Mapsted®

...Leading the World Indoors

A SURVEY OF

Current Indoor Positioning Technologies

CONTENT

INTRODUCTION

The Indoor Positioning and Indoor Navigation markets are estimated to reach $43.51 billion globally by 2025, at a 42% Compounded Annual Growth Rate. This means the market is large and there is tremendous demand for an innovative wayfinding solution.

We've all heard of GPS technology. Almost everyone has used a GPS while driving; it's been the societal norm for outdoor navigation. The problem with GPS is that it only works well for outdoor locations. In today's technologically progressive society, businesses are looking to use GPS technology indoors. In theory, GPS looks to be a great choice for businesses because it's a technology we're all familiar with, and now it would not only lead us to the mall, it could help us find stores or products inside the mall as well. But, in practice, we've seen that GPS, like many other indoor navigation technologies, falls short when it comes to indoor navigation.

There are a plethora of other types of indoor navigation technologies, aside from GPS's, that are part of the current indoor navigation landscape. Indoor navigation technology comes in many different forms, and not all are created equal. Understanding the pros and cons of each platform is important to truly appreciating Mapsted's world class technology.

The following whitepaper will educate you on some of the pros and cons of the current location positioning technological landscape.

1.0 GLOBAL POSITIONING SYSTEM (GPS)

Almost everyone has used a GPS navigation system at some point in their lives. GPS is great for when you're headed out for a drive or a walk through the city.

But what exactly is GPS?

GPS is a system made up of three parts: satellites, ground stations, and receivers. The basic GPS service provides users with approximately 8 meter outdoor accuracy 95% of the time. This works by satellites emitting signals to receivers to determine their location by computing the difference between the time that a signal is sent and the time it is received. This data contains information about where the satellite is located and other adjustments to determine location accuracy. Once these data ranges are determined the receiver can then compute its own three dimensional location called trilateration. At least four satellite signals are required to accomplish this positioning otherwise there is room for multiple outcomes.

GPS is a common technology that has helped tremendously with outdoor navigation. But what about indoors? It seems like it would be a simple solution to bring GPS technology inside but it falls short in performance.

Challenges with the technology:

- Needs uninterrupted satellite signal to work properly
- Can not determine the floor level the device is located on
- Walls and similar obstacles in large facilities interfere with the signal
- Users demand better than the 30 to 100-metre accuracy you would typically get indoors using GPS technology

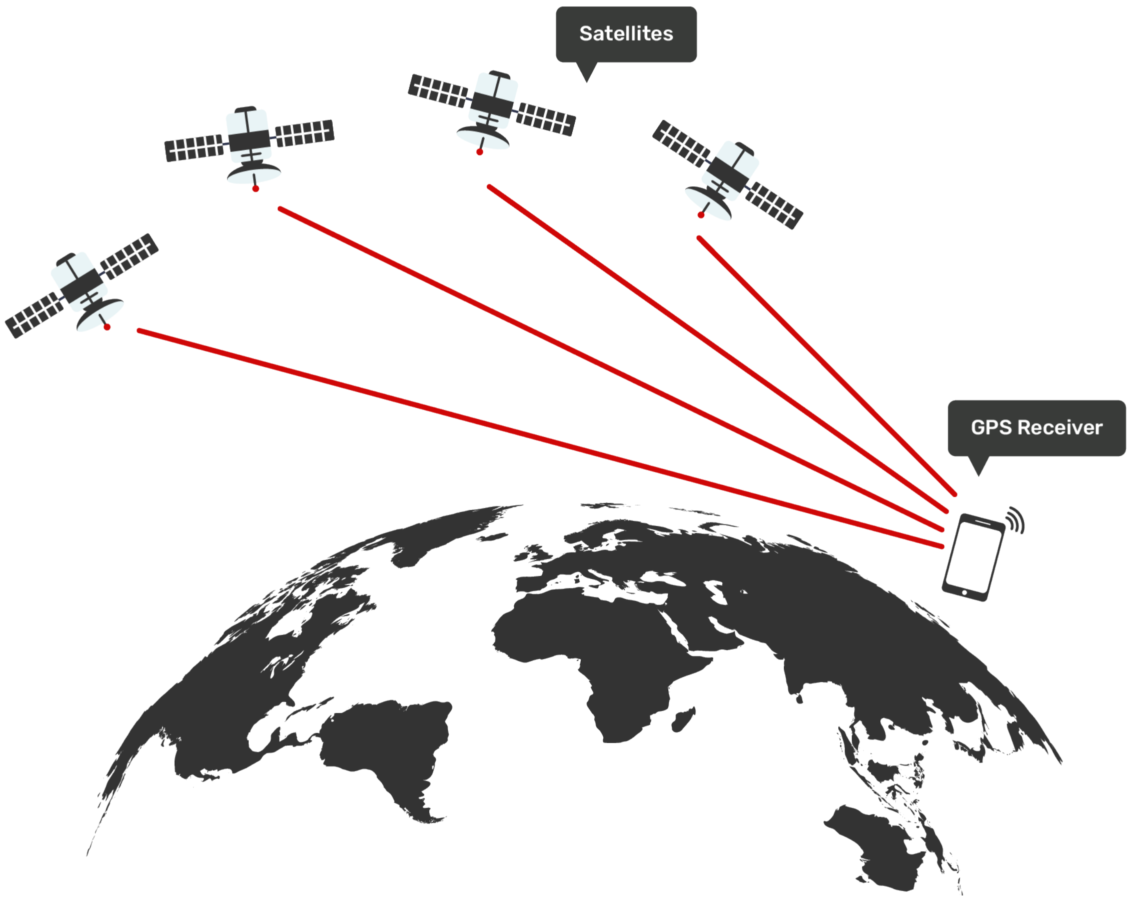


Figure 1: GPS requires at least 4 satellites to accomplish location positioning. It is based on the trilateration of satellite signals which helps determine distance. The GPS receiver e.g. smartphone receives signals from the satellites which compute position from calculated distances. Data is transferred to a ground station when in range, which transfers to a cloud server that can be viewed through an internet connection.

1.1 RADIO FREQUENCY IDENTIFICATION (RFID)

Radio frequency identification (RFID) is a technology that has been around since the 1980s. If you are familiar with contactless payment which allows you to pay for an item by the tap of your credit or debit card then you've used a form of RFID.

RFID is widely used for electronic identification and RFID positioning. RFID offers substantial advantages for businesses allowing automatic inventory and tracking on the supply chain. This technology plays a key role in pervasive networks and services. Data can be stored and remotely retrieved on RFID tags enabling real-time identification of devices and users. However, the usage of RFID could be hugely optimized if identification information was linked to location.

There are three types of RFID tags. Active, passive, and semi passive. They are comprised of a microchip or integrated circuit (IC), an antenna, and a protective material layer that holds all the components together. For navigation purposes, passive RFID tags are used because they don't require an external power source making it easier to implement around a facility. Passive tags are placed around a physical space, like a course, to map out a navigation path.

A RFID tracking system is composed of three different entities, RFID tags, readers, and servers. RFID utilizes Received signal strength (RSS), Angle of arrival (AOA), Time of arrival (TOA) and Time distance of arrival (TDOA) although when used indoors the above methods, excluding RSS, may fail to provide accurate positioning location due to interference with the line of site to the RFID reader. RFID is a popular option for indoor positioning because of its simplicity, low cost, and effective range.

Challenges with the technology:

- Requires additional hardware
- Only useful for spot detection
- Short-range of < 1m
- Installation requires extensive planning

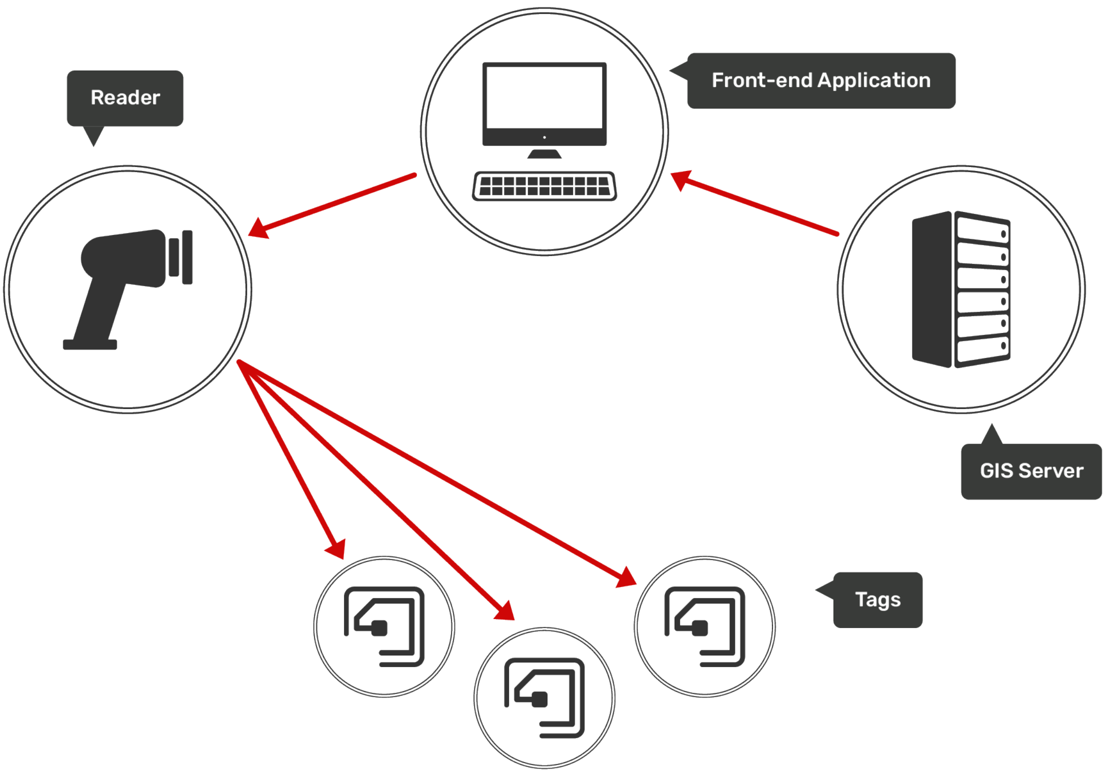


Figure 2: RFID. The antenna converts the RFID reader's signal into radio frequency waves that can be picked up by RFID tags. RFID tags are attached to objects which are then read by an RFID reader. The GIS server determines which properties are important to be sent to a front-end application that then relays information about the location of the object.

1.2 ULTRA WIDE BAND (UWB)

Ultra WideBand Positioning (UWB Positioning) is one of the most recent indoor positioning technologies to emerge. Prior to UWB Positioning, there were similar technologies referred to as base-band, impulse, and carrier-free technology. The United States of America Department of Defense was the first to use the term "ultra wideband". UWB indoor positioning became commercially available in the late 1990's. UWB radio is a method of spectrum access that can provide high speed data rate communication over the personal area network space.

UWB or ultra-wide band technology is a short range radio frequency that delivers fast and stable data transmission sent every couple of nanoseconds as a pattern across a wide frequency spectrum of at least 500 MHz. This allows UWB positioning transmitters to transmit large amounts of data while consuming little transmit energy. UWB can be used for positioning by utilizing the time difference of arrival (TDOA) or the RF signals to obtain the distance between the reference point and the target.

UWB positioning systems rely on transmitting extremely short pulses and use techniques that cause a spreading of the radio energy (over a wide frequency band) with a very low power spectral density. This high bandwidth offers high data throughput for communication. The low frequency of UWB pulses enable the signal to effectively pass through common objects such as falls, furniture, and other objects.

One advantage of using an UWB indoor navigation system is that it is license-free because of its low power. UWB is not classified as radio equipment because its low power signal does not interfere with most of the existing radio systems. UWB consumes low power in comparison with other positioning systems that enable power efficiency for better battery life of devices. UWB localization uses a pulse that allows transmitters to send only during the pulse transmission which in turn produces a strict duty cycle on the radio in order to minimize the baseline power consumption.

Although using very short pulses in UWB has many advantages, the UWB receiver requires signal acquisition, synchronization and tracking to be done with very high precision in time relative to the pulse rate. These steps are time-consuming.

Challenges with the technology:

- In general, most smart phones do not have UWB receivers, so it is typically only available using specialized hardware which is very expensive
- Requires external hardware ie. tags
- Expensive
- Deployment is very difficult in complex building structures
- May cause harmful interference to GPS and aircraft navigation radio equipment

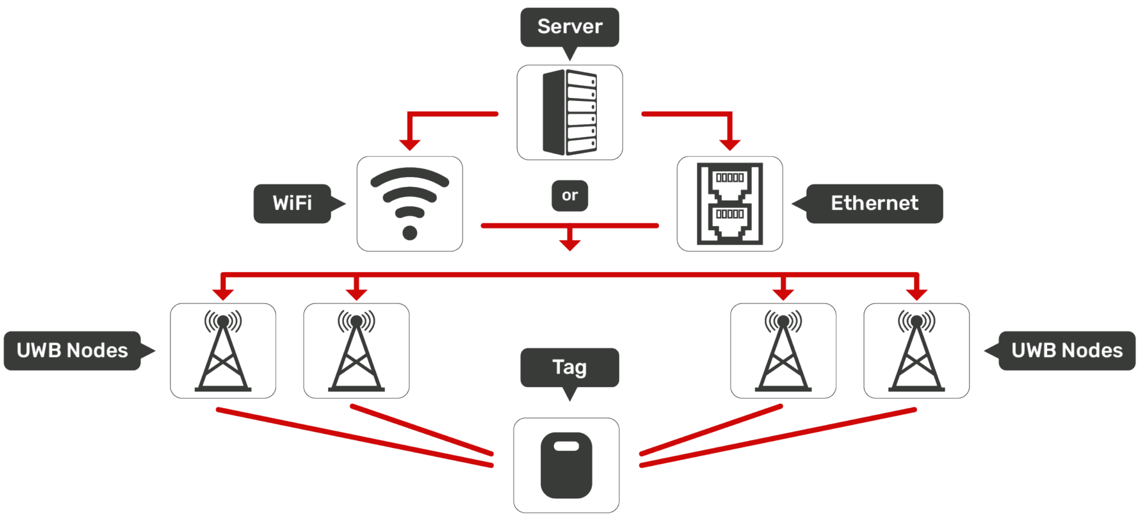


Figure 3: UWB works by tags that are equipped with UWB technology. The anchors are electronic devices that detect UWB pulses emitted by UWB tags and forward them to the location server for calculating the location of the tags.

1.3 BLUETOOTH LOW ENERGY BEACONS

Figure 4: Bluetooth Low Energy Beacons

Beacons have become quite common in indoor navigation. They are small wireless devices that are typically mounted throughout an indoor venue on walls or other physical entities. The beacon devices emit wireless signals, which Bluetooth low energy (BLE) receivers (e.g. smartphones) can receive. Usually, beacons are battery-powered and must be replaced approximately every 6-12 months, depending on the beacon quality and configuration parameters.

The technology behind these beacons is BLE or bluetooth low energy. Beacons are useful in indoor positioning technology because they can use distance data from two or more beacons and position the user on an indoor map. They also can administer targeted information such as a sale to the user.

There are several methods in which BLE beacons can be used for positioning.

- BLE proximity
- BLE trilateration
- BLE fingerprinting

BLE proximity identifies a rougher user position based on which BLE is visible at the time. BLE trilateration infers the distances between the user and each visible Wi-Fi router and calculates it's position based on those distances.

BLE fingerprinting does not need to know the locations of the Wi-Fi routers but instead creates a large fingerprint map of the RSS of each beacon at various locations and then in real-time compares the measured RSS to the fingerprint map to determine the users position. Constructing the Wi-Fi fingerprint map can be time-consuming and requires a site-survey.

Current smartphones can support the Bluetooth 4.0 protocol. In the future, when smartphones support the Bluetooth 5.1 protocol, they can take advantage of a new feature for direction finding, which is capable of also measuring the direction of the beacon, which can help improve the positioning accuracy significantly.

BLE signals contain metadata which can be processed and used to determine the user's location. There are two popular protocols for BLE communication, iBeacon and Eddystone.

Challenges with the technology:

- Additional hardware needed (beacons)
- The maintenance required for battery replacement is very costly
- 1-5 beacons needed per 150 square meters to ensure full coverage (not the most accurate but sufficient for most cases)
- Only works if the user has Bluetooth enabled on the smartphone

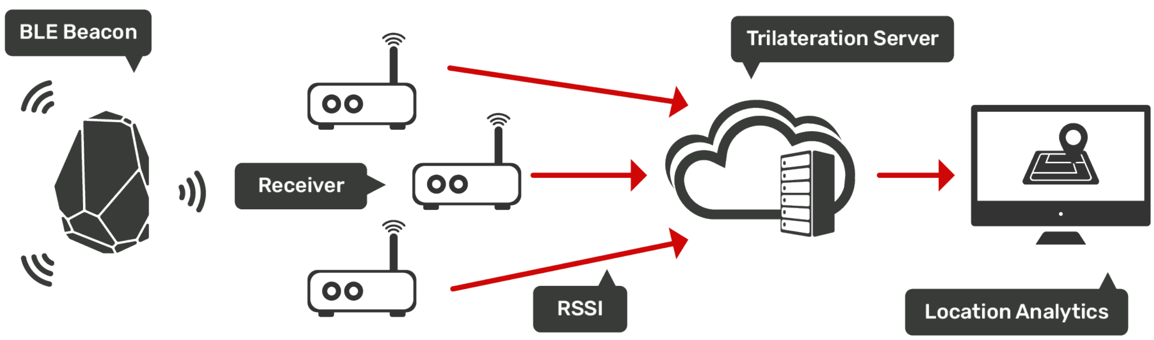


Figure 5: BLE. The Bluetooth beacon speaks to the receiver based on RSS to determine the user's position. The closer the user is to the beacon, the more knowledge we have about where that user is positioned.

1.4 WI-FI POSITIONING

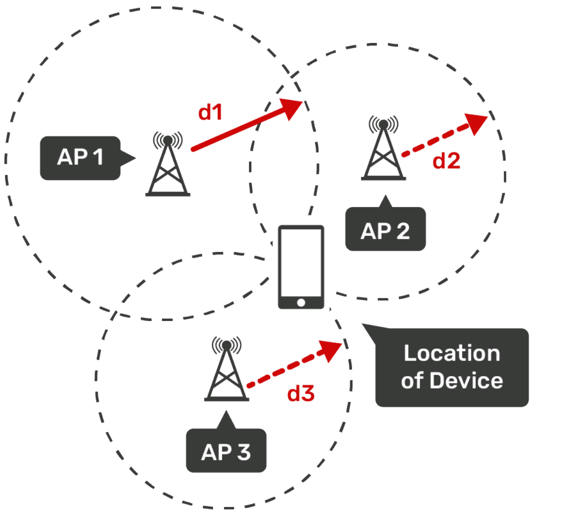


Figure 6: Wi-Fi positioning during trilateration requires knowledge of where each Wi-Fi router is. Then by calculating the RSS from each router, a distance can be estimated between the user and the routers which can help determine the user's position.

Wi-Fi is commonly used for the transmission of data and is a great alternative to be used indoors when GPS capabilities are limited. Each Wi-Fi access point relays data to allow users to access the internet. Wi-Fi positioning can take advantage of the signals emitted from Wi-Fi routers to gain some insights into the users location.

When a Wi-Fi router sends a wireless signal, Wi-Fi receivers (e.g., smartphones) can accept those signals. Each signal contains some metadata which can be processed and used to determine the users' location.

Wi-Fi Metadata:

- MAC address (unique ID for the router)
- RSS (received signal strength)

The MAC address is unique for each Wi-Fi router and the RSS provides a rough measurement of how far away the device is.

Intuitively, a strong RSS would show that the user is close to that Wi-Fi router and a weak RSS would indicate that the user is far from the Wi-Fi router.

The challenge for indoor environments is that the signal strength is weakened as it passes through obstacles such as walls, furniture, or people's bodies. Therefore, a weak RSS could imply that either the user is far away or that they may be close but there are obstacles in the way (e.g., walls or furniture).

There are two main ways Wi-Fi MAC address and RSS can be used for positioning. The first is Wi-Fi trilateration and the second is Wi-Fi fingerprinting.

Wi-Fi trilateration requires knowledge of the location of each Wi-Fi router. Then, based on the RSS, it estimates a distance between the user and each visible Wi-Fi router and calculates its position based on those distances.

Wi-Fi fingerprinting does not need to know the locations of the Wi-Fi routers but instead creates a large fingerprint map of what the RSS of each MAC address looks like at various locations and then in real-time compares the measured RSS to the fingerprint map to determine the users position.

Assembling the Wi-Fi fingerprint map can be time-consuming and requires a site-survey, but tends to provide more accurate results than Wi-Fi trilateration.

Challenges with the technology:

- iOS devices have restricted access to scan for Wi-Fi
- Android data through the Wi-Fi network can be limited for scanning
- Accuracy alone is not sufficient for indoor positioning (10-15 meters)
- Wi-Fi signals propagate through various walls and obstacles leading to high signal variance and ambiguity which makes it difficult to extract distance

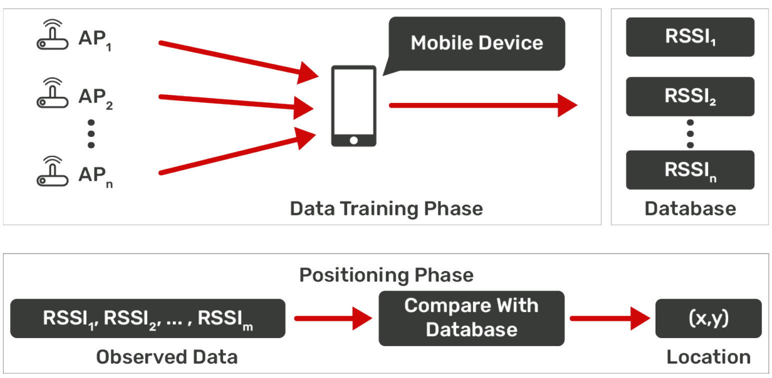


Figure 7: Wi-Fi fingerprinting creates a map based on the RSS of each MAC address and compares the measured RSS to the fingerprint map to determine position.

1.5 IMAGE BASED NAVIGATION

Figure 8: Image-based navigation occurs when a user takes a photo of their whereabouts in a facility and is provided with a navigation path based on their current location.

This method of navigation requires the facility to have a massive database of photos of all the stores within the building that act as landmarks for wayfinding. The user would then take a photo of their surroundings and the algorithm finds the best route for their destination.

Challenges with the technology:

- The user has to grant access to their mobile camera which causes privacy concerns
- Image quality is hard to reach a 100 accuracy rate due to lighting conditions, angles, and phone quality
- The success rate is therefore not at an acceptable level for navigation
- Concern from other users that they are being recorded/photographed without their consent while the technology is being used

1.6 MAGNETIC FIELD

Magnetic fields are all around us and play an important role in our existence. For example, without magnetic fields, the earth would be exposed to harmful radiation. The magnetic field can help with indoor wayfinding and also provide navigation bearings for some animals. The idea behind using the magnetic field as a way to navigate the indoors is exciting because it doesn't rely on any external hardware, although it does come with some challenges.

To use the magnetic field for Indoor positioning services (IPS) involves measuring the magnetic flux density. This is defined as the magnitude of a magnetic B field over a surface. Magnetic B field can be measured over certain man made material structures within buildings. If the facility has pre existing structures that have remained the same over a period of time, the magnetic flux measured in a particular location of a building will also remain the same. Magnetic fields make geomagnetic IPS a seemingly great option for businesses looking to map the interior of their buildings.

The problem with using magnetic fields for indoor navigation is that there are too many magnetic disturbances. Magnetic disturbances are caused by a variety of things such as renovations, hospital equipment, structure beams, and kiosk placement. Magnetic-field anomalies inside buildings have an impact on compass sensor readings on smart devices. The magnetometer found in smartphones is there to detect spatial direction but the accuracy of this varies greatly by the device.

Compass sensors share the information with the software, and the software knows more about the magnetic field characteristics for that specific building. The more information the software collects the more it recognizes the location and therefore the accuracy or precision gets better.

While using a compass for outdoor navigation is generally a reliable source of wayfinding, trying to calculate your positioning indoors by the magnetic field poses significant technical challenges.

Challenges with the technology:

- Magnetometer readings can vary in intensity by the device which leads to inaccuracies
- If the environment changes within the building it causes drastic inaccuracies for navigation

Figure 9: Hospital equipment, structure beams, kiosk placement, etc. cause magnetic disturbances measured by a magnetic flux which can be used to map out a facility. The map can change if these disturbances are moved and create issues with accurate wayfinding bearings. If the disturbances remain the same, they can be great location markers for identifying user position.

1.7 VISIBLE LIGHT COMMUNICATION (VLC)

Visible light communication (VLC) uses Light Emitting Diodes (LED), operating in the visible part of the electromagnetic spectrum, as optical sources for optical wireless communication. The basis of the technology involves switching LEDs ON and OFF within nanoseconds at a very high frequency to relay information to the smart device via the camera. This pattern of light from the LED luminaires works in a dense network that provides illumination while also functioning as a positioning grid.

As the visible light spectrum is 10,000 times larger than the radio frequency spectrum, VLC is regarded as a solution to radiofrequency (RF) bandwidth limitations. Wireless local area network (WLAN) or mobile connection is not required, however, there must be a constant "line of sight" between the mobile phone camera and the light source. This causes limitations if the user is walking and puts their phone in their pocket, bag etc, or if the camera is temporarily tilted or blocked leading to the inaccuracy of location. This technology is often coupled with BLE beacons to provide a buffer if the smart device goes "out of sight" of the LED.

The data stream is also a one-way street for VLC. This means that no data and/or analytics can be obtained from customer movement.

Using VLC as an indoor positioning technology allows the retailer to save on energy costs for switching to LED yet due to the issue with a line of sight it requires a vast amount of lighting to be installed throughout the facility. Even then, it still poses challenges when the device leaves the line of sight unless you invest in additional hardware to act as a backup to correct these irregularities.

Challenges with the technology:

- The VLC alone is not enough to produce accurate location positioning
- Requires extensive planning and multiple LED installations
- VLC alone can not provide additional data about the customer

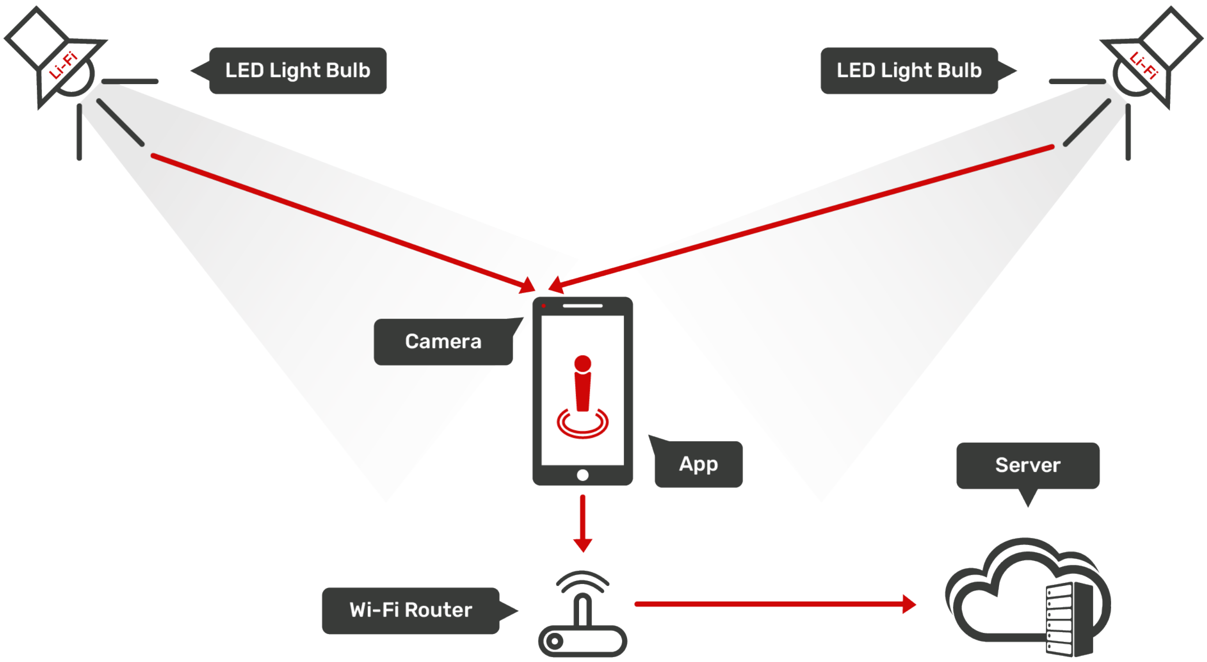


Figure 10: Visible light communication uses LED lightbulbs to transmit a pattern of light within nanoseconds to act as a positioning grid. The receiver e.g. smartphone receives this light pattern through the phone camera which allows the device positioning to be determined.

1.8 ULTRASONIC

Ultrasonic technology uses sound frequencies higher than the audible range (beyond 20 kHz) to determine the user position using the time taken for an ultrasonic signal to travel from a transmitter to a receiver.

Ultrasonic technology requires the installation of microphones within the rooms of the facility. User location is calculated using the principle of trilateration; at least 3 microphones receiving a sound pulse are needed for finding the user position. Some say that the soundwaves can pinpoint people and objects more accurately than radiofrequency waves which can be picked up by multiple sensors.

Ultrasound signals have short wavelengths and when they are emitted it confines the signals to the walls and doors of that room. To refine the accuracy of these wavelengths, microphones can be designed to be more sensitive to pick up sound waves in a particular direction, allowing a more accurate location of specific objects or people.

This technology comes with privacy concerns as location information is disclosed to the infrastructure administrators. It also proves unscalable as the number of simultaneous microphones in an environment will affect system performance. With multiple microphone installations, the sound emissions will collide with each other creating too much interference.

Challenges with the technology:

- Requires direct line of sight
- Additional hardware required
- Privacy concerns due to microphone access
- Not scalable due to interference of multiple microphones

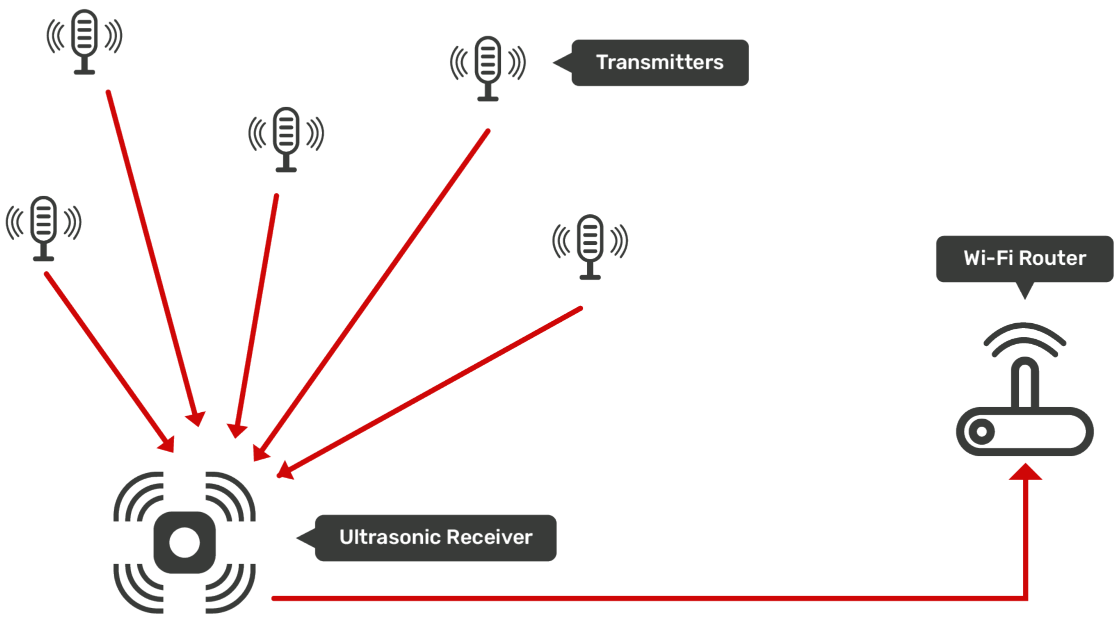


Figure 11: Ultrasonic location requires 3 microphones to calculate the position of the user using the principle of trilateration. The position of the user is determined by measuring the time taken for an ultrasonic signal to travel from transmitter to receiver.

1.9 INFRARED

Infrared uses electromagnetic radiation with wavelengths longer than the visible light spectrum. An infrared system is composed of an infrared light emitter diode, which emits an infrared signal as bursts of non-visible light, and a receiving photodiode to detect and capture the light pulses, which are then processed to retrieve the information.

IR accuracy is affected by multiple factors including directivity as well as the way that it can refract and scatter off of objects causing irregularities in direction. This poses significant challenges when being used for IPS purposes because a direct line of sight is required. The presence of sunlight also affects the accuracy of the system. This is why infrared can be an acceptable choice when used in applications that require a short range line of sight, such as a communication signal from your remote control to your tv, but not as useful for IPS purposes.

Challenges with the technology:

- Not suitable for IPS
- Requires direct line of sight
- Sunlight causes interference
- Privacy concern for users

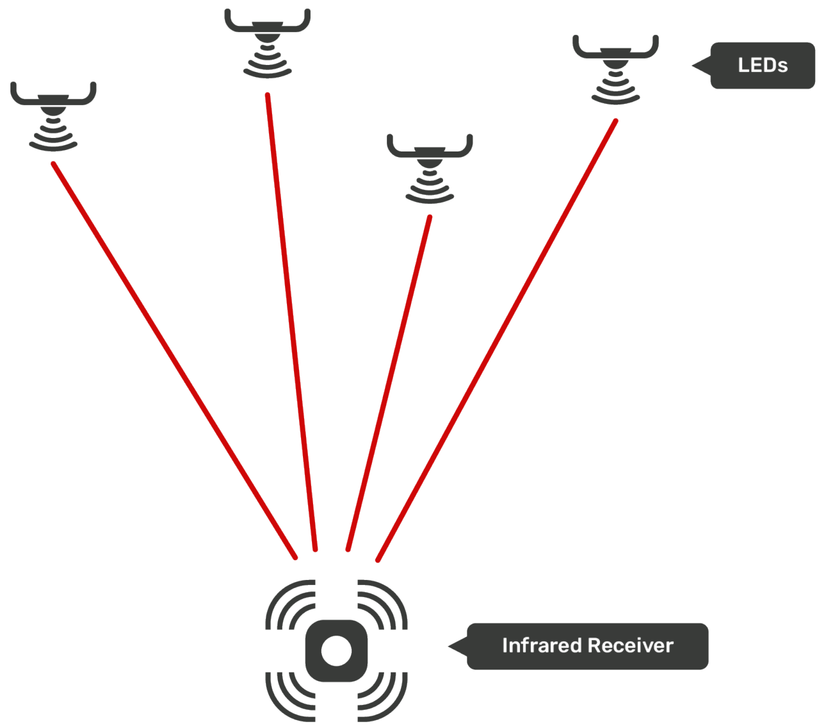
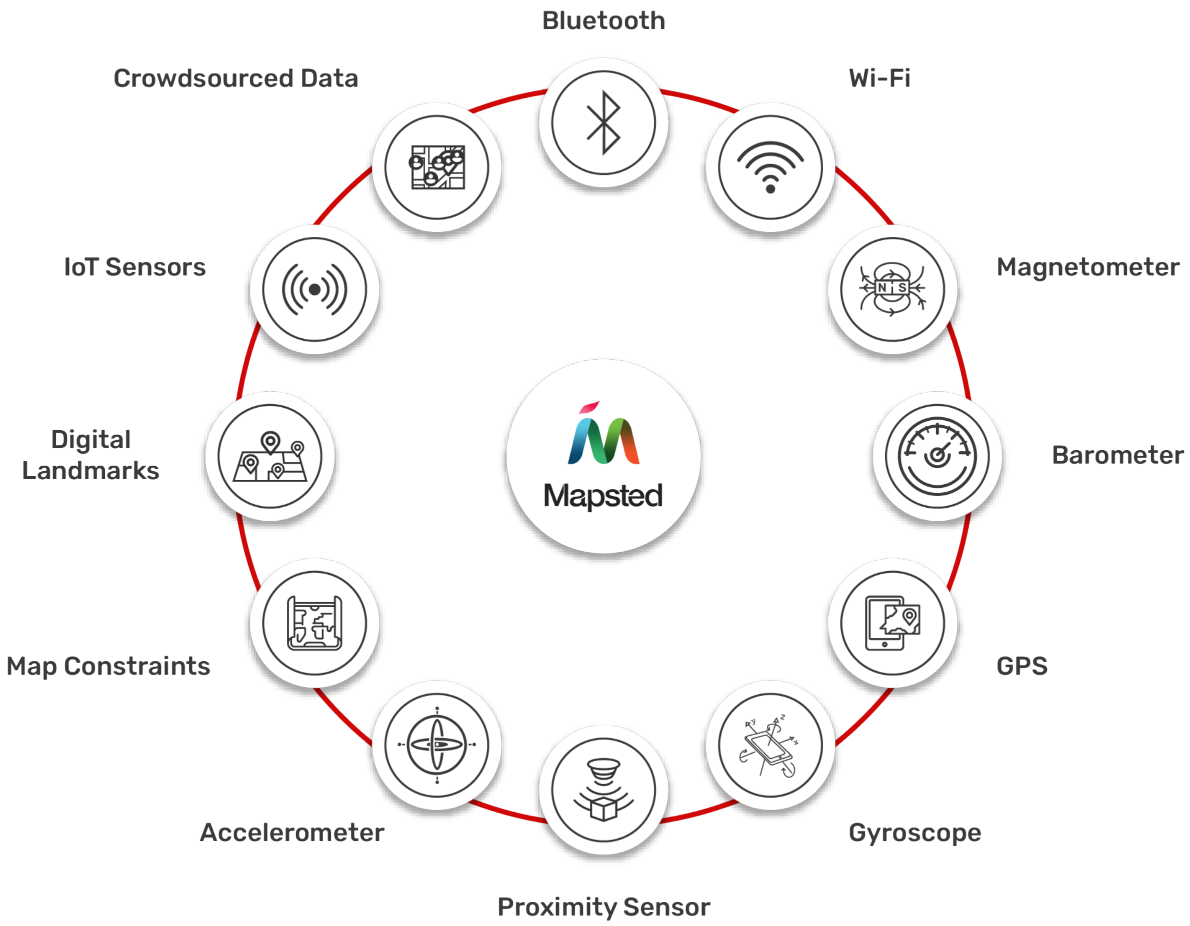


Figure 12: Infrared light pulses are emitted from a light source, sometimes as a red beam or oftentimes invisible to the eye. Receiver devices are installed throughout a facility and when an infrared light pulses, the QADA receiver acquires it, and the location is determined.

A NEW ERA OF LOCATION TECHNOLOGY



"After looking into many different hardware-based technologies, I'm excited to have chosen Mapsted as our one-stop shop for real-time location solutions."

John Chung, VP - Building Technology and Data Architecture
QuadReal Property Group

QuadReal

Mapsted - Advanced Machine Learning & AI Location Technology

Mapsted understands the needs of consumers. That is why Mapsted has engineered a unique algorithm that sources over 50 data points, ensuring accuracy and scalability. This allows us to respond effectively to the changing needs of our clients and design solutions that will work best in their type of environment, ensuring their visitors have the best experience possible when interacting with their properties.

Mapsted's hardware free location positioning solutions make the impossible a reality through groundbreaking innovations in technology, ensuring our clients can deliver cutting edge indoor navigation, targeted marketing, and real-time location intelligence solutions to their customers without Bluetooth beacons, Wi-Fi connectivity, or additional external hardware. To date, we have enabled approximately 400,000,000 square feet (sq.ft.) of physical space with Mapsted Location Services across 6 continents.

At its core, Mapsted offers a patented, accurate, scalable, and low-cost real-time location-based mobile SDK for indoor-outdoor positioning with offline support, without the use of dedicated external hardware. Mapsted also offers a collection of SaaS applications for content and marketing management, interactive web maps, and location-based analytics insights, each of which are multi-tenant, single codebase, continuous delivery platforms, powered by a cloud infrastructure.

Our market differentiation stems from the fact that our technology and platform combines elements not typically offered together:

- Precise scalable location. We offer a 1-3 meter real-time indoor navigation solution without the need for Bluetooth beacons, Wi-Fi, or additional external hardware.
- Multi-tenant SaaS. Our solution takes advantage of the speed, ease-of-use, high-performance, and continuously-updated benefits associated with multi-tenant SaaS.
- Enterprise functionality. Our enterprise-grade functionality is capable of supporting sophisticated use cases.

We prioritize our customer's needs. Our flexible and customizable solutions are built to be scalable, cost-effective, and work in any type of environment. This allows us to respond effectively to the changing needs of our clients and design solutions that will work best in their type of environment, ensuring their visitors have the best experience possible when interacting with their properties.

To create this type of responsive and immersive experience, we have built our service offerings around three distinct areas: Location Positioning, Location Marketing, and Location Analytics.

Location Positioning Platform - Under the Location Positioning division, we offer a suite of Maps, Positioning, and Wayfinding products that deliver seamless outdoor-indoor navigation without the need for beacons, Wi-Fi, or additional external hardware.

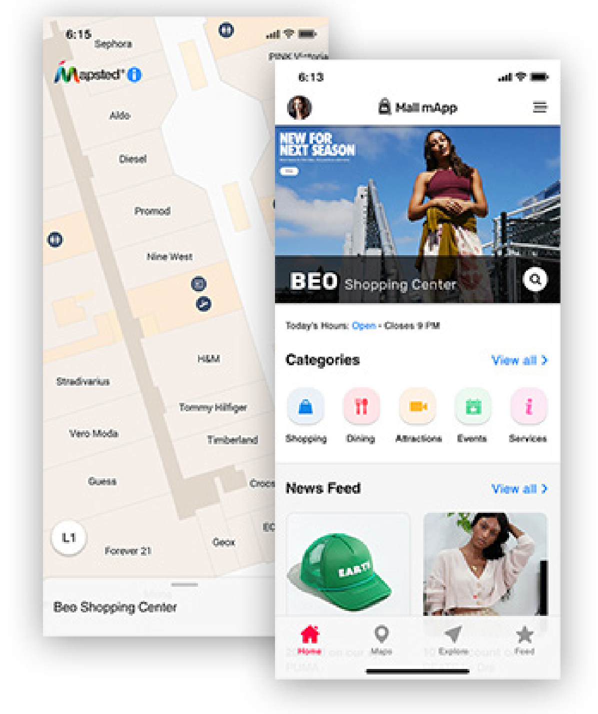


Figure 13: Location Positioning Technology

Location Marketing Platform - - Our Location Marketing arm helps clients find the right audience for their services and improves customer engagement with advanced market segmentation, customer engagement, and targeted notification tools.

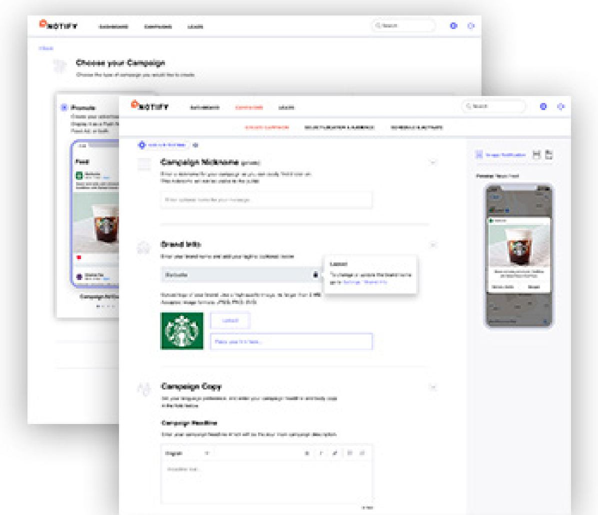


Figure 14: Location Marketing Technology

Location Analytics Platform - The Location Analytics unit provides business clients with deep insights into customer behaviour and a comprehensive location-based analytics suite to help them manage traffic flow on their properties, predict customer behaviour, and visualize patterns and trajectories for effective decision making.

Figure 15: Location Analytics Technology

The key benefits of using our technology include the ability to:

- Offer seamless indoor and outdoor navigation with pinpoint 1 - 3 metre accuracy
- Feature detailed, searchable interactive maps throughout the property
- Customize and update property maps across all platforms, including mobile and Web, in real-time
- Increase conversions with location- and behaviour-based market segmentation and customer engagement tools
- Gain deep insights into customer behaviour with real-time data visualization tools
- Use location-based predictive modelling and pattern visualization for effective decision making

MAPSTED USE CASE

Figure 16: This figure highlights only a portion of the technology that Mapsted offers to personalize your unique wayfinding experience. With Mapsted's continuous innovation, the possibilities are endless!

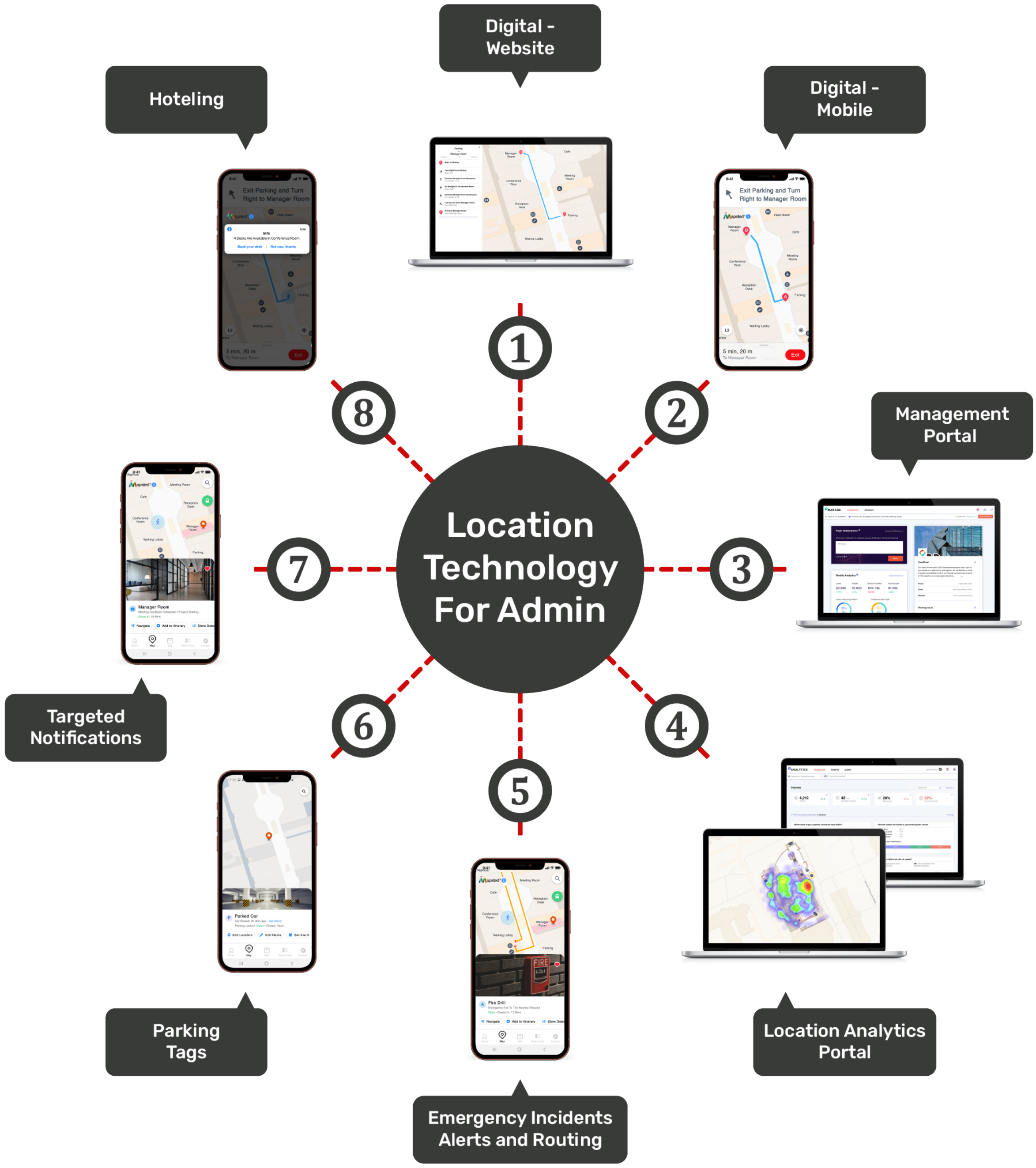


Figure 17: As a business partner with Mapsted, you will have access to all of these location technologies and more.

Mapsted adds tremendous value to many different industries including, but not limited to:

- **Higher Education.** Provide students and visitors with seamless outdoor-indoor campus navigation, send personalized location-based messages, understand traffic flow and much more.

Figure 18: Higher Education

- **Retail Mall.** Enhance the traditional mall experience, send personalized messages, upsell products based on data-driven customer behaviour, and much more.

Figure 19: Retail Mall

- **Resorts & Parks.** Enrich the guest experience, optimize staff placement, send personalized notifications for near-by excursions, and much more.

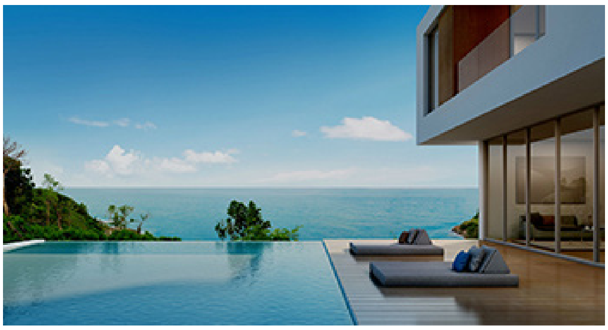


Figure 20: Resorts & Parks

- **Trade Shows & Exhibitions.** Connect attendees with their colleagues, send live session updates, provide effortless navigation, and much more.

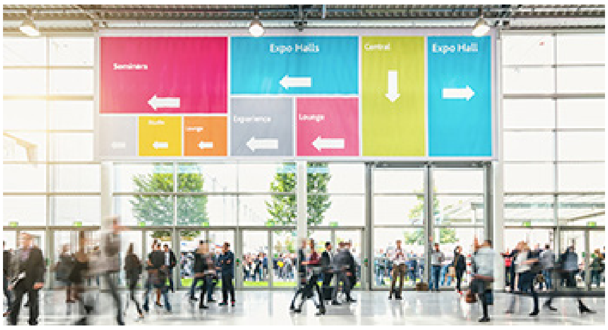


Figure 21: Trade Shows & Exhibitions

- **Museums & Art Galleries.** Delight visitors with advanced indoor navigation, upsell items in boutiques and cafés, understand visitors' interests, and much more.

Figure 22: Museums & Art Galleries

- **Hospitals & Healthcare.** Support patients, visitors, and staff by providing interactive indoor navigation options, improving operational efficiency, and much more.

Figure 23: Hospitals & Healthcare

» Banking. Deliver personalized banking experiences with powerful targeted marketing tools to reach your ideal customers in the right place at the right time, and much more.

Figure 24: Banking

» Big Box Retail. Send contextual messages to shoppers, upsell products based on data-driven customer behaviour, provide effortless navigation, and much more.

Figure 26: Big Box Retail

» Transportation Hubs. Redefine the travel experience, understand passenger analytics, increase sales, and much more.

Figure 25: Transportation Hubs

LET'S TALK

If you have any questions about the technology landscape or you want to discuss your business's location based needs please reach out to us today.

Request a Demo

Talk to one of our experts about how Mapsted's technology can help your business.

Book now

Watch us on Youtube

Stay informed about our latest technology updates and features!

Let's go!

Check out our blog

Read about the latest innovations in the indoor navigation industry, learn more about the technologies being used, and more!

Read our blog

ADDITIONAL RESOURCES

For more information specifically about Mapsted's innovative hardware free indoor positioning solutions, make sure to download the whitepaper Mapsted: Innovation Reimaged.

ABOUT MAPSTED

Founded in 2014, Mapsted is a Canadian Technology company leading a new era of location technology. We provide groundbreaking, patented location-based digital products that help our clients reach and exceed their business goals. Mapsted makes the impossible a reality through groundbreaking innovations in technology, ensuring our clients can deliver cutting edge indoor navigation, targeted marketing, and real-time location intelligence solutions to their customers without Bluetooth beacons, Wi-Fi connectivity, or additional external hardware. To date, Mapsted Location services have been enabled throughout approximately 400,000,000 square feet of physical space, across 6 continents. For more information, please visit https://mapsted.com/