BeDIPS Development Environment (BDE)

The tasks of selecting a right location of each beacon, determining the coordinates of the location and installing the beacon at the coordinates would be prohibitive without the tools provided by the BeDIPS Development Environment (BDE) illustrated by Fig. 1. With the tools, however, the tasks are only slightly more demanding than the tasks of deploying RFID tagged and smoke detectors throughout the building.

![BeDIPS development environment](image)

Before describing how the BDE tools can support the design, configuration, installation and maintenance of the IPS for individual buildings, we note that BDE has three parts. The first part is the Building/environment Data and Information (BeDI) repository illustrated by the top part of Fig 1: The repository of a building is built on the BIM/FM database that was created and maintained for purposes from design, architect and construction of the building to managing the building and its facilities. We assume that every large public building has a BIM/FM database for reasons stated in Section II(C). The virtual BeDI repository provides access to selected datasets within the BIM/FM database and supports digital exchange standards (e.g., [54]) for retrieving the data.

From the perspective of BeDIPS, it suffices that the BeDI repository provides exact 3D coordinates of every Lbeacon. The beacon is surely mounted on an object (e.g., a ceiling, a wall or next to a light) that is characterized by data in some datasets in the BIM. The coordinates are kept up to date during remodeling, renovation and maintenance since the BIM datasets on the model and characteristics of the object are updated during the BIM processes.

**Tools from BeDIPS Development Environment**

The second part of BDE is a project management system illustrated by the bottom part of Fig. 3. Through a dashboard, the system presents to the developer an overview of his/her projects. The developer can find here documentations and specifications. In particular, a catalog of Lbeacons provides everything he/she needs to know about them.

With rare exception, Lbeacons are installed on the ceilings. types of Lbeacons differ in their ranges and antenna radiation patterns. The lower right corner of Fig. 3 shows four types as examples. Each dashed circle or oval provides a rough view of the coverage area of a beacon. A complex building is likely to require several types. While Lbeacons with range around 3 meters are suitable for typical rooms, beacons with range 20 meters or more may be needed for multi-level halls. All of them have directional antennas with conical beams. Beacons with 3-meter range and 60-degree radiation pattern can provide 1.5-3 meter horizontal accuracy. Beacons with larger ranges need to have antennas with narrower (e.g., 30 degree) radiation patterns to achieve the same accuracy.

The third part of BDE is a plugin of the widely used BIM software Autodesk Revit [57], which the developer can access from his/her dashboard. According to its Wikipedia definition, Revit enables users to design a building and building components in 3D, annotate the 3D models with textual and diagrammatic drafting elements, and maintain the design in the building’s BIM database. Revit rendering engine enables the user to visualize the stored models as 2D and 3D images.

The middle part of Fig. 3 illustrates a typical use scenario of BDE: The developer accesses the BDE Revit plugin by clicking the Autodesk button in the panel for his/her current project. In response, the plugin presents to the developer with 2D and 3D images of parts of the building selected by the developer.

**Design and Deployment**

The process of design and deployment of a positioning system in a building starts from getting Revit plugin to display the floor plan and 2D-3D images of each area (e.g., office area, a corridor, and a large hall) to be covered by Lbeacons. Graphical and visualization tools built on the 2D-3D geometric models such as the ones illustrated by the middle part of the Fig. 3 can help the developer select the right type of Lbeacon for each location, experiment with the placements and orientations of the selected beacons, and visualize and assess the coverage provided by them. In the example scenario shown in Fig. 3, the developer is working on the selections and placements of Lbeacons in an office area. The floor plan in the middle shows a partially completed layout of beacons for the area. Except for the corridors, where the desired accuracy is around 1.5 to 3 meters, the desired accuracy is room level. This is indicated by the developer’s choices of using beacons with small coverage area in corridors and beacons with large coverage in rooms.

Upon finding a satisfactory design for the area, the developer has the plugin generate, for each beacon to be installed in the area, its 2D barcode (i.e., its UID), type and coordinates. In addition, the plugin also generates the coordinates of a reference point for the area. The reference point is a location in the area that can be easily pinpointed by the installer. Examples include the south-west corner of the room and the left inside frame of a specified door. The coordinates of the reference
point is used during installation as described below. The data generated by the Revit plugin for each area of the building when the design process completes are stored in the BeDI repository and managed by the BeDIS server.

To make Lbeacons for each area ready for installation, the installer fixes the barcode and loads the coordinates and location description of each Lbeacon on the beacon using the user interface and tools provided by the BeDIS server. The installation is carried out with the help of an installation tool that has a barcode scanner, a servomotor controlled laser pointer and network connection to BeDIS server. To install Lbeacons in an area, the installer places the tool at the reference point of the area and uses the tool to retrieve from the server the coordinates of the reference point and the barcode ids of all the Lbeacons for the area. To install a Lbeacon, he/she has the barcode of the beacon scanned by the tool. After verifying that the Lbeacon is for the area, the tool reads the coordinates of the beacon and based on the coordinates of the reference point and the beacon, directs the laser pointer to point to the spot on the ceiling where the beacon should be placed. In this way, the tool enables the installer to easily locate the point on the ceiling with the beacon's coordinates. Fig. 2 shows a photo of the installation tool and illustrates this scenario: Here, the installation tool points to the location on the ceiling where the beacon on the right should be installed.