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RTLS VS RFID - PARTNERSHIP OR COMPETITION?

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ABSTRACT. The constant technological development entails increasing needs of a precise identification and location of objects. A natural and proved way of fulfilling identification needs is using Optical Character Recognition (OMR, mostly bar codes) or Radio Frequency Identification (RFID). However, applying RFID to locate objects is a big challenge. In applications, which require both identification and location of objects, RTLS (Real-Time Location Systems) can be very helpful. Apart from the identification, RTLS ensures also the real-time objects' location. A range of possible RTLS applications coincides with the ones of RFID. Does that mean that RTLS is a next stage of RFID development? In the following paper, the authors are pursuing to answer a question, if RTLS is complementary or competitive towards RFID?

Key words: RTLS, RFID, objects' location.

INTRODUCTION

The continuous growth of the population and the constant technological development creates the increasing needs for the identification and the location of objects. The necessity of a rapid and efficient identification has become an essential element of a competitive advantage of the supply chain. The emergency of the technology for the automated identification was a milestone in this area.

The automatic identification, known also as AutoID (abbreviation for Automated Identification) or ADC (Automated Data Collection), are systems, which main task is to identify goods, locations, animals and persons without the direct human intervention (e.g. without the entering data into the computer by the use of the keyboard). The name “Automated identification” covers many various techniques and methods, used for the identification process. The best known and the most widely used are [Halas 2000]:

OCR – Optical Character Recognition,

MCR – Magnetic Card Recognition,

OMR – Optical Mark Recognition.

RFID – Radio Frequency Identification.

OCR (Optical Character Recognition) are systems, which rely mainly on a special kind of software, that is designed to recognize individual characters or their series, that occur e.g. in scanned documents. Previously, the systems of this type were fairly primitive and allowed only the identification of printed characters, but thanks to the rapid development of the information technology, the present OCR systems are able to recognize even the handwriting [Halas 2000].

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The MCR system (Magnetic Card Recognition) is a slightly different technique for the automated identification. The magnetic cards e.g. credit cards or phone cards, are the best examples of the implementation of this technique. The principle of their operation is based on reading the information in magnetic strip, placed mainly on a plastic carrier [Finkenzeller 2003].

The Optical Mark Recognition (OMR) is one of the most recognizable and most frequently used AutoID methods. The OMR method is based on searching and recognizing specially coded tags, which contain information. These systems may be responsible e.g. for scanning of the surveys or voting cards. This method is often found in the identification systems using bar codes [Jones et al. 2004].

The RFID method (Radio Frequency Identification) is last one of mentioned technologies. The RFID method is considered by many experts to be the successor of OMR systems, especially in the area of bar codes applications. Already for a few years, there are implementations of RFID methods, which successfully complete or replace the bar codes methods [Vijayaraman&Barbara 2006].

These four main identification methods are not the only ones, which exist. The other ones, not described above and used more and more commonly are: biometric identification, touch identification, smart chip cards as well as Real-Time Location Systems. The active RFID systems are the closest to RTLS technology regarding the way of action, possibilities and the implementation. The ability of a precise location of the label in the space is the main distinguishing feature of RTLS system, not available in other technologies.

The aim of considerations of this paper is the comparison of possibilities of the implementation of identification methods based on modern technologies such as RFID and RTLS in certain economic conditions. The authors undertake the attempt to answer the question whether the RTLS system is complementary or competitive to the RFID system.

THE ESSENCE AND THE APPLICATION OF SOLUTIONS BASED ON RADIO FREQUENCY IDENTIFICATION (RFID)

RFID (Radio Frequency Identification) is the ADC technique consists in the modulation of a radio signal emitted by the reader (interrogator) by the use of a response signal of data encoded in transponders (tags) and indentifying objects [Halas 2000]. The idea of the necessity of creating the identification system, in which the human interference would be limited to minimum, is not a new one. It emerged already a few decades ago. However, the technological limitations prevented the development of such technology at the time when this idea appeared. Only due to the rapid development of the information and communication technologies in last twenty-five years, it became possible to develop an efficiently working system. Until recently, OMR systems were the only ones, which were close to the ideal automated identification system. Nevertheless, over years, they became no longer sufficient as well as many disadvantages associated with their use, were brought to light. Therefore, there was a need to create a system, having all advantages of bar codes and at the same time eliminating as many their disadvantages as possible. The biggest disadvantages of bar codes system is the emergence of so-called “bottleneck” effect, which originates in technical limitations of previously used systems. It consists in fact, that one scanner can read only one code in the given moment. The strong dependency on human activity is another disadvantage of bar codes. It is a man, who is responsible for scanning the code of a good during the goods’ acceptance and collecting processes in the warehouse. The situation was slightly improved by introducing systems, which automatically scan the codes of products. Unfortunately they also have some disadvantages and can be used only in selected cases e.g. automated sorting of consignments. The above-mentioned disadvantages were eliminated by developing the RFID technology. Additionally many new functions, offered by this system, became available. First of all, due to the implementation of special anti-collision systems, a single reader is able to read up to 200 tags at the same time, which eliminates the “bottleneck” effect. The integration of RFID tags with antivol systems was successful, which eliminates the additional protection, necessary in the case of bar codes systems. RFID allows also tracking goods in real time, and therefore the quick inventory is possibly [Sweeney 2005].

RFID systems, used at present, can be applied as self-reliant identification systems or can supplement systems based on bar codes, mainly due to the fact, that there is still relatively small number of companies using RFID systems. Every RFID identification system needs a few elements to operate properly: a tag, an antenna, a reader and a middleware. The RFID systems are in fact the advanced form of antivol gates, used successfully for fast 50 years. And just as in these systems, in case of RFID system, an object with a tag is detected, when it is within the reach of the gate. In contrast to antivol gates, it is not an alarm, which is started, but the procedure of reading the content of a tag.

Just as it was in case of bar codes, the main task of a tag is to transmit the code, which is only a link to appropriate databases containing the data about goods. However, there are also special tags of significant storage capacity, which are able to hold relatively large amounts of data. The data carried by tags are encoded in most of cases according to standards set by the global RFID standardization organization – EPCglobal. The main EPCglobal's focus is put on the unification and the standardization of formats and interfaces of radio tags, i.e. by Electronic Product Code (EPC), which is sometimes identified with "radio bar code" or "bar code of next generation". It is not too far from the reality, since the same identifiers are written in a GS1 bar code and in an electronic code and whose uniqueness is supervised by the international organization GS1.

The next step of reading information encoded in the tag is to start the proper communication procedure via the special antenna transmitting signals. After reading the encoded information, the reader controls the checksum to verify the correctness of read information. In case it reads correctly, it sends the information to the middleware, whose main task is to mediate between the reader and the appropriate databases, from which data, assigned to a specific code, are collected. The middleware is also responsible for filtrations (e.g. elimination of duplicates), queuing and anti-collision solutions [Sweeney 2005].

The RFID technology is used in many areas of an economy. The most commonly used applications of RFID technology of the serious business importance are presented below. They include:

- logistics,
- pharmacy,
- airports,
- libraries,
- food industry.

The progress of the RFID technology is caused mainly by the logistics. The application of RFID technology allows achieving the highest level of the supervision of goods' flows throughout the supply chain (traceability). The accurate tracing of the path of goods is possible by collecting information in each element of the supply chain from the producer, through wholesalers and distributors up to retailers. It allows optimizing the supply process, to eliminate all errors and shortcomings, such as unjustified retentions of goods, losses and thefts, etc. The information about present locations of specific production batches is extremely essential from the point of view of some industry branches.

The increasing interest in the RFID technology is shown by pharmaceutical companies, not only because of the above-mentioned possibility to withdraw from the market the specific batch of products at the relatively low costs of such operation. The RFID based technology allows counteracting one of the main threats existing on the pharmaceutical market – the introduction of counterfeit medicines.

At present, the widely used technology for the identification of luggage in airports is bar codes. However, the technology of bar codes becomes very unreliable under conditions when the luggage moves with a passenger among various airports all over the world. The bent, fuzzy, damp or dirty labels often cannot be properly read. The efficiency of reading them is 90% at best, and rapidly drops below 85%, when equipment used for this purpose gets older or dirty. The situation is quite different if the radio tags replace the bar codes technology. The efficiency of the system based on RFID in the area of luggage management reaches the level above 99% [Sokolowski 2006].

RFID tags are regarded by librarians as successors of bar codes, traditionally used by them. The application of RFID system speeds effectively the work of a library by combining the activation of antivol RFID label and the registration of book's lending into one operation, even in case of several books at once, what had to be done sequentially in case of using of bar codes readers. The popularity of RFID among librarians is caused mainly by facilitating to conduct the inventory of the library. This operation is very simple and involves systematic moving an antenna of reader/programmer along the shelves. The additional advantage of application of antivol protection is the ability to determine immediately what was stolen in case the reader takes a book and will be not stopped in time by the security [Elmuti&Abebe 2005, Kern 2004].

RFID system are so far the only ones, which can provide the full and easy implementation on a large scale, the control of production and the identification of raw materials in the production process. It is very important for the implementation of a system "from the field – to the table". The attention to health quality of products introduced on the market by companies of the food industry is not a novelty. At the moment of Poland's entry into the European Union, the regulations regarding the safety of products tightened up and companies had to fulfil additional requirements, such as the implementation of HACCP system. However, the date of 1st January 2005 was a breakthrough in the area of food safety, because the Regulation 178/2002 of the European Parliament came into the force since that date. It regulates all matters of the obligation of monitoring and tracing of the movement and the origin of food and feed by all foods operators. Therefore, all participants of the supply chain are responsible for food tracing process and not only producers and distributors, but also the retail chains and shops, which are the last link in this chain [Sokolowski 2006].

RFID has been considered the most important identification tool for the establishment of an effective traceability system [Wang et al. 2006]. RFID tags allow a manufacturer of food items to have an audit trail of moments of the retail unit's life, monitoring correct handling, storage, transportation and delivery. Some tags have also the capability to monitor temperature-controlled product on a per unit basis, hence allowing manufacturers to find out exactly where a temperature abuse occurred [Kumar & Budin, 2006].

The comparison of applications of Hazard Analysis and Critical Control Points (HACCP) on one hand, and RFID tracking on the other, for the purpose of reduction of recalls and the subsequent impact in the processed-food industry shows [Kumar & Budin, 2006] that:

- the long history, long-time understanding among experts, the prevention of the food contamination by identifying potential hazard in the food processing chain are strengths of the HACCP; while being most advanced technology, an ability to track units of sale to the cash register and product traceability being those of RFID,
- the perception of being bureaucratic and frequent misunderstanding are the weaknesses of HACCP; while the facts that microorganisms take time to manifest themselves, and that in-plant control capabilities not as clear apply in case of RFID,
- the potential for the further improvement, and re-training of workers are opportunities existing in HACCP; while the potential to change the retail practice, and direct consumer tracking in the event of an emergency in the case of RFID,
- eventual obsolescence in the wake of an improved technology is a threat to HACCP; while system crashes, risk of hacking and loss of data are threats to RFID.

Hecker [2006], on the other hand, argues that RFID promises to solve problems associated with linear bar codes by enabling item-level automatic tracking throughout the supply chain, but this promise has been tempered by accuracy problems, high costs, and environmental limitations when used around metals and liquids. Therefore, he argues, it might be prudent to slow down a bit, until such time, that these issues are fully addressed. This issue is even more important to the food and feed industries as such features are dominant in food and feed items. Another application of RFID technology in traceability is its use in the animal identification. The radio frequency animal identification standard (ISO 11784/85) is a well-tested [IDEA Project Team, 2001] application where animals are tagged and identified automatically, as required. The frequency of standard operation is

134.2 kHz [Kampers et al., 1999], owing the low absorption rate, high penetration depth in non-metallic materials and water at this frequency [Finkenzeller, 2003]. The tag may be attached to the animal in one of three modes, namely ear tags, the subcutaneous injection, or ruminal bolus (only applicable to ruminants). The bolus has been identified as the best tamper proof animal identification tag (99% retention rate, and 100% recovery rate) provided it is implanted at the right age and weight of animals [IDEA Project Team 2001, Fallon et al. 2002, Ayalew et al. 2006].

THE ESSENCE AND THE APPLICATION OF SOLUTIONS BASED ON REAL TIME LOCATING SYSTEMS (RTLS)

The idea of RTLS systems is based on the possibility to determine the location of objects in the space. This operation takes place so quickly comparing to supervised processes, that one can talk about the position's location in real time. RTLS systems may operate based on various physical phenomena but at present the radio system are the dominant ones. Two main trends can be distinguished among them: based on the pattern of the radio waves propagation in the supervised areas (fingerprint) and on the analysis of parameters of radio waves propagation emitted by the label. The second type of RTLS systems are the most often used – based on active tags. The idea of the operation of systems with active tags is based on physical characteristics of the radio wave propagation, which cover the distance from the transmitter to the receiver in the shortest way and with a specific speed. The receiver, called also a sensor, receives the signals emitted by a tag with the help of an array antenna. The processing of received signals allows determining the angle of propagation of the signal, i.e. the angle at which the tag is seen by the sensor. It is so called a method of an analysis of the angle of the signal's propagation (AoA – Angle of Arrival). Another approach is an analysis of time differences of signal's propagations (TDoA – Time-Difference-of-Arrival) - two or more sensors determine time differences of the moment of receiving the tag's signal. The analysis of this information allows determining the location of a tag in the space. The best RTLS systems allow simultaneous use of both types of the signals' analysis.

The industrial environments are generally difficult ones for the propagation of radio waves, due to reflections, interferences and the signal attenuation occurring in them. The variability of these parameters over time should also be taken into account. These requirements cause that radio RTLS use short-term, ultra-wideband radio impulses (UWB). On the one hand, these signals are difficult to be interferenced; on the other hand, they allow relatively easy detection and elimination of reflected signals.

Similarly as in the case of RFID systems, the identificator is contained in the signal emitted by the tag, which allows its unambiguous identification. The identification properties of the RTLS system are similar to those, offered by active RFID systems. In contrast to RFID allowing the localization in control points, RTLS allows the continuous localization of tags in 3D space with an accuracy of up to 15 cm in supervised areas. It enables to realize the business scenarios, which are practically inaccessible by the use of other technologies. RTLS allows realizing the full identification and traceability in the company. In case of above-mentioned pharmaceutical companies, it makes possible not only to analyze the products flow on the level of control points but wherever it is significant. It allows determining, which raw materials had contact with each other during the production process. Therefore, it reduces the possibility of errors. In conjunction with measuring devices installed in a company, it is possible to determine, whether the products remained only in areas, where the required environmental conditions were hold. The staff, having a potential contact with products, can be also included in the process of traceability.

The first RTLS systems appeared in 1998 year. Due to the high price, they were used only in the military and government agencies. The technological progress enabled to reduce the price and RTLS systems were started to be used for industry purposes. Still this technology is hardly known and little used. The automobile industry is a typical example of the application of RTLS. The personalization of the production process, which transforms from the mass production to the make-to-order production, is a big challenge of the technological and logistic nature. The BMW production plant in Regensburg

could be an example, where cars of three various series are produced on the same line and the total daily number of produced cars is about one thousand [Swedberg 2009]. The application of RTLS eliminated the necessity of scanning of bar codes, in order to properly program the tools. At present, the whole process is an automated one. It is enough to bring a tool near the just mounted car. The strength of this solution could be seen in the fact, that the company Atlas Copco offers tools integrated with RTLS as standard ones. Their sophistication allows not only to program tools but also to provide feedback to the system, and thus supervising the correctness of the assembly, e.g. checking, whether a proper bolt or a required washer was used, etc.

In case of BMW, the full and actual visualization of the production process is the benefit of the implementation of RTLS system. RTLS can play an important role in the improvement of the work of hubs, regardless of whether the incoming goods are marked with bar codes or RFID. The benefit could be the security of extremely valuable items, which movement can be monitored by the camera system, controlled by RTLS. The human factor in the handling processes cannot be totally eliminated but it could be minimized. The RTLS tag, installed on the forklift provides information not only about moved goods, but also about the characteristics of the forklift's work. It allows eliminating dangerous behaviours e.g. speeding, work under the influence of intoxicants or not keeping the safe distances between forklifts. The prevention of collisions between forklifts and the staff could be the main task, which would contribute to a significant increase in the safety.

The diagnosis and then the optimization of logistic and production processes is another application of RTLS technology. This application of RTLS allows seeing the real flow of goods, raw materials and staff within an operating company without any interference in the processes. What is only necessary is to install RTLS system and label all significant objects and then it is possible to collect information about their movements, mutual relations and to correlate them with business events. Once the information is gathered, they can be used for the deep analysis of the company, which is the basis for the optimization of processes. The flexibility and quick adaptation to changes are the important elements of modern industry. RTLS systems help to face these challenges. The once installed RTLS system can be freely configurated and adapted to changing needs without the necessity of physical changes in the infrastructure. The defining of zones, checkpoints, required dependencies could be done on the level of the software. Another important use of RTLS system is its application for the localization of individual animals in big herds in the area of large-scale livestock farms. The knowledge of animals' location allows their observation and decreases the costs associated with supervision and searching of individual animals.

RTLS system used in Danish dairy farms, apart from the localization of specific cows in the herd, allows diagnosing the first symptoms of possible diseases. The dedicated software allows the visualization of the movement and the behaviour of animals, which makes easier e.g. to detect the beginning of the ovulation of females and thus to plan the insemination. The analysis of data obtained from RTLS system is more effective than the estimation of reproductive cycle of animals based on a calendar. Moreover, the integration of RTLS with the application CowDetect of SmarterFarming Company helps to optimize the process of milking cows by the exact localization of animals, which have not been recently milked. The above-presented applications of RTLS systems do not cover all possibilities of the exploration of this system in the industry.

In the addition to typical industrial applications, RTLS systems are used also in security and entertainment industry. However, these applications are outside the scope of this paper.

THE COMPARISON OF THE TECHNOLOGY OF AUTO-IDENTIFICATION SYSTEMS: OMR, RFID AND RTLS

Auto-identification systems are constructed according to similar principles and consist of similar elements. There are both many similarities but also significant differences among OMR, RFID and RTLS systems. Table 1 presents this comparison.

Table 1. Comparison of bar codes to RFID tags
Tabela 1. Porównanie kodów kreskowych do etykiet RFID

Characteristics	Bar codes (OMR)	RFID passive	RFID active	RTLS (based on UWB)
Content modification	lack	available	available	lack
Protection	weak	from weak to good	very good	very good
Capacity	8-30 characters	up to 64KB	up to 8MB	-
Weight	0	small	average	average 8-25g
Costs	low, below 1 cent	average, below 10 cents	high, up to 100$	high, app. 50$
Standards	steady	evolving	evolving	evolving
Power supply	lack	lack	battery	battery
Life length	short	infinite	3 to 5 years	3 to 7 years
Distance from reader	eyeshot of scanner max 150 cm	up to 15 m	up to 100 m	up to 70 m
Accuracy of localization	-	15 m (within operation field of reader)	100 m (within operation field of reader)	15 cm
Obstacles in reading	everything, which can blocked the eyeshot of a scanner	fields disturbing the radio waves	strong signal, difficult to be disturbed	UWB difficult to be disturbed

Source: own work based on Sweeney [2005], www.zebra.com [2011], www.ubisense.net [2011]

There are many technologies on the market, which enable the identification, indispensable for the realization of the supply chain and production processes: starting from the simplest ones, based on optical reading of graphic symbols (OMR), through the radio identification systems (RFID) and ending with RTLS systems. In terms of the functionality, each consecutive technology eliminates the disadvantages of its predecessor and extends its functionality.

RFID systems have reduced the significance of human factor in the identification process increasing the reliability of the identification process. The susceptibility of labels to damages has decreased significantly. The simultaneous identification of many labels became possible. Additionally, there is a possibility to modify the information written in tags. RFID systems enabled the efficient localization at the level of checkpoints. In case of active RFID, the memory capacity and the reading distance have increased significantly. Finally, RTLS systems, which offer not only effective identification, but also full localization possibilities, both in open space as well as in buildings and especially in difficult industrial environments. So, will RTLS overtake other methods of the identification? RTLS tags are relatively large; therefore, small objects cannot be labelled with them. They are also expensive, therefore they are not suitable to label mass products, and additionally there is a need to take care of their retrieval. Their utilization is forced by the use of electronic part and battery as a power supply, even if their cost is very small in comparison to labelled goods. On the surface, these features restrict the use of RTLS to obvious ones – big products of high values or

situations, where there is a necessity to determine precisely the localization of objects or their mutual localization, especially in the conditions of the changing configuration of work environment, ensuring the safety, etc.

Maybe instead of rivalry, it is better to put focus on their cooperation. In case of a plant using bar codes, it is necessary only to equip the bar codes readers in the RTLS tags. In this way, each reading will be automatically marked spatially. In case of the use of RFID, the means of their transport can be included in RTLS system and equipped in RFID readers. The suitable computer system will combine readings of RFID readers with localization data from RTLS tags and determine correctly the position of objects marked only by RFID tags. In this way, some kind of virtual RTLS tags will be created, based on the cooperation of RFID and RTLS. Additionally, the high configurability of the work environment will be received, where all kinds of spatial configurations will take place in virtual space of information system, without the necessity of moving gates or RFID readers. And it seems to be a way, both technologies should follow, where the mutual cooperation is more beneficial in comparison to possibilities offered by the application of only one of them.

The very wide spectrum of the use of RTLS system is another factor, which persuades to regard the implementation of this system. RTLS system applied in the warehouse to optimize the work of forklifts can be used to create an anti-collision system. The system, which delivers semi-products to work cells, can be the base to create a system of supervision of the production process.

The range of the applications of RTLS system is similar to those of RFID systems. Under certain conditions, there are some indications to use only one of mentioned technologies (considerations concerning the determination of clear criteria for the selection of one of these technologies will be the next step of Authors' researches). There are also examples of parallel use of various technologies of the products' identification, which can be found in the practice. Such an example can be one of German forwarding company, which installed RTLS in its distribution centre, with an area of 13 500 m^2 and 3 000 loads handled per day. Previously, the company had significantly high costs of searching individual items or transport of incomplete loads. Due to that, it decided to implement RTLS system connected with the video monitoring. There are now almost 20 forklifts and 140 gates monitored by 160 cameras. Additionally, there are 30 bar codes scanners, equipped in RTLS tags. The system enables to locate these tags, and therefore scanners. It is possible to locate the items by knowing a position of a reader at the moment of reading, which simplifies the work of the monitoring system.

CONCLUSIONS

The aim of the considerations of this paper was to compare the possibilities of applications of identification methods based on RFID and RTLS in certain economic conditions. Numerous presented examples of possibilities of using both technologies demonstrate broad possibilities for their applications. Many cases prove the complementarity of described solutions, although in some respects they are competitive to each other. Therefore, finding the answer to the question, whether RTLS system is complementary or competite to RFID system, remains a matter of a future.

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RTLS VS RFID - PARTNERSTWO CZY RYWALIZACJA?

STRESZCZENIE. Nieustanny rozwój technologiczny rodzi coraz większe potrzeby związane z identyfikacją i lokalizacją obiektów. Naturalnym i sprawdzonym sposobem zaspokajania potrzeb identyfikacyjnych jest wykorzystanie technologii wizyjnej detekcji znaków OMR (najczęściej kodów kreskowych) lub identyfikacji radiowej (RFID). Jednak użycie RFID do określania lokalizacji obiektów stanowi już duże wyzwanie. W aplikacjach, w których jednocześnie wymagana jest identyfikacja i określanie położenia obiektów znajdują zastosowanie systemy RTLS (Systemy Lokalizacji Czasu Rzeczywistego). Systemy RTLS oprócz identyfikacji zapewniają precyzyjną lokalizację obiektów w czasie rzeczywistym.

Paleta zastosowań RTLS jest zbieżna z zastosowaniami RFID. Czy w takim razie RTLS stanowi kolejny etap rozwoju idei RFID? Na łamach poniższego artykułu autorzy podejmują próbę odpowiedzi na pytanie, czy system RTLS jest komplementarny czy konkurencyjny względem technologii RFID?

Słowa kluczowe: RTLS, RFID, identyfikacja położenia obiektów.

RTLS VS RFID – PARTNERSCHAFT ODER KONKURRENZ

ZUSAMMENFASSUNG. Die ständige technologische Entwicklung bringt dem zunehmenden Bedarf für die Identifizierung und die Lokalisierung von Objekten. Die Methoden von der optischen Zeichenerkennung oder der Identifizierung mit Hilfe elektromagnetischer Wellen (RFID) sind die natürliche und geprüfte Methode für die Identifizierung. Allerdings, die Bestimmung von den Objekten-Positionen ist eine große Herausforderung. In Anwendungen, in denen zur gleichen Zeit die Identifizierung und die die Bestimmung von den Objekten-Positionen erforderlich sind, werden RTLS-Systeme (Echtzeit-Lokalisierung) verwendet. RTLS-Systeme ermöglichen zusammen mit der Identifizierung auch die genaue Lokalisierung von Objekten in der Echtzeit. Der Bereich der möglichen Anwendungen von RTSL ist sehr ähnlich den Anwendungen von RFID. In solchen Fall, ist RTLS die nächste Etappe der Entwicklung der Idee von RFID? In dieser Arbeit versuchen die Autoren diese Frage zu beantworten: ist RTLS eine Ergänzung oder eine Konkurrenz für RFID?

Codewörter: RTLS, RFID, Identifizierung der Lokalisierung von Objekten.

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