Demo: Indoor Location for Smart Environments

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***Abstract*—The rapid growth of ubiquitous location-based services has made indoor localization and navigation an interesting topic. This demo will present Smart Syndesi, a system for creating indoor location-aware smart building environments using wireless sensor and actuator networks (WSANs). Smart Syndesi includes a smartphone-based indoor tracking system and a WSAN for indoor environmental monitoring and activation automation. The smartphone indoor positioning system tracks the real-time location of users with high accuracy, which works as a basis for indoor location-based sensor actuation automation.**

Keywords: Indoor Positioning, Smart Environment Automation, Wireless Sensor and Actuator Networks.

I. Introduction

Smart environments, for instance smart offices, are expected to be intelligent and human-aware. Understanding human beings and their context certainly helps to facilitate the development of smart environment applications. Home or office automation, targets to provide convenient, comfortable, and energy efficient home or working environments to their occupants via the automation of home or office appliances. For instance, when a person enters the office room, the lighting system should be switched on and configured to a luminance level that is of his/her preference.

Given the previous examples, intelligent automation is the key target in smart environment applications. To achieve this, both software intelligence and hardware automation procedures are needed. That means the ”smart environments” are really ”smart” only if they are aware of human status such as their location, preferences, intentions, etc. Intelligent algorithms should detect human status first, which will then trigger the hardware automation procedure.

To provide software intelligence aware of human status, such as indoor location, an efficient and accurate indoor positioning system is required. Moreover, an infrastructure management platform, such as a wireless sensor and actuator network, should be established to connect the software intelligence with hardware appliances such that intelligent decisions could trigger the electrical appliances.

This demonstration will showcase a smartphone-based indoor positioning system in a smart office testbed, integrated with an indoor location-aware electronic appliances automation procedure [1]. We will also showcase the automatic sensor data retrieval procedure, which is a feature of the smartphone application. We will distribute multiple smartphones to the audience and let them try out the smart environment system.

II. System Architecture

Figure 1 details the architecture of the proposed indoor location-aware smart environment system. The smartphone application encloses two of the main system components, the indoor localization engine and the human-centric actuation automation engine. The app also gathers the smartphone’s sensor measurements for monitoring purposes, although this is not the focus on this demo. The indoor localization and navigation engine estimates the indoor location of users in real-time and the human-centric actuation automation module is responsible for activating the correlated actuators automatically based on the estimated user locations. This happens through the WSAN management platform which is responsible for creating and managing personalized smart environments and it can control electronic appliances via an electrical interface. A full deployment of the Smart Syndesi framework was performed in four offices at the University of Geneva with a successful overall system evaluation [1].

The core of the WSAN management platform is implemented on the gateway server [2]. It serves as a connection point for all the elements and components of the WSAN, the mobile application, the web etc. Every service or resource is provided as a web service, in the form of a RESTful API deployed also in the gateway server, and linked to the web through a proxy service. As REST architecture implies, the API calls have the simple form of an URI utilizing GET or POST methods. At the University of Geneva, we have implemented a gateway server using a Linux machine, although a lightweight implementation, where the gateway server is hosted on a Raspberry Pi 3, has also been tested and will be used for this demo.

To localize a person in an indoor environment, we have designed an indoor positioning system to support real-time indoor localization. Our approach [3] is able to provide high accuracy by fusing smartphone’s on-board sensor readings, such as Inertial Measurement Unit (IMU), Wi-Fi received signal strength (RSS), and floor plan information in a particle filter. Figure 2 shows the design of the indoor localization module. Information about the area of interest is used to further improve the tracking accuracy. Radio information needs to be converted to range values. In order to achieve high ranging accuracy we adopt the Non-Linear Regression (NLR) model [4]. We propose a particle filter approach by fusing PDR, Wi-Fi, and floor plan information to support real-time tracking in indoor environments. Algorithm details can be found in [3].

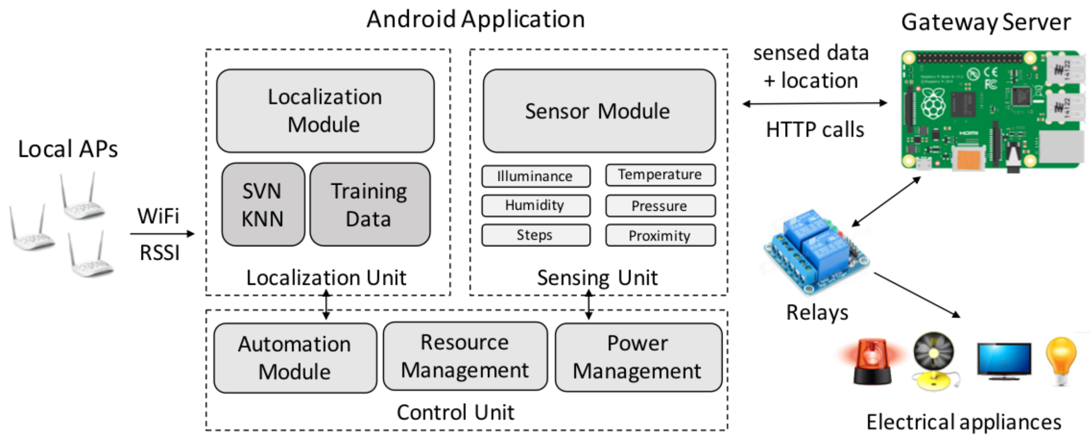

Figure 1: System architecture

III. Demonstration

We plan to demonstrate Smart Syndesi by disseminating smartphones to the audience and asking them to walk normally through the demo venue. The audience should walk while holding smartphones equipped with the Smart Syndesi app installed and running in the front-end. Automatic triggering of electric lights installed on our booth, based on detected indoor location, will be then enabled from the app via the WSAN. In detail, when a person holding the smartphone walks through the room his/her indoor locations is estimated in real-time fashion. When the person approaches the actuators, his/her estimated indoor location should automatically trigger the actuator, once a location match is detected on the app thanks to the accurate indoor localization mechanisms. When that happens, the relay receives a 3V output from the actuator mote and the current generated from this voltage enables the relay's underlying circuit, which provides the 220V power supply to the electric lights and they are switched on automatically. As shown in the screenshot in Figure 3, the "environment control" feature of the app correctly triggers the specific appliances based on user settings, displaying in its graphical interface the automation status based on the current location. Figure 4 shows the application home screen, where the latest sensor values are displayed as well as the current location and the server status.

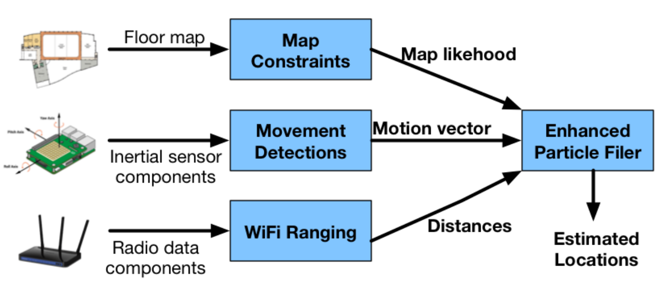

Figure 2: Indoor positioning system

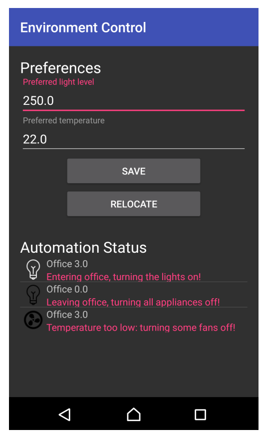

Figure 3: Automation.

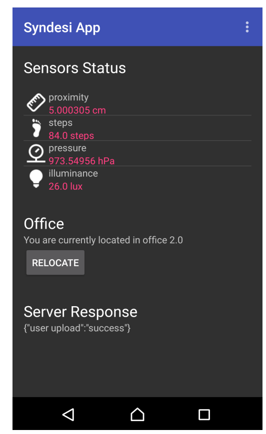

Figure 4: Sensors monitoring.

Before the live demonstration, we need to deploy the system in the room of the demonstration event. The deployment procedure includes the installation of multiple Wi-Fi APs (only need to be powered on, no internet connection required), and the data collection and training phase for the indoor localization module. On our poster booth, we will deploy the WSAN comprising of a Raspberry Pi 3 Model B [6] and XM1000 sensor motes [7]. Electrical appliances will be used as end actuation devices (e.g., desk lights), which will be connected to the sensor motes via solid state relays [8]. We will also deployed some electrical appliances to show that they can be triggered by detected indoor locations. The Smart Syndesi Android application will then be able to connect with the WSAN and trigger the actuators remotely.

The proposed prototype has been already implemented and tested in an experiment scenario with predefined walking paths at the premises of the University of Geneva. Figure 5 shows a plan of the 4 offices along with the walking paths. The green dashed line represents the walking path, and the black dots show the checkpoints, where the localization accuracy is evaluated. In Figure 6 the accuracy of the deployed system in terms of correct localization (blue) and appliance automation (yellow) is depicted. As we can see, the system demonstrated high localization accuracy as well as robustness and reliability in appliance actuation. Evaluation details can be found in [1].

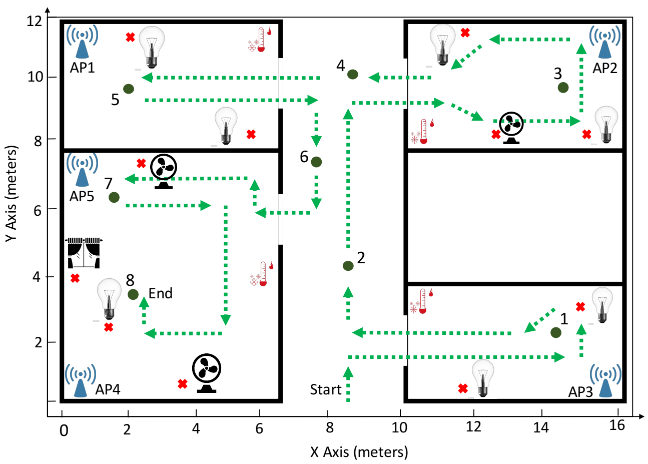

Figure 5: Experiment scenario with predefined paths.

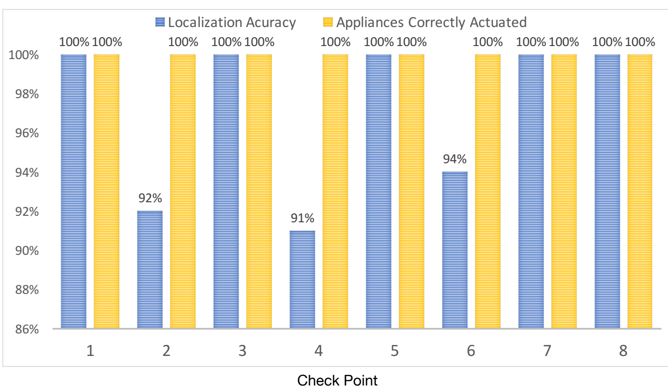

Figure 6: Evaluation results.

IV. Demo Requirements

In order to deploy the indoor location-based smart environment system properly, the following requirements are needed:

- **Full access to the demonstration venue for system deployment**. Depending on the size of the demonstration room/venue, we need to survey the whole area and conduct data measurements to train the indoor localization algorithm. To speed-up the training phase we would like the position of our stand/demo to be close to one of the room corners. To ensure all the required measurements are completed, we hope to be able to access the areas at least 1 day before the demonstration event.
- **Installation of multiple Wi-Fi access points**. Our smartphone indoor localization system is based on Wi-Fi RSSI fingerprints and trilateration. Therefore, we need to deploy multiple Wi-Fi access points (APs) such that the demonstration venue is fully covered. The Wi-Fi APs are only needed to be powered on, and it is not necessary to connect them to the Internet. To achieve high localization accuracy, our system utilizes the location of the APs. Therefore, once the system is deployed, Wi-Fi APs can not be moved to another location.
- **Wireless sensor and actuator motes**. To show that the detected smartphone location can trigger electrical appliances, we will deploy the backbone WSAN that is connected with them. Electric lights will be installed on our desk and will be connected to the WSAN to demonstrate the system functionality.
- **A Raspberry Pi working as Smart Syndesi server**. For the purposes of the demo, we will form the WSAN using a Raspberry Pi to host the network sink/gateway and management infrastructure.
- **Scaled indoor map of the demonstration venues**. Our indoor localization system requires the scaled indoor maps of the room where our poster and demo will be hosted. These information will enable us to control the estimation of person movements.
- **Multiple Android smartphones with system configured**. Our smartphone indoor localization system is implemented on Android smartphones. We will bring multiple Android smartphones for the demonstration.
- **A table**. A table will be needed to store all the related devices, such as laptops, smartphones, appliances, sensors and actuators that will be used in the demo, etc.

Acknowledgment

This work was partly supported by the Swiss National Science Foundation via the SwissSenseSynergy project under grant number 154458.

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