MAPPING OF WIRELESS TECHNOLOGIES TO SUPPORT REAL TIME LOCATION SYSTEMS FOR TRACKING RESOURCES OF LARGE ENTERPRISES

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ABSTRACT

This study aims to present a methodology that helps to select the most appropriate technology for resource tracking in large projects such as refineries, offshore, mining, among others. The method used is the correlation between the metric performance parameters and technical characteristics of the sensors that Real Time Location System (RTLS) are based, such as: Infrared, Ultrasound, Bluetooth, UWB, RFID, Zigbee and GPS. Thus, is obtained a table with qualitative indicators that are subsequently aligned in ascending order of operation, generating a radar chart to view evaluative rating clearly. The development of this method and its application aims to minimize mistakes in planning and achievement, enabling the development of RTLS's systems with more appropriate technologies.

Keywords: Real time Locating Systems, wireless, metric performance, appropriate technologies

1. INTRODUCTION

It's possible to notice in the current Brazilian panorama of civil construction some large technological advances. Some significant investments were spent in the last few years, mainly in the industrial base, such as refineries, shipyards, mining and hydroeletrics. These large ventures have as a characteristic on the construction or even the operational phase, the capacity to encompass large areas divided by activities. All of these activities are naturally dynamic and encompass a lot of processes which must follow protocols and rules that are generally monitored based on results. But, having the knowledge about all the practices and measuring the evolution of the activities opposing the investment and the operational chronogram may be a difficult task depending on how big is the enterprise.

So, the possibility to identify and track points, which are critical and essential to the enterprise through automated processes, can be a powerful resources management tool. Specially, detecting failures on the production and risk areas may not only affect directly the enterprise's budget but also represent a significantly decreasing in the number of job accidents.

As a result, the calculation of the activities and resources' statistics has to be extremely detailed and studied as well as the aggregated values of the actives must have priority , aiming the production chain's dimension.

Through this study, it's intended to indicate one actives classification base in order to facilitate the identification of critical moments on the processes. Thus, it'll be indicated through a table the behavior of the tracking sensors related to the nature of the objects' materials which will be contained in the devices or will possibly act as an obstacle in the system's application environments.

Moreover, taking the GPS and active capture sensors as main line, a table comparing the techniques used by the different tracking systems will be offered. This table will indicate what is possible to achieve regarding precision, easiness to install, cost and other characteristics.

By the use of the table with indicators measuring the tracking systems' operation capacity together with visualization of the generalized classification of the sensors' operation, it will be generated a mesh of the positioning related to the operation of the system.

Therefore, the main goal is to obtain a mapping of the most adequate technology through the correlation of the sensors and also prioritize their performance. With the help of the qualitative indicators, which were elaborated to the Selection Table RTLS, it's intended that the user, having or not having technical knowledge, can visualize the necessities that the ideal system may has in order to solve the great demand of the project, minimize mistakes regarding the project and the installation. This will create safer choices.

2. HOW THE TRACKING AND REAL-TIME LOCATION SYSTEMS WORK: PRINCIPLES AND TECHNIQUES

According to TAPIA et al (2011), a location system is basically constituted by three entities, fixed sensors, mobile modules and an element that will manage the devices or sensors network, depending on the chosen technology. The mobile modules are monitored by fixed unities that are positioned on higher levels compared to the rest of the system's components.

According to MALIK (2009), the transmitters operate through tags and fixed landmarks and they can act as transmitters, receivers or both, generating many technological combinations.

The sensors are part of the positioning tool, which the RTLS solutions are based. They can have different types with different operating principles, such as geo-positioning by GPS, cellphone tracking or systems that use tracking through RFID passive tag\s. The information about location, usually don't include speed, direction or spatial orientation.

2.1 Technical characteristics

RTLS are used most of the times, in confined areas. The tags are attached to items that are going to move with the purpose of knowing their movement, tracing the route, or merely monitoring them. The landmarks RTLS, called AP- Access point, can be either transmitter or receiver, distributed in the defined area of range for data collection. Most of the cases, the more landmarks are installed, the better will be the accuracy of the localization until the performance find some technological restrictions (HJELM, 2006).

There are some models of projects of real-time localization systems. However, there are two primary tracking models: Location by shock points and relativity of coordinates. The first consists of fixed networked readers that will find identification signals transmitted by short-range "tags" in motion. And the latter, on which location signals of a tag are received by multiple readers connected on the same network, estimating the position by the calculation of location algorithms such as trilateration, multilateration or triangulation (MALIK, 2009).

2.2- Techniques of tracking and tracing.

The tracking systems are categorized according to the techniques used to estimate the location of mobile devices. Following, there is a summary of the location techniques and then the operation of the algorithms used in location systems.

a. Direct identification

These are devices that are only detected when they are close to the reader and may be attached to antennas or even portals. As an example, we can observe infrared-based systems, in which information is transmitted when the sender and receiver establish eye contact. Another example is the system based on "radio-frequency identification" (RFID) present in the access cards to restricted areas.

b. Difference of the time of emission and perception of the sign

This technique consists of the perception of the difference of time between the spread of signal, considering the emission and the arrival at the receiver of the network components. It's necessary to previously know the velocity that the signal spreads, together with the measure of time, in order to estimate the distance of the device in relation to a lot of raised points. Among the techniques based on this notion, the most used are: Time-of-Arrival (ToA), Times-Difference of Arrival (TDoA) e Time-of-Flight (ToF) Pags-Zamora, 2006).

c. Angle of arrival - AOA

Through prior knowledge of the distance between the various receptors and angles of arrival detected in each landmark, it is possible to estimate the object's position via trigonometric functions (HJELM.J., 2006).

d . Received-Signal-Strength-Indication (RSSI)

RSSI are values that make a sensor able to determinate the location of a mobile device, when there is an approximation between them, by analyzing the intensity of the received signal. From these RSSI values, there is also the possibility of knowledge of the location through the interpolation of three reach balls from three sensors calculated from their centers. The area that matches will be the likely location of the device. This method is called Triangulation.

e. Location by pattern - Fingerprinting

In order to have a bigger precision, there is the technique of "Fingerprinting" or location by pattern. It calculates the position through the intensity of the received signal and its default behavior, mainly when it comes to its location, this way, forming a database. This technique is divided between the "online" and "off-line" phases. In the "off-line" phase, through the values of the RSSI the points are mapped in an area of interest. During the "online" phase, this process is used to create parameters of the propagation model. According to KAEMARUNGSI (2005), the location of the mobile station is determined by the identification of the closer points, present in the "Fingerprinting".

3. DEFINITION OF THE ENVIRONMENT, ASSETS AND PROCEDURES THAT ARE GOING TO BE TRACKED

We can take "indoor" as the environments that have a delimitation of space, with previously known obstacles such as buildings subdivided between walls or between floors and fixed points of entry and exit. For this study, it's possible to classify environments "outdoors" as uncovered areas, without assuming to be free of obstacles. In the case of big ventures, it's a large area, that is able to present subdivisions and mainly uncontrollable interferences that can't be measured most of the times. These environments present the biggest complexity, when it comes to the control of the relation between devices that form the wireless network, tracking targets and installing antennas in strategic points for monitoring, due to the coexistence of a diverse range of materials and processes.

3.1. Processes and methods of definition of the actives

Processes and methods of definition of the assets defining a method of evaluation and hierarchy of labor input can be an essential step so that it becomes possible to implement monitoring tools and process automation. Once the nature of the environment of work, of the materials, of the tools and the own routine of work of each enterprise can be diverse and even unstable, we propose a kind of roadmap with guidelines that will assist an essential phase for the implementation of a monitoring system: data collection. Considering that the review of the literature doesn't present an automatic way for a definition of guidelines and to make the scope of the project more consistent by defining critical points and identifying productivity we suggest an approach that will transform parameters in indirect indicators of need. The assessment should follow these hints:

1. Are there indirect parameters[1]?
2. If yes, how can they be measured?
3. Once collected and classified, how can they be converted to direct parameters[2] in order to be analyzed and represent future effective improvements in the project?

3.2 Definition of the object and indirect parameters: materials, machinery and people.

During the parameters definition phase It's interesting to see the integration with the existing project management systems (PM's – Project Management), which approach performance standards such as Project Management Pyramid.

At this moment, the actives which will be tracked according to their priority order in the enterprise operating context will be enumerated.

a. Materials: Inventory and Quality Control

About the elements that comprehend the big enterprises industry, according to CHENG et. Al. (2011), construction materials, installation and base tools are estimated to be between 50 and 60% of the construction total cost. During the project phase, these materials are classified among three categories: Off-the-shelf: easy to replace, Long-lead Bulks: items to weigh, Engineered items: hard to replace. These different categories vary in cost, waiting time for supplying and waiting time for replacing.

[1] It is possible to understand indirect parameters as actives such as materials, equipment, tools and people that may have their paths and activities tracked and delimited.

[2] Direct parameters are the result indicators of this monitoring that come in the shape of data. This data will serve as base to automated routines and enterprise's processes.

Generally, engineering items have a high cost and they are offered in a small quantity. These items have unique properties and require not only a long time to be replaced but a bigger plan for theirs field use.

The nature of the material can be an obstacle to some kind of sensors. Metallic, transparent and liquid materials cause interference, spoiling the operation of some technologies. We will present further a table that classifies the technologies' performance related to the material.

Both the active's value in the process' context and the easiness to replace them are factors that will also guide the choice of the sensors, because many times, the investment in the technology may be bigger than the profit generated.

The storage requirements, the handling and the transportation will also define the structure's design, which will be built to the RTLS operation. As an example, it's necessary to relate the storage way to the packing ways: pallet, metal boxes, cardboard boxes.

The ways of transportation, regarding the materials that are moved, may also define the structure. As example, it's necessary to measure the size of the trucks and the forklifts in order to make them adequate to the installation of the monitoring portals.

Based on the technical restrictions of the active sensors and the GPS, which works as base of the tracking systems, a table was built. This table establishes a relationship between the material's nature of the possible trackable targets and sensors' operating limitations showed against these materials. On the table 1 – Indicator of sensors operation related to the nature of tracked objects' material, it's possible to understand that the X (red color) is used for situations when there is no good operation, or even when there are blocking failures. In the case of V signal (green color), there is a possibility to install the system and its operation won't be connected to the inter-related conditions in the table. However, it's necessary to highlight the fact that in some situations represented by X, there's a possibility to avoid this operating difficulty using hybrid hardware solutions, or even increasing the number of antennas to transcend the obstacles.

These information were taken from tests presented in varied studies that served as theoretical base to this study.

Table 1: Indicator to the operation of the sensors related to the nature of the tacked objects' materials.

SENSORS / MATERIALS	IV	US	BT	UWB	RFID	ZIGBEE	GPS
LIQUID	V	V	V	X	X	V	V
GLASS	V	V	V	V	X	V	V
METAL	X	X	X	X	X	V	V
WOOD	X	X	V	V	V	V	X
PLASTIC	X	V	V	V	V	V	V

b- Machinery

It's possible to attach sensors to the equipment, allowing the localization of small tools which are not only used by different teams but also necessary to the activities.

These sensors can store information regarding the use of these tools, such as time, local and who used them. These data may indicate to the responsible technicians if the equipment is worn out, defining a correct moment to start the maintenance. The sensors may still contain information about permission of use related to the tool that the operator is allowed to use.

c- People: monitoring safe areas

To begin the planning it's necessary to make a calculation of operators' behavior general statistics. Both the safety standards and the possible restrictions in the work place are information that must be inter-related in order to make possible having a map of the risks and their correct evaluation. The occurrence of risks increases when the workers either do their job away from the safety inspectors or out of the control zones or near the work places boundaries.

It's important to elicit that the activities prediction with their routines and risks prevention must be planned during the project phase (PTD – Prevention through Design). So, it's essential to have the measurement of both the area and the resources' path. The monitoring of the workers and the analysis of their routine and the management of the actives must be shaped to make available the correction of the project. This can lead to improvements in both the safety and the performance of the activities.

As an example, it's possible to permit or deny the access of people from the group to restricted areas. It would avoid the exposure of people to areas of risk or even the contact with unauthorized people in places that valuable objects or even content with contamination are stored.

- Monitoring of the activities

In case of people, the sensor is attached to objects that are going to be part of the employees' uniforms, as badges or tags attached to helmets.

These accessories will be able to record information about schedule, for example, allowing that the journey of work to be automatically monitored. They can also work as keys of access to areas where the managers are going to determine as appropriate or not for each employee. This automation would increase the control over the lost objects, avoiding the embarrassment of those employees who may not have any relation with what happened.

The badges can be keys of access to some tools, stricting the use to employees who are trained.

Another feature of this track is to generate data as execution time of tasks and locations on which employees are passing by. These are factors that will serve as tools for analyzing team performance.

In Picture 1, it's possible to notice a representation of the field implementation of the monitoring system for employees, where 1 indicates a fixed portal signal reading (receiver) and the number 2 represents the transmission signal tag with information carried by the employees.

Picture 1: Representative scheme of monitoring workers

3.3. Definition of project strategy: taking decision for the adoption of the system at the organizational level of the enterprise.

The cycle of movement of assets can pass through the following cycles: Open and Closed.

a- Solutions to open cycles

The solutions to open cycles comprehend multiple organizations and tend to benefit multiple industry sectors as control of retail items and tracking of raw material.

The "Business Case" for open cycles is more complex to develop because it's necessary to identify problems in the whole supply chain. The value of information at various points and of different interested parts should be quantified by evaluating the benefits of different natures.

b- Solutions to closed cycles

The solutions to closed cycles solve specific problems as lost, strayed or stolen assets, manufacturing flaws, storage that generates waste and lost time due to lack of knowledge in the implementation of activities. This "business case" presents less difficulties than the later, because the problems will be identified in only one organization. Therefore, quantification of losses that relate to assets becomes more direct and controllable. In terms of investment, the same organization that pays for deployment experiences the benefits.

3.4. Site analysis: lifting restrictions of the deployment environment RTLS (Site Survey)

A crucial activity to the proper application of the tracking system is the analysis of the place where the field monitoring will work. Through the observation of the routine of performance of tasks, it should delimit favorable conditions and the limits that the space offers. This way, the installation of means of capture of data should be well performed, so that the next stage together with the technical information sensors obtain the final choice of the system. The collected information will help, for example, in the choice among the structures of capture as portals or handheld readers.

This step influences directly in the chance of success, since the good adaptation of the team in relation to the system is directly connected to the little change in operating habits. In Picture 2, we can see an illustration of the performance of a portal in areas where there is flow of trucks and other transportations.

Picture 2: Scheme representative portal for capturing identification signals. Part of the localization system. 1 - Portal with antennas / 2 - Truck tagged RTLS

4. DECISION MAKING: RATING FOR SENSORS AND EXPOSURE OF METRIC PARAMETERS OF ASSESMENT.

The systems can be classified according to the kind of sensor used. In active systems, the signal emitted by the sensor determines the distance between the mobile devices, that in the case of tracking individuals is an accessory and the sensor is generally fixed. From the moment in which the positioning of the sensors is known, the location can be computed.

This study aims to gather information and evaluate the application of RTLS's based on assets sensors, that present lots of developed solutions for the area of big ventures, besides the possibility of association between sensors, forming hybrid solutions for a better range in situations of severity of conditions. The GPS, which is a passive sensor, is included in the evaluation's selection, because it has robust long-ranged and well-spread commercial solutions.

Active sensors may have many different types: based on communication through network such as 802.11 – specification of the type of network or in dedicated sensors which use others electromagnetic bands. In this study we will approach the following sensors: Infra-red, ultrasound, UWB (ultra wide band), RFID and Zigbee.

4.1 Active Sensors

a- Infrared sensors

Short range transmission of a mobile device's identification to a fixed receiver with a known location. Because of the limited range of infra-red transmission, the optical spread needs to be in the line of sight (LOS – line of sight).

The cost of the components is basically cheap, yet the development of the transceiver is expensive. Besides that, the interference rate is high in places where there are machines operating and equipment that emit infra-red light. Another interference factor is the solar beams, which block the infra-red beams' communication.

b- Ultrasound Sensors

A positioning system based on Ultrasound technology has as main advantage the precision of the obtained positioning calculation. The Ultrasound promotes a refined measure with the smallest precision unities through the application of a technique that calculates the arrival time of the signals to the sensors (TOS – time of sight). The calculation of the positioning generates three-dimensional information and it's obtained through the distance between the transmitters and the receivers which change their fixed position among themselves. The definition of the access points and the antennas' positioning which will need to have their coordinates configured or sent to the database manually is made in the mapping phase of the area that will be covered. This previous positioning knowledge is necessary to the system.

To minimize interferences, a lot of antennas need to be placed in close spaces, which can become a big obstacle to the installation of this system.

Therefore, apart from the sensors provide an extremely high calculus precision, the usage of this system may be discarded when facing the prediction of investments in infrastructure and manual adjusts. The system can also present the disadvantage of failing by the trivial interferences, easily found in varied environments such as strident noise, intermittent fluorescent lights or even people talking noise. Because of this, the system uses sophisticated algorithms to filter these errors. This makes the investment even more expensive.

A consolidated example of the usage of these sensors is the MIT Cricket system, which encompass a fixed infrastructure of nodes that emit signals and through the trilateralization technique it obtains the mobile nodes' positioning with decentralized dependency.

c- Sensor based on radio transmission: UWB - Ultra Wide Band

Ultra Wide Band - broadband is based on sending ultra-short pulses (smaller than 1ns) in a low cycle (1:1000). The frequency range that the UWB system uses is higher than 500MHz. Unlike the conventional RFID systems which operate on individual wavebands in the radio spectrum, UWB transmit a signal along many wavebands simultaneously, between 3,1 and 10,6 GHz. UWB signals are transmitted faster than RFID signals. UWB device not only consume less power than RF tags but also operate in large areas with a bigger signal range.

UWB neither suffer nor cause interference if used near other radio signals, because of the different type of spectrum used. UWB short length pulses are easily filtered with the purpose to define correctly the signals that are generated from multiples platforms. The signal is able to transcend easily walls, furniture and clothes. On the other hand, both metal objects and liquids cause interference. This disadvantage can be avoided by positioning more UWB readers.

The short pulse of the wavebands allows not only defining precisely the arrival time (TOA - Time of Arrival) but also orienting, through the time of flight (TOF), the correspondent receivers that will receive a volley of pulses (GEZICI, 2005).

Currently, some systems were created using UWB. The Ubisense system, as an example, is a system that uses an unidirectional platform with control through a bidirectional channel TDMA - "time division multiple access". The devices transmit signal to the network`s receivers and they are located with the application of the angle detection and the signal time of arrival techniques (AOA and TDOA). The Ubisense network operates creating cells, which require at least four sensors or readers. Through the buildings or even through a group of buildings, an unlimited number of readers can be connected over the network, looking like how a cellphone network operates. The readers receive the emitted data from the devices, coming from 45 meters maximum and pass them to the "Ubisense Smart Space" platform.

The UWB microwaves frequencies are used by Siemens positioning radars (Gulden 2003). This radar use the RTOF technique, which measure the reflection time through the frequency modulated continuous wave (FMCW) among transponders and base stations. This system was installed in industrial equipment to monitor their activities, such as positioning of a forklift or even a crane. However, this system is feasible only in environments that allow having a direct view LOS (Line-of-sight).

d- Sensor based on radio transmission: Bluetooth

Bluetooth uses a communication protocol by short range radio frequency, which allows establishing a communication with many mobile devices if they are compatible. Being able to establish a communication with multiple points (point-to-multipoint), the Bluetooth operates freely on industrial, scientific and medical frequency bands (Industrial Scientific Medical - ISM band) at 2.4GHz. It has a propagation spectrum in a variable frequency, oscillating among a range up to 1600 channels per second.

As a consequence of using the short range protocol, the Bluetooth devices connect through the network can estimate their positioning through measuring the variation of the signal`s magnitude (RSS - Received Signal Strength) among devices that have defined this location information. So, each device embraces a position of either master or slave, being possible to change it later. The latest Bluetooth versions have a propagation spectrum in an adaptable varying frequency (AFH - Adapt Frequency-hopping) which allows having a coexistence with other technologies from different frequencies of the same band.

The short range and the time a Bluetooth device takes to detect another similar device isn`t fast enough to track an object or people moving.

e- Sensor based on radio transmission: RFID - Identification by Radio Frequency

RFID is an integrated circle that stores and recovers data by electromagnetic transmission compatible with the radio frequency (RF). This technology is reaching improvements on handling and processing of data. A RFID system is composed by some elements. Among them we have RFID readers, tags and the mean of communication among them.

A reader transmits the signal through radio frequency. When it reaches the tags, the signal is reflected by modulation with the added information. However, it`s necessary to into account that the investment on readers is relatively big compared to the tags. They also present a quite limited reading range, varying from 1 to 2 meters. Passive RFID systems usually use four frequency bands.

RFID active tags are small transceivers that can transmit actively their respective identifications (ID) or other additional data answering to transmitted question.

The frequency bands used are similar to the ones used for the passive tags, except the low and high frequencies. The advantage of using an active system is the range, which through the use of antennas can be extended to meters away. The active tags are designed to track objects with a great aggregated value which move in mounting processes at severe environments.

The UHF passive tags transmit through the frequency between 860MHz and 960MHz. They don't need batteries as power source. On the other hand, they have an active transmitter and use backscatter.

f- ZigBee

Zigbee follows the low cost pattern and the low power waste pattern with communication through wireless networks that can increase the signal range through the combination of different topologies. The low cost allows the technology to get its usage spread in wireless monitoring applications. The small request for energy increases the battery life in at least 2 years.

The Zigbee network is composed by three types of different devices, as it's illustrated in picture 10: coordinator (ZC), router (ZR) and final device (ZED). The coordinator composes the base of the network as tree and it's allowed to store information. The routers not only run the application but also are capable to act as intermediary leading the data to other devices. The router is an optional component that can be associated to the coordinator and be part of a multiple points connection (multi-hop routing) and message distribution.

Summing up, the final devices have only the function to establish a communication among themselves and the similar devices, being unable to retransmit data from others devices. Their operating is optimized to operate with a low energy consume, connecting just one coordinator or router each.

The Zigbee networks may be configured among the following topologies: star, bus, tree, mesh and ring. We usually see Zigbee networks configured to operate as mesh, opposing the other topologies, this one offer options to substitute router that eventually may fail. Because of this, in thousandths of a second, new nodes will be recognized and associated to the network. The allying and router`s changing activities is operated by the managers of the network, called access points (APs). The flexibility proposed by this organization manner of the network makes a scalability of up to 65.536 nodes feasible.

The applications encompass usages in the industrial control area, reception of medical data, smoke alert and burglary, automation of buildings and houses, among others.

g- Passive Sensors: GPS - Global Positioning System

The Global Positioning System is an outdoor system of positioning more spread, supplying the geographic localization of mobile devices anywhere in the world. To determine a precise positioning of a device, traditionally technologies based on GPS require a visual contact with the satellites which circle the Earth from a distance about 20000 kilometers. With the help of 24 satellites and a redundant backup, the information is transmitted with great accuracy.

To get this positioning, the local devices receive signals from at least 3 satellites. After that this data is processed locally.

The GPS has a solid operation in open and large areas, but, without the LOS with the satellites, the signals become weak, or even inexistent. The majority of the reflected signals in close environments are significantly smaller than the necessary distance to establish communication.

4.2. Measurements Parameters

It`s intended to evaluate the presented technologies through the conceptual parameters that measure the technological performance of the sensors. The parameters` concepts chosen for this study will be list ahead:

a- Safety and privacy

These parameters are focused exclusively on the user needs related to privacy and control of the collected information. Factors that measure the privacy of the system are related to the control of the access to data that inform the localization history of a selected active and its distribution. Investments in applied software architecture can present effective gains on safety and privacy.

b- Cost

The cost of a positioning system encompasses some variables such as: the cost of the components that will compose the infrastructure, the positioning devices used by each user and the cost of the installation and maintenance of the system.

Some systems need a big and complex infrastructure which requires more investment and time. Other systems reuse the infrastructure that may be already installed, eliminating hardware costs. The calculation of the cost to the user may consider not only the investment in hardware but also the maintenance, which is a big part of the final cost. It`s still necessary to consider the useful life of the battery and its requirement of consumption, which will lead to smaller necessity to change it, decreasing the maintenance cost. A device that is able to calculate its own positioning, may have a bigger investment because of the hardware complexity, but the benefits with the increasing in the useful life and the safety gains while transferring data may compensate the money spent.

c- Accuracy

It`s possible to consider one the most important selection standard. The accuracy makers reference to an average of the distance mistakes and can present a variation on the range that can vary from millimeters to kilometers, depending on the technology used. As long as the accuracy is increased, the positioning system acquires a performance improvement in its operation. This can be the main parameter to use as base for the choice.

d- Precision

The exactness of the positioning system is the ability to reproduce a same result facing different tests. The accuracy indicates an average of the distance mistake and the exactness indicates the probability of success in the approximation made from the average calculated before.

e -Delay

It`s possible to understand by delay, the time that the system takes to calculated the positioning and return the information to the base until the positioning become formalized. The delay in the duration may happen because of two reasons: either the target/device tracked moves very quickly or there are external interferences and the environment present dynamic changes.

f- Scalability

The scalability is defined by the number of objects that the system can locate related to the infrastructure of the devices (network) within a defined period.

g- Complexity

The complexity makers reference to the structure of the components of the hardware, software and the operational factors which encompass the installation of a particular system. An aspect that influences the complexity level is the intervention the user will need to do in order to make the system work. The following factors influence the system complexity: the difficulty level of the system`s interface, the number of configuration the user will need to do and the quantity of hardware that will be installed. These activities will be evaluated during the installation and the maintenance.

Considering the restriction of the CPU capacity and the energy that a battery is able to store, a system that uses less complexity to calculate must be evaluated better.

h- Responsiveness

The responsiveness of a system is indicated by the location rate. The difference of the tracked object`s moving time between two points and time the system take to recognize the new positioning provide the system location rate.

In conditions of use to big areas, it will be required by the system a rescaling encompassing the increase of the covered area`s range. In another words, the sensibility rate of the devices that compose the system must be enough to absorb a quick change in complex scenarios, which is the environment applied to the theme of this dissertation.

i -Robustness and tolerance to absence

Robustness is connected to the capacity of the system to keep operating even if it’s facing some absences such as theft/ failure in some of the network sensors or obstruction of the communication channel.

j- Commercial availability (market)

Among the existing positioning systems, some are available on the market but others are developed through academic researches. Most of the developing companies maintain the essential characteristics to the operation of the system in secret. The already developed systems and tested through researches, expose clearly the project details, which can be an advantage to the implementation of future improvements.

l-Limitations

In spite of having effective evolutions on performance, the positioning systems still have restrictions. Some technologies that can present low cost installation advantages, offer a short range on coverage. Others may initiate interferences if used together with other wireless communication systems. So, these restrictions have to be pondered when choosing the system.

To evaluate the system`s performance it`s necessary to take into consideration which parameters will be necessary to obtain the positioning are offered as base for the applications. Yet, this evaluation must be aggregated to the goal and to the necessity of the tracking answer.

5. METHOD'S PRESENTATION

It`s proposed a construction of a qualitative mesh establishing a correlation between the measurable parameters and the technical characteristics, with applications aiming a situation that encompass the necessities and peculiar demands to an environment with big enterprises, previously classified.

Through the table 2- RTLS selection table, it`s possible to obtain a mapping of the indicators extracted from the realization of a theoretical listing that had as goal, review the main RTLS usages existing in the market nowadays and through academic researches, which somehow presented results and situations arising from field tests.

Table 2: RTLS selection table

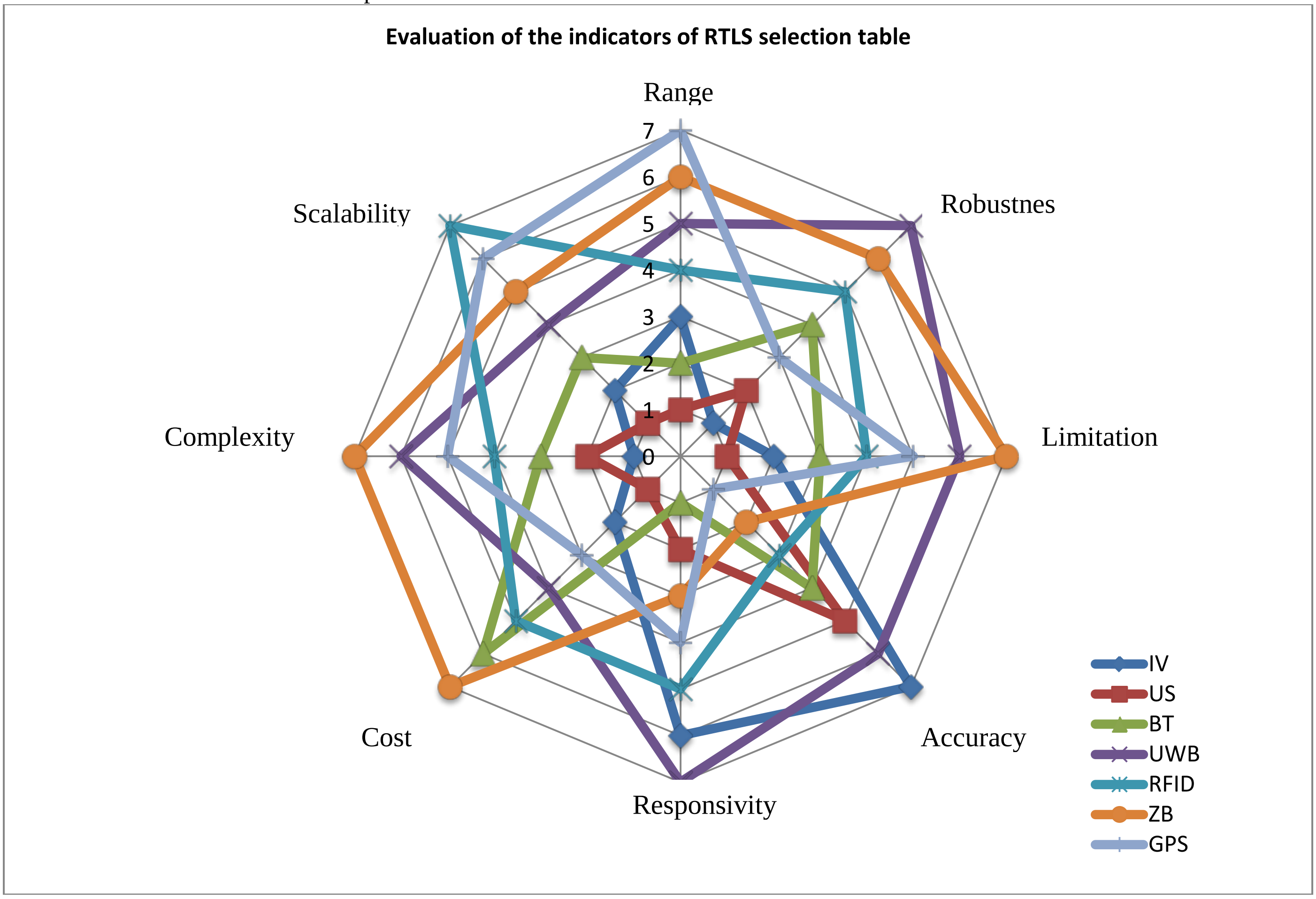
ACTIVE SENSORS E GPS PERFORMANCE PARAMETERS	INFRARED	ULTRASOUND	BLUETOOTH	UWB	RFID	ZIGBEE	GPS
COST	MEDIUM	HIGH	LOW	MEDIUM TO HIGH	LOW TO MEDIUM	LOW	MEDIUM
ACCURACY	10CM	16CM	2M	15CM	2-3m	5M	5M - 50M
PRECISION		95% - 9CM	95% - 2M	50% - 0,3M	50% - 1M		50% - 25M
RANGE	30M		10 to 20M	Better than RFID	up to 30m (active RFID)	10 to 200M	global
LIMITATIONS	Do not penetrate walls or other opaque materials	**Noises / Lights/ Metalic materials/ Irradiation** causes malfunctioning	Long delay during the network update	The systems use the same frequency of the others autorized systems. The usage of UWB is prohibited in some countries.	Presents malfunctioning with metalic and liquid materials. Short reading range. It's necessary the use of portal or hand collectors.	The end device gets low range because their low-battery consume.	**Line of sight** Covered areas provide low GPS signals
ROBUSTNESS AND TOLERANCE TO ABSENCE	Signal gets blocked and performs poorly in the presence of direct sunlight	The systems uses good outlier detection algorithms to filter out many such sources of error.	**AFH**-adaptive frequency hopping Technology once the communication channel lost his signal because of the congestion, the devices start a new channel search.	**Imunidade MULTIPATH** It goes trough walls. Do not suffer interference from another signals of RF.Ultrapassa paredes. Não sofrem interferência de outros sinais de RF.	Utilizes techniques of spectral spreading to obtain a better rejection of the interferent signals originated from other systems acting in the same frequency range	Using a mesh network the system do not stop working if some device stop.	Some Gps models such a RTK, are rugged enough to resist a bad environmental conditions.
SCALABILITY	Scales poorly due to the limited range of IR	not scalable	Each sensor could recognize 200 more devices	Up to 128 devices works at the same network. Transmits signal in differents frequency bands simultaneusly. Increasing the abrangency zone for data transfer	**unlimeted**	Scalability of **65.536 devices.**	Global scale coverage
RESPONSIVIDADE	Update com mais de 60Hz e uma latência de **menos de 10 milisegundos.**	.Determining the positions of and interactions between moving objects requires each to push its location to a central service at regular intervals.	Slow mechanism that provides a short number of samples within an determineted time period.	**Very fast.** Transmission capacity of **100 Mbits/sec. Delay- 50msec** Wide bandwidth.It's capable of transmitting a lot of data simultaneously spending low energy.	The tags can be interrogated by the readers up to 1500 times per second. Delay- **less than 100msec.**	To save energy the device hibernates. The system works better when is at 1% of the function capacity.	To reach their localisation the device gets at least 03 different satellite signals
COMPLEXITY	Incurs significant installation, reconfiguration, and maintenance costs.	The system require excessive manual intervention	The system have to be restarted everytime a new link is created.	Uses pre-existing network infraestructure	Manually configurated tags. It`s necessary a reconfiguration to set a new position.	**Low complexity of configuration Open source.** No need for additional harware and use a free frequency	**High complexity** of configuration

5.1. Evaluation of indicators of RTLS

Selection Table In order to generate a relative comparison between the performance of the sensors. The evaluations between the indications for each parameter were ranked with an evaluating grade between one and seven, that is the total number of valued sensors, in crescent order, being 1 the worst performance. This classification was represented through graphical radar, in order to make possible to see more clearly the performance of the sensors, applied to a situation that was the closest to the environment with severe and extreme conditions. It's generally the case of large ventures.

We can see, in the graphic the evaluation of the indications of the RTLS selection table and following, the description of the logical assessment of 5 of the 8 parameters starting from the last parameter of the first columns of the RLTS selection table following until the first parameter.

Graphic 1 / Radar: Evaluation of the indicators of RTLS selection table



Accuracy: The values on the RTLS selection table indicate a better result obtained by each system. Usually these cases occur under propitious and controllable conditions. Without relation to the other`s performance evaluations, the order from the worst result to the best result is the following: **GPS, Zigbee, RFID, Bluetooth, Ultrasound, UWB and Infrared.**

The systems based on UWB obtain less accuracy as long as they reach a large range. In case of auxiliary applications to GPS, such as the D-GPS which through the obtainment of the difference regarding the positioning based on terrestrial stations can provide accuracy in the positioning of 10cm.

Range: the indicated values in the RTLS selection table are the best obtained by each sensor. The organization of the system`s infrastructure is directly related to this parameter. For example, a RFID system can increase its range by positioning antennas diagonally among themselves. So, the signal transmits further, increasing the communication range value.

If the configuration of a **Zigbee** network doesn`t take as priority the obtainment of a greater energy autonomy, the final device which will be connected to the router or gateway, it will be possible to increase the range up to 200m.

Related to the **Bluetooth**, the better range result is assigned to those from class 1 in maximum energizing conditions. On the other hand, the major quantities found on market devices are the ones from class 2, which have a maximum range of 10 meters. Bluetooth has three classes and 4 versions and in every case, the range depends on the transmitting conditions, enclosure material of the sensor, antenna`s configuration and battery conditions.

The RFID active Tags have an internal battery that last 1 to 3 years and can reach a 30 meters range. The passive tags have a good interaction and transmission quality. However their range is less than 1 meter or up to 10 meters to the semi-passive tags. The passive tags don't operate very well with metals and liquids and the semi-passive ones require a high power from the hand readers.

To make feasible the installation of these systems, the environment's layout must be studied because the positioning of the system's infrastructure can't interfere on the local movement. This parameter is directly connected to the restriction specifications, since the possible interferences must be solved, mainly with the system infrastructure's positioning combinations.

Limitations: Most of the interferences that hit the **Ultrasound** operation are present in the environment. So these system restrictions may be many ones, such as noises, lights, irradiations from other equipment and metals.

Infrared sensors may be uncertain since they present failures on the emitted signals in the presence of sunlight. Considering this restriction, the application of a RTLS based on infra-red becomes unfeasible for outdoor environments.

Bluetooth present a delay in the network update, the positioning information is sent only when it's required by the system and not automatically, spoiling the real time communication.

RFID sensors present interferences against liquids and metals, but some active tags models are already using techniques to neutralize these effects.

In spite of having great long range solutions, the restrictions of a closed environment create a barrier to the **GPS** signals. Yet, this restriction was already solved in conformity with the evaluation regarding robustness and tolerance to absence that will be presented afterwards.

UWB uses the same frequency band as other licensed systems, so, to avoid interference in some countries, its use is prohibited or as an alternative, the short range transmissions are used.

The **Zigbee** restrictions aren't connecting to environment conditions, but to the infrastructure configuration that restrict the range in order to get a better energy autonomy.

Robustness and tolerance to absence: the evaluation about this parameter measure the technical capacity the system has to solve the difficulties and keep running.

The **infrared** doesn't have any specific technique. The replication of the infrastructure's components is enough to solve the interferences. In this case, the chances of being incompatible with the environment increase because physically, the system will take more space. To keep operating against the many types of interferences that hit the **Ultrasound** operation, the system applies sophisticated algorithms, which make the investment more expensive. GPS applications to outdoor environments are well solid and resistant to interferences, but indoor environments with walls and ceilings weaken the signal reception from the satellites. To solve this situation there's a technique known as A-GPS (Assisted-GPS) that uses additional links with radio communication to generate more information about the local positioning.

Through the AFH technology, the **Bluetooth** increases its acting field because of the compatibility with a lot of channels. It does it until find a free band.

The make possible working with other devices solving the possible interferences, the **RFID** uses the spectral mirroring technique.

If there's a malfunction in one of the **Zigbee** sensors, the mesh topology allows the others sensors to keep operating.

UWB has the multipath immunity, generating more resistance to interferences and a greater capacity to penetrate opaque materials.

Scalability: Systems based on **Ultrasound** are considered not scalable, in other words, they focus all the positioning information in one component with the purpose to locate all the others. So, in this evaluation they have the worst result. Followed by **Infrared** sensors, which have a configuration quite similar to Ultrasound. They present a small scalability rate because the limited range and specially for presenting a lot of failures facing physical barriers.

The next on the list is the **Bluetooth**. Its network is composed by 7 active slave devices and p to 200 inactive devices when the network is in parked mode. As a conclusion, within the range that Bluetooth accepts, each sensor is capable to detect other 200 devices.

The **UWB** acts in varied simultaneous bands and allows many devices to stay interconnected through a network. Followed by: **Zigbee** with an expansion capacity up to 65536 devices, **GPS** with a global scale and finally, **RFID** which doesn't have a limited number of tags per network.

Therefore, for large environments, RFID should be the most indicated because of the expansion capacity.

Complexity: infra-red needs to have a constant maintenance. The access points of the system based on Ultrasound will need to be configured manually every time when the positioning changes.

Every time a new **Bluetooth** communication link is created, the device must be rebooted.

On the same complexity level of the previous ones, but with simpler configuration steps, all RFID tags belonging to the system must be reprogramed if there's a positioning change. These four cases require time and investment in training the team.

The process of localization detection of a **GPS** device goes through detection of satellite signals, reading, acquisition of data and then processing an outcome occurs.

UWB uses existing infrastructure that are already installed for other purposes.

Zigbee has a low complexity with procedures of simple configurations without the need of network, hardware already add to the deployed network, besides the use of the frequency band without the need of a license and an open protocol.

6. METHOD'S APPLICATION: SELECTION TABLE RTLS + GRAPHIC 2/RADAR

Evaluating the presentation of 2/Radar graphic, we can notice by analyzing the ranking the following relationship: the more externally positioning technology, the better will be its performance.

Thus, the search to identify the most appropriate technology can be associated with the analysis of the graphic. However, it is worth noting that not always the best performance of the technology can be considered the most suitable for the occasion of the system application.

Nevertheless, the table lookup is essential to obtain the indication of the technology part, because the indicators show the physical and real and individual capability of the components that make up the tracking systems.

Therefore, together with the analysis of the table, the method consists in using the chart to have a view of the performance rating, since the guidelines for implementing the system are well defined the user can visually notice the comparative relationship between technologies.

6.1. Prioritization of indices for evaluating performance according to the nature of the assets and the environment.

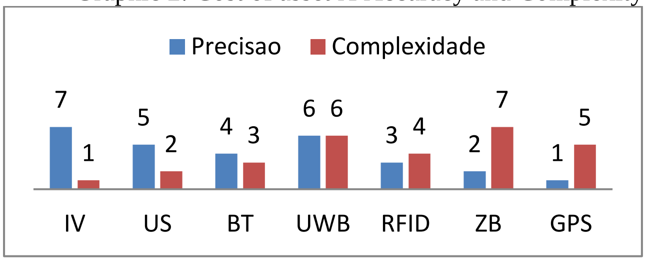
Regarding the priority of the user's projects necessities, the characteristics of assets are directly related, such as equipment, cost and the environment, as the flow of assets and delimitation, being outdoor or indoor.

The graphics from 2 to 4 are going to be presented with an indication of some of the possible direct relationships between variables relating to the assets and the environment, as previously noted, with the definition of the requirements of evaluation that directly influence the performance of the RTLS's for such situations.

The sensors discussed are listed in the left column for each metric parameter, the sensors receive a review ranging from 1 to 7, 1 being the worst performer and 7 the best performance in a given situation generally. The main point for the evaluation of sensors is based on qualitative indications in determined in the RTLS Selection table.

a- **The cost of the asset X - accuracy and complexity**

Graphic 2: Cost of asset X Accuracy and Complexity

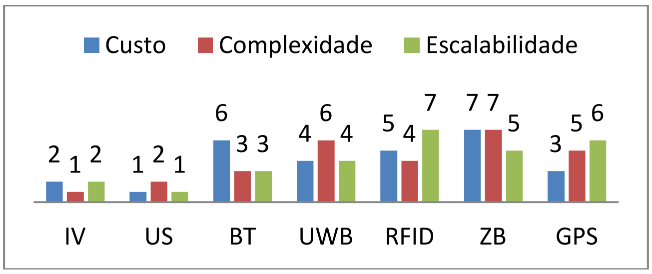


Greater complexity, higher cost of deployment of the system. If the cost of the asset is high and representative within the project budget, the investment justifies the purpose: have greater control and monitor more assertively such assets. If they get lost, misrouted or break, that mean a considerable loss. Likewise the high cost of the asset may require a more refined screening accuracy, and is also justified as in the previous case. We understand the high cost, not only as the investment in kind which involves the assets, but also the added value that can be their indispensability to the functioning of the project activities of the enterprise.

P.s: Because the range does not affect this case - the cost of the tool will not determine that it is necessarily tracked in extensive areas. When it comes to large enterprises the largest range can be definitive for different situations

b-Number of Asset X Cost, Complexity and Scalability

Graphic 3: Number of Asset X Cost, Complexity and Scalability



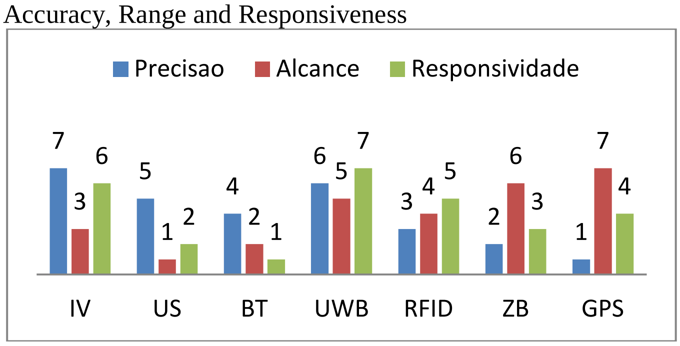
The amount of the asset directly influences the final cost of RTLS deployment, it is considered basically the amount of tags / devices that comprise the solution will increase.

Some systems have the complexity directly proportional to the level of difficulty of setting up the infrastructure solution. Certain settings point to point are operated manually. Either devices, or the network, or the access points and stations may require constant maintenance and reconfigurations. Thus the system comprehends a larger number of components; the demand for labor may be increased.

Finally, the ability of scalability that is the definition of the number of objects that the system can find is an important direct factor.

c- Default flow in the environment X Accuracy, Range and Responsiveness

Graphic 4: Default Flow in the environment X Accuracy, Range and Responsiveness



The default flow of people, materials and machines defines the layout that the system will be able to install its structure. In this way the range is directed to the space within the system's range in order to collect all the necessary movement routine. The accuracy will define if the actives are or not in specific places such as rooms and aisles. In case this is a relevant requirement, the accuracy will need to have good results. The responsiveness determines the tracking capacity in real-time. If the question about the positioning identification of the active is immediate, the systems which have low responsiveness rate will be eliminated from the selection.

7- CONCLUSION

At the moment that is decided to use the automatization of the data the control of the processes by the entrepreneur, the conception of the system's project begins. Many times, occur that the RTLS consultants required to suggest the most adequate system are representatives from certain technologies. So the solution is guided to the commercial interests and not to the best application through adequacy and implementation studies. To minimize the consequences of these situations and to help future improvements on research and development, it's suggested to use the RTLS selection table presented in this study.

The intention of elaborating the RTLS selection table was the gathering of the main indicators that could qualify each sensor according to the performance evaluation parameters that influence more in the final choice. Obtaining with this, a mesh that serves as base to the analysis of the feasibility and the restrictions applying the RTLS technology in big enterprises.

Moreover, the order by grade defines the positioning technology in the ranking. However, it's possible to see that the grades are too much absolute many times, regarding numerous application variables. The regular gaps for ordering, in other words, grades from 01 to 07 with uniform spacing in some situations don't measure the real performance difference among the technologies.

These particularities of the classification intensity must be compensated with the table indicators though. In other words, each item described in the table was filled with technical characteristics inherent to the technologies, with its restrictions and advantages against the physical restrictions of the devices the system may use, independently of the conjecture about the application.

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