Research on Indoor Positioning Technology

Based on Passive RFID Technology

Objective:

Provide a concise overview of three integrable

asset tracking technologies – including their transmission medium.

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Abstract. This study introduces the various forms of asset tracking medium – passive radio frequency identification, global positioning system, and ultrasound indoor positioning system – and their respective necessity. The study briefly describes three technologies, how they are used, and why they are being used; this will help pick an optimal indoor tracking system – considering hardware cost, reproducibility, and scalability.

Keywords: radio frequency identification, global positioning system, and ultrasound indoor positioning system; hereafter, will be written in their respective acronym form – RFID, GPS, and IPS.

Introduction: Industrialization has increased the ability to mass produce products of necessity and leisure. As we continue to manufacture products, we become interested in where these products are going; when products are being used, whether, at the manufacturing site, at a place of business, or within institutions; who is using a certain product, wherein, permission might have or have not been given; and how long it took someone to use a product – in most cases, how long it took to deliver product[s]. Asset tracking used to be resource intensive: with the advent of technology, asset tracking has become an expansive and efficient system.

GPS:

Note: There are many forms of receivers available. The receiver, to the right, is a common form – sold in most retail stores.

Illustration 1: Magellan, Marine GPS Receiver

Background: GPS was initially developed to provide location and time information to the military – later it become a popular form of tracking for civil and commercial entities around the world. There are twenty-four (24) main satellites in orbit – a minimum of four (4) satellites are needed to triangulate position – and two additional satellites that are used as backups.

Analysis: The GPS system is maintained by the United States government and is freely accessible to anyone with a GPS receiver. GPS is used in our every day lives to help protect us and give us direction. It is also useful in providing whereabouts of property and people. The table below illustrates some common uses of GPS in everyday life:

Name of service	Service Provided
uLocate	Used to locate childrren.
911	If you are unable to speak the operator will activate the GPS in your phone to pinpoint your location.
OnStar	Used in modern automobiles to provide accident assistance and give directions.
Garmin, Magellan, etc.	Used for driving directions.
Air Traffic Control	Used to coordinate flights.

Table 1: Depicts brief examples, showing the use of GPS in everyday life.

GPS is wonderful for tracking assets, especially when an asset is in motion; however, it does not provide the amount of accuracy needed to track assets indoors, the signal degrades – becomes intermittent, i.e., detecting a GPS signal on Earth is comparable to detecting the light from a 25-watt bulb from 10,000 miles away– due to high density construction materials[1]. The system becomes cost prohibitive when scalability increases exponentially, or a database is needed to track information over a long duration – databases need to be custom tailored to specific needs, which, can be expensive.

Conclusion: Although GPS is proven to be quite useful for tracking assets, it would be inappropriate to use a GPS system to track indoor assets because of signal obstruction, inadequate accuracy, cost of scalability, and the necessity of a database.

1 e.g., concrete, mesh, and other high density materials,

IPS:

The illustration below was found using Google Image (http://images.google.com)

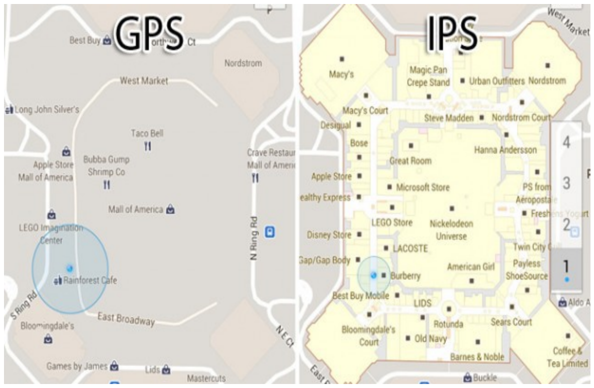


Illustration 2: Depicts how IPS delivers a higher accuracy compared to GPS, providing more details of relative position.

Background: IPS technology produces greater accuracy, uses less sophisticated backbones, and comes in various shapes and forms. The standard GPS model works wonders when you need to get a rough sense of where you are – pinpoint accuracy is not really a concern, more or less, a generalization of where you are is acceptable – in a matter of seconds. I researched popular GPS forums and frequently asked questions (FAQs) pages and found that GPS has an expected accuracy between 10-50 ft. (i.e., 3 to 15 meters), 95% of the time ("How accurate is GPS? (Q0116)," 2006). If you need to respond to – good uses for IPS systems include tracking firefighters going into blazes, patients in the hospital, or even retail merchandise – life threatening, or time sensitive situations, the more accuracy the better. In the beginning, IPS technology used the Earth's magnetic field for positioning, e.g., similar to a homing pigeon. The entire Earth – from the core to the surface area – emits a magnetic field, which, can be altered by man-made objects. Rather, instead of using the Earth's magnetic field and tracking alterations made to it's path by assets, to further accurize and expand the technology, ultrasound has been used for tracking assets with astounding accuracy and dependability.

Analysis: The system comprises microphones [detectors] and transmitters: the transmitter pings the signal and the microphones detect the ping, i.e., echolocation, giving the location of the asset. Ultrasound IPS technology can be adjusted and fine tuned to adapt to different buildings and scenarios: the microphones sensitivity can be adjusted in a particular direction – the microphone can pick up a specific signal from a specific asset, instead of all signals. The actual wavelength – ultrasecond signals use short wavelengths for transmission – protects against signal overlap, i.e., the signals are emitted in a room and contained within that specific room, the doors and walls confine the signal. The latter is ideal for creating subzones where monitoring is critical, e.g., hospital environments. Sonitor Technologies in Norway has deployed it's ultrasound IPS technology in twenty hospitals, in the U.S. & Europe – that is how accurate and reliable the technology is.

Conclusion: Ultrasound IPS technology is valuable, highly accurate, and can deliver positioning capabilities well beyond GPS; it is still experimental, expensive, and has a flaw that can be disastrous in a massive logistics environment. This technology, when used in an environment with a lot of assets, has a tendency to overlook some of the assets. This his is correctable through further development, but, right now it is a flaw that is being tolerated. This system, although not perfect, strives to provide accurate positioning at low cost, with integrity, and remains highly scalable – it does just that.

RFID:

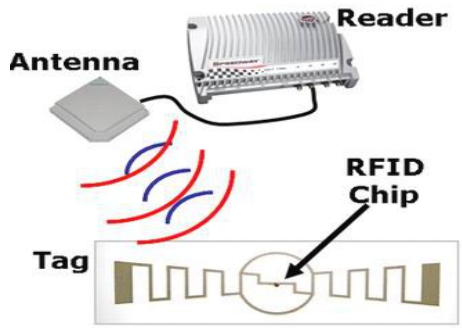


Illustration 3: Simple RFID system, provided by LogSystems

Decades of RFID

Decade	Event
1940 - 1950	Radar refined and used, major World War II development effort. RFID invented in 1948.
1950 - 1960	Early explorations of RFID technology, laboratory experiments.
1960 - 1970	Development of the theory of RFID. Start of applications field trials.
1970 - 1980	Explosion of RFID development. Tests of RFID accelerate. Very early adopter implementations of RFID.
1980 - 1990	Commercial applications of RFID enter mainstream.
1990 – 2006	Emergence of standards. RFID widely deployed. RFID becomes a part of everyday life.

Illustration 4: Image provided by SlideShare

Background: RFID systems were developed for a simple way to track assets – tracking assets in a supply chain became a necessity as inventories became more robust. Increasing efficiency in the supply chain was a must, but also reducing: inventory error, lost stock, out-of-stock products, and labor, were a major concern. The advent of RFID technology allowed supply chains, such as Walmart, to maintain their stock rate, healthful inventory, logistics cost, et al. RFID technology also became essential in border crossing, pay-as-you-go car insurance, baggage tracking, and child-tracking.

Introduction: The simplicity of RFID systems is depicted above, in Illustration 3. To have a sufficient RFID system, you only need:

- A RFID reader – with an antenna – to query tags.
- A tag, or in most cases, multiple tags – assets each have a tag – that have a transmitter and receiver built into them, i.e., transceiver.

Although, an RFID system in itself is simple, the methods of communication can vary, and can become sophisticated. For breadth of conversation, we are concerned with the two main methods of communication, active and passive RFID – both methods still use radio waves to identify, store, and send tag information. Active RFID is a self-autonomous form of communication: the tag operates under its own power – often requires it's own battery, embedded within the tag. A signal is sent from the RFID reader, also known as an interrogator, to the RFID chip on an asset – the signal does not need to be strong. The chip receives the signal, retrieves the data requested, and sends a signal with the encoded data, in return. Passive RFID tags operate a little differently; they do not have their own power source, i.e., a battery, and require a stronger signal – they are less “intelligent”. The RFID reader sends it's signal to the chip, the chip uses some of the signal strength as power, the data is retrieved, and the chip mirrors the signal back – the signal is further degraded (the chip, in this case, does not have the capability to generate it's own signal). Both methods of communication work well and have many advantages and disadvantages:

Active RFID Chip	Passive RFID Chip
Can modify chip information.	Chip information cannot be modified.
Considered smart: operates under it's own power.	Degrades signal in acquiring it's power.
Chip damage is common.	Chips are harder to damage.

Table 2: Gives brief advantages and disadvantages of RFID chip technology.

Because RFID chips take advantage of micro-embedded-systems they can be manufactured extremely small, i.e., as small as a postage stamp, and at low cost. Many articles written on RFID establish that the RFID system is well developed, however, the underlying protocols[2] are not standardized yet, and the medium itself can pose a problem in certain environments – radio frequency transmission. Transmitting information, over radio frequencies, has minor setbacks; they can be resolved, but require customization, by manufactures or programmers. Radio frequencies are not self-contained, they tend to penetrate through walls, doors, and can be intercepted by other devices that operate on the same frequency – overlap and can be replicated. These concerns can be resolved easily, even if multiple readers are used within the same facility, by using multiple protocols. For example, if there are two or more readers responsible for communication between, say, one-thousand RFID chips, one would want to use a an anti-collision protocol. This type of protocol resolves ambiguity between the multiple readers, and the chips themselves: allowing the readers and tags to take turns communicating, respectively. This protocol is similar to how a teacher – applies to multiple teachers in the same room -- would expect multiple students to respond to a question in a classroom environment, i.e., the teacher asks a question and the students respond with raised hands. The teacher then selects a student to respond. Not all the students are allowed to respond altogether. This is just one example of how a protocol can be used to alleviate collisions and transmission set-backs, produced by transmitting via radio frequency. Another protocol used often to ensure security – the inadvertent interception of an RFID signal by an outside reader – is encryption. This allows a signal to be sent in code, received, decoded, processed, and sent back re-encoded. Because there aren't standardized protocols in industry, most of the developed protocols are "opensource" – free to be modified by the general public – and can be used painlessly. However, sometimes a protocol does not exist to resolve a certain issue, thus, one needs to be developed.

2 Protocol - The established code of procedure or behavior

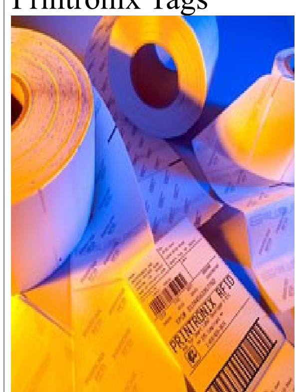
Study Conclusion: The RFID technology available today has become rather sophisticated compared to it's initial development, but remains to be cost effective, efficient, and useful – whether it is being used in industry, mom-and-pop stores, retailers, manufacture sites, etc. Like the latter technologies, RFID systems have their deficiencies; they can be resolved easily, at low cost, and creatively. Because RFID tags – chips – can be manufactured so small they are hard to remove, identify visually, or damage, making them viable in loss prevention, reproducibility, and scalability. RFID technology is preferable in any environment, especially when tracking an abundance of assets, and line-of-sight transmission of information is tedious – in some cases impossible. Finally, RFID systems can be mixed with the latter technologies, allowing hybrid systems to be developed; this can allow for a fortified backbone and seamless transition between large facilities.

Cost Analysis: The equipment pricing is subject to change, on a daily basis, as systems are expanded, researched, and developed more thoroughly. The GPS prices were made available by ShopMania; the RFID reader and scanncer prices were made available by Barcodes Inc.; however, the Ultrasonic IPS prices were not disclosed on the website, only by per order request form.

<table>
<tr><th>GPS</th><th>Ultrasonic IPS</th><th>RFID</th><th>Price Range</th></tr>
<tr><td>Garmin Edge 800
</td><td rowspan="3">Requested a quote from Hexamite, but did not receive a response.

Ultrasonic IPS systems tip the scale at the most expensive – there are a lot of standalone accessories that make up the system, as a whole, i.e., the microphones, transceivers, antennas, et al.</td><td>Motorola Reader
</td><td>Garmin Edge 800
$450 - $650

Motorola Reader
$2775.50</td></tr>
<tr><td>Garmin Approach S1
</td><td>ThingMagic Reader
</td><td>Garmin Approach S1
$200 - $350

ThingMagic Reader
$795.00</td></tr>
<tr><td>Garmin Rino 120
</td><td>Printronix Tags
</td><td>Garmin Rino 120
$190 - $300

Printronix Tags
$110.00 per roll
[4 x 6, 500 labels/roll]</td></tr>
</table>

Table 3: Shows a brief overview of prices for the three different tracking technologies.

Note: Table 3 depicts some of the general forms of each specific technology available, and some of the accessories required, per technology. This table is not a sufficient representation of everything that is available on the market – public or private; it does, however, show the drastic difference in price.

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