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A COMPARATIVE ANALYSIS OF INDOOR POSITIONING TECHNOLOGIES IN SHIPYARD DIGITALIZATION CONTEXT

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Abstract: *Purpose*: In the last few decades, there has been an increasing growth in research into the use of positioning technologies in open environments. Most of the technologies developed for outdoor environments are used successfully, however, they cannot be considered as fully successful indoors. In this context, various technologies based on Radio Frequency, Infrared, Ultrasound, Magnetic, Optical, and computer vision are proposed to improve positioning indoors. In addition to their individual use, it is also seen in hybrid applications. In particular, Radio Frequency based technologies have potential use in shipyard environments. For this purpose, technologies such as Bluetooth, Ultra broadband, Wireless Sensor Network, Wireless Local Area Network, Radio Frequency Recognition and Near Field Communication are seen as suitable technology options for shipyards. The indoor positioning system is a technology that has the potential to significantly improve work efficiency and safety in the shipyard area. It is difficult to achieve a successful digital transformation of the complex shipyard environment without identifying an Indoor positioning technology for the shipyard. In this study, it is aimed to design a positioning technology that will be most appropriate for the shipyard. *Methodology*: This paper analyses the challenges for the selection of Indoor positioning system for shipyards in evaluating Indoor-positioning technologies. The methodology followed in this study is a comprehensive comparative analysis of existing IPS technologies on how to digitize shipyards. This article provides an advanced assessment of indoor positioning technologies and their use in the challenging shipyard site. In this context, it provides an evaluation framework for different positioning measures such as accuracy, coverage, scalability, cost, privacy and usability of technologies that can be used within the scope of IPS. *Results*: The work carried out here on indoor positioning systems and components makes a significant contribution to the shipyard industry. Because it has a great impact on the suitability of technologies, especially in relation to the shipyard environment. Both the evaluation model and solution method, and the Bluetooth-based positioning technology, which stands out at the end of the evaluation, are important contributions of the study. *Conclusion*: To determine which indoor positioning systems are more suitable for the shipyard environment, both a detailed analysis of the shipyard environment and an evaluation were made to select the most suitable technology. The comparison was made based on observations of the shipyard site and the available literature on the field. This article makes important contributions to future shipyards' application of positioning technologies.

Key words: Indoor positioning systems, Indoor positioning technologies, Shipyard, IoT, wireless technologies,

1. INTRODUCTION

The shipyard sector, like other sectors, wants to benefit from the developments by implementing Industry 4.0 principles and is struggle to realize digitalization [1]. The positioning of objects in shipyards is the first step of this process and forms the basis of its digitization. This is achieved by positioning systems (PS). Positioning is defined as the determination of the position of objects or people in a closed area using radio waves, magnetic fields, acoustic signals and sensor data collected by mobile devices [2].

The most popular among location-based services is the Global Positioning System (GPS) [3]. The GPS for locating and tracking the position of an object indoors is hardly recommended for indoor use, since the signals transmitted from a satellite to a device indoors are weakened due to obstacles indoors. The GPS cannot provide location information with the same accuracy in closed areas due to the negative effects of blockers and insufficient signal level in closed areas, so in open areas, IPS are indispensable technologies due to their high accuracy and low cost. Indoor positioning systems (IPS) can be considered as a special version of GPS for indoor areas [4].

IPS offers great convenience in locating and tracking living and non- living objects in indoor areas. Therefore, the IPS have become a new research focus in technology. In recent years, various technologies have been proposed for positioning indoors [5]. The IPS is considered a useful system in indoor environments such as large buildings, shipyard, construction sites, campuses, hospitals, schools, shopping malls, and helps to give the most accurate results in other large complex closed structures.

The IPS are used to find and track the location of a particular object. In today's world, where the PS are becoming more and more widespread, different solutions are being discussed. The IPSs can be designed in different ways. Positioning can be done by receiving the signal information sent by the objects, whose location is desired, by the fixed nodes whose location is known beforehand, and by performing the necessary calculations by these devices, or by receiving the signals from the fixed node points whose location is known beforehand, by the object whose location is desired to be determined.

In order to determine the positions of the objects in the closed area, it is necessary to obtain the signals from the fixed and mobile devices in the area to be positioned. For this, signal measurement techniques are used. Among the signal measurement techniques used in the IPS, arrival time, arrival time difference, arrival angle, round-trip time, received signal strength indicator (RSSI) are the commonly used signal measurement techniques. It is necessary to design an ideal system that can meet the requirements according to the closed area where the positioning will be made, the expected sensitivity, and the cost criteria.

According to the technique to be positioned, the fixed device whose location is known beforehand or the object whose location is desired can perform the necessary calculations, or the central device can also perform the positioning calculations by sending the received signal properties to a central device.

The RSSI technique is a signal measurement technique that is often used to detect the positions of objects in the IPS. The RSSI value, which is a standard feature in many technologies such as Bluetooth and Wi-Fi, can be obtained without the need for external hardware. For this reason, PSs based on RSSI measurement technique are preferred more than other signal measurement techniques because they provide convenience in terms of time and cost. The fingerprint method, on the other hand, consists of two parts, the training and the positioning. During the training, a reference signal intensity map is created that characterizes the indoor area [6]. At this stage, measurements are taken from fixed devices placed at reference points at certain intervals in the form of a grid inside the closed area, and these measurements are recorded on a server and the training phase is completed. These processes are called field analysis. During the positioning phase, the signal intensities of the device to be located and the devices placed at the reference points are measured, and these measurements are determined by determining which point is closest to the signal strength map recorded on the server during the field analysis phase. In PSs performed with the fingerprint method, which makes positioning independent of angle and distance, the number of signals obtained during the training phase, which is the characteristic of the indoor area, and the increase in the number of transmitters emitting signals can increase the positioning accuracy [7]. Machine learning methods such as artificial neural networks, N-nearest neighbor, and random forest are used to increase the accuracy of location estimation when analyzing the measured signals with the signals on the map created during the training phase. Since RSSI values can be obtained easily from Wi-Fi and Bluetooth devices, fingerprint method is the most commonly used method in the IPS [8].

More and more devices are joining the IoT world. More importantly, IoT devices are improving manufacturing processes, from quality control to production floor monitoring. Providing these IoT devices will make businesses life easier, but first you have to understand how it all works. The first step is to understand the many wireless technologies around IoT connectivity, such as LoRa, Wi-Fi, ZigBee, Bluetooth, and 5G. This study comparatively explains each wireless technology in detail to help you understand them better.

The following sections in the article are arranged as follows: first, characteristics of shipyard and challenges for IPS were determined. Then, comprehensive information was given about the IPS for the area and presented a framework for performance meter for IPS. Finally, a comparison of discussed systems was made and the results obtained were discussed.

2. CHARACTERISTICS OF SHIPYARD AND CHALLENGES

This section discusses the general characteristics of shipyard environments and outlines the challenges IPS will face in shipyards. Shipyards are complex and dynamic environments, vast areas where a wide variety of ships are built as well as repairs. The ships themselves are gigantic products, and the interior is very complex, resembles a multi-storey enclosed building, and consists of metal walls [9].

Considering the IPS related challenges, shipyards are covered with a multitude of obstacles and blockers. These barriers are dynamic barriers that change over time and constantly generate interference for signals. Large metal blocks, oversized cranes, heavy tonnage equipment and machinery, and large numbers of people working in motion are objects in shipyard environments [10]. All these assets in the shipyard environment are not only obstacles, but also their positions must be constantly monitored. In these conditions, choosing an IPS that is resistant to these challenges is a difficult process. Shipbuilding is an environment where closed areas are dense as well as open areas. For this reason, it is among the places where GPS fail or cannot provide sufficiently precise data.

The shipyards are also production environments where there are liquids, metal-weighted, acid and salt-intensive environment, corrosive substances, many obstacles, high temperature values, toxic gases are

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intense, and mobility is high. Determining the most suitable indoor positioning technologies (IPT) that is resistant to these constraints significantly affects the success of the digitization performance of the shipyards. IP systems are needed to obtain functional information about the positions and movements of people, welding machines and other moving and stationary resources in the shipyards [11]. The IPS system has the potential significantly to improve work efficiency and safety in the shipyard area. Successful digital transformation of the complex shipyard environment cannot be achieved without selecting an IP technology that is best suited to the shipyard environment. This article analyses potential difficulties in determining the most suitable IP technology in shipyards and makes a comparative evaluation of IP technologies [12].

Some of the currently available technologies, such as camera systems, audio and light technologies, are ignored because they do not adequately meet any of the challenges of shipyard requirements, that is, they are not suitable for shipyards [13]. Since the remaining technologies meet the technical requirements of the shipyards at different rates, that is, some of them are good in terms of some criteria, some of them are insufficient in terms of other criteria, therefore, the advantages and disadvantages of these technologies should be analyzed comparatively.

3. INDOOR POSITIONING SYSTEMS

This section introduces the IPS, which will significantly increase shipyards' efficiency, productivity and safety. So far, researchers have proposed IPS that work and perform well, appropriate for different industries in different fields. IPS is covered extensively in the literature and is well defined and classified. Comprehensive assessments have been made in literature [13 - 15]. In addition, it is a fact that comprehensive evaluations about which technologies are resistant to difficulties and suitable for shipyards are not made at a sufficient level and studies in this area are still lacking.

The IPS are made of the technologies, the techniques and the methods. The basic components that make up the IPS are shown in Figure 1. The techniques applied in IPS primarily depend on the technology used. Methods for the IP are algorithms used to calculate the position of a target object. They depend on the technology and techniques used.

Based on the technological perspective IPSs are divided into RF signals or not. A basic classification for SPSs is (1) radio frequency (RF) based, (2) light-based, (3) audio-visual and non-audible, (4) Inertial sensor based systems, and (5) computer vision systems [16]. Recently, hybrid technologies have been developed in which these technologies are used together. Thus, by combining the strengths of technologies, systems that are resistant to difficulties are developed.

Indoor Positioning Technologies
- Infrared
- Computer Vision
- Audible Sound
- Ultrasound
- Radio Frequency

Indoor Positioning Techniques
- Triangulation
- Fingerprinting
- Proximity
- Vision Analysis
- Scene Analysis

Indoor Positioning Methods
- Triangulation-based
- Scene Analysis-based
- Proximity-based
- Geometric-based,
- Fingerprint-based

Figure 1 Indoor positioning systems

IPS can be classified into 4 groups according to their size, namely the geographical area they cover: i) WPAN (Wireless Personal Area Network). IR can be given as an example. ii) WLAN (Wireless Local Area Network). It allows users to access the internet wirelessly. Wi-Fi is an example. iii) WMAN (Wireless metropolitan area networks). It provides the connection of multiple networks with each other. For example, inter-building wireless networks. WiMAX can be given as an example, iv) WWAN (Wireless Wide Area Network). It is used in very large areas. They use satellites. 5G, GSM connections are examples of WWAN (Figure 2).

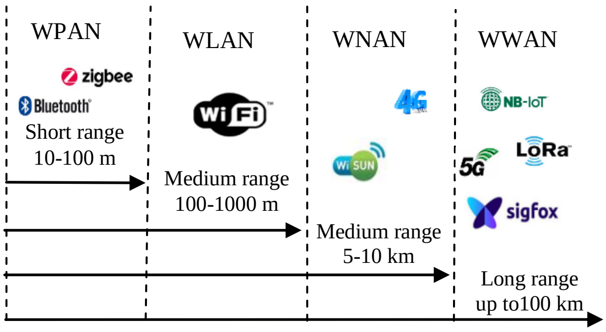

Figure 2 Classification of the IPT

3.1 *Radio Frequency Based Systems*

RF-based PSs usually consist of receivers and transmitters that communicate with each other via radio signals. These are named as receiver, transmitter and RF radio signal. Wireless network technology is a communication method in which electromagnetic waves emitted from the air are transmitted from one point to another in a certain frequency channel without a physical connection. The receiver receives radio waves flawlessly as they energize a distant receiver. The system was first developed under the name RADAR [17]. The goal of these researchers was to track and locate people in indoor areas through radio signal strength data collected from pre-placed transmitters at different points. Many studies have been carried out to produce a reliable and highly accurate IPS. Despite the popularity of GPS in

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detecting people's positions in open areas, this technology cannot be used indoors because satellite signal waves cannot pass through walls and thus the connection between satellite and receiver is interrupted [18]. Since radio waves have the ability to pass through obstacles such as walls, floors, and the human body, RF-based technologies are extremely suitable for use in IPS with wide coverage areas.

3.2 Systems Based on Infrared

An infrared (IR) signal is an electromagnetic signal that is longer than the wavelength of visible light but shorter than the wavelength of the radio wave. Infrared is just below the visible spectrum of light in frequency and is strongly emitted by hot bodies. Many objects such as humans, vehicle engines, airplanes, etc. generate and retain heat and are thus particularly visible in the infrared wavelength of light compared to background objects. Infrared cannot pass through walls and obstacles. Those detected by heat detectors are those with the longest wavelengths. Approximately, wavelengths are between 0.8 microns and 1000 microns. Therefore, it has a very limited area in closed environments. Indoor lighting interferes with this type of signal and creates a problem in correct detection. Compared to ultrasonic devices, infrared devices are generally smaller. Today, infrared is used to provide communication between the remote control of electronic devices such as televisions and videos and the device. These infrared receivers and transmitters operate with a frequency between 36-40 KHz. Transmission is unidirectional since there is only one transceiver pair. It can be used in single-storey closed areas where there is no obstacle between the infrared transceiver. Infrared provides communication between two points that see each other via ultra-low frequency infrared light waves. It is used for short distances not exceeding a few meters. It is used for data communication in portable computers devices such as mouse and printer in personal computers. Because these devices communicate with infrared rays, a direct line of sight must exist between the two devices.

3.3 Sound-Based Systems

Ultrasound is sound waves that propagate at a frequency too high for the human ear to hear. Ultrasound-based systems provide much more efficient information than BLE or Wi-Fi technology in buildings with many rooms, such as hotels and hospitals, and require less infrastructure. The Time of Arrival algorithm is used as the calculation algorithm in ultrasound systems. However, since the power of ultrasonic sound waves is not enough to pass through walls, each indoor room must have its own system. Although ultrasound operates in the low frequency bands, it has good sensitivity for position detection at the slow propagation speed of sound compared to the other signal technologies. A medium is required for sound to be transmitted. The propagation of sound is the transport of energy from one place to another. The speed of propagation of sound waves depends on the density of the medium. The advantages of ultrasonic devices are their simplicity and low cost. Ultrasound cannot pass through walls, but it is reflected from many interior barriers. It has a short range of 3 to 10 m, with a distance; measure resolution of 1cm. Operating temperature affects the performance of ultrasound.

3.4 Visible light communication

Light-emitting diode (LED) technology has developed rapidly in recent years. Thanks to this technology, illumination was provided in an economical and efficient way, and at the same time, visible light communication at high speeds was also enabled. Visible light communication (VLC) has several advantages over conventional RF communication in many ways. Some of those; VLC systems can be used in many RF sensitive environments such as power plants, mines, hospitals. At the same time, since VLC use existing lighting systems used indoors, they can be adapted to existing systems with little expense and little modification. Until now, many solution approaches have been proposed for positioning in VLC-based systems. In these systems, LED light sources act as emitters, while photodiode and image sensor act as receiver. Positioning algorithms used for VLC-based the IPS; proximity algorithm, fingerprint algorithm, triangulation algorithm, vision analysis and hybrid algorithms. The fingerprint method needs a database where the received signal strength (RSS) information is kept. RSS information of a channel is pre-recorded under various conditions such as low light, high light environment, etc. and then this information is used during location determination.

3.5 Computer Vision-Based Systems

Vision-based systems use omnidirectional cameras, 3D cameras or built-in smartphone cameras to obtain information about internal environments. Cameras are actively used in structural systems; they detect and monitor the location of people in closed environments. There are various approaches to the use of image detection devices for example, video cameras used for security purposes in buildings. Image detection based position detection systems are divided into two categories considering different working principles. In the first category, the target user whose location will be detected carries a mobile image detection device, while the working principle of the second category is based on a fixed camera detecting the moving users by analyzing the images obtained. The high cost of an advanced image processing system and the need for comprehensive hardware in this direction is stated as the main disadvantage of these systems. The fact that installation, testing, and system performance verification is a difficult and time-consuming process, and privacy concerns arising from the continuous monitoring of living and

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working areas are also listed as other constraints on the spread of image detection-based systems.

A general view of the technologies evaluated within the scope of this study can be seen collectively in Figure 3. In the following section, only RF-based technologies are introduced, as non-RF-based technologies are not suitable for shipyard environments or cannot meet the desired performance. Infrared technology is not suitable for the shipyard, as the rays cannot pass through the walls, as any solid object blocking the lights blocks the Infrared connection. Likewise, since ultrasonic waves cannot pass through obstacles such as walls, they are not suitable technologies for shipyards. The other non-RF technologies are not considered suitable for similar reasons.

4. RF - BASED TECHNOLOGIES

RF-based technologies are the most widely used in IPS. Heavy and oversized metal blocks are located inside the ships under construction at the shipyard and in other enclosed shipyard environments, and they can significantly weaken the signals. This can significantly adversely affect the coverage of some types of signals, for example, red light, ultrasound and infrared [19]. Despite the significant contributions made by many researchers to IPS technologies over the years, gray areas still exist that need to be addressed as the technology matures.

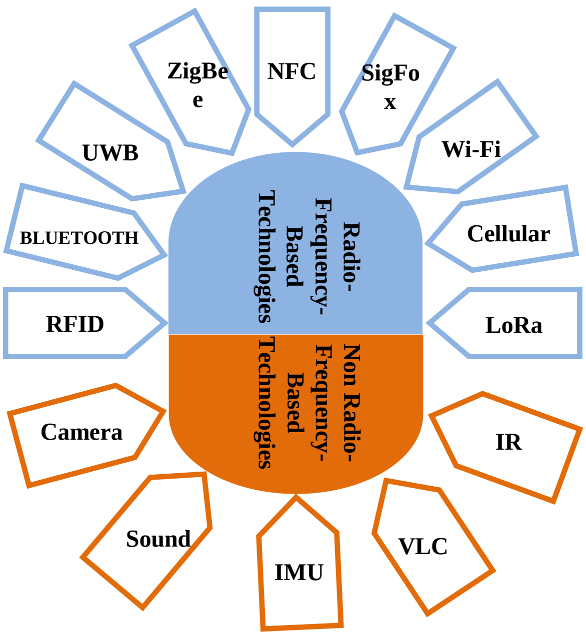

Figure 3 A classification scheme of IPT

In today's world, the IPS have been widely adopted in many parts of the world. Because IoT is diverse and versatile, there is no one-size-fits-all networking solution. Each communication solution best serves a particular area. There is wireless technology out there now, and as technology advances and people's needs change, there are possibilities for more in the future. It is common for most people to use these terms interchangeably, although they are quite different. It all comes down to the layer of the telecom device with which the network interacts. Descriptions of the most commonly used IPTs are described below. A comparative graph in terms of data rate, power consumption and range is shown in Figure 4.

4.1 WLAN (Wi-Fi)

Wi-Fi (Wireless Fidelity) is the common name of the IEEE 802.11 standard. Wi-Fi has ability to expand easily as their coverage can be increased by adding new access points. The very popular and widely used Wi-Fi has been applied in various places such as campuses, buildings, hospitals, museums and so on. At the same time, Wi-Fi has been integrated with all types of electronic devices such as mobile phones, laptops, tablets and televisions. It has a reading range of 100-150 Meters.

Wi-Fi - based systems also have some disadvantages. Negative effect of changing equipment layout on radio signal values, high initial setup cost for structures without the necessary infrastructure, high variability of Wi-Fi signal strengths over time, and the possibility of interference of radio signals with signals from other devices are the main issues against Wi-Fi based systems.

4.2 RFID Based Indoor Positioning Systems

RFID is a general term used to describe systems used to wirelessly transmit object or person identification information via radio waves. The system generally consists of two main components. The IPS infrastructure is created by forming the system components as the tag, which is considered as a transmitter connected to this tracked target, and the receiver, which receives the transmitted radio wave signal and performs the positioning process. There are two types of labels; Inexpensive, small and short-range passive and expensive, active tag with higher coverage and working as a transceiver. The disadvantages of the RFID-based IPS are that it is not easy to integrate with other systems and has a small coverage area. It has a reading area of 3 meters.

4.3 Ultra Wide Band Indoor Positioning System

Ultra Wide Band (UWB) is a wireless technology that transmits large amounts of data with a wide range of low power and short-range frequency bands as it has a bandwidth of more than 500 MHz. It makes it possible to filter the reflected signal from the original, thus guaranteeing a high precision system. The advantages of the UWB system are that it effectively penetrates walls and passes through obstacles, is isolated from any existing RF signals and does not cause any interference. Finally, UWB is a very high precision system. The disadvantage of this system is that it is a costly system

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and liquid and metallic materials cause interference. This interference situation prevents the system from operating with correct sensitivity. Its effective range is limited to 100 meters. Ultra-wideband technology is based on the principle of exchanging data with very short radio signals. An UWB-based PS consists of unique tags to be carried by the targets to be located, fixed radio signal receivers and a positioning management platform. UWB-based systems have high precision positioning capability with low energy consumption without the need for a clear line of sight. Since radio signals emitted from UWB tags use a wider radio spectrum than signals emitted from other RF-based devices, they are not affected by surrounding signals and are resistant to multipathing in signal propagation. In addition, the wide bandwidth of UWB technology enables high resolution in position detection and tracking, both in terms of position and time. Although UWB-based PSs allow higher sensitivity and accuracy than all other systems in position determination, its use has not become widespread due to the need for a comprehensive signal receiver-signal transmitter infrastructure and being a very costly technology.

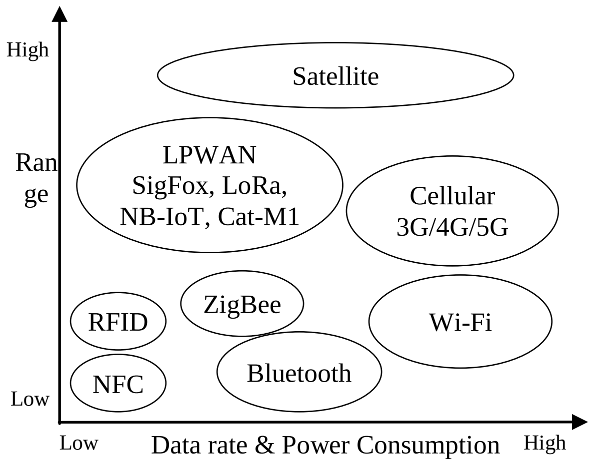

Figure 4 Characteristics of the technologies

4.4. Bluetooth Based Indoor Positioning Systems

Bluetooth is a common technology embedded in various devices such as mobile phones, laptops, and so on. The total gross bitrate of Bluetooth is lower compared to Wi-Fi and it is disadvantageous in distance compared to effective Wi-Fi up to about 30 meters. In addition, Bluetooth is a low-cost device and low-power equipment. The latest emerging technology to use Bluetooth for the IP is Apple's iBeacon device. Apple introduces BLE technology to iBeacon technology to provide location-based information and services to all iPhone smartphones and iOS devices. BLE ensures months of use of batteries due to low power consumption. IBeacon sends a universally unique identifier received by an operating system or an application. The received identifier is used to indicate the location of the device.

4.5 ZigBee Based Indoor Positioning System

ZigBee is the name given to the standard consisting of a number of communication protocols that provide wireless short distance and low speed data communication. The ZigBee has some similarities with Wi-Fi and is easily affected by the environment, which is an IEEE 802.15.4 standard. ZigBee equipment is capable of working for years without the need for battery replacement. One of the most important features of the ZigBee standard is the mesh network capability. In a large mesh network, the message is transmitted from one device to another until it reaches a remote destination. Similarly, when honeybees dispersed over a wide area want to convey a message to the hive, they convey their message with a similar approach. The bee that wants to convey a message creates a dance figure by moving in a zigzag pattern, and other bees close to the hive repeat this figure until it reaches the hive. Since the communication of the devices in the network with each other is similar to the communication of bees, the technology in question has been defined as ZigBee. ZigBee system consists of three different devices. These devices are coordinator, router and endpoint device.

4.6 Near Field Communication (NFC) is a Radio

Frequency Identification based technology that enables two electronic devices to communicate in short distance, high frequency and low bandwidth. Near Field Communication (NFC), which also supports existing RFID technologies, is preferred in applications where security is at the forefront. NFC enables contactless data exchange between two devices at a distance of up to 10 centimeters. NFC technology is very similar to RFID, which is still being used successfully, but it also brings brand new features. It is also compatible with contactless technologies such as Bluetooth, Wi-Fi and RFID. FC communication operates at 13.56 MHz frequency, which does not require a license all over the world. The maximum data transfer rate of NFC is 424 Kbit/s. This is quite slow compared to Bluetooth's 2.1MBit/s. The data communication distance of NFC is also below 20 cm. This distance is below the range of Bluetooth. However, the short distance increases the safety. NFC devices consume less energy than Bluetooth devices.

4.7 Cellular Networks

Cellular networks refers to a long-range wireless network distributed over the cells where each cell is served by at least one fixedly located transceiver known as a base station. It is the equivalent of a wireless

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network created with radio cells. It works with higher capacity and lower energy requirement than normal networks. It requires more base stations for positioning to give good results. There are studies with cellular networks that give accurate results up to 2.5m.

2G/3G/4G: Although it is true that in some countries the 3G network is already being dismantled, it is already going to 4G but with an eye on 5G, the one that will best resist is 2G because today there are many devices that use this network deployed around the world. It has the advantage of almost global coverage, but against it is that the consumption of communications is much higher and therefore the duration of the batteries. 5G will be the standard that will be valid for everything. Of course, 5G is going to be a revolution in terms of data speed, latency, number of connected devices, etc. Thanks to it, real time will not be limited to sending sensor measurements, but rather, at the image sending level, the impact will be more than notable.

NB-loT is a cellular, licensed band and transmission range of less than 10 km, which is a radio technology standard developed by 3GPP. NB-loT is used for waste management, utilities and transportation. By installing these sensors, the fill level of the container can be centrally monitored. In one study, it showed great benefits in cost reduction, environmental impact and collection efficiency.

LTE-M is a cellular technology, which has super low latency and can support voice. This network technology is extremely energy efficient and also has non-static applications and voice support. It has been applied in many life-saving medical applications. If the device is used, perhaps on a public beach or swimming pool, a message is automatically sent to the paramedics. LTE-M has also been used in mobile telemetry systems that require high reliability, such as voice-controlled emergency wristwatches that must be able to transmit small data volumes. When the user says a trigger word, the device sends an alert message.

Devices that require batteries, at least for now, will continue to use other communication networks that minimize their replacement. The implementation of 5G in these types of devices will be closely linked to their improvement. Currently, different technologies are being worked on to improve batteries, recharging or the use of communications, but in the short term the typical IoT communication networks will remain. Another different thing is the case of devices that do not use batteries and that are connected to the network, there it will be much easier for them to be updated with communication modules that support 5G and that they can enjoy its advantages.

4.8 LoRa

LoRa allows sending small data packets and lets the creation of private networks. Its low consumption means that its maintenance is minimal due to the long life of the battery. At an industrial level and in projects in the water sector, it is having great relevance. Paredes et al. conducted tests in Italy to measure the performance of LoRa, including three different scenarios. In the first two scenarios, the point-to-point communication method consisting of receivers and transmitters was used, and in the last scenario, a star network topology consisting of a receiver and more than one transmitter was used [20].

4.9 SigFox

SigFox is suitable for a variety of applications. Large construction sites with many moving parts and many workers may have several cranes on site, each of which must be operated by lift attendants. With the optional service system, there is no attendant in each elevator; one person operates more than one elevator. The button solution serves to call the elevator attendant/driver to the respective elevator. While it may seem simple enough, it can deliver huge efficiency gains in large infrastructure and building projects. Its main characteristic is that it sends small data packets and at most six times per hour. It may seem scarce, but the reality is that it may be more than enough in some scenarios, such as weather stations in the agricultural sector. These small shipments of information also make your consumption minimal, so your battery can last for years.

5. PERFORMANCE METRICS FOR IPS

First, when choosing technology, you should consider the structure of the region, the local ecosystem, the efficiency you need etc. You need to make your choice by determining your future goals. If you are going to carry out a monitoring project, you need to analyze the current situations with users and project managers. Factors such as the current state of technology, possible conditions, device location, and battery level are critical. It will then be necessary to define different technology information with a dashboard to verify this information. Accordingly, you can expand your network knowledge, include new application criteria and increase your viewing range. In order to create a successful PS, some references must be calculated and well defined in terms of cost, accuracy and precision, scalability, coverage and limitations. References such as different dimensions, money, time, space will affect the system. Since the IPS works in real-time environments, it must perform with high precision. At the same time, it has the ability to notify the desired number of places by entering more than one command. The locations of more than one person can be determined in the same time period and the desired results can be obtained at the same time.

The following metrics can be evaluated as performance criteria in the IPS [21] [22]:

Accuracy: Different systems provide different accuracies. Accuracy is assessed by how accurately location information is given in terms of the IPT. Accuracy is one of the most important criteria in PSs, shows the performance of the system according to the closest points calculated to reach the target object. As the

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margin of error between the values obtained from the system and the actual position values decreases, the accuracy of the system increases. Most IPS solutions provide poor accuracy under some adverse conditions. So far, only visible light and magnetic systems have been tested to show a high level of accuracy. In general, the accuracy of a technology determines its reliability.

Precision: It refers to the speed at which the instant location is updated for the tracked individual in motion. If the location for the tracked individual can be updated simultaneously, the system has been successful. It is used to measure how accurately the precision system works and the consistency between the results obtained from the PS. It can also be defined as the standard deviation in the IP errors and is defined in percent (%) format.

Coverage Area: In the IPS, the larger the area that the system can reach, the more efficient the system is. Coverage is another factor that must be considered before the selection of IPT. The coverage area defined the area covered for the correct indoor localization. Diverse IPT has not the same characteristics for coverage. Consequently, short-range technology may need more devices that will cover the same area.

Scalability: Scalability: It means that the system has a wider coverage area and performs well when applied to other areas easily. It is a desired feature in almost every system. Two basic aspects affect the size of the system: Geography and the number of users. As the size of these two elements increases, the need for intervention in the system does not increase at the same rate, which is a feature that should be in a successful system.

Cost: When the concept of cost is mentioned, financial situations are directly associated in the human mind. However, although money is an important criterion in the IPS, situations such as time, energy and covered area are also included in the cost. Successful systems are systems that achieve maximum efficiency at minimum costs. Cost refers to the maximum savings of extra infrastructure, additional bandwidth, space, weight, time, money, energy and material of the distributed technology in a PS. To calculate the total cost incurred for an IPS, three different cost need to be considered: the purchasing, the installation, and the maintenance.

Data Size: When the data reaches the end user, it should not be too large and should be transferred to the user on a minimum scale as filtered and meaningful data as much as possible.

Robustness: In cases where the signal is not available, the transmitter malfunctions, or previously unseen RSSI values or angle characters are seen, the system is least affected by the errors that may occur, means the robustness of the system.

Complexity: It refers to the computational complexity of positioning methods depending on the hardware, software and operating factors in a PS. If the positioning operations are performed on the server side, the positioning can be calculated quickly due to the powerful processing capacity and sufficient power supply.

Response Time: Response time measures how fast the IPS systems can update the location information to the user after the location query is sent. Response time is an important criterion for the implementation of IPS in the shipyard, as targets such as people often operate in motion. The faster a system is, the more successful it is. At the same time, the more frequent the duration of the detection pulse in the coverage range, the less likely the individual will not be detected. However, frequent detection at short intervals means more processing frequency, which means more power consumption. For a successful system, the size of the region included in the coverage range, speed and power consumption should be configured in the most optimal and most balanced way.

Integrality: In the IPS, various integrations can be made in order to add additional functions to the system or to strengthen existing functions. An efficient system must be compatible with being integrated.

Power consumption: Power consumption measures the average power consumed in an IPS under the same usage rate. More energy is consumed to transmit more data. The choice of policies and algorithms determines the amount of memory consumption and computation time to perform the location estimation, which affects the energy consumption per location query.

Security: Regardless of the content of the transported data, security is perhaps the first of the topics that should be kept at the forefront. The airborne transmission of RF provides the opportunity to be tracked by undesirable persons. Point-to-point transmission systems are difficult to monitor communication methods; however, point-to-multipoint transmissions are a type of communication that is technically easier to monitor. Wireless network technologies have security features that are almost equivalent to wired networks.

Confidentiality: It is a strong access control when collecting, processing and storing users' data.

6. RESULTS AND DISCUSSION

The article provides a detailed description of the different indoor localization technologies for shipyard suitability. The assessment considers various criteria of IPT such as energy efficiency, accuracy, scalability, reception range, cost, latency and availability. Existing IPS approaches when examined, it has been determined that RF based approaches are more applicable than others for the shipyard. However, it is seen that there is no widely accepted and used indoor location system among the wireless approach for Shipyards. The advantages and disadvantages of IPTs are summarized in Table I.

The key challenges facing IPS endeavors in shipyards were highlighted. A key challenge in shipyards is the multipath effects and noise. Signals can be reflected and interrupted at the shipyard by obstacles, metals and even people in some cases. This feature has a significant impact on accuracy. This problem can be

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solved with energy efficient and noise suppression algorithms.

IPS operate with higher energy to provide higher accuracy and better range, however energy efficiency is a very important factor and is not ideal for energy efficiency. The main challenge to IPS adoption is privacy. No one is willing to share data about their location. They ignore the current IPS privacy concern and are more concerned with accurate and effective indoor localization. For IPS to develop better, security issues that may arise because of lack of trust and privacy breach must be resolved comprehensively. Therefore, privacy and security is an area that requires further research.

Widespread adoption of a system for positioning is measured by the cost-effectiveness of IPT, low energy use, high accuracy, low latency, and high scalability. However, it is a known fact that a technology will not meet all these criteria at the highest level for each application area. Luo et al. compared Cellular Based, UWB, Wi-Fi, RFID and Bluetooth in detail in terms of sensitivity, accuracy, complexity, scalability and robustness [23]. Cil et al. criticized and classified the IPT. The performance comparisons such as accuracy, precision, complexity, scalability, robustness and cost are provided using MCDM methods [12]. The most important parameters of positioning approaches in indoor areas are precision and accuracy in positioning. There is a trade-off between accuracy in geolocation and other system features in most studies where efforts have been made to provide a reliable geolocation approach. For example, in UWB-based approaches, where the accuracy in location determination is achieved at very high levels, the installation and maintenance costs are very high. Similarly, the accuracy rate decreases as the spatial sensitivity value increases. Optimizing all system features is essential to produce a widely applicable IPS. Although the main purpose of location detection systems is to detect the location of objects as accurately and accurately as possible, it is a useful and viable approach when issues such as ease of system installation and testing, extensibility based on needs, system cost and minimizing system maintenance need are not taken into account [24].

Table 1. Advantages and disadvantages of the IPT

	Advantages	Disadvantages
Wi-Fi	Receivers and transmitters do not need to see each other directly. There is no need for any additional equipment A low cost solution as it does not need extra devices. Pretty good signal strength in most environments.	Poor performance in very dense areas. Variable signal strength due to signal reflection and dynamic network structure. Fingerprint method is time consuming.
RFID	Receivers and transmitters do not need to see each other directly. The signal can pass through any solid material. It can work in any environment. Active tags have 100m distance Very light and small tags, Long lifetime of labels. Large data storage facility in tags and Cheap passive tags	It is not easy to integrate into other systems. The signal cannot pass through metal materials. Passive tags may experience a power outage. Distance is less than 3 m and active tags are expensive. Low coverage.
BLUETOOT H	Variable reading distance and Requires low transmission power. Small-scale installations are relatively inexpensive. Available on most mobile devices and Low cost system. Long-time operation with thin batteries.	Costly in large-scale In a complex environment is not efficient. Short connection distance Distance is about 30 meters Delay in real time data,
WUB	It does not cause any interference with the existing RF signal. High accuracy system and wide frequency range Requires low transmission power & Low interaction with other devices, Ability to pass through building elements.	Costly and Expensive equipment. Interaction with metal materials. Limitation of the working area to 100 meters Mixed signal structure.
ZigBee	It requires less energy. It does not require much network bandwidth. Has higher latency	It needs extra hardware. Attenuation of interference and signal strength. Not connecting by phone.
NFC	Low cost, high accuracy. It provides secure and private navigation.	Accuracy depends on the number and proper placement of tags.
LoRa	Long range, covers large area and It serves larger active nodes. It consumes very low energy and Devices have long battery life Ideal for single building and LoRa devices work effortlessly Easy to set up and manage personal network	There may be signal attenuation. Long distance between server and device. Low data rates Long/High latency
SigFox	Costs are low and It consumes very low energy. Long range, covers large area and It serves larger active nodes. It send small data at a slow rate.	Data transfer is difficult when assets are mobile. Long distance between server and device. Signal attenuation outdoor to indoor

When comparing Lora, which is one of the newer technologies, and other older technologies (such as Wi-Fi), the following can be said. LoRa is better in that it has a wide communication range and improves receiver sensitivity. Any network type can have only two of the three properties; Long distance, low power consumption, and high bandwidth. While Wi-Fi excels when it comes to bandwidth, it suffers when it comes to battery life and range. Most networks have struggled to work in the past 15 meters, which is not suitable for distributed IoT devices. By comparison, LoRa's low power and long-range nature makes it ideal for these devices. Still, LoRa will struggle to send a single image, let alone large files. It is good at sending small packets of data, such as temperature and humidity. Z-Wave and ZigBee are quite similar in that they are both low-power networks that operate under a network protocol and are designed for short to medium distance data exchange. Numerous criteria such as accuracy, scalability, cost and coverage. These criteria are used in most projects and are used to identify the benefits of certain technologies for developing an IPS. These criteria can be used because they have been widely described in other studies and guide the choice of one technology over others in a particular application. In Table 2, the some criteria for different technologies are summarized in a tabular form. Each technology corresponds to an IEEE standard. Obviously, Wi-Fi and UWB offer a higher data rate, while ZigBee and Bluetooth provide a lower data rate. Other important features are shown in the Table 1.

Table 2. Features of the indoor positioning technologies

IPT	Data Rate	Frequency	Range	Power	Cost
LoRa	50 kbps	Unlicensed	5km - 20 km	Low	Medium
SigFox	100 bps	Unlicensed	10 km-40 km	Low	Medium
NB-IoT	200 kbps	License LTE	1km -10 km	High	High
ZigBee	250 kbps	2.4Ghz	300 feet	Low	Medium
Bluetooth	1-3 Mbps	2.4Ghz	300 feet	Low	Low
Wi-Fi	0.1-54 Mbps	2.4,5 Ghz	<300 feet	Medium	Low
2G/3G/4G/5G	~10 Mbps	Cellular Bands	Several km	High	High
Z-wave	40 kbps	subGhz	100 feet	Low	Medium

7. CONCLUSIONS

The comparative study presented in this article systematically introduces current IPT and evaluation criteria. Each different technology, with its own advantages and disadvantages, contributes to the shipyards with its specialty in certain areas. In addition, it will also make an important contribution that the technology can be used as a hybrid to increase the performance of IPS to be applied in shipyards.

This article provides a broad overview of a wide range of IPT. It gives special importance and priority to RF-based technologies in terms of being more suitable for shipyards. It is not meant to draw any conclusions about which is superior, as the technology to be applied is greatly influenced by practical shipyard applications where many factors are involved. In any case, each shipyard will require them to evaluate according to their particular circumstances, taking into account the cost, accuracy, scalability and criteria described in the previous sections.

Although GPS gives satisfactory results outdoors, it does not seem appropriate to use in these environments due to the weakening of the signals from the satellite indoors by the solid materials in the shipyards, and therefore, IPSs are needed. In many studies on the IPS, it has been observed that the most common technologies are Wi-Fi-based, Bluetooth-based, RFID-based technologies. With these technologies, RSSI or fingerprint approaches are usually combined. The reason for this is the high cost of devices that require high precision in terms of hardware for approaches such as arrival angle and time of arrival. Even if the selection of technologies and approaches used together is made carefully, it is seen that the manipulative effects on the signals due to various reasons, interaction and environment behavior cannot be completely avoided.

One of the interesting results in this study is that standards may need a third space between the local area (closed area) and the large area (open area). There are large open spaces that are still semi-private, such as shipyards, campuses, ports, airports, and convention centers. What is important here is the necessity of determining a standard for the areas where both open and closed areas are together, and the development of IPS systems in line with this standard. There is a need for another standard that focuses on the main area. The new standard to be developed will be cost-effective, flexible enough to be flexible and more qualified for both indoor and outdoor areas. IPS is an emerging technology that is gaining interest among researchers. These technologies not only provide commercial benefits to their implementers, but stand on the side of shipyards as an imperative of technology push strategy.

9. ACKNOWLEDGMENTS

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10. REFERENCES

[1] Fraga-Lamas P, Noceda-Davila D, Fernández-Caramés TM, Díaz-Bouza MA, Vilar-Montesinos M. *Smart Pipe System for a Shipyard 4.0. Sensors*. 2016; 16 12), 2186. 2016. doi:10.3390/s16122186.

[2] Cil, I., Arisoy, F., & Kilinc, H.. Ozgurbuz, E, Cil, A Y. *Fuzzy AHP-TOPSIS Hybrid Method for Indoor Positioning Technology Selection for Shipyards*, 2021 5th International Symposium on Multidisciplinary Studies and Innovative Technologies (ISMSIT), 2021.

[3] Constantin-Antonio, G., & Bogdan-Alexandru, S. (2019). *Global Solutions -Intelligent Security and Safety of Life.* Journal of Marine Technology and Environment, 2019, Vol., 1, 27.

[4] Dachev, Y. *The satellite navigation systems: status, problems, future.* Journal of Marine Technology and Environment, 20151, 23-28.

[5] Liu, H.; Darabi, H.; Banerjee, P.; Liu, J. *Survey of wireless indoor positioning techniques and systems.* IEEE Trans. Syst. Man Cybern. Part C (Appl. Rev.) 2007, 37, 1067–1080.

[6] Kolodziej, K. W., & Hjelm, J. (2006). *Local positioning systems: LBS applications and services.* Boca Raton, FL: CRC/Taylor & Francis.

[7] Mautz, R. *Indoor Positioning Technologies.* Ph.D. Thesis, ETH, Zürich, Switzerland, 2012.

[8] Sakpere, W., Adeyeye-Oshin, M. and Mlitwa, N.B.W. (). *A state-of-the-art survey of indoor positioning and navigation systems and technologies.* South African Computer Journal, 2017, 29 (3), 145-197. https://doi.org/10.18489/sacj.v29i3.

[9] Cil, F. Arisoy, H. Kilinc, E. Özgürbüz, A. Y. Cil and E. Uysal, *Challenges and Trends in Shipbuilding Industry: Digitization of SEDEF Shipyard in Turkey, 2021 5th International Symposium on Multidisciplinary Studies and Innovative Technologies (ISMSIT)*, 2021, pp. 799-804, doi: 10.1109/ISMSIT52890.2021.9604757.

[10] Basiri, A.; Lohan, E.; Moore, T.; Winstanley, A.; Peltola, P.; Hill, C.; Amirian, P.; Figueiredo e Silva, P. *Indoor location based services challenges, requirements and usability of current solutions*. Comput. Sci. Rev. 2017, 24, 1–12.

[11] Cil, I., Arisoy, F., & Kilinc, H. *An analysis on industrial internet of things in digital transformation of shipyard industry in Turkey*. Global Journal of Computer Sciences: Theory and Research, 11(2), 67–87. https://doi.org/10.18844/gjcs.v11i2.5430, 2021

[12] Çil, İ., Kılınç, H., Özgürbüz, E., Ünver, M., Özkurt, N. *Bulanık MULTIMOORA ve Bulanık COPRAS Yöntemleriyle Tersanelerde İç Mekân Konumlandırma Teknolojisi Seçimi*. Avrupa Bilim ve Teknoloji Dergisi 2021, 248-254.

[13] Mendoza-Silva, G.M.; Torres-Sospedra, J.; Huerta, J. *A meta-review of indoor positioning systems*. Sensors 2019, 19, 4507.

[14] Zafari, F.; Gkelias, A.; Leung, K.K. A Survey of *Indoor Localization Systems and Technologies*. IEEE Commun. Surv. Tutor. 2019, 21, 2568–2599.

[15] Gu, Y.; Lo, A.; Niemegeers, I. *A survey of indoor positioning systems for wireless personal networks.* IEEE Commun. Surv. Tutor. 2009, 11, 13–32.

[16] Kunhoth, J., Karkar, A. G., Al-Maadeed, S., & Al-Ali, A. *Indoor positioning and wayfinding systems: a survey*. HCIS 10 (1), 1- 41 (2020).

[17] Bahi, P. and V.R.A.D.A.R. Padmanabhan, 2000. *An in-building RF based user location and tracking system.* Proc. IEEE INFOCOM, 2: 775-784.

[18] Farid, Z., Nordin, R., & Ismail, M. (2013). *Recent advances in wireless indoor localization techniques and system. Journal of Computer Networks and Communications*, *2013*.

[19] Tan, K. G., Aung, K. Z., Aung, M. S., Soe, M. T., Abdaziz, A., Liew, C. P., ... & Wong, H. Y. *Review of Indoor Positioning: Radio Wave Technology*. Applied Sciences, 2021, 11(1), 279.

[20] Paredes-Parra, J. M., García-Sánchez, A. J., Mateo-Aroca, A., & Molina-García, Á. *An alternative internet-of-things solution based on LOra for PV power plants: Data monitoring and management*. Energies, 2019, 12, (5), 881.

[21] Pascacio, P.; Casteleyn, S.; Torres-Sospedra, J.; Lohan, E.S.; Nurmi, J. *Collaborative Indoor Positioning Systems: A Systematic Review. Sensors* 2021, 21, 1002. https://doi.org/10.3390/s21031002

[22] Alarifi, A., Al-Salman, A., Alsaleh, M., Alnafessah, A., Al-Hadhrami, S., Al-Ammar, M. A., & Al-Khalifa, H. S. (2016). *Ultra wideband indoor positioning technologies: Analysis and recent advances*. Sensors, 16(5), 707.

[23] Luo, Junhai, Liying Fan, and Husheng Li. *Indoor Positioning Systems Based on Visible Light Communication*: State of the Art. IEEE Communications Surveys & Tutorials 19.4 (2017): 2871-2893.

[24] Dorji, L., & Horanont, T. *Comparative Assessment of Indoor Positioning Technologies, Techniques, and Algorithms.* In 2018 International Joint Symposium on Artificial Intelligence and Natural Language Processing (iSAI-NLP) 2018, pp. 1-6. IEEE.