RFID techniques
for indoor warehouse location sensing
An overview paper of RFID techniques that are used for indoor location sensing

Marcel Flipse
1473379
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Vrije Universiteit, Artificial Intelligence Department,
De Boelelaan 1081a, 1081 HV Amsterdam, The Netherlands,
marcel.flipse@gmail.com
Course: Bachelor Referaat , supervisor: Zhisheng Huang

Abstract. Remote Frequency Identification (RFID) has always been known for its wireless identification of products and proximity detection. That it also could be used for more precise location sensing does not usually pop into someone's mind when talking about applications using RFID. There are numerous application thinkable for precise location sensing but there are limitations of this technology. This document gives an overview about Remote Frequency Identification and tries to awnser the question if RFID can be used for precise location sensing. It contains the basics of RFID, a global overview of the uses of RFID, two approaches for RFID precise location sensing (SpotON and L.A.N.D.M.A.R.C.) and a short comparison of these techniques. There are many extensive papers about all of these subjects. None of these papers combine a full introduction to RFID with a short, but full description about L.A.N.D.M.A.R.C. and SpotON. This paper is written in such a way that no knowledge of RFID techniques is needed.

1 INTRODUCTION

In the next section the basics of Remote Frequency Identification will be explained: What it is used for, different types and how it works. The rest of the document will describe how the papers for this overview were selected, two RFID precise location sensing techniques, a comparison of two RFID techniques for precise location sensing and the conclusions of the comparison. Also a full list of references can be found at the end of this document.

2 RFID BASICS

Remote Frequency identification normally needs the following elements: a rfid tag that links the physical product to an identification number, a rfid reader that connects this identification number to the system and a system that connects this identification number to more information stored in a database. It is sometimes possible to store more information on RFID tags but the memory available, around 2Kbits for passive tags, only allows short codes as information where the tag has been. A passive RFID tag consists of an antenna or coil, a semi conductor chip connected to this antenna and usually some form of encapsulation to protect the tag from tempering, dust and interference. An active RFID tag also contains some kind of power source, usually a battery but it can also be connected to a powered infrastructure of a building. The battery capacity determines the operational life time, the signal strength, range, but also the size and costs of the RFID tag. The life time expectancy of an active RFID tag also depends on how many read actions there are performed on it. Active RFID tags have a range from between 20 and 100 metres. With range we mean distance from where there tag can be read by a reader without losing data. Passive RFID tags are cheaper, smaller, less maintenance sensitive, but also have a smaller range from 5 to 20 metres. Nonetheless, because they are mainly used by businesses, their price and level of maintenance sensitivity make them easier to implement and more popular than active RFID tags. Passive RFID is more popular and easier to implement and that's why more techniques are well documented like "Near field coupling" and "Far field coupling" [1, 7, 6].

With Near field coupling, a tag comes into range of the altering magnetic field of the reader and receives an electro magnetic signal. Both the reader and the tag can have an electro magnetic field, but the reader is usually the stronger one. The electro magnetic signal from the reader is than stored by the tag in an on board capacitor and the tag's coil produces a small current of its own, which is called *magnetic induction*. A tag can than variate the current by changing the load on it's antenna coil. This technique is called load modulation. Any variation in current of the coil will be picked up by the reader.

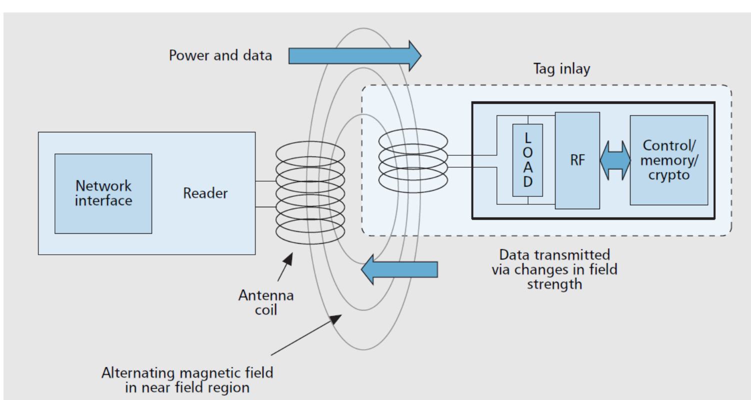


Fig. 1: Near field communication using inductive coupling [1]

With Far field coupling, coupling occurs by the tag's capturing of the electro magnetic energy from the reader as a potential difference. Part of the energy is reflected back to the reader due to a impedance mismatch between the antenna and the load circuit toward the reader. By changing the impedance or mismatch of the tag's antenna, the antenna can vary the amount of reflected energy which can be picked up by a reader. This technique is called *backscattering*.

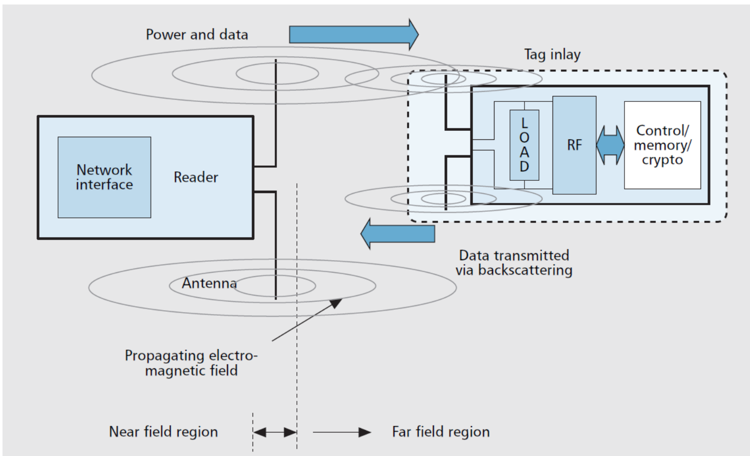


Fig. 2: Near field communication using inductive coupling [1]

3 RFID USAGE

Remote Frequency Identification (RFID) enables remote identification in many applications. The most well known application that almost everybody has been in contact with, is prevention of shoplifting. An alarm goes off when an active tag passes a reader. Other applications include: Chipping animals for identification, Supply Chain Management, access control, transport payment, the internet of things and location sensing.

3.1 SUPPLY CHAIN MANAGEMENT

In a production facility it is very important to have an up to date resource overview. Barcodes are used by the majority of production facilities for unique product identification, because they can identify resources for low costs. This technique comes with a lot of difficulties. Two of them are that close contact and line of sight are needed to identify the resource. Another is that dirt and dust affect readability of the barcode and finally only one resource can be read at a time. For product identification RFID is an improvement, compared to barcodes.

RFID can read multiple tags in one pass, it does not require line of sight and it is not affected by dirt or dust. The area where barcodes are still better than RFID is at the cost level. Printing a barcode is almost free, because a home printer can be used to print barcodes on stickers with normal black ink. RFID printers do exist, but the printer itself isn't standard and the ink it uses must contain a conductor, because RFID uses electro magnetic pulses to communicate. Due to the costs of identification, RFID technology can't replace barcodes completely. The price of a cheap candy bar will increase significantly, when RFID will be used as identification instead of a barcode. However, pallets of cheap products can be identified, so RFID can still be used at a higher level. An example of implementation of RFID technology in a supply chain is the usage of RFID tags to support the loading of supplies into cargo containers for the U.S. Navy [7]. The mean purpose was to reduce the number of errors that occur while loading containers. The container that contained the supplies passed a portal and the content of this container was read. Next to a reduction in content error one other result was less time spent on checking the cargo. This lead to the possibility to reassign employees that were in charge of checking the cargo, to a function such as driving a forklift. All of this costs 0.93 US dollars per shipment.

3.2 THE INTERNET OF THINGS

The Internet of Things [8] is a vision in which internet extends our everyday life using uniquely identified objects. The idea is that every item we use could contain an RFID tag and RFID readers collect information about them. One application that comes into mind is a search engine for The Internet of Things. Someone could give a search query such as "Where are my Keys". The application than searches for the id of "your keys" and returns a location, such as "bookcase living room 3rd shelve", by using tag references together with location sensing. Another possible application is more about the location of persons. It is possible to connect your personal tag to sites such as Twitter. The location you visit has a certain RFID tag and the application connects it to your personal tag and posts both on Twitter. The mayor problem is that the internet of Things has to deal with its lack of acceptance by the general public, due to privacy issues.

3.3 UBIQUITOUS COMPUTING

The ubiquitous home [2] is similar to The Internet of Things, but it has some differences. The ubiquitous home integrates computation into the home without actually being aware of it. The advantage to The Internet of Things is that it could be used on a more local scale. So for many items local identification codes are sufficient and in that way there are less privacy issues: It is using user information inside the comforts of only the user's own house instead of the outside world. The information is captured with "pressure plates", video camera's, microphones, infrared sensors, but also RFID tags and readers. The RFID readers are placed so they cover the whole house or just a room and the information collected is connected to the proper applications. There are refrigerator applications that automatically inventory the products that are stored inside the refrigerator and take proper actions like a warning when the milk is past its due date or ordering new products that are almost out of stock. A working model of this application was build at the ”Living Tomorrow House” in Amsterdam, which offered many technologies that would soon be available on the consumer market. Another example is RFID tags in your clothes. A washing machine application can infer information about the best washing temperature or can warn you if you have clothes in the washing machine that ca not be washed together. Precise location sensing could also be used in a ubiquitous home, but normally it is only used for entered-room detection. Precise location sensing can be used by an application that shows you a map result of a search query for a specific item, but other solutions are also thinkable.

3.4 REASONS TO USE RFID FOR LOCATION SENSING

There are many other technologies that make location sensing possible, like the Global Positioning System, ultra sonic technologies like the Cricket Location Support System and Active Bat System, infra red technologies, IEEE 802.11 technologies like radar, but all have features that make them less usable for location sensing than RFID [3, 4]. The next table will address a few of those features

Technology	Positive Feature	Issue
GPS	great accuracy	does not work indoors
Cricket Location	great indoor accuracy	high deployment costs
Active Bat System	great indoor accuracy	high deployment costs tightly controlled dense network infrastructure needed
Infrared technologies	works indoors	need line of sight and short range
RADAR	uses existing network requires few base stations easy to setup	poor accuracy

Table 1: Alternatives of RFID for location sensing

4 LITERATURE

All articles that are used to write this paper can be found with Google Scholar. Three papers [1, 7, 6] where selected to get a good and clear overview of how RFID works and what it can be used for. Only one of these papers [1] contained clear and easy to understand graphics, but the other two where needed for examples of RFID uses. Another paper [5] was selected because it gave some insights of why a company should adopt RFID and what the expectations were of those companies. Two other papers [8, 2] where selected to get some insight in other important RFID implementations other than industrial usage. The final two papers [3, 4] where selected to compare different approaches of RFID location sensing. Because, the first paper described a well known technique called SpotON, which is referred by all other papers about RFID and location sensing, but because it was never tested and results were never published, it is difficult to make a comparison. Only the results got published of the first prototype for SpotON. All these papers together make it possible to write a relatively easy to understand overview paper containing most of the basics of RFID.

5 ASPECTS

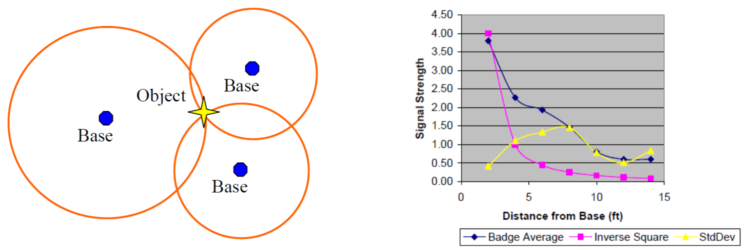
5.1 SpotON

SpotON [3] is one of the first experiments using RFID for precise location sensing. It is using measured signal strength to calculate the position of a badge in 3 dimensions. The first experiment used components that where available on the commercial market and these products had relatively low costs. AIR ID was chosen. AIR ID is an *"adjustable long range active ID badge, reader and software solution for desktop computers"* from the company RFIDeas. It is used for automated login and locking of the desktops of employees when they enter or leave a certain radius around their workstation. AIR ID only supported serial connections, so an hydra web server was used for each base station to connect each base station to the ethernet.

FIRST STAGE In the first test to see if AIR ID could be used, 12 tags where placed in a radius around 1 base, a reader, and the signal strength to the tags was measured. After measuring the radius was increased by approximately 1 foot and the signal strength was measured again. This process was repeated until the tags where out of range. The results of this test were good enough to proceed with the main experiment with AIR ID hardware.

SECOND STAGE The experiment itself used multiple base stations that measured the signal strength of the tags and from these findings the distance between the tag and each base station was calculated. When you connect the data from multiple base stations a probable location for the tag can be calculated. The results showed that the strength of the signal reduces in inverse proportion to the square of the distance.

RESULTS There were a few problems during this experiment. The system was not very accurate, objects could only be fixed to a position 3 meters on a side. Another problem was that calculating the signal strength for one tag from all base stations while using a multi-threaded server takes 10 to 20 seconds. The decision to use AIR ID hardware was questioned. The hardware used was an



(a) (b)

Fig. 3: a) Setup used for SpotON approach [3] b) results of the first SpotON experiment [3]

AIR ID prototype that had only 8 bits of accuracy and a limiting Application Programming Interface (API). The experiment had a follow-up, which used self-made hardware that could solve a few of the problems, but the results never got published.

SpotON was the first attempt to see if RFID could be used for precise location sensing. It resulted in a partial yes, due to its problems with accuracy.

5.2 L.A.N.D.M.A.R.C

The Location Identification based on Dynamic Active RDIF Calibration approach [4] is much more extensive. It uses similar components, as the SpotON project that are available on the commercial market. This time the Spider System manufactured by RF Code was selected, based on specifications values that are not mentioned in it's paper [4]. One logical specifications would be a certain range of active tags. The Spider System Active Tags have a read range of 150 feet, but with another antenna attached to it could be increased to 1000 feet. The readers can be set to 8 different power signal ranges where it can detect tags.

FIRST STAGE The first idea was to use 9 RFID readers with each their own predetermined power level, thus region, to read a RFID tag. With proper placements different subregions would be created. The location of a RFID tag would than be determined to see which readers could find the RFID tag. By combining the data of which RFID reader would find the tag, a subregion was found, that was smaller than the entire region of one reader. So the accuracy of this system depends on the number and placement of the readers. Unfortunately, there are factors that variate the power levels that are read, like static and dynamic human obstruction. Due to this interference, tags can appear at other subregions than their real locations.

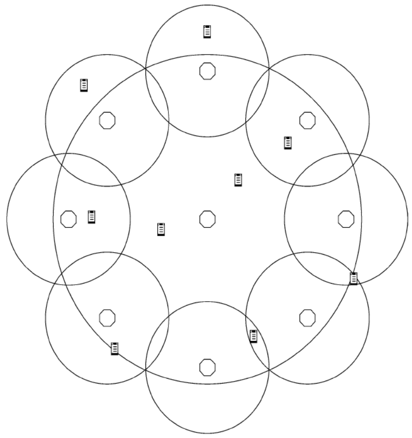


Fig. 4: Placement of 9 readers with two different ranges and the subregions [4]

SECOND STAGE In order to cope with the static and dynamic obstruction, reference tags were introduced to help calibration. The reference tags are subjected to the same static and dynamic obstructions as the normal tags so any interference has been canceled out. The next stage in this experiment used a maximum of 4 RFID readers due to cost constraints, 16 reference tags and 8 object tags. One of the results, that will be mentioned further on, showed that the best accuracy is acquired when looking at the four nearest neighbors of the object tag.

The difference between the computed location of the object tags and the real location were measured in 4 different types of experiments. One of the experiments was meant to find out how many reference tags where needed to calculate a position with the least amount of error. Another experiment was executed during one night and one day to investigate if interference would have major impact on the amount of error. The third experiment checked if using less RFID readers would be of any influence on the results. The last type of experiments tested different layouts of tracking tags, influence of barriers and different placements of object tags.

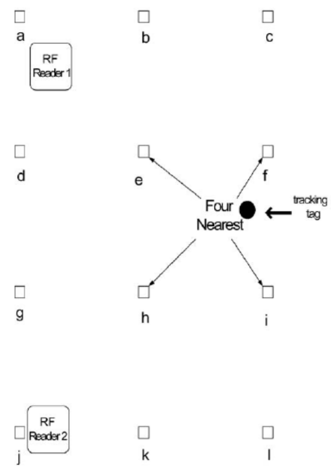
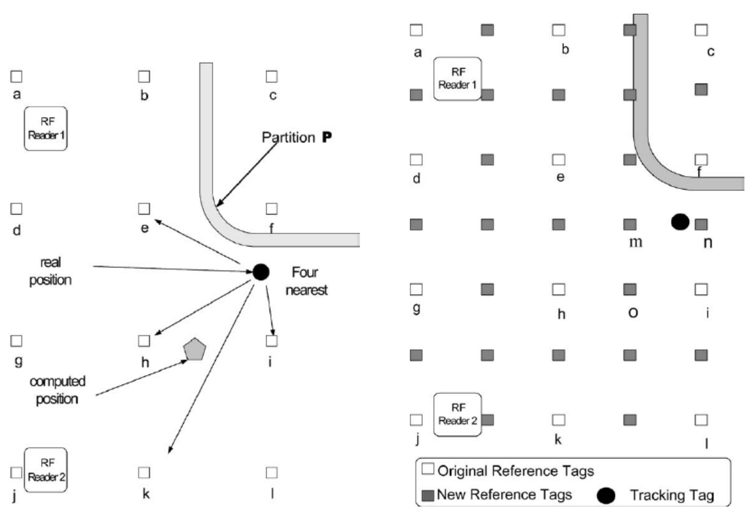


Fig. 5: Basic setup and performance of LANDMARC experiment [4]



(a) (b)

Fig. 6: *Layouts LANDMARC with a partition [4]* a) Performance standard layout with a partition b) Performance adapted layout with a partition

RESULTS Using 4 reference tags to calculate a position, while the original setting was used and using one reference tag per square meter with a maximum of 4 readers used, resulted in an error distance of maximum 2 metre with an average of 1 meter. Active RFID is not designed for accurate indoor location sensing but the L.A.N.D.M.A.R.C. approach shows that it can be a cost effective candidate when certain problems are dealt with by the producers of the RFID systems. The first problem is that the reader only reports when a tag can be found and not its signal strength. When using L.A.N.D.M.A.R.C. all readers have to scan all their 8 ranges and the system than calculates an average. This was not only a problem with the Spider System, but with all RFID technology that was available at the moment of the experiment. The second problem was that the interval for rescanning RFID tags was fixed at 7.5 seconds. Adding any functionality to alter this interval would be an improvement. The third problem was that there was a difference in signal strength of RFID tags while they were on the exact same position due to component differences. This could be eliminated by first testing all the RFID tags and classify them.

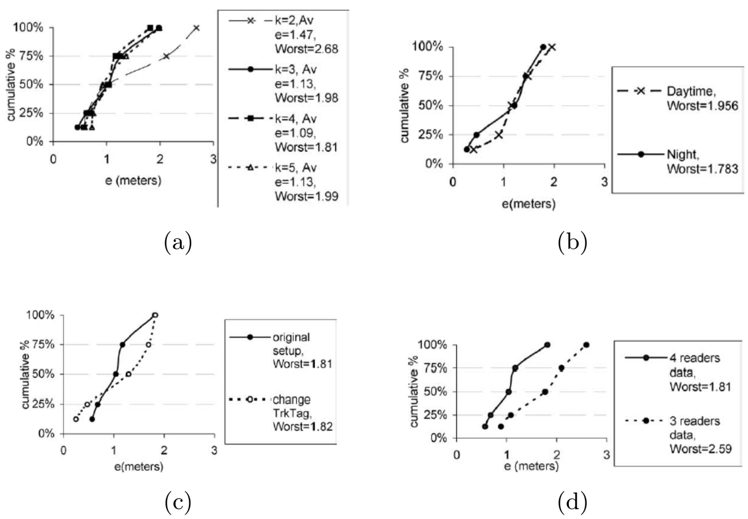


Fig. 7: *Some of the results of the LANDMARC experiment [4]* a) Cumulative percentile of error distance for k from 2 to 5 b) Cumulative percentile of error distance in the daytime and at night c) Cumulative percentile of error distance between two tracking tag placement configurations in figure 4b d) Cumulative percentile of error distance for 3 and 4 RF readers.

5.3 COMPARISON OF FEATURES

It is difficult to see AIR ID prototype from SpotON and L.A.N.D.M.A.R.C. separated from each other, because the L.A.N.D.M.A.R.C. solves the problem where the AIR ID prototype stops. The experiments were performed 4 years apart, so the technologies used were at completely different levels. Nonetheless, we can make a basic feature comparison of the used hardware and results of the both approaches. Both make use of RFID readers, active RFID tags and have means to communicate over a network. LANDMARC uses active RFID tags as reference tags and as object tags while SpotON only uses object tags. Possible scalability is only mentioned in the LANDMARC paper. It is possible to use another kind of antenna which increases its range 1000 feet. There is also a possibility to use LANDMARC for 3d location sensing, but at least 8 readers are needed.

Technique	Year	Range	Number of bases needed
SpotON (AirID)	2000	less than 15 ft	3
LANDMARC	2004	150 ft	4

Table 2: Features of the prototypes for SpotON and LANDMARC

Technique	Networking technique	Uses tags types	Physical partitions proof	dimensions
SpotON (AirID)	serial port	1	no	3
LANDMARC	802.11b wirless	2	yes	2

Table 3: More features of the prototype for SpotON and LANDMARC

UNAVAILABLE FEATURES The next information would have made interesting comparisons, but can not be found in both papers about the techniques:

- How many tags can be read within a certain amount of time.
- How much time it takes to calculate one position of an object tag.
- The lifespan of the active RFID tags used.
- Error distance.

6 CONCLUSIONS

Although *precise* location sensing is not reached with either systems, just location sensing using RFID works well. It might be possible that, in the near future, we can find RFID location sensing in consumer and producer environments. The ubiquitous home could profit from precise location sensing, but could do with only location sensing due to its costs. Production environments might adopt location sensing with RFID sooner, because there is a high chance of return of investment when parts of the supply chain work smoother and faster. Automated warehouses could use RFID location sensing, but the precision should be improved first. In the mean time the location sensing techniques could be used for automated path finding in non-automated warehouses. When the RFID hardware is improved and the recommendations from L.A.N.D.M.A.R.C. project are implemented, more precise location sensing will be possible. This will probably lead to more research in the RFID location sensing field and increased implementation speed in production environments.

References

1. Vipul Chawla and Dong Sam Ha. An overview of passive rfid. *IEEE Applications & practice*, September, 2007.
2. Sumi Helal, William Mann, Hicham El-Zabadani, Jeffrey King, Youssef Kaddoura, and Erwin Jansen. The gator tech smart house: A programmable pervasive space. *computer*, March, 2005.
3. Jeffrey Hightower, Gaetano Borriello, and Roy Want. Spoton: an indoor 3d location sensing technology based on rf signal strength. *UW CSE Technical Report*, February, 2000.
4. Lionel M. NI, Yunhao Liu, Yiu Cho Lau, and Abhishek P. Patil. Landmarc: Indoor location sensing using active rfid. *Wireless Networks*, 10, 2004.
5. B.S. Vijayaraman and Barbara A. Osyk. An empirical study of rfid implementation in the warehousing industry. *The International Journal of Logistics*, vol. 17 No. 1, 2006.
6. Roy Want. An introduction to rfid technology. *Pervasive computing*, January-March, 2006.
7. Ron Weinstein. Rfid: A technical overview and its application to the enterprise. *IT Pro*, May-June, 2005.
8. Evan Welbourne, Leilani Battle, Garret Cole, Kayla Gould, Kyle Rector, Samuel Raymer, Magdalena Balazinska, and Gaetano Borriello. Building the internet of things using rfid. *IEEE internet computing*, May-June, 2009.