Reprogrammable wireless ad-hoc client-server solution for geofence applications

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1 Introduction

The geofencing concept is a dynamically developing field of studies nowadays. Furthermore, this technology is applied in many areas such as IoT, autonomous systems, security, automotive, aviation, fleet & freight or even marketing. Geofencing technology is used to monitor objects (e.g. cars, airplanes, animals) mainly by the GPS system and it also can be supported by cellular network infrastructure to get more accurate results [1]. Geofencing system consists of virtual fences which can be represented in different forms e.g. shapes, real objects like cities, streets or geofences based on cell-ids or WIFI networks. The main functionality of the system is to determine in real-time whether the object is in the area of a virtual fence or not.

In our project, we will combine GPS technology which is used in the transceiver to determine the localization and short-wavelength ultra-high frequency radio waves (e.g. Bluetooth) which will enable the beacon to broadcast the coordinates of a geofence or send data between the two devices. In comparison to existing solutions, where geofences are accessed using the Internet, our solution will be local - the beacon will not be connected to the Internet. Every time our transceiver approaches new geofence, it receives a new set of coordinates from the beacon.

2 Context

One of the fields where geofences are becoming more widespread is the transport industry. Existing solutions are essentially applied in fields like transport and logistics where the delivery vehicles are assigned to reach specific destination points e.g. clients, warehouses [2]. Each of the points is represented as a geofence. Monitoring vehicles crossing these points can help to plan efficient goods movements. In fleet management, geofences can track the fleet and report to a public monitoring vehicles system if some of them left the designated area. For instance, public bus crossing the border of a city what is not allowed for a specific bus line. Another example can be using this technology for security and defense. This technology is nowadays used by governments of the United States, Singapore or Sweden. Also, some Research & Development programmes are working to prevent possible terrorist attacks on dangerous transport goods (explosives, toxic wastes, chemicals).

One of the challenges of using geofences is the violation of privacy. According to the studies performed, [3] by collecting data about users of the GPS system, it is possible to profile them based on localization history and predict their attributes and lifestyle. Our solution will deal with this problem by establishing a GPS connection when the beacon is reached and, optionally, provide a simple authorization mechanism.

3 Goals and Challenges

Our goal is to deliver a geofence solution consisting of a transceiver and a reprogrammable beacon. The challenge here is to design the two devices such that it is no longer necessary to provide the coordinates of the vertices manually by connecting the beacon to a computer and programming them. The main components of the transceiver will be a 2.4GHz radio transmitter (e.g. BLE), a GPS device(e.g. Arduino GPS Shield), and a SoC (e.g. Arduino Uno). The first transceiver challenge will be to send its current GPS coordinates to be stored on the beacon. These coordinates will be the coordinates of a geofence vertices. The second challenge will be to interpret data broadcasted by the beacon. The data will consist mainly of the GPS coordinates of the geofence vertices and, optionally, some meta information about the beacon (e.g. ID). Point in polygon (PIP) algorithm, for example, ray casting will be used to determine whether the device is inside or outside the polygon. We will compare different PIP algorithms in terms of latency and accuracy. A primitive human-machine interface (HMI) will be used to display the result (e.g. LED).

The main component of the beacon will be a 2.4GHz radio transmitter (e.g. BLE). The beacon's challenge will be to receive and store the GPS coordinates of the transceiver. The coordinates will be stored in a data structure (e.g. linked list) and constantly broadcasted to nearby devices.

4 Approach

Our plan is to provide a working minimum viable product. We will, however, focus on the optional features if the project deadlines are met. As regards goals and evaluating them, we will focus on four areas - usability, scalability, power, and performance.

- Usability. We completely changed the original concept in terms of usability and instead of having hard-coding the coordinates on the beacon, it will reprogrammable using the transceiver. We will evaluate the goal from the end user experience, for example, it should be trivial to add / remove a vertice by going to the desired location and pushing a button on the transceiver. HMI, for example, an LED, will inform the end user about the status of adding / removing a vertice, being inside / outside the polygon, etc.
- Scalability. It will be possible to add new transceivers or beacons to increase the rate of setting new vertices on a single beacon or to increase the number of beacons programmed by a single transceiver respectively. Evaluation of this goal will mean introducing more beacons and testing how well they work under certain criteria, for example, programming two nearby beacons simultaneously, meaning they are near each other i.e. in the same physical range.
- Power. We will use hardware solutions, for example, Arduino Uno and BLE, which are designed to consume very little energy resources yet provide all the functionality necessary. We will not evaluate this goal because we have no plans on porting the solution to other systems, for example, other types of computers, GPS and BLE devices with different characteristics. We believe that having only as much performance as required will have the best results regarding power consumption.
- Performance. We will focus on writing code and algorithms that yield good results in terms of latency, accuracy. To evaluate this point we will compare algorithms, for example, the ray casting and the winding number algorithms. Will will measure, log and compare the time of execution (latency) and the precision (accuracy) on the transceiver device.

As regards evaluating the system as a whole, we will perform testing of the system as soon as the prototype is ready. We will consider two different test scenarios. First, in an area with obstacles that may have an impact on 2.4GHz radio, GPS, and BLE. For example, a street in the city with high buildings and cars. Second, in an open area with little to no potential distraction sources. In each scenario, we want to test the system in terms of our four general focus areas. In order to improve on the weaknesses of the system, we will do incremental tests, where each following system iteration will have improvements over the previous ones. In the end, we will analyze our final test results and draw conclusions.

5 References

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