Available online at www.sciencedirect.com

ScienceDirect

IFAC-PapersOnLine 49-25 (2016) 311–317

Summary of available indoor location techniques

Jiří Kárník [*] **Jakub Streit** [**]

[*] BRNO UNIVERSITY OF TECHNOLOGY, Antonínská 548/1, 601 90 Brno Czech Republic (e-mail: xkarni05@vutbr.cz)
[**] BRNO UNIVERSITY OF TECHNOLOGY, Antonínská 548/1, 601 90 Brno Czech Republic (e-mail: xstrei03@vutbr.cz)

Abstract: Outdoor location is currently mostly resolved. Contrary to this, indoor location have not yet been completely resolved. No global solution for complete range of possible applications is developed. Development of new wireless technologies gives developers a lot of possibilities to solve location problems inside buildings. Furthermore, new approaches and algorithms to solve location problems are developed too. In this article we discuss these technologies and their practical applications in indoor location systems.

Keywords: Indoor location, WiFi, Bluetooth, FM, ZigBee, UWB, RFID, Geomagnetism, ToA, TDoA, AoA, SDS-TWR, CoO, RSS, CSI, Inertial sensors.

1. INTRODUCTION

The need for accurate location is currently growing. Outdoor location techniques are commonly used by millions of people and various devices. In contrast to this fact, indoor location is in development and currently not widely used. Compared to the outdoor location, the indoor location have to be more accurate. This need makes great demands on developing new position systems. Inaccuracies and errors in order of meters are not significant in the outdoor location. In case of the indoor location, these inaccuracies are unacceptable - rooms and corridors are very small, compared to the outdoor environment.

Many research groups around the world are engaged in developing accurate indoor location system. The biggest problem in indoor location is fact, that one approach can't be used for all possible cases. It's caused by greater diversity of indoor environment. Therefore, researchers try to find various approaches and implement them to the buildings. Most of these approaches try to be universal for use e.g. as navigation system for people in shopping malls, offices and the other public buildings.

In light of these facts, researchers want to use widespread and cheap wireless technologies. There are several techniques, based on mostly existing infrastructure, e.g. WiFi (Wu and Liu (2013) and Wang et al. (2012)) and FM (Chen et al., 2012). Other technologies needs an additional infrastructure of their own, like a ZigBee, Bluetooth, UWB or RFID.

To estimate location some signal features need to be measured. We can mention e.g. Time of arrival (ToA), Time difference of arrival (TDoA), received signal strength (RSS), etc.

We discuss all these techniques, features and approaches in section 2. In section 3 we describe two different approaches to make an indoor location system, concretely model-based systems and fingerprint systems. In next section (sec. 4) are listed sensors, usable for improving accuracy of indoor location systems. As location systems are mostly composed from more techniques, combined to increase accuracy (i.e. WiFi and Inertial sensing), we discuss these hybrid systems in section 4. Next section we is conceived as comparsion of used techniques and here we introduce some approaches, practically tested in the real-world.

2. MEASUREMENT TYPES

Indoor location is field, which can be realised by many technologies and approaches. Every technology suitable for indoor location has some features, which can be used together with various measuring principles. These approaches we discuss in this section.

2.1 Used wireless technologies

Variety of wireless tech. can be used to locate inside buildings. Some of these technologies are already frequently used in buildings for communication purposes. In this subsection we discuss this technologies and types of signal and how they can be used for location.

WiFi
WiFi is very popular and one of the most used wireless technology. It is often used for wireless Internet connection in a lot of building types, e.g. shopping malls, public spaces and factory buildings. Big advantage is that this technology is implemented in a large range of devices, like mobile phones, notebooks and tablets have implemented this technology and users commonly use it. Every wireless card allows measuring some signal parameters, which can be used for indoor location. It predetermines WiFi for cheap indoor location applications. (Wang et al. (2012), Liu et al. (2012) and Wu and Liu (2013))

10.1016/j.ifacol.2016.12.055

WiFi is based on standards IEEE 802.11. Currently, users can use two unlicensed bands on frequencies 2.4 GHz and 5 GHz. It may be important to have large number of APs due to high WiFi signal attenuation, especially in cases where signal passes through the walls. Ideally, there is at least one AP per room. We can use this feature, thus limit distance for received signal from particular AP, for minimizing estimated position errors.

Then, user can walk through the building and his phone or tablet measures parameters describing received signal from every AP in range. Measured parameters are subsequently processed. Most used measured parameter is received signal strength (discussed in 2.2.6), which will be discussed in next section.

Bluetooth

Bluetooth is another very popular wireless technology. Many of consumer electronic devices, such as notebooks, tablets, smartphones, or even smartwatches are equipped with it. Bluetooth uses 2.4 GHz band, as WiFi. Compared to WiFi, Bluetooth has shorter range, smaller bandwidth, but it is much more power efficient.

Currently, there are two major versions of the Bluetooth devices. Devices compliant to older standard, Bluetooth 2 and newer deviced, comliant to Bluetooth 4. Although there are systems based on Bluetooth 2 (like ZONITH Bekkelien (2012)), this standard does not fit localization requirements very well. Bluetooth 4 is much more suitable, but still has some shortcomings.

Main disadvantage of Bluetooth 2 is its measurement rate. Localization techniques, which use Bluetooth, are mostly based on RSS (discussed in chapter 2.2.6) Bluetooth 2 uses its Inquiry protocol/command to obtain address of devices in range. This command takes more than 10 seconds to complete. The Inquiry command can be interrupted earlier, but not all devices in range might be discovered in that case. The Inquiry command is the only way to obtain accurate RSS, because during standard communication a Bluetooth transmitter reduces its output power to reduce energy consumption. While Inquiry command, transmitter uses its maximum output power. Another potential complication is that according to standard, Bluetooth stack has to inform uesr only whether RSS is under, in, or above "Golden Receiver Power Range", which is 0 dBm Bekkelien (2012). Most implemetations fortunately offer higher degree of granularity, but there are significant variations between devices, which makes calibration essential.

As mentioned, Bluetooth 4 is more appropriate to localization purposes. Especially its subsection called Bluetooth Low Energy, known as BLE. For purposes of RSS based localization using Bluetooth, it is advisable to have a beacon in every room, in case of office building, or every few meters in case of larger open areas, like a shopping mall. From technical perspective, power source for such a number of devices is a problem (especially in open spaces). WiFi based beacons are too much energy-intensive for battery operation. Bluetooth 2 based devices are capable of operating from battery in matter of days. On the other hand, BLE devices are able to operate from several months to more than year from a single coin cell battery, like CR2032 Kamath and Lindh (2012). This, together with very low cost (on order of $), make BLE suitable for RSS based localization. BLE also particularly solves major disadvantage of Bluetooth 2 devices - measurement rate. BLE device can be configured to advertise itself with period down to few milliseconds (according to Faragher and Harle (2014)). The BLE stack on a receiving device then informs user software each time it receives a beacon advertisement packet and also reports the RSS value. Unfortunately, there is a small issue with this. BLE standard defines 3 channels for device advertisement. These channels are relatively far away from each other and advertising device periodically hops over these channels. The BLE stack on a receiving device provides information about the RSS, but not about the channel, at which the packet was captured. This information would be very useful, especially for a fingerprints based localization (see 3.2), because of effects of multipath propagation and fading. While this is not mandatory by standard, some implementations of BLE stack provide this information - for example those, used on an Apple iOS Faragher and Harle (2014).

ZigBee

ZigBee, like a Bluetooth, is short range communication technology, aimed at power efficiency. Where Bluetooth is especially designed for peer-to-peer communication, ZigBee is more suitable for larger mesh networks. It is mainly used in building automation systems. ZigBee operates in one of 3 bands: 868 MHz (Europe), 915 MHz (USA, Canada) and 2.4 GHz (wordlwide). These are open ISM bands, which makes it more susceptible to interference from other radios, using same frequencies (especially 868 MHz and 915 MHz bands).

ZigBee PHY and MAC layers are defined in IEEE 802.15.4 standard. There are more RF technologist using this standard. ZigBee standard specifies a communication protocol laying on the top of IEEE 802.15.4. This proprietary protocol is developed and maintained by ZigBee Alliance. XBee is another communication protocol, based on IEEE 802.15.4. It is particularly compatible with ZigBee, but it is free.

Although there may be some solutions using ToA, TDoA or AoA (see chapter 3.1) localization methods, RSS fingerprints, or CoO based approaches are the most common.

FM Broadcast signal

FM Broadcast signal is primarily used as available information channel. FM radio broadcast signal is distributed over long distances, from distant FM towers to the user's FM receiver. FM signal is stronger in comparison with WiFi signals. It means that the signal is available on more places and also probability of receiving the signal in indoor environment.

Range of frequencies, used in Western and Central Europe is from 87.5 MHz to 108 MHz (ECC and CEPT, 2016) Because of used frequencies, signal is only little affected by passing through the walls.

In case of indoor location, FM Broadcasting is used i.e. in mobile phones containing FM receiver or in dedicated chips. For this application we can use some measured