Preface

Wireless Ad Hoc Sensor Networks (WASNs or WSN) have shown strong potential in various applications, where many are location-dependent applications. Currently, researchers still face several challenges for massive deployment of such networks. While identifying the locations of wireless sensor nodes is one of the most canonical and enabling problems, it is also a challenging task because of the severe constraints on cost, energy, and effective range of sensor devices.

We address several aspects of the location discovery problem in wireless sensor networks. From the application point of view, high-accuracy location discovery is our ultimate goal. We present high-precision location discovery algorithms while satisfying the user's constraints and when compared with other state-of-the-art location discovery algorithms. From the modeling point of view, our goal is to identify factors that influence location discovery accuracy and establish relationships between different properties of the network and the corresponding location error, in addition to dependencies among the properties. We use nonparametric statistical methods and rely on the concept of joint probability to construct measurement error models, environmental/field models, and location error models. From the optimization point of view, we post the location discovery problem as a Nonlinear Programming problem due to its NP-completeness. However, if a related subproblem can be solved optimally, we linearize the set of equations and use existing linear or Convex Programming techniques to solve. Other NP-complete subproblems are proven and solved using Nonlinear Programming methods. To be relevant and useful in reality, we make the abstractions, assumptions, and the experimental settings resemble reality as much as possible. All of our techniques and algorithms are data-driven in the sense that all the models and algorithms are developed based on sensor data collected in actual deployed networks. We evaluate our techniques by varying realistic parameters and simulating indoor and outdoor environments. All the instances are generated based on the properties extracted from real sensor data.

We organize this book in a top–down and easy-to-complex manner. We first assume the availability of known models that can be served as the location discovery optimization objective. This is served as a lower bound for the purse of

performance comparison. Then, we establish solutions in more comprehensive and realistic situations, such as when there are missing, faulty, and shortage of measurements, and there is no golden standard a priori. Then, we address the problem of how to improve the location accuracy post deployment by adding a single beacon or an unknown node. Finally, we target the problem of creating network infrastructure, infrastructure engineering change, and organizing the beacon broadcast operations.

Our location discovery techniques are all based on data-driven coordinated algorithms and statistically constructed models. In addition to constructing error models that guide the optimization process, we also address system issues such as the beacon broadcast and beacon-scheduling problems. We introduce the location discovery Infrastructure problem and analyze the solution by varying numerous parameters such as the average connectivity and network size. With the average and median input measurement error being 6.73 and 0.74 m, respectively, we were able to achieve an average location error of 0.05 m when the optimization objective is the error model constructed using Kernel density estimation method (Chap. 3); an average location error of 0.03 m when the optimization objective is the consistency-based error models (Chap. 4). In terms of location discovery infrastructure, our beacon placement technique (Chap. 5) was able to reduce the average location error by 40 and 20% when compared with placing beacons randomly and based on the greedy heuristic respectively. Our location discovery engineering change technique (Chap. 6) was able to improve the average location error by 16.9% when positioning additional nodes simultaneously.



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