The angle of arrival (AOA) technique uses an array of receivers to evaluate the incoming reception angle. Calculating the location of the source is done by combining the angles of different receivers [43].   
Relative Received signal strength (RSSI) is a WiFi based indoor localisation system which uses the signal strength of radio communication to estimate the distance between devices. The main idea is to measure a set of signals signatures, known as fingerprints, based on different locations in the area of interest and build a fingerprint database. The location is then estimated by mapping the measured fingerprints against the database. This approach requires a considerable manual effort to build the fingerprint database and the resulting system is relatively inflexible to changing environments. RSSI is not well suited to tracking users in real time, due to the lengthy time taken to calibrate for channel propagation parameters [39].  
[22] and [50] propose methods of tracking users movements within a space with wearable devices embedded on the person or user motions from mobile phones.

[20] describes many of the issues in deploying an ultrasound based localisation system. In general, ultrasonic wave emission is usually directional, which introduces difﬁculties in orienting the transceiver precisely. Only when the listener is inside the transmitter’s beam pattern, can the listener derive distance measurement value from the beacon. One solution to this issue is described in [55]. They developed a 2-D isotropic ultrasound transmitter with a beam width of 360° using an array of eight ultrasound transducers placed in a round body. The angle of aperture of one transducer is 45°. By using eight ultrasound transducers, the coverage range can be increased by a factor of 8. [20] also determines that more beacons are required grows linearly with the size of the area of interest.

IBeacon

lazik-alps:

Lazic et al propose a system that use a combination of ultrasound and Bluetooth to obtain precise localizatoin in small and medium sized areas using a TDOA. The system was designed using time synchronized ultrasonic signal

Range-based approaches use measured distances or angular estimates between known anchor points to compute a position. Range-free approaches on the other hand typically attempt to match either synthetic or naturally occurring signatures to a particular location. TOA and TDOF systems both require bidirectional coordination between the infrastructure and the device being tracked which generally limits scalability.

[An Ultrasonic Multiple-Access Ranging Core Based on Frequency Shift Keying Towards Indoor Localization]

Our ultrasonic ranging system is composed of one receiver (Figure 1) and multiple transmitters. The transmitters emit an orthogonal ultrasonic coded signal, which is received and processed by the receiver. Both transmitters and receiver are equipped with an embedded FPGA, which has two major purposes. On the one hand, it facilitates the generation of the orthogonal ultrasonic signal, while on the other hand, due to the high degree of parallel processing capabilities, the FPGA enables the real-time embedded processing of the orthogonal ultrasonic signals. Transmitters and receiver are synchronized by means of a wire, which minimizes the synchronization error during the experiments.

[Design and Implementation of a Fully Distributed Ultrasonic Positioning System]

This is the basic idea of iterative multilateration. [Distributed FPGA-based architecture to support indoor localisation and orientation services] one of the most promising approaches in localisation/orientation of users in indoor environments is the analysis of video streaming from the consumer electronic devices that users carry

[Gradient-Based Fingerprinting for Indoor Localization and Tracking]

Localization can be achieved by performing lookups within a pre-established database. On the basis of basic fingerprinting, Horus [46] adopts a probabilitybased inference model, where the RSSI from an AP is modeled into a random variable in both time and spatial domains Another issue of fingerprinting is the time-varying signal strength and biased observations reported by heterogeneous devices

[GSM indoor localization]

This paper demonstrated that accurate indoor GSM-based localization is possible thanks to the use of wide signal-strength fingerprints that include readings of up to 29 GSM channels in addition to the 6-strongest cells. We also showed that the localization performance can be further improved by carefully selecting a subset of highly relevant channels to be used for fingerprinting matching.

[Robust wireless signal indoor localization] an approximation method using Bluetooth signals in conjunction with a fuzzy classifier. Bluetooth RSSI

[Indoor Localisation Using a Context-Aware Dynamic]

RSSI/ We used the ZigBee/ 802.15.4 wireless communications protocol to implement our smart meter network. ZigBee is a low data rate wireless communications protocol that can operate on devices with limited computing or power res

[Performance of time-difference-of-arrival ultra wideband indoor localisation]

The Gaussian pulse generator, which is triggered by the 10 MHz clock, generates a UWB pulse with centre frequency around 4 GHz.

[Ultra-wideband-based multilateration technique for indoor localisation]

proposed solution as time reflection of arrival (TROA). They demonstrate in this study how the position estimation error is improved upon by carefully considering the inherent properties of the UWB technology and the reflection properties of transmitted UWB signalsThis paper presented a novel UWB-driven multilateration technique for position estimation in an indoor environment. The presented approach exploits the inherent properties of UWB signal propagation and its definition is in conjunction with the operational principles of the lesser studied TSOA position estimation technique

[TDOA-Based Localization Using Interacting Multiple Model Estimator and Ultrasonic Transmitter/Receiver]

360 mobile transmitter, receiver anchors

[INDOOR LOCATION BASED ON IEEE 802.11 ROUNDTRIP TIME MEASUREMENTS WITH TWO-STEP NLOS MITIGATION]

In this paper, a complete location scheme based on RTT measurements is proposed, analyzed and put into practice in a rich multipath indoor environment. The PCB proposed in [12] has been taken as RTT measuring system, and an IEEE 802.11 wireless infrastructure, already deployed, has been used as indoor wireless technology.

[Implementing Primary Synchronization Channel in Mobile Cell Selection 4G LTE-A Network]

In this paper, we presented an Implementing PSS in mobile cell searching 4G, which has been proposed cell search and selection for 4G LTE-A system. The proposed includes synchronizations and cell identification by using the Zadoff-chu Algorithm and standard roots , when the based on P-SCH and S-SCH cell specific pilot symbols, respectively. Frequency synchronization performance can be improved through oversampling SCH at the receiver

2016 entries

lessons learned

With this in mind, we organized the Microsoft Indoor Localization Competition [1]. The main motivation behind the competition was to give different academic and industry groups the opportunity to test their indoor location technologies in a realistic, unfamiliar environment. This environment established a common baseline for assessing the relative accuracy and overhead of the different indoor location technologies. At the same time, it allowed researchers working on the indoor location to meet and interact with each other, and closely observe the competing solutions in action.

Hoppe

smartphone tracking TDOA multiple recievers mounted phone emits pulses receivers record and send to server for processing Hammer

TOF CSS hyperbolic frequency modulated signal (HFM) UWB probably First peak picking to account for MPE fm radio synchronisation

perez cruz

TDOA Devices emits reference signal RF (2.4GHz) receivers measure ToA Mulrilateration using ToA measurements

zhi wang

3d Combines TDOA and TOA beacons connected over wifi beacons calibrated manually(boo) linear frequency modulated signal which is CSS i guess

The Indoor Location Problem is NOT Solved

After more than a decade of intensive work in this area, the indoor location problem remains unsolved. There does not seem to exist a technology or a combination of technologies that can recreate the experience that GPS offers outdoors in the indoor environment. Even though Klepal et al. managed to achieve an impressive 1.6m accuracy solely based on off-the-shelf access points, and Bestmann et al. were able to achieve 0.72m location error, this level of accuracy can only enable a subset of the envisioned indoor localization scenarios. Applications that require room-level or even meter level accuracy (i.e., indoor navigation), can be easily powered by such technologies. However, more sophisticated applications such as dynamic personalized pricing, and product placement and advertisements in the context of retail stores (i.e., grocery or clothing stores) require much higher granularity of location information. In such scenarios, there might be tens of different products within a meter distance from the user, rendering the current systems inefficient.

FIGURE 4. Average location error and its standard deviation across all teams for each of the 20 evaluation points. TABLE 3. Automatic evaluation using the EVARILOS benchmarking platform. For Klepal et al., the robot evaluation included only 18 out of the total 20 evaluation points. Obstacles or failures in robot’s navigation, prevented the robot from placing the system-under-test above the remaining two evaluation points. Approach Manual Robot

Bestmann et al. 0.72 0.72 Klepal et al. 1.56 1.71 TABLE 2: Average Location Error (meters) [(ALMOST) UNPUBLISHABLE RESULTS] 30 GetMobile OCTOBER 2014 | Volume 18, Issue 4 Deployment Overhead Remains Too High Most of the teams that participated in the competition had to deploy custom infrastructure, and the rest had to manually profile the evaluation area. From directly observing all the teams during the setup day of the competition, it became clear that the deployment/profiling cost of current approaches is prohibitively high. All teams were given 7 hours to deploy their hardware and/or profile a relatively small area of 300m². Even though one would think that 7 hours should be way more than enough time for the teams to setup their systems, this wasn’t the case. Most teams (with a couple of exceptions) required all 7 hours to set up, and for some teams 7 hours was not enough to profile the whole 300m² of the competition space. This is particularly concerning given the fact that the teams did not have to worry about any practical issues that any commercial deployment would impose (i.e., aesthetics, properly hiding the deployed equipment, etc.). In addition, the whole process of deploying custom hardware and profiling the space was quite intrusive. We don’t believe that any business owner would like to perform either of these two tasks while real customers are in the business. When considering the massive size of deployment candidate sites (i.e., shopping malls) and how intrusive, time consuming and labor intensive the processes of deploying hardware and profiling the space are, realistic indoor location deployments that can achieve centimeter-level accuracy seem infeasible at this point. Reducing the overhead and manual labor required by the different indoor location technologies is of paramount importance for their success.

Custom Hardware Solutions Are Not Mature Enough Most of the competing teams employed customized hardware in their systems. However, only Bestmann et al. was able to achieve better accuracy than the top two infrastructure-free approaches (Klepal et al., Laoudias et al). Even though solely based on commercially available access points and sensors, these two approaches were able to achieve less than 2 meters location error, performing significantly better than most infrastructure-based approaches. Even worse, the winning system by Bestmann et al., achieved a location error of 0.72m, which is only half of the infrastructure-free approaches’ error. Given that infrastructure-based solutions require orders of magnitude higher deployment cost (i.e., more time consuming, higher financial cost, more intrusive etc.) compared to infrastructurefree approaches, the improvement they currently offer in terms of localization accuracy does not justify their existence. We believe that infrastructure-based approaches are promising, but nowhere close to where they should be. To become an interesting alternative, any approach in this area needs to achieve significantly higher localization accuracy than traditional WiFi-based indoor location techniques. Changes in the Environment Impact Accuracy Even though previous studies have already shown that large objects such as furniture and human presence can impact localization accuracy, indoor location technologies are typically evaluated on static environments. By modifying the furniture setup in one of the rooms in the evaluation area we were able to quantify the impact of large objects on different indoor location approaches. Infrastructure free approaches that rely on WiFi signals can experience up to 1 meter of location error increase due to furniture setup changes (Table 2). This is particularly high considering that the average location error of the top infrastructure-free approach was 1.6m. However, the increase in location error depends heavily on the implementation. For instance, the top two teams in the infrastructure-free category experience less than 0.5m or even no increase in error at all when the furniture setup is altered.

[ Real-Time Indoor Localization in Smart Ho]

2.1 Notable Indoor Localization Technologies

Technologies used for positioning around the world are numerous

and vary both in size and cost, but also in their precision and

difficulty to actually deploy them. However, when trying to locate

people or items in a closed environment, different factors have to

be considered: radio wave based technologies suffer from wall

penetration problems, which either stops the signal or causes

interferences. Cost and scalability is another factor to be

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considered: indoor systems work on a much lower scale and thus

need smaller and more precise hardware.

2.1.1 Bluetooth (IEEE 802.15)

Bluetooth is a wireless protocol operating in the 2.4GHz ISM band.

It has a shorter range than other wireless protocols, such as WLAN

(IEEE 802.11), but can provide signal using small size tags with

unique IDs used for localization. It has been observed [2] that

Bluetooth performed better, in most cases, than WLAN with the

same number of bases. Several commercial implementations of this

technology already exist [3] such as Topaz and BLPA.

2.1.2 RFID

RFID can be used in two different ways: actively and passively. In

a comparable environment, active RFID tags are much more

effective than passive tags thanks to the use of an internal power

source. Implementation by Hekimian-Williams et al. [4] achieves

an accuracy to the millimeter. On the other hand, despite a

decreased accuracy, passive RFID tags are powered by the emitting

antenna, making them smaller and cheaper.

RFID localization systems have already been the object of an

implementation [6] and will therefore not be further discussed in

this paper.

2.1.3 WLAN (IEEE 802.11)

WLAN, commonly known as Wi-Fi, imposed itself as a technology

of choice for midrange wireless communication. The signal range

varies with the norm used, the most common (802.11 b/g) having a

theoretical range of 100m. It is now widely used by the general

public to connect to the internet at home and through public

hotspots. For the same reasons, this technology is also implemented

in most enterprise locations. Most portable devices (computers,

smartphones) now have embedded Wi-Fi antennas and can be used

to localize a person. Liu et al. reports [3] a precision varying from

1m to 5.4m when used on its own, depending on the solution used.

When implemented in pair with an ultrasound solution, it’s

precision can be greatly improved to 2-15cm.

2.1.4 Ultrasounds

Ultrasounds are sound waves with frequencies higher than the

upper audible limit of human hearing. Therefore, they can be used

without disturbing people in the vicinity. Several methods exist to

measure distances using ultrasounds: Received Signal Strengths

(RSS); Time of Arrival (TOA); Time Difference of Arrival

(TDOA); and Round-Trip Time-of-Flight (RTOF). RSS, TOA and

TDOA all require separate emitters and receivers. They are the

most used and measure the distance using either the attenuation of

the signal strength, or the Time-of-Flight (TOF) in the case of

synchronized emitters and receivers. RTOF on the other hand only

needs one transceiver, acting as both a transmitter and a receiver.

Whenever a sound is emitted, it will bounce off the first object on

its path and return to the source. The distance is then derived from

the velocity of the radio signal in the air and the travel time. This

implementation has the advantages of being small, precise and easy

to implement as a part of a cost-effective infrastructure