Introduction: Which is the best indoor positioning technology for mobile apps?

Indoor positioning technology for smartphones is developing rapidly, driven by the demand for indoor mapping, indoor tracking, and real-time location analytics. So we regularly publish tech updates to help you keep up to speed with the latest changes. For each technology, the costs need to be balanced against the delivered accuracy. For all the talk about ‘sub-meter accuracy’, it’s seldom required. For indoor navigation systems, an accuracy of a few meters is needed.
There are lots of exciting technologies on the horizon. But for 2021 we recommend sticking with a Bluetooth beacon infrastructure, combined with inertial data. This technology provides mobile apps with a location accuracy of 2 to 5m. It’s quick and cheap to install and configure.

The major contenders in 2021 for this use case are:

WiFi

The great promise of WiFi positioning is that it leverages existing infrastructure. However, iOS doesn't give access to WiFi signal strengths. So positioning has to take place on the infrastructure, not the phone. And this means there's no access to inertial information. This greatly limits the accuracy that WiFi signal strength positioning can achieve.
If 802.11mc (RTT) or 8.2.11az reach mass adoption, this could all change. These technologies use time of flight ranging instead of signal strength, making them much more accurate. Inertial information is still helpful, but it's not so important. So WiFi-based location may become a more attractive technology. For 2021, these technologies aren't yet viable, mainly because iOS doesn't support RTT.

Bluetooth Beacons

Currently the best balance between cost and performance. Installation is needed. But the beacons are low-cost and battery-powered, with battery life measured in months or even years. So both installation and ongoing maintenance are minimal. Bluetooth beacons alone don't provide great accuracy. But when combined with inertial data, the accuracy is good enough for almost every use case.

Infrastructure-free

Fingerprinting technologies are sometimes sold as infrastructure-free. But caution is needed. If iOS and Android both need to be supported, most environments will still need some additional Bluetooth beacons.
Fingerprinting also comes with the overhead of updating the system periodically. So even if it's infrastructure-free, it's not maintenance-free.

Other higher-accuracy technologies

Specialist technologies like Angle of Arrival Bluetooth, UWB or ultrasound may achieve 1m accuracy. This is impossible using Bluetooth or WiFi. But it comes at a cost. The hardware makes deployment much more expensive and more complex. And it's not yet supported on enough phones.

2021 Comparison of Indoor Positioning Technologies

There are broadly three types of information that drive indoor positioning systems. **Fixed anchors**, **fingerprinting,** and **inertial**.

Fixed Anchors

Fixed anchors are the direct replacement for GPS (Global Positioning System) in indoor environments.

Many systems rely on knowing the location of a transmitter or receiver. A signal between the fixed anchor and a mobile device can then tell us the distance, or angle between them. Once you know the distance or angle to multiple fixed anchors, you can determine the position of the mobile device.

The transmitters or receivers have to be installed within a building as the signals used don’t have the range reach outside the building. In the future, it may well be possible to use a network of fixed anchors across a wide area for indoor positioning - like a ground-based GPS.

Signal Types

Very often a radio signal is used, for example, Bluetooth, WiFi, or UWB. But there are systems that use ultrasound too.

Transmitter or Receiver

Sometimes the fixed anchor is the transmitter, and the signal is received by the mobile device. Examples are Bluetooth Low Energy (BLE) beacons and ultrasound beacons.

Sometimes the fixed anchor is the receiver, picking up signals transmitted by the mobile device. An example is the WiFi Indoor Location offered by Cisco and Aruba.

Signal Strength Range Measurement

Many systems measure distance by using the received signal strength (RSSI). This is always prone to considerable error. Systems based solely on RSSI will always be less accurate.

Time of Flight Range Measurement

Much more accurate indoor positioning can be achieved if the distance between anchors and mobile devices is measured with precision. Technology options are increasing, and are starting to become available on smartphones. For instance, WiFi RTT times the signal rather than using signal strength, and is capable of sub-meter accuracy. It’s available now on Android phones.

Angle Measurement

Other technologies measure the angle from anchor to mobile device, rather than the distance. One example Bluetooth 5.1 which supports AoA and AoD.

Fingerprinting

Fingerprinting is a completely different approach. Rather than knowing the exact location of fixed anchors, fingerprinting relies on mapping the signal fluctuations across the area to be covered. The signals may already exist in the environment (like the earth's geomagnetic field, or WiFi signals from an existing installation). Or existing signals may be supplemented by installing additional transmitters like Bluetooth beacons, but without having to record their precise location.
The great advantage of fingerprinting is that it avoids installation and mapping of fixed anchors. However, there is considerable work in building and maintaining the fingerprint map in order to achieve the required accuracy. And solutions are seldom completely free of infrastructure.

Inertial

The final source of data is inertial, from movement sensors on the mobile device.
It is possible to locate people just from these sensors (pedestrian dead reckoning). But you need to know their starting point and initial heading. And after a short time, the location data will drift off track.

So inertial data is most useful when combined with another technique (fixed anchors or fingerprinting) capable of absolute rather than relative positioning.

Future sources of location information

In the future, 5G may well enable better indoor location. For public 5G networks, we'll have to wait and see whether and how the networks open up location data to third parties.

And WiFi 802.11az may make infrastructure positioning accurate enough without adding inertial information.

Summary of technologies

Technology	Pros	Cons	Summary
Bluetooth Beacons Low cost battery powered Bluetooth Low Energy transmitters installed and mapped. Signal strength sensed by the mobile device.	Installation is low cost and simple. Beacons are increasingly integrated into access points, light fittings etc. When combined with inertial data from smartphones, accuracy of 2-3m is possible. No fingerprinting or calibration is required.	Sub-meter accuracy isn't possible. Without inertial data, accuracy is more like 10m.	Tried and tested technology that delivers a balance between accuracy and cost.
Fingerprinting Multiple signals: Earth's magnetic field, WiFi, Bluetooth	Little or no infrastructure needed. Transmitters don't need to be mapped.	WiFi fingerprinting isn't possible on iPhones, meaning beacons are often required anyway. Overhead of creating and updating fingerprint maps.	The holy grail of positioning with zero-infrastructure is enticing. But available solutions don't yet deliver a robust enough product.
WiFi location based services	If you already have the WiFi network installed, there's no additional hardware. Works across all smartphones.	Access points are often in the wrong places for optimal accuracy. And there are often insufficient access points for optimal accuracy.	If zone level accuracy is required, can be a good solution. But for indoor navigation systems, the accuracy seldom delivers.

WiFi 802.11mc (RTT) Measures location at the mobile device.	By using time of flight, sub-meter accuracy is possible.	Supported by newer Android phones, but not by iPhones. Supported by some WiFi providers (eg Aruba), but not all.	One to watch. If and when Apple support 802.11mc, it will be a front-runner for any indoor environment that has enterprise WiFi.
WiFi 802.11az (Next Generation Positioning) Detects device location at the access point.	By using time of flight, sub-meter accuracy is possible.	Not yet part of the WiFi standard.	One to watch. May end up leap-frogging 802.11mc to become the leading WiFi location technology.
UWB (Ultrawideband) Short range wireless, a competitor to Bluetooth Low Energy (BLE).	By using time of flight, sub-meter accuracy is possible.	Supported only by the iPhone 11 and above, and (at the time of writing) accessible only by Apple. UWB chips are more expensive that Bluetooth, but prices appear to be coming down.	Could be a great solution. But only if Apple open up access, Android phones start integrating the technology, and prices continue to fall.
Ultrasound Beacons	By using time of flight, sub-meter accuracy is possible.	Ultrasound beacons are more expensive than Bluetooth beacons. Technology is not yet widely adopted or proven.	An interesting option that deserves consideration.
Bluetooth-based WiRa	By using time of flight, sub-meter accuracy is possible.	A new technology invented by Dialog. But not yet supported by phones, or adopted into the Bluetooth specification.	Might be interesting if it becomes part of the Bluetooth standard.

Bluetooth Angle of Arrival / Departure	By using accuracy angle measurement, sub-meter accuracy may be possible.	Expensive beacons with multiple antennas need to be carefully installed, making the system more expensive.	Current solutions are quite specialist (high performance, but also higher cost).
Inertial	Doesn’t require any signals at all - so works anywhere.	Needs a known starting position and heading, and quickly drifts off track	Very valuable when combined with one of the other technologies. But doesn’t deliver on its own.

Crowd Connected’s Sail technology uses Bluetooth beacons and inertial data. Combining both inputs results in positioning accuracy of around 2 to 5 meters. No fingerprinting is involved. Sail is already compatible with WiFi 802.11mc, and if iOS supports this technology in the future, Bluetooth beacons may no longer be required.