traxmate
tracking everything everywhere

Overview of Indoor Positioning and how to use that with Traxmate

Introduction

Indoor positioning solutions have been around for a long time but yet there is no standardised way to deploy such solutions. The exact solution to be used is dependent on the customers use-cases and which problems to be solved. The purpose of this white paper is to outline different options and things to consider that will hopefully help you to make their right choices for your needs.

Positioning based on GPS

When we talk about positioning, many people are familiar with GPS so that is a good start. Satellites orbiting 20.200 km[1] from the earth and your GPS based tracker performs triangulation based on the signals received from these satellites. The more satellites you see the better accuracy you will get. The signal from the GPS satellites are so weak -125dBm so they are hard to capture indoors in most buildings.

Indoor positioning techniques

So indoors we have to use other techniques. One common way is to use Bluetooth and Wifi signals. They are already present in many indoor environments. But other radio waves that can be used as well, like Ultrawideband (UWB) or Laser, Infrared, sound and earth's magnetic fields[2][3].

The choice of technique

When selecting which technique to use, you have to look into the problem you are about to solve and what kind of equipment you can mandate users or assets to carry. One question to ask is what kind of accuracy do I need? Number of meters or centimeters in XY and/or Z? Another question is that hardware sensors/radio waves are present and how much am I willing to invest in infrastructure to meet my accuracy requirements? In many buildings or facilities there is already a deployed network of Wi-Fi access points. This network might already meet the accuracy requirements. Depending on set-up, algorithms and conditions, Wi-Fi positioning can deliver an accuracy of 1-10 meters. UWB can give you cm-dm precision, but will require deployment of infrastructure since this is nothing normally is present. UWB and light based solutions like Laser and Infrared will require a free line of sight between the emitter and the receiver. Magnetic field is always present but the signals are quite sensitive to changes in the environment

The object to be tracked

Which solution to choose is also dependent on which type of object or artifact you are about to track. Is it a forklift with a lot of physical place for a tracker and availability of power to charge a tracker, or is it a hand drill at a construction site? The drill is small and you do not want a bulky battery to charge a power leaking tracker.

The infrastructure

Do you have control of the infrastructure? Is it your premises so you can mandate the deployment of more Wi-Fi Access Point or Bluetooth beacons? Or to install an UWB network? Or your devices are travelling into various places around the city or around the

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[1] https://www.nxp.com/docs/en/brochure/75016740.pdf
[2] https://www.eit.lth.se/sprapport.php?uid=901
[3] https://ieeexplore.ieee.org/document/8683984

world and you need a tracking solution to utilize whatever is available?

Network Based Positioning
This is a technique that can be used if you have control and access to the back-end of your infrastructure. If you have deployed an UWB network, the UWB anchors can receive pings from an UWB tag, and then the network calculates the location of the tag.

Device Centric Direct Positioning
The device is responsible for making the scan of available radio signals and sending this information to a back-end for processing and calculation of the location. Typically this could be a tracker device equipped with Bluetooth and Wi-Fi modules. It performs a scan and collects MAC address and signal strength from Bluetooth beacons and Wi-Fi access points in the proximity of the device.
The results from the scanning (the MAC address and signal strength) is sent to positioning cloud-service via typically 2G/3G/4G (GSM/WCDMA/LTE), NB-IoT, SigFox or LoRA. So in this case the Bluetooth and Wi-Fi is only used for positioning, and then another radio technique is used for the uplink communication. This set-up gives a self-contained tracking solution, but the uplink communication requires physical space and battery. Traxmate supports Device Centric Direct Positioning.

Device Centric Indirect Positioning
To save battery life and space, an option is to rely on other devices' possibility to send the position to the cloud. If we go back the hand drill at the construction site, there could be a Bluetooth beacon attached the drill. The signal from this beacon can be picked up by tracking devices for SmartPhones app that have the possibility to send this information to the internet. The location of the hand drill will be determined of the position of the device that was sensing its Bluetooth signals. Traxmate supports Device Centric Indirect Positioning.

Uplink Communication
Depending on your use-case and available trackers you can select from different types of uplinks. So far has 2G/3G/4G been the most common uplink techniques from trackers. But these cellular techniques require a lot of power. More power efficient is LPWAN[4] techniques like NB-IoT, SigFox and LoRaWAN. For NB-IoT and SigFox[5] you have to rely on such coverage where you need it. For LoRaWAN you have the possibility to deploy your own LoRaWAN network if the coverage is not available or good enough for third-party LoRaWAN network providers. Traxmate is uplink agnostic.

LoRaWAN Networks
LoRa in LoRaWAN comes from Long Range. It is a radio protocol that provides data over long distances to a low power consumption. Ideal for IoT sensors to uplink sensor values up to the cloud. Either you set-up your own LoRaWAN network by deploying LoRa gateways and attach them to your own, free or commercial cloud-service, or you use free or commercial LoRaWAN networks[6] already deployed and active in your needed area. Traxmate is already connected to several

[4] https://en.wikipedia.org/wiki/LPWAN
[5] https://www.sigfox.com/en
[6] https://www.semtech.com/lora/ecosystem/networks

LoRaWAN providers and it can with limited effort be integrated to others.

The Physical tracker
If you should track the location of an asset, one way is to place a physical tracking device onto that tracking object. A bluetooth beacon on a hand drill. A LoRa based and credit card size tracker as a badge that is worn by your security staff. Or if you want to track an equipment that already has Wi-Fi and Bleutooth built in? Instead of placing a bulky tracker on that device, the software of the device can be modified to perform the Wi-Fi and Bluetooth scans and send that information to the positioning cloud-service. Infusion pumps at hospitals is just one example of such implementation. Traxmate has partnerships with various tracker providers and can deliver Traxmate pre configured devices.

From Hardware to Software
Once the physical objects like infrastructure, trackers, uplinks have been decided it is time to take a closer look at the software and the procedures related to that. The hardware establishes some kind of playground, a base, we have some physical laws and limitations to consider. Without any radio signals available it will be impossible to perform any radio signal based indoor positioning. So to analyse the physical conditions, we suggest performing indoor surveys.

Indoor Surveys
Independent of which technology you choose, it is interesting, valuable or mandatory to perform an indoor survey to see which signals are available and that can be used for indoor positioning. This indoor survey can also be used to train the positioning algorithms. A typical outcome of such surveys is a heat map showing where you have radio signals for Wi-Fi networks, Bluetooth beacons. Another outcome could be a heatmap showing the estimated median error of the selected indoor location solution. A process to follow is perform surveys in all areas where you would like to enable indoor positioning. Analyse the results of the radio heap map and median errors. If there is no radio available and the estimated median error is above your use-case requirements, you can decide if you should deploy more infrastructure to meet these requirements or not. With Traxmate you easily perform a survey in your facility by using the Traxmate Android app.

The cost of indoor surveys
Depending on physical conditions, use-case requirements and software based algorithms, the need of surveys and the need of repeated surveys will vary. Fingerprint based methods can be more sensitive to changes in the environment than traditionally trilateration based algorithms. Both methods are using the signalstrength (RSSI) from for example Wi-Fi access points and Bluetooth beacons, but fingerprint based methods are looking for fingerprint-like patterns.

Fingerprint vs Trilateration
It can require a lot of surveys and detailed surveys to build up a large enough pattern database to be able to provide good accuracy. When the environment changes, and pattern changes, a re-survey could be required. A disturbance in the pattern can lead the calculated position to “jump” to the wrong location. On the other hand, trilateration based algorithms have harder to

adapt to physical obstacles like thick walls. In an ideal world for trilateration algorithms, you should have open space and a free line of sight 360 degrees around the access point or beacon. The most accurate and stable solution is most likely a combination of the two methods. Traxmate supports such a combination.

Angle of Arrival (AoA)
Fingerprint and trilateration based methods have more or less just the unique id of the Wi-Fi access point or Bluetooth beacon to calculate the location. For Angle of Arrival based solution, you also have the direction, the angle, to the object. By an advanced antenna system in the Wi-Fi access point or Bluetooth gateway, they can calculate the direction to the tracked device. If the solution also can get the distance it can provide a location, or as an alternative, you can have several Angle of Arrival based gateways, and by calculation of the intersection point you will get the location of the tracked device. Traxmate can support AoA gateways.

Time of Arrival / Round-Trip-Time
Instead of using the signal strength of the received signal from Wi-Fi and Blueooth to calculate the distance for performing trilateration, an alternative method is to measure the time it takes for the radio signals to travel between the access point to the device to be tracked. The technique is either called Time of Arrival (TOA) or Round Trip Time (RTT). The new Wi-Fi standard 802.11mc supports RTT. The technique can be used if both the Wi-Fi access point and the receiving Wi-Fi module in the tracking device is supporting it. With RTT you can expect a median error around 1-2 meters, compared to 3-5 meters with RSSI (signal strength). The reason for this difference is that the noise ratio in RSSI is much higher than in RTT. Traxmate supports ToA and RTT based positioning.

Indoor positioning accuracy
The need of accuracy depends heavily on the use-case. The actual accuracy depends heavily on the available infrastructure. The interest in investing in infrastructure depends on the use-case and the business-case. So it can be a good tactic to define the need of accuracy before investing more in infrastructure than needed. Some use-cases are fine with floor level accuray (“On which floor is Device X or Person Y?”), some use-cases need room level accuracy (“In which room is Device X or Person Y?”). Some other use-cases require high floor level accuracy (Z) plus an accuracy of a couple meters in XY. To achieve 3-5 meters accuracy in XY, plus floor level accuracy >95%, as rule of thumb, make sure you have placed Wi-Fi Access Point or Bluetooth beacons as grid with 10 meters in between each other. To save costs and if your use-case does not require more accuracy, you can make a grid 20x20 meters and you can achieve around 7-10 meters accuracy in XY. The actual results will depend on the physical environment and how the radio signals propagate through walls and reflects. Every facility has its own characteristics.

Self learning systems
To minimize or reduce the cost of performing surveys, you might have the possibility to select a system that is a self learning system and performs surveys and corrective actions automatically. This is done either by smart phones apps running in the background of mobile devices active

in the areas, or by some portion of the tracker device taking a more active roll. The scanning results for these learning devices will help to determine changes in the radio environment, Wi-Fi access points or Bluetooth beacons that have stopped emitting or that have been moved. The self learning system can also capture enough of data to detect walls and the thickness of walls and detect walking paths. Traxmate is a self learning system.

Summary

Analyse the requirements from your use-case. Select an architecture and infrastructure that meet your needs. Select from infrastructure based, infrastructure fee, Network Centric or Client Centric solution. Client Centric direct or indirect positioning. For Client Centric Direct positioning choose positioning technologies (Wi-Fi, Bluetooth, Magnetic), choose uplink communication (2G,3G,4G,NB-IoT, SigFox or LoRa). Choose a cloud-service provider, e.g. Traxmate, that can integrate your devices and perform the seamless indoor/outdoor positioning.

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