THEME ICT
ICT 2009.3.9 Microsystems and Smart Miniaturised Systems
Programme Title
Collaborative project / Small or medium-scale focused research projects
Project Title
Smart Efficient Location, idEntification and Cooperation Techniques
Acronym
SELECT
Project No
257544

DELIVERABLE D1.2

Description of Requirements for WP2, WP3, WP4

Work Package 1

Leading Partner: FIIS

Document Editor: NIELS HADASCHIK (FIIS)

Dissemination Level: PUBLIC

Delivery date: 23/03/2011

Version 1.0

SEVENTH FRAMEWORK PROGRAMME

Contributors

Partner	Contributing authors
DATALOGIC	Marco Bottazzi
Fraunhofer	Niels Hadaschik, Stephan Otto
CEA	Raffaele D'Errico
CNIT	Davide Dardari
CEIT	Unai Alvarado
ARMINES	Christophe Roblin, Alain Sibille
NOV	Dag Wisland
ORIA	Kristina Bogataj

Versioning and contribution history

Version	Description	Contributing authors	Date
0.1	First draft	Niels Hadaschik, Kristina Bogataj, Stephan Otto, Unai Alvarado, Marco Bottazzi	23/12/2010
0.2	Individual requirements collection for System, Reader and Tag	Niels Hadaschik, Unai Alvarado, Marco Bottazzi	19/01/2011
0.3	First requirements merge	Niels Hadaschik	20/01/2011
0.4	RAMS section, minor changes	Stephan Otto	21/01/2011
0.5	Changes according to the project meeting included	Niels Hadaschik	28/01/2011
0.6	All chapters – aggregated data, executive summary	Stephan Otto, Kristina Bogotaj, Unai Alvarado, Marco Bottazzi, Niels Hadaschik	08/02/2011
0.7	Merge and jump to new template, added introduction, provided chapter two with a more detailed view	Stephan Otto	11/02/2011
0.8	New system description, cosmetic changes, priority settings	Marco Bottazzi	17/02/2011
0.9	Tag revisions, Reader section, Annex II , Merge and minor changes	Unai Alvarado, Niels Hadaschik, Stephan Otto	21/02/2011
0.95	Revision and layout of the whole document	Niels Hadaschik, Dag Wisland	21/02/2011
1.0	Final revisions	Marco Bottazzi, Davide Dardari, Alain Sibille	07/03/2011
1.0	Final edits	Niels Hadaschik	23/03/2011

LIST OF ACRONYMS

Acronym	Name
2D	two-dimensional
3D	three-dimensional
AC	Alternating current
API	Application programming interface
ASK	Amplitude shift keying (modulation technique)
CMOS	Complementary-metal-oxid-semiconductor (technology for integrated circuitry)
DAA	Detect and avoid (interference mitigation)
DC	Direct current
DoW	Description of Work
ECC	Electronic Communications Committee
EIRP	Equivalent isotropically radiated power
EMC	Electromagnetic compatibility
EMS	Electromagnetic susceptibility
EPC	Electronic Product Code (for RFID)
ERC	European Radiocommunications Committee
ETSI	European Telecommunications Standards Institute
EU	European Union
FCC	Federal Communications Committee (US regulation authority)
FPGA	Field programmable gate array
EC	European Commission
ID	Identification (number)
IEC	International Electrotechnical Commission
IP	Internet protocol (packet switched transport protocol) or International Protection (according to the context)
ISO	International Organization for Standardization
LDC	Low duty cycle (interference mitigation)
MIB	Management information base (for hierarchical network management)

Acronym	Name
PSD	Power spectral density
Qn	question n (from the questionnaire)
RAMS	Reliability, Availability, Maintainability, Safety (requirements)
RFID	Radio Frequency Identification
RTD	Research & Technical Development (EC work package format)
RTLS	Real Time Location System
RTT	Round trip time (measurement in order to determine the distance, cf. ranging)
SELECT	Smart and Efficient Location, idEntification, and Cooperation Techniques
SCM	Supply chain management
SRD	Short range device
SW	Software
TCP	Transport control protocol (packet protocol with error correction)
TPC	Transmit power control
UC	Use case (from the interviews)
UDP	User Datagram Protocol (streaming protocol without error correction)
UWB	Ultra-Wideband Technology
WP	work package

EXECUTIVE SUMMARY

The first research work package, WP1, deals with the requirements of a configurable SELECT system concept for identification, detection and location. Therefore the SELECT Deliverable D1.1 [1] focused on the scenario whereas SELECT Deliverable D1.2 strongly depends on the use cases extracted from the user interviews and scenarios compiled in D1.1. It formulates a technical base for subsequent work packages.

SELECT Deliverable D1.2. "Description of requirements for WP2, WP3, WP4" presents technical requirements of SELECT system to be developed. It is expected to define a technical guideline for further project development activities (identification – location – modelling, Tag design, system architecture and Reader design) and for the evaluation and validation.

The deliverable starts with the summary of scenario definition and use cases, deriving from deliverable D1.1. These present strong bases for transforming company's business needs into technical requirements of the system to be developed. The core of the document is oriented to present the identified technical requirements for SELECT in a tabular way. They are subdivided into 3 parts.

Chapter 3: System - overall, logical architecture

The chapter presents the requirements for the overall system from the perspective of the End User. It is composed of a network of cooperative Readers interacting with a Central Unit Server.

The logical architecture and technical requirements of overall system are defined through the perspective of: Functional, Environmental, Electrical, Configuration and RAMS requirements.

Chapter 4: Tags

The chapter presents the requirements for the Tag development as defined in the Description of Work [1]. They are presented through the perspective of: Functional, Environmental, Electrical, Configuration (Test) and Fabrication requirements.

Chapter 5: Readers

The chapter presents the requirements for the Reader. Here, also the connections of the Readers via the backbone network to the Central Unit and possibly also to the other networked Readers are presented. The requirements for the Reader development are presented through the perspective of: Functional, Environmental, Electrical and Configuration requirements.

The last chapter of this deliverable presents also guidelines, driving research activities of the subsequent RTD WPs.

INTRODUCTION: THE SELECT PROJECT

The SELECT project focuses on studying innovative solutions enabling high-accuracy detection, identification, and location of objects/persons equipped with small ultra-low power Tags using a network of intelligent self-configuring radio devices. Network functionalities will be enhanced to include the detection and tracking of moving objects/persons without Tags eventually present in the same area.

To achieve this goal, several technologies such as radio frequency identification (RFID), ultra wideband backscattering modulation, relaying, and associated advanced algorithms, will be considered and partly or totally integrated in a demonstrator. This will require the design of multi-frequency/multi-technology Tags for system-neutral identification along the use lifetime of a Tag, based on advanced concepts in low-consumption chip and antenna design.

Innovative techniques will be considered to improve the location accuracy, increase Tag energy efficiency and extend system coverage by a mixture of progress in the system architecture, in the detection and Tag activation techniques, and in the complexity-performance trade-off of chip design.

Special emphasis will be given to the analysis and design of "green" solutions by considering low complexity and low power Tags through the exploitation of (semi-) passive communication (without integrated energy supply for communication).

Finally, single system components and the overall system performance will be validated through experimental characterization, hardware implementation, as well as simulation.

Identification/detection reliability, tracking accuracy, power consumption will be amongst the major evaluation criteria.

A wireless network integrating detection, identification, and location would lead to relevant improvements in the development of a wide range of advanced applications including logistics (package tracking) and supply chain management (SCM).

Table of contents

CONTENT

1. Objectives, System Overview, Methodology

1.1. Objectives

D1.2. "Description of requirements for WP2, WP3, WP4" presents technical requirements for the SELECT system to be developed. It is expected to present a valuable, technical guideline for the further project development activities in the upcoming work packages (identification – location – modelling, Tag design, system architecture and Reader design), as well as for the final evaluation, validation and demonstration.

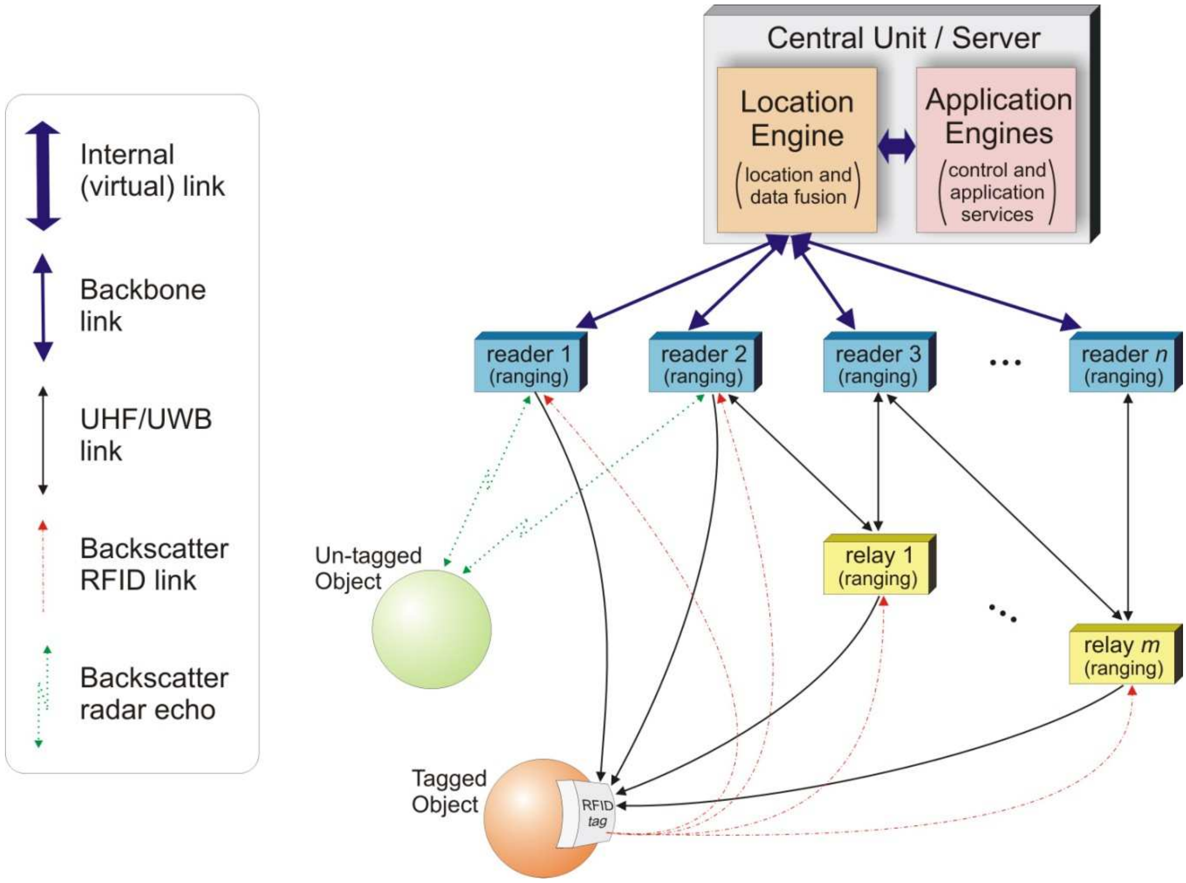

Fig. 1 General system architecture

1.2. System Overview

The SELECT System as depicted in Fig. 1 taken from [1] comprises a Central Unit, Readers and Tags. These are communicating via fixed wired (Central Unit – Reader, Reader - Reader) and wireless connections (Reader – Tag, Reader – Relay, Relay – Tag) in a standard UHF-RFID mode or in a newly defined UWB mode. Relays are understood herein as devices unconnected to the wired core network, but providing an indirect link between Tags and a

Reader. Their complete functionality remains open and will be defined completely at the end of WP2.

1.3. Methodology

In technical terms the requirements described in this document are called requirement specifications for the overall system, Readers and Tags. The methodology for this project places them as a middle tier between high-level requirements (see D1.1 [2]) and system specification and design documents to be delivered in WP2, WP3 and WP4. The numbers and requirements described in this document allow for verification during WP5. The derivation and formulation of the requirements is based on the IEEE recommendations for standard specification [3] with modifications due to the research nature of the SELECT project resulting in a demonstrator as a final result. Many requirements of designs going into manufacturing, e.g. considering safety, maintenance, and manufacturing requirements will not be considered.

1.4. Notation Note

If in the text the clear reference to a SELECT system component is considered, the term is introduced by a capital letter, i.e. Central Unit, Tag, Reader, and Relay. In more common contexts, the usual English notation with leading lower case letter is employed (the Central Unit references always the SELECT context).

2. Summary of Scenario Definition and Use Cases

This chapter is an aggregation of the result obtained from the interviews and of the use cases recorded in D1.1. The following pictures show the answers to the most significant questions (see questionnaire in the appendix of D1.1 [2]) in the form of an aggregated graphical overview with a short explanation. The interviews represent sufficiently the most important applications, but their number is not large (10 in total). The graphical representation selected for showing the results is good for a quick understanding, but it is based on a limited population, so cannot be interpreted as a general representation of trends, preferences, etc. The questions are mainly extracted from the table under Q19 of the questionnaire and are reported as titles of the following paragraphs.

2.1. What kind of items have to be tracked?

This question deals with the types of objects that have to be tagged and tracked most commonly in the application at hand as displayed in Fig. 2. Most objects to be tracked are products or goods themselves (43%). People are needed to be tracked in 25% of all cases, forklifts in 19% and pallets in 13% of all use cases.

Thus, SELECT shall foresee the capability to cover all or most of these object and subjects, even if tracking persons requires further privacy considerations.

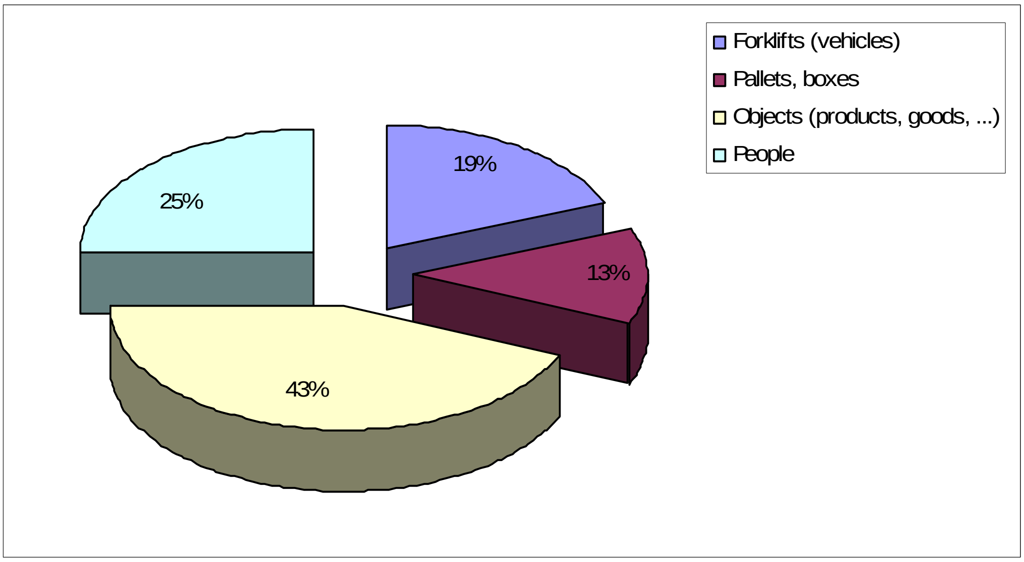

Fig. 2 Item types to be tracked

2.2. How many objects have to be located in parallel?

Fig. 3 shows how many objects have to be located in parallel in the different use cases. In most cases (44%) the claimed number is between 1 and 10 objects, but there are also many cases (22%) where the required number is between 10000 and 100000. The mean number has no real meaning as the number differ in vast orders of magnitude.

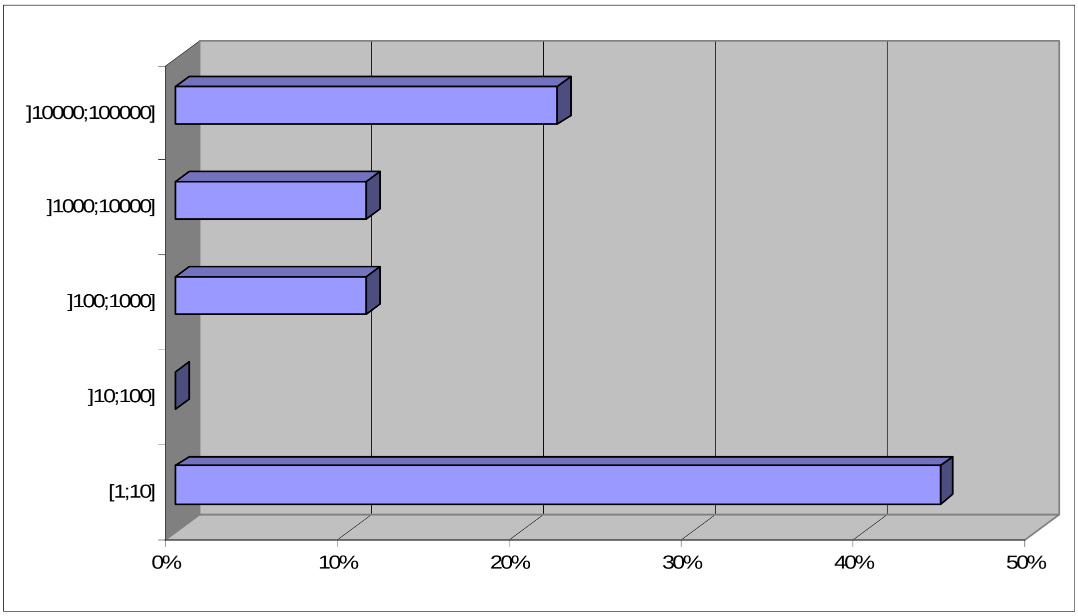

Fig. 3 Number of objects to be located in parallel

Additionally, the covered areas differ in orders of magnitude. They range from 100 m² to several 10.000 m² (cf. Section 2.12), such that the large numbers may be easily covered by a multi-cell approach (requiring however a scalable hardware/software platform for the Central Unit or several Central Units). However, the order of magnitude of some hundreds tags per cell seems reasonable.

2.3. Is it necessary to capture several tags at the same time?

The question tries to find an answer if there is a need to track multiple objects or persons at the same time (bulk capturing). Fig. 4 shows evidence that more than half of the interview partners expect bulk capturing from an RTLS. Hence SELECT should definitely implement such a possibility as do most existing RTLS competitors.

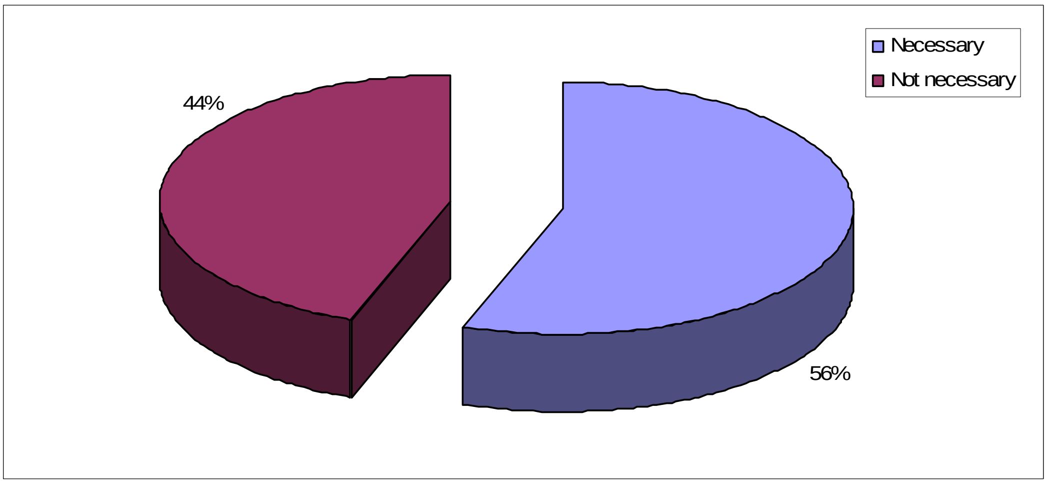

Fig. 4 Necessity of bulk capturing

2.4. How accurate has the system to be?

Fig. 5 shows the different use cases with their required accuracy on a logarithmic scale (in cm). 8 out of 9 interview partners need accuracy between 10 cm and 100 cm. Only for one use case, the position estimate needs to be less accurate (10m). The desired accuracy of 10 cm will not be possible due to the passive communication scheme envisioned for SELECT. Nevertheless the requirements will have to consider relatively low deviations of the estimates from the real position (cf. numbers in Chapter 3). Furthermore higher accuracies in hot-spots can be achieved by increasing the reader density i.e. reducing the mean distance to the readers.

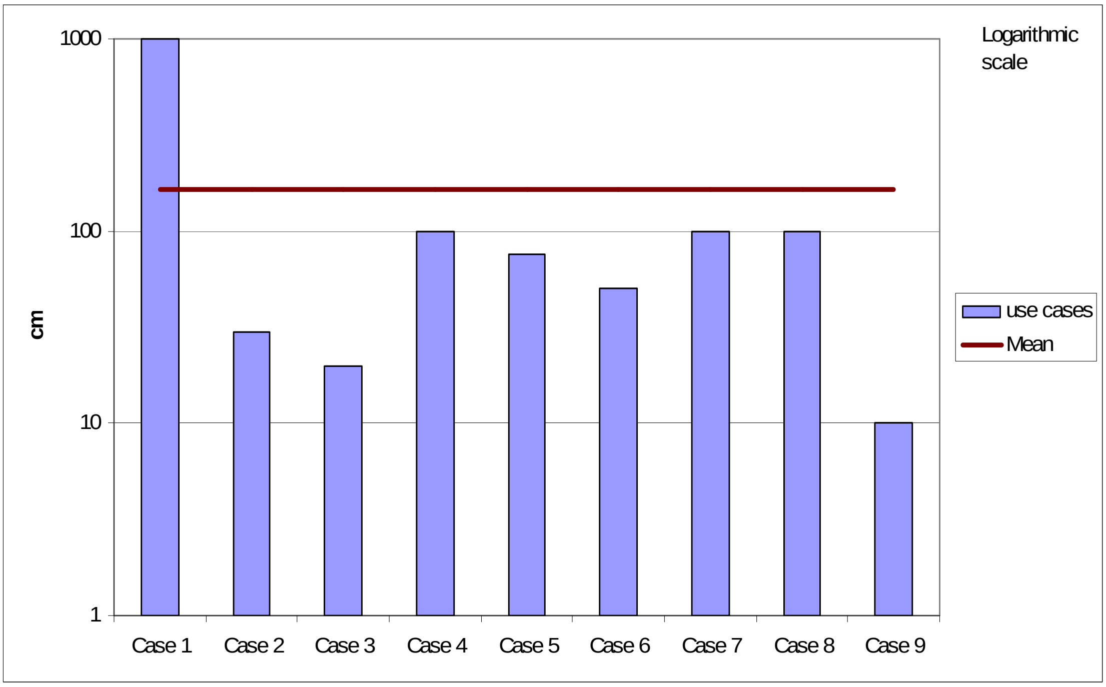

Fig. 5 Required location accuracy in cm

2.5. Is the locating process initiated by an event?

The aim of this question refers mainly to process monitoring where an event triggers the tracking in an unspecified manner – or a manner to be specified in the runtime of the project. This is useful if there are many objects in the same area, but only one or some Tags need to be tracked for a certain time span (cf. Fig. 6).

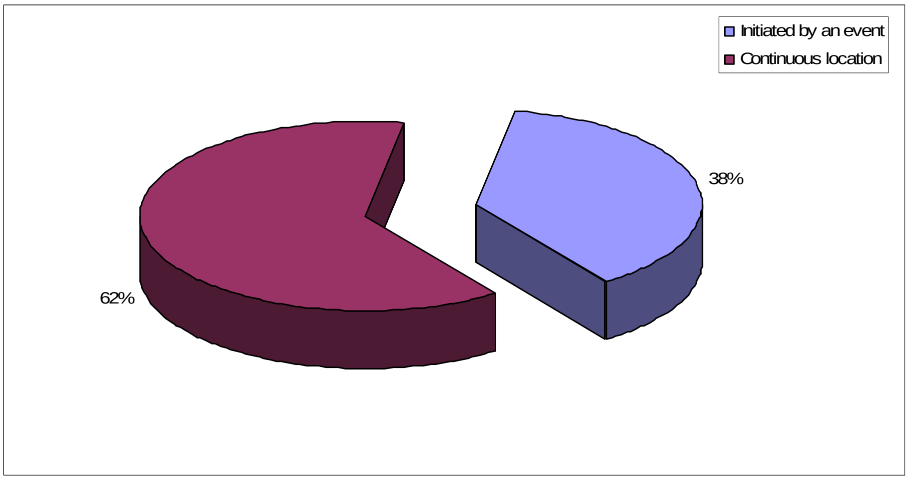

Fig. 6 Initiation of tracking

Such a feature becomes also extremely helpful if there is nothing to track in a general process state, unless an object just enters the coverage area. This would enable a self-decided shut-down of the system for the rest of the time saving energy and spectral/spatial capacity.

Even if the majority (52%) of use cases prefers continuous tracking versus triggered tracking (38%) this possibility should be kept in mind.

2.6. How often should there be an update of the position in the RTLS?

The required tracking rate has been declared in the interval between 0,003 Hz and 1,000 Hz, whereby the mean is 0,236 Hz corresponding to locating intervals of 1 s to 10 min. These numbers relate to a single Tag in a time interval of consideration. The recorded values are presented in Fig. 7.

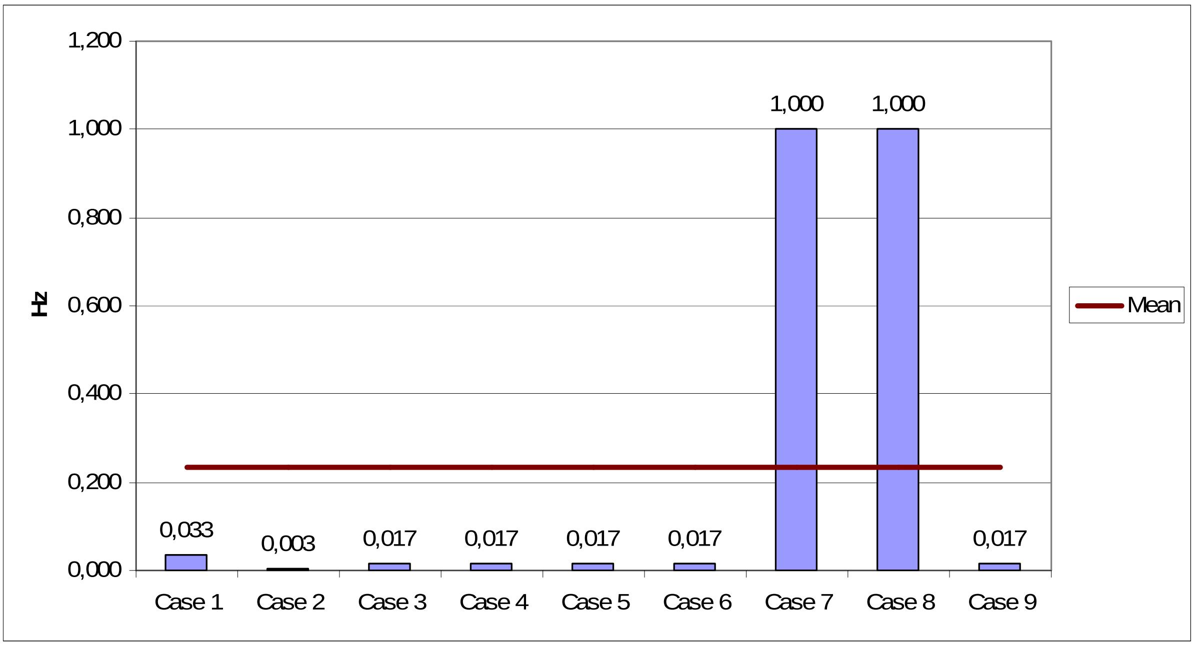

Fig. 7 Tracking rate requirements

However, the end users seemed to be unaware that moving objects like forklifts need considerably higher update rates to be tracked reasonably. Also most commercial locating systems and RFID hardware provider support update rates around 10 Hz for that purpose, such that SELECT should aim at similar numbers. The update rates may also vary for static and moving objects taking the different needs into consideration.

2.7. Besides positioning, is there any other information to be measured?

Six of the use cases as depicted in Fig. 8 need only positioning information. Three use cases demand the temperature to be measured and stored directly on the object respectively on the tag in order to be remotely read.

In one case, there has been the request to integrate a quality indicator for the tagged product or good (such as the imbalance of an item taken from a turning centre or some manufacturing state of some other working item) in the tag data. However, the SELECT Tag will certainly not be able to measure any quantity or quality related to the object, but perhaps to store externally measured quality data in the RFID memory banks.

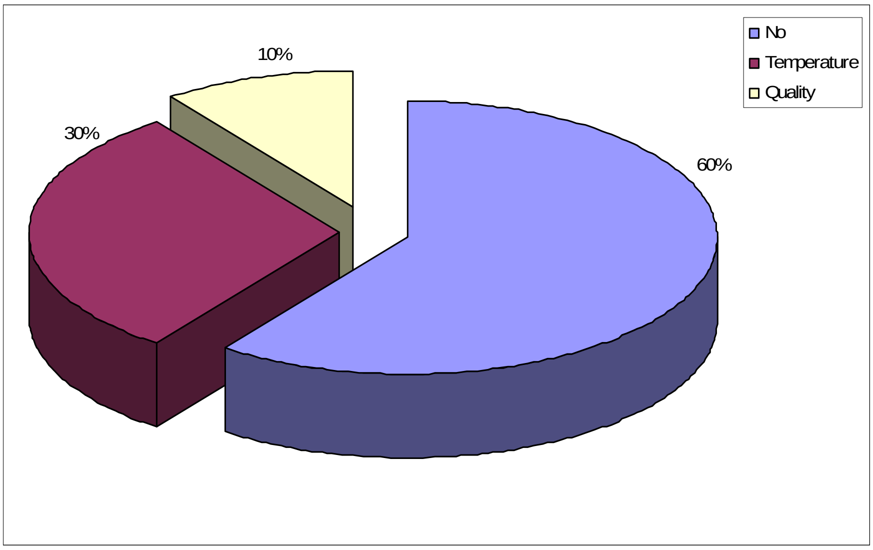

Fig. 8 Measurement of other information

2.8. How robust and well protected have the Readers to be?

For product development there are various crucial requirements besides the purely technical and/or functional specifications. Depending on the environment this question asks for various kinds of robustness statements. It was an open question with no predefined answers, more than one category per use case is possible.

Only a tiny fraction of use cases demand no special protection requirements at all for readers and tags. The most required protection seems to be against dust (tags 29%, readers 38%). Water splash resistance is required for 21% of the tags and 23% of the readers. Further requirements are shown in Fig. 9 below.

Beyond that, the SELECT Tags will need to cope with mechanical stress up to some level due to their attachment on the movable objects demanding a robust case or box as well as an enduring strategy attaching them (gluing, screwing). This demand is less severe for the Readers because they will be attached in secure spots out of reach of mechanical hazards, e.g. due to forklifts.

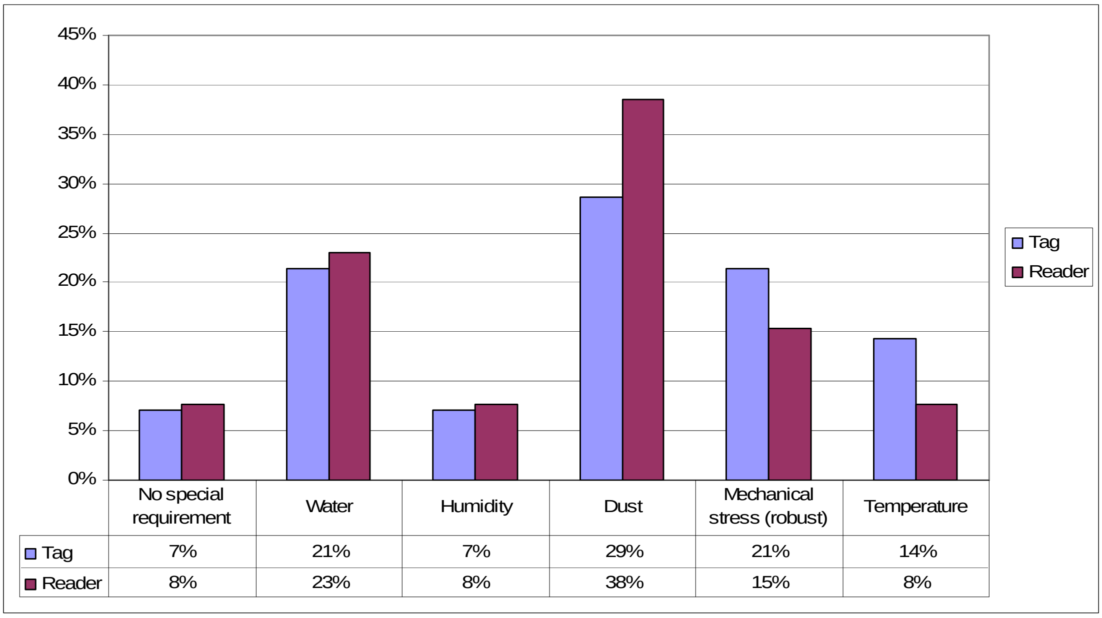

Fig. 9 Protection and robustness requirements for tags and readers

2.9. Should the power supply of the Tag be external or internal?

This question has been included in order to find out, how much effort should be invested in the existence and optimization of battery supply. In the majority of use cases (60%) displayed in Fig. 10, it is intended to track objects which have neither power connector nor supply available (e.g. pallets, persons, static goods). Therefore internal power supply or completely passive tags must be chosen. Since the UWB part of the SELECT Tag cannot be powered in a completely passive way batteries will have to be integrated to power the control logic of the UWB part.

In contrast, 40% of the objects (mainly forklifts) to be tracked could well provide an external power supply for the attached Tags if they provide a respective interface.

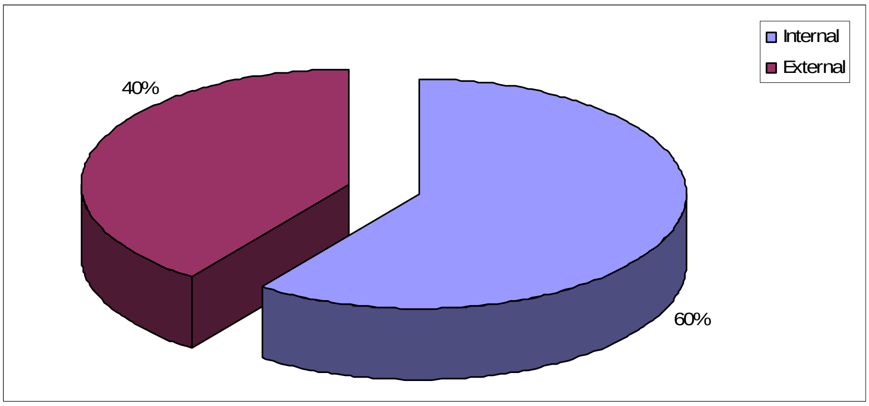

Fig. 10 Power supply of the tags

For the Readers due to their fixed attachment and the existing network cabling, the power supply is a less severe problem. Power over Ethernet may be a good choice if the power consumption remains below the current specified limit of 15 W.

2.10. Is there a maximum for the weight of the Tags with the battery included?

The majority of the use cases (cf. Fig. 11) does not rely on light weight tags. This means there are no strict requirements on the weight – but also on the size – of the tags and/or there exists no constraint on this issue.

Nevertheless, since SELECT will be in competition with other solutions on the market, the size shall be already in this first step as small as possible, e.g. have the area of a credit card with slightly higher thickness. Another reason for minimum sized SELECT Tags is the potential to attach (glue) the Tags to non-plain surfaces.

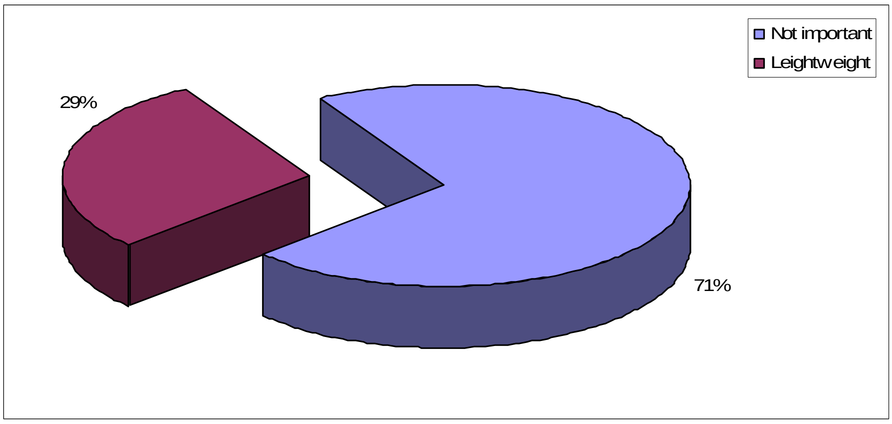

Fig. 11 Maximum weight of tags

2.11. Should the Tags be able to store data? If so, which data?

The question has intended to give the project workers a clue of the amount of data to be stored on the Tags. This open question without predefined answers has allowed multiple answers per category for all use cases as shown in Fig. 12.

Nearly half of the use cases (46%) do not need to store any information at all. The temperature is required in 11%, manufacturing or material information is needed in 11% and order information is needed in 22% of the use cases. This question and its results are closely related to those in Section 2.7. Thus for examples of quality indicators please have a look there.

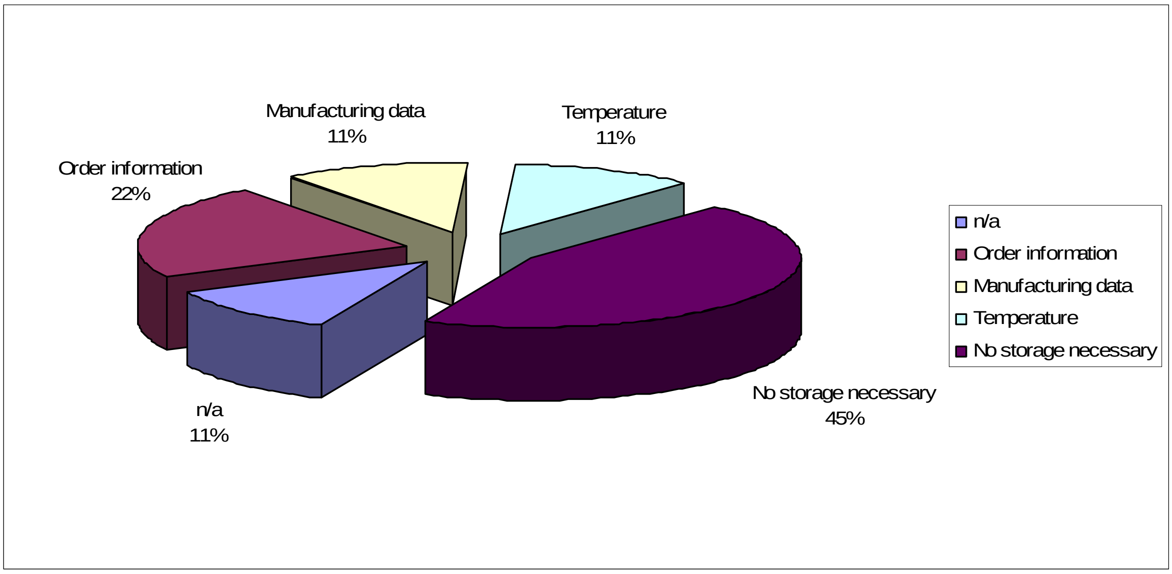

Fig. 12 Data which should be stored by a tag

2.12. How large is the area, which has to be monitored?

When it comes to object tracking a crucial factor is the area. This factor has strong influence on the cost of a localisation system. The following figure shows the size of the area in m^2. The intended coverage areas differ from 45000m^2 to several dozen m^2 depending on the use case at hand (see Fig. 13). This large variance may be covered with a scaled multi-cell or even multi-network approach, the latter with spatially separated coverage and serving areas.

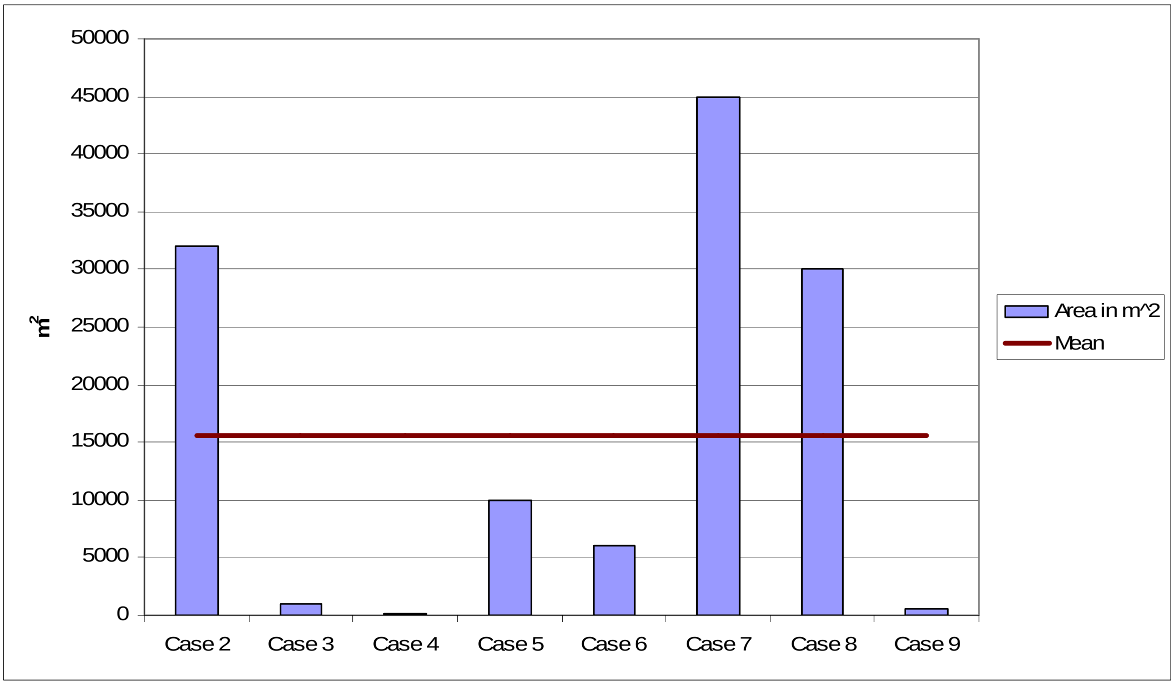

Fig. 13 Size of the coverage area

3. Requirements for the System

As shown in Fig. 15, the SELECT system will have three layered hierarchical architecture:

- At the top level, a **Central Unit** will act as Location and Application Engine server (see details below), evaluating the spatial position for the Objects and providing interfaces and services for Application modules, as well as basic system Control and Configuration services.
- At the middle layer, a network of **Readers** will operate as "measurement devices", providing the basic ranging information to the Location Engine (e.g. estimated distances between Objects and the Reader), making use of the two ways UWB link. To do so, the Readers execute periodically a sort of polling operation to check the presence of Tags; the Tags answer this request with their unique identity information, making possible for Readers to identify each Tag and to compute the Round Trip Time and thus to estimate the distance from each of them. These ranging data (ranging events) are then transferred to the Central Unit to be further evaluated.

  As described in [2], there are use cases characterized by a huge Tag density or by a low Tag density but a very large surface to cover. To better satisfy these contrasting requirements, improving system scalability and modularity, the network of Readers will be organized in logical **cells**:

  - each cell will be dedicated to cover a specific area with a minimum number of Readers, able to satisfy the requested Tag density;
  - the coverage of big surfaces will be obtained by means of multiple adjacent cells working in parallel. In this way it will be possible to exploit large installations with a simple incremental approach.

  The effective architecture and interconnection of Cells will be analyzed and defined in WP4. Additionally, the application of relays (cf. Fig. 1) has been neglected in the system structure as displayed in Fig. 14.

- At the lower level the **Tags**, associated to the physical object, will provide the basic identification information to the Readers, by means of the UWB, backscattered link. The Tags will be designed to "answer" to periodical "polls" performed by the Readers by means of the backscattering modulation scheme presented in [4]. By estimating the Time of Flight of these messages, the Reader will be able to estimate the distance from each Tag.

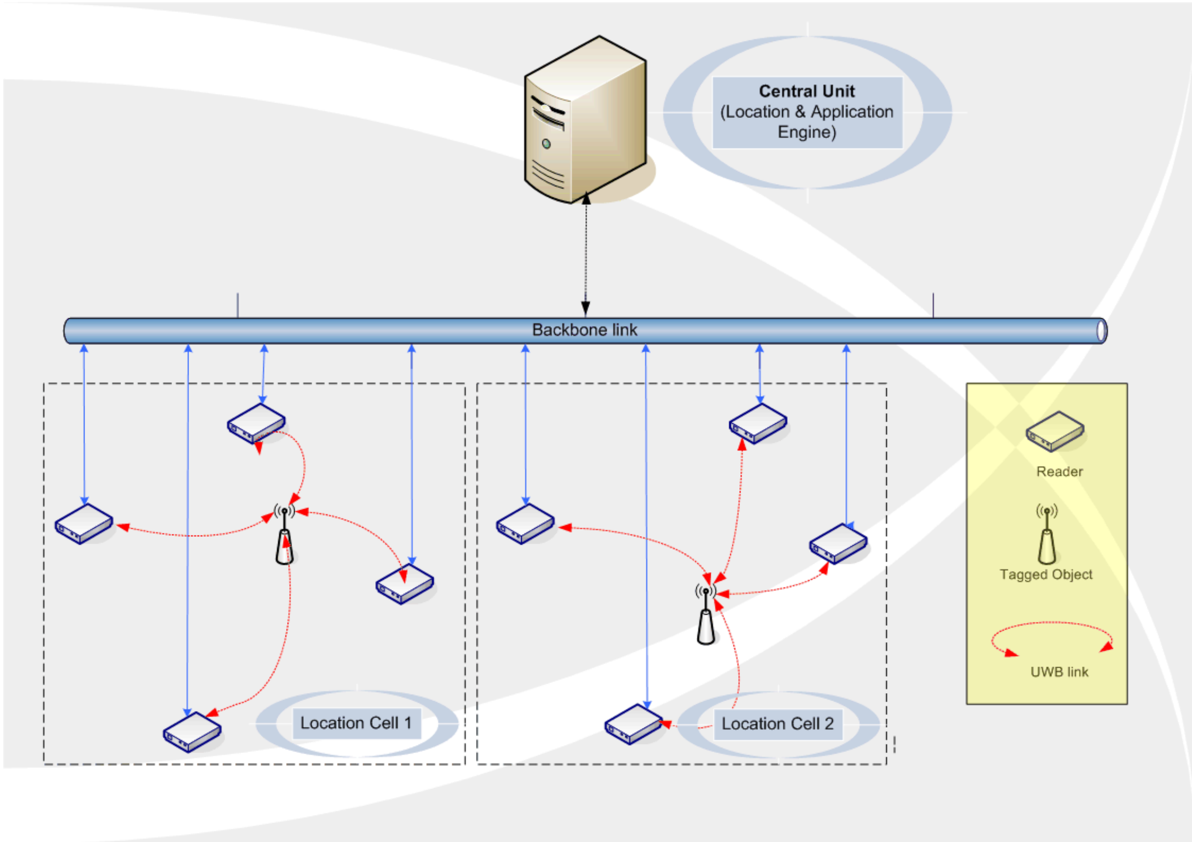

Fig. 14 Hierarchical architecture of the SELECT system with multiple location cells (without relays)

More specifically, the main functionalities performed by the Central Unit will be the following:

- Location and data fusion:
  - The main goal of the Central Unit is to compute, in real-time, the spatial location of each objects detected by the Readers. To accomplish this task, the Central Unit has to collect all the ranging events provided by the Readers, merging, filtering and fusing them[1], by applying the location algorithm(s) that will be defined in WP2. As final result, a **location event** will be generated and made available for further computation. The location event is basically composed by the following data:
    - object ID,
    - object spatial position (e.g. Cartesian or Polar coordinates),
    - timestamp,
    - quality/reliability indicator for the location
  - The second goal of the Central Unit is to store the location events related to every detected object, in order to create and update in real time the object tracking information database, the basic input to the Application Services. To

[1] The fusion task is made more easy thanks to the use of the Cells

accomplish this task, a proper software interface will be implemented, in order to ease the integration of the location service to external User Applications performing user processes. Please note the clear separation existing between the two levels, Location Engine and User Applications.

- Finally, the third goal of the Central Unit is to generate and distribute the synchronisation information needed to maintain the correct synchronicity between every system elements (with the accuracy required by the baseline location technology).

- Basic Application Service and System Configuration Service
  - Even if the main goal of SELECT system deals with the location process and not with application processes, it is important to implement, for the debug, testing and demonstration purposes of WP5 and WP7, a simple visual application service that
    - graphically represents the tracked object position and movements,
    - queries the current location of specific objects.
  - It very important also, to be able to perform the control and configuration task for the whole system, in orders to make possible the installation and setup activities required by the demonstration/pilot system of WP7.

Considering the SELECT systems as a black box, the Central Unit level implements the interface between the whole system and the User Applications. For this reason, **this section presents functional and numeric requirements defining the overall system functionalities and performance as perceived by the End User**, even if the responsibility to implement these functionalities is spread across the whole system. Moreover specific requirements for the Central Unit will be defined.

Inputs for requirements definition are coming from two sources:

- Analysis of the use cases coming from the interviews
- State of the Art of UWB RTLS (Ubisense, Mojix, Time Domain, ZES)

Since, in terms of measuring the performance of the system, accuracy and precision are important here a short definition of both is included.

Accuracy (**sometimes total accuracy**) is a measure for the statistical deviation of an estimate from the real position usually given as (root) mean square error. A high accuracy is defined as a low (root) mean square error.

Precision (**sometimes relative accuracy**) describes the statistical deviation from a mean position, usually presented as the variance or the standard deviation of the (potentially biased) estimate. Therein, a high precision is represented as a low variance or standard deviation.

Other representations of accuracy and precision include (temporal) ratios of confidence, i.e. being lower than some threshold for a certain percentage of time or of measurements. This representation can be seen as outage probability with the definition of exceeding the error threshold as outage event. For unbiased estimates both – accuracy and precision – coincide as do their respective measures the mean square error and the variance. The same holds true for their related outage probabilities.

If interpreted with respect to position estimates, it must be stated that due to the propagation conditions at certain spatial areas, system inherent or systematic errors (or biases) occur. These are directly related to these areas in the room, and are caused, e.g. by blocked LOS paths or extreme signal cancellations due to multipath for only one or some – sometimes also for all – Readers.

In principle from the RTLS point of view, the accuracy is the most important measure because it describes the task/objective related – i.e. locating an object in a room – performance measure, with contrast to the measurement related precision. For this reason the SELECT system requirements are given in terms of Accuracy. However the accuracy requires an accurate reference (position) determined externally. Due to the nature of the location measurement problem, biases and the relevant systematic errors cannot be prevented.

3.1. Functional Requirements

3.1.1. Interfaces

ID	Title / Description	Priority	Criticality	Feasibility	Risk	Source
S11_1	The Central Unit shall collect the “ranging” information coming from the network of Readers, basically these are • Reader ID, • object unique ID, • ranging data (e.g. a round trip time or distance), • ranging Timestamp, and • reliability or quality of location indicator.	high	medium	easy	high	[1]
S11_2	The Central Unit shall compute the spatial location of each tagged object detected by the Readers, based on the ranging information provided by the Readers. For each location event the following data shall be made available as location result (location event data) • object unique ID (i.e. the Tag id), • object spatial position (e.g. Cartesian or Polar coordinates), • location timestamp, • reliability or quality of location indicator, and • object type (→ tagged). These are the minimal data that shall be computed for every location event detected by the SELECT system and made available automatically to the User Application via a proper API and an open protocol for presenting location data.	high	high	medium	high	[1]

ID	Title / Description	Priority	Criticality	Feasibility	Risk	Source
S11_3	The Central Unit shall compute the spatial location of moving, untagged objects detected by the Readers, based on the radar information provided by the Readers. For each located event the following data shall be made available as location result (radar event data) • object unique ID (determined by the Central Unit), • object spatial position (e.g. Cartesian or Polar coordinates), • location timestamp, • reliability or quality of location indicator, and • object type (→ untagged). These are the minimal data that shall be computed for every radar detection by the SELECT system. They are made available automatically to the User Application via a proper API and an open protocol for presenting location data. If necessary to system operation, other possible information may be • a moving object destination, • a coarse size of the object, and • meta-information on the object.	low	high	hard	low	[1]
S11_4	The location event data must be stored in a permanent relational database, made available to the User Application server.	medium	low	easy	low	[1],[2]
S11_5	A basic User Application should be provided, showing in a graphical way, the located objects and their movements.	low	low	easy	low	[1],[2]
S11_6	External LAN: • The SELECT system shall use, for its interconnection to the host LAN infrastructure, standard Ethernet (IEEE 802.3 10 Base T, or IEEE 802.3U 100 BaseTX or IEEE 802.3z 1000 Base X Gbit) links with standard TCP/- or UDP/IP based protocols.	medium	low	easy	low	[1],[2]

ID	Title / Description	Priority	Criticality	Feasibility	Risk	Source
S11_7	Internal LAN: • The SELECT system, for its internal data transfer, shall use standard LAN Ethernet (IEEE 802.3 10 Base T or IEEE 802.3U 100 BaseTX or IEEE 802.3z 1000 Base X Gbit) connection with standard TCP/- or UDP/IP based protocol. This wired infrastructure should be used also to distribute the synchronisation signals.	medium	low	easy	low	[1]
S11_8	LAN separation: • The internal and external LAN shall be separated at physical layer.	low	low	easy	low	[1]

3.1.2. Functionality

ID	Title / Description		Priority	Criticality	Feasibility	Risk	Source
S12_1	The SELECT system shall be able to locate :	a) tagged objects (objects with an attached Tag),	high	medium	medium	medium	[1]
	These location objects (tagged and untagged) are differentiated within SELECT.	b) moving, untagged objects.	low	medium	hard	medium	[1]
S12_2	The location type shall be either	a) two-dimensional (2D) with, or	high	medium	medium	medium	[1],[2]
		b) three-dimensional (3D).	medium	high	medium	medium	[1],[2]
S12_3	The choice between the two location types (2D and 3D) shall be a user configuration choice.		low	low	easy	low	[1],[2]
S12_4	In a square cell of four Readers in a cell of 10 m by 10 m with each one Reader each in one corner attached at 2 m height, the 2D location accuracy [2] for tagged objects shall be	a) 20 cm with 75% of confidence for static object, For the measurements the Tag shall be located in the centre of the square of Readers, i.e. within the central 1 m × 1 m, The measurement rate shall be 1 Hz.	medium	high	hard	high	[1],[2]
		b) less than 1 m with for moving object at maximum speed. The Tag shall be located in the centre of the square of Readers, i.e. a central square of 5 m × 5 m, the rate shall be 10 Hz.	low	high	hard	medium	[1],[2]

[2] The location accuracy derives non-linearly from the accuracy of the employed ranging values and is in total (regarding x, y, and z component) decisively larger than the ranging accuracy – at least for minimum configurations of Readers (three Readers for 2D or four Readers for 3D).

ID	Title / Description	Priority	Criticality	Feasibility	Risk	Source
S12_5	Another important scenario is given by the conveyor belt. Thus the system (4 Readers in a square of 5 m × 5 m in 2 m height with LOS condition to the Tag) shall be able to locate three consecutive objects at a speed of 3 m/s with an accuracy of less than 20 cm. In effect this enables the system to differentiate between consecutive objects, respectively, determine their order on the conveyor belt. The shape of the test objects shall be cubic with 0.5 m dimensions. Their minimum distance shall be 20 cm. The Tag position on the objects (top, bottom, left, etc.) shall be varied during the test. Other test cases, especially concerning NLOS scenarios, will be defined in a latter part of the project within the work on WP2.	low	high	hard	high	
S12_6	The aggregate event location capacity shall be • 1.500 events per second maximum. An important feature of the overall system is the capacity to process multiple location events per second, i.e. the total number of location events generated per second. This parameter depends on many other factors, mainly from • the number of objects in the location area, and • the update rate. At Central Unit server level, the aggregate capacity has to be considered, in order to estimate the computation power needed to match requirements for huge capacity applications. Nevertheless it should be noted that • the SELECT system will be logically organized in “cells”, each covering a defined area and characterized by a “cell location capacity”. The overall location area can be covered by “cell tailing”. • At Central Unit level, the computational power can be scaled up (e.g. using more powerful system and/or using cluster architecture). For these reason it is also important to specify the cell event location capacity (cf.S12_7).	medium	medium	medium	medium	[1],[2]

ID	Title / Description	Priority	Criticality	Feasibility	Risk	Source
S12_7	The cell event location capacity shall be • 300 events per second maximum within a 10 m × 10 m cell covered by 4 Readers. This number takes into consideration to have 1 Tag per square meter, on 5 vertical levels, 3/5 space usage, and an update rate of 1 Hz (cf. S13_2). (1 Tag/m² × 5 levels × 10 m × 10 m × 0,6) × 1 Hz= 300 events/s.	medium	medium	medium	medium	[1], [2]
S12_8	The maximum speed for located object shall be • 3 m/s. There is the need to locate static objects and to track moving objects (e.g. forklift).	low	medium	hard	medium	[1], [2]
S12_9	The operating range of UWB shall be • up to 15 m in open field conditions.	low	medium	hard	medium	[1], [2]
S12_10	The maximum number of Tags to manage shall be • 300 Tags per cell (cf. S12_7).	medium	medium	medium	low	[1[. [2]
S12_11	The maximum number of Readers and Cells to manage by the Central Unit shall be • 32 Readers in • 8 cells.	low	medium	medium	medium	[1[. [2]

3.1.3. Timing

ID	Title / Description	Priority	Criticality	Feasibility	Risk	Source
S13_1	The location latency shall be • 250 ms maximum. This is the total processing delay between the receiving of a Tag backscatter signal by a Reader and the generation of the location event on the Central Unit.	low	medium	medium	medium	[1],[2]
S13_2	The update rate shall be • 10 Hz maximum and • 1 Hz standard. In the standard operation mode 1 Hz update rate for active Tags is targeted. The use of passive or (semi)passive Tags as well as the need to track untagged object, leads to a solution in which the Readers have to "poll" periodically the presence of Tags, therefore an update rate shall be defined. The specified value allows for achieving the requested accuracy for moving objects.	medium	low	medium	medium	[1],[2]
S13_3	The time stamping accuracy (jitter) shall be • 10 µs maximum. It is very important that the event location time stamping has - besides a high accuracy – a high stability in order to ease cross-referencing the SELECT system location event data with other sensor systems. A possible way to define this requirement is to specify a maximum value for the location event time stamping jitter.	medium	low	low	medium	[1],[2]
S13_4	The Central Unit server shall provide the synchronisation signal to the Readers, with the precision and stability requested to reach the location accuracy specified.	medium	medium	low	medium	[1],[2]

3.2. Environmental Requirements

3.2.1. EMC

ID	Title / Description	Priority	Criticality	Feasibility	Risk	Source
S21_1	The Central Unit shall comply with the EMC rules and standards for industrial environments. according to the standards IEC EN 50081-2, IEC EN 55022 Cl. B and IEC EN 61000-6-2.	medium	low	easy	low	[1],[2], [5],[6], [20]

3.2.2. Temperature

ID	Title / Description	Priority	Criticality	Feasibility	Risk	Source
S22_1	Derived from the description of work, the operating range of the Central Unit in terms of the temperature shall be • from 0 °C to 50°C. On the one hand, this is the suitable range for commercially labelled electronic devices, and on the other hand, it considers that the Central Unit may be placed in a climatically controlled room.	low	low	easy	low	[1],[2],

3.2.3. Humidity

ID	Title / Description	Priority	Criticality	Feasibility	Risk	Source
S23_1	The operational humidity range for the Central Unit shall be • 0 – 95% non-condensing. This range is usually achieved in a climatically controlled room (cf. S22_1).	low	low	easy	low	[1],[2]
S23_2	The IP protection level of the Central Unit shall be • IP30 according to EN 60529.	low	low	easy	low	[1],[2], [18],[19].

3.3. Electrical Requirements

ID	Title / Description	Priority	Criticality	Feasibility	Risk	Source
S33_1	The Central Unit shall operate at a voltage of 230V (110 V) AC with a effective current of less than 16 A.	medium	low	easy	low	[1],[2]

3.4. Configuration Requirements

ID	Title / Description	Priority	Criticality	Feasibility	Risk	Source
S34_1	The Central Unit server shall act as a central configuration device for the complete system. For this purpose, • a logical, hierarchical model (management information base, MIB) for the configuration parameters shall be defined, • the MIB shall be stored in a permanent memory on Central Unit, • an agent functionality shall be made available to each system component to actuate the configuration, • a protocol should be defined to exchange data between Agent and Configuration server, • a graphical interface, based on internet technology shall be implanted on the Central Unit server to allow to a human user to manage the MIB element, • a special configuration parameter is represented by the SW running on the Readers, that shall be upgradeable under control of the Central Unit server.	medium	medium	medium	medium	[1],[2]
S34_2	The Central Unit server shall provide services and utilities to support and make easy the system installation and calibration procedure.	low	medium	medium	medium	[1],[2]

3.5. RAMS Requirements

The RAMS requirements, where RAMS stands for Requirements, Availability, Maintainability and Safety, are important measures for commercial product development in order to assure the market-readiness of the resulting apparatus or product. However the impact of the RAMS requirements on a prototype as developed in the context of SELECT are low. Therefore in this document we restrict ourselves to provide a few RAMS requirements on full system level, and we restrain from defining any RAMS requirements for the Tag and for the Readers.

In an intended commercial product development subsequent to the work on this project, RAMS requirements will have to be defined with great care and to a decisively greater extent.

3.5.1. Reliability

ID	Title / Description	Priority	Criticality	Feasibility	Risk	Source
	No reliability requirements have been defined due to the research nature of SELECT.					

3.5.2. Availability

ID	Title / Description	Priority	Criticality	Feasibility	Risk	Source
S35_1	Every Reader shall be self checking.	medium	medium	medium	medium	[1],[2]
S35_2	A cell (made by 4 Readers) shall work, even if a Reader is not working, with reduced performance: • In case of 2D location the accuracy should be reduced in a scalable way (graceful degradation, cf. S12_3) In case of 3D locating, a 2D position shall be provided.	medium	medium	hard	medium	[1],[2]

3.5.3. Maintainability

ID	Title / Description	Priority	Criticality	Feasibility	Risk	Source
S35_3	The system shall be easy to install and deploy.	low	low	easy	low	[1],[2]
S35_4	The system interfaces shall be easy to use and high level.	low	Low	medium	low	[1],[2]
S35_5	The system interface shall follow industry standards.	low	medium	easy	low	[1],[2]

3.5.4. Safety

ID	Title / Description	Priority	Criticality	Feasibility	Risk	Source
S35_6	The Central Unit shall be a standard, commercially available server and thus it shall be Marked at the origin with the CE and TÜV Marks, certifying the conformity to Electrical Safety requirements for Europe and Germany.	low	medium	easy	low	[1],[2]

4. Requirements for Tags

The Tags are the second core component of the SELECT system as defined in the DoW [1] and as displayed in Fig. 1. The Tags shall be attached to the objects to be identified and to be located. Thus, Tag and tagged object will be considered as one unified object. The Tags are capable of communicating with the Readers – or with the Central Unit via the Readers – in two widely independent transmission modes

- the Ultra High Frequency (UHF) mode of standard EPC Class-1 Gen2 [12], and
- UWB transmissions according to the regulation [7],[8].

The Tag will operate by pure signal backscattering and will be semi-passive. Semi-passive means that the Tag comprises a battery that is not used to actively transmit or amplify a signal, but the Tag requires the energy supply of the battery for the internal control logic. A (totally) passive Tag is not considered because the UWB pulses do not comprise enough energy to power-on the Tag. The UWB mode is used for location purposes, while the UHF mode is used for compatibility (e.g. to make possible the Identification outside the SELECT system) and possibly control purpose. Therefore, the UWB functionality may be considered as an extended add-on to the existing RFID functionalities to allow Tag localization. In principle, those two subsystems are totally independent from each other; however, the possibility to use the UHF signal to power-on the UWB section (as a means of RF energy harvesting) will be explored during the implementation phase of the SELECT project within task *T3.4: Analog front-end design of WP3*.

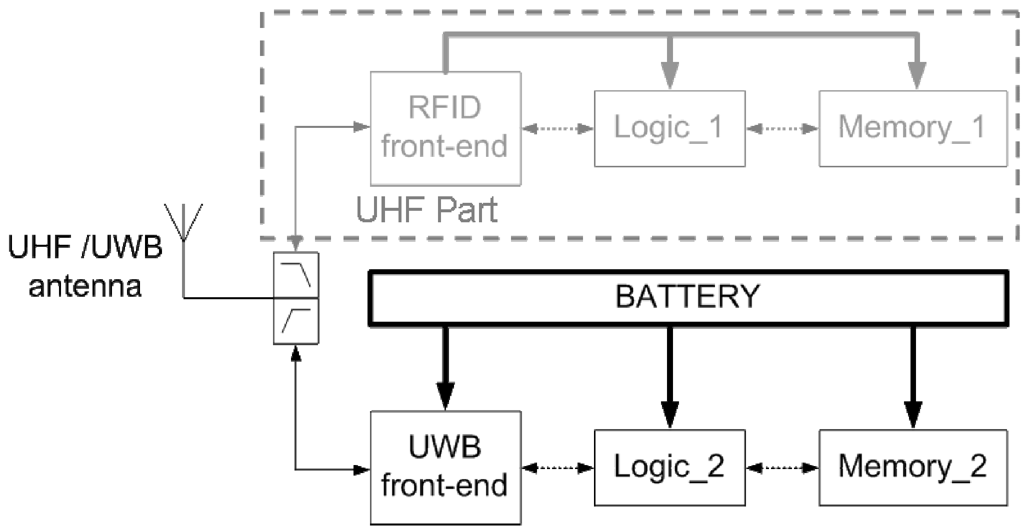

Fig. 15 Simplified block diagram of the SELECT Tag (battery is disconnected from the UHF part)

Fig. 15 displays a simplified block diagram of the preliminary tag architecture. The two subsystems (UHF and UWB) are totally independent from each other. UHF is fully passive, by harvesting the required power supply from the RF electromagnetic signal in the UHF band. One option under investigation in WP2 and WP3 considers the UWB section continuously powered on. However, according to energy budget evaluations, a wake-up mechanism initiated by UHF signaling may be required.

In Fig. 15, a diplexer has been used as tag to antenna interface only for a better comprehension of the drawing. In the case of two feeding ports on the dual UHF / UWB antennas, the diplexer will be avoided. This will be investigated within *T3.3: On-tag antenna design*.

To avoid the duplication of functionality between the UHF and the UWB, these two sections share the internal memory structure:

- A standard EPC memory is provided by the UHF section (Memory_1).
- A memory registry location is provided by the UWB section, mirroring the EPC memory value of the UHF section (Memory_2).

In this way, the EPC memory value can be used as Object ID information source for both Identification and Location functions. Moreover it will be possible to write the tag memory using the UHF mode only, without the need to implement "write commands" in UWB mode. In addition the UWB section has a second memory location to store the Tag Spreading Code, used to identify each Tag in the UWB backscatter link.

In the UWB mode the communication between Reader and Tag will follow the method described in [4], whereas the RFID section will operate as state-of-the art RFID systems, by back-scattering the AM-modulated incoming UHF CW as a PSK-modulated backscattered signal. Although the presented architecture is a preliminary selection as a starting point, the final architecture of the Tag will be selected within T3.4. However, more information about the tag architecture and preliminary decisions is available in D3.1 [21].

4.1. Functional Requirements

4.1.1. Interface

ID	Title / Description	Priority	Criticality	Feasibility	Risk	Source
T11_1	The Tags shall be capable of communicating with RFID Readers within all or any part of the frequency band ranging from 865,0 MHz to 868,0 MHz.	high	medium	easy	medium	[1],[2]
T11_2	The Tags shall be capable of communicating with UWB Readers within the lower UWB frequency band, ranging from 3,1 GHz to 4,8 GHz (cf. R11_2).	high	high	medium	medium	[1],[2]
T11_3	For Tag to Reader (and Reader to Tag) communication, a single Tag antenna shall be used for both UHF – UWB frequency bands.	medium	medium	hard	low	[1],[2]
T11_4	The antenna impedance shall be chosen at best in relation with the RF circuit design.	medium	medium	medium	low	[1],[2]

4.1.2. Functionality

ID	Title / Description	Priority	Criticality	Feasibility	Risk	Source
T12_1	The maximum Tag area shall be equivalent to the size of a credit card, i.e. 85 mm × 54 mm. The thickness is according to the use cases [2] less important and is mainly determined by the employed battery. It shall be limited by 10 mm.	medium	low	easy	low	[1],[2]
T12_2	The Tags shall communicate ID information by backscatter modulating the RF carrier coming from an RFID Reader in UHF and in UWB.	medium	low	medium	medium	[1]

ID	Title / Description	Priority	Criticality	Feasibility	Risk	Source
T12_3	The Tags shall be fully RFID compliant (EPC Class-1 Gen2, [12]).	medium	medium	medium	medium	[1]
T12_4	The Tags shall communicate ID information (i.e. the EPC code) by backscatter modulating the RF signal coming from a UWB Reader.	high	medium	medium	medium	[1]
T12_5	The maximum communication range with the Reader shall be 10 m (RFID) and 15 m (UWB). It may be required to trigger the Tags via UHF for UWB. Then one way communication with UHF from the Reader to the Tag over 15 m shall be achieved.	medium	high	hard	high	[1]
T12_6	Simultaneous UWB responses of multiple Tags shall be possible in order to allow a high system capacity.	low	low	medium	medium	[1],[2]

4.1.3. Timing

ID	Title / Description	Priority	Criticality	Feasibility	Risk	Source
T13_1	The Tag response latency of the Tags shall be equal with a tolerance in the order of 0.1 ns (3 cm).	medium	low	easy	low	[1],[2]

Due to the (semi-) passive communication schemes, no timing issues other than the upper and those arising from the compliancy with EPC Class-1 Gen2, [12] in T12_3 are expected to arise. Especially, the UWB backscattering is uncritical in these considerations.

4.2. Environmental Requirements

4.2.1. EMC

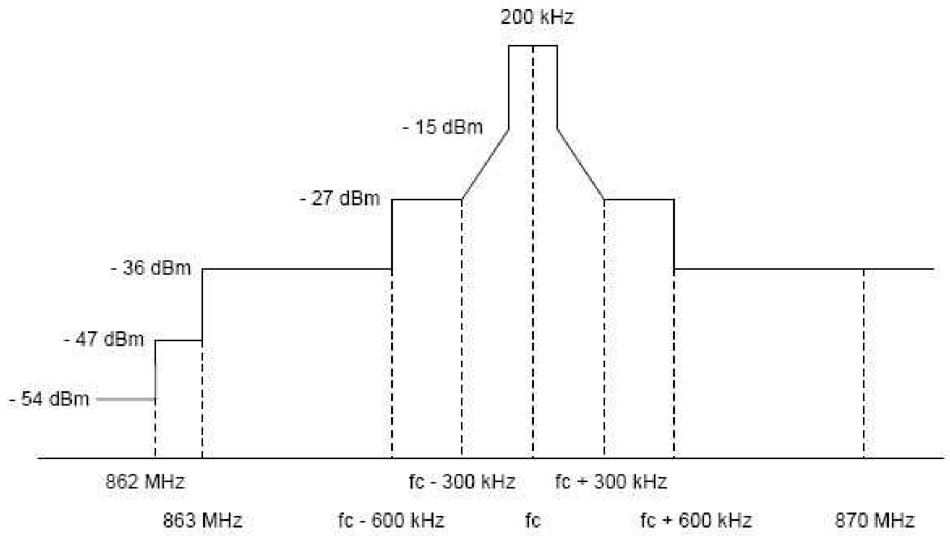

Fig. 16 Spectrum masks for UHF [13] (UWB mask is found in Annex I)

ID	Title / Description	Priority	Criticality	Feasibility	Risk	Source
T21_1	Tag emissions in the UHF band as defined in EN 302 208-1, clause 10.1 shall not exceed the limits in EN 302 208-1, clause 10.3.	medium	high	medium	medium	[13] clause 4.4.1
T21_2	Unwanted tag emissions in the UHF band as defined in EN 302 208-1, clause 10.1 shall not exceed the limits in EN 302 208-1, clause 10.3.	medium	high	medium	medium	[13] clause

ID	Title / Description	Priority	Criticality	Feasibility	Risk	Source
						4.4.2
T21_3	Tag emissions in the UWB band as defined in FCC Part 15 shall not exceed the limit of -41,3 dBm/MHz which is uncritical since the Readers provide already compliant signals that are backscattered with additional power loss due to propagation and in the Tag (cf. [8], [10], R21_6).	medium	high	easy	low	[7],[8]

4.2.2. Temperature

ID	Title / Description	Priority	Criticality	Feasibility	Risk	Source
T22_1	The Tag shall operate under the following temperature range: • -25 °C to +40 °C.	low	high	easy	medium	[13] clause 5.4.1.2

4.2.3. Humidity

ID	Title / Description	Priority	Criticality	Feasibility	Risk	Source
T23_1	The Tag shall operate under the following humidity range: • 5% - 95% (non-condensing).	low	high	easy	medium	[1]

4.2.4. Water and dust

ID	Title / Description	Priority	Criticality	Feasibility	Risk	Source
T24_1	The Tag shall be protected against dust and water splash according to IP 65 in EN 60529.	medium	medium	easy	medium	[1],[2], [19]

4.3. Electrical Requirements

ID	Title / Description	Priority	Criticality	Feasibility	Risk	Source
T3_1	The Tag can eventually incorporate a built-in battery to assist its operation.	high	medium	easy	low	[1]
T3_2	The battery lifetime shall have a minimum duration of 2 years under operation conditions.	high	high	medium	medium	[1],[2]

4.4. Configuration/TEST Requirements

ID	Title / Description	Priority	Criticality	Feasibility	Risk	Source
T4_1	The Tag shall be configurable in a test mode, so that, in the presence of an interrogation field, it transmits a continuous modulated response.	medium	medium	easy	low	[13] clause 4.2.4
T4_2	Normal test signals shall represent the normal modulated carriers received by the Tag.	medium	high	easy	low	[13] clause 6.1.1
T4_3	The Tag emissions outside the UHF sub-band edges shall be tested in accordance to ETSI 302 208-1, clause 10.2.	medium	high	medium	medium	[13] clause 10.1
T4_4	For normal test conditions, the Tags shall be tested under the following temperature range: • +15 °C - +35 °C.	low	medium	easy	low	[13] clause 5.3.1
T4_5	For normal test conditions, the Tags shall be tested under the following relative humidity range: • 20% to 75%.	low	medium	easy	low	[13] clause 5.3.1

ID	Title / Description	Priority	Criticality	Feasibility	Risk	Source
T4_6	For tests at extreme temperatures, measurements shall be made in accordance with the procedures specified in ETSI 302 208-1, clause 5.4.1.1, at the upper and lower temperatures of the range specified in section 4.2.2.	low	medium	easy	low	[13] clause 5.4.1

4.5. Fabrication requirements

ID	Title / Description	Priority	Criticality	Feasibility	Risk	Source
T6_1	The Tag chipset shall be fabricated with standard CMOS technology.	medium	high	medium	medium	[1]

5. Requirements for Readers

The networked Readers are the last key component of the system. They are connected via the backbone network to the Central Unit (cf. Fig. 1). The Readers or, as called in the context of RTLS, the anchor nodes have the capability to communicate via a UWB connection with the Tag and use the round trip time (RTT) data of the travelled data package to determine the distance to the Tag. Additionally, the Readers will compute the distance of untagged objects from reflection of the UWB signal in monostatic[3] or multistatic[4] way. However the latter structure will be hard to achieve because of very strict synchronisation requirements.

The Readers need to be synchronised to some common time base in order to attach time stamps to the RTT data conveyed to the Central Unit. Since the Central Unit is performing the main communication with the anchor nodes, the central time base will be, most certainly, situated there. The synchronization procedure will be executed via the wired backbone network.

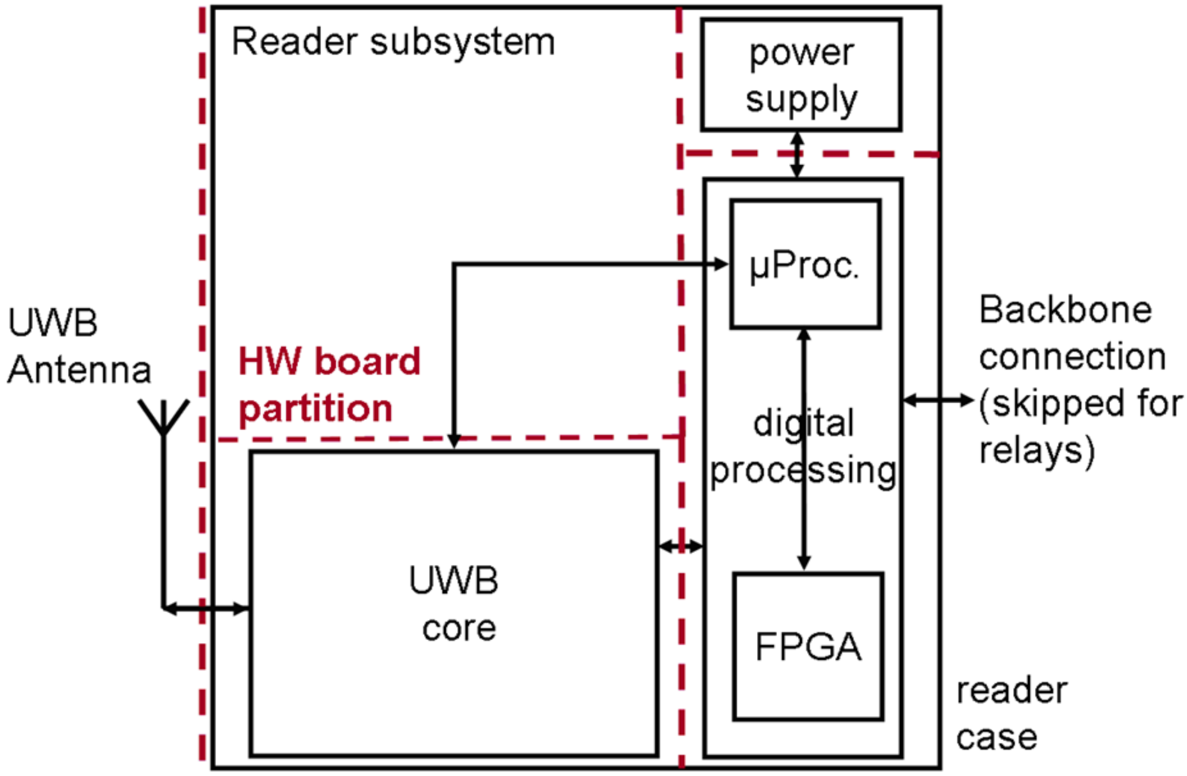

Fig. 17 Structural Reader architecture

The Readers will have a structure similar to the one depicted in Fig. 17 with

- one or two UWB antennas (for receiver and transmitter chain),
- a UWB core providing the analogue frontend with pre-processing and an ADC,

[3] monostatic: each reader employs only the UWB signals that it has radiated itself for radar detection.

[4] multistatic: the reader employ UWB signals emitted from other readers for radar detection. This requires a very strict synchronisation of the readers.

- a digital processing board, comprising FPGA and microprocessor, for digital processing tasks,
- the connection to an Ethernet based LAN in order to interconnect Readers and Central Unit (also enabling the temporal synchronisation), and
- a power supply.

Beneath the standard Reader, Relay nodes are planned in the DoW [1]. Those Relays are connected to a Reader via a wireless link, most probably in the UWB mode. The functionality of the Relays remains open in the requirement and will be decided after the system evaluation phase in WP2.

Relays as known in the application in large radio networks for data transmission and in the literature to work in two main flavours:

- decode and forward (DF), where the received signal is decoded firstly, before it is recoded and forwarded to the mobile unit respectively to the core network. These Relays need a complete analogue and digital transceiver lines.
- amplify and forward (AF), where the signal – together with the noise – is just received , amplified and retransmitted. Relays according to this idea, do in principle only need an analogue part with a limited (digital) controller.

The latter type of Relays is significantly easier to realise from the technical point of view, but the noise is amplified with the useful signal, which reduces the range with respect to DF Relays.

UHF RFID capability will be provided by commercial UHF readers.

5.1. Functional Requirements

5.1.1. Interfaces

ID	Title / Description	Priority	Criticality	Feasibility	Risk	Source
R11_1	The Reader shall comprise a built in LAN adapter (Ethernet IEEE 802.3 10 Base T, or IEEE 802.3U 100 BaseTX or IEEE 802.3z 1000 Base X Gbit)) for wired communication with the Central Unit and eventually with other Readers. Communications will be based on an IP protocol stack (LAN standard according to other requirements).	low	medium	easy	medium	[1]
R11_2	The Reader shall be capable of sending and receiving *high-layer* requests, acknowledgements, triggers, and data messages, like the ranging and radar data (Tag ID, distance and reliability), as well as control messages related to Reader status, to update data, etc. according to an open protocol. Especially, the Reader shall pass the following ranging data to the Central Unit • Reader ID, • the object unique ID (RFID) or, for radar, a radar identifier, • the ranging data (e.g. a round trip time or distance), • a ranging timestamp, and • a reliability or quality of location indicator.	high	high	medium	high	[1]
R11_3	Relay nodes shall be connected to the core network via a wireless connection to the Reader node of interest. The Reader shall be capable of passing the required data between the Central Unit and at least one relay node.	medium	medium	hard	medium	[1]
R11_4	The Reader shall provide the prerequisites to be synchronized via the fixed LAN network, and in order to synchronize with UHF transmission if needed, and in order to produce reliable time stamps. Synchronisation may be needed if simultaneous UHF and UWB backscattering or reception in the Reader proves infeasible within the project.	medium	medium	medium	medium	[1]

ID	Title / Description	Priority	Criticality	Feasibility	Risk	Source
R11_5	The Reader shall provide a wireless duplex communication capability: wireless communication with Tags and Relays, using the UWB and/or UHF links. The relay shall provide the same kind of wireless communication with Tags and Readers. The Reader shall comprise all physical and software components for wireless communication (antenna, receiver, and transmitter) via a UWB link and a wireless protocol. The Readers shall be capable of sending all the messages to the Central Unit and receive all of them wirelessly from the relay (see above R11_2), especially the ranging information.	high	medium	hard	medium	[1],[12],[14]
R11_6	The Reader shall provide the necessary hardware and software capabilities for wireless synchronization of the Relays available in order to synchronize Relays with other Readers and in order to produce reliable time stamps.	low	medium	medium	medium	[1]

5.1.2. Functionality

ID	Title / Description		Priority	Criticality	Feasibility	Risk	Source
R12_1	The Reader node shall be capable of ranging Tags, i.e. determining the distance from round trip time (RTT) measurements of the signal travelling from the signal to the Tag and back. These capabilities shall be compatible to the location accuracy of the system (see S12_4).	The Tag ranging accuracy at a distance of 7.35 m (corresponds to a 4 reader constellation with the Readers at 2 m height and 10 m distance) shall be in LOS condition below • 12 cm corresponding to 20 cm for 2D accuracy within 75% of confidence.	medium	high	medium	medium	[2] Q20.5: UC 2,3,6; resp. UC 4,7,8
		At maximum velocity of 3 m/s radially approaching or departing the Reader, the ranging accuracy shall be at a distance between 4.85 m and 9.85 m below • 60 cm corresponding to 1 m for 2D accuracy.	low	medium	medium	medium	[2] Q20.5: UC 2,3,6; resp. UC 4,7,8
R12_2	The capacity of a Reader for locating Tags shall be 300 ranging events per second.		medium	medium	easy	medium	S12_7
R12_3	The resolution of the output values of the Reader (value resolution and quantization, and not theoretical) in the Tag ranging mode shall be in the order of 1 cm, which is an order of magnitude below the values defined in R12_1 and R12_2.		medium	medium	easy	medium	T11_1A
R12_4	The Reader node shall be capable of radar operation i.e. determining the distance from round trip time (RTT) measurements on UWB signals reflected from surrounding objects without Tags. The radar accuracy at a distance 7.35 m shall be measured at a maximum velocity of 3 m/s radially approaching or departing the Reader in LOS conditions. The resulting ranging accuracy shall be between 4.85 m and 9.85 m distance below • 60 cm corresponding to 1 m for 2D accuracy		low	medium	medium	medium	[2] Q20.5: UC 2,3,6;

ID	Title / Description	Priority	Criticality	Feasibility	Risk	Source
R12_5	The resolution of the output values (value resolution respectively quantization) of the Reader in radar mode shall be in the order of 1 cm which is an order of magnitude below the values defined in R12_1 and R12_2.	low	medium	easy	medium	T11_1A
R12_6	The minimum object size to be detected from a distance of 15 m shall have an active radar area cross-section of • 0.5 m², which is the approximate size of a small person from the side 1.5 m x 0.3 m), at a maximum distance of 20 m. The person can be simulated by a non-metalized cylinder of 1.5 m height and 0.3 m diameter and similar reflection properties of the material (water). • 0.5 m² with metal surface from 20 m distance. The object is the minimum part of an obstacle or a fork lift to be detected. It can be simulated by a cube with 71 cm side length. Both detection events shall have a probability of detection misses below 10% and a probability of false alarms below 10%.	medium	medium	medium	medium	UC 4,7,8 [2] Q20.1

5.1.3. Timing

ID	Title / Description	Priority	Criticality	Feasibility	Risk	Source
R13_1	The normal update rate for Tag ranging shall be above 1 Hz. The maximum update rate for moving Tags shall be 10 Hz.	medium	low	easy	low	Max(UC) [2] Q20.9
R13_2	The update rate for radar ranging shall be 1 Hz.	low	medium	low	medium	Max(UC) [2] Q20.9
R13_3	The minimum time resolution of the Reader for radar and Tag ranging shall be below 1 ns.	medium	medium	hard	medium	UC 2,3,6 [2] Q20.5

ID	Title / Description	Priority	Criticality	Feasibility	Risk	Source
R13_4	The maximum allowed jitter of the ranging values shall be below 0.3 ns.	medium	medium	hard	medium	UC 2,3,6 [2] Q20.5
R13_5	The maximum delays for a message passing from the Tag to the Central Unit is 250 ms. The maximum delay for a ranging message is 250 ms (cf. S13_1).	medium	medium	hard	medium	S11_2
R13_6	The timing jitter for the time stamps shall be weaker than 10 µs (cf. S13_3).	low	medium	hard	medium	S11_3
R13_7	The synchronisation accuracy of the Reader initiated from the Central Unit shall be below 10 µs (root mean square).	low	medium	hard	medium	S11_3

5.2. Environmental Requirements

5.2.1. EMC

ID	Title / Description	Priority	Criticality	Feasibility	Risk	Source
R21_1	The Readers must abide to EMC regulations for the manufacturing and warehouse environments according to the standards IEC EN 50081-2, IEC EN 55022 Cl. B and IEC EN 61000-6-2.	medium	low	easy	low	[1],[2], [5],[6], [20]
R21_2	The Reader operation must comply with the regulation in EN 301 489-1 [15] for radio systems and ERC Recommendation 70-03 [14] for short range devices.	medium	medium	medium	medium	[14], [15]
R21_3	The Reader shall be conformant to the regulation [8], [10] (cf. ANNEX I: UWB regulation) use • - 41.3 dBm/MHz (0 dBm/50 MHz peak) from 3.1 GHz to 4.8 GHz. The use of the frequency bands 3.1 GHz – 4.8 GHz implies extra measures in Europe, like DAA requiring interference detection capabilities according to ECC Report 120 [10]. LDC will be implemented as a demonstrating the possibility to abide to the regulation in	medium	high	medium	medium	[1], [7], [8], [10]

ID	Title / Description	Priority	Criticality	Feasibility	Risk	Source
	Europe, however LDC will reduce the number of events according to S12_6 and S12_7. Another demonstration will use no interference mitigation to show the capability to reach the specifications S12_6 and S12_7 with the above limit of -41.3 dBm/MHz. The minimum bandwidth of the Reader signal must be beyond 500 MHz in order to comply with US regulation.					
R21_4	Theoretical research shall provide path to a SELECT system with DAA mechanisms. DAA will not be implemented in the prototype for the SELECT Readers.	low	medium	medium	low	[1], [10]
R21_5	The use of the frequency bands 6 GHz – 8.5 GHz with Power spectral density at most -41.3 dBm/MHz without extra interference countermeasures according to Commission Decision L 55/33 [8] remains as an option for SELECT.	low	medium	hard	medium	[8]

5.2.2. Temperature

ID	Title / Description	Priority	Criticality	Feasibility	Risk	Source
R22_1	The temperature range for the guaranteed Reader operation shall be • 0° C – 40° C. In [13] a temperature range between -25° C and 40° C is proposed which has been set for T22_1. However electronic components in the (cheapest) "commercial" specification (e.g. [16], [17]) are only guaranteed to work properly in the range from 0° C to 60° C. Due to the prototype nature the operation range of the Readers will be restricted. In commercial version the components could be chosen according to the "industrial" classification.	low	low	low	low	supplier [16], [17]; [13], clause 5.4.1.2

5.2.3. Humidity and Particles

ID	Title / Description	Priority	Criticality	Feasibility	Risk	Source
R23_1	According to ISO 20653 and EN 60529, the IP protection level shall be • IP 10 for prototyping in laboratory (protection against dust, no protection against humidity) • IP 13 for the demonstrator (protection against dust, protection against water spray) • IP 54 for the product in industrial environments (protection against dust, protection against water jets).	low	low	easy	low	[2].Q19.11, [18],[19]

5.3. Electrical Requirements

ID	Title / Description	Priority	Criticality	Feasibility	Risk	Source
R3_1	The power supply of the SELECT Reader shall be external (for Relays eventually also internal). Eventually Power of Ethernet shall be considered, which supports in the current standard 15 W (in future standards 30 W will be achieved).	medium	low	low	low	[1]
R3_2	The power dissipation of the SELECT Reader, i.e. Front End, FPGA, Microcontroller, shall be smaller than 30 W.	low	low	easy	low	[1]
R3_3	The used supply voltage of the Readers shall be in between 12V and 20 V in order to use standard power supply adapters or devices.	low	low	easy	low	[1]
R3_4	External power supply of the Reader shall be water resistant for outdoor usage. Low priority is set due to the prototyping nature of SELECT.	low	medium	easy	low	[2].Q19.11

5.4. Configuration Requirements

ID	Title / Description	Priority	Criticality	Feasibility	Risk	Source
R4_1	If RFID capability is implemented within the Reader a test mode according to ETSI 302 208-1 must be implemented.	medium	medium	easy	low	[13]
R4_2	For normal test conditions, the Readers shall be tested under the following temperature range: +15 °C - +35 °C in the UWB (and if used the UHF mode).	medium	low	easy	low	[13]

CONCLUSIONS AND FUTURE WORK

CONCLUSIONS

The essential role of Deliverable D1.2 is to define the requirements specification for the SELECT systems to be developed. The requirements have been compiled from three main sources:

(1) the interview data base assembled for the previous SELECT Deliverable D1.1 [2],

(2) general requirements determined by standardisation and regulation, and

(3) technological issues determined by the project definition [1] itself or technological and physical constraints.

The resulting requirements have been assessed with respect to their priority, the criticality of the task for the whole project, and its feasibility with intended means and technologies. From these input values, a risk factor has been created. Thus in the runtime of the project, risk assessment can be based on this preliminary work.

Where possible, numeric values and integrated testability issues have been provided in order to grant the verifiability of the requirements. In each development step, where feasible, the requirements and the risks shall be counterchecked with the current system, Central Unit, Tag, or Reader design and simulation and emulation values.

NEXT STEPS

This document will be used within the SELECT consortium as a basis for the work packages WP2, WP3, WP4, and WP5). Based on these results, system specifications will be developed in strong cooperation of the work packages WP2, WP3, and WP4. They will allow for designing suitable architectures employing reasonable technologies to achieve the project targets.

In M14 there will be a short reevaluation of this document in order to verify the achievability of the given goals and adding a second Appendix, with test scenarios assembled in a matrix table shape.

REFERENCES

TABLES

FIGURES

LITERATURES

[1] SELECT Consortium, "SELECT – Smart Efficient Location and idEntification, and Cooperation Techniques: Description of Work", Technical Report, April 2010.

[2] K. Bogataj, T. Groboljšek, S. Lesjak, M. Molan, M. Bottazzi, S. Otto, and N. Hadaschik. "Report on Initial Problem Definition", available on www.selectwireless.eu, Tech. Rep., Nov. 2010.

[3] IEEE-SA Standards board, "IEEE standard 1233, 1998 Edition, IEEE Guide for developing system requirements specifications," Standard specification, Dec. 1998.

[4] D. Dardari, "Method and apparatus for communication in ultra-wide bandwidth RFID systems", International Patent Application PCT/IB2009/000 360, Feb. 2008.

[5] International Electrotechnical Commission, "IEC EN 50081-2: Electromagnetic Compatibility - Generic Emission Standard Part 2: Industrial Environment ", International standard, 1993.

[6] International Electrotechnical Commission, "IEC EN 61000-6-2: Electromagnetic compatibility (EMC)-Generic standards - Immunity for industrial environments ", International standard, Jan. 2005.

[7] Federal Communications Committee (FCC). "Revision of Part 15 of the Commission's rules regarding ultra-wideband systems", FCC first report and order 02-48, February 2002.

[8] Electronic Communications Committee. "ECC Decision of 1 December 2006 on the harmonized conditions for devices using Ultra-Wideband (UWB) technology with low duty cycle (LDC) in the frequency band 3.4-4.8 GHz", (ECC/DEC/(06)12), Dec. 2006.

[9] The Commission of European Communities. "Commission Decision on allowing the use of the radio spectrum for equipment using ultra-wideband technology in a harmonized manner in the Community, L 55/ 33", Official Journal of the European Union, Feb. 2007.

[10] Electronic Communications Committee. "ECC Report 120 (June 2008) on Technical requirements for UWB DAA (Detect And Avoid) devices to ensure the protection of Radiolocation in the bands 3.1 -- 3.4 GHz and 8.5 -- 9 GHz and BWA terminals in the band 3.4 - 4.2 GHz", Kristiansand, June 2008.

[11] European Parlament and Council. "Directive 2004/108/EC of the European Parliament and of the Council of 15 December 2004 on the approximation of the laws of the Member States relating to electromagnetic compatibility and repealing Directive 89/336/EEC", Dec. 2004.

[12] EPCglobal, "EPC Radio-Frequency Identity Protocols Class-1 Generation-2 UHF RFID, Protocol for Communication at 860 MHz – 960 MHz, Version 1.2", Industry standard specification, Oct. 2008.

[13] ETSI Standard, ”EN 302 208-1 – Electromagnetic compatibility and Radio spectrum Matters (ERM); Radio Frequency Identification Equipment operating in the band 865 MHz to 868 MHz with power levels up to 2 W; Part 1: Technical requirements and methods of measurement, Product Standard for 2 W RFID at UHF”, Nov. 2008.

[14] ETSI Standard, "EN 301 489-1: Electromagnetic compatibility and Radio spectrum Matters (ERM); ElectroMagnetic Compatibility (EMC) standard for radio equipment and services; Part 1: Common technical requirements", Aug. 2008.

[15] European Radiocommunication Committee, “ERC Recommendation 70-03 (Tromsø 1997 and subsequent amendments) RELATING TO THE USE OF SHORT RANGE DEVICES (SRD)”, Recommendation, Oct. 2010.

[16] http://www.xilinx.com/itp/xilinx10/help/iseguide/mergedProjects/xpower/html/xp_d_temperature_grade.htm.

[17] http://www.altera.com/products/devices/ind/ind-temp.html.

[18] International Organization for Standardization (ISO), "ISO 20653:2006, Road vehicles - Degrees of protection (IP-Code) - Protection ofelectrical equipment against foreign objects, water and access", Aug. 2006.

[19] International Electrotechnical Commission, “IEC EN 60529, Specification for degrees of protection by enclosures (IP Code)”, International standard, Jan. 1992.

[20] International Electrotechnical Commission, “IEC EN 55022, Information technology equipment. Radio disturbance characteristics. Limits and methods of measurement”, International standard, Dec. 1998.

[21] Unai Alvarado, “SELECT Deliverable D3.1 “Green” Tag design aspects and IC technology choice”, Technical Report, March 2011.

ANNEX I: UWB regulation

The Reader emission must abide to regulation of European (Commission Decision L 55/33) [8] and US (FCC Revision of Part 15) [7] authorities for ultra-wideband systems. Its power spectral density must be indoors (for hand held devices slightly lower limits are valid) in the US below

frequency range	average PSD limit
0.96 GHz – 1.61 GHz	-75.3 dBm/Mhz
1.61 GHz – 1.99 GHz	- 53.3 dBm/MHz
1.99 GHz – 3.1 GHz	-51.3 dBm/MHz
3.1 GHz – 10.6 GHz	-41.3 dBm/MHz
> 10.6 GHz	-51.3 dBm/MHz

Table 1. PSD limits according to the FCC [7]

In Europe, UWB devices must obey the stricter values given in the tables.

frequency range	average PSD limit (EIRP)	peak PSD limit(EIRP)
0.96 GHz – 1.6 GHz	-90 dBm/MHz	-50 dBm/50 MHz
1.6 GHz – 2.7 GHz	-85 dBm/ MHz	-45 dBm/50 MHz
2.7 GHz – 3.4 GHz	-70 dBm/MHz	-30 dBm/50 MHz
3.4 GHz – 4.8 GHz	-70 dBm/MHz	-30 dBm/50 MHz
4.8 GHz – 6 GHz	-70 dBm/MHz	-30 dBm/50 MHz
6 GHz – 8.5 GHz	-41.3 dBm/MHz	0 dBm/50 MHz
8.5 GHz – 10.6 GHz	-65 dBm/MHz	-25 dBm/50 MHz
> 10.6 GHz	-85 dBm/MHz	-45 dBm/50 MHz

Table 2. PSD limits according to the ECC [8]

If detect and avoid (DAA) or low duty cycle (LDC) according to ECC Report 120 [10] is used these limits can be raised in two main regions (while for LDC the region begins at 3.4 GHz).

frequency range	average PSD limit (EIRP)	peak PSD limit(EIRP)
3.1 GHz – 4.8 GHz	-41.3 dBm/MHz	-0 dBm/50 MHz
8.5 GHz – 9 GHz	-41.3 dBm/MHz	-0 dBm/50 MHz

Table 3. PSD limits according to the ECC with DAA (and LDC) [10]

Another intended interference mitigation technique related to DAA in the European regulation also includes transmit power control (TPC) where the power level of the radiated signals is adjusted according to measured signal strengths of nearby users. In their presence the power level is lowered. The main difference with DAA techniques is that bands with primary users are not completely avoided. The above tables of the spectral masks are summarized within the diagram in Fig. 18.

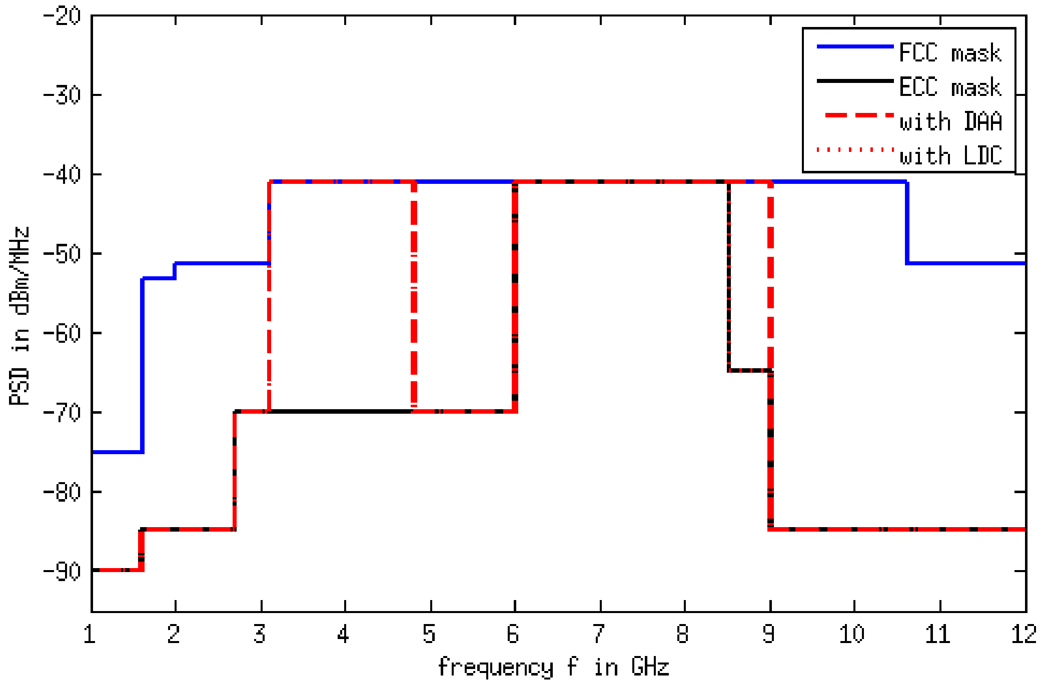

Fig. 18 Spectrum masks for UWB in the USA [7] and in Europe [8] with DAA and LDC regulation [10]