information [13]. After calculating weight w_i, an AP's estimated position $(\hat{x}, \hat{y})$ can be calculated using the following equation where (x_i, y_i) means the positions where the signals are captured.

$$(\hat{x}, \hat{y}) = \frac{\sum_{i=1}^{n} w_i \cdot (x_i, y_i)}{\sum_{i=1}^{n} w_i}$$

However, estimating distance d_i using all the RSS information is often inaccurate due to interference and shadowing. Therefore, we propose two filtering strategies to improve the accuracy of a VNDB: RSS filtering and Grid-based filtering.

RSS filtering uses only strong RSS data to estimate APs' positions. It only uses top 1% rank of strong RSS data for the estimation. RSS filtering is simple and easy to apply. However, if strong RSS data are not uniformly distributed, the estimation of AP positions might be inaccurate.

To overcome this sampling bias problem, we propose the second strategy called Grid-based filtering. We first divide the area into $5 \times 5m^2$ grids and assign the average of strong RSS data to each grid. We then use the average of each grid to estimate an AP's position. If the number of RSS data samples in a grid is less than two, we exclude the grid from the calculation since the data of the grid might be too biased. This approach can overcome the sampling bias problem, but the computing cost is higher than RSS filtering.

3. EXPERIMENTATION

In this section, we evaluate efficacy of the proposed methods to construct a precise VNDB and the performance of localization using the VNDB on a real testbed.

We arrange 3×3 APs at distance of 200m in a parking place. The parking lot is an open place and there are no other APs, thus we can carry out experiments without any interference from environments.

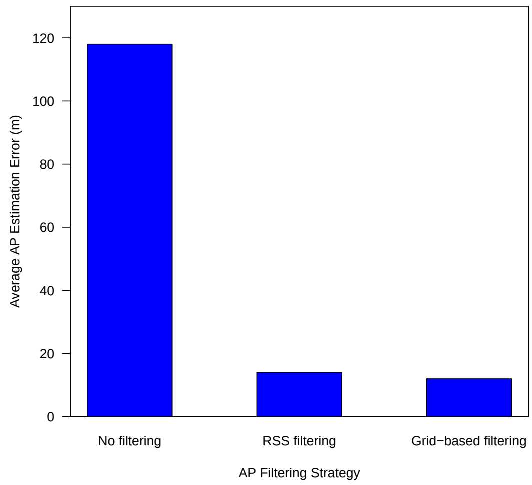

Figure 2: VNDB accuracy for each filtering strategy

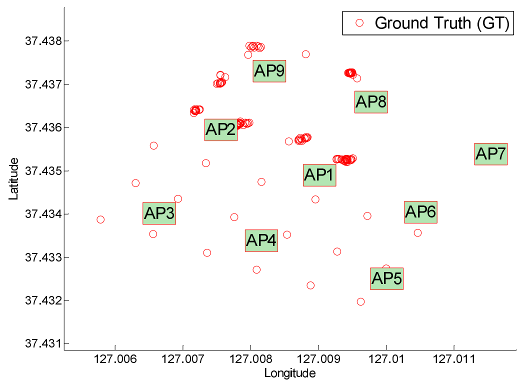

Figure 3: Some specific positions for real localizations in a parking place

We first collect 802.11 beacon signals from the APs using NetStumbler v0.4 through war-driving [10]. Figure 1 illustrates real positions of APs and a trajectory of war-driving. We then construct a VNDB for each of the three approaches (i.e., No filtering, RSS filtering, Grid-based filtering) as explained in the previous section.

Figure 2 shows the estimation error of APs' positions for each method. When we use all collected RSS data from 9 APs (i.e., No filtering), the average estimation error is about 118m. However, with RSS filtering, the mean estimation error for APs' positions is only 14m. From this result, we infer that strong RSS information is more useful since weak RSS might be influenced by interference and fading. Meanwhile, the average error of Grid-based filtering is just 12m which is the best result among the three strategies. Even though the computing cost of the Grid-based filtering method is higher than others, the Grid-based filtering method overcomes the sampling bias problem, which results in the highest performance.

To validate the effectiveness of VNDBs, we perform real localizations at some specific positions using an RNDB and VNDBs. Figure 3 shows the specific positions at which we perform localizations. We use three different VNDBs

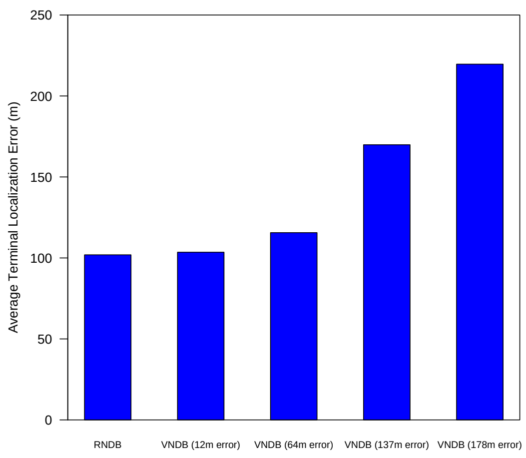

Figure 4: Terminal Localization using RNDB and VNDBs

of which average estimation errors are 12m, 64m, 137m and 178m as the grid size varies $5 \times 5m^2$, $100 \times 100m^2$, $200 \times 200m^2$ and $300 \times 300m^2$, respectively. Figure 4 shows the results of the average terminal localization errors when using the RNDB and three different VNDBs. As shown in Figure 4, when the average error of a VNDB is small, the VNDB shows comparable performance to the RNDB. Therefore, an accurate VNDB estimates terminals' locations as accurately as the RNDB.

4. RELATED WORK

To localize APs' positions (i.e, to construct VNDBs), WiFi beacon signals should be collected. This signal collecting process is called war-driving [10] since it is done by driving or walking through the area of interest. Many academic and industrial groups [6, 7, 8, 9, 12] have exploited the war-driving data from the web archives [4, 5] or their own data for their experiments. Also some private companies such as Skyhook Wireless [3] collected war-driving data by themselves and have maintained their own AP maps (i.e., a VNDB) for the commercial LBSs. However, none of them considered the accuracy of war-driving data which might contain erroneous noise due to complex nature of signal propagation.

M. Kim et al. [10] showed the risks of using biased war-driving data for the localization. Since measurement points might be biased towards war-driving paths, the authors stressed the proper war-driving strategy for path-planning. Even though their suggestion is considerable, they did not mention any filtering method for the war-driving data to improve the accuracy. In this paper, we proposed two filtering methods and showed that they can be used to refine war-driving data, and consequently to improve the accuracy of the estimation of APs' locations. Also, to the best of our knowledge, this is the first work which shows that localization with an accurate VNDB achieves comparable performance to an RNDB-based one.

5. CONCLUSION AND FUTURE WORK

As WiFi based localization technologies are viable, accurate VNDB construction is becoming more important. In this paper, we proposed two novel methods to construct accurate VNDBs for the WiFi-based localization. Experimental results on a real testbed show that the proposed methods construct VNDB accurately and the localization results with an accurate VNDB are comparable to those with an RNDB. We are planning to explore a stochastic approach to construct a precise VNDB and carry out more experiments on urban areas.

6. ACKNOWLEDGMENTS

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