Abstract

Estimating the position of a target device using Wireless Sensor Networks (WSN) has gained significant usage in smart indoor applications. This is typically accomplished by a to-and-fro communication between the device and wireless beacons which are essentially sensor nodes with known spatial locations. For indoor environments, the research over localization has evolved using the signal's propagation time, phase and strength in combination with popular short range communication standards such as WiFi, Bluetooth, ZigBee etc.

One of the promising domains in this direction remains with identifying the locations of beacons that provide optimum coverage and accuracy of localization while keeping the involved cost constrained. Finding an optimal configuration of sensors that maximizes localization accuracy and coverage, conforming to given placement constraints for indoor environments, is frequently termed as Beacon Placement Problem (BPP) or Sensor Placement Optimization (SPO). Solving a BPP is typically approached by linear programming or meta-heuristics optimization methods and proved to be NP-Hard with reference to the classical art gallery problem. Hardship in BPP's tractability is primarily attributed to the size of its search domain comprising of Candidate Device Locations (CDL) and correspondingly visible Candidate Beacon Locations (CBL) within the Region of Interest (RoI). The complexity of BPP's implementation gets severe with the transition from two dimensional (2D) to three dimensional (3D) localization perspective due to the significant increase in coordinate counts within the RoI. Also, due to the presence of static and dynamic obstacle elements in the RoI of practical indoor spaces along with application dependent constraints, benchmarking of BPP's complexity and optimization methods stands infeasible.

Available BPP approaches usually consider a 2D coordinate grid or floor planned designs for the RoI and perform Single Objective Optimization (SOO) for objectives such as coverage maximization, beacon count minimization and localization accuracy maximization. The research still lacks an exhaustive approach that can guide a system designer to choose a suitable beacon configuration in the presence of multiple practical objectives and algorithmic constraints. This thesis proposes a methodology that works by considering an indoor RoI comprising of 3D point clouds of CDL, CBL and Obstacle coordinates. We developed a novel point-to-point LoS detection algorithm that discovers CDL-CBL connectivity as an adjacency matrix. Using this adjacency information along with minimum connectivity and precision constraints, the BPP is approached by Multi Objective Optimization (MOO) for coverage-accuracy assessment. The proposed methodology is an optimization tool-chain that explores a set of Pareto optimal beacon configurations using the Non-dominated Sorting Genetic Algorithm (NSGA)-II. The optimizer generates beacon configurations prepared to tolerate 10, 20 and 30% of observation noise while providing GDoP values within 1, 2 and 5 as per the requirement. The derived non-dominant solutions are then analysed by simulations for their performance for accuracy and coverage over different indoor designs. The results suggest that configurations with over 80% of coverage and < 1 unit of accuracy are achievable for all the designs generated above using NSGA-II. Finally, a performance based ranking system is presented to recommend users a single optimal solution.