Routes to Market Report

17 - Satellite Technologies for Indoor Positioning and Navigation (IPIN) Systems

Innovate UK

CATAPULT Satellite Applications

Contents

1. Introduction and scope

To get a GPS 'fix' it is necessary for each GPS receiver to have a line of sight with at least 4 GPS satellites at a time. This means that there is interrupted or severely limited signal both inside buildings and in areas with limited or interrupted views of the sky such as in tunnels, car parks, under cloud cover, in the forest and in urban canyons.

The need to locate humans and objects accurately in real time whilst indoors is driving the demand for indoor navigations and positioning (IPIN) technology. In addition, GPS cannot currently deliver 3D location information which is essential for indoor environments to obtain floor and room-level accuracy.

This market opportunity report aims to:

- Briefly outline current indoor navigation technologies and services and how they may develop.
- Outline the challenges faced by using GNSS indoor and in restricted environments
- Present the current indoor navigation value chain and where the space sector is/may be positioned
- Identify the business opportunities if a seamless system can be developed
- Identify use cases and applications for which this market opportunity will be useful.

2. Market Overview and Opportunities

In complex facilities with several floors such as airports, exhibition halls and hospitals, accurate navigation is desirable. However, for applications such as asset tracking, staff tracking, location based services and geofencing, an accurate location determination is essential. Being able to determine your position and navigate whilst located inside is therefore a big issue in many industries.

2.1. Technology Overview

There is currently no single standard for IPIN Systems, and multiple approaches are adopted by various commercial and public providers. The technologies used vary depending on criteria such as hardware required, the pre-existence of networks, etc. There are different mediums used to determine position and so the IPIN systems could be classified based on using vision, radio frequency, magnetic field, audio and ultrasound technologies[1].

WIFI	**Beacons**	**Bluetooth**	**Sensors**	**Mobile Tower Signal**
Indoor Lights	**Camera Technology**	**Indoor Mapping**	**RFID**	**Satellites (in LEO)**

Vision-based positioning uses the principle of landmarks and maps to determine position. Basic implementation of vision based positioning is an image captured and compared with pre-recorded images from a database which have a position associated with it.

[1] http://www.sensewhere.com/types-indoor-positioning-approaches/

Radio frequency is one of the key technologies widely used for IPS. This is due to the availability of already existing networks and hardware. This category can be further divided depending on the type of the different wireless technologies such as **cellular, Wi-Fi, ultra-wide band (UWB), Radio-frequency identification (RFID) and Bluetooth:**

- **Bluetooth Low Energy Beacons (BLE beacons)** are battery powered small devices that transmit a signal in a very small area (usually ≤20m), allowing apps to react to a person's location within range. These focus on proximity, not exact location.
- The so-called 'fingerprinting method' is used to locate users of wireless networks through their wireless access points. A **WiFi** positioning system can be used to identify WiFi hotspots, or to locate signals from a particular user device, such as a smartphone. The strength of WiFi signals are significant but in order to achieve 10m accuracy with WiFi, many access points need to be installed throughout a venue.

Geomagnetic positioning profits from the fact that modern buildings have a unique magnetic landscape produced by the Earth's magnetic field that interacts with steel and other materials found in structures of buildings. By utilizing the smartphone's built-in compass as well as other sensing technologies, software can pinpoint and track a user's location indoors to achieve sub-2m positioning accuracy.

Audible and ultrasound positioning based on fingerprinting generally uses two approaches;

1) passive fingerprinting which uses ambient sound to estimate the position and
2) active fingerprinting which emits and records specific sound patterns for positioning.

Another indoor positioning approach is based on using **inertial navigation** systems. As this approach uses the accelerometer and gyroscope already available in most smartphones, it is another viable technology which is used in conjunction with other technologies that find the initial location and then use inertial positioning to fine tune the accuracy[1].

Applications for these systems include **proximity marketing/advertising, way-finding/navigation, search and asset or people tracking** in verticals such as:

Hospitals & Medical Sector

- App for patients including indoor navigation, reminders and services
- App for visitors including navigation
- Position determination of employees and patients
- Tracking of mobile medical devices
- Integration into hospital information systems
- Process optimisation

Retail & Shopping Centres

- Customer app for better orientation
- Intermodal arrival, car finder, parking
- Indoor localisation, navigation & routing
- 2D/3D maps including shops and facilities
- Frequency measurement & motion profiles
- Sales promotion at the POS (couponing, location-based ads, push notifications)
- Cashless payment

Trade fairs, Exhibitions and Conferences, Commercial Buildings and Offices

- Visitor app with details about exhibitors, products, events etc. incl. navigation
- Intermodal arrival and parking information

- Identification of relevant exhibitors based on user behaviour and profile data
- Frequency measurement & motion profiles
- Location of staff
- Asset tracking
- Support of facility management
- Access control
- Theft protection

Transport, Logistics & Parking

- Passenger apps, incl. intermodal traffic routing, mobile ticketing, delay alarm
- Location based marketing through geo couponing and location based ads
- Security relevant tracking, incl. alerts
- Optimisation of car-park occupancy rate at traffic through user navigation and reservation
- Preparation for future changes in the parking sector (autonomous mobility)
- Car finder & Cashless payment

2.2. Satellite use in Indoor Positioning Indoor Navigation

GNSS satellite systems have not up until now been used indoors due to their poor performance in restricted areas, as it is necessary to have a 'line of site' of 4 satellites to get an accurate fix. In reality, what is necessary is that the receiver **receives a signal from 4 separate satellites**. The 'line of sight' requirement is due to the otherwise poor signal strength caused by attenuation of the signal through surfaces such as walls and bridges etc.

Key questions that will drive the technology choices made by decision makers are:

1. **Accuracy vs Cost**: How important is accuracy? This will depend on the use case; some don't rely on accuracy (are we in the store or not) and for others accuracy is key (e.g. proximity marketing)
2. **Ubiquity vs Proprietary**: Do you want the application to work everywhere? Some big retailers/companies want proprietary apps that only work in their store, others want it to work ubiquitously.
3. **Ease of Integration** – Must it work with consumer devices or can specific tech/infrastructure be acquired? This again depends on use case – most consumer applications will require the technology to be compatible with smartphones/iPads, or will require a partnership with these companies for future integration.

The combination of answers to the above questions will usually dictate the chosen technology used of a case by case basis. However, for wide-spread use of IPIN systems which will enable the growth of services like what GPS did for LBS, ubiquity will be necessary meaning that the technology needs to work wherever you go. If able to work indoors, satellite (GNSS or other) signals could offer ubiquitous coverage using a consistent technology and enabling accelerated development of indoor-location-based apps and services which can be used seamlessly in any location. Products and services would not need to rely on a certain infrastructure being present or would not have to be compatible with multiple technologies at once.

There are two ways GNSS solutions could be enabled indoors, representing an opportunity for the space sector:

1) Improve the receiver technology – can work with lower signals
2) Improve the signal strength – boost the signal or increase signal at the source

LEO Satellite Constellations

There are emerging alternatives to GNSS and even space-based Position, Navigation and Timing (PNT) in the US because of raising concerns on GNSS resilience and dependency. GPS satellites are currently in medium earth orbit (MEO). If PNT information was available from Low Earth Orbit, this would provide several benefits over its MEO counterpart, including increased resilience to jamming, spoofing, and significantly stronger signals due to reduced path loss, potentially enabling signals to be received whilst indoors.

Due to this, there has been a renewed interest in large LEO systems, evolving industrial models (lower cost, shorter development time) and involving major players of the European space industry. The changing space market is seeing new players such as OneWeb and SpaceX with proposals to build constellations of hundreds and even thousands of satellites in low Earth orbit (LEO) with the aim of delivering Internet to the world by providing global broadband coverage. These constellations could potentially be leveraged to carry a hosted payload, allowing them to act as navigation satellites. This unprecedented number of satellites gives rise to better geometry than GPS, enabling the use of lower cost clocks. This coupled with the more tranquil LEO radiation environment, allows for a design based on low cost commercial-off-the-shelf (COTS) components.

This, and other LEO – based concepts is potentially an opportunity that (ESA especially believes) could be seized by the European space industry - thanks to a large number of satellites, can large LEO systems enhance a GNSS backbone?

One example is the strategic alliance announced in December 2016 between US companies Orolia and Satelles which included the product development and go-to-market strategy for a unique space-based PNT solution based on Satelles' 'Satellite Time and Location' (STL) technology. This uses the iridium LEO constellation to provide signals up to 1000 times stronger than GNSS signals and able to reach into buildings and other restricted areas[2]. Satelles claims many positioning and timing applications can be enabled or achieve improved performance through the use of STL, enabling applications such as: Network security, Financial transaction security, Urban canyon positioning, Indoor positioning, Shipping container tracking, Power grid timing synchronization, Blue Force Tracking, Parolee tracking, Nuclear material tracking, Software license geofencing & Digital media playback geofencing.

GPS Repeater Technologies

GPS repeaters are devices that are used to transmit signals to places where they normally cannot reach. They operate by receiving satellite signals with an antenna located outside of a building, and re-transmitting the signals to the indoor area or covered space, resulting in consistent and uninterrupted access to signals underground or in other hard-to-reach areas. The use of re-transmitted signals means that the GPS receiver is tracking the current GPS status, so that when the receiver is moved from indoors to outdoors, the receiver is instantly tracking the location, instead of taking several minutes on the acquisition of the current GPS satellites[3].

[2] http://www.satellesinc.com/wp-content/uploads/2016/05/Satelles-White-Paper-Final.pdf
[3] http://www.terrisgps.com/how-do-gps-repeaters-work/

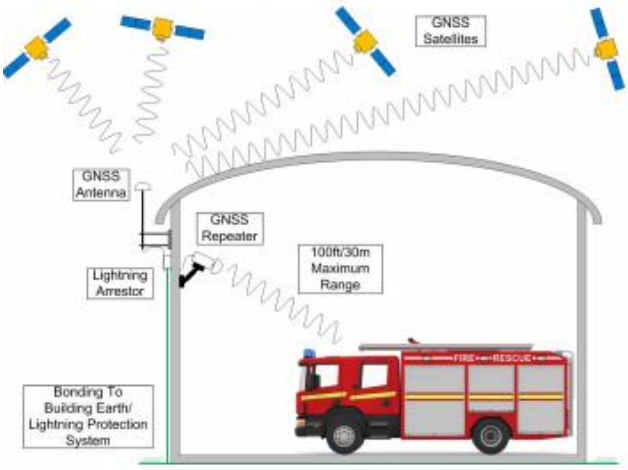

Figure 1: GPS Repeater Diagram[4]

This technology is mostly suitable for 'in out' applications where accuracy is not important, such as:

- **Fire stations:** Ensures that satellite navigation equipment in each appliance has a constant signal when indoors; so that when they leave the station they immediately acquire GPS lock.
- **Police stations:** Ensures that all personal radios receive a live GPS signal while indoors. Upon exiting the station the radios immediately start to transmit accurate location data with zero GPS acquisition delay.
- **Aircraft Servicing Hangers:** Aeroplanes do not need to be taken outside to receive a signal. A GPS repeater system provides a signal over a large floor area - approx. 35M x 35M if the repeater is located 10M above floor level.
- **Electronics Industry:** Electronics companies from a wide variety of backgrounds find that an indoor GPS signal removes the requirement to take GPS-enabled devices outdoors for testing.

There is a potential opportunity for further development of these systems using several repeaters to allow indoor positioning requiring only a software update on current user devices, making this applicable for larger number of use cases.

Hybrid GNSS-IPIN Systems

The greatest opportunity for the space sector is likely to derive from hybrid GPS-IPIN However there is significant value in ensuring that 1) Indoor Location technologies are compatible with GPS technologies to ensure the changeover between indoors and outdoors is seamless, and 2) IPIN systems are compatible with the most commonly used devices today, almost all of which have GPS receiver chips and rely on LBS.

The table below shows a comparison between the major IPIN system technologies and the two GPS technologies above. For comparison purposes, a 1-5 scale is used with every technology starting at a perfect 5 and a point deducted for each major drawback or limitation. The range required depends on the application and so this has been stated but not scored.

[4] Source: www.gps-repeaters.com

Table 1: Technology Comparison[5]

Technology	Typical Range	Accuracy	Accessibility	Cost
LEO Constellation	Ubiquitous	Likely ≥ GPS		
GPS Repeater	<20m	5-20m		
Hybrid Software Solutions	Ubiquitous	5-20m		
BLE Beacons	1-75m	1-8m		
Wifi	20-50m	5-15m		
Geomagnetic	n/a	1m		
RFID	<1m	<10cm		

*Key: **Bad**, **Not good**, **Not bad**, **Good***

2.3. Opportunities Summary

With the ground-based technologies currently available and in development, it will likely be difficult for satellite systems to find significant traction in this fragmented mass-market unless GPS technology can be developed to make it work indoors to the same degree of accuracy. In this case, there would be significant opportunity and incentive for the use of GPS over current technologies due to its ubiquity, simplicity and ease of integration.

Table 2: Summary of Opportunities

	Opportunity Title	Opportunity Description
1	**Hybrid Software Solutions**	A system such as S-GPS by focal point positioning claims that they can enable this with a simple software update. Technologies like this would open a whole new market for the satellite industry.
2	**GPS Repeater Technologies**	For some simple applications, there is opportunity for today's proven GNSS technology to compete with incumbent IPIN technologies. GPS repeater technologies seem to offer the opportunity for GPS to be used indoors for simple positioning applications such as 'which building is an asset/person in.' This could be exploited further and developed to allow for more specific applications.
3	**LEO Constellations**	Finally, there is growing interest in LEO constellations and how these can improve space-based PNT solutions, reduce reliance on GNSS solutions and enable stronger signals able to penetrate surfaces due to the reduced path loss compared to MEO systems. This represents a significant opportunity for the space sector to develop new solutions that would not only enable Indoor Positioning and Navigation, but better timing and greater resilience to jamming and spoofing for all PNT – based services.

[5] Source: Satellite Applications Catapult analysis and Lighthouse.io

3. Customer and value proposition to the customer and end user

As a consumer service, the end-user is the private citizen holding the device and using the service. The customer is the person paying for the service. For non-satellite-based IPIN Systems, the customer for specific use-cases such as in hospitals, museums or exhibitions will likely be the venue itself – those who will install any infrastructure and will likely develop a customised application for use by its staff and/or general visitors.

The customer for a GNSS-enabled service depends on the implementation. If new hardware is required such as chipsets then the customer will be one of a few handset manufacturers (Samsung, Apple, Soy, Motorola, HTC etc.) and the end user will again be private citizens using their devices who, as with LBS today consider it one of the many services offered by their handset. This will then enable the development of Indoor location based apps and services.

However, for most applications such as wayfinding and proximity marketing, indoor location-based services will likely require a partnership or transfer of data with the venue/establishment itself. This is because App developers relying on indoor LBS will require accurate indoor base maps to make sense of the location. This would work slightly different to using GPS outdoors, where global companies like Google, Bing and Apple easily acquire their own street maps using satellite imagery and in-situ sensors, and then make these available to developers. For indoor LBS services, a partnership with the establishment will be required to ensure accurate and up to date indoor maps are integrated into the solution.

4. Market Competition

The market is very competitive in terms of possible technologies on offer. However, depending on the use case; cost, ubiquity, compatibility and scalability requirements constrain plausible technologies to just a few. Once a technology has been chosen, there are relatively few companies operating in each space.

4.1. Generic IPIN companies

Some of the major current players in current Indoor Positioning and Navigation System are:

- Accuware Inc (US)
- Apple Inc. (U.S)
- Google Inc. (U.S)
- Nokia Corporation (Finland)
- Microsoft Corp (U.S)
- Cisco System Inc. (U.S)
- Qualcomm Technologies Inc. (U.S.)
- Sapient Corporation (U.S.)
- Ericsson (Sweden)
- Zebra Technologies (U.S.)
- SenionLab AB (Sweden)
- STMicroelectronics N.V. (Switzerland)
- IndoorAtlas (US & Finland)
- Rukus SPOT (US)
- Infsoft (Germany)
- Polaris Wireless (US)
- **Sensewhere Ltd (UK)**

4.2. IPIN companies focused on Hybrid GNSS-IPIN

- Next Nav (US)

4.3. GNSS Companies enabling IPIN

- **Focal Point Positioning (UK)**
- Satelles' STL (US)
- Chronos (UK)
- **Faltech GPS (UK)**

5. Role of UK Companies

In general, all global chipset, handset and device manufacturers, have significant presence in the UK (e.g. Qualcomm, Broadcom, Mediatek, Samsung, Apple, Intel, Google, Garmin etc.) and software developers and service providers (UK and non-UK held) are also widely represented across the value chain. The IPIN System market is already forecast to grow dramatically in the coming years. However, a ubiquitous indoor GPS service would likely cause a large increase in innovation from developers and start-ups in the UK based around offering indoor services that would be enabled by this.

Focal Point Positioning is a UK company who claim to be developing a smartphone-based sensor fusion, machine learning, and signal processing suite to provide satellite positioning capabilities in areas that have until now been unreachable. Its new technology called **S-GPS** claims to 'dramatically improve' the sensitivity and performance of existing radio-based positioning systems, providing new capabilities indoors and in urban environments.
Updating the software of the existing mobile phone chip with this technology claims to enable:

1) Improved ability to pick up GPS signals
2) Elimination of the interference caused by signal reflections off buildings and surfaces

If this company's claims are correct and this technology or similar penetrates the market, the UK will be in a very strong position as the enabler of LBS indoors.

FalTech GPS Ltd is a UK provider specialising in GPS repeater technology solutions that provide GPS coverage inside any building or structure where it was previously unavailable[6].

Sensewhere Ltd is a UK company based in Edinburgh delivering positioning indoors and tight urban areas without the need for beacon technology or GPS.

[6] https://www.gps-repeaters.com/blog/gps-repeater-system-enables-use-of-limmex-emergency-watch-indoors/

6. Revenue Projections

Table 3: IPIN Market Size

	2017	2020	2030
Total IPIN Market (£B)	5	14	99
GPS Enabled Market Estimate (£B)	0	2	19

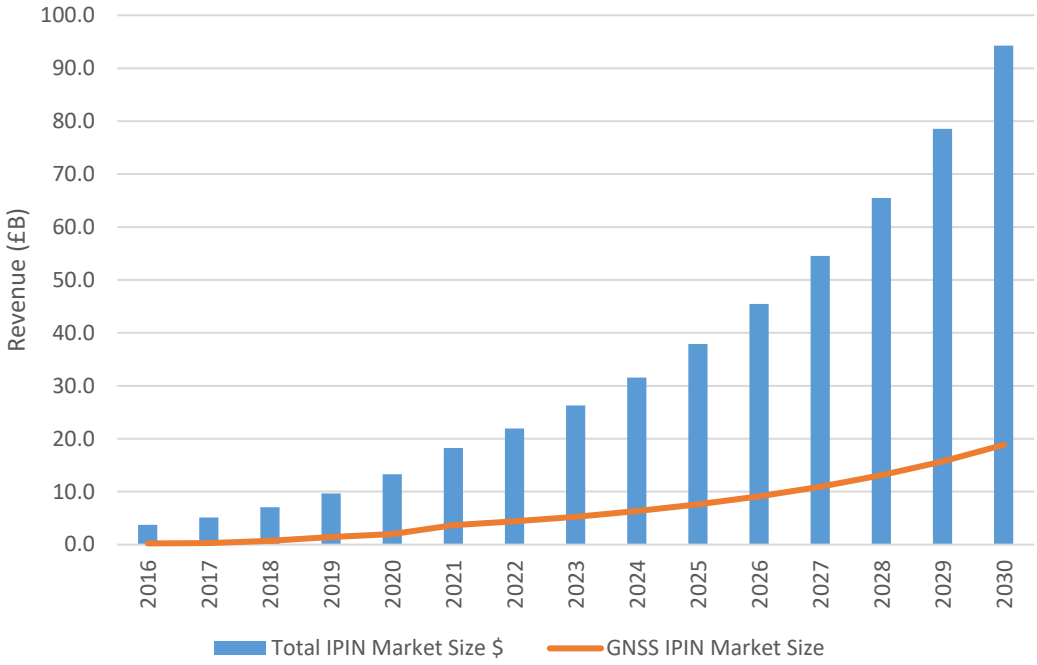

Figure 2:IPIN Revenue Projection 2016-2030

6.1. How are these figures calculated?

Table 3 above is based on the IPIN market size to 2021 derived from the marketandmarkets Indoor Positioning Systems Report. However, market figures for IPIN Systems are currently driven by the lack of availability of GNSS signals indoors. A 5% increase in total market size was assumed due to the introduction of GNSS-enabled indoor LBS.

The following assumptions were then used:

- CAGR of total IPIN Systems is 37.4% to 2021 (marketandmarkets) and then 20% to 2030.
- Market Size of GPS used for IPIN systems is currently 1% - limited to the current use of GPS repeater technologies in large indoor locations such as airport hangers and fire stations to ensure a GNSS signal is constantly available and seamless (time to first fix = 0).
- Step changes (5%,10%,15%) of GPS technology used indoors enabled by either LEO constellations and/or software solutions such as S-GPS by Focal Point Positioning, to a maximum of 15% total market share.
- GPS accuracy is not improved (or only marginally improved) over the period.

7. SWOT Analysis

Table 4: SWOT – Opportunity 1: Hybrid Software Solutions

Strengths	- Ease of implementation:
	  - No need for new space infrastructure - Allows current GNSS systems to be utilised indoors (GPS, Galileo, Beidou, Glonass)
	  - No need for indoor infrastructure or devices (beacons, repeaters..) - will be ubiquitous and seamless both indoors and outdoors.
	  - No need for dedicated receivers – Only requires a software update to current devices such as smartphones.
	- Allows a seamless service both indoors and outdoors – eliminates the time to first acquisition of a signal when exiting a building.

Weaknesses	- Does not improve on the poor accuracy of GNSS services detecting changes in height as needed for floor-level information. - Poor accuracy in current standard mobile devices – in the order of 10m. May not be useful for applications such as close-proximity marketing without augmentation.
Opportunities	- The scale and speed of implementation represents an opportunity to have a system like this enabled across all smart-devices within weeks of first use.
Threats	- Competition with incumbent IPIN technologies with better accuracy

Table 5: SWOT – Opportunity 3: GPS Repeater Technologies

Strengths	- Can be implemented (almost) immediately using technology currently available - No change to receiver devices (hardware or software) required - Relatively inexpensive - Allows a seamless service both indoors and outdoors – eliminates the time to first acquisition of a signal when exiting a building.
Weaknesses	- The range of each repeater is limited - will need multiple in a large room and on each floor - Poor accuracy in current standard mobile devices – in the order of 10m. May not be useful for applications such as close-proximity marketing without augmentation.
Opportunities	- Possibility to develop technology further
Threats	- Competition with incumbent IPIN technologies with better accuracy

Table 6: SWOT – Opportunity 3: LEO Constellations

Strengths	- Will enable multiple applications, both new (space) markets such as IPIN systems but also improvements in resilience and security to current GNSS markets. - Can be designed to meet the specific needs of these markets – market driven solution rather than retrofitting a legacy system.
Weaknesses	- Dedicated systems will be very expensive – can the business case be closed?
Opportunities	- Opportunity to launch as a hosted payload on mega constellations that are already planned
Threats	- Competition with incumbent IPIN technologies with better accuracy

8. Opportunity Blockers and Enablers

Table 7: Satellite Technologies for Indoor Position and Navigations Systems - Blockers and Enablers

Blockers	Enablers
- Signal attenuation through walls and surfaces - Reduced accuracy in altitude making floor-level information difficult	- Increased market-incentive due to adoption of location-based services indoors by business owners. - Continued development of small satellite and LEO constellation market. - Improvements in software solutions offering better accuracy from GNSS data.

Table 8: General Indoor Position and Navigations Systems - Blockers and Enablers

Blockers	Enablers
- Inadequacy of position, orientation and direction accuracy - Insufficient coverage and availability - High purchase cost and high maintenance cost - Unappealing in terms of usability, hindering wide-scale consumer adoption - Possibility of identity theft and invasion of privacy - Lack of standardization (use of various technologies) - Availability and usability of indoor maps - lack of data security	- Increased adoption of location-based services by business owners. - Inadequacy of Global Navigation Satellite Signals to cater to indoor positioning systems. - Increased usage of smartphones with in-built motion and location/navigation sensors.

9. Market Dynamics and Trends

According to market and markets, the indoor location market size is estimated to grow from USD 4.72 Billion in 2016 to USD 23.13 Billion by 2021, at a Compound Annual Growth Rate (CAGR) of 37.4%. However, this market is driven by the absence GPS technologies indoors, the emergence of which would significantly change the dynamics, size and projections.

In general, Indoor Positioning and Navigation is used dominantly in advertising, logistics, retail and healthcare. More end use industries are being captured and will be soon exhibit high adoption as the applications grow. Retail and logistics are holding the major indoor positioning and navigation market when compared to other markets. However, the lack of awareness regarding these systems among other industries has so far hindered their growth. The market is rapidly growing as improving technology combined with growing awareness spur the market.

According to market and markets, the Americas is expected to hold the largest market share and will dominate the indoor location technology, software tools, and service market from 2016 to 2021, owing to the increasing demand for new technologies such as 3D-based indoor positioning applications and information security. There are huge opportunities for chip manufacturers,

telecommunication companies, handset manufacturers, and infrastructure providers in the space as more retail stores, multiplexes, universities, and airports are deploying these solutions for an enriched customer experience.

The APAC region is expected to witness the highest growth rate during the forecast period as the existence of large population, developing technology, and affluence will drive the growth of indoor location in this region.