Master Thesis

Bluetooth Low Energy Supported Indoor Location

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Abstract—Abstract

I. INTRODUCTION

Indoor positioning systems have greatly evolved in the past few years due to the great success of its counter-part, the global positioning system (GPS), in outdoor environments but failure to reproduce the same results in indoor environments. Since GPS is an outdoor position systems and is based on a network of satelite, when the required scenario for position tracking is inside a building, new constraints are presented onto the process such as the attenuation and reflection of eletromagnetic waves upon collision with building walls and obstacles [1]. As such there was a need to find reliable indoor systems that by nature would already be able to heavily reduce the impact of some of the mentioned constraints.

In order to understand indoor position there is a need to understand the full scope of variables that come to surface when moving from outdoor to indoor. When developing a system there is a need to make sure that it can tackle the chalenges such as small space dimension which reforce the need for higher precision, a higher probability of non existent line of sight, influence of obstacles such as walls, furniture, moveable objects such as doors and human beings[3]. All of the previously mentioned affect the way electromagnetic waves propagate in an indoor environment leading to problems related to severe multipath and reflection on existent surfaces [2]. Besides propagation challenges, there are energy consumption, accuracy and deployment costs that play a critical role in deciding the viability of a proposed indoor location technique.

With the evolution of mobile devices there has been a sizeable number of different technologies that can possibly be used in indoor locationing [2], [4], [5] such as GPS-based technologies, using high sensitivity antenas to overcome GPS's indoor issues, RFID , Wireless LAN and Bluetooth among others, allowing even for hibrid systems which make use of more than one of the technologies mentioned above.

Another important aspect besides the chosen technology is the location detection technique which are widely varied in terms of accuracy and complexity. The simplest available category would be proximity detection which has Cell of Origin (CoO) as its most famous technique, allowing for room-based detection by assuming that the mobile target is at the cell with the strongest receiving power. This technique is widely used by system using RFID, Bluetooth and Infrared. The next category would be triangulation which uses the geometric properties of the triangle to obtain a position. The method utilized to obtain the values used in the position's calculation can be angle-based, which have implementation costs are their worst limitation; time-based, using Time-of-flight (ToF) or Round Trip Time (RTT) to obtain measures of distance from beacons; signal property based, using received signal strength indicator (RSSI) as a metric, altough it's only possible of using this metric with radio signals; dead reckoning, which calculates the actual position utilizing the last determined position and incrementing based on estimate of the device's speed.

The solution in this paper is based on the Bluetooth Low energy technology using the CoO method to obtain the device's location and as such for what technologies and location methods are concerned, only the used ones will be focused.

In this paper is structured in a way that in II an overview of Bluetooth low energy (BLE) and existent projects and their associated architecture are presented while shedding light on the benefits and limitations of the chosen technologies, in **??** the proposed system is described based on technology and method used as well as the architecture of the would system, IV analyzes the different aspects of the presented solution in terms of energetic efficiency, accuracy and response timings, finalizing in V by overviewing what could be carried out in order to further develop the existing work and by concluding the paper.

- Falta de framework, não tenho bases, vale a pena mencionar na introdução?

II. RELATED WORD

Bluetooth is a wireless technology that was created in 1994 with the objective of replacing cables connecting fixed or portable devices. At this point in time Bluetooth Special Interest Group is in charge of developing and managing this technology characterized by its robustness, low energy consuption and low cost. The Bluetooth Low Energy protocol was introduced with the Bluetooth Core Specification version 4 (also called Bluetooth Smart) circa 2010 alongside two other protocols. Out of the three, BLE standed out for its lower power consuption, lower complexity and lower cost, while allowing for device discovery, connection establishment and connection mechanisms.

The BLE radio operates at the 2.4GHz band and employs a frequency hopping transceiver to combat interference and fading. It also employs two multiple access schemes: FDMA used to separate the 40 available physical channels, 37 of them are used as data channels and the remaining as advertising channels and TDMA in a polling scheme that is used when one device transmits a packet at a predetermined time and a corresponding device responds with a packet after a predetermined interval.
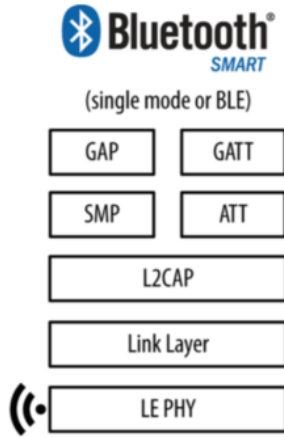
Fig. 1: Bluetooth low energy architecture

Fig. 2: Gatt-based profile hierarchy

When looking at the BLE's architecture , which can be seen at 1, the Generic Access Profile (GAP) is one of the most relevant since it's responsible for working in conjunction with Generic Attribute (GATT) to define the base funcionality of BLE devices. The services that are made available by the GAP are: BLE device discovery, connection modes, security, authentication, association models and service discovery. In addiction to this, it also defines four different roles to describe a device, allowing for the controllers to be optimized in funtion of the device's desired roles: Broadcaster, role optimized for transmitter-only applications; Observer, role optimized for receiver-only applications and it's complementary to the broadcaster role; Peripheral, role optimized for devices that only want to suppot a single connection, allowing for a much less complex controller due to the fact that it only needs to support the slave role and not the master one; Central, role supports multiple connections and funtions as the initiator for all of them. These connection are all made with Peripheral devices and its controller must support the master role in a connection and allow for more complex funtions, in comparison to the remaining roles.

Another important component is the Attribute Protocol (ATT) Protocol which is responsible for implementing the Peer-to-peer(P2P) protocol between an attribute server and client. This communication happens in a dedicated fixed channel and a server can send through it responses, notifications and indications, while the client can send requests, commands and confirmations. The ATT allows the clients to read and write values of attributes on a peer device acting as a server.

The last component is the Generic Attribute (GATT) Profile which is responsible for creating a framework for the ATT, in which it's represented the funcionalities of an ATT server. This profile describes the hierarchy of services, characteristics and attributes existent in the server and provides an interface for discovering, reading, writing and indicating service characteristics and profiles.

Bluetooth low energy devices utilize profiles which define the required functionalities of the device. It also defines application behaviour and data formats and as such when two dev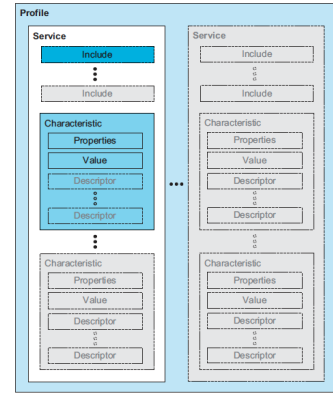ices comply with all the requirements of a Bluetooth pro-file, application interoperability is achieved. Each Bluetooth profiles describes its requirements necessary for devices to create a connection, to find available services and connection information required for making application level connections.

The base profile that any Bluetooth system needs to include is the GAP. From this point, any additional profile implemented will be a superset of GAP, where GATT is included and specifies the profile hierarchy, or the structure in which profile data is exchanged. Figure 2 shows the hierarchy in a Gatt-based profile, with the profile being the top level and services and characteristics below. A profile is composed by one or more services. A service is a collection of data and associated behaviors to accomplish a particular function or feature of a device or portions of a device. A service is composed of characteristics and/or references to other services. A Characteristic is a value that is used in a service that has properties and configuration information that descrive how the value should be accessed as well as information on how to display the value. A characteristic is defined by its declaration, its properties, its value and may also be defined by its descriptor, which describes the value or permit configuration of the server relative to the value.

- BLE
- BLE Projects
- Architecture similar stuff?
Images: - BLE Architecture - BLE Profile

III. Implementation

- Overview of Architecture
- Location Provider - BLE Search - GATT Comunication - Server Calculation - Voting System and CoO
- Google Maps - Indoor maps - Map insertion possibility
Images: - Architecture Overview - Location Provider Diagram - App Screen

IV. Performance Analysis

V. Future Work

References

[1] Hakan Koyuncu, Shuang Hua Yang ;A Survey of Indoor Positioning and Object Locating Systems http://paper.ijcsns.org/07$_book$/201005/20100518.pdf

[2] Hui Liu; Survey of Wireless Indoor
    Positioning Techniques and Systems
    http://www.pitt.edu/ dtipper/2011/Survey1.pdf
[3] Zahid Farid, Rosdiadee Nordin, and Mahamod
    Ismail; Recent Advances in Wireless Indoor
    Localization Techniques and System
[4] Hakan Koyuncu, Shuang Hua Yang; A Survey of
    Indoor Positioning and Object Locating Systems;
    $http://paper.ijcsns.org/07_{book}/201005/20100518.pdf$
[5] Jiang Xiao, Zimu Zhou,Youwen Yi and
    Lionel M. Ni; A Survey on Wireless Indoor
    Localization from the Device Perspective;
    http://www.tik.ee.ethz.ch/ zzhou/paper/csur16-xiao.pdf
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