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Third Generation Active RFID from the Locating Applications Perspective

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1. Introduction

Location systems, both for indoor and outdoor use, are rapidly developing due to the practical need of knowing the position of objects and persons (Harrop, 2008). If for the outdoor world, the GPS system and its variants (DGPS, etc.) is the best possible solution, for indoor use, things are not yet completely solved. Indoor GPS is developing, but in parallel, other projects are running. The vast majority of papers dealing with the subject (Bess, 2009; Chang et al., 2011; Goncalo, 2009; Kathiravan et al., 2009; Khan & Antiwal, 2009; Jeon et al., 2010) present systems based on RF signal measurements. Multiple ways of solving the problem are technically imaginable, starting with those using the signals emitted by the nodes of a common WLAN / Wi−Fi wireless network (Bal et al., 2009; Clulow et al., 2006; Kaemarungsi & Krishnamurthy, 2004; Kushki et al., 2006; Kwon & Song, 2008; Tsui et al., 2010; Yousef & Agrawala, 2005), continuing with RFID systems, WSN networks and finishing with proprietary solutions derived from one of the above, where specialized nodes with one or more coordinators are deployed over the desired locating area (Bahl & Padmanabhan, 2000; Baunach et al. 2007; Chang et al. 2011; Coca et al. 2008; Dai & Su, 2008; Koyuncu & Yang, 2010).
RFID tags are the main factor of progress in identification application development. There are more than 40 year from the first generation (Finkenzeller, 2003), equipped with passive components where the energy is captured from the radio−frequency field generated by the reader, to the third generation where the energy supplied by a battery is used to power a microcontroller and one or several on−board sensors. In terms of price, in 2011 the passive tags may be found at prices as low as 0.05 USD each, whereas the active RFID tags equipped with complex sensors and low−power microcontrollers may cost as much as 100 USD a piece (Harrop, 2008).
From the point of view of RFID tag structure, the changes are obviously influenced by the progress in semiconductors technology. The software for the reader and applications evolved also on the same trend. For the Generation 1 UHF tags, manufacturers provide hardware with their own protocols. Therefore, tags from one specific manufacturer would only work with the RFID reader from the same manufacturer. From the point of view of users, this represents a major limitation and for large-scale implementations, single supplier solutions are not acceptable. Generation 2, the second-generation RFID UHF tags, developed in order to establish a standard for RFID tags, used by the big retailer inventory applications

and operating in the ultrahigh frequency (UHF) band (860−960 MHz), offer long range operating distances (at least 8 to 10 meters). A comparison between the differences between Gen 1 and Gen 2 protocols may be found in Table 1 (EPC, 2005).

Four UHF RFID standards exist: Class 0 and Class 1 − from EPCglobal, and 18000−6 Type A and Type B from ISO. ISO's 2006 approval of Gen 2 as an 18000−6C extension opened the way to a single UHF global protocol. Such a protocol will create an open market as well as an open standard, which will force the prices to go down. Even the great efforts made in the direction of unifying the standards, a large RFID market with a strong supply chain and industrial backbone − China, has not accepted either the ISO or EPCglobal standard. Instead, China hopes to develop own standards compatible with Gen−2 tags, their readers being able to communicate with the standard tags (Bijl & Dil., 2010; Roberti, 2005; Razaq et al. 2005).

Gen 2 frequency range is from 860 to 960 MHz and it covers all international frequency spectrums. Tags that comply with EPCglobal's Gen 2 standard operate between these ranges without performance degradation. Gen 1 didn't do well in Europe due to European radio frequency spectrum allocation didn't leave enough open bandwidth for US radio frequencies, but Gen 2 offers Europe's required frequency range of 865 to 868 MHz, while fulfilling US frequency sub band of 902 to 928 MHz. The ISO 18000−6C extension makes Gen 2 a real flexible international standard (Jong & Bijl, 2010; Roberti, 2005; Razaq et al. 2005).

Description	**Gen 1**	**Gen 2**
Acceptance level	Not a global standard Global standard after an amendment in	ISO−UHF 18000−6 standard
Arbitration	Deterministic binary tree for Class 0 and deterministic slotted for Class 1	Probabilistic slotted
Anticollision/tag-sorting algorithm	Binary tree algorithm with persistent state/wake states	Q algorithm, which is a variant of the slotted aloha protocol
Air interface	Pulse width modulation (PWM) for Class 0 and Class 1	Pulse interval encoding (PIE−ASK), Miller, FM0
Data rate	40/80 Kbits for Class 0 and 70/140 bits for Class 1	40 to 640 Kbits
Distance	Less than 10 meters	Less than 10 meters
Frequency range	850–930 MHz	860 to 960 MHz
Security password	8 and 24−bit passwords, respectively, for Class 1 and Class 0	32 bits
Data write verification	No	Yes
Write speed (for 96−bit electronic product code)	Three tags per second	Minimum five tags per second

Table 1. Main differences between the Gen 1 and Gen 2 protocols

The working frequency is a key design issue in RFID locating systems. The ability for signals to propagate within crowded environments is dependent on the signal wavelength. Within warehouses, truck yards, office buildings, and other industrial or commercial facilities, the ability for an RFID system to operate in and around obstructions is critical (Han et al., 2008; Hsu et al., 2009; Jeon et al., 2010; Kiang et al., 2009). These obstructions are often made of metal, such as vehicles and metal racks, requiring signals to propagate around rather than through them. Signals propagate around obstructions by means of diffraction, and the level of diffraction is dependent on the size of the object over the signal wavelength ratio. Diffraction occurs when the wavelength approaches the size of the object. For example, at 433 MHz the wavelength is approximately a meter, enabling signals to diffract around vehicles, containers, and other large obstructions.
Regarding the frequencies used by active tags systems regulations, a summary is presented in Table 2:

Band	303 MHz	315 MHz	418 MHz	433 MHz	868 MHz	915 MHz	2400 MHz
Working frequency band	302−305 MHz	314.7−315 MHz 42 dBuA/m @10m	418.95−418.975 MHz 10 mW ERP	433.050−434.790 MHz 10mW ERP 10%	868−868.6 MHz 25mW ERP 1%	902−928 MHz	2400−2483.5 MHz
USA	x	x	x	x		x	x
Canada	x	x	x	x		x	x
UK				x	x		x
France				x	x		x
Germany				x	x		x
Netherlands				x	x		x
Singapore		x		x	x	x	
Taiwan	x	x	x	x		x	x
China		x				x	x
Australia				x		x	x

Table 2. Summary of global frequency regulations for the most common Active RFID bands

At 2.4 GHz, the wavelength is approximately 10 centimeters and diffraction is very limited with these obstructions, creating blind spots and areas of limited or even no coverage. Frequencies above 2 GHz present significant challenges for operation in crowded environments and are therefore not recommended for most RFID applications.
One may notice only 433 MHz and 2400 MHz working frequencies bands systems are allowed in almost all countries. Even both frequency bands overlap with the ISM bands, these are the most accepted in the RFID world. Despite in the 2400 MHz band there are many wireless systems (Wi-Fi, Bluetooth, ZigBee, etc.) making the frequency spectrum very crowded, producers continue to develop new systems and communication protocols working in this free band, design simplicity, small dimensions and low power consumption being solid arguments for continuing the researches.

2. RFID systems in localization applications

Real Time Locating Systems (RTLS) help users to locate and track objects in real-time. This could be done in many ways, along the time different technologies being developed around the idea. The RTLS term was introduced in 1988 to describe a technology that provided the Automatic Identification capabilities of active RFID, but added the ability to see the physical location of the tagged object.

From the locating perspective, the RFID has a long history. Conventional active RFID tags are the first used for real time locating applications. Starting with Gen 2 tags, the EPCglobal Class−1 Generation−2 UHF RFID Protocol for Communications standardized the active tags working in 860 − 960 MHz frequency band (EPC, 2005). The included battery helps them to initiate a signal, giving longer range compared to passive tags. This type of tags are mostly known for the end users as locking the cars as over two billion dollars were spent on car clicker systems to date (Harrop, 2008). Millions of other tags were also deployed in postal services monitoring applications, and supplies or assets management. Localization systems were developed for this type of active tags, an example being the RFID radar (RFID−Radar, 2005). RFID radar is a mixed localization system, based on both ToA − Time of Arrival and AoA − Angle of Arrival methods (Coca & Popa, 2007). It uses a system based on one emitting and two receiving antennas. The working principle, based on a tag-talks-first protocol (Coca et al., 2008), is as follows: when a transponder enters the area covered by the emitting antenna, it will send its ID and memory content. Two dedicated antennas receive the signal transmitted by the transponder. Based on the time difference between the two received signals and the range information, it computes the angle and the distance. The system uses a central frequency of 870.00 MHz with a bandwidth of 10 kHz. The performances in term of localization precision are modest, even the location information is available for tags placed up to 40−45 meters in front of the antennas (Popa et al., 2010).

The second generation of active RFID tags is present in the true Real Time Locating Systems (RTLS) used today for continuous monitoring applications. The active tag includes a battery used also to supply the on-board sensors and a low power microprocessor, improving the capability to store the measured data over a significant period. When using many readers, distances over several hundred meters are usually obtainable. Even these systems were initially designed for assets tracking, localization applications were position and speed information were added as a plus. In terms of location precision, it is strongly influenced by the reflections on obstacles and moving objects positioned between the reader and the tags.

The third generation of active RFID tags overlaps with the well-known Wireless Sensor Networks (WSN) or Ubiquitous Sensor Networks (USN) (Bess, 2009; Harrop, 2008). The most important characteristic of the tags is they communicate one with each other and in the same time with the central node. A central node, named also the coordinator or the gateway, pays the role of the RFID reader from a classic system. Even the maximum distance between the two nodes is limited to 10 to 30 meters (mainly due to maximum power emission regulatory restrictions but also due to attenuation, reflections and interference with other systems), the networks could be easily extended over hundreds of meters or even more, based on the inter−nodes communications capabilities.

3. Third generation RFID system in localization applications

Wi-Fi technologies, developed for delivering wireless communications between mobile terminals, are also used in locating applications by processing the identification data from multiple Access Points (AP) and the Received Signal Strength Indication (RSSI) information.

The signal strengths of received signals from at least three access points are used to determine the location of the object being tracked. To increase accuracy, more sophisticated methods use RF fingerprint maps that are based on calibrations of the strength of Wi-Fi signals at various points in a predefined area. Applications using Wi-Fi combined with Time Difference of Arrival (TDOA) techniques were also developed.

In an RSSI system, the distance between a tag and a reader is computer by converting the value of the signal strength at the reader into a distance measurement, based on the known signal output power at the tag and on a particular path loss model.

Wi-Fi location technique has some advantages over other systems:

- It uses the existing infrastructure;
- Position information is available both at the coordinator and at each node, information that could be shared with neighbor nodes.

Some major disadvantages of these systems include:

- Signal power measurements are affected by fixed and mobile objects, thus generating random measuring errors, even a power map was created for the specified measuring area;
- Network traffic congestions affect the system availability and the results;
- Power consumption is higher compared to RFID or WSN solutions.

To be effective, RSSI requires a dense deployment of Access Points, which adds considerably to the systems cost. The key problem related to RSSI based systems is that an adequate path loss model must be found for both non-line-of-sight and non-stationary environments. In practice, the estimated distances are not quite precise. RSSI locating systems may also be disqualified from security applications as an attacker can easily alter the strength of received signals by amplifying or attenuating it, or by other methods distorting the signal strength received from one more Access Points used as fixed references.

The disadvantages above made the Wi-Fi locating system not to develop as rapid as other technologies did, and positioning system solutions based on it are not widely spread in the real world.

RFID locating implementations were investigated and test setups are already used in real world applications both for indoor or outdoor locating services, even this technology was created as a bare code replacement. RFID systems were initially developed with the need of data storage in mind, and other aspects were not taken into consideration. Many efforts were done in order to modify RFID systems and make them suitable for indoor locating applications. A proprietary system derived from a RFID system (RFID Radar, 2005) is a good example for outdoor and indoor location, as only a small quantity of information is transmitted, the processing power being used for position estimation. One of the major disadvantages of such systems is the user is unable to modify the application or to write his own code due to copyright restriction. Communication protocol details are not always completely disclosed, so creating new system configurations could be a difficult task. In addition, the high power level used by the system makes it unsuitable for indoor location application or for populated areas (Coca et al., 2008).

The third generation RFID systems have the characteristics of a network of wireless sensors, the nodes being the tags. There are even no notable differences between the active RFID tags and WSN nodes, as both are powered from external energy sources, contain sensors and

small data processing capabilities. This is the reason the research was focused on the WSN networks for using them in applications where standard active RFID systems were unable to deliver the required performance levels.
Wireless Sensors Networks contains nodes with one or more sensors connected with a RF transceiver. When multiple WNS nodes are deployed over an area, signals transmitted by them could easily used for location purposes. The performances in the cited literature (Buta et al., 2010; Halgamuge et al., 2009; Kim & Yang, 2008; Jeong & Nof, 2008; Kuang et al., 2008; Lanzisera et al. 2004; Mao et al., 2007; Miorandi et al., 2007, Ota & Wright, 2006) are low enough to justify future investigations. For stationary environments, especially for indoor situations, location of objects is a relatively easy task. When moving objects have to be located and eventually traced, the WSN is a challenging solution. The typical structure of a third generation RFID locating network is shown is Figure 1. The message transmitted from one node to the gateway contains the node IDentification data along with the physical coordinates.

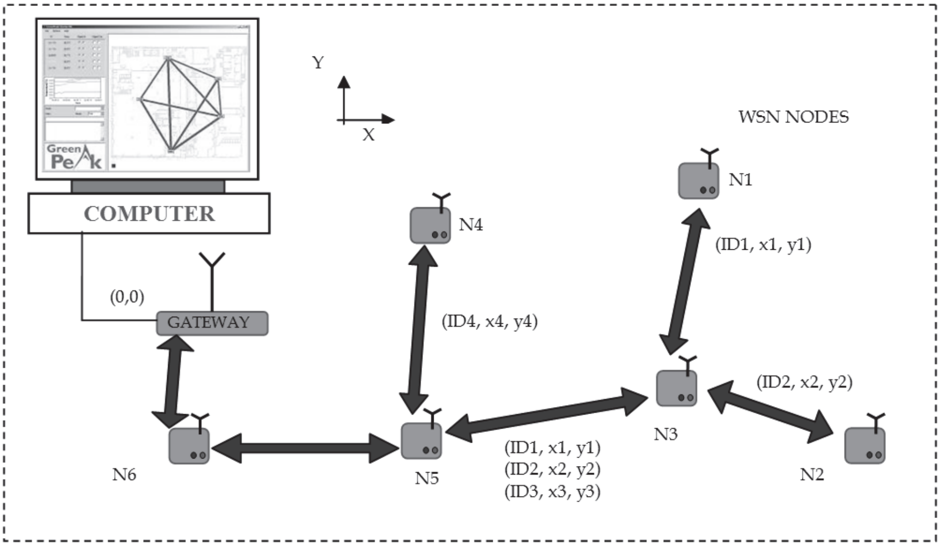

Fig. 1. Typical third generation RFID locating network overview

The position information may be obtained from on-board sensors (like GPSs, accelerometers, etc.) or may be computed from the information received from nearby nodes (RSSI is the most common information computed in order to obtain position information). The key of this architecture is the communication protocol that allows the information to be transmitted from one node to the gateway through any available path. This way in the event a node is not available, the information is routed through the healthy nodes.

4. Experimental results

4.1 Test system characteristics

For performance evaluation, we used a Wireless Sensor Network development system from Green Peak Technologies (GreenPeak, 2010). The system consists of a coordinator node (known as Gateway) and nine nodes, operating in the ISM band (2.4 GHz), with 16 channels and 250 kbps data rate and is certified to meet EN 300 440 (Europe), FCC CFR47 Part 15 (US) and ARIB STD−T66 (Japan) standards. The node architecture is presented in Figure 2:

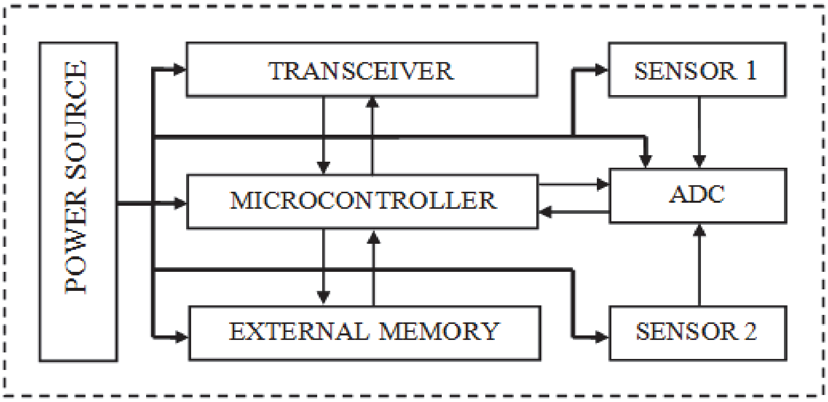

Fig. 2. WSN node architecture

The node is built around an Atmel AVR 1281 microcontroller and powered by 3 AAA batteries (Figure 3). On the board, there are temperature and humidity sensors, analog and digital inputs. In complex applications, the node may be upgraded to support a more powerful processor and multiple inputs.

In terms of operating distance, the typical values declared by the producer vary from 40−100 meters indoor, to 160−400 meters outdoor and up to 1000 meters outdoor in light−of−sight view. In the presence of blocking objects, shorter ranges are expected. The gateway is equipped with a RISC processing unit and a RF module, very similar with the one on the node.

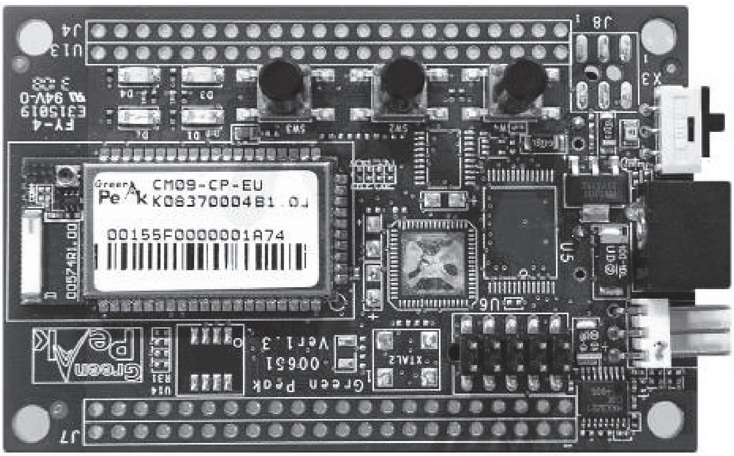

Fig. 3. WSN sensor node with integrated temperature sensor (Power provided by 3 AAA bateries placed underneath)

The WSN Gateway has a wireless communication module connected to its interface board (Figure 4), allowing TCP/IP, USB or RS232 serial communication with the external world (the processing software installed on a standard PC). The main characteristics of the communication stack are:

- Mesh network: messages travel from source node to destination node through intermediate nodes thereby multiplying range as a function of number of hops. The multi-hop feature does not require any application intervention.
- Self-forming: mesh network forms automatically, without any application intervention
- Self healing: when individual links fail the mesh network reestablishes a reliable route autonomously
- Security: data transfer through message encryption (AES 128 bit)
- Support for mobile nodes: Nodes can physically move through the network without requiring network re-association
- Support for ultra low power end devices: Reduced functionality devices can operate for years without replacing batteries
- Support for network visualization: network topology can be visualized using the optional JadeMonitor PC software component
- Robust against interference: able to operate in the presence of other wireless devices such as Wi-Fi, Bluetooth and others
- Scalability: the network can scale up to 100s of nodes without reconfiguration

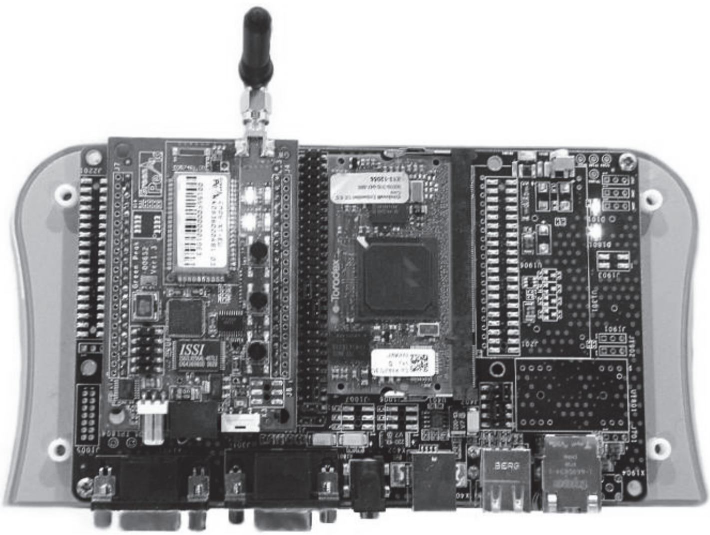

Fig. 4. Gateway/Coordinator node built around a RISC microcontroller

From the communication protocol side, we have to choose between 2 types of network stacks, namely PeakNetZ and PeakNet LPR. The API to both stacks is almost identical. The different properties are given in Figure 5.
In applications where the nodes have access to mains power instead of batteries and some devices operate on batteries, the PeakNet™ Z is the best solution. The network consists of Full Functionality Devices (FFD), Reduced Functionality Devices (RFD) and one or more

Network Coordinators. All FFDs automatically become part of the wireless mesh networks and take active part of routing messages.
Sensors may be connected to these nodes. The RFDs nodes interface to sensors and actuators and connect wirelessly to a nearby FFD. As they are set in a sleeping−state most of the time, they consume very little power. The RFD will not actively route messages for other devices. The Network is self−healing and self−forming and is managed by the coordinator node(GreenPeak, 2010).
When all nodes are battery−powered, PeakNet™ Low Power™ (LPR) is the most convenient solution. PeakNet LPR does not require always−on, mains−powered devices. All devices are in low−power state and still form a mesh and route messages through the network. The low−power routing meshing capability is obtained by occasionally waking up the low power nodes along a synchronized scheme.

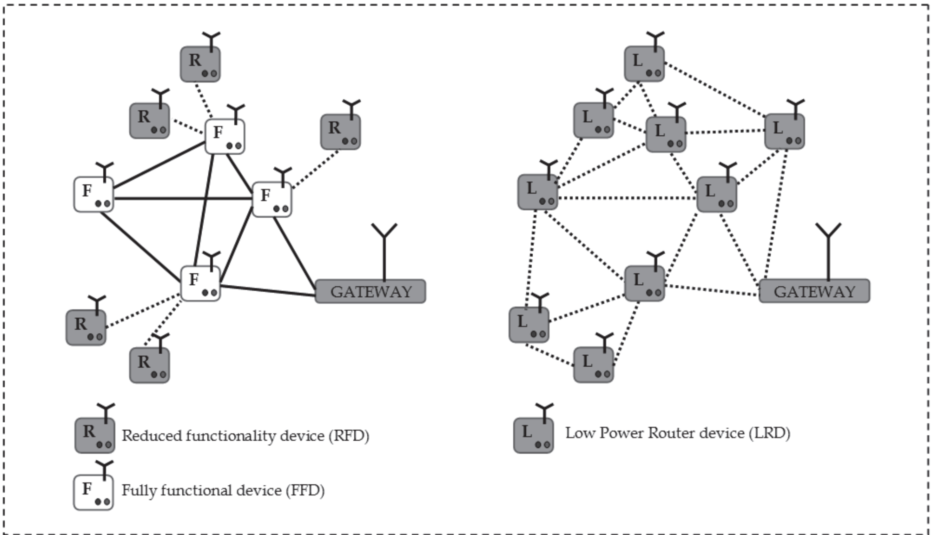

Fig. 5. The 2 types of network stacks PEAKNET™ Z (left) and PEAKNET™ LPR (right) (GreenPeak, 2010)

Hence, devices can pass messages through the network and in the same time conserve the battery power. Devices can be woken up according to a pre−defined schedule or when an external event occurs, or on a combination of both.
When powered up, the nodes automatically associate to the coordinator node. This coordinator also functions as a serial gateway: it allows the user to access the remote nodes in the network from a PC connected to the coordinator module.
All the software necessary for the network to work is embedded in the coordinator node. This means that the network can run stand−alone, without attaching a PC to the gateway/coordinator module.
The development software offered by the producer has an interface showing each node relative to other nodes positions. A map of the installations location permits to calibrate the distances and to display the real positions of all nodes having the coordinator node as a reference. For each node, the software displays the information read from the sensors and

from the inputs (Figure 6). Graphs showing the history of values recorded from the sensors are also available. Outputs may be activated remotely, making the system also useful in controlling remote processes where mobility is necessary.

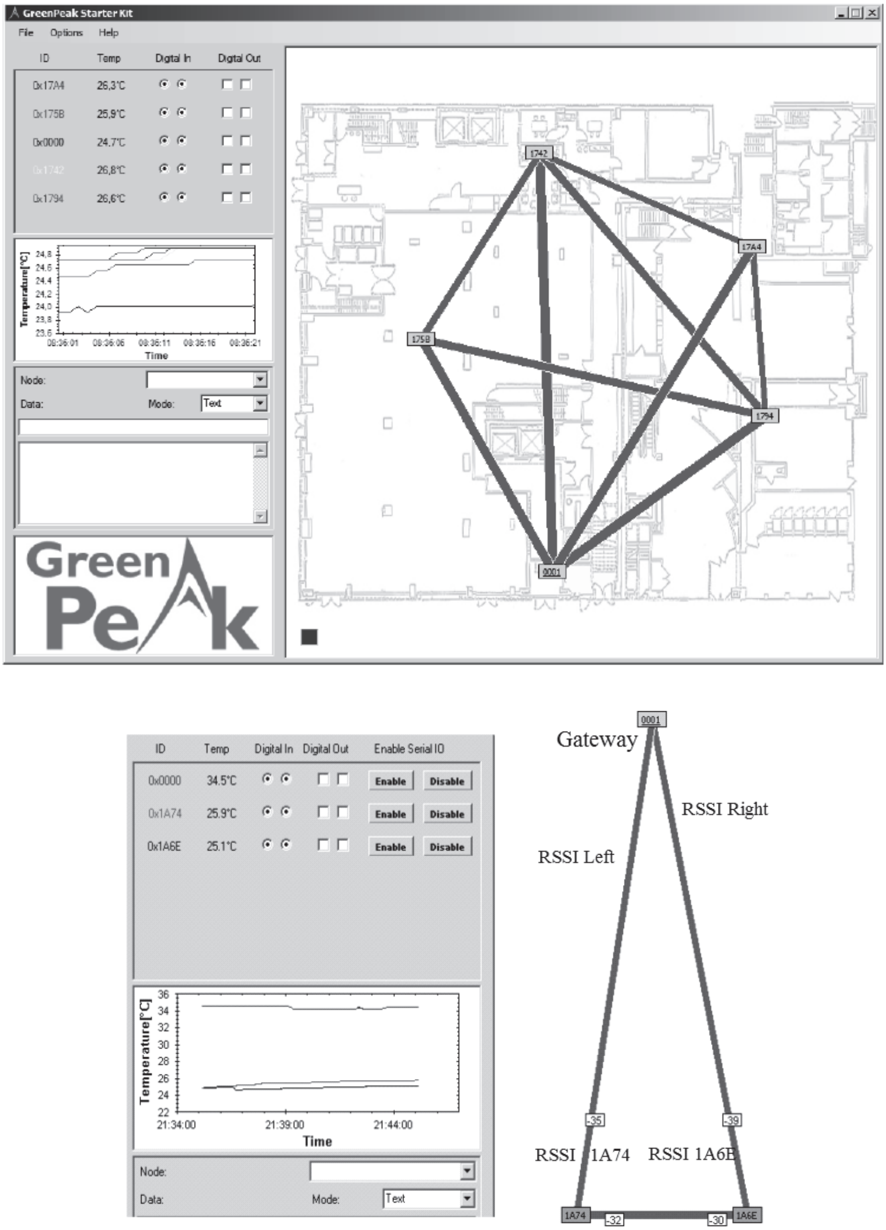

Fig. 6. Green Peak Development Software interface with RSSI measurements

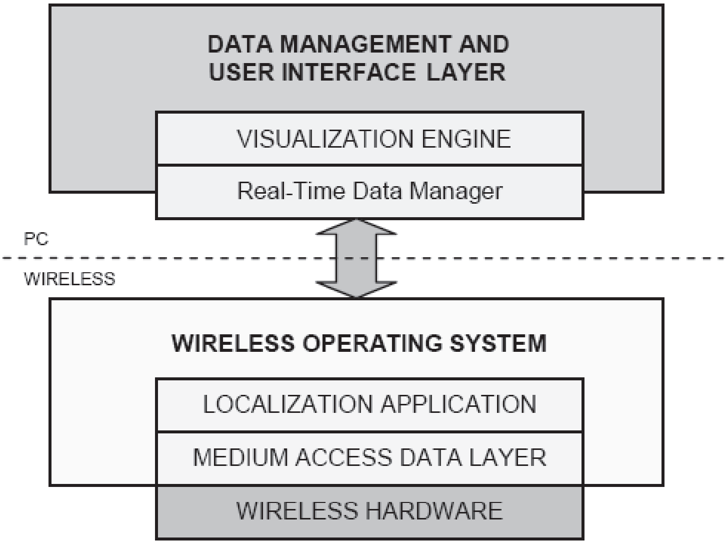

Fig. 7. Development software architecture

4.2 Test configuration

We used a dedicated LAN interface for connecting the gateway (Fig. 6) to the computer. As we already mentioned in the introduction, in WSN networks, a sensor node (Fig. 7) can have different roles, like network coordinator, router node (Full Functionality Device – FFD) and end device (Reduced Functionality Device – RFD, as described in IEEE 802.15.4 standard). The user can select the role of a WSN node, by modifying the software installed on–board.

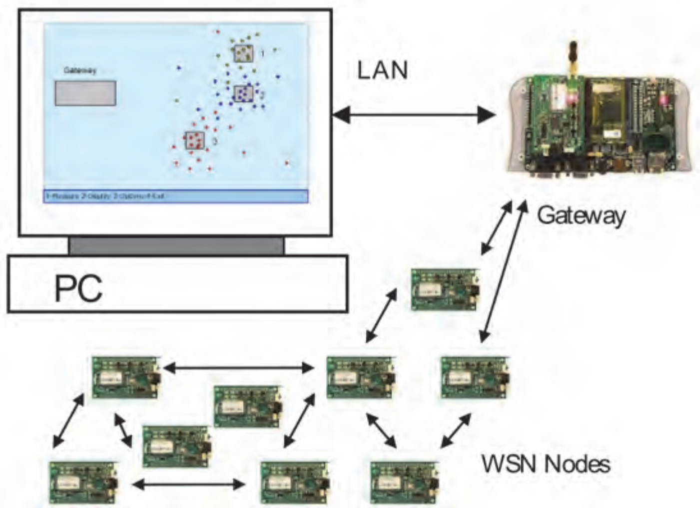

Fig. 6. WSN system overview

In our experiment, the WSN nodes were configured in FFD mode, in order to eliminate the effects of wake-up routine delay (when the node is in standby mode in order to reduce the power consumption).

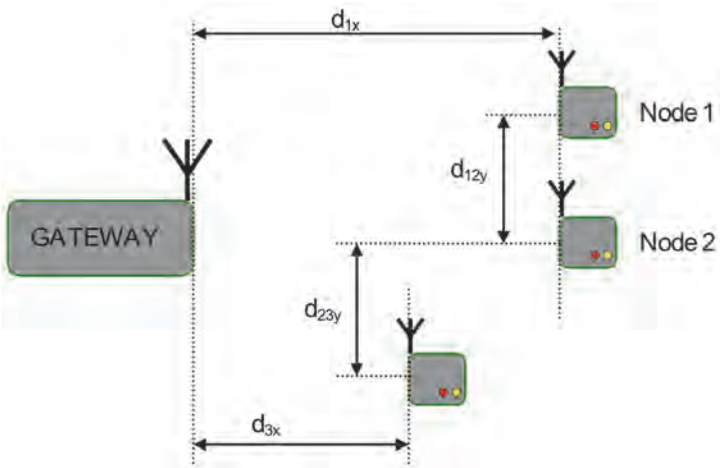

Fig. 7. Test setup with the Gateway and three WSN nodes (d_{1x}=2.5m, d_{3x}=2.2m, d_{12y}=0.4m, d_{23y}=0.8m)

The control software installed on the PC communicates with the gateway and process the RSSI information transmitted by the nodes. RSSI is a relative value (between 0 and the RSSI maximum), and a conversion routine transforms it in distance.
Regarding the physical positioning of the nodes and the gateway, we used for the tests the same configuration, both for the laboratory office room and for the anechoic chamber measurements. In Fig. 7 one may see the arrangement of the coordination node (the gateway) and the WSN nodes. The nodes and the gateway where placed 1 m above the ground level. As shown in Fig. 7, the distances were d_{1x}=2.5m, d_{3x}=2.2m, d_{12y}=0.4m and d_{23y}=0.8m.
In Figure 8 there is a photo taken in the anechoic chamber, showing the whole setup: the three nodes at 3 meters in front of the antenna and the coordinator node behind it (presented in a detailed photo in Figure 9).
For the measurements inside the laboratory, the nodes were positioned on the same relative distances between them and the gateway node, the same as in the semi anechoic chamber test. Wood furniture, other equipments emissions and moving humans are the perturbing elements present in this setup.

4.3 Experimental measurement results

The software on the PC was developed using the information provided in the SDK kit. For connectivity between the PC and the gateway, the LAN option was the single choice, as we had to extract the data from the semi anechoic chamber without using any metal cables from outside to the inside of the room. Ethernet cooper to optical fiber converter were used for this task. For the tests in the laboratory, both the serial RS−232 and the Ethernet interfaces may be used.

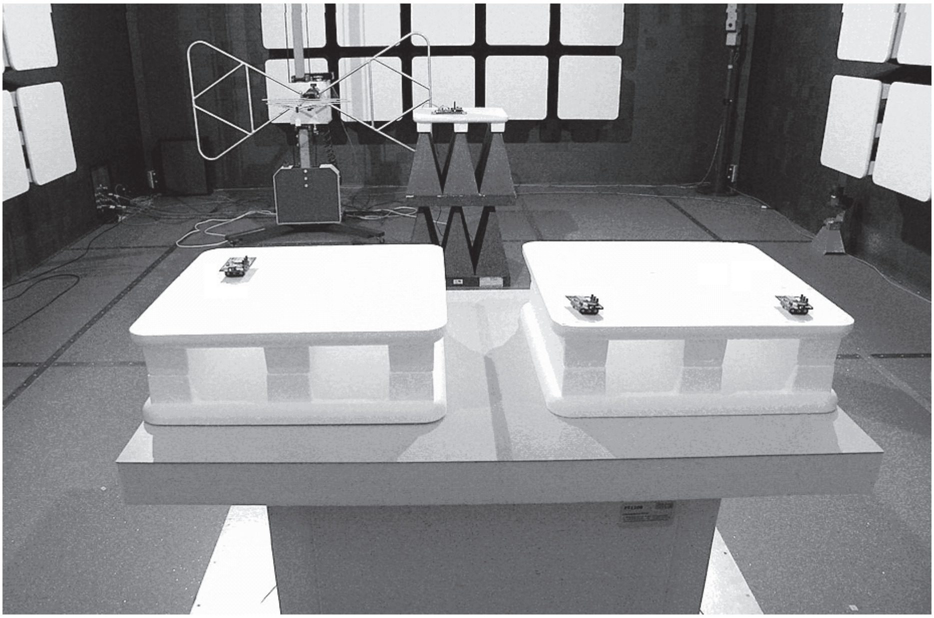

Fig. 8. Semi−anechoic chamber setup with threee WSN nodes and the Gateway node

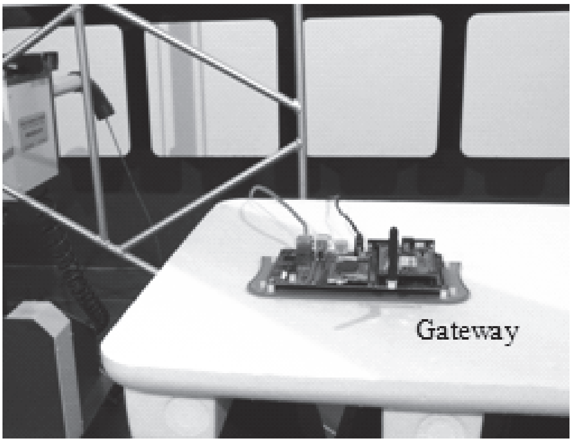

Fig. 9. Detail with the Gateway node positioned behind the receiving antenna

The RSSI signal received by the Gateway from the three sensors nodes and the similar information transmitted between the nodes were recorded, in order to compute the distances. The developed software calculates the distances d_{1x}, d_{3x}, d_{12y}, d_{23y}, save them in a local file for future processing, and displays on a picture the positions of the nodes, considering known the gateway position.

For every setup, we made a set of 30 measurements, one at each 10 seconds.

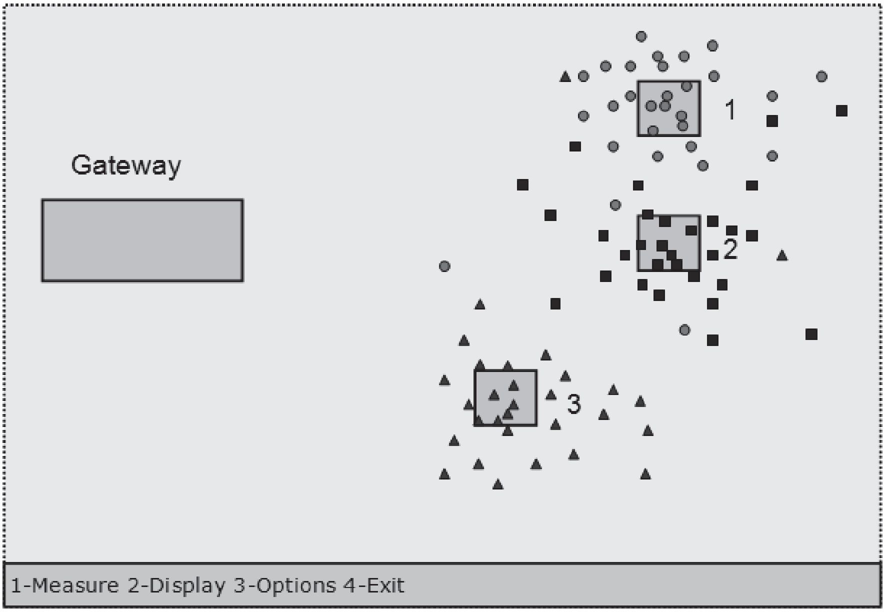

Fig. 10. Graphic display of the distances computes using the RSSI information from the laboratory

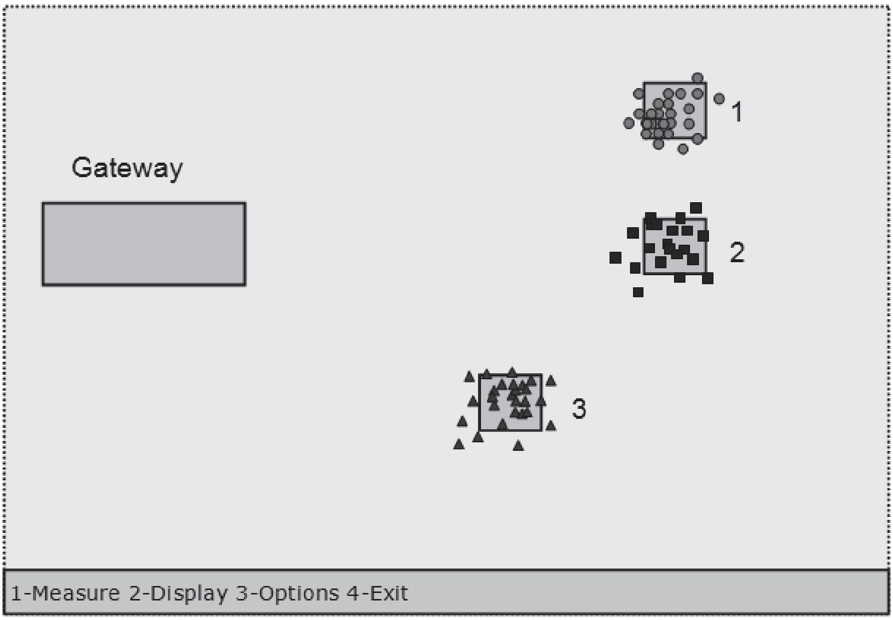

Fig. 11. Graphic display of the distances computes using the RSSI information from the anechoic chamber setup

For the first set of measurements, we used a standard laboratory room with furniture, chairs and moving humans. In addition, there were nearby emissions from two WLAN access points and other personal communication devices (mobile phones, PDAs, laptops, etc.).
The graphical representation of the positions of the three nodes in Fig. 10 shows us a great dispersion of the computed values.
For the second set of measurements, we used the same setup in terms of gateway and nodes positions and distances, but the equipments were positioned in the semi anechoic chamber, with virtually zero emissions from the outside world (noise floor at less than 120 dBm) and no furniture or humans present. The link between the computer and the gateway was made by using a pair of fiber optic to Ethernet converters. The graphical representation of the positions of the nodes is presented in Fig. 11.

Laboratory Room	**Distances**			
	d1x	**d3x**	**d12y**	**d23y**
Real distance (m)	2.50	2.20	0.4	0.8
Average value (m)	2.24	2.19	0.38	0.82
Max/Min value (m)	2.80/1.95	2.65/1.85	0.65/0.10	1.25/0.45
Standard deviation	0.39	0.29	0.24	0.26

Table 3. Results from the laboratory room measurements

Numerical results for both situations are summarized in Table 3 and Table 4. The results from the laboratory room setup show a great dispersion of the values for all distances. Despite this, the average values calculated for the distances between the nodes are quite good, with very small errors, while instantaneous ones may lead to wrong conclusions (Fig. 11). For larger distances, the standard deviation is greater, indicating the reflections on the walls and objects, and the presence of electromagnetic field emitting devices have a big influence on the results.

Anechoic Chamber	**Distances**			
	d1x	**d3x**	**d12y**	**d23y**
Real distance (m)	2.50	2.20	0.4	0.8
Average value (m)	2.42	2.20	0.39	0.81
Max/Min value (m)	2.65/2.20	2.45/1.95	0.60/0.15	1.05/0.55
Standard deviation	0.09	0.14	0.12	0.07

Table 4. Results from the anechoic chamber measurements

The influence of external electromagnetic fields from wireless devices operating in the 2.4 GHz band could not be neglected, and the results from the open area measurements are relevant in this direction.
The results obtained in the anechoic chamber are much better, the average values being closer to the real distances between the nodes. In addition, the standard deviations are smaller, meaning one single measurement have a better chance to be near the real value than in the previous case.

4.4 Electromagnetic field measurements

In order to estimate the emission level of a single WSN node, we measured it in an isolated environment. The measurements have been done in a 3m TDK semi anechoic chamber using

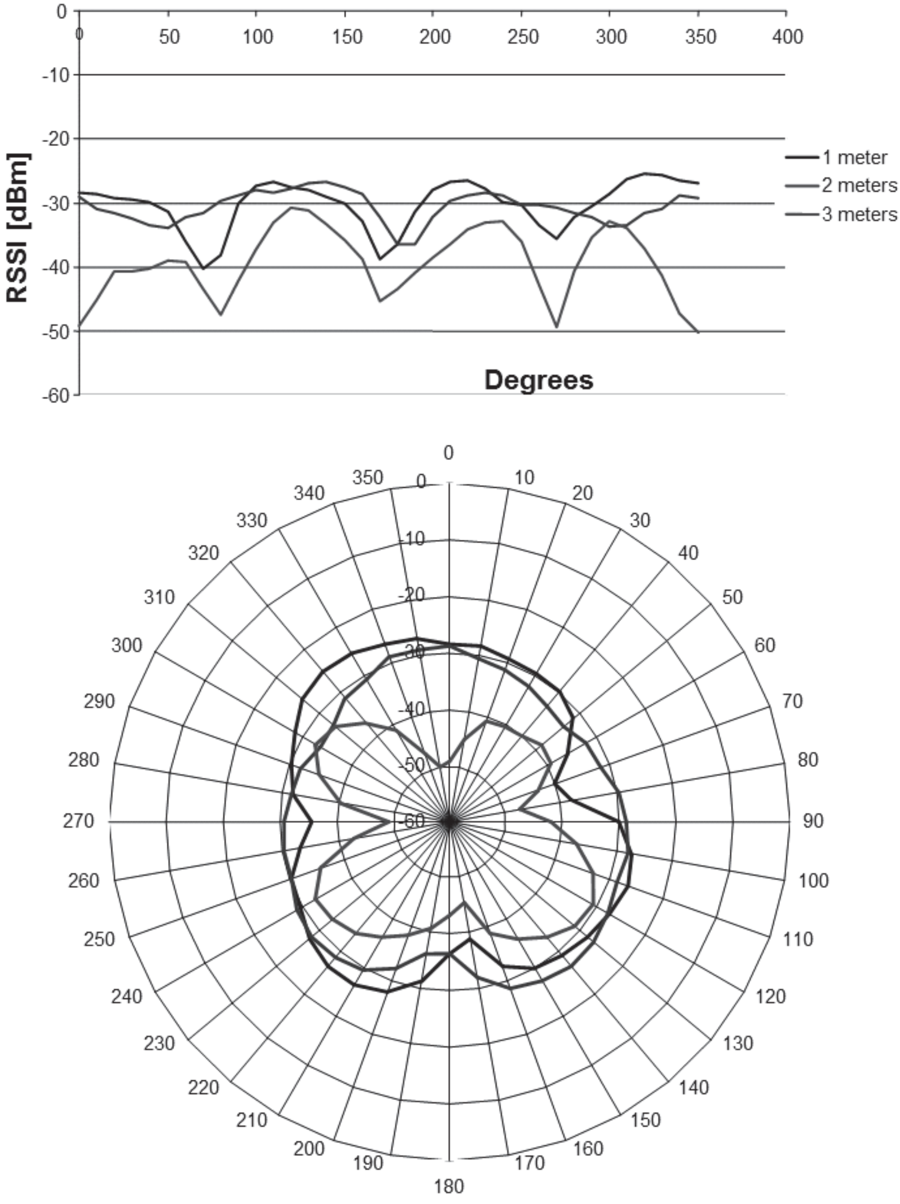

Fig. 12. WSN antenna radiation pattern at 1 meter, 2 meters and 3 meters distance away of the gateway

a Rohde & Schwarz - ESU 26 EMI Test Receiver, calibrated antennas and cables. The turntable and the antenna mast were operated by using an in-house made software program. The international standard specifying the emissions level for SRD−RFID

equipments is EN 55022 (CISPR 22) - "Information technology equipment - Radio disturbance characteristics - Limits and methods of measurements", while EN 300−220 - "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD)" is used for the operating performances and functional characteristics evaluation.
A standard configuration was used for the tests, as the equipment to be measured (EUT − Equipment Under Test) was positioned on a turn table at 0.8 meter above the ground and at 3 meters distance from the antenna tip. The gateway was positioned behind the receiving antenna system at 0.8 meter height. During the measurements, the antenna moved from 1 m to 4 m height and the EUT rotated 360 degrees, to find out the maximum emission level in the 30 to 3000 MHz band (more than the 1000 MHz limit specified in the standards, in the final scan procedure the operating frequencies being excluded from the measurement interval). In accord to the standards mentioned above, the readings were made continuously, one measure per second, using quasi-peak and peak detectors for the pre-scan and the final scan measurements, respectively. Even the standards do not specify a limit for the radiated emissions for frequencies over 1000 MHz we recorded those levels.
The maximum power level recorded for one measured node was around −30 dBm (with a minimum of −55 dBm) in the working frequency band, no other emissions being detected.
If there are multiple nodes in the same indoor environment, the field strength increases, but due to discontinuous emissions of nodes, the average field will remain much lower compared to the field generated by the continuous emission of an IEEE 802.11 b/g access point, for example.
The electromagnetic pollution will increase in the future due to extensive use of 2.4 GHz ISM band devices, including all types of portable computers, mobile phones, wireless gadgets, locating RFID systems contributing also to this increase but with a small quota.

5. Conclusions

Radio signals based indoor location systems is a hot topic. Even many papers deals with this subject, and some solutions were tested, currently we have no mature commercial implementations. Based on Wi-Fi, RFID, WSN, ZigBee or proprietary solutions, locating systems working principles implies the measurement of radio signals of information transmission using radio signals. Due to propagation issues in real working conditions, the practical demonstrated performances are far enough from theoretical calculated or simulation results. In indoor environments, the presence of different objects in rooms may cause multiple propagation paths, dynamic position changing objects or human presence may influence the measurement precision.
An evaluation of a WSN system was made by using it in a distance measurement and position estimation application. The obtained results, from measuring the distances in two different situations, were compared: in real life conditions (in a laboratory room with furniture and moving humans inside) and in a shielded room (completely isolated from the outside world electromagnetic fields and without interfering objects or humans). A set of 30 measurements for all distances were done, at 10 seconds time interval, in both situations.
From the results obtained in the two cases, one may conclude the average values for all distances are good enough in both cases, but the dispersion is greater in real life conditions. In mission critical applications where the position of an object must be known in real time, the WSN positioning solution could not be recommended. On the contrary, in applications where the position of an object have to be known, but the time is not critical, this solution

could be implemented with success, the price of a node being the single restrictive factor for large deployment areas.

Problems related to human safety will also emphasize due to high level of electromagnetic field intensity levels generated by all the wireless devices, not only in the free bands but also in regulated frequency bands. Continuous exposure to low levels of electromagnetic fields in domestic and industrial areas is a hot debate theme among the specialists and a definitive and scientific demonstrated conclusion is not yes available for the public.

Despite the significant research work in the area, there are still many difficult problems in indoor wireless sensors localization. In terms of positioning precision, different software algorithms may be used in order to process the measurement data and estimate the position of the nodes with only a small set of results. If we add a RF map and use path loss models adapted to particular application, the results may justify a rapid adoption of this technology in the real world applications.

6. References

Bahl, P., Padmanabhan, V., (2000). "RADAR: An In−Building RF−Based User Location and Tracking System," Proc. IEEE INFOCOM, vol. 2, pp. 775−784

Bal, M., Liu, M., Shen, W., Ghenniwa, H., (2009). "Localization in cooperative Wireless Sensor Networks: A review", 13th International Conference on Computer Supported Cooperative Work in Design, Santiago, Chile, April 22−24, pp. 438−443

Baunach, M., Kolla, R., Muhlberger, C., (2007). "Beyond Theory: Development of a Real World Localization Application as Low Power WSN," lcn, pp.872−884, 32nd IEEE Conference on Local Computer Networks (LCN 2007)

Bess, C., (2009). Third Generation RFID and the expanding Edge of the Enterprise, The HP Blog Hub, 27 Feb 2009

Bijl, M., Dil, B., (2010). Ambient 3000 Series White Paper − Localization, Ambient Systems, 2010

Buta, G., Coca, E., Graur, A., (2010). "Path Loss Exponent Influence on Distance Estimation between Wireless Sensor Nodes," Advances in Electrical and Computer Engineering, vol. 10, no. 1, pp. 110−115, 2010. [Online]. Available: http://dx.doi.org/10.4316/AECE.2010.01020

Chang, J. M., Huang, Yo−., Liu, S., (2011). "Real−Time Location Systems and RFID," IT Professional, pp. 12−13, March/April, 2011

Clulow, J., Hancke, G. P., Kuhn, M. G., Moore, T., (2006). "So Near and Yet So Far: Distance−Bounding Attacks in Wireless Networks", Computer Laboratory, University of Cambridge

Coca, E., Popa, V. (2007). "Experimental Results and EMC Considerations on RFID Location Systems", Proceedings of the 1st International RFID Eurasia Conference, 4−6 September 2007, Istanbul, Turkey, pp. 279−283, ISBN 978−975−01566−0−1, Digital Object Identifier 10.1109/RFIDEURASIA.2007.4368138

Coca, E., Popa, V., Gaitan, V.G., Turcu, C.O., Turcu, Cr., (2008). "Speed Measurement of a Moving Object by using a RFID Location System and Active Transponders", Electronics and Electrical Engineering (Elektronika ir Elektrotechnika), Kaunas

University of Technology, Lithuania, No. 8(88), 2008, ISSN 1392−1215, pp. 63−66

Dai, H., Su, D., (2008). "Indoor Location System Using RFID and Ultrasonic Sensors," Proc. 8th International Symposium Antennas on Propagation and EM Theory, IEEE Press, 2008, pp. 1179−1181

Finkenzeller, K., (2003). RFID Handbook : Fundamentals and Applications in Contactless Smart Cards and Identification: Wiley, 2003

Goncalo, G., Helena, S., (2009). "Indoor Location System Using ZigBee Technology," sensorcomm, pp.152−157, 2009 Third International Conference on Sensor Technologies and Applications, 2009

Halgamuge, M. N., Chan, T.−K., Mendis, P., (2009). "Experiences of Deploying an Indoor Building Sensor Network," sensorcomm, pp.378−381, 2009 Third International Conference on Sensor Technologies and Applications, 2009

Kaemarungsi, K., Krishnamurthy, P., (2004). "Properties of Indoor Received Signal Strength For WLAN Location Fingerprinting," Proc. First Ann. Int'l Conf. Mobile and Ubiquitous Systems: Networking and Services (MOBIQUITOUS), pp. 14−23, 2004

Kathiravan, K., Pradeep, P., Ronak, G., Roshan, S. S., (2009). "Modeling Location Monitoring System Using Directional Antennas," Computer Modeling and Simulation, UKSIM European Symposium on, pp. 488−493, 2009 Third UKSim European Symposium on Computer Modeling and Simulation, 2009

Khan, M. A., Antiwal, V. K., (2009). "Location Estimation Technique using Extended 3−D LANDMARC Algorithm for Passive RFID Tag," Proc. International Advance Computing Conference, IEEE Press, 2009, pp. 249−253

Kim, H.−J., Yang, J., (2008). "The Practical System Architecture for the Wireless Sensor Networks," MUE, pp.547−551, 2008 International Conference on Multimedia and Ubiquitous Engineering (MUE 2008)

Koyuncu, H., Yang, S. H., (2010). "A Survey of Indoor Positioning and Object Locating Systems", IJCSNS International Journal of Computer Science and Network Security, Vol. 10, No. 5, pp. 121−128, 2010

Kuang, X. H., Shao, H. H., Feng, R., (2008). "A New Distributed Localization Scheme for Wireless Sensor Networks," Acta Automatica Sinica, 34(3), 344−348, 2008

Kushki, A., Plataniotis, K., Venetsanopoulos, A. N., (2006). "Location Tracking in Wireless Local Area Networks with Adaptive Radio Maps," Proc. IEEE Int'l Conf. Acoustics, Speech, and Signal Processing (ICASSP), vol. 5, pp. 741−744, 2006

Kwon, O. H., Song, H. J., (2008). "Localization through Map Stitching in Wireless Sensor Networks," IEEE Trans. on Parallel and Distributed Systems, 19(1), 93−105, 2008

Han, X.−L., Zhao, W.−D., Ji, J., (2008). "Indoor Location Algorithm Based on RFID Technology and Its Improvement," Computer Engineering, vol. 34, Nov. 2008, pp. 225−270

Harrop, P., (2008). Third−generation active RFID bursts onto the scene, Retail Technology Review, 14 Oct 2008

Hsu, P.−W., Lin, T. H., Chan,g H. H., Chen, Y. T., Yen, C. Y., Tseng, Y. J., Chang, C. T., Chiu, H. W., Hsiao, C. H., Chen, P. C., Lin, L. C., Yuan, H. S., Chu, W. C., (2009). "Practicability Study on the Improvement of the Indoor Location Tracking Accuracy with Active RFID," Communications and Mobile Computing, International Conference on, pp. 165−169, 2009 WRI International Conference on Communications and Mobile Computing, 2009

Huang, Y., Lui, Z., Ling, G., (2008). "An Improved Bayesian−based RFID Indoor Location Algorithm," Proc. International Conference on Computer Science and Software Engineering, IEEE Press, 2008, pp. 511−514

Jeon, S., Choi, M., Kim, G., Hong, B., (2010). "Localization of Pallets Based on Passive RFID Tags," Information Technology: New Generations, Third International Conference on, pp. 834−839, 2010 Seventh International Conference on Information Technology, 2010

Jiang, X., Liu, Y., Wang, X., (2009). "An Enhanced Approach of Indoor Location Sensing Using Active RFID," Information Engineering, International Conference on, pp. 169−172, 2009 WASE International Conference on Information Engineering, 2009

Jeong, W., Nof, S. Y., (2008). "Performance evaluation of wireless sensor network protocols for industrial applications," Journal of Intelligent Manufacturing, vol.19, pp.335–345, 2008

Jong E., Bijl, M., (2010). Ambient 3000 Series White Paper − Technology Overview, Ambient Systems, 2010

Lanzisera, S., Lin, D., Pister, K., (2004). "RF Time of Flight Ranging for Wireless Sensor Network Localization," 4th Workshop on Intelligent Solutions in Embedded Systems (WISES), June 2006

Liu, M. L. Y., "LANDMARC: Indoor location sensing using active RFID," Wireless Network, vol.10, Jun. 2004, pp. 701−710

Li, Y., Wang, Z., Song, Y.Q., (2006). "Wireless Sensor Network Design For Wildfire Monitoring," Proc. of The Sixth World Congress on Intelligent Control and Automation, WCICA, Vol.1, pp. 109−113, Dallan, 2006

Mao, G., Fidan, B., and Anderson B. D. O., (2007). "Wireless Sensor Network Localization Techniques," The International Journal of Computer and Telecommunications Networking, vol. 51, pp. 2529−2553, 2007

Miorandi, D., Uhlemann, E., Vitturi, S., Willig, A., (2007). "Guest Editorial Special Section on Wireless Technologies in Factory and Industrial Automation—Part II," Industrial Informatics, IEEE Transactions on , vol.3, no.3, pp.189−190, Aug. 2007

Nikitin, P. V., Martinez, R., Ramamurthy, S., Leland ,H., Spiess, G., Rao, K. V. S., (2010). "Phase Based Spatial Identification of UHF RFID Tags," in Proc. IEEE International Conference on RFID, 2010

Ota, N., Wright, P., "Trends in wireless sensor networks for Manufacturing," Int. Journal of Manufacturing Research, Vol. 1, No. 1, 2006

Popa, V., Coca, E., Dimian, M., (2010). "Applications of RFID Systems − Localization and Speed Measurement", Radio Frequency Identification Fundamentals and Applications Bringing Research to Practice, Cristina Turcu (Ed.), ISBN:

978−953−7619−73−2, InTech, Available from: http://www.intechopen.com/articles/show/title/applications−of−rfid−systems−localization−and−speed−measurement

Razaq, A., Luk, W. T., Shum, K. M., Cheng, L. M., Yung, K. N., (2008). "Second−Generation RFID," IEEE Security and Privacy, pp. 21−27, July/August, 2008

Roberti, M., "Understanding the EPC Gen 2 Protocol," RFID J. Special Report, 28 Mar. 2005

Tsui, A. W. T., Lin, W.−C., Chen, W.−J., Huang, P., Chu, H.−H., (2010). "Accuracy Performance Analysis between War Driving and War Walking in Metropolitan WiFi Localization," IEEE Transactions on Mobile Computing, 28 Jun. 2010. IEEE computer Society Digital Library. IEEE Computer Society. [Online]. Available: http://doi.ieeecomputersociety.org/10.1109/TMC.2010.121

Wada, T., Uchitomi N., Ota Y., Hori, T., Mutsuura K., Okada H., (2009). "A Novel Localization Scheme for Passive RFID Tags Communication Range Recognition (CRR)," in Proc. IEEE International Conference on RFID, 2009

Wang, Q., Yan, C., Liu, F., (2009). "Knowledge integration based operation mode for workshop manufacturing system," Computer Integrated Manufacturing Systems, vol. 15, Apr. 2009, pp. 698−704

Youssef, M., Agrawala, A., (2005). "The Horus WLAN Location Determination System," Proc. Third Int’l Conf. Mobile Systems, Applications, and Services, pp. 205−218, 2005

Yihua, H., Zongyuan, L., Guojun, L., (2008). "An Improved Bayesian−Based RFID Indoor Location Algorithm," Computer Science and Software Engineering, International Conference on, pp. 511−514, 2008 International Conference on Computer Science and Software Engineering, 2008

Zongwei, L., Chan, T., Li, J. S., (2005)."A Lightweight Mutual Authentication Protocol for RFID Networks," Proc. IEEE Int'l Conf. e−Business Eng., IEEE CS Press, 2005, pp. 620–625, 2005

***, Green Peak WSN Development Tool, Green Peak Technologies [Online]. Available from: http://www.greenpeak.com

***, EN−55022:2007 Information technology equipment. Radio disturbance characteristics. Limits and methods of Measurement

***, EPC Radio−Frequency Identity Protocols Class−1 Generation−2 UHF RFID, EPCglobal, Jan. 2005

***, ISO/IEC 24730−1:2006 Information technology −− Real−time locating systems (RTLS) −− Part 1: Application program interface (API)

***, ISO/IEC 24730−2:2006 Information technology −− Real−time locating systems (RTLS) −− Part 2: 2,4 GHz air interface protocol

***, ISO/IEC 24730−5:2010 Information technology −− Real−time locating systems (RTLS) −− Part 5: Chirp spread spectrum (CSS) at 2.4 GHz air interface

***, ISO/IEC 18000−6:2004/FPDAM 1, Amendment 1, extension with type C and update of type A,

ISO/IEG Available from:
www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=43923

***, ISO/IEC FDIS 18000−6:2003(E, Information Technology Automatic Identification. and Data Capture Techniques, ISO/IEC, JTC 1/SC 31/WG4, Nov. 2003

***, RFID−Radar − Brochure on Development model of RFID−Radar, Trolley Scan(Pty) Ltd, 2005. [Online]. Available: http://www.rfid−radar.com