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Message of Interest: A Framework of Location-Aware Messaging for an Indoor Environment

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Abstract

Widespread adoption of smartphones brought significant technical advances in technology in today's world. As a consequence, however, it has almost become impossible for us to separate our personal lives from work. Work-life balance is hard to achieve in the current scenario: our business emails keep arriving on our phones even when we are at home or on the beach. Our research goal is to develop and deploy a location-aware messaging framework that is based on indoor location detection. This framework will only deliver messages when users are at work. The system uses beacon technologies to accurately determine the position of a user inside a building. The users, in return, communicate with the system using an application running on their smartphones. The framework delivers customized messages according to the user (i.e. it can distinguish between the owner and visitor in the same location).

Key words: indoor positioning, location based messaging, Internet of Things, smart buildings

I. Introduction

We are living in the era of Internet of Things (IoT) and Smart Spaces which are controlled by several ubiquitous computing systems. Smart Buildings are capable of controlling HVAC (Heating, Ventilation, and Air Conditioning), lighting, security cameras, water, WiFi, and fire alarms depending on user preferences. Using the available sensor data, the systems adapt themselves according to the preferences set by the users. However, location-based messaging inside a building is still a challenge. Even if the buildings are getting smarter, the way smart devices communicate with users inside a building has still not been made fully location aware.

In such a scenario, we propose *Message of Interest: A framework of Location-Aware Messaging for an Indoor Environment* to enhance communication between the users inside a building. The main challenge is to determine the location of the user accurately inside a building. "Message of Interest" explores beacon technology for enhanced indoor positioning. The delivery of messages in this framework is location aware for both the senders and the receivers.

II. Motivating Scenarios

As explained in the previous section, our approach is based on the users' locations and applies to both scenarios in which users are inside or outside a building. Some of these scenarios are dependent on i) accurate indoor location detection, ii) user categorization, and iii) delivery of messages in a location-aware manner. In the following section, we present sample scenarios where our system would be useful.

Scenario 1:

Roberto, a professor from the University of California, Irvine and an adviser of ten Ph.D. students, wants to notify all his graduate students about the upcoming department meetings. However, he does not want to bother them when they are at home. He wants to deliver the message only when the students reach the department building. He composes a message and the message gets mapped to their corresponding office locations inside the building. When the students return to their office after the weekend, they receive Roberto's notification, and possibly other messages whose delivery has likewise been tied to proximity to the department building.

Scenario 2: David, a professor from Carnegie Mellon University (CMU), is visiting his friend John at the University of California, Irvine. The meeting is at 2 p.m. and John sends out a message with an embedded policy specifying that he wants to be notified when David is about twenty miles away from the building. While David was driving to Donald Bren Hall (DBH), his approximate arrival time was delivered to John. When David meets the policies specified in the message, John receives a notification.

III. Related Work

In the world of Internet of Things, the use of beacon technology is on the rise. Beacons are a massive step forward in ambient location identification. Companies are exploring the use of beacons for various purposes, from merchandising, advertising, to accurate indoor navigation systems. The leading mobile-at-retail advertising platform [1] uses beacons for product promotion in stores. Bluetooth beacon technology [2] introduced by Facebook [3] is helping businesses to improve customer experiences. As people bring their smartphones everywhere whether they are shopping or dining, there is an opportunity for businesses to connect with the customers while they are in the store.

BLUENION [4] uses beacons to assist indoor navigation. Their indoor positioning system, named "BLUENION Indoor

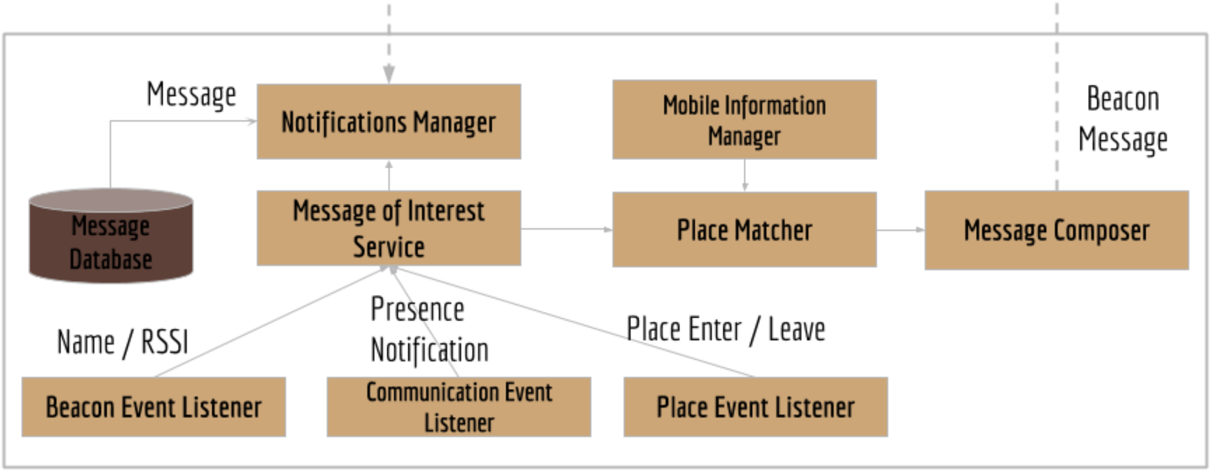


Fig. 1: Diagram of the Architecture

Positioning and tracking System" (BIPS), can precisely pinpoint users' locations using smartphones. They offer several value-added services to the customers who are visiting those buildings equipped with BIPS. The system also offers customers the latest information about services available in the shops.

Prior work related to location-based messaging deals with emergency situations or special use cases. The works reported in [5] and [6] are representative for emergency situations. [5] introduces the Mona Emergency System that uses context information when providing emergency services such as sending warning messages to an identified location. [6] analyzes the scalability of message flooding protocols in networks with various node densities, which can be expected in vehicular scenarios. However, users are not capable of communicating with the system to reply to received message. In our framework, both users and systems can communicate with each other.

IV. Architecture of the System

This framework uses a distributed architecture, where the required data collection and data analysis happen in participating smartphones. In our approach, the message is stored in a local database in the receiver's smartphone. The beacon monitors a user's location using low Bluetooth energy (BLE) sensors. The smartphone constantly monitors the Received Signal Strength Indicator (RSSI); when its value exceeds the default threshold of -70 dBm, this signifies the arrival of a person near the vicinity of the beacon. Users then get notifications depending on the events specified in the web service, users get notifications accordingly. We used the *Gimbal Manager* web service to set up all the communication rules between a beacon and a smartphone. The phone number of the user is used to determine whether the person is a visitor or an owner of the beacon.

We would like to explain the architecture based on Scenario 1 in section II. The sender is Roberto, who wants to leave a message to his students. And the owner of the beacon is Sarah, who wants to receive a messages from her colleagues when she is away from the office. From now on, we will describe the architecture based on this setting.

As shown in Figure 1, the *Messages of Interest* architecture consists in five components: the *Message of Interest Service*, *Place Matcher*, *Mobile Information Manager*, *Notification Manager*, and *Message Composer*.

At first, Sarah sets a communication message that will be displayed as a notification through the *Gimbal Manager*. Sarah has to create at least one semantic place with attributes such as the name (e.g. Sarah's Place) and the threshold value of the beacon's RSSI (e.g. -70 dBm). The values of these attributes will be monitored by the *Beacon Event Listener*. Once Roberto is close to the place and the signal strength is above threshold, the region entrance event will be triggered through the *Place Event Listener*. If Roberto leaves the beacon range, then the leave event will be triggered through the *Place Event Listener*. The *Communication Event Listener* receives communication messages according to the location of Sarah or Roberto.

As a central component, the *Message of Interest Service* listens to Beacon Events, Communication Events, and Place Events by dedicated Listeners for each of these events. The output of *Message of Interest Service* is then passed to a *Place Matcher*. The *Place Matcher* determines whether the user's location matches with the target location (e.g. Sarah's Place) or not. Here Sarah's Place is the semantic name of the location where Roberto sends a message. The *Mobile Information Manager* is responsible for setting static mobile information of the user such as the phone number and welcome messages. Once a place is matched, and depending on whether the user is an owner (Sarah) or a visitor (Roberto), the message is sent to *Message Composer* which sends a reply back to Sarah. These messages are stored in a local database called *Message Database* in Sarah's smartphone.

V. Implementation

We implemented this application on Android Lollipop platform version 5.0.1 using Android Studio 2.0 [7]. The beacon

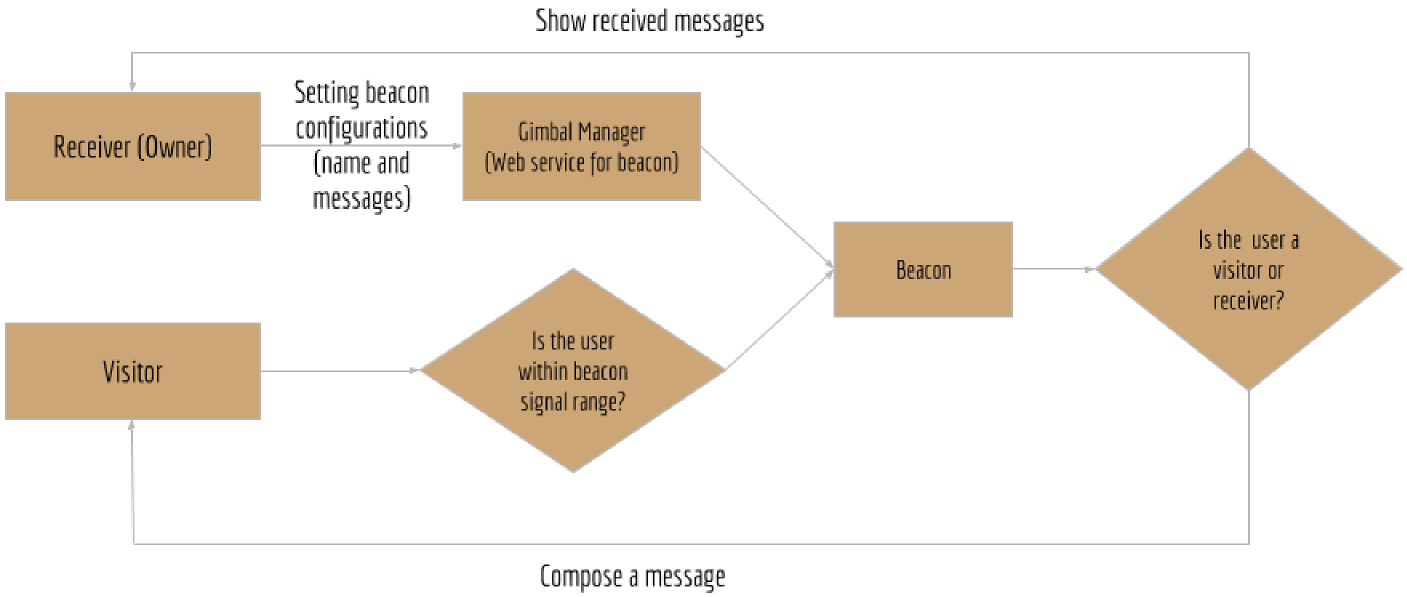


Fig. 2: Workflow of *Message of Interest*

we used for detecting user location is manufactured by Gimbal Inc. [8] and is equipped with Qualcomm chips. The beacon comes with access to a web service *Gimbal Manager* in which the owner can set up several attributes like places of interest, predefined messages, and rules how the messages should be delivered. In the following section, we will describe the implementation of both the smartphone application and the beacon.

A. Smartphone application

On the smartphone, we are running an Android application on both Sarah and Roberto's devices. The application keeps track of beacons' broadcasting messages using the Bluetooth sensors. Figure 2 describes the workflow of *Message of Interest*. Whenever one smartphone enters within the range of one beacon, it will trigger one event. Beacons provide three types of events: entering a place, staying in the place and leaving the place. Whenever a smartphone enters the beacon range, the application decides whether this user is the beacon's owner or not. For Sarah, the beacon presents one interface (Figure 3a) and for Roberto, it provides another messaging interface (Figure 3c). In the message interface, Roberto types a message and sends it. Sarah's mobile number is never revealed to Roberto. The application sends the message to Sarah accordingly.

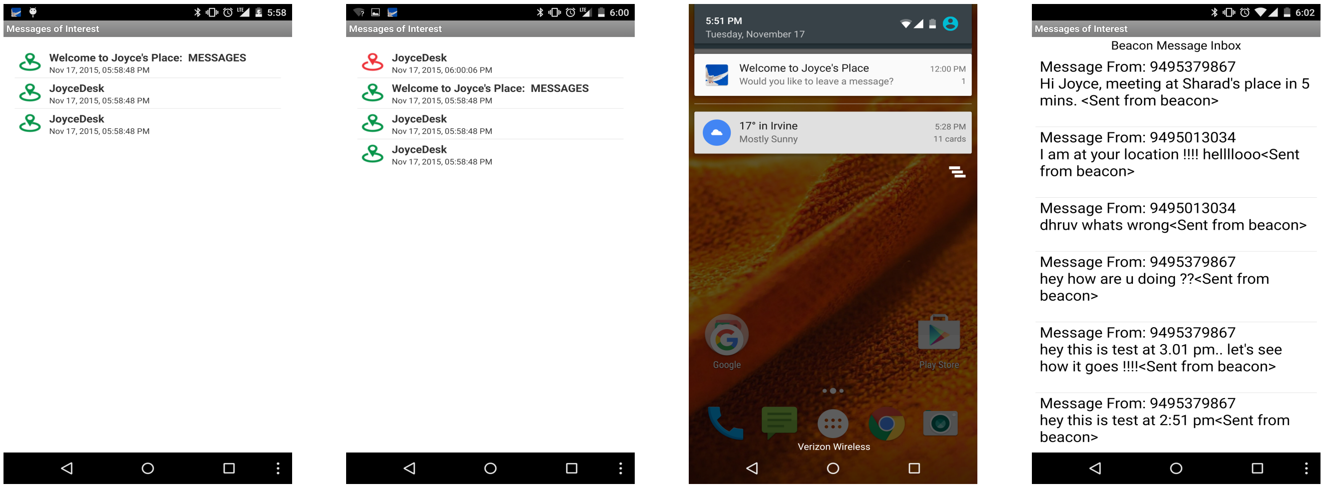
On Sarah's smartphone, the application keeps track of range-related beacon events (entering/staying/leaving). When Roberto sends a message, the message gets stored in the application, without notifying the user. When Sarah comes back within the beacon's range, she gets a notification about the messages left by Roberto. The application opens up another type of interface in which all received messages are shown to Sarah.

B. Beacon configuration

The beacon has access to a web service *Gimbal Manager* through which Sarah or administrators can set the values of several attributes such as places, messages, rules of communication. Places can be set according to geo-location sensors or can be set using beacons. Depending on the strength of the signal emitted by the Bluetooth sensor, Sarah defines the perimeter of the location. For example, if the RSSI value is less than -70 dBm, then this is outside the range. If the value is higher, the smartphone is within the range of THE beacon. Similarly, different places and communication protocols can be defined in the web service. When someone is entering the region, they will receive certain messages; while leaving, they will receive different sets of messages. All these messages can be considered static messages, which can be set by the Sarah or the administrators. During the development of our application, we chose suitable communication methods in the web service through which we can distinguish between Sarah and Roberto.

C. Complete Execution of the application

Initially, Sarah sets up some indoor places and messages using the web service. The places can be someone's office cubicle, lab desk, etc. Then she sets up some static communication protocols and messages. Protocols define rules of entrance and exit. Messages are static in nature and consist of welcoming or exiting messages. All this information is specified by Sarah or the administrator of the beacon. Sarah can



(a) A visitor is nearby the place (green beacon sign indicates the user is nearby)

(b) A visitor is away from the place (red beacon sign indicates the user is out of range)

(c) A notification that a visitor receives by approaching the place

(d) A message box for the receiver

Fig. 3: Screenshots of *Messages of Interest*

activate or deactivate the beacon, message or place whenever she wants. When she is away from the desk, and Roberto visits her place, the application running on Roberto's smartphone first determines whether he is the owner of the place. If he is not the owner, then a welcoming message is presented that asks whether he wants to leave any message for Sarah. If the visitor agrees with this, then a messaging interface appears in the visitor's smartphone. Roberto types in the message and clicks send button. Roberto will not be shown the mobile number of Sarah. The beacon itself determines the appropriate receiver and sends the message to the appropriate smartphone.

The application running on Sarah's smartphone takes care of the receiving part of the message. It searches for the broadcasting signals from the beacons. When Sarah's device enters the beacon's range, the beacon determines whether she is the owner or not. If she is the owner, then all the messages left by the visitors including Roberto are presented to Sarah. In this way, Sarah receives all those pending messages at the most appropriate time and location. To save storage space on the smartphone, the application only keeps track of messages from the moment that Sarah leaves the location.

VI. Conclusions and Future Work

We developed a location-based messaging framework for an indoor environment using beacon technology to enhance communication inside a building. This system gives a new avenue to merge conventional messaging applications – like SMS – with the domain of location-aware applications and indoor positioning systems. Location aware applications built with the help of indoor localization techniques are a new approach to messaging in an indoor environment.

We would like to continue experimenting with other types of beacons. For example, "Estimote" [9] supports better accuracy by placing three beacons nearby. "Roam" [10] recently came up with seven years of battery life and remote firmware upgrades. By storing users' locations and messages on the server side, we can benefit other users in other scenarios. Another issue is scaling from one beacon to multiple beacons. Large office environment might bring issues that we have not encountered yet.

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