# FP7-ICT-2009-4 WHERE2 D1.1

*Scenarios and Parameters*

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# Scenarios and Parameters

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**Abstract:**

This document specifies the typical scenarios defined by the WHERE2 consortium that will be used as a reference for the design and evaluation of the positioning and communication techniques to be investigated and demonstrated in this project. One scenario is characterized by an underlying wireless infrastructure deployed in a given context and a validation and test case. The retained solution consists of a heterogeneous wireless infrastructure in which a wide-range centralized system coexists and cooperates with a short-range ad-hoc peer-to-peer structure. The centralized system is based on 3GPP-LTE. It includes relaying and deployment of femto-cells. The short-range system relies either on ZigBee (IEE.802.15.4) or Impulse Radio - Ultra Wideband (e.g. IEEE 802.15.4a). The wireless infrastructure is considered in a given context characterized by the physical environment in which the infrastructure is deployed, the type and modalities of the used terminals, the level of cooperation of the heterogeneous systems, and the user mobility. A validation and test case describes a particular implementation of specific applications on the wireless infrastructure. These applications utilize the algorithms and technological solutions proposed by WHERE2. In this way these algorithms and solutions are validated and tested in (close-to-)real conditions. In total 1 generic scenario and 6 validation and test cases are defined in this document.

**Keyword list:** Scenarios, Heterogeneous systems, Cooperative positioning, LTE , Cognitive Radio

# Executive Summary

The availability of position information plays an increasing role in wireless communications networks already today and will be an integral part of future systems. These systems inherently can offer the ability for stand-alone positioning especially in situations where conventional satellite based positioning systems such as GPS fail (e.g., indoor). In this framework, positioning information is an important enabler either for location and context-aware services or even to improve the communications system itself. The WHERE2 project is a successor of the WHERE project and addresses the combination of positioning and communications in order to exploit synergies and to enhance the efficiency of future wireless communications systems. The key objective of WHERE2 is to assess the fundamental synergies between the two worlds of heterogeneous cooperative positioning and communications in the real world under realistic constraints. The estimation of the position of mobile terminals (MTs) is one of the main goals in WHERE2. The positioning algorithms combine measurements from an heterogeneous network infrastructure and complement them by cooperative measurements between MTs, additional information from inertial sensors, and context information (e.g. prior or acquired knowledge of physical maps and radio conditions). Based on the performance of the geo-aided positioning strategies (in the sense of accuracy, complexity, overhead of signalling, reliability of the provided information, etc.) the interaction with coordinated, cooperative, and cognitive networks is assessed. This is done under realistic scenarios and system parameters following on-going standardization processes. A joint and integrated demonstration combining multiple hardware platforms provides a verification of the performance of dedicated cooperative algorithms.

This first technical deliverable of the WHERE2 project defines the key scenario and its parameters. Numerous use cases exist today and many more will be developed tomorrow based on innovative algorithms improving key performance criteria. It is not possible to list and identify all potential future use-cases for now and quantify them properly.Therefore, we chose a more general approach that allows us to answer questions about the expected performance in canonical configurations first (i.e. with a given bandwidth, number of anchors, RAT, environment, etc.). This pragmatic approach spans a multi-dimensional matrix of parameters to interpolate the performances between the different - already evaluated - use-cases. The use-cases presented in Section 2 belong to six different domains. The well known location based services are part of the multimedia services, as well as social networks and applications in shopping mall environments (e.g. commercial services). The second domain describes use-cases to improve communication networks from the view of network operators. The third domain focuses on green applications, like city lights and energy efficient communications. The fourth domain outlines numerous challenges in transportation systems, like parking garage assistance for cars or the security on the track of railway workers. The fifth domain focuses on health and automated applications at domestic homes. The last domain looks into security and safety applications in different environments, like airports or other public places. All these domains have in common mostly GPS-denied environment and the presence of multiple cooperative, mobile, and multi-standard terminals.

The key parameters of the use-cases are extracted and grouped under a single umbrella - - called generic scenario as discussed in Section 3.1. This generic scenario is characterized by five major properties. First, the *potential of the terminal* itself, e.g. which RATs can be processed by the mobile terminal, are these RATs available at the same time, etc. Second, *the mobility of mobile terminal or of the environment* defines e.g. impacts on the validity of (relative) positioning information. Third, the *physical environments* considered are mainly indoor environments or environments where satellite-based solutions are not applicable in an efficient way. The different kind of indoor environments impact the mobility as well as the connectivity. The fourth property is the *existing and available infrastructure* around the mobile terminals. Here a special focus is on femto-cells addressing the *indefinite* availability, interference issues between femto-cells and macro-cells and the imprecise location of the base stations. Finally, the fifth property is the *level of cooperation* between mobile terminals. All properties and the appropriate parameters are grouped into a single comprehensive table and linked to the described use-cases. The generic scenario is also depicted in Figure 13. Based on the generic scenario six validation and test cases are defined. They all have in common to specifically address one of the defined working environment (or a combination of multiple ones). The first subsection in Annex (cf. Section 5) provides an in-depth description of how the

different research tasks defined within WHERE2 address and include the specific validation and test cases to concede a common framework for the algorithmic research work. Two subsections follow, that provide a brief overview of knowledge gained in the WHERE project such as the models designed in that STREP. For instance, the channel models, mobility models and error models of TOA or RSS measurements. In month six of the WHERE2 project WP4 will start to define its specific scenario setup that will be used for system integration and to address how the different hardware platforms will cooperate. A first overview of the individual platforms serves as an initial link how the validation and test cases will be used. Finally, numerous FP7 EC projects are examined as to how they use positioning information.

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## List of Acronyms and Abbreviations

| | |
|---|---|
| 3G | $3^{rd}$ Generation (A mobile communications system of the $3^{rd}$ generation.) |
| 4G | $4^{th}$ Generation (A mobile communications system of the $4^{th}$ generation.) |
| AAU | Aalborg University |
| ABS | Antilock Brake System |
| ACO | Acorde Technologies S.A |
| ADC | Analog To Digital Converter |
| AOA | Angle Of Arrival |
| AWGN | Additive White Gaussian Noise |
| BS | Base Station |
| CBRNE | Chemical, Biological, Radiological, Nuclear Or Explosive |
| CEA | Commissariat l'Energie Atomique - Leti |
| CoA | Care of Address |
| CR | Cognitive Radio |
| DBPSK | Differential Binary Phase Shift Keying |
| DLR | Deutsches Zentrum Für Luft- Und Raumfahrt E.V. |
| DSSS | Direct Sequence Spread Spectrum |
| DVB-H | Digital Video Broadcasting Handheld |
| ECID | Enhanced cell identification |
| EEPROM | Electrically-Erasable Programmable Read-Only Memory |
| EPS | Evolved Packet System |
| EUR | Eurecom |
| FAP | Femto Access Point |
| FPGA | Field Programmable Gate Array |
| GNSS | Global Navigation Satellite System |
| GPS | Global Positioning System |
| GSM | Global System For Mobile Communications |
| GUI | Graphical User Interface |
| HDTV | High Definition Television |
| HDF | Hybrid Data Fusion |
| HI-FI | High Fidelity |
| HKC | City University Of Hong Kong |
| HSDPA | High Speed Downlink Packet Access |
| HSPA | High-Speed Packet Access |
| I/O | Input/Output |
| ICIC | Inter Cell Interference Coordination |
| ICT | Information And Communication Technology |
| IEEE | Institute Of Electrical And Electronics Engineers |
| IF | Intermediate Frequency |
| IMU | Inertial Measurement Unit |
| IP | Internet Protocol |
| IPTV | Internet Protocol Television |
| ISM | Industrial Science And Medical |
| IT | Instituto Telecomunicaes |
| JTAG | Joint Test Action Group |
| LAN | Local Area Network |
| LBS | Location Based Services |

| | |
|---|---|
| LDR | Low Data Rate |
| LNA | LOw Noise Amplifier |
| LOS | Line Of Sight |
| LPP | LTE Positioning Protocol |
| LTE | Long Term Evolution |
| MAC | Medium Access (Medium Access Layer) |
| MER | Mitsubishi Electric Merce |
| MIP | Mobile IP |
| MHZ | Megahertz |
| MT | Mobile Terminal |
| NLOS | Non Line Of Sight |
| OFDM | Orthogonal Frequency-Division Multiplexing |
| OQPSK | Offset Quadrature Phase-Shift Keying |
| OTDOA | Observed Time Difference Of Arrival |
| OTE | Hellenic Telecommunications Organization |
| PAN | Personal Area Network |
| PCB | Printed Circuit Board |
| PER | Probable Error In Range |
| PHY | Physical (Physical Layer) |
| PI | Positioning Information |
| PLL | Phase Locked Loop |
| QoE | Quality Of Experience |
| QoS | Quality Of Service |
| RAT | Radio Access Technology |
| RF | Radio Frequency |
| RSSI | Received Signal Strength Indication |
| RT | Ray Tracing |
| RTOA | Round Trip Time Of Arrival |
| SDK | Software Development Kit |
| SDRAM | Synchronous Dynamic Random Access Memory |
| SIG | Sigint Solutions Ltd |
| SINR | Low Signal To Interference And Noise Rate |
| SIR | Siradel |
| SME | Small-And Medium Enterprises |
| SMS | Short Message Service |
| SNR | Signal To Noise Ratio |
| SOC | System On Chip |
| SPI | Serial Port Interface |
| SQL | Structured Query Language |
| TCP | Trasnmission Control Protocol |
| TDOA | Time Difference Of Arrival |
| TOA | Time Of Arrival |
| TV | Television |
| TWI | Two Wire Interface |
| UE | User Equipement |
| UMTS | Universal Mobile Telecommunications System |
| UNIA | University Of Alberta |

| | |
|---|---|
| UNIS | University Of Surrey |
| UPM | Universidad Politecnica De Madrid |
| UR1 | University Of Rennes 1 |
| USB | Universal Serial Bus |
| UWB | Ultra Wide Band |
| VoiP | Voice Over Internet Protocol |
| WHERE | Wireless Hybrid Enhanced Mobile Radio Estimators (Project Acronym Of Phase 1) |
| WHERE2 | Wireless Hybrid Enhanced Mobile Radio Estimators (Project Acronym Of Phase 2) |
| WiFI | Wireless Fidelity |
| WiMAX | Worldwide Interoperability For Microwave Access |
| WLAN | Wireless Local Area Network |
| WPx | Work Package x |
| WSN | Wireless Sensor Network |

# 1 Introduction

This document aims to be an harmonizing preliminary document to synchronize objectives, conventions and parameters for further developments to be achieved during the WHERE2 project. It is intended to be an internal reference document facilitating benchmarking between partners, algorithmic solutions and demonstration platforms.

In the first section we make a first non exhaustive inventory of uses-cases (UCs) which are or could be related to the WHERE2 project technical target. It turns out that there are numerous UCs related to positioning in cooperative networks. Out of the previous UCs list, one generic scenario is described and 6 specific validation and test cases were identified and formalized, covering the common features and requirements for representative families of applications. The combination of 1 generic scenario with 6 inheriting validation and test cases will be used as a reference framework for the design of the heterogeneous cooperative positioning and communication techniques to be investigated and demonstrated in the WHERE2 project.

Conditioned on the working context and environment, representative parameter values are provided and preliminary models are referenced (as a starting point to further WP1 investigations), e.g. as regards to terminal density or mobility of the nodes.

A wide-range centralized infrastructure system coupled with local short-range peer-to-peer or mobile to mobile links are considered operating in the same environment (mostly indoor), where the two systems embody cooperation capabilities. The wide-range centralized communication system investigated in WHERE2 focuses on 3GPP-LTE. It also includes the consideration of coming extensions like femto-cells and relaying.

As the cooperation of different terminals is the key to address the potential of positioning under the constraints of low latency or robustness in indoor environments, a special focus is put on positioning and cooperation capabilities.

The short-range peer to peer system are based on ZigBee IEEE 802.15.4 and Impulse-Radio Ultra Wideband IEEE 802.15.4a standards. This short range RAT being the only one not already implemented in current commercialized terminals, and which is widely anticipated to play a key role for cooperation between terminals.

Inertial sensors and context-awareness are also considered complementing the heterogeneous infrastructure of radio nodes.

Finally, in the Annex, Section 5.1, we specify how the presented scenarios and validation and test cases are related to each working task of the project. As a continuation of the WHERE project we build on the expertise gained in the predecessor project in channel modelling, mobility modelling and different error models for time measurements or signal strength measurements. Furthermore, the different hardware platforms that will interact with each other are presented in Section 5.5. Finally, we describe the current activities in ETSI and other ICT projects (Section 5.6).

# 2 Use Cases and Applications

## 2.1 Introduction

Cooperation takes advantage of positioning and the converse as well. WHERE2 project focuses on investigating new modalities offered by cooperative positioning in various emerging contexts.

Positioning in an operated network allows a lot of anticipation, saving and optimisation in a large variety of applications and services. The matter is to provide the right information at the right place at the right moment.

This is particularly important each time human beings behave in clusters as for example in transportation systems where energy saving concerns are going to be more and more important. This is also true in the Green and Smart Grid context as well as for safety and security context. In the following, several use cases are proposed and listed covering the following fields of application in line with target outcomes described in [1].

- Location Based Services
- Network Improvement
- Green and Smart Grid
- Transportation System
- Security and Safety

For each use case, different environments relative to the application are categorized as follows:

- Indoor
  - IP: Indoor Public (Mall, Railway station, Airport )
  - IO: Indoor Office
  - IH: Indoor Home
- Outdoor
  - OU: Outdoor Urban (Including urban canyon)
  - OR: Outdoor Rural

Moreover, for each use case the main parameters related to the application are precised following the classification (Low,Medium,High), which is assumed to correspond to the typical figures shown in Table 1.

Additionally, the classification of WHERE2 scenarios and systems assesses the performance of systems which are not explicitly investigated but whose parameters are close enough to those being evaluated in WHERE2. Performance assessments and estimations can then be done by interpolation or extrapolation methods. A first step is to define an appropriate parameter space. Table 1 defines such a parameter space with dimensions “target S(I)NR”, “bandwidth”, “throughput”, “mobility”, “MT density”, “coverage” and “localization accuracy”. For any system, these parameters depend on each other. For instance, the dependency of S(I)NR and performance parameters like throughput and localization accuracy is obvious. Moreover, these dependencies are continuous, i.e., they show correlations. A slight increase of the S(I)NR typically results in a slight improvement in throughput. Due to parameter dependencies and correlations we can sample the parameter space.

- Determination of an appropriate set of basis functions.
  Available knowledge about functional dependencies and correlations of the parameters together with applied interpolation methods determines the density of the sampling grid. Often, the functional dependency of parameters is not known analytically. However, there may be a basis of functions which we can use for an approximation. Using appropriate samples, the parameters of such approximation can be found by (linear) regression for instance.

| | **Low** | **Medium** | **High** |
| --- | --- | --- | --- |
| **Target S(I)NR** | $< 10$ dB | $10 \ldots 20$ dB | $> 20$ dB |
| **System bandwidth** | $< 0.1$ MHz | $0.1 \ldots 1$ MHz | $> 1$ MHz |
| **Throughput - Data Rate** | $< 0.1$ MBit/s | $0.1 \ldots 1$ MBit/s | $> 1$ MBit/s |
| **Mobility** | $1 \ldots 10$ km/h | $10 \ldots 50$ km/h | $> 50$ km/h |
| **MT density** | $< 10^{-3}$ MT/m$^2$ | $10^{-3} \ldots 10^{-2}$ MT/m$^2$ | $> 10^{-2}$ MT/m$^2$ |
| **Coverage/Range** | $< 10$ m<br>office environment, systems like Bluetooth, UWB, etc. | $10 \ldots 100$ m<br>building environment, systems like WLAN | $> 100$ m<br>regional environments, systems like GSM, UMTS, WiMAX, LTE, etc. |
| **Localization performance** | $> 10$ m<br>suitable for outdoor navigation | $1 \ldots 10$ m<br>suitable for navigation in large open buildings (e.g. malls) | $< 1$ m<br>suitable for indoor navigation |

Table 1: Parameters and typical values for classification of systems and scenarios

- Determination of the main parameter subspace.
  It is obvious that systems and scenarios do not cover the  parameter space. For instance, there is no system which offers high throughput and localization performance at low bandwidths and SNRs. Therefore, it is necessary to identify those regions in the whole parameter space, which contain the majority of systems and scenarios.

Figure 1 exemplifies the dependency between bandwidth $B = (2L + 1)\,\Delta f_{\mathrm{SC}}$ and ranging accuracy (standard deviation) $c\,\sqrt{\mathrm{VAR}(\hat{\tau})}$ using the Cramér-Rao lower bound

$$\mathrm{VAR}(\hat{\tau}) = \frac{1}{8\,\pi^2\,\Delta f_{\mathrm{SC}}^2\,\mathrm{SNR}\,\frac{L(L+1)(2L+1)}{3}} \tag{1}$$

for time of arrival estimation in OFDM systems with uniform power distribution among subcarriers and AWGN propagation conditions. Here, $2L+1$ is the number of used subcarriers (including subcarrier zero), $\Delta f_{\mathrm{SC}}$ is the subcarrier spacing and SNR denotes the subcarrier signal-to-noise ratio.

In Figure 1 we have samples of the system at bandwidths 0.5 MHz, 4.5 MHz and 8.5 MHz for an SNR of 0 dB. Using these samples we may predict the ranging performance of a system using a bandwidth of 3 MHz. By linear interpolation, the approximation would be quite high. For higher prediction accuracy, we can additionally sample the parameter space at B = 2 MHz or we may use a more complicated interpolation method. A functional basis for instance could be $\mathrm{VAR}(\hat{\tau}) \approx a + b\,L^{-1} + c\,L^{-2} + d\,L^{-3}$, since this  dependency derived from the Cramér-Rao lower bound.

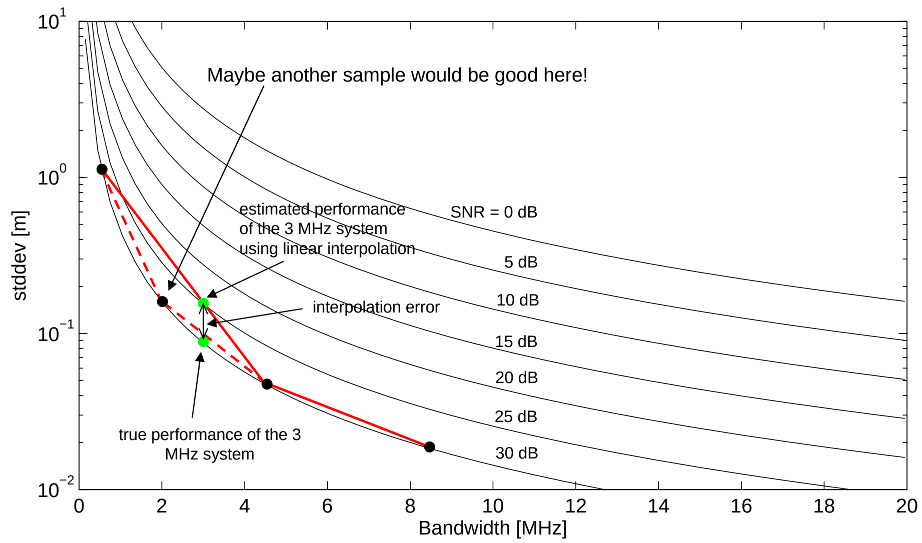


Figure 1: Ranging performance in AWGN for OFDM with uniform signal power distribution vs. the signal bandwidth for different SNRs.

## 2.2 Location Based Services

### 2.2.1 Context Aware Multimedia Services (CAMS)

As mobile terminals become more powerful, location based multimedia services [2] will increase in appeal. For example, trends such as improved display technologies, increased memory for storing maps, higher data rate to download maps and current traffic data, various sensors (e.g., accelerometer, odometer) have the capacity to initiate the take off of various new context aware location based multimedia services. What is innovative and could be promoted by WHERE2 project, is the new set of applications rising up when higher positioning accuracy becomes available. Mobile devices with positioning allow to build a lot of services which relate to the user context combining:

- the type of situation i.e.
  - Travel (Any information to optimize my transfer is welcome)
  - Work (Secure access matters)
  - Leisure
  - Hobby - Focused interest (e.g only interested about the historical information of a city between 1515 and 1535)
- the environment i.e.
  - Home
  - Office
  - Airport
  - Museum
  - Restaurant
- the user mood i.e.
  - I welcome pushed commercials

  - I welcome commercials if premium content is offered in exchange
  - I only accept premium content - I am paying for that.

The urban world is likely to become enriched with various levels of informational content (commercial or not). In those intensively information tagged areas, dedicated multimedia contents could be broadcasted.

For example the content is pretty much the same as in a today modern museum, but here potentially augmented to a whole city.

In order to circumvent the maintenance of context data, multimedia content is likely also to be produced by users themselves in a Web 2.0 manner. An historian or philosopher could sell or share its live commented visit of a cathedral or a quarter of historic city have a lot of followers (here in the very first sense of the word), happy to see by themselves what was emphasized few minutes or years before.

**Interest of PI**

- To access sufficient accuracy in indoor and outdoor environment in order to offer new kind of small scale multimedia services.
- To deliver a multimedia information which is tightly related to the user position (and, or trajectory).

**Accuracy Requirements** $1 - 10$ meters

**Related FP7 Project** TALOS (See p. 90 ) C-CAST (See p. 83 )

| | |
|---|---|
| Throughput | High |
| Mobility | Low |
| Coverage/Range | Medium |
| MT density | Medium |
| Environment | Ix + OU |
| Localization performance | Medium |

Table 2: CAMS use case parameters

### 2.2.2 Small Scale Social Network (SSSN)

A group of people are moving in the same environment. They are in the same shopping mall, airport, office and they want to cooperate in order to enhance their mutual interaction. Location information is obtained jointly with or without the help of the infrastructure. The position information can be exploited for gaming, fast regrouping iand for coordinated collective behavior applications. Various informational or bio-mechanical feedback could be associated with the cluster configuration. The telecommunication operator infrastructure is providing a secure environment allowing an efficient and private cooperation between nodes.

**Interest of PI** PI is sought for itself and for augmented perception and social interaction.

**Accuracy Requirements** The kind of accuracy which is sought lies between 1 meter (indoor$\leftarrow$) and 10 meters($\rightarrow$ outdoor). The highest accuracy being mostly for highly populated indoor places. For this kind of application the accuracy is strongly related to the user density. The highest the user density, the shortest the mean distance between users, the highest is the constraint on the accuracy. The application requires that spatial relationships between users are correctly retrieved.

| | |
|---|---|
| Throughput | High |
| Mobility | Low |
| Coverage/Range | Medium |
| MT density | High |
| Environment | IP+IO |
| Localization performance | High |

Table 3: SSSN use case parameters

#### 2.2.3 Shopping Mall Statistics (SMS)

Shopping center manager/owners, airport and railway station managers, exhibition centers, art galleries and museums often want to understand the way their customers or passengers flow through their centre. Indoor localization of mobile phones carried by customers can provide the desired information.

**Interest of PI** The statistical analysis of customers PI can provide insight to marketers on sell optimisation. This business model is promoted by the pathintelligence company [3]

**Accuracy Requirements** $1 - 10$ meter

| | |
|---|---|
| Throughput | Medium |
| Mobility | Low |
| Coverage/Range | Medium |
| MT density | High |
| Environment | IP |
| Localization Performance | Medium |

Table 4: SMS Use Case Parameters

### 2.3 Network Improvement

#### 2.3.1 WiFi to WiMAX (W2W)

The wireless networks such as WiMAX, WiFi, etc. are becoming congested traffic due to the high bit rate demands of users that expect to use advanced services such as fast browsing, IPTV or even HDTV. Additionally, in case many users access the network, it is possible that the network will not be able to accommodate all the users in the available frequency spectrum or existing interference will deteriorate system performance and thus the user will be denied from accessing it. The above services are very demanding to the networks and they require these networks to support high throughputs everywhere for the end users. In addition, if a user wants to use the services anytime and anywhere, then the network has to offer good coverage in every place including outdoor as well as indoor environments. Positioning information concerning the accurate location of the end user is also important since the knowledge of position enables the network to offer the requested service at the proper quality and bit rate. An integrated solution consisting of WiFi and WiMAX access networks can provide better coverage and increase the network throughput to the users by offloading traffic from one network to the other, or reallocating frequency in case of heavy interference or even handing off traffic from one network to the other.

The collaboration of WiMAX & WiFi networks is expected to decongest traffic load from a heavily occupied network to a lighter one, or by reallocating a user's frequency from one channel to another for interference avoidance. For the entire above purposes WHERE2 project proposes cognitive and positioning platforms to be used for the entire management of the whole system.

A typical cognitive system is an intelligent management system that possesses a management wireless system, which possesses rapidly reconfigurable radio functions, and that is aware of its environment due to its spectrum occupancy and transmission quality and also can learn from its environment and adapt to new situations based on previous experiences. This makes a cognitive platform capable of collaborating with any heterogeneous network.

The positioning platform is a way of providing the user's position with high accuracy for indoor and outdoor cases. Figure 2 illustrates a proposed use case that will be demonstrated in the WHERE2 project. Different users are in certain times controlled by the two pre-mentioned platforms. As it is observed, there are three different coverage areas each one using a different access technology.

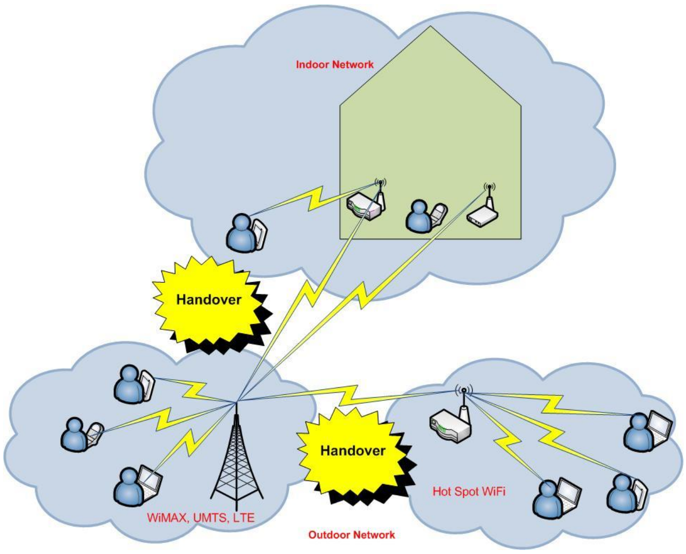


Figure 2: Description of W2W use case

A number of users are moving at the indoor area of a hotel that a workshop takes place and there is a high demand of WiFi coverage. Each WiFi node is responsible for measuring the RSSI levels of the user tagged device, in order to send feedback to the positioning platform to reveal its exact position.

Other users are located at the outside area, where there exists only WiMAX coverage. After a period of time, the cognitive platform realizes much congestion and the WiMAX user who is at that moment at the edge of the cell, looses gradually quality of his services. The cognitive platform tries to fix this problem initially by giving at the second user any unused amount of bandwidth that is available. If the problem insists then this platform transports this user at the nearest uncongested area that is the WiFi area. Another user is also attached to the WiFi node, so at the time that goes into the indoor area the positioning platform finds its exact position. In case that the WiFi coverage is very congestive, then the user is handed off to WiMAX infrastructure which provides lower speeds (say for VoIP service) but at better quality.

**Interest of PI** PI is needed since the accuracy for both indoor and outdoor environments will improve the performance of the network in terms of offering suitable and better services to the end users

**Accuracy Requirements** The accuracy of the user position is important especially in indoor environments where there is congestion of users and sensitive services, such as VoIP, which need to be offered with high quality. In this case a user may be handed off from one access network to another, or have terminal frequency reallocation and therefore 1-2 m accuracy is needed. For outdoor cases the accuracy is relaxed and about 6-8 m accuracy is needed.

**Related FP7 Projects** SELFNET (See p. 89)

| | |
|---|---|
| Throughput | High |
| Mobility | Low |
| Coverage/Range | Medium |
| MT density | Medium |
| Environment | IH+OU |
| Localization Performance | Medium |

Table 5: W2W use case parameters

#### 2.3.2 Femto-cell Location Discovery (FLD)

In this use case, the location of femto-cells is made available for the mobile cellular network.

**Interest of PI** In order to improve the cell-edge terminal throughput this location information may be used to perform efficient inter-cell interference coordination between:

- macrocells and femto-cells
- femto-cells

The location information may be also useful for closed femto-cells, which cannot be accessed by every terminal. If a terminal knows the position of the femto-cell it has access to and its own position, it is able to restrict the femto-cell search to areas where it knows it could connect to a suitable closed femto-cell. Furthermore, a femto-cell may be switched off when it does not serve any terminal in order to perform energy saving. In order to switch it on again, when a terminal which has access to this femto-cell enters its coverage area, the networks may use the femto-cell and terminal locations.

| | |
|---|---|
| Throughput | High |
| Mobility | Low |
| Coverage/Range | Low |
| MT density | Low |
| Environment | IP + IO + IH |
| Localization performance | Medium |

### 2.4 Green Applications and Smart Grid

#### 2.4.1 City Lighting On Demand (CLOD)

Street lights could be activated on demand when a pedestrian is passing through a given area. The default could be a light off mode. The on switching could be exploiting the knowledge of human presence on the field, at a small scale level. Location of the user is relevant in order to dynamically light along the user trajectory, eventually with some anticipation. In that respect, it is important to be able to make a distinction between users which are moving outdoor which requires lighting from users which are moving indoor. A highly reliable indoor/outdoor decision engine is required. Positioning could be useful for energy saving in the smart grid.

**Interest of PI** The positioning information is exploited as an actuator of various dedicated energy consuming devices serving the public. The goal here is energy optimisation while keeping isoquality of service. Street light control is one obvious example among many city automation services which could be built over a universal Indoor/Outdoor positioning system as promoted by WHERE2 project.

**Accuracy Requirements** $1 - 10$ meter

| | |
|---|---|
| Throughput | High |
| Mobility | Low |
| Coverage/Range | Medium |
| MT density | Medium |
| Environment | IP+OU |
| Positioning Accuracy | High |

Table 6: CLOD use case parameters

#### 2.4.2 Energy Efficient Heterogeneous Communication (EEHC)

Beyond-3G-communication envisages high data rates and multi standard radio interfaces (UMTS, LTE, WiFi, DVB-H, Bluetooth, ...) to provide users with a continuous IP-connection. However, state of the art multi standard devices have high power requirements for maintaining two or more radio interfaces, in addition to advanced imaging features (camera, high-definition display, etc.) and GPS/Galileo receivers which increase considerably the power demand of such handsets. A mobile user, whose terminal would be equipped with multiple RAT adapters, should be capable of vertically handing-over between heterogeneous RATs in order to meet Quality of Service (QoS) or end to end Quality of Experience (QoE) requirements. A limiting factor would definitely be the mobile terminal battery lifetime, as state of the art multi standard devices have high power requirements for maintaining two or more radio interfaces. For a user moving in a heterogeneous environment, where the requirement would be "always-be-connected" the immediate effect on the terminal battery would be "always-being-drained". The challenge is to optimise this battery draining while maintaining the user IP connection and his QoS and/or QoE requirements. The optimum would have been to always have only the communicating adapter switched on. In such a technology adapters may be switched on, only if the terminal somehow *predicts that it's moving out of the coverage of one Radio Access Technology while entering the coverage of another RAT where it is supposed to vertically handover*. This prediction can be achieved by using mobility and positioning information. Positioning, however, comes with high degree of battery consumption if for example -for an outdoor user- a GPS is the preferred localisation method. The need for a GPS can be bypassed if positioning is achieved using context (RSSI, ToA etc.) from the existing terrestrial wireless network or any other secondary terrestrial technology which would have been less battery demanding (e.g. a network of wireless sensors, or another RAT) than satellite positioning. Figure 3 shows a user who performs his every-day trip to the airport where he works and demonstrates the principle of "always-being-connected" in heterogeneous networking environment where the concept of location-based-energy efficient vertical handover is employed. For example, given the positioning information from terrestrial networks and mobility information (either from inertial sensors or previous locations of the user) the terminal may be able to recognise that its moving into the vicinity of a radio access network where the radio communication requirements are less battery demanding and thereafter vertically handover the connection to that technology.

**Interest of PI** Positioning and mobility information can be used (as described above) as a means of identifying the motion of the user and predicting whether he is moving into a less-battery demanding technology where he should transfer his live IP-connection.

**Accuracy Requirements** 1-10 meters

**Related FP7 Project** C2POWER (See p. 84 )

#### 2.4.3 City Bikes Balancing (UC-CBB)

All over the world, big cities are deploying city bikes services. In certain cities the utilization is literally booming because it corresponds strongly to new citizen aspirations regarding mobility.

One problem of such systems which increases exploitation costs is the bikes balancing problem. The ideal situation would be to have all the time at any bikes station as much as bikes as free places in order

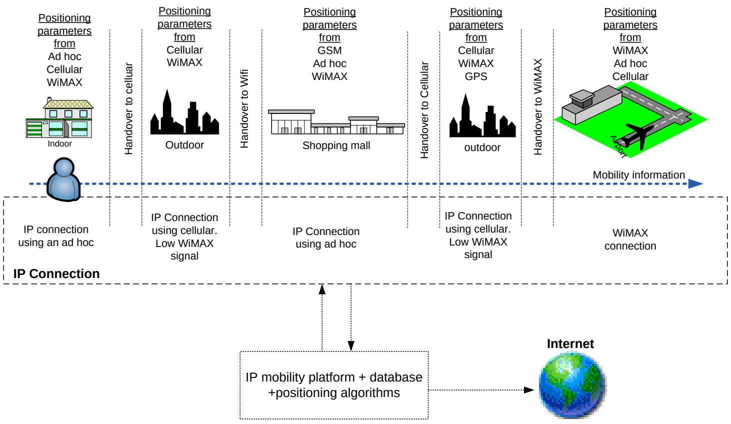


Figure 3: Energy Efficient Heterogeneous Communication Use Case

| | |
|---|---|
| Throughput | High |
| Mobility | Medium |
| Coverage/Range | Medium |
| MT density | Medium |
| Environment | IP + OU |
| Positioning Accuracy | Medium |

Table 7: EEHC use case parameters

for any user of the service to always be sure that there is either bikes available or room available to let a bike. This idealistic balanced situation is hard to obtain because all stations are not equally attractive, partly due to topography and unequal spatial spot interest. If a station is on the top of a hill it will have a natural trend to be empty, and a station very close to the city hot spots will be always full and you can't let your bike in every station, what is particularly annoying and which constitutes an obstacle to a wider adoption by a larger population. Today in order to fix this problem the city bikes management system is doing the balancing in a centralized manner. Taking bikes from one place and replacing them in another place using dedicated heavy transport systems. This is either costly or inefficient because the centralized management service cannot follow fast enough the underlying bikes network dynamics.

**Interest of PI** Positioning information obtained from high accuracy positioning systems could be used to offer mobility points or attractive commercial offers in exchange of a service a user can offer to the city bike management service. Mobility points could be used for example on other transportation modalities as metro or bus.

If a partnership between the telecommunications operator and the bike management service is done the former can send an SMS to a subset of subscribers offering them some tasks to do. "Take a bike from station A and bring it to station B". This demand for small services could be very simple and the number of earned mobility points could depend of the amount of energy necessary to send the bike from point A to point B (offering a bigger reward to climb the hill ). The relation to the customers is reverse as we are asking for user participation and as such can bring a very positive image from the operator which could be exploited for efficient advertising. "I give you the offer if and only if you fulfill the service". With time, many people would be happy to accomplish such mission even for free and will enjoy such incentive as a way to introduce some funny randomness in life, earn a few amount of cash, practice a fitness activity, or simply as a civic manner to participate to $CO_2$ emission reduction. Green applications always require users consent and involvement.


Figure 4: City Bikes Balancing concept

**Accuracy Requirements** Required accuracy 10 meters - Including indoor to maximize the pool of users targets. Indoor/Outdoor decision.

**Underlying Scenario** LTE and short-range communication capabilities with medium mobility (bikes motion)

| | |
|---|---|
| Throughput | Medium |
| Mobility | Medium |
| Coverage/Range | Medium |
| MT density | Medium+High |
| Environment | OU + IP |
| Localization performances | Medium |

Table 8: CBB Use Case Parameters

## 2.5 Intelligent Transportation System

Intelligent Transportation Systems (ITS) include a wide and growing suite of technologies and applications, ranging from variable message signs and control of traffic lights to advanced traveller information systems.

ITS applications target not only private vehicles such as cars, but they span from pedestrians to truck fleets, including public transport (buses and trains) as well.

In order to introduce intelligence to roads and transport systems, information about road situation should be available. After collecting and processing information about e.g. a number of cars on a road segment, an advance control and regulation can be applied to increase efficiency of usage of transport infrastructure and increase safety on the roads.

Recently, special attention is on fully integrated ITS, such as vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) integration that enables communication between different elements in ITS, e.g. from vehicles to roadside units, traffic lights and other vehicles.

To realize a V2V and V2I communication, an on-board unit (OBU) has to be installed basically in every car being able to collect information about car's current position and to transmit and receive data. Currently available commercial solutions are typically based on usage of embedded GPS receivers in vehicles' OBUs. GPS receives signals from several different satellites to calculate the device's (and thus the vehicle's) position.

However, it is well known that GPS might perform badly in downtown settings due to "urban canyon" effects. Additionally, in situations where a vehicle is in e.g. parking house or a tunnel other localization methods should be used to get a device position, e.g. methods suitable for indoor localization. To summarize, in order to support development of ITS, robust localization methods are required that can also work in environments where GPS signals are absent or unreliable, as many ITS applications rely on availability of localization information of different players in transport systems.

#### 2.5.1 Cluster Handover (CHO)

Within the scope of ITS it is often possible to make a good route prediction, maybe the route is even explicitly planned. As an example the coverage and instantaneous network load can be very different from operator to operator, and if one operator network is in a poor condition, a cooperative cluster could be formed to relay traffic through other nodes with a better operator.

**Interest of PI** PI can be used to optimize vertical handover procedure for OBUs, and to establish cooperation between entities by forming a cluster.

**Accuracy Requirements** Probably around 2-10 meters. But it will be an item to investigate for the proposed clustering mechanisms.

| | |
|---|---|
| Throughput | Medium |
| Mobility | High |
| Coverage/Range | Medium |
| MT density | High |
| Environment | OU |
| Localization Performances | Medium |

Table 9: CHO use case parameters

#### 2.5.2 Parking Garage Assistance (PGA)

It is possible to optimize the usage of a parking garage by directing cars to free spaces. Inside a parking house GPS is no longer working and alternative localization methods are needed. It is assumed that each parking space has a sensor that is able to detect whether the space is occupied or free.

Short/medium range communication links inside parking house to communicate with parking house infrastructure. Further, localization can be done using these links, or via a hybrid scheme that also takes ad-hoc links between different vehicles into account. The environment is a multi-story building with concrete walls.

**Interest of PI** PI is needed for the application showing directions to a driver inside a parking house.

**Accuracy Requirements** 1-2 meters

| | |
|---|---|
| Throughput | High |
| Mobility | Medium |
| Coverage/Range | Medium |
| MT density | Medium |
| Environment | IP (Garage + Parking) |
| Localization performances | High |

Table 10: PGA use case parameters

### 2.5.3 Traffic Jam (TJ)

Lot of cars are located very close to each other e.g. in a traffic jam and they are interested in exploiting the benefits of ITS to get information about the traffic situation. A typical 2G/3G deployment could have difficulties serving that many terminals in one cell. The ITS platform could utilize the knowledge about closely located users and make them cooperate e.g. in clusters instead of competing for the network the cellular network could be off-loaded.

**Interest of PI** PI can be used to optimize communication flows between vehicles and infrastructure exploiting short range communication links between cars in case of a dense network formed by cars.

**Accuracy Requirements** Probably $1 - 10m$, but it depends on the cluster routing mechanisms.

| | |
|---|---|
| Throughput - Data Rate | Medium |
| Mobility | High |
| Coverage/Range | Medium |
| MT density | Medium |
| Environment | OR+OU |
| Localization performance | Medium |

Table 11: TJ Use Case Parameters

### 2.5.4 Commuters in Public Transport (CPT)

People that are commuting by bus or train to get to and from work, are typically close together while traveling. Clustering could be used to share e.g. access to the internet.

Figure 5: Example of users clustering

**Interest of PI** Positioning information can be used to determine the cluster members and for choosing relaying and routing strategies.

**Accuracy Requirements** Probably $1-10m$, but depends on the cluster relaying/routing mechanisms.

### 2.5.5 Railway Workers Security Systems (RWSS)

A group of railway workers equipped with some sort of location-aware personal devices are considered. The device should be able to warn the workers if a potentially dangerous situation arises, i.e. if a train

| | |
|---|---|
| Throughput | High |
| Mobility | Low |
| Coverage/Range | Medium |
| MT density | High |
| Environment | IP+OU |
| Positioning Accuracy | High |

Table 12: CPT use case parameters

is approaching. The workers are supposed to work inside a safe zone, but may need to leave this zone from time to time, e.g., to get a tool or to move between work locations. From time to time trains or track maintenance vehicles may approach the working site, and it becomes crucial that the workers can be localized accurately, so that when outside the safe zone or about to leave the safe zone they can be warned or other safety measures can be taken. An important aspect is that the warnings given by the ALARP (See p. 82) system must be trustworthy. If workers experience occasional false alarms, this will lead to distrust of the system, and the workers may then choose to ignore the alarms. The main objective in this use case is

1. to obtain a location estimate of each of the workers, but more importantly
2. to inform the ALARP system how accurate this location estimate is, since an inaccuracy of a couple of railroad tracks may be fatal for the workers

**Interest of PI** The warning system described above is based on availability of PI and notifications (warnings) are sent to devices based on their positions. An additional important aspect is the reliability of PI: a system will go into a safe state when a positioning algorithm cannot provide a required accuracy.

**Accuracy Requirements** As the distance between the track where the workers are located and a track where a train might be passing can be as low as 1-2 meters, the accuracy requirements are well below 1 meter, and the location must be available within 100-200 ms, so that workers can be warned before a potentially fatal situation.

**Related FP7 Project** ALARP (See p. 82)

| | |
|---|---|
| Throughput - Data Rate | High |
| Mobility | Low |
| Coverage/Range | Medium |
| Environment | Typically rural, possibly trees in surroundings. A tunnel could also be the case. |
| Localization performance | High |

Table 13: RWSS use case parameters

### 2.5.6 Smart Roads (and Intelligent Vehicles)(SR)

The main idea here is to equip roads with sensors that gather information about the weather, traffic and road condition. The data is then processed and used to dynamically define the speed limit, the optimal routes or detect abnormal situations (e.g. accidents, fog, snow) and so on. This information is then sent to the cars, and can be used to warn the drivers about an imminent danger or speed limit, and prompt them to tune their internal systems such as ABS, speed controller or trip planning system (Figure 6). A potential "spoofing attack" to a smart road system would use malicious nodes that masquerade as legitimate road sensors so that they either transmit fake information or try to disrupt the communication protocols. To avoid an easy visual detection, such nodes could be inside a vehicle.

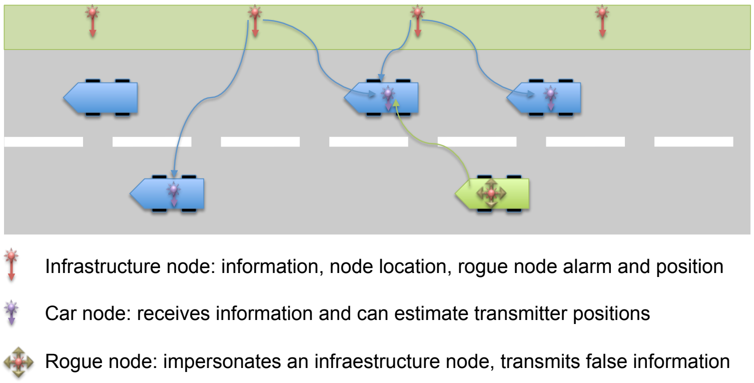


Figure 6: Security on smart roads

**Interest of PI** The information received by the car should be validated before being presented to the driver. The validation is based on the positioning information. Hence, knowing the sensors are located statically beside the road, the data received from any other location or from moving source can be discarded.

**Accuracy Requirements** 1-10 meters

**Related FP7 Project** AWISSENET (See p. 83)

| | |
|---|---|
| Throughput | Medium |
| Mobility | High |
| Coverage/Range | Medium |
| MT density | Medium |
| Environment | OR |
| Localization performance | Medium |

Table 14: SR use case parameters

## 2.6 Domestic Applications

### 2.6.1 Domestic Health and Safety Management (DHSM)

The WHERE2 architecture could be a building block of future health management systems in domestic or familiar environments (typically in residential houses or flats).

The idea is to provide support for more ergonomic, comfortable, less intrusive and highly reactive monitoring or rescue systems, in a wide range of health and safety oriented applications:

- Detection of critical situations (e.g. fall, dizziness...) for fast rescue and/or alarm launching,
- Medical physical auto-diagnosis (e.g. early prevention from heart attacks),

- Physical rehabilitation at home through motion or posture capture,
- Assisted mobility for disabled or blind people,
- Off-line modelling or statistics of the patient mobility/activity with measurable/tangible indicators (e.g. elderliness monitoring, assistance to alimentary diets in obesity treatment, etc.).

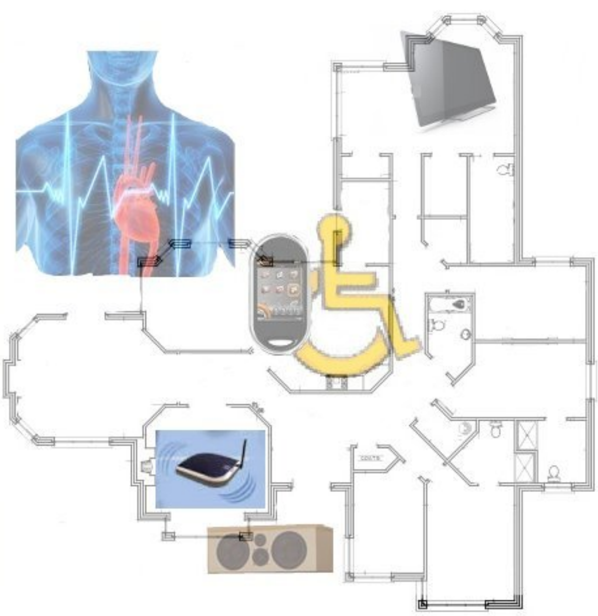

Figure 7: Domestic Health and Safety Management (DHSM)

One can indeed:

- retrieve the user/patient trajectory, while collecting directly physiological measurements as a function of the occupied position,
- augment indoor navigation capabilities through motion/posture capture with limited use of extra and costly equipments at home (e.g. video Coda system),
- ensure distant patient monitoring (e.g. from an hospital or medical centre).

Obviously, this use case is strongly related with emerging Body Area Network applications. Moreover, in private areas, privacy is crucial for the collection and storage of personal measurements.

**Accuracy Requirements** 1-10 meters

**Related FP7 Project** EUWB (See p. 86 ) SENSEI (See p. 89 )

**Interest of PI** Positioning information, if coupled with sophisticated inference or decision tools can bring relevant and valuable information about the health of elderly or disabled people. In this use case, the density of MT is likely to be low. However additional anchors in the infrastructure might be deployed to ensure real-time high precision tracking in the context of augmented motion capture.

| | |
|---|---|
| Throughput - Data Rate | Low (collection of location dependent physiological parameters monitoring ) to Medium (e.g. enhanced radio-navigation through inertial-based body motion capture) |
| Mobility | Low |
| Coverage/Range | Low |
| MT density | Low |
| Environment | IH |
| Localization performance | High |

Table 15: DHSM use case parameters

#### 2.6.2 Smarter and Automated Homes (SAH)

In addition to the components of remote monitoring and support, units might include new control features of the environment for home automation purposes, enabling "smarter" and adaptive domestic contexts. Home positioning is also expected to meet mass market needs, especially in the context of building energy efficiency, house security, as well as for domestic gaming, leisure or entertainment (e.g. musical adaptive spatialization, smart Hi-Fi). These applications are strongly related to Wireless Sensor & Actuator Networks.

In a private area context, if cooperation happens to be exploitable, the involved mobiles are very likely to have a strong propensity to collaborate together (for belonging to the same community, or family, etc.)

**Accuracy Requirements** 1-10 meters

**Related FP7 Project** EUWB (See p. 86 ) SENSEI (See p. 89 )

**Interest of PI** In houses, in a WSN-oriented context, one first obvious usage of the location information is to associate physical parameters (e.g. temperature, light readings etc.) with the actual location of the measurement (if needed enabling further physical mapping or 3D interpolation of the measured parameters under non-uniformly distributed sensor locations). Another possibility is to detect and track in real-time so that to make sure that the ambient temperature, light and broadcasted music in the rooms they have been going through, fit exactly and automatically the personal preferences (e.g. maintaining other unoccupied rooms silent and dark). Alternatively, retrieved people trajectories could enable to draw off-line personal statistics to fulfill the same needs as previously and to design efficient decision engine or tools to optimally adapt the energy consumption. The retrieved location information could also be intended for the simple detection of intruders. For instance, some external people could be allowed to check from the outside the house integrity, being informed through a distant access that someone has entered the house and that this person accepts or not to be identified on demand and to collaborate to get located.

### 2.7 Security and Safety

#### 2.7.1 Airport Security Management (ASM)

Airport security attempts to prevent attackers from bringing weapons, bombs or suspicious objects into the airport. If they can succeed in this, then the chances of these devices getting on to aircraft are greatly reduced. As such, airport security serves several purposes:

- To protect the airport from attacks and crime,
- To protect the aircraft from attack,
- To reassure the travelling public that they are safe.

| | |
|---|---|
| Throughput/Data Rate | Low (e.g. collection of location-dependent physical environmental parameters) to Medium (e.g. real-time people tracking) |
| Mobility | Low |
| Coverage/Range | Low |
| MT density | Low |
| Environment | IH |
| Localization performance | High |

Table 16: SAH Use Case Parameters

Two problems are assumed in a common security wireless use case implemented at the airport, the first one is related with the situation where the surveillance device is located in unknown place, for instance, a camera which is hold by a robot or another kind of motion security device for real-time record. The second challenge is to avoid attacks or jamming by means disabling the signal transmission and replacing it with a pre-recorded one. The camera robot can be connected to an ad-hoc network and mobile infrastructure. The image of the camera is available both at the security vehicles and the command and control station. In this way, the airport security staff can handle directly the camera, independently from the fixed infrastructure.

This topology allows monitoring the position of the camera and tracking the route of any suspicious event. Thanks to this outreach, security staff can manage the situation faster and more effectively.

The main interest is to manage each potential threat by data transmission technologies which provide more information about parameters, an increased knowledge of those relevant events to enable a faster and more efficient protocol of safety. A security platform allows combining location and positioning services with video broadcasting capabilities in order to provide framework where security staff can detect and foresee any realistic problem on time. This security and safety use case can combine different technologies, such as LTE, WiFi and ZigBee.

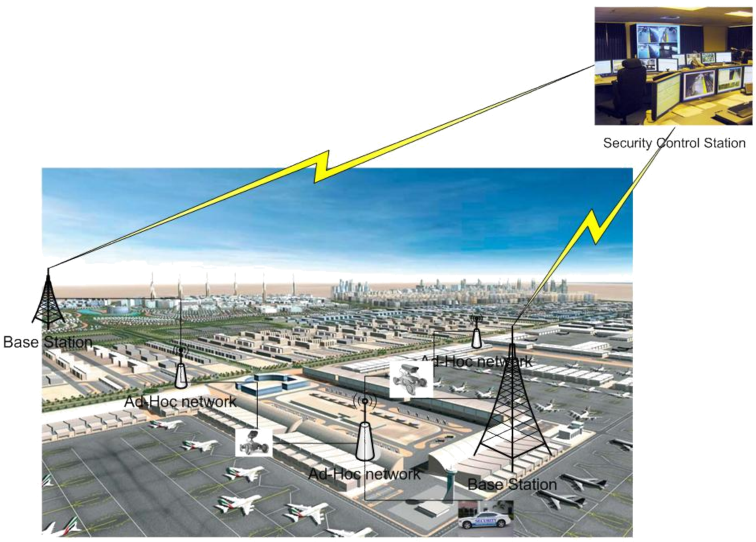


Figure 8: Airport Security Management example

As an example regarding the indoor public area of the airport, we consider our target to be a multi modal device with WiFi and ZigBee communication capabilities. Several other mobile devices (equipped with WiFi and/or ZigBee interface) are randomly placed inside the airport, and those are potential cooperating nodes. The level of cooperation is assumed to be very high, e.g. all nodes are willing to cooperate. Static ZigBee sensors are deployed to serve as anchor points, and their number depends on the desired accuracy. WiFi access points are complemented with a ZigBee sensor and serve at the same time as ZigBee coordinator. Their number may vary, but has to match some typical values. In that sense, anchors will follow deterministic deployment patterns, while target and other mobile nodes can be randomly placed.

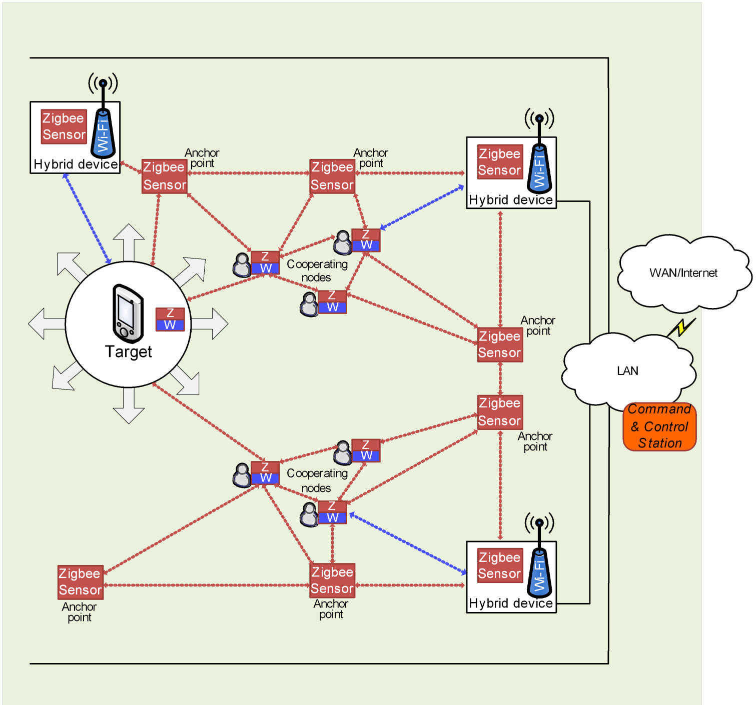


Figure 9: Short-range cooperative positioning inside airport

**Interest of PI** PI is needed to know the real time camera position in order to predict suspicious events. Also, positioning information could be exploited to make a statistical analysis of the environment to avoid possible attacks. Besides, the cooperation between clusters and the vertical handover process could improved accuracy and reliability.

**Accuracy Requirements** desirable less than 1 meter

| | |
|---|---|
| Throughput | High |
| Mobility | Low - Medium |
| Coverage/Range | Medium |
| MT density | Medium - High |
| Environment | IP + OU |
| Localization performance | Medium |

Table 17: ASM use case parameters

### 2.7.2 Homeland Security and Perimeter Surveillance (HSPS)

Homeland security is one of the most promising applications for Wireless Sensor Networks (WSNs). In such use cases, WSNs can be easily deployed permanently (e.g., public places) or on-demand (e.g., high risk events) in a very short time, with low costs and little or no supporting communications infrastructure, and can also be removed and reused anywhere else very rapidly. Sensors can be used, for instance, to prevent terrorist attacks by detecting Chemical, Biological, Radiological, Nuclear or Explosive (CBRNE) weapons in public places (airports, stations, stadiums,...), and also inside trains, aircrafts or ships. A variant of this use case consists in using built-in sensors in smart cargo containers, with processing capabilities to collaboratively detect and track CBRNE elements still in transit (Figure 10). Another closely related application is the timely detection of environmental disasters (e.g., wildfires). An attacker to such systems would try to either avoid the detection of a real hazard or trigger a false-alarm in the WSN by using malicious nodes that interfere with the legitimate communications.

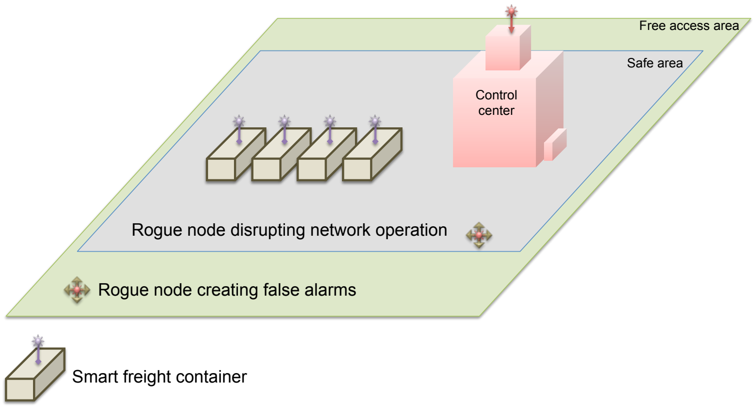


Figure 10: Smart container security example

**Interest of PI** The control center should be able to determine the position of the node in order to validate the receiving information. For example, if the node creating alarms is outside the "safe area" those warnings will not be taken into account. If for instance, the malicious node manages to get inside "safe area" it might to overload the network traffic, this way disabling the network. Nevertheless, if it is not emitting from the position where that kind of node is supposed to be, the control center can ignore its traffic and at the same time issue the alert on another level.

**Accuracy Requirements** 1-10 meters

**Related FP7 Project** AWISSENET (See p. 83)

| | |
|---|---|
| Throughput | Medium |
| Mobility | Low |
| Coverage/Range | Medium |
| MT density | Medium |
| Environment | IP + OU (Airport) |
| Localization performance | Medium |

Table 18: Use case HSPS parameters

### 2.7.3 Crowd Analysis (CA)

The population growth, along with urbanization on a global scale, has made the crowd phenomenon more frequent. It is not surprising, therefore, that crowd analysis has received attention from technical and social research disciplines. The crowd phenomenon is of great interest in a large number of applications and especially for telecommunication network modeling and dimensioning. Moreover, recent dramatical accidents related to crowd panic in Germany and Cambodia suggest that there could be an interest to exploit upcoming positioning technology to prevent such dramas. Highly accurate positioning could lead to crowd density estimation and dramatical events detection. This could be a way to offer tools for authorities for preventing panic triggering. Crowd analysis is today addressed mostly through computer vision techniques [4], cooperative positioning techniques could be a good complementary anticipation tool in early phases of human high density events.

**Interest of PI** The position is exploited for crowd real time analysis to complement and enhance computer vision techniques.

**Accuracy Requirements** 1-10 meters

| | |
|---|---|
| Throughput | Medium |
| Mobility | Low |
| Coverage/Range | Medium |
| MT density | High |
| Environment | IP+OU |
| Localization performance | High |

Table 19: CA use case parameters

## 2.8 Conclusion

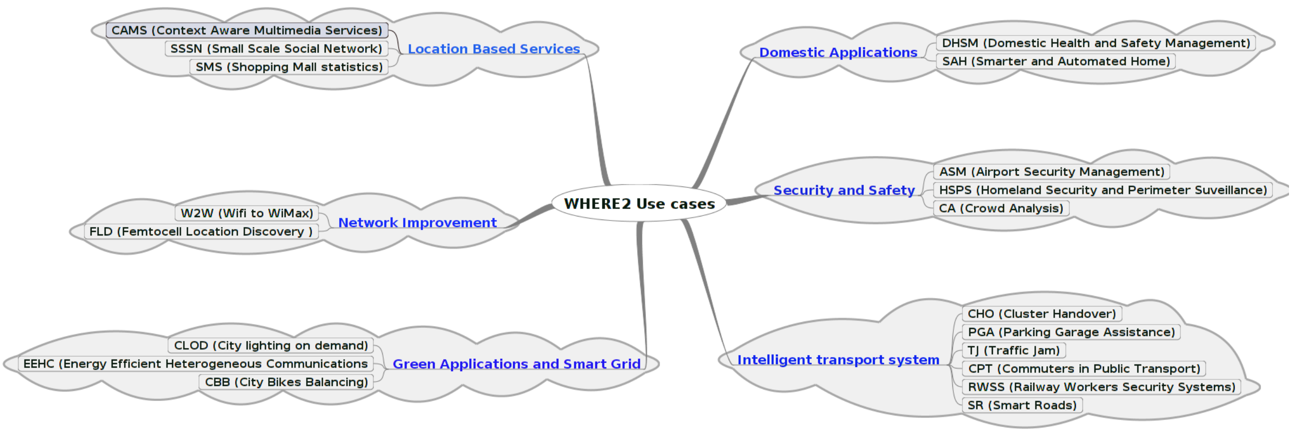


Figure 11: Use cases sorted by application domain

When considering the range of use cases summarized in table 2.8 and Figure 11, one realizes that they are preferentially concentrated in situations of high-density environment for UE public indoor or urban outdoor (cf Figure 12). It makes senses to organize scenarios according to the environment criterion, because it is directly related to the density of MT and it offers rather different propagation conditions

| Use Case | Throughput | Mobility | Coverage | MT density | PA | Env. |
|---|---|---|---|---|---|---|
| SMS (See p. 16) | Medium | Low | Medium | High | Medium | IP |
| SSSN (See p. 15) | High | Low | Medium | High | High | IP + OU |
| CAMS (See p. 14) | High | Low | Medium | Medium | Medium | IP+IO+IH + OU |
| W2W (See p. 16) | High | Low | Medium | Medium | Medium | IH + OU |
| FLD (See p. 18) | High | Low | Medium | Low | Medium | IH +IO |
| CLOD (See p. 18) | High | Low | Medium | Medium | High | IP+OU |
| EEHC (See p. 19) | High | Low | Medium | Medium | Medium | IP+OU |
| CBB (See p. 19) | High | Medium | Medium | Medium | Medium | IP+OU |
| CHO (See p. 22) | Medium | High | Medium | High | Medium | OU |
| PGA (See p. 22) | High | Medium | Medium | Medium | High | IP (Garage+Parking) |
| TJ (See p. 23) | Medium | Medium | High | Medium | Medium | OR+OU |
| CPT (See p. 23) | High | Low | Medium | High | High | IP+OU |
| RWSS (See p. 23) | High | High | Low | Medium | High | OR (Trees) +Tunnel |
| SR (See p. 24) | Medium | High | Medium | Medium | Medium | OR |
| ASM (See p. 27) | High | Low | Medium | High | High | IP + OU |
| HSPS (See p. 30) | Medium | Low | Medium | Medium | Medium | IP + OU (Airport) |
| CA (See p. 31) | Medium | Low | Medium | Medium | Medium | IP + OU (Airport) |
| DHSM (See p. 25) | Low to Medium | Low | Low | Low | High | IH |
| SAH (See p. 27) | Low to Medium | Low | Low | Low | High | IH |

Table 20: Summary of uses cases parameters

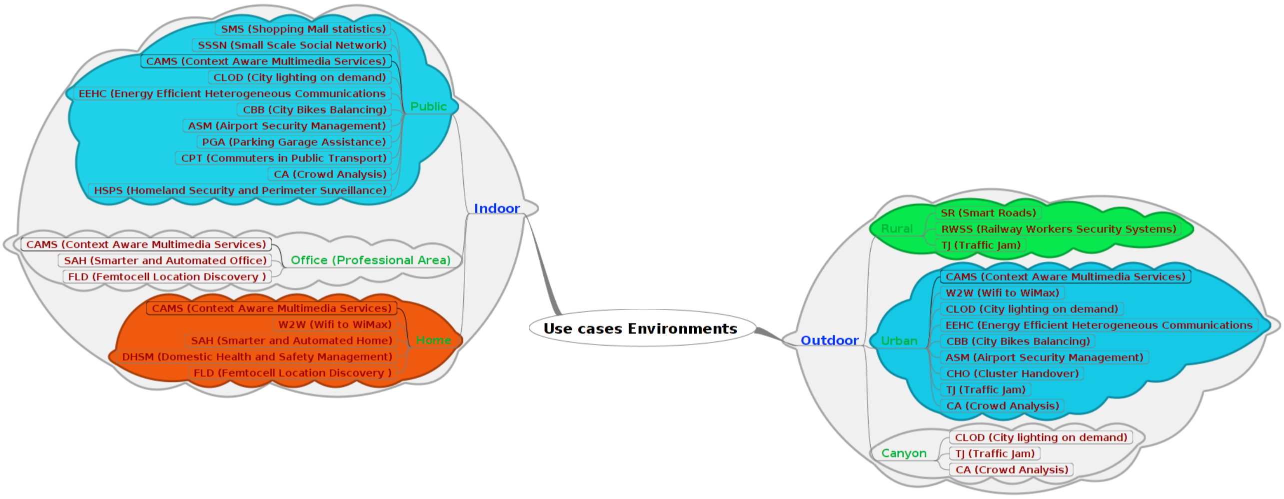


Figure 12: Use cases sorted by type of environment

(hence,strongly impacting the final radio-location performance). Opportunity and nature of cooperative schemes will also differ from one type of environment to another. Accordingly, an environment-dependent classification will be retained in the following, as a basis for the definition of particularized embodiments of the generic WHERE2 scenario (See Section 3).

# 3 Definition of Scenarios

This section describes a generic scenario that will be investigated in the WHERE2, along with inheriting validation and test cases. Note that applying this scenario to different working environments, most of the previous UCs listed in Section 2 would be covered.

In the first section, we provide the main features and parameters are provided in following order:

- Available Terminals and Modalities
- User Mobility
- Physical Environments
- Network Deployment and Elements of Infrastructure
- Levels of Cooperation

In the second section, six validation and test cases are identified including:

- Indoor navigation through cooperative and heterogeneous networks
- Positioning aided by alternative techniques
- Cooperative cellular systems
- Cognitive radio
- Vertical handover
- Security and safety

Note that security and safety, as well as vertical handover items are related to a physical demonstrator, where several hardware platforms (developed by WHERE2 partners) will be integrated together in the frame of WP4.

Two major outcomes of the scenario and cases definition proposed herein are:

- providing a common and realistic evaluation frame for all the algorithmic investigations carried out in WHERE2 (i.e. in WP2, WP3, and less marginally WP4),
- identifying key physical environments for the upcoming T1.2 task on channel modelling.

Moreover, in order to assess the performance of the WHERE2 algorithms under realistic operating conditions, the common evaluation frame shall:

- make references to relevant mobility models, accounting for a realistic human behaviour (at both short and long-terms, for single pedestrian or groups, etc.),
- include critical parameters as regards to terminal maximum speed and spatial density,
- identify the available RATs (and hence, the radio-location metrics) under realistic network deployment constraints and anticipating the penetration of the selected technologies.

Hence, for each of the critical parameters that have been identified, a spanning range and a nominal figure (selected for being the most representative value lying in the previous interval) are provided, conditioned upon the environment.

Such harmonized models and parameters will enable defining common test conditions (e.g. simulation set-ups, as inputs into WP2 and WP3) so as to:

- evaluate and benchmark the designed algorithms,

- identify the complementarities of the proposed solutions, highlighting e.g. their respective limits/benefits depending on the environment or working conditions.

In turn, one more idea would be to determine adequate working domains for combined algorithms, in order to ensure a seamless and pervasive continuity of the WHERE2 services. As an example, in a given working environment, the common evaluation frame might help determine the conditions/criteria to optimally switch from one algorithm to a combination of other solutions.

On the other hand, for the sake of providing WHERE2 with adapted propagation channel models, the key physical environments expected in each scenario have been clearly identified and classified:

- indoor office
- indoor private house/flat
- indoor public area
- outdoor-urban canyons

along with their involved radio links and RATs

- indoor-to-indoor short-range links
- outdoor-to-indoor long-range links in the most complete heterogeneous indoor context

Note that further issues have been pointed out on this occasion e.g., the difficulty to produce realistic models for jointly cooperative and heterogeneous channels in one single environment. Activities carried out in T1.2 (See Section 5.1.1) will advantageously take into account the scenario parameters and models defined hereafter (e.g. conditioning dynamic channel variations on some mobility features specified hereafter).

## 3.1 Generic Scenario Definition

### 3.1.1 Available Terminals and Modalities

In the generic scenario (Figure 13), the focus is mostly put on mass market applications. Hence, the aim is to localize mobile end-users, endowed with a handset multi-standard radio terminal. Beside radio capabilities, a portion of these terminals might also be augmented with inertial measurement units (See e.g. task T2.2 5.1.4)

By default, the heterogeneous network infrastructure shall comprise the following RATs:

- large-range macro-cellular , such as LTE and/or WiMAX,
- medium-range femto-cellular and/or WLAN WiFi,
- short-range Low Data Rate Wireless Sensor Networks, based on Impulse Radio - Ultra Wideband and/or ZigBee.

Note that terminals do not have necessarily full access to all RATs, but most probably to a subset of RATs (e.g. in case of limited embedded radio capabilities or timely/locally unavailable radio coverage).However, in the cognitive radio case, the terminals should be aware of the spectral usage of a primary. This implies the need of communication with the primary, so as to implement cooperation and to optimize the spectrum use. The primary should then broadcast information and terminals must pay attention to this RAT beside their own. It is up to the algorithmic investigations carried out in WP2 and WP3 to determine to which extent one should exploit the available heterogeneity potential, and to define proper cooperative (i.e. including potentially censorship mechanisms) or non-cooperative strategies. This choice does not fall in the scope of the scenario definition here.

One first concern is about the physical and protocol layers abstractions required for WP2 T2.1 (See 5.1.3) studies, which shall be as much as possible compliant with the previous existing or upcoming standards. If a core interest clearly concerns cooperation and heterogeneity, other specific and research-oriented

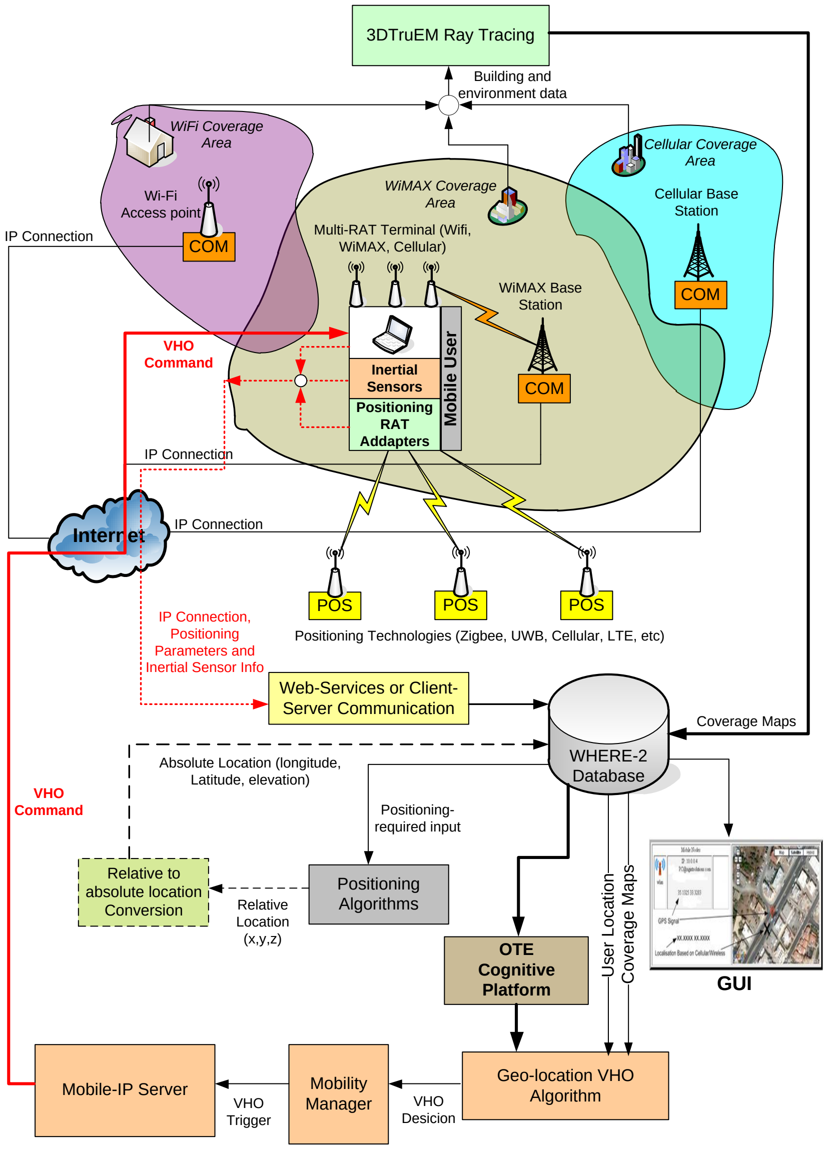


Figure 13: Generic WHERE2 scenario architecture for joint positioning and communication

studies in T2.2 (See 5.1.4) and T2.3 (See 5.1.5), which are by nature more exploratory and focused, might occasionally consider mono-RAT, non-cooperative, and/or proprietary solutions (e.g. single-link environment characterization through IR-UWB in T2.3 or radio parameters self-learning and auto-calibration for narrowband RSSI-based location in T2.2). However, it does not mean that those techniques could not be successfully integrated afterwards in cooperative and heterogeneous contexts.

### 3.1.2 User Mobility

For the intended applications, one common point is that each single user carries a hand-set terminal in various kinds of GPS-less environments. The practical consequence is that only two mobility patterns are considered:

- pedestrian mobility in indoor (public/professional/private areas) or urban canyon (streets) environments
- on-board mobility for transportation vehicles in urban canyons (e.g. cars on roads or tramway on its rail tracks).

with following restrictions:

- Group/social mobility models (with correlated movements) are to be taken into account for pedestrian mobility, depending on the use case
- Specific model assumptions might be also applied in certain working environments to constrain further mobility (e.g. map-based linear piece-wise trajectories on roads or railway tracks)
- The observed maximum speed per user shall be on the order of $10m/s$ for pedestrians and $70km/h$ for transportation vehicles (typical maximum vehicular speed in urban environment).

The performance of WHERE2 algorithms will be assessed and guaranteed for representative time durations, in compliance with most of the foreseen use cases and applications. With respect to location robustness, one shall consider addressing not only short-term and small-scale failures/outages, but the overall behaviour over longer-term and larger-scale trajectories. This is absolutely mandatory to fairly evaluate the claimed pervasive nature of the designed solutions. Here, "pervasive" indicates that they can be robust across various conditions in a given application environment. Hence, the mobile pedestrian trajectory can be intended in a wider-sense, including stances in certain locations.

As an example, for a pedestrian walking in an indoor environment, the idea is not to assess uniquely the performance of the navigation service in a few rooms or in a particular corridor, but over much more significant portions of space and time (i.e. integrating and averaging the effect of typical human behaviour as a function of time during the day). Accordingly, one has to alternate situations when the pedestrian is static (and check e.g. if tracking filters can still properly operate) and occasionally mobile. Intuitively, one can also state that the portion of time spent in a static position is highly dependent on the considered context. This was already pointed out and illustrated in the FREEDOM (See p. 86) project, where long-term mobility models have been differentiated and conditioned upon the application environment (e.g. See Sections 5.4 and 5.4 for the office and house environments, respectively). On the other hand, over shorter-term and spatially continuous portions of the travelled trajectories, one still has to account for local and transitory effects.

For this sake, two kinds of models, different by nature, will be considered and coupled in the frame of WHERE2:

- "Shorter-term" mobility models accounting for steady state mobility (mostly intended between static periods and including potentially group/social mobility) e.g. See [5] from the WHERE project,
- Longer-term mobility models accounting for static phases (e.g. with a certain probability and time distribution, conditioned on the environment and/or the room) e.g. See Sections 5.4 and 5.4 [6].

### 3.1.3 Physical Environments

The WHERE2 project will address in priority representative indoor environments, where:

- neither conventional satellite-based means nor any homogeneous/non-cooperative radio access technology have proved yet to provide sufficient location precision and/or constant quality of service under practical propagation conditions (at least constant sub-meter precision)
- the potential benefits from cooperation and/or network heterogeneity are expected to be optimal (or at least significantly better), since:
  - indoor environments are naturally more densely crowded, hence providing better mobile-to-mobile cooperation availability through short range radios,

  - a wider variety of static (and possibly geo-referenced) network elements or pieces of infrastructure are already (or will be) massively deployed in the buildings. These elements can advantageously serve as landmarks/references for absolute positioning purposes (e.g. WLAN access points, femto-cells, short range WSN collectors/coordinators).

However, as already mentioned, WHERE2 investigations apply to any kind of environments where satellite based solutions are not sufficient. Beside usual indoor cases, this includes urban canyons as well, where relative connectivity to WiFi access points and macro-cell base stations is still available. As regards to channel modelling, two main points should be addressed:

- Conditioned on the chosen mobility models, dynamic indoor propagation models are required for both medium-range and short-range RATs (or at least derived models for relevant measured radio-location metrics, e.g. TOA, RSSI, etc.).
- For the algorithms that also consider incorporating macro-cellular means, dynamic out-door-to-indoor propagation models shall be required as well (or at least models for radio-location metrics).

Two main challenge for channel modelling in the very context are to account simultaneously for:

- the spatial correlation under terminal mobility of distinct radio signals from one single point in space, coping with both mobile-to-mobile cooperative links and heterogeneous access,
- NLOS link blockages due to the building/walls/pieces of furniture (classical environmental obstructions), but also due to other mobile users walking around.

### 3.1.4 Network Deployment and Elements of Infrastructure

Beside mobile terminals, according to the multi-standards and heterogeneous context, most of the involved RATs might provide connectivity with respect to fixed network entities, which can play different roles:

- From the communication perspective → Macro/micro-cell base stations in cellular systems, access points in WLAN systems, data collectors, coordinators and/or gateways in short-range WSN, or even static relays in any multi-hop or cooperative wireless system,
- From a localization perspective → Static anchors/references with known locations.

In the generic scenario, the network deployment is also characterized by density variables (intended "per floor" and expressed in entities/$m^2$), which account for network deployment on both user and infrastructure sides:

- Spatial density parameter for mobile users $\rho_{MT}$
- Spatial density parameters for anchors/landmarks, including:
  - macro-cells $\rho_{A,MC}$
  - WLAN WiFi access points $\rho_{A,LAN}$
  - Femto-cells $\rho_{A,FC}$
  - Fixed WSN LDR anchors $\rho_{A,WSN}$

In terms of network deployment (with respect to both mobile terminals and fixed elements of infrastructure), several density parameters will play a critical role in both WP2 and WP3 investigations:

- $\rho_{A,MC}$ shall be set as a constrained/typical value (i.e. imposed by cellular operators).
- $\rho_{MT}$ and $\rho_{A,LAN}$ shall depend mostly on the application or use case environment, but still with typical values (e.g. in homes, offices or public areas).

- $\rho_{A,FC}$ shall remain as a free parameter of the study (unpredictable technology penetration so far, although probably in line with current WiFi access points density).
- $\rho_{A,WSN}$ shall also remain as a free parameter of the study (depends on the indoor infrastructure deployed by WSN operators to provide a certain quality of service/level of precision). This may be the relevant variable to achieve a target application precision or quality of service.
- For the three last kinds of anchors, based on the specified density parameters, classical 2D/3D random (e.g. uniform) or deterministic deployment patterns should be considered. Continuous random variables will be used for the coordinates (with pseudo 2D densities intended "per floor") and discrete random variables will be used for the number of floor.

In WP2, the previous density parameters are useful to highlight the most relevant operating trade-offs between location performance and infrastructure cost. Moreover, they also enable to point out who shall support the cost for potentially new deployments (i.e. end-users, cellular or WSN operators, other external service providers, etc.)

For network security oriented applications with more stringent constraints, such as location-aided attack detection and counter-measures, one anchor per 100 square meter is used (as an order of magnitude). It is assumed that out of total number of anchors only half of them can be malicious, and that they are not synchronised in the attack. When the attack occurs, the malicious anchors report incorrect location (this could also happen if two anchor nodes are accidentally switched) and if no counter-measures are taken mobile terminals use this malicious information to position themselves.

Femto-BS, which are expected to be core building elements of future indoor wireless systems are small base stations intended to improve the cellular coverage in residential and business environments. They are linked to the core network via Digital Subscriber Line or an optical access and deployed by the customer (plug and play deployment). The deployment of femto-cells allows for unloading the macro cell network and improving the indoor coverage. They are assumed to be deployed indoor. It is foreseen that thousands of femto stations might lie under the coverage of a macro station, sharing the same resource. For instance, in 3GPP LTE-A evaluation scenarios, for a home environment they are deployed in clusters, each cluster being a $5 \times 5$ square grid with a $80m$ diagonal (See Figure 14). Thus, there is at most one femto station per

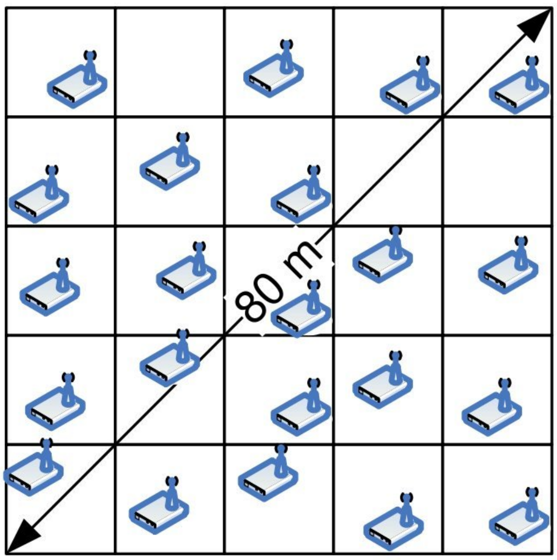


Figure 14: Home environment grid in 3GPP LTE-A evaluation scenarios

square of $111m^2$. In a hexagonal deployment with 3-sectorised macro cells and 500m inter-site distance, there might be more than 600 femto-cells in a sector and even more considering buildings with several floors. The femto stations have a transmission power which is lower than for macro base stations, e.g., more than 20 dB lower in 3GPP LTE. In practice, in a home environment, the femto station transmit power is set in order to cover an apartment (e.g., $100m^2$), in order not to interfere too much the macro station. In an office environment or a shopping mall, the femto cell coverage is higher, around $2000m^2$.

Femto-cells can be used for localizing mobile users in environments where traditional geo-location techniques do not show high performance (Figure 15). When deploying a femto-fleet, i.e. a cooperating set of nodes, network-based optimisations can be implemented. This kind of cooperative deployment targets small to medium sized enterprises (SMEs), apartments in cities, malls and public areas such as airports, hospitals ant train stations. The femto stations deployment can be considered as random, an initial step of geo-location of the nodes being mandatory before providing geo-location to user-terminals.

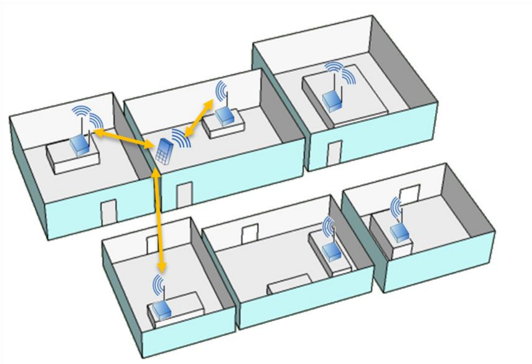

Figure 15: User terminal localization by femto-cells

Femto-cells might perform a joint relative positioning from their measurements. If reference nodes (such as macro base stations, GPS located femto stations, or by O&M ) are available, the absolute position of each node can be computed (Figure 16).

Additionally, future femto-cells are expected to have altimeter built in, so that vertical position can also be provided to emergency personnel.

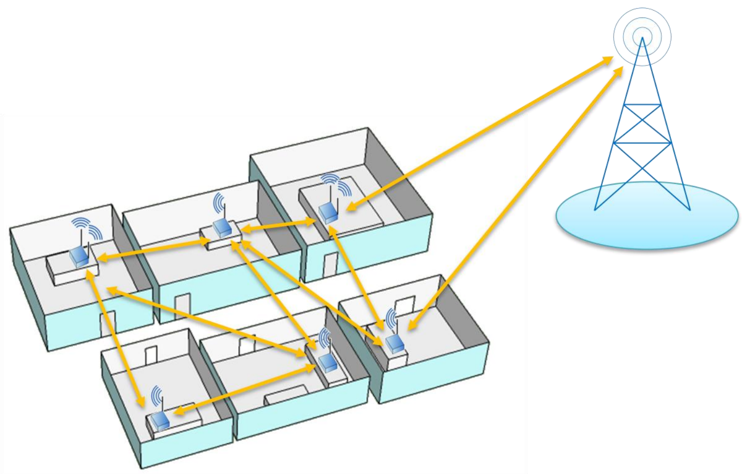

Figure 16: Femto-cells localization use case

### 3.1.5 Levels of Cooperation

As already mentioned , typical cases of reduced mobile-to-mobile cooperation can be due to unintentional radio blockages, poor coverage areas, or the deliberate selection of cooperative links to reduce traffic, latency, computational complexity and/or energy consumption. But it might also happen that some users do not will to cooperate a priori with other mobile neighbours or specific elements of the infrastructure, even when the latter are available and relevant from the performance point of view. This might typically depend on the kind of contract subscribed with the operator(s) and/or service provider(s). Hence, one shall also introduce a new optional parameter $R_{coop}$ to account for the average rate of willing cooperative terminals (among all the terminals). Typical figures for $R_{coop}$ are obviously unknown so far, depending on market trends, business models and commercial agreements. Accordingly, one recommendation is to keep this optional parameter free as well.

Moreover, concerning the level of cooperation $R_{coop}$ can be artificially set to zero, keeping in mind that the figured techniques figured out in WHERE2 (even if non cooperative at first sight), could remove[upm]anyway take part in a wider cooperative context.

### 3.1.6 Generic Scenario Parameters

The intended validation and test cases (See 3.2) shall consider one particular (or a combination of the) working environment(s) described in table 21.

| **Application Environment** | **GPS-free transportation environments** (e.g. cars, buses, or tramways in urban canyons) | **Public areas** (e.g. shopping malls, train stations, airports, cinemas, crowded street on foot) | **Professional areas** (e.g. offices, hospitals) | **Private areas** (e.g. houses, flats) |
|---|---|---|---|---|
| **Physical Environment** (wrt. radio propagation) | Urban Canyons | Indoor + Urban Canyons | Indoor | Indoor |

| | | | | |
|---|---|---|---|---|
| **Examples of Related Applications and Use Cases** | • Robust GPS-free navigation<br>• Intelligent transportation<br>• Network access and rates optimisation | • Location-dependent commercial offers<br>• Context-aware services or information broadcast<br>• Nomadic social networking | • Building energy efficiency<br>• Better ergonomics at work<br>• Saved time and costs | • House automation<br>• Location-dependent HiFi and entertainment<br>• Domestic patient monitoring<br>• Assisted mobility for elderly people<br>• Physical rehab<br>• Off-line statistics of the human physical activity |
| **Area Covered by the Location Service** | City area | Wide<br>Up to $50.000m^2$ | Medium<br>Up to $5.000m^2$ | Reduced<br>Up to $500m^2$ |
| **Density of Mobile Terminals**<br>$\rho_{MT}$ | High to very high<br>0.01 to $> 0.1UE/m^2$ | High to very high<br>0.01 to $0.1UE/m^2$ | Medium<br>0.001 to $0.01UE/m^2$<br>Pseudo-2D terminal random distribution per floor, Number of floors per building drawn as a discrete random variable | Low<br>A few persons (e.g. 1 family of $< 10$ users)<br>$< 0.001UE/m^2$<br>Pseudo-2D terminal random distribution per floor, Number of floors per building drawn as a discrete random variable |
| **Density of WiFi APs**<br>$\rho_{A,LAN}$ | N/A | Medium, up to 1 AP per $1000m^2$ | Medium, up to 2 AP per $1000m^2$ | Low to high, up to 2 APs per $150m^2$ |

| | | | | |
|---|---|---|---|---|
| **Density of femto-cells** $\rho_{A,FC}$ | N/A | Medium, up to 2 femto-cell per $1000m^2$ | Medium, up to 2 femto-cell per $1000m^2$ | Low to high, up to 1 femto-cell per $150m^2$ |
| **Density of WSN Anchors** $\rho_{A,WSN}$ | To be assessed by WP2/WP3 studies | To be assessed by WP2/WP3 studies | To be assessed by WP2/WP3 studies | To be assessed by WP2/WP3 studies |
| **Users Intentional Cooperation Level** $R_{coop}$ | Low to High<br>0 to 100% | Low to High<br>0 to 100% | Medium to High<br>50 to 100% | High<br>75 to 100% |
| **Mobility Models** | **Transport dependent**<br>• Piece-wise model, with linear portions trajectories, under map constraints<br>• Traffic models (including car traffic jams or bus tramway frequency)<br>• Maximum Speed $70km/h$ | **pedestrian**<br>• Group mobility<br>• Rare and short static periods (e.g. sitting consumers in a mall → Static for 15min once per hour)<br>• Occasionally, further map constraints (e.g. in Urban Canyons)<br>• Maximum Speed $10m/s$ | **pedestrian**<br>• Small group mobility<br>• Long static periods (e.g. sitting workers → Mobile for 5min once in 2 hours)<br>• Maximum Speed $10m/s$ | **pedestrian**<br>• Independent users mobility<br>• Medium-term static periods (e.g. sitting family members → Mobile for 5min once per 1/2 hour)<br>• Maximum Speed $10m/s$ |

Table 21: Scenarios parameters as a function of the working environment

## 3.2 Validation and Test Cases

The following validation and test cases inherit fully or partly from the generic scenario which has been described in the previous section. In other words, they are intended for illustration purposes, pointing out some particular technical goals, innovative concepts or functionalities required by UCs, while relying on the same common and overall frame described before (in terms of involved RATs, working environments, etc.).

### 3.2.1 Indoor Navigation through Cooperative and Heterogeneous Networks (INCHN)

Here, we consider real-time tracking in representative indoor environments of mobile pedestrians equipped with multi-standard terminals. The aim is to provide a seamless and precise navigation service, along with an instantaneous figure of merit (or reliability/integrity) regarding the delivered location information.

Ideally, the achieved quality of the location service shall be constant (as a function of time) and at least equivalent to that of GPS systems in clear outdoor contexts. Accordingly, the average 2D positioning error intended "per floor" must be on the order of 1m. So as to ensure the continuity of subsequent location-based services, the navigation service also claims to be robust enough, in the sense no significant outage is expected as a function of time e.g., with a typical 2D positioning error equal to 2m in 95% of time. The previous "average" and "worst case" precision specifications would then comply with most of the location-based use cases intended in indoor environments (See e.g. Sections 2.2.3, 2.6.1). Obviously, this QoS shall be ensured independently of the indoor propagation conditions that are locally experienced (e.g. in case of generalized radio links obstructions) and independently of the connectivity conditions, which obviously depend on terminals mobility.

Since the focus is clearly put on indoor environments in this scenario, only the private, professional and public areas defined in Section 3.1.6 will be considered as working environments (the "street" environment being excluded for the latter area). The corresponding nominal parameters (and models) will then be retained to account for representative spatial distributions of mobiles and anchors, terminal maximum speed and mobility patterns. The three investigated environments hence characterize three different sub-scenarios (with a common set-up but with distinct values for the critical parameters).

As already pointed out, typical indoor environments in the near future are expected to comprise a wide variety of fixed elements of infrastructure associated with specific RATs, as well as mobile, cooperative and multi-standard terminals. So, under realistic network deployment constraints (i.e. depending on the working environment), the most generic scenario frame will assume default availability for:

- Outdoor-to-indoor large-range links with respect to macro-cell LTE/LTE-A and/or WiMAX BSs,
- Indoor-to-indoor medium-range links with respect to fixed femto-BSs and/or WLAN WiFi APs,
- Indoor-to-indoor short-range Low Data Rate links (based on Impulse Radio - Ultra Wideband and/or ZigBee, depending on availability) with respect to
  - fixed Wireless Sensor Network sinks/anchors
  - other mobile terminal (through peer-to-peer links)

However, it is up to the algorithmic studies carried out in WHERE2 to identify the most relevant combination of such resources (i.e. relevant hybrid data fusion strategies and cooperation mechanisms), as well as practical trade-offs for the remaining free parameters (e.g. spatial density of fixed WSN anchors, level of cooperation, etc.).

### 3.2.2 Positioning Aided by Alternative Techniques (PAAT)

Beside (and/or as a complement to) cooperative and heterogeneous approaches, additional techniques can always be applied to enhance the radio-location functionalities in a wide variety of environments. Note that most of these techniques can be intended independently of the cooperative context, and might apply to single link, and/or single RAT and/or single mobile estimation problems. Depending on the particular working environment however, the appropriate parameters and models defined in Section 3.1.6 will be still considered In WHERE2 related studies.

The corresponding sub-cases are classified into three main categories, as follows.

**Map-aided Positioning** In this first sub-case, the idea is to benefit from the prior knowledge of roads, streets, city maps, or building layouts to assist:

- car positioning and tracking in urban canyons,

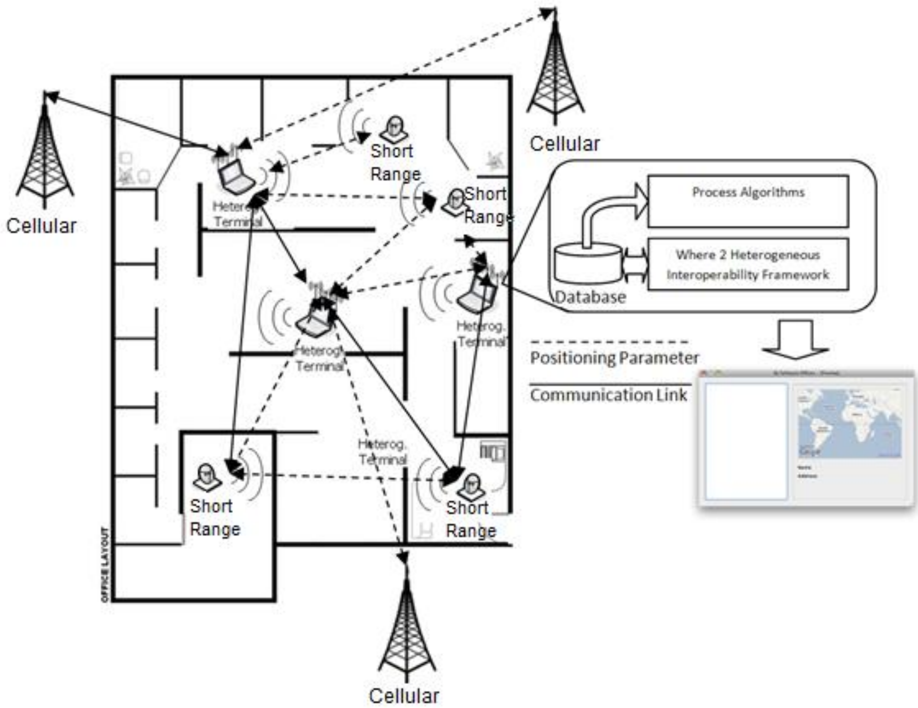


Figure 17: Example of generic indoor scenario for cooperative positioning and tracking in heterogeneous networks

- pedestrian positioning and tracking in urban canyons (e.g. street navigation),
- pedestrian positioning and tracking in indoor environments (in public, professional or personal areas).

The prior knowledge of the map information can for instance be incorporated:

- by setting constraints on the mobility models assumed in tracking filters (e.g. assuming piece-wise straight trajectories for a car or a bus, walking pedestrian in the street or in a corridor)
- by removing improbable estimated locations or outliers measurements, after jointly taking into account the history of past estimates and further geometrical or mobility constraints.

**Inertial-aided Positioning** Just like in the previous sub-case, inertial measurement units embedded in terminals can be used to assist:

- car positioning and tracking in urban canyons,
- pedestrian positioning and tracking in urban canyons (e.g. street navigation),
- pedestrian positioning and tracking in indoor environments (in public, professional or personal areas).

The inertial measurements sensors can be used:

- directly into tightly or loosely coupled HDF strategies with available radio-location metrics

- directly into decoupled fusion strategies between an independent radio-location system and an inertial navigation system
- indirectly to assist the radio-location functionality with further contextual information (mobility indicator, orientation information, etc.)

**Self-learning Procedures** Finally, in the last sub-case, self-learning techniques are used to get adapted to the working context and to:

- jointly estimate mobile location and the in-site radio model parameters required for location estimation (e.g. using iterative self-calibration procedures for positioning algorithms based on parametric approaches)
- Jointly estimate mobile location and the surrounding physical environments, mostly in indoor (e.g. performing mapping or inferring the volume of the room)
- Jointly estimate mobile location and mobility models/parameters (e.g. performing a live update of the underlying state evolution model assumed in tracking filters, based on previous location estimates)

### 3.2.3 Cooperative Cellular Systems (CCS)

Cooperative communication is one of the fastest growing areas of research of cooperative strategies which already started to find their way into practical implementation systems [7]. Therefore, we define a sub-scenario of the generic scenario that focuses on cooperative networks.

The idea of cooperation is based on resource-sharing among multiple nodes in a network. It is possible if users are willing to share computational power with neighboring nodes. It can lead to saving of overall network resources and improved performance. It is anticipated that knowledge of location information can facilitate the choice of cooperative counterpart(s) and make the implementation of cooperative strategies more feasible in practical networks.

Cooperation is possible whenever the number of communicating terminals exceeds two. The three-terminal relay channel (first introduced by [8]) is a classical example of cooperation. Depending on the number of cooperative nodes and depending on which communication links are used for cooperation, we distinguish the following 4 cases of cooperation in cellular settings:

- **Intra-Cell Cooperation** Evaluation and test case regarding establishing intra-cell cooperation are presented as follow (Figure 18):
  - LTE Advanced supports fixed relay stations in order to enhance the radio coverage and flexible radio resource management.
  - Installation of fixed relays should fulfill the following conditions:
    - Relays have line-of-sight connection with the home base station,
    - Relays should be fairly distributed within the cell.
  - Relay stations can be equipped with multiple antennas.
  - Location information can help relays to perform local radio resource management.
- **Inter-Cell Cooperation** This evaluation and test case describes cooperation between cells. (Figure 19).
  1. Cooperation for inter-cell case can be employed to offer performance improvement, e.g., cooperative positioning and interference alignment/cancellation.
  2. Relay stations can be equipped with single or multiple antennas.
  3. Location information can be used to offer partial channel state information.

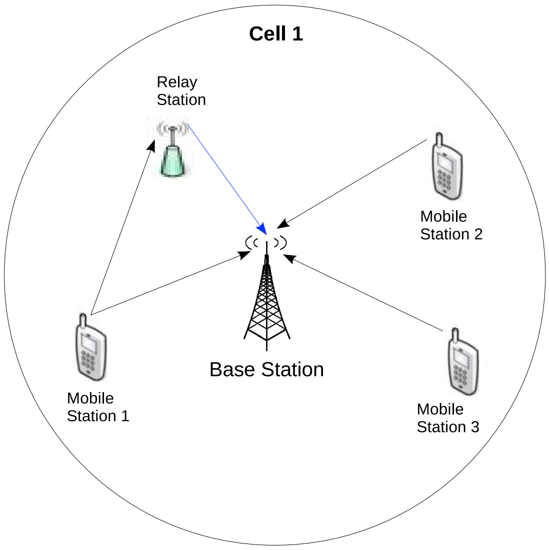


Figure 18: An example of intra-cell cooperation

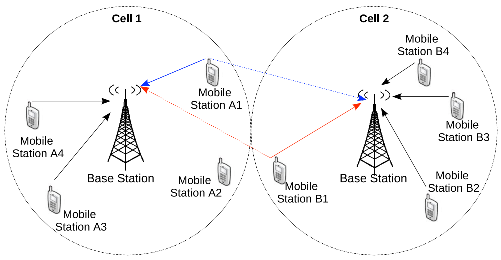


Figure 19: An example of inter-cell cooperation

- **Co-existing Systems Cooperation** can also be established in co-existing systems through opportunistic relaying. (Figure 20).

  1. Relay station opportunistically occupies the primary network's spectrum to offer performance improvement, e.g., opportunistically beam-forming.
  2. Relay stations can be equipped with single or multiple antennas.
  3. Location information can be used to offer partial channel state information.

- **Cluster Cooperation** considers cooperation among a group of nodes that form a cluster. (Figure 21).

  – A cluster is formed by individual nodes that use short-range links for internal communication, however each node preserves its long-range links. Long-range communication capabilities of selected nodes are used for data exchange with the "outside world". This combined with the following information exchange among cluster members can reduce the amount of redundant information transmitted via long-range connections and thus reduce the network load.

  – A cluster is a temporary structure that can be changed over time: nodes can potentially leave a cluster, new nodes can join, or a cluster can stop functioning when no longer needed.

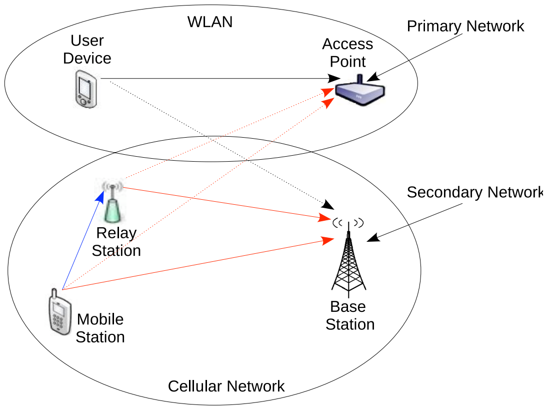


Figure 20: An example of co-existing systems cooperation

- The heterogeneous network infrastructure comprises:
  * a large-range cellular-based network, that can be realized as 3G/ LTE/ WiMAX or WiFi and
  * a medium or short-range network, that can be realized as WiFi, WAVE, ZigBee, UWB, whose data rate is higher than the data rate of the large scale network.
- Besides the network deployment parameters specified for the generic scenario in Section 3.1, this scenario requires the size of a cluster to be added as free parameter.

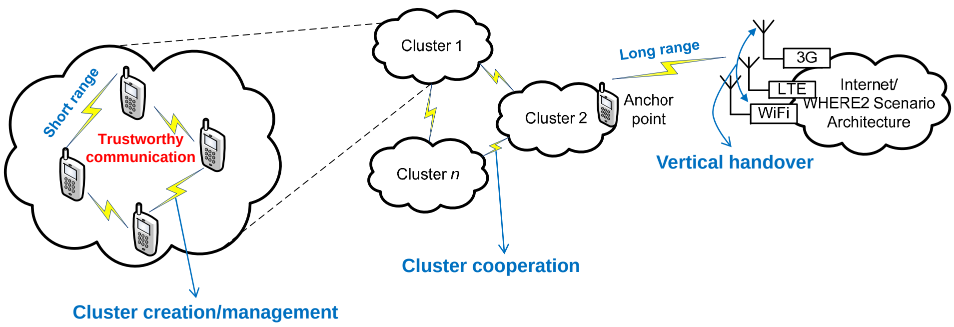


Figure 21: An example of clustering

### 3.2.4 Cognitive Radio (CR)

Global evaluation and test case regarding cognitive radio (CR) techniques for each of the contemplated tasks of WP3 are presented as follows:

- **CR validation case 1 (Figure 22)**:
  - Primary network is the classical cellular network.
  - Secondary network is femto-cell.
  - Position information can be potentially used to predict attenuations from secondary network to primary network, and hence predict interference levels in different paradigms of CR, e.g., for underlay CR.

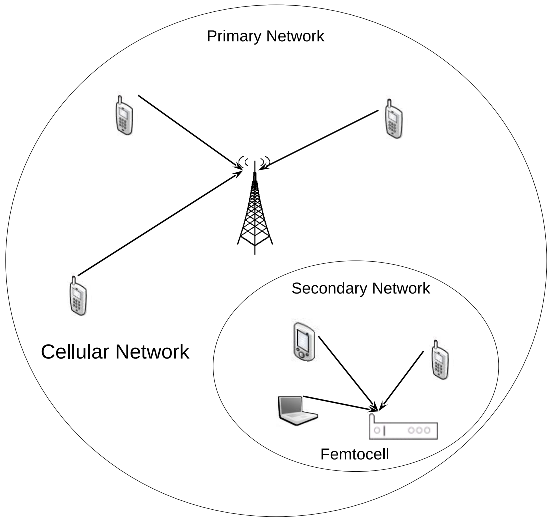


Figure 22: An example of Cognitive Radio validation case 1: primary network is classical cellular network and secondary network is femto-cell.

- **CR validation case 2**:
  - Primary network is a network that either occupies the unlicensed spectrum i.e., WLAN, or has specific spectrum patten, i.e., broadcasting network.
  - Two types of networks are considered as secondary network.
    - **CR validation case 2-a (Figure 23)**: any crowded network, i.e., classical cellular networks.

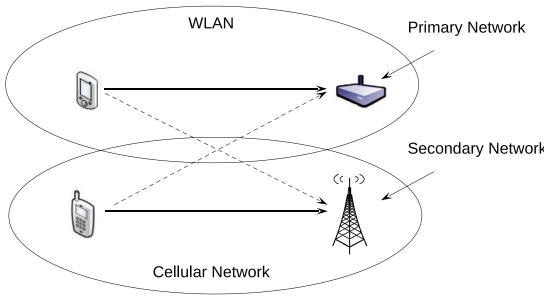


Figure 23: An example of Cognitive Radio validation case 2-a: primary network is WLAN network and secondary network is classical cellular network.

    - **CR validation case 2-b (Figure 24)**: any network connectivity is essential, i.e., secure connectivity in wireless sensor networks.
  - Location information is assumed to be accessed by either primary user, secondary user or both in order to offer partial channel state information, i.e., channel gain map, user services status, etc.

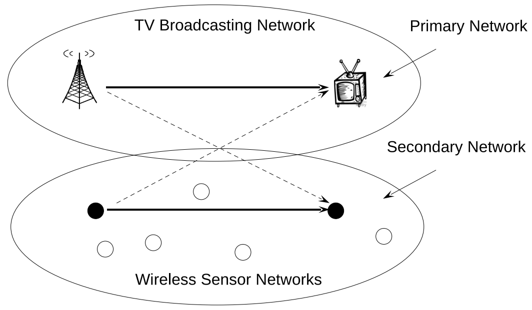


Figure 24: An example of Cognitive Radio validation case 2-b: primary network is TV broadcasting network and secondary network is wireless sensor network.

### 3.2.5 Positioning Assisted WiMAx-LTE/WiFi Vertical Handover(VHO)

The Vertical Handover trial evaluation and test case, will be used to demonstrate as defined in Task T4.6 the capabilities and performance of heterogeneous communication platform (as described in Section 5.5.2) which utilises positioning information made available from the various positioning algorithms and/or modules. This test case aims to serve two purposes:

1. To demonstrate the benefit in positioning by using a multi-technology platform by obtaining parameters from different Radio Access Technologies (RATs) and

2. To demonstrate the benefit in communications in a heterogeneous wireless networking environment when the exact position and mobility of the user are known (e.g. benefit in the energy saving at the terminal through the use of geo-location vertical handover)

The demonstration architecture which is shown in Figure 13, apart from the mobility platform which will provide the vertical handover functionality also incorporates a cognitive platform which can act as an optimizing mechanism once the geo-location VHO has been decided. Cooperation and interworking between the positioning and the cognitive platform will take place in order to achieve the optimized situation for a user to communicate to the RAT. This scenario demonstration architecture (shown in Figure 13) consists of two types of Radio Access Technologies.

- *Positioning RATs (e.g. ZigBee, UWB, Cellular)*: Context (signal-related parameters) extracted from these technologies will be used by the positioning algorithms in order to obtain the position. No IP-connectivity will be established through these technologies.

- *Communication RATs (e.g. WiFi, WiMAX, Cellular)*: They will be used to demonstrate geo-location vertical handover. IP-connectivity is required.

A mobile user is roaming in a heterogeneous networking environment of various communication RATs while at the same time is receiving signal parameters from the various positioning RATs which are stored in the database and are used by positioning algorithms to determine his location. The location of the user is made available from the positioning modules in conjunction with his mobility information made available from inertial sensors and the signal coverage maps (for the communication RATs) pre-calculated using Ray Tracing and stored in the database. This location is then used (by the VHO algorithms) to determine whether the user is moving out of the coverage of one technology and moves into the coverage area of another and therefore instruct the terminal to switch on the appropriate radio adapter and vertically handover the connection to it.

The cognitive platform shown in Figure 25 is placed between the positioning algorithm platform and the WHERE2 database and takes communication information from the interfaces of the RATs. This information acquired by the platform through the Network Element Cognitive Manager (NECM) is related to communication parameters that are set between RAT and user terminal, such as SINR, PER, RSSI and CU and optimizes the communication between the above entities of the user terminal and the RAT.

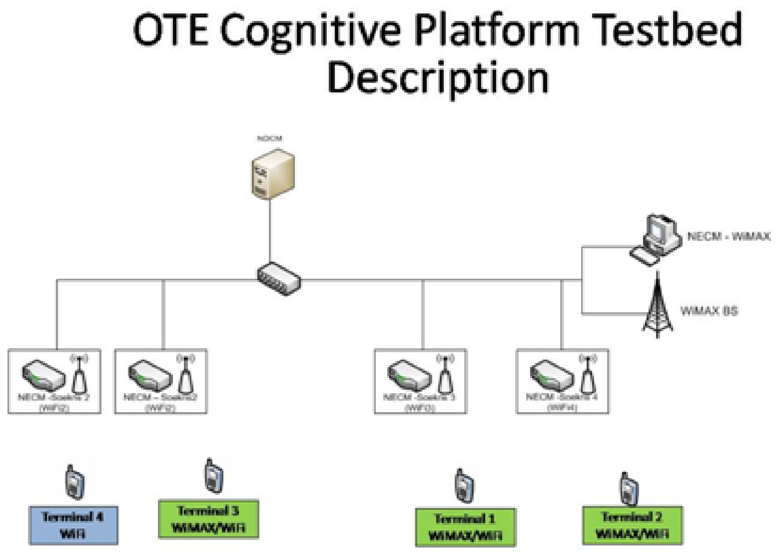


Figure 25: OTE cognitive platform testbed description

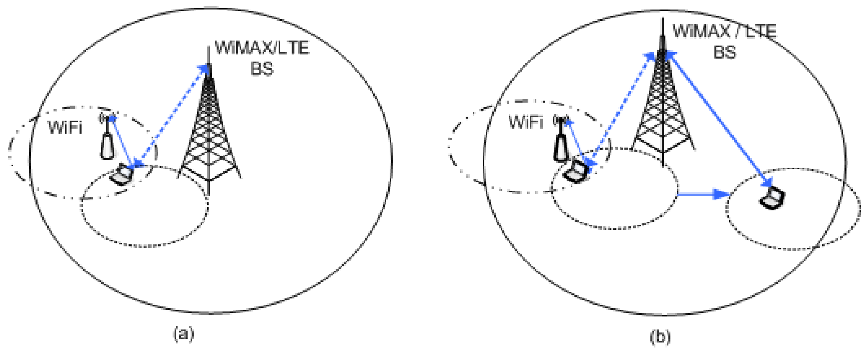


Figure 26: User's terminal(UE) has WiMAX/LTE and WiFi coverage in indoor and outdoor. In case(a) UE is attached to WiFi RAT while in case (b) the UE is attached to WiMAX

Vertical and horizontal handover or channel reallocation occur by instructions given by the NDCM in case that the communication parameters deteriorate. This instruction is given by the Network Domain Cognitive Manager (NDCM) module. The cognitive platform can act as an optimizing mechanism after the VHO platform has initially decided to which cell or RAT the user terminal should be placed based on the location of the user.

For example in case (a) of Figure 26 the UE can be either attached to WiFi or to the WiMAX/LTE network. In this case the positioning RATs may not give enough information in order for the NDCM to decide for the UE to stay in WiFi or to be handed over to WiMAX/LTE network. In this case the cognitive platform will provide additional criteria related to the throughput capability or the interference situation in both networks and then the UE will be instructed by the NDCM to switch to the most favorable, by communication means, network.

For the positioning platform VHO is instructed and executed through a Mobility Manager and an IP-Mobility Platform provided by Sigint Solutions as described in Section 5.5.2. A GUI will also be developed to display the moving user and his/her connection status. The potential benefits in terms of energy efficiency of this geo-location VHO approach will be exploited.

### 3.2.6 Security and Safety (SS)

For this test case we also consider combining different technologies, e.g. LTE, WiFi and ZigBee. This heterogeneous systems context intends to achieve indoor/outdoor secured cooperative positioning and communications always ensuring maximum security of sensitive data provided by what we denominate as security-sensitive mobile terminals. The security-sensitive mobile terminals are connected to an ad-hoc network and mobile infrastructure. Sensitive data coming from the security-sensitive mobile terminals should be available at the command and control station, as well as at some particular authorized MTs in the public areas (indoor or outdoor). The main concern is to guarantee secure handovers between clusters of devices in order to transmit the sensitive data effectively, as the security-sensitive mobile terminals move, indoors or/to/from outdoors.

**Required infrastructure:**

- Fixed/anchor devices (single or hybrid interface)
- Multi-interface mobile terminals
- Indoor and outdoor nodes
- Security-sensitive MTs

Security:

- Cooperative positioning (indoor/outdoor authenticated positional data)
- Cooperative communications (indoor/outdoor sensitive data transmission)

The general framework for this test case is represented in the Figure 27.

| | |
|---|---|
| **Network delay** | $< 280ms$ |
| **Delay jitter** | $< 50ms$ |
| **Packet loss** | $< 1\%$ |
| **Packet errors** | $< 0.1\%$ |
| **Handover delay (between clusters)** | $< 280ms$ |

Table 22: Security validation case parameters

Table 22 summarizes parameters of this test case. The corresponding values take into account recommendations from both the ITU-T (Y.1541) [9] and the IEEE 802.20 Working Group [10]. They assume support for high interactive streaming data from the security-sensitive MTs (class 2 application). In low bit rate technologies, such as ZigBee, small variations regarding these values occur. An evaluation interval of 1 minute should be considered for these parameters values.

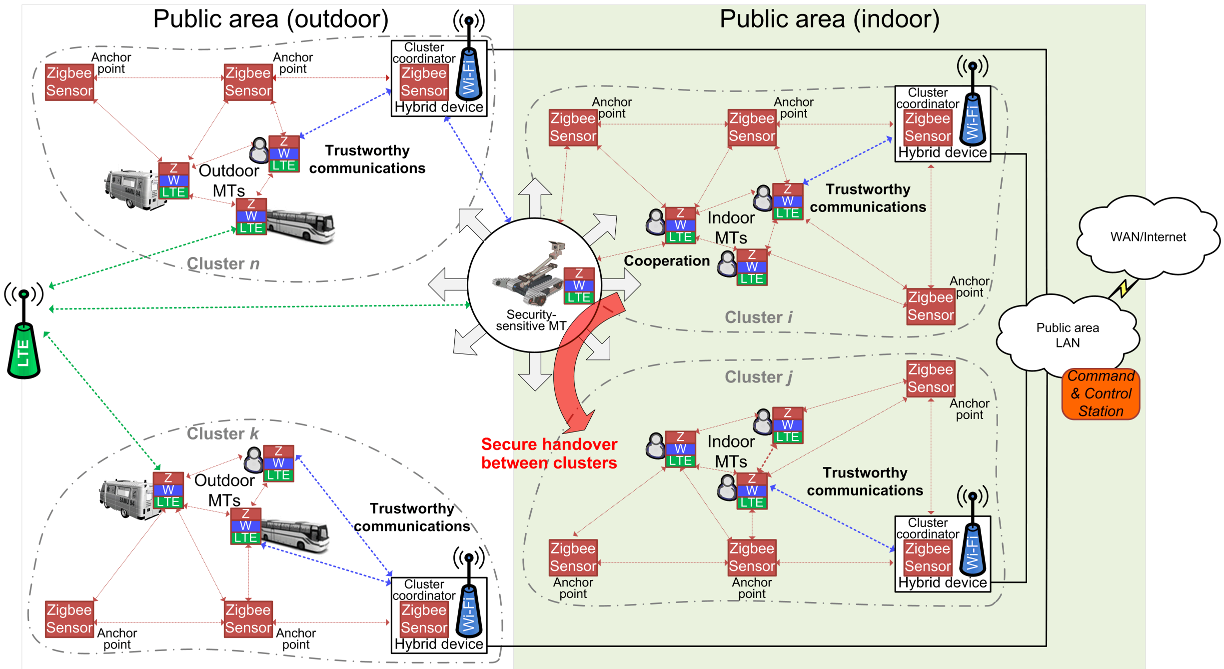


Figure 27: Security and Safety validation case

# 4 Conclusion

First of all, an effort has been made to identify a set of key use cases, which are closely related to the scope and objectives of WHERE2. The corresponding applications are also compliant with current market trends and expectations. Based on the use cases defined herein, it appears clearly that the terminal localization and/or tracking task can take advantage of the future cellular infrastructure. At this point, one strong trend is to make the network denser through the massive dissemination of indoor femtocells. This deployment, combined with the short-range communication and multi-standards capabilities embedded into mobile terminals, are expected to offer a favourable eco-system to improve substantially both the achievable positioning accuracy and the radio access in various environments, where classical GNSS solutions are either impossible or extremely challenging.

Furthermore, the use case analysis has shown that terminal location information is central in a growing number of services because it is strongly related to user context (which is itself important for the application layer). Several kinds of actors (network operators, services or applications brokers, manufacturers, etc.) are already competing to offer location based services and developing new business opportunities accordingly. Here, there are many open important aspects which have strong implications on added value creation, trust and privacy.

Then, out of the set of use cases, one generic scenario as well as important technical validation and test cases have been derived, addressing both localization and communication aspects (e.g. indoor pedestrian navigation based on cooperative heterogeneous networks, location-aided vertical handover or cellular cooperation, etc.). On this occasion, representative values have been provided for critical system parameters (e.g. terminal density or mobility of the terminal) and preliminary models have been referenced, either from the WHERE project or from the recent literature.

Hence, based on this material (which might be updated during the runtime of WHERE2 due to e.g. revised standards), unified simulation set-ups shall be considered for the future investigations carried out in WP2, WP3 and WP4. The idea is to enable a fair benchmark of the solutions put forward in WHERE2 (i.e. under the same realistic working conditions), in order to highlight their respective limitations and complementarities. Another related goal was to identify the physical environments and RATs of interest for other WP1 tasks, which have been recently initiated on radio channel modelling.

The synergies existing between the tasks defined in the project and the proposed use cases, scenarios and the validation and test cases have also been discussed. Moreover, important connections between WHERE means and objectives with respect to other EU-funded projects have been identified and outlined. These contributions are part of the Annex.

# 5 Annexes

## 5.1 Relations between WHERE2 Validation Test Cases and Tasks

In this section the different tasks of the project are recalled and linked with the defined validation and test cases described in 3.

### 5.1.1 WP1-T1.2: Radio-based Characterization, Modelling and Methods

**Subtask 1.2.1 Channel Models for Cooperative Communication and Localization Systems**
The objective of this task is to derive realistic channel models suitable for cooperative heterogeneous systems equipped with localization capabilities.

These models need therefore to incorporate any propagation effect that will have a notable impact on the behaviour and performance of these systems.

The WHERE2 consortium has identified four relevant aspects that need to be investigated and clarified in order to achieve this objective. Their importance with respect to the validation and test cases is addressed below.

- ***Statistical dependence between links in a cooperative heterogeneous system.***
  The statistical dependence between the radio links is a relevant feature in the planning and performance assessment of any cluster of cooperative nodes. Especially if these nodes are confined in the same surroundings. This will be the case in most scenarios addressed by WHERE2, as the focus will be on densely crowded indoor environments (like shopping malls) and outdoor street canyons. In such situations, the communication systems involved in the heterogeneous cooperative architecture are likely to experience similar propagation conditions, and therefore their channels will exhibit similarities that the planned investigations will unveil.
  The outcome of the investigations will be particularly relevant to the following test cases: INCHIN (See 3.2.1), CR (See 3.2.4), VHO (See 3.2.5), and CCS (See 3.2.3).

- ***Characterization of the outdoor-to-indoor channel.***
  Several scenarios considered in WHERE2 consist of a cluster of cooperative mobile nodes located indoors. Some of these nodes are connected to anchor nodes (base stations) located outdoors. In such scenarios, the anchor nodes are used among others to obtain the absolute positions of the mobile nodes. A critical aspect in the determination of the position of indoor nodes using outdoor anchors is the outdoor-to-indoor channel. The investigations in this activity aim at providing a characterization of this channel, especially for localization purposes.
  The outcomes of the investigations will be particularly relevant to the following test cases : INCHN (See 3.2.1), CCS (See 3.2.3), VHO (See 3.2.5).

- ***Non-stationary behaviour and time variance of the channel.***
  The channels of a cluster of confined cooperative nodes are subject to time-dependent obstructions of the links, when for instance a moving person or car obstructs the strongest path of a specific radio link. This is particularly true for shot-range networks, e.g. nomadic social networks. In this respect it is important to assess the statistical properties of these time-variant attenuations, like the fade depth and duration. The channel models to be designed will also include the mobility models developed in WHERE and the model of coordinated group movements to be designed in WHERE2.
  The outcome of the investigation will be particularly relevant to the test cases INCHN (See 3.2.1) and CCS (See 3.2.3).

- ***Characterization of the dependence of the above mentioned features in respect to the different types of environments.***
  The idea here is to exploit the information on the channel conditions in the multiple links of a cluster of cooperative nodes to infer on the properties of the surroundings, like size of the rooms, wall types, etc. This information can be exploited for localization too.
  Especially test cases INCHN (See 3.2.1) and CCS (See 3.2.3) will be concerned by the outcomes of these investigations.

**Subtask 1.2.2 Evolved Ray-Tracing for Localization** Ray Tracing tools can naturally bring the connection between radio channel observables and Tx/Rx positions.

The main objective of this subtask is to study dedicated evolutions for Ray Tracing tools to address the positioning simulation needs of WP2 and WP3. It first consists in building the connection between the RT functional block and the mobility model block which has been proposed in WHERE. The second important evolution is to build the capability to bring at once the radio channel observables on several MS with different air interfaces (e.g IR-UWB and LTE)

One specific objective is to integrate into a ray tracing simulator:

1. Multi node/Multi RAT capabilities
    - Specific evolution for IR-UWB waveforms
2. Mobility models for multi node dynamics
    - Incremental RT which consist in taking advantage of the knowledge of a set of rays at a given position to make a fast evaluation of the next set of rays at a close position on the simulated trajectory.

### 5.1.2 WP1-T1.3: Market and Standardisation

The standards followed in T1.3 are related to some critical RATs involved in our generic scenario This task will survey and report on regular (quarterly) basis the current market feedback and standardisation activities. This is the key to assure reasonable investigations for future markets.

Current market studies forecast, e.g., a wide introduction of femto base stations in home and business environments together with a fast decrease of their costs. During the project life, WHERE2 will survey this femto product development, in order to validate hypotheses and scenarios considered by the project.

Moreover, following standardisation progress will be a key issue for the management of the project, and in particular for the validation cases. As an example, potential impact of especially LTE-Advanced progress on femto base station specification, localisation and collaborative communications, including relaying, will be assessed.

Concerning femto cells, there is a strong move of standardization bodies to provide 3GPP femto specifications, as a result of a strong pressure from operators in 3GPP. In particular, enhanced inter-cell interference coordination (ICIC) addressing heterogeneous networks and in particular ICIC between macro cells and femto cells are being addressed in Release 10 and further work will continue in Release 11. A first solution for the mobility from macro cell to femto cell has been specified in Release 9, but further improvements using a direct interface between the macro cell and the femto cells under its coverage (or a femto cell gateway) should be specified in future releases. The femto cell to femto cell mobility is also being specified for open femto cells or cells belonging to the same closed subscriber group (CSG) but further work is still needed for femto cells belonging to different CSGs. Local breakout has been addressed in Release 10 and further enhancements as mobility are foreseen for Release 11. The security for a direct interface between femto-cells is still to be addressed.

Concerning collaborative communications, in LTE-Advanced, cooperative communications including relays have been identified as an efficient tool to increase the system performance and are being specified for Release 10.

Concerning localisation, UE-based (terminal-based) positioning has been specified in Release 9. New optional positioning reference signals (PRS) have been specified in [11] (Section 6.10.4), to be used in situations, where timing estimation with the synchronization signals or already available reference signals does not provide the desired accuracy. Two positioning methods are specified in Release 9. In Observed Time Difference of Arrival (OTDOA) method, the time differences of arrival of reference signals from different neighbouring base stations are used. For this purpose, new measurements have been introduced in [12] (Section 5.1.12) and in [13] (Section 9.1.9.2). The second method is based on angle of arrival at the base station plus terminal timing advance (AOA+TA). In 3GPP specifications, this method is referred to as enhanced cell identification (ECID). Timing advance is used to evaluate the base station (eNB) to terminal distance. New measurements have been introduced for this purpose in [12] (Sections 5.1.15, 5.2.4 and 5.2.5) and [13] (Section 9.1.10.3), measuring the time difference between reception of downlink subframe and transmission of the uplink subframe at the terminal ($\Delta T_{UE}$), the time difference between reception of an uplink subframe and transmission of a downlink subframe at the base station ($\Delta T_{eNB}$) and the timing advance itself. The timing advance can be measured at the eNB using two ways:

- either using a terminal $\Delta T_{UE}$ report and in this case the timing advance is equal to the sum $\Delta T_{eNB} + \Delta T_{UE}$,
- or using a random access signal from the UE (RACH) and in this case the timing advance is equal to $\Delta T_{eNB}$.

LTE Positioning Protocol (LPP) details are specified in [14] and [15]. Specification [15] describes the architecture part of LPP (LPPa), i.e., procedures used to handle the transfer of positioning information between the base station and the positioning server, which is the entity centralising the information and computing the terminal position. Specification [14] describes LPP between the terminal and the positioning server. Concerning current LTE work items, network-based positioning is being studied but has not been finalised yet. In this work item, different base stations measure the time of arrival of terminal uplink signals and these informations are centralised at the network level in order to compute the terminal location. It will be important to follow the progress of this Work Item in order to take into account any change in the standard relative to localisation, and to identify any possibility to contribute to LTE on this subject.

Furthermore, reports from the OMA standardization group from which the SUPL standard emerged will be followed and reported.

### 5.1.3 WP2-T2.1: Synergetic Cooperative Location and Communications for Dynamic Heterogeneous Networks

In this task, advanced distributed and cooperative algorithms will be investigated in the dynamic heterogeneous context and benchmarked with more classical centralized approaches. A typical scenario of interest for instance considers locating mobile users based on wide area 3GPP-LTE, complemented by one or several femto-cells and further peer-to-peer links between users. One general goal consists in evaluating the robustness of proposed algorithms in realistic conditions, e.g. with partially known BS/anchor locations, imperfect network synchronization, dynamic channel or changing network topology (experiencing temporary peer-to-peer link failures). This is totally in line with the developed scenarios and validation test cases in this deliverable. Another objective here is to assess achievable position precision vs. critical parameters such as anchors/mobiles density (e.g. required neighbourhood connectivity...). Further problems inherent to cooperative/distributed approaches (e.g. convergence issues due the presence of loops in graphs) will be also mitigated. Whenever possible, self-organization methods will be also favoured for instance to retrieve the (relative) location of femto-BSs that are not necessarily fixed but turned on/off by the subscriber, in such a way that the location process is no more controlled by the network operator. Regarding new synergies with communications means, one goal of this task is to identify new possible synergies between communication means and location functionalities, for instance through advanced cross-layer design. Furthermore, interoperability and interference issues due to network heterogeneity will be addressed in this task. Integrating femto-cells for 3GPP-LTE networks including a comparison of licensed vs. unlicensed bands and evaluating the impact of different specifications of femto-cells to real base stations on the positioning approaches is for instance part of this investigation.

One target of this deliverable D1.1 is to provide precise and coherent scenario descriptions for a realistic performance evaluation of these new proposed algorithms. This requires realistic parameters and constraints, e.g., the description of the environment, mobility and error models, plausible network topologies, user density/distributions, or constraints with respect to connectivity. This is delivered especially by the generic scenario description. It finally will allow an assessment and detailed comparison of the proposed techniques and will make sure drawing stable conclusions about the overlying use cases in terms of, e.g., achievable positioning accuracy or communications overhead for the WHERE2 approach.

### 5.1.4 WP2-T2.2: Location Information Extraction

This task is connected to the validation case PAAT (See 3.2.2). The objective is to enhance localisation precision by extracting and integrating new information such as inertial information, position constraints imposed by maps, slow fading characteristics in addition to fast fading and environment characterisation. The task is broken down into two subtasks depending on the source of the information to be extracted and exploited. In the first subtask (T2.2.1) information gets extracted from sources other than radio links like inertial sensors and map matching techniques. This subtask will perform an analysis of the usefulness of inertial sensor information for localisation purposes and whether this kind of context may reduce the need for parameters from radio links. The analysis will be performing for indoor and outdoor situations especially in Intelligent Transport systems in Section 2.5 and Security and Safety validation case in Section 3.2.6

State of the art exploitation of inertial sensor information so far considers centralized and non-cooperative schemes (in LOS settings) whereas in WHERE2 we investigate cooperative approaches for enhanced fusion with peer-to-peer radio links between multiple IMU enabled devices in heterogeneous radio-location context. The various parameters defined in the Generic Scenario in Section 3.1 will serve as a starting point for this investigation. The generic scenario defines an indoor heterogeneous networking environment with low pedestrian mobility. An investigation of potential improvements of the accuracy of localisation process by using constraints imposed by maps will be carried out. The investigation can be carried out for indoor and outdoor scenarios for users of low or medium mobility.

The second subtask investigates the exploitation of information extracted from radio links. The focus of the WHERE approaches on the fast fading channel elements are extended by incorporating slow fading dynamics. Also specific statistical models which are used to mix two relevant piece of information such as local statistical laws binding range and radio observables (e.g. RSSI, ToA etc.) and local statistical position of the users. Such information can be stored in a database and assist in positioning algorithms. Finally, the radio channel response can be used to extract environment related parameters such as the electrical parameters of the building interfaces/walls which could then be used in Ray Tracing simulations to improve the accuracy of a potential fingerprinting database. This subtask includes a number of Ray Tracing simulations and use of in-situ measurement results. Just like in T2.3 a synthetic environment will be used as a starting point for these investigations. The measurement campaign conducted within the scope of WHERE in the SIRADEL indoor environment will be used (Figure 28).

Figure 28: A Pedestrian Trajectory for Algorithmic Evaluation Extracted from the WHERE Database

### 5.1.5 WP2-T2.3: Self-learning Positioning using Inferred Context Information

The objective of T2.3 includes developing the mechanism that allows accurate self construction of the indoor environment maps based on context information. Afterwards, these maps are used for enhancing the positioning methods and enriching the mobility model by for example excluding movements through the walls. The context itself is gathered from measurements of wireless communication properties and it includes both, environment data and user movement trajectories.

Inside this task a synthetic test environment is being constructed which will serve as a common test-bench for all developed algorithms. Since all partners are involved in investigations of indoor environments it was decided to use the WHERE measurement campaign as a basis for common environment. The measurement campaign was conducted in the SIRADEL headquarter building in Rennes, France (Figure 29). The selected environment can be described as a set of offices at one building floor occupying approximately $400m^2$. As such, this environment complies perfectly with generic scenario description. Nevertheless, in case of T2.3, the heterogeneous network structure is restricted to only one RAT of medium or short range, while user mobility patterns are limited to pedestrian mobility.

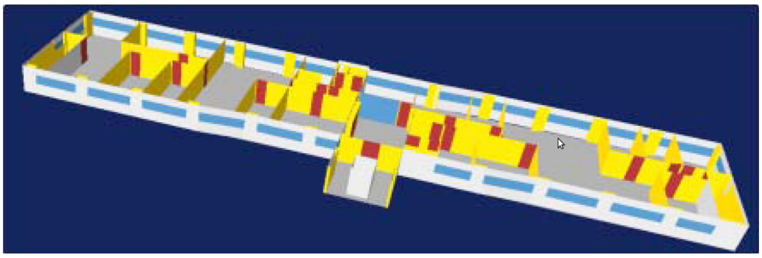

Figure 29: Indoor view and partition of walls of the building floor used for constructing the synthetic test environment of T2.3

Since context information is obtained from peer-to-peer measurements of communication properties it depends highly on the selected RAT. It is for this reason that various wireless technologies covering different bandwidths are investigated starting with several tens of MHz, continuing with 100MHz and 500MHz bandwidths and ending in UWB. The selection of the RAT implemented inside the selected environment depends on the partner involved.

When considering cooperation, it is assumed that all terminals are willing to share their context or map information and the only factor restricting the cooperation is the coverage area.

#### 5.1.6 WP3-T3.1: Coordination and Cooperation between Network Nodes

The investigation work to be carried out in the scope of task T3.1 has the ultimate goal of improving cellular communications. For that, several improved techniques will be proposed for coordination and cooperation between network nodes, and cells, with reduced signalling overhead, including the cooperation between femto and macro cells, by exploiting location and environment info. The assessment of most techniques and algorithms addressed in the correspondent three subtasks can be taken considering in essence the Cooperative Cellular test case specified in section 3.2.3).

Regarding that validation case, most of the techniques to be proposed are in the scope of subtask T3.1.1. Fixed Relays for Cellular Systems can consider specifically the first approach (Intra-Cell Cooperation), where LTE-Advanced technology is considered, supporting fixed relay nodes for radio coverage enhancement and flexible radio resources management. The green wireless aspect can also be evaluated considering this specific scenario, when employing relay nodes to help overcome near-far effects and minimize slow fading variations, reducing transmit power. Moreover, assuming in this scenario multiple deployed relays, it is possible to address and assess the issues concerning multi-hop relaying, and inherent coordination of transmissions in a relay set.

The second approach (Inter-Cell Cooperation) of the above mentioned validation and test cases can be considered to deal and evaluate the investigations on the T3.1.1 subtask Inter-cellular Interference Management topic. Most of the remaining topics concerning subtasks T3.1.2 Location-aided multi-cell processing and T3.1.3 femto-cell based communications can also consider this second validation and test case for inter-cellular cooperation, targeting performance improvement through interference coordination/cancellation, and femto-cells synchronization.

The test case Security and Safety presented in 3.2.6, should be considered in principle for the deliberation and evaluation of the specific Node Selection issue, in the femto-cell based communications subtask, taking into account the communications aspect. In that scenario it is possible to abstract and assess the establishment of femto-cell cooperative nodes clusters, as well as its maintenance and operation.

### 5.1.7 WP3-T3.2: Cooperation among Mobile Terminals

The goal of Task 3.2 is to design efficient algorithms for clustering management and relaying in mobile settings, where it is assumed that both terminals and relays are moving. Therefore, the generic scenario as described in Section 3.1 describes a network architecture that reflects network heterogeneity and different types of nodes present in the network. The choice of routing protocols for both inter-cluster and intra-cluster communication as well as protocols for cluster head election procedure is not defined in this scenario, but will be chosen as a part of work in Task 3.2.

Some parameters in the scenario can be fixed from the beginning, some other parameters, such as nodes and APs density, can be chosen to be variable supporting studies on how different network constellations effect system performance. The same considerations go for node mobility. Impact of mobility on the efficiency of developed communication protocols and algorithms for cluster management is in focus of this task. Thus, it is desirable to test behavior of protocols under different mobility patterns and to derive how e.g. average node speed affects cluster longevity.

Development of algorithms in this task heavily relies on availability of positioning information. Network settings will determine what kinds of localization solutions are visible. As different localization methods can be applied, it can be chosen to keep localization accuracy as a parameter. Investigating protocol behavior under different localization errors can give the necessary insights in what performance improvement can be achieved.

Another important aspect of the work planned is reliability and security issues. Investigations of location-aided attack detection are planned and thus,critical parameters of the generic scenario within the addressed validation and test cases should enable to define the severity of attacks, e.g. in terms of what percentage of nodes in the network exhibit malicious behavior.

### 5.1.8 WP3-T3.3: Location Aided Cognitive Radio Networks

Task 3.3 aims at improving efficiency and reliability of CRs through exploitation of location information about network nodes and MTs. To approach this primary goal, the technical focus of this task is on PHY/MAC layer issues about advanced CRs. The CR case described in section 3.2.4) offers a general network structure to this task. Location information usage and specific CR paradigms, i.e., overlay, underlay and interweave, will be chosen according to the each specific work in Task 3.3.

In CR validation case I, both primary and secondary networks always have the same spectrum pattern, which is referred to as the femto-cell scenario. The cognitive radio techniques employed by femto-cell network node aims at adapting the radio coverage. The work will contribute to one of our objectives in this task, i.e., reliability improvement.

CR validation case II describes the case that the secondary network does not always have the same spectrum pattern as the primary one. In CR validation case 2-a described in section 3.2.4, primary network is considered as a type of network that occupies the unlicensed spectrum. Hence, the crowded secondary network can opportunistically enter the primary network spectrum. The work here targets on improving spectrum efficiency, which is one of the objectives specified in Task 3.3. In CR validation case 2-b, primary network has the specific spectrum patten, i.e., broadcasting network. The secondary network employs cognitive radio techniques to improve the network connectivity, which contributes to the objective of reliability as specified in Task 3.3.

### 5.1.9 WP4-T4.1: Heterogeneous Interoperability Framework Definition

WP4 builds upon the research work in WP2 and WP3. The first task in WP4 evaluates how the platforms that are described in Section 5.5 can interact with each other. The outlined scenarios and validation and test cases are the contribution of the algorithmic and theoretic WPs. Therefore, this document feeds WP4 and will be used in T4.1 as a first input.

## 5.2 WHERE Outcomes on Sensor Error Models

The WHERE Deliverable D2.3 [16] reports the results achieved in the WHERE WP2 task T2.1 on localization and tracking techniques utilizing hybrid data. The contributions of the deliverable fall in three parts:

1. Contributions on sensor models and fingerprint databases.
2. Contributions on location estimation using hybrid data.
3. Contributions on tracking using hybrid data.

Part one proposes RSS, TOA and AOA ranging error models for LOS and NLOS conditions in indoor and outdoor-to-indoor scenarios. The derivations of these models are based on HW platforms, measurement databases and channel models available from WHERE WP4 and WP5. Additionally, a TDOA ranging error model is proposed for localization with 3GPP-LTE along with a sensor model for GNSS in an urban canyon scenario. Part one also gives a description of the use of ray-tracing tools for predicting TOA and AOA for a fingerprinting database. An outdoor-to-indoor and an indoor scenario is considered.

Part two gives a thorough investigation of theoretic performances (in terms of CRLBs) of hybrid and non-hybrid localization techniques based on RSS, TOA and TDOA. These localization techniques are then evaluated with fused RSS and TOA data. The results show that fusing RSS with TOA significantly improves the positioning accuracy performance compared to using RSS only.

Part three presents a hybrid data fusion and tracking algorithm for the combination of 3GPP-LTE and GNSS. The results show that supporting GNSS systems with 3GPP-LTE data allows for an overall performance improvement. Part three continues by proposing a particle filter based tracking algorithm for indoor scenarios. The algorithm was tested and verified with TOA and AOA data, and a combination of these. Performance evaluations show that this algorithm allows for a RMSE reduction of 46% compared to the extended Kalman filter. A single stage particle filter based target tracking algorithm is proposed as an alternative to conventional methods. Three extended Kalman filters using RSS and TOA for tracking in NLOS situations are then presented and compared. Finally, the part gives a discussion on algorithmic approaches for augmenting a Kalman filter with adaptive, simultaneous tracking and acceleration parameter estimation capabilities.

## 5.3 WHERE Outcome on Channel Modelling

Deliverable WHERE D4.5 [17] reflects the work that was carried out in WHERE T4.2. It describes in detail the channel used for modelling the variations in the fingerprinting signatures stored in the database which arise from variations (or uncertainties) in the propagation environment. It presents the results of the profile variability study and its effect on the fingerprints stored in the database for outdoor, indoor and outdoor scenarios. It presents the effect of various environment uncertainties on the accuracy of the Impulse Responses which are stored as fingerprints in the database. The study includes uncertainties about the morphology of the material (electrical parameters), uncertainties about the geometry of the environment (location, size and height of buildings). An analysis of TOA dependence on material properties variation and the influence of indoor furniture are also presented. It also describes analytically the main Radio Propagation modelling techniques and the specific tools/simulators used for modelling the profile variability. This includes the deterministic approach using narrowband and ultra wideband Ray Tracing techniques, a channel model using stochastic propagation graphs and a semi-deterministic approach for outdoor to indoor propagation modelling. The specific Ray Tracing simulators that have been used for this study (the 3DTruEM from Sigint Solutions Ltd and the UWB simulator from University of Rennes) have been also calibrated using the measurements carried out in the SIRADEL offices (see deliverable WHERE D4.1 [18]). The calibration results can be found in WHERE D4.2 ([18]). In addition, a stochastic channel model based on the concept of a propagation graph is presented. This model uses physical parameters such as the room volume, room surface and average wall absorption coefficients to describe the environment. The model yields an impulse response which exhibits a specular-to-diffuse transition as observed from measurements. It also replicates the typically observed exponentially decaying delay-power spectrum. The localization problem is often solved by relying on observations of the received signal power. To infer the corresponding distance of a radio link, the localization algorithms typically relies on a path-loss model. Therefore we have proposed an in-room path-loss model motivated from observations of the delay-power spectrum behaviour. In this model the delay-power spectrum consists of a dominant and a reverberant component. The model allows the prediction of the path-loss, the mean delay and the (root mean square) rms delay spread. The proposed model is validated with a set of measurement data from the WHERE measurements and provides a plausible explanation to the low path-loss exponents observed in in-room environments. In addition, a stochastic channel model based on the concept of a propagation graph is presented. This model uses physical parameters such as the room volume, room surface and average wall absorption coefficients to describe the environment. The model yields an impulse response which exhibits a specular-to-diffuse transition as observed from measurements. It also replicates the typically observed exponentially decaying delay-power spectrum. The localization problem is often solved by relying on observations of the received signal power. To infer the corresponding distance of a radio link, the localization algorithms typically relies on a path-loss model. Therefore we have proposed an in-room path-loss model motivated from observations of the delay-power spectrum behaviour. In this model the delay-power spectrum consists of a dominant and a reverberant component. The model allows the prediction of the path-loss, the mean delay and the (root mean square) rms delay spread. The proposed model is validated with a set of measurement data from the WHERE measurements and provides a plausible explanation to the low path-loss exponents observed in in-room environments. The deliverable also describes the impact of mobility on channel variability and accordingly on measured radio-location metrics. It also gives an overview of the noticeable effects of mobility on popular radio-location metrics such as ToA and RSSI.

## 5.4 Mobility Models

As already mentioned in Section 3.1.2 two kinds of models, different by nature, will be considered and coupled in the frame of WHERE2:

- "Shorter-term" mobility models accounting for steady state mobility (mostly intended between static periods and including potentially group/social mobility) e.g. See [5] from the WHERE project,
- Longer-term mobility models accounting for static phases (e.g. with a certain probability and time distribution, conditioned on the environment and/or the room) e.g. See Sections 5.4 and 5.4 [6].

Mobility models for network nodes can classified into two big categories: models related to the movements of a single node, and models that characterize a group of nodes moving in a coordinated way. The choice of an adequate mobility model for a node (or a group of network nodes) has a decisive impact on the design of tracking algorithms [17]. For instance, the underlying restrictions on the kinematic parameters of a node (position, linear and angular velocity, acceleration, etc.) imposed by a given model should be translated to equivalent constraints on the estimations of those parameters performed by the tracking filters. Furthermore, if the movements of a group of nodes are not independent, an optimal treatment of the global positioning problem should be based on jointly tracking the parameters of the whole group. Single-node mobility models can be classified in the following broad categories:

- State-space models: they force a temporal correlation of the linear and/or angular velocity of the mobile so that the mobile always describes physically realistic trajectories. The components of the state vector are the kinematic parameters of the node, and the state equations can be tailored to restrict the types of allowable maneuvers of the mobile. Examples of these are the white noise acceleration model, the Gauss-Markov process velocity model, the Markov process acceleration model, the Markov jump-mean process acceleration model, and the coordinated-turn state-space models.
- Memoryless random models: they allow abrupt changes in the velocity of the node, thus violating the laws of dynamics, but are simple to implement and can be easily tuned to force the position of the mobile to be bounded within a given area. Among these, we have the random walk, random waypoint and random direction mobility models.

- Geographically restricted models: the movements of the mobile should follow predefined paths (so as to, for instance, avoid obstacles). Examples of these models are the pathway mobility and the obstacle mobility models (the well-known Manhattan model is a particular case of pathway mobility).

Group mobility models usually employ a common reference point for a whole set of nodes: the reference element moves according to a single-node mobility model, while the displacements of the other nodes of the group are always related to the position of the reference member. Examples in this category are:

- Column mobility model: the group of nodes coordinately moves in a certain fixed direction.
- Nomadic community mobility model: the group of nodes collectively moves from one point to another.
- Pursue mobility model: the group of nodes tries to "catch" another "target" moving node.
- Reference point group mobility model: the group of mobiles has a logical "centre", that can be either an arbitrary point or a particular node of the group that acts as a "leader" of the remaining nodes. In both cases, all the movements in the group are referenced to those of the group centre.

Beside, short-term mobility models, other longer-term models have been introduced in the frame of the FREEDOM project [6]. The latter is particularly relevant to WHERE 2 since it addresses FemtoCell-based contexts as well. More particularly, two different models of indoor movement are defined for generic scenario environments (professional areas and private areas). The house model corresponds to the UE movement inside the family house or flat covered by one or two Femto Access Points (FAPs). The second model is more related to the conventional movement of users in the office area covered by a higher number of FAPs.

**Office Building Movement** The movement in office is a combination of direct outdoor movement (at the corridor) and movement in the house (in the office). The model of movement is depicted in Figure 30. If the UE leaves the personal office, then it randomly selects the destination room (other office/kitchen/bathroom/stairs/elevator) with the equal probability for all of them. If the UE enters the room, it selects the point of stay again with the equal probability. If the UE leaves the room excluding personal office, the probabilities of selection of next room is: $P(\text{Personal Office}) = 0.85$, $P(\text{Other}) = 0.15$ If the user enter its personal office, it selects its personal point of stay with probability $P(personalplace) = 0.9$, the probability of 0.1 corresponds to the selection of another point of stay within the personal office with the equal probability for all other points of stay.

If two (or more) floors in office are considered, all floors assume the same deployment of rooms for the sake of simplicity. The change of the floor can occur when the user is located only in the corridor at green point (elevator). The following floor is selected with an uniform distribution.

The parameters of the distribution for determination of the time spent in the offices and office dimensions are presented in table 23

| Parameter | Value |
|---|---|
| Distribution of time in personal office | $\mathcal{LN}(\mu = 7.6, \sigma = 0.45)$ |
| Distribution of time in other office | $\mathcal{N}(\mu = 5.2, \sigma = 0.35)$ |
| Distribution of time in kitchen and bathroom | $\mathcal{N}(\mu = 300, \sigma = 70)$ |
| Size of office | $5 \times 5m$ |
| Size of floor | $40 \times 15m$ |
| Height of floor | $3m$ |

Table 23: Typical parameters for office movement (taken from [6])

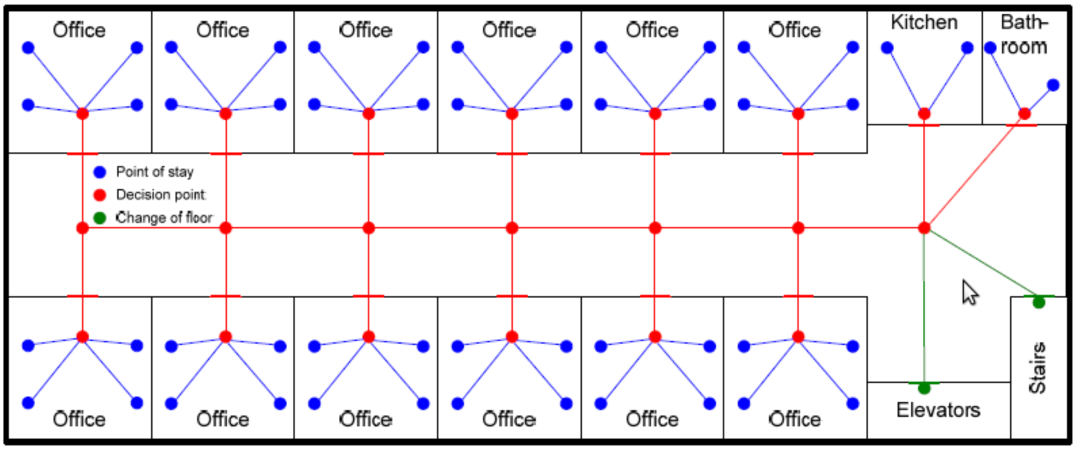


Figure 30: Office model for movement taken from [6]

**House Movement** The UE moves from different rooms within the house spending certain amount of time at each waypoint in the room (blue points) before moving on to another room. The speed of UE is $1m/s$. The red points represent the places where the movement decision is taken. If the UE gets at decision point, the next point is chosen with equal probability to all possible destinations. For instance, if the UE can move to three different waypoints, the probability for each waypoint is 1/3. The UE spends a certain amount of time at a waypoint at each room. The time spend by the UE at the waypoint is described by a normal distribution [19].

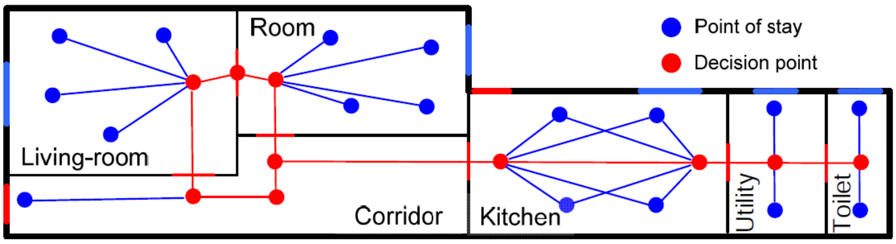


Figure 31: Terraced house model for movement (taken from [6])

Two shapes of houses are defined. The first one is a terraced house (Figure 31) according to [19].

The parameters of the distribution for determination of the time spent in the rooms and house dimensions are presented in Table 24.

| Parameter | Value |
|---|---|
| Distribution of time in room and living-room | $\mathcal{N}(\mu = 1800, \sigma = 150)$ |
| Distribution of time in kitchen | $\mathcal{N}(\mu = 1200, \sigma = 150)$ |
| Distribution of time in toilet and utility | $\mathcal{N}(\mu = 300, \sigma = 22)$ |
| Distribution of time in corridor | $\mathcal{N}(\mu = 80, \sigma = 22)$ |
| Size of terraced house | $4 \times 8m$ |
| Size of square house | $10 \times 10m$ or $15 \times 15m$ |

Table 24: Typical parameters for House/apartment movement (taken from [6])

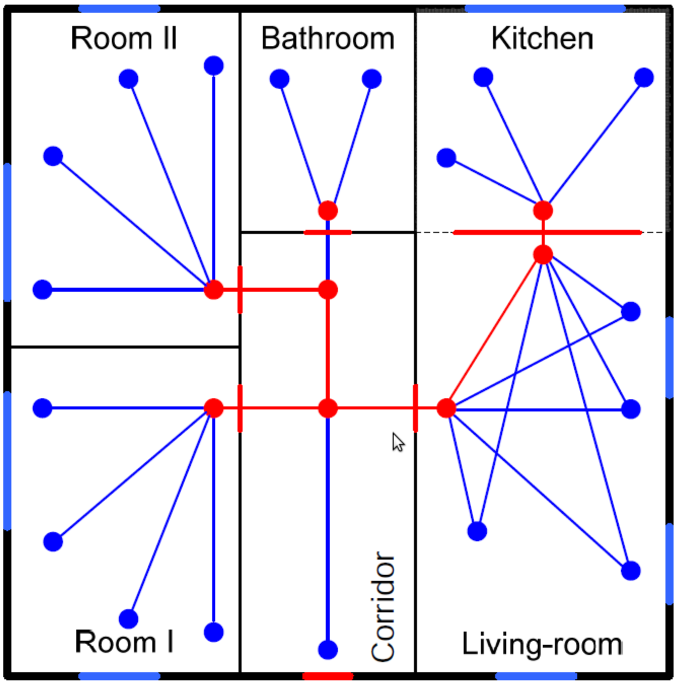


Figure 32: Square house model for movement ( taken from [6])

### 5.5 Building Platforms for Future WHERE2 Demonstration

Inspired by D1.1 validation/test cases and relying on the building platforms listed below, a specific demonstration scenario will be defined in T4.1. The interrelation of the hardware activities between WHERE and WHERE2 are outlined in the following:

- In WHERE a selection of hardware platforms (UWB 802.15.a, ZigBee, WiFi like, UMTS) were tuned and individual set of results was created.
- In WHERE we aimed to adapt, design and develop current available communication platforms, in order to get location and position parameters, being able to enhance the existing hardware platforms. The origin were single communication platforms, and the results were single "location parameters enabled and communication" platforms.
- In WHERE we only focused on the communication features that can be employed for location and position estimation, like the received power strength or the signal time of arrival.

In addition to the work performed in WHERE, WP4 of WHERE2 provides the following features:

- Part of the WHERE platforms (UWB, 3GPP-LTE) will be integrated into one single demonstration platform to show cooperative positioning and cooperative communications.
- In WHERE2 we aim to go one step further, this means, to combine all the single available platforms on a common integrated framework, being able to interoperate all together, exchanging not only communication information, but also location and position parameters i.e. a cellular network may work outdoors, while a WLAN may work indoor, in areas without cellular coverage. The global position of the mobile devices can be received from the cellular network infrastructure, while it can be combined with the indoor position estimation achieved by the WLAN.

- In WHERE2 new strategies will be investigated, including those ones not directly related to the communication architectures, like the inertial sensors, where they will be employed just for location aided parameter extraction.

### 5.5.1 OTE Platform

**Software and Hardware Infrastructure Description**

The OTE-UoA test bed platform that will be used for the experimentation of the "Network optimisation (Coverage and capacity) of wireless access systems" use case (See p.16) and the VHO validation and test case platform consists of two main network based wireless systems which are both used as access networks meaning that the users can be attached to them according to some predefined conditions related to the performance of the network, the first system is related to the WiMAX BS and the other to WiFi APs which are one of the most promising techniques for future wireless networks. The proposed technologies are fully packet switching since they are using the IP protocol and their synergy is very promising for providing Internet access.

The platform consists of:

- a WiMAX base station (BS)
- four WiFi access points (APs)

The goal is to develop the necessary configuration capabilities and operational features for a heterogeneous Future Internet environment, in order to enrich the demonstration scenario where the Self-NET (See p. 89). Self-management mechanisms are being deployed and tested. The hardware and the software components that provide the means for the validation and verification of the developed mechanisms, algorithms and protocols are described below.

**Hardware Infrastructure Description**

Figure 33 depicts the test-bed for the "Coverage and Capacity Optimization" use case.

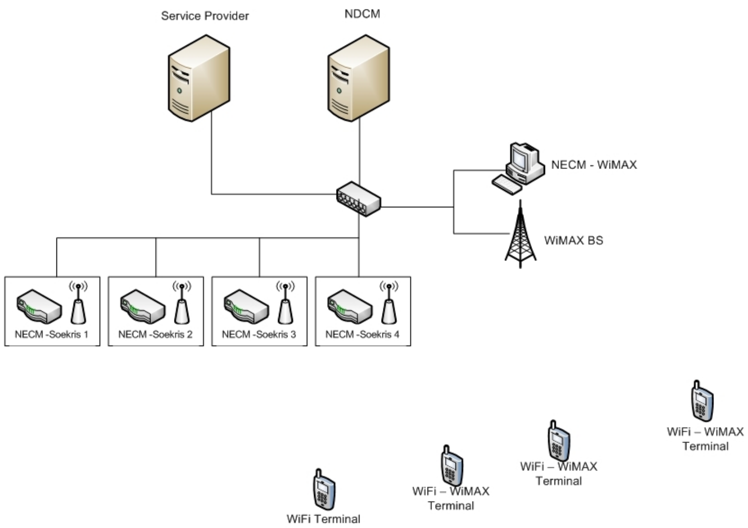


Figure 33: High Level View of the Test Bed for the "Coverage and Capacity Optimisation"

The hardware components that are being used in this test bed are:

- 2 WiMAX base stations

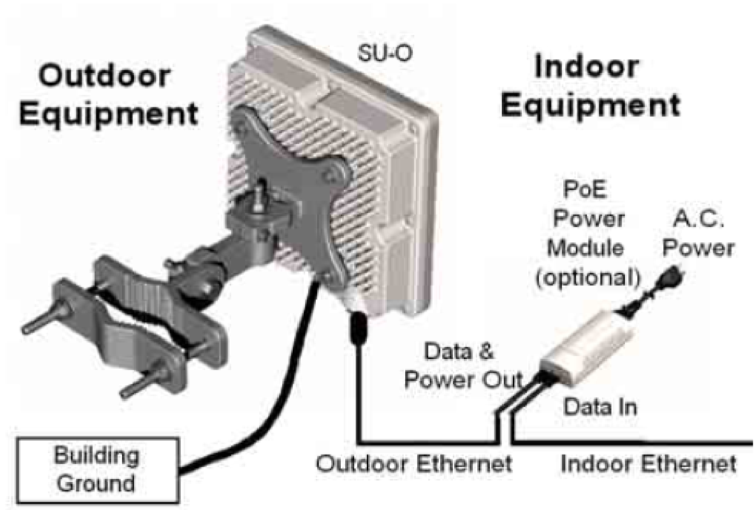


Figure 34: Outdoor and Indoor Equipment of the WiMAX CPE

- 3 WiMAX user terminals CPEs 2. The CPEs (Figure 34) are the equipment for the interconnection to the WiMAX BS and are used as receivers in order to develop multi-RAT mobile terminals.
- 6 Soekris AP (Soekris Engineering net5501). These devices (Figure 35) are low-power, low-cost, advanced communication computers that act as programmable WiFi routers using the installed AR5413 mini-PCI Card


Figure 35: Front and Rear Views of Soekris AP

- 2 laptops that have the role of network domain management node (NDCM) which is the highest in the hierarchy SW control elements that decides if vertical handover from WiMAX to WiFi and vice versa is to take place.
- 4 laptops that act as mobile terminals. In order to provide more wireless interfaces for these terminals Linksys WUSB54GC USB cards are used

**Software Infrastructure Description**
The hardware infrastructure described above mainly uses Linux based software. More specifically:

- “Debian GNU Linux 2.6.32.3-486” operating system is installed in “Soekris Engineering net5501”. Moreover the Soekris devices use the NDISWRAPPER patch for kernels 2.6.31 and 2.6.32.3 in order to properly deploy the Linksys WUSB54GC USB WiFi cards.
- “Ubuntu GNU Linux 2.6.24-24 386” is installed in the laptops used for the demonstration scenario. Furthermore the laptops used as terminals are also patched with the NDISWRAPPER for the corresponding kernels in order to use the WUSB54GC USB cards.

The various mechanisms and algorithms (Network Element Cognitive Manager –NECM, Network Domain Cognitive Manager –NDCM ) have been incorporated in the Soekris devices and in the WiMAX BS, by using an external PC that undertakes to utilise the available monitoring and configuration interfaces that the proprietary WiMAX BS provides.

### 5.5.2 Sigint Platform

The Vertical Handover (VHO) platform, provided by Sigint Solutions will be used to demonstrate the benefit in beyond-3G communications from having the knowledge of the user’s exact position and mobility/movement information. The idea is to demonstrate any potential benefits in the preparation/execution of a vertical handover in a heterogeneous environment due to the a priori knowledge of this kind of positioning information. Knowing the exact position of the user and possibly some mobility information (for example towards which network’s vicinity is moving in) the “network resources”(like switching on the adapter) can be prepared before entering the network, or we can force a handover to another technology before the Quality of Service (QoS) or Quality of Experience (QoE) received by the currently connected technology deteriorates a lot. This addresses the concept of “proactive vertical handover”and in the scope of higher layer implementations the concept of fast hand off.

The VHO Platform is a centrally controlled distributed system and is responsible for provisioning mobility through the execution of Vertical Hand Over. It includes the routing functionality to implement a vertical handover between heterogeneous IP-based Radio Access Technologies (WiFi, UMTS, WiMAX, etc.) and ensure seamless mobility and uninterruptible service provision (data, voice or media). This functionality is implemented on top of an IPv4 Mobile IP core which ensures that the mobile terminal maintains its TCP/IP address and all its live TCP/IP sessions whenever and wherever is attached to a network, and effectively ensures a transfer of a call/or connection from one RAT to another when needed (vertical handover) in a continuous and seamless way. Apart from the IP-mobility functionality, it includes a central database which houses all the parameters needed for the decision and execution of the VHO. An abstract view of this platform is shown in Figure 36. The red parts in the figure are the ones provided by Sigint Solutions.

**Mobile IP Server** The Mobile IP (MIP) Server implements the Home Agent (HA) and Foreign Agent (FA) functionality. As it is accessible via IP it can be sitting centrally or anywhere on the Internet (e.g. any public IP address). A strict requirement is that dedicated TCP port should be made available (e.g. TCP 334). The HA is a server in the users’ home network. It keeps track of the location of all the mobile users by registering every mobile node’s care-of-address (CoA). This CoA is the valid address in the foreign network and it is associated to the specific mobile node in addition to its home address. When traffic/packets designated for a mobile user reach the home network, the HA intercepts the traffic and forwards it to the user’s current location (the CoA) using an IP tunnel. In this way any mobile node can be reached by its home address regardless of its point of attachment to the network. The Foreign agent (FA) is essentially a routing component that enables the use of Mobile IP in a foreign network visited by the mobile user. This agent rejects access and collects information. Although the agent is not required by Mobile IP, it makes the whole protocol more efficient and enables network accounting and access control.

The following example demonstrates the process while a mobile user moves into a foreign network. The mobile node registers with it’s HA using the Mobile IP registration protocol. To complete the registration, the mobile node needs a valid care-of address. During the registration procedure, mobility bindings for the mobile node are created in the foreign and home agents. After a successful registration, the home agent will intercept every IP packet destined for the mobile node, encapsulate it in another IP packet

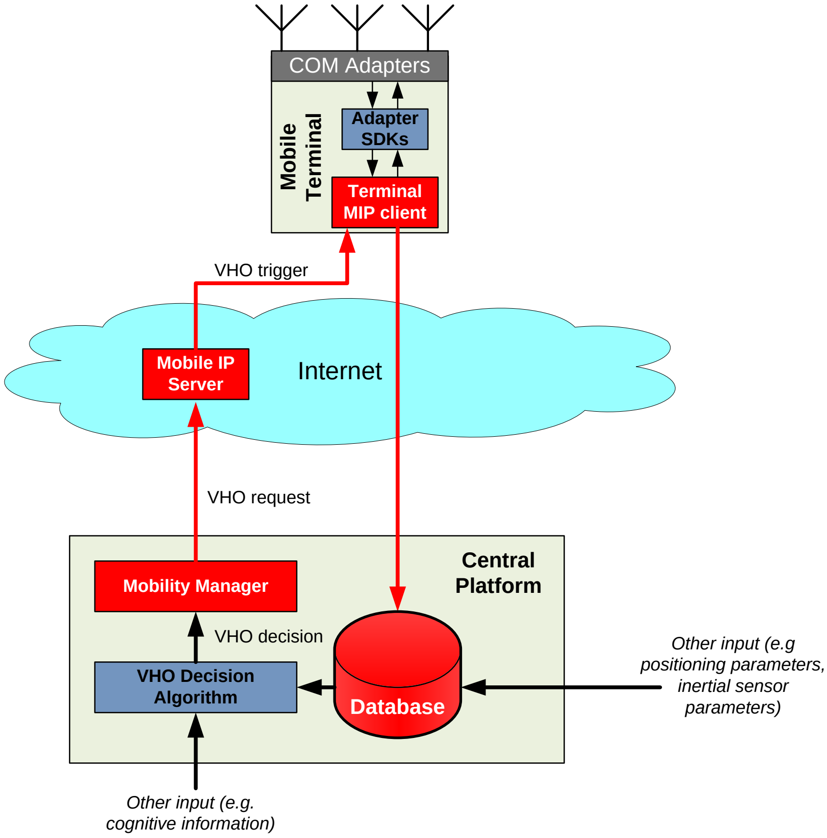


Figure 36: Vertical Handover Platform

RFC2003, and send it to the foreign agent. The foreign agent will de-capsulate the packet upon receipt, and delivers the original packet to the mobile node. Alternatively, the mobile node may register directly with the home agent, using a care-of address assigned using through, DHCP. The home agent will then deliver the encapsulated packets directly to the mobile node. During this process, and if the user was in the middle of a live TCP/IP session (e.g. a VoIP call) he will not loose his IP connection because its IP address will remain unchanged. The Mobile IP server which implements the functionality of the HA and FA will make sure that the point of attachment to the network (the CoA) will change internally without affecting the “target “address (Home address) of the mobile user.

**Mobile IP Client** The Mobile Terminal is envisaged to have the ability to connect to any RAT through a number of adapters, which are installed on the terminal. A basic requirement is that for the specific adapter installed on the Mobile Terminal there should exist a Software Development Kit SDK which provides access control and obtain parameters from the adapter. While roaming through different RATs, the terminal is able to monitor the status of his current connection and the availability of any other candidate Radio Access Technologies (RAT) in his vicinity. This information is going to be reported to the database which is sitting central unit. A command server on the Mobile Terminal enables the Terminal to accept and execute the handover commands that receives from the central unit. As described above, the mobile client will maintain its current session since he will still be reachable through his home address via the new CoA. On the MT the Mobile IP client is implemented and includes the necessary functionality to communicate remotely with the Mobile IP Core.

**Mobility Manager** The Mobility Manager is developed and operating in a Linux-based server and is responsible for generating and forwarding the appropriate set of commands to the terminal unit in order for the vertical handover decision to be executed. It is designed to receive the handover decision from the VHO algorithms and forward the VHO trigger to the terminal unit. An example of the decision format that the Mobility manager accepts from the VHO algorithms in order to send a handover trigger to a specific Terminal Unit is shown in Table 25. It includes the ID of the Terminal Unit in which the VHO will occur, the MAC address of its adapter that it is currently connected (source adapter MAC) to the Internet and the MAC address of its adapter that the live IP connection will be handed over (destination adapter MAC). It also includes another field that defines the type of command that is to be executed on the Terminal Unit (for a VHO this is `SWITCH`).

| **Command** | **Mobile Device ID** | **Destination Adapter MAC** | **Source Adapter MAC** |
|---|---|---|---|
| `SWITCH` | `10.0.0.1` | `00:01:02:03:a1:a2` | `00:01:02:03:a1:b2` |

Table 25: Example of VHO trigger

**Database** The Central Unit will consider a database entity that will house all the available network related parameters that can be utilized by the VHO algorithms. The Database has a central role, allowing each module to store and retrieve up to date information for every connected user at any point in time in an independent way. It is envisioned that the database will be accessed over the Internet through Web-Services or any other client server application. The various modules which will be developed in the context of WHERE2 in order to obtain positioning-related or mobility-related information will be given access to update the database (via Web-Services) and make this up-to-date information available to the VHO algorithms.

**Platform Requirements** The platform has the following requirements:

1. *Radio Access Technologies (RATs)*: In order to investigate, develop and demonstrate vertical handover at least two Radio Access Technologies need to be available. Current infrastructure allows the integration of WiFi and WiMAX but also the integration of a UMTS/HSDPA technology through an operator should be considered. LTE is also an option as far as appropriate equipment (base station, adapters) are made available.

2. *Dedicated TCP/IP for the platform*: A mobility platform is required to be responsible for interoperability, cooperative control and provisioning of services to both the underlying radio access networks and the IP layer. It will host the necessary Mobile IP functionality that will provision the vertical handover between the various RATs. This mobility platform will be sitting centrally on a server and should be accessible via IP. A dedicated TCP port should be made available (e.g. TCP 334).

3. *Radio adapters and SDKs*: There should be available radio adapters for the RATs to be investigated. It is envisioned that these adapters will be installed on a laptop computer. Apart from the necessary drivers, the Software Development kits (SDK) for these adapters are a basic requirement in order to be able to programmatically obtain and communicate various information/context (battery consumption, location, network parameters, received signal strength etc.) with the central mobility platform and store them in a local database.

4. *Network Discovery Modules*: A basic requirement is that the mobile terminal is equipped with network discovery modules for the Radio Access Technologies under investigation in order to discover the availability of links in the vicinity of the terminal.

5. *Cognitive Database*: A central database which will be used to store all the context received from both the Mobile stations and the network operator needs to be defined and implemented. The pre-processing unit will gather all the context (via a client-server application) will put it into the necessary format and through appropriate queries will store it into an SQL database which will be accessible either via mobile-client application or Web-Services.

6. *Vertical Handovers Algorithms*: This requirement included the design and implementation of the vertical handover algorithms which will decide whether a mobile terminal should transfer its live IP connection from one RAT to another based on the context-awareness made available from the MT and the network through the database. The main metric into the VHO algorithm will be the position of the user, on the condition that the network resources and the Quality of Service can be committed (the targeted network is not congested).

### 5.5.3 Siradel Platform

Siradel platform is a measurement vehicle (Figure 37) currently used to produce realistic 3D models of cities (Figure 38), including:


Figure 37: Siradel truck

Figure 38: 3D model of Rennes

- five cameras with a resolution of 2448 x 2048 pixels
- one 110° scanning laser that allows reflectivity measurement
- two 180° lateral lasers

Furthermore, geo-location of measurements is made thanks to:

- 2 GPS: GNSS antennas (GPS, Glonass and Galileo compatible) and in addition in case of black out (e.g. tunnel):
  - 1 inertial central (accelerometer and inclinometer)
  - 1 odometer: 1024 measurements per wheel turn.

A centimetric or decametric positioning precision can be achieved.

This platform will be adapted and exploited to investigate outdoor and outdoor-to-indoor radio propagation characteristics, mainly in the vicinities of the transmitter. An evolution consists in enhancing the platform with radio measurement capabilities, i.e. by developing an antenna support designed to avoid perturbation between optical sensors and radio antennas. Synchronization and data fusion issues will be also examined: We clearly envisage to link spatially the radio measurement to the optical capture of the scene.

Siradel platform could be used, for example, to analysis the correlation between radio signal variation and some specific geometrical arrangements observed in a city, like crossing roads, or at a smaller scale, urban pieces of furniture (walls, windows...). The time-variations radio channel (mobility aspect) are naturally accessible from the vehicle displacement.

#### 5.5.4 CEA Platform

In the scope of WHERE2, an enhanced version of CEA UWB platform will be used. This platform is an impulse-radio Ultra Wide Band transceiver. It is able to perform joint distance measurement and data communication. In addition, it is equipped with a set of sensors for inertial navigation, opening the door for dual-mode localisation and tracking.

This platform was designed as an autonomous (battery-powered) handhold device, focusing on form factor reduction.

The overall packaged platform is depicted on Figure 39.

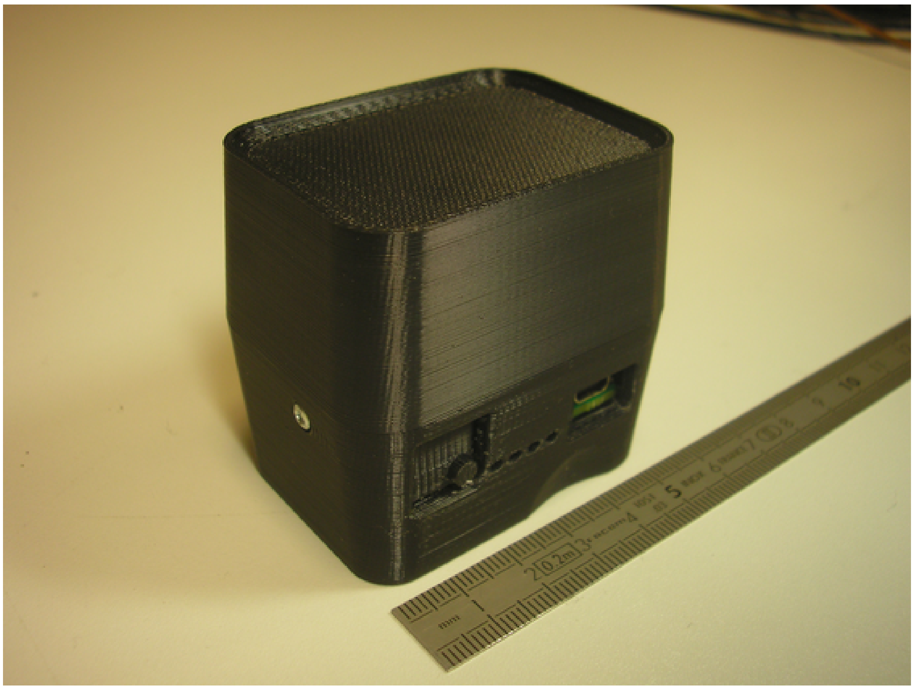

Figure 39: CEA packaged platform

This platform is composed of 4 modules:

- A **MAC and Baseband module**, in charge of digital processing. It is also connected to the battery.
- A **sensor module**, equipped with inertial sensors.
- A **PHY/RF module**, equipped with the IR-UWB transceiver and antenna.
- An **I/O optional module**, for debug or demonstration purpose.

The MAC and Baseband module is in charge of digital signal processing, from the PHY up to the application layer. It is equipped with the following components:

- An Atmel ARM9 processor (AT91SAM9261B), in charge of running the software stack. It is interfaced with the following components:
  - 16MBytes parallel SDRAM (MT48H8M16)
  - 8MBytes SPI FLASH (M25P64)
  - 2kBytes I2C EEPROM (24LC16)
  - 32.768kHz and 18.432MHz crystal clocks
  - USB device link
- A Xilinx FPGA (XC3S1400) with:
  - Its dedicated configuration flash (XCF08P)
  - A 19.2MHz clock oscillator
- The IO board connector access
- The PHY/RF board connector access
- The Sensors board connector access
- Battery charger with two status LED
- On/Off button
- Two MAC activity LED

The battery pack is directly connected to this board on the back side. It is a Lithium-Ion 1.15Ah one. A full battery charge and an average device activity will give 6h30 of autonomy.

MAC board dimension is 35x50x2.5mm3, battery dimension is 35x40x9mm3.

The Sensors Board is a daughter board of the MAC one. A small part of the FPGA resources is used for the ADC management. This module is seen as a SPI peripheral from the ARM processor. It is equipped with the following sensors:

- Honeywell magnetometer: a single axis sensor (HMC1041Z) and dual axis sensor + signals processing block (HMC 1062)
- STMicroelectronics accelerometer: triple axis sensor (LIS344ALH)
- STMicroelectronics gyroscope: two dual axis sensors (LPY450AL)

Analog to digital conversion is performed by a multi-channels 12bits ADC from Analog Devices (AD7265BCP). Sensors activity and ADC sample frequency are defined by software configuration. Sample frequency can be set from 0 to 1kb/s. It is also possible to generate an interrupt for interrupt-driven software processing.

Sensors board dimension is 29.2x23x1.5mm3.

The PHY/RF mezzanine module is composed of two boards: a RF board and an antenna.

The Radio Board is based on CEA-LETI TCR ASIC. This ASIC is completely integrated IR-UWB transceiver. Depending on the ASIC version, the ASIC provides the following features:

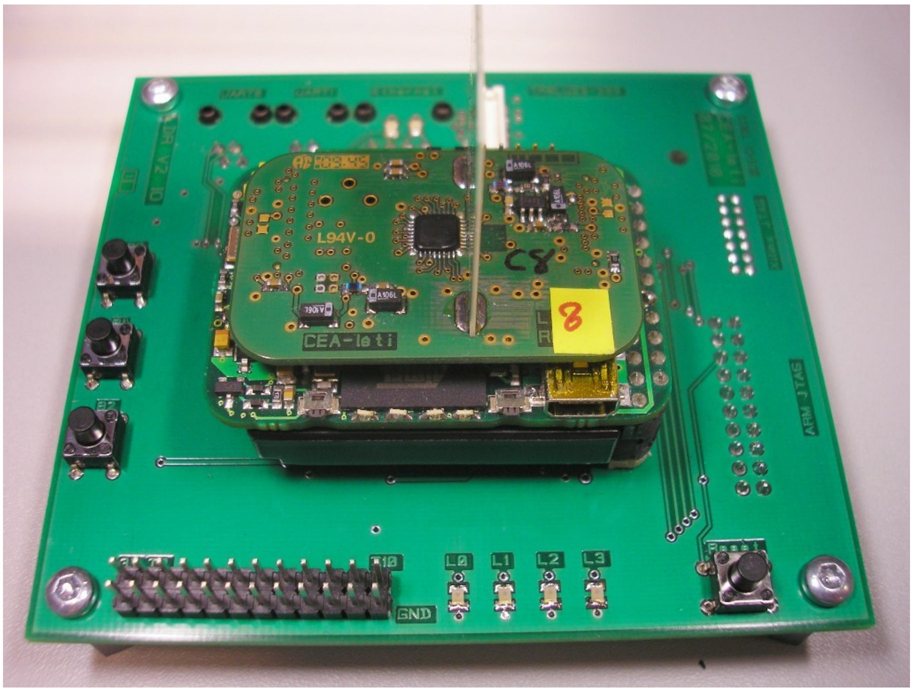


Figure 40: CEA Assembled Platform

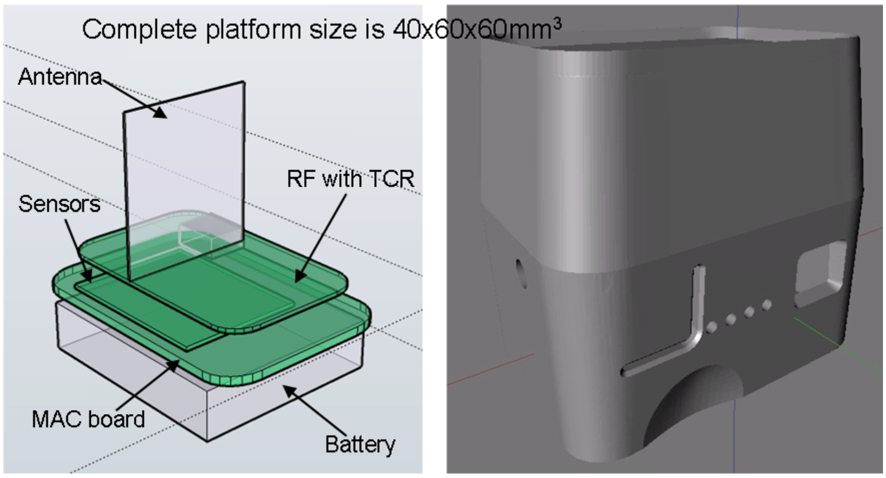


Figure 41: CEA Platform mechanical view

- An UWB programmable pulse generator.
- An UWB LNA covering with 500MHz bandwidth, centered on 4.5GHz
- A digitizer, allowing the following sampling options
  - 1-bit energy detection at 1GHz (version 2 and higher)
  - 1-bit polarity detection at 1 GHz (version 2 and higher) or 2 GHz (version 5)

– 1.5-bits sampling at 1GHz (version 2 and higher)

- A digital baseband module, with the following features:
  - Modulation schemes: DBPSK (version 2 and higher) and 2-PPM (version 5)
  - Programmable PRP length (version 4 and higher)
  - Link quality estimator (version 3 and higher)
- A Reed-Solomon channel CODEC for payload and a Hamming channel CODEC for preamble (version 5)
- A fine resolution ranging module, with the following features:
  - 1-ns resolution first path detection (version 2 and higher)
  - Ranging performed on modulated data (version 2 and higher)
  - 1-ns channel energy profile estimation and dump (version 5)
  - Programmable length of first path search window (version 5)

The RF side is directly connected to the filter and antenna through a dedicated PCB pattern. The Digital side is connected to the MAC/Baseband board FPGA. An on-board PLL circuit is in charge of the optional 1GHz external sample frequency. A small non-volatile memory is stores the individual RF configuration (auto-calibration procedure is not implemented inside the chip). The PHY boards dimension is 43x28x30 mm3. The optional IO extension board provides several communication and debug interfaces:

- A 10BaseT Ethernet link (ENC28J60)
- Serial links:
  - UART0: the main ARM DBGU
  - UART1: ARM UART0 or PHY configuration processor
  - Optional Bluetooth: PHY configuration processor or ARM USART0
- ARM and XILINX JTAG links
- The ARM reset push button
- 4 test LED
- 10 test points
- 3 push buttons

UART0 can use any baud rate value but UART1 and Bluetooth are limited to 9600Bd (up to 19200 and 38400Bd with very tolerant PC serial port). The optional Bluetooth module is an EZURIO TRBLU23-00200. IO board dimension is 95x85x20mm3. From the processor point of view, the platform is organised as follows:

- Memory: 128Mb SDRAM organized in 8Mx16bits (16Mbytes), accessed through the EBI bus.
- Code non-volatile memory: 64Mb FLASH (8Mbytes), accessed through the SPI0 bus on chip select 0.
- User PROM: 16kb EEPROM (2kBytes), accessed through the TWI (I2C) bus.
- USB device, connected to a mini B type connector. USB detection and pull-up are present.
- Serial debug UART connected to DBGU port.

- Hardware MAC coprocessor, mapped on FPGA and accessed through SPI0 bus on chip select 1. Interrupt input connected to PC2 pin.
- PHY configuration module, mapped on FPGA and accessed through SPI0 bus on chip select 2.
- Sensors acquisition module, mapped on FPGA and sensors board. Accessed through SPI0 bus on chip select 3. Interrupts input connected to PC1 pin.
- Ethernet 10BaseT MAC/PHY, accessed through SPI1 bus on chip select 0. Interrupt input connected to PC11 pin.

It is to be noticed that IO board can be replaced by a custom board to adapt the platform to a specific demonstration scenario. SPI1 can be used to access other sensors, for example.

The overall platform architecture as seen from the software is given below.

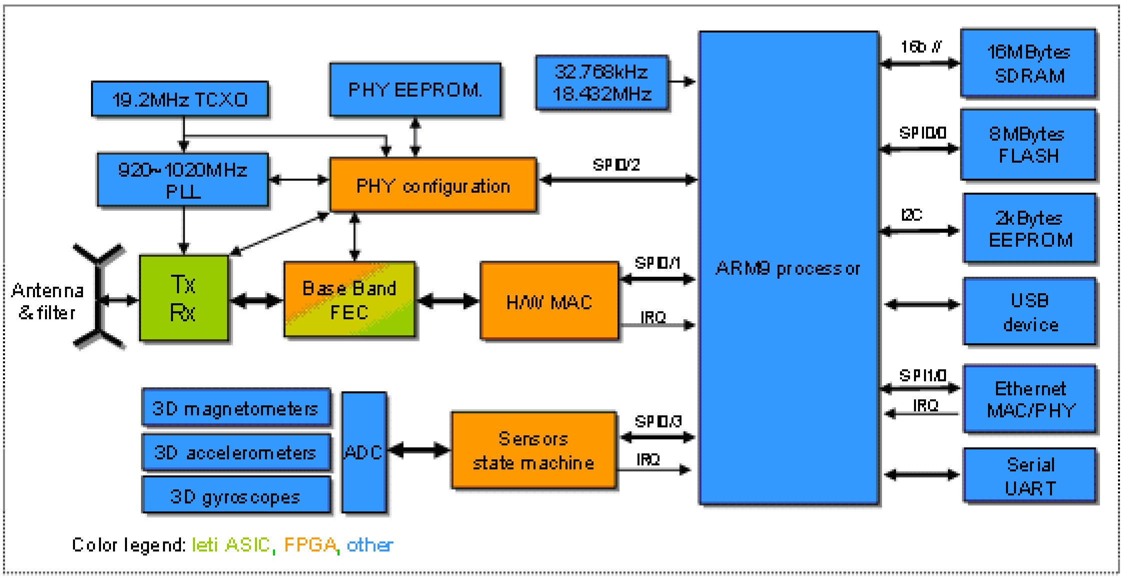


Figure 42: CEA Platform - Software view

Platforms are provided with an embedded linux operating system pre-installed.

The whole software package is stored in SPI flash as follows:

- 0x0: patched version of AT91 boostrap. This executable is a low-level firmware in charge of configuring IOs multiplexing, enabling/disabling peripherals (in particular the SDRAM controller), copying the actual bootloader to SDRAM and executing the bootloader.
- 0x10000: bootloader environment storage. One block is reserved for storage of the environment variables used by the booloader.
- 0x20000: U-boot booloader. This is the actual bootloader. It is in charge of copying the linux kernel to RAM, passing command line parameters and then booting linux.
- 0x50000: compressed linux kernel image and its initial ram filesystem. This is the actual operating system.
- 0x200000 – 0x800000: JFFS2 root filesystem. Once linux kernel is booted, this filesystem is mounted and the init scripts it contains are executed. It contains a minimal filesystem with:

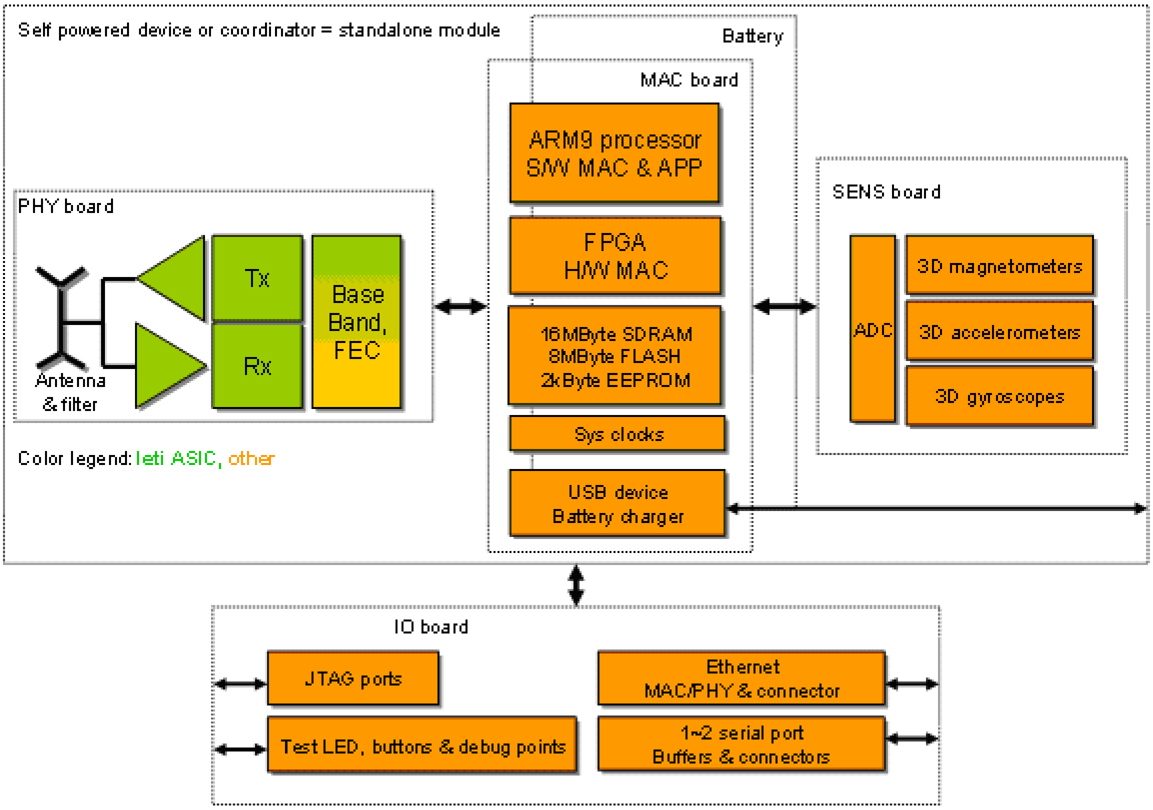


Figure 43: CEA Platform - System view

- a shell
- several system utilities and base system libraries
- a configuration file used to individualize MAC and IP addresses for example
- CEA-LETI MAC software library, providing high level interface to data communication and ranging capabilities of the hardware platform
- CEA-LETI localization library, providing embedded localization engines for tests and demonstration purposes.
- CEA-LETI demonstration applications.

This software stack will be adapted and enhanced to fit with experiments and demonstrations scenarios envisioned in the project.

### 5.5.5 Acorde Platform

An enhanced version of the ZigBee platform developed in WHERE project, will be used in WHERE2 developments. The idea is to integrate the capabilities of the initial location platform with inertial sensors, which will improve the accuracy of positioning outputs. Moreover, to frame this platform inside the security scenario, a robust camera will be implemented to achieve a reliable surveillance solution. Besides, the integration of some environmental sensors will be subject to study, for the purpose of improving the knowledge of each place and valuating any potential risk of suspicious event. First of all, in the picture below it is shown the high-level architecture of ACORDE platform.

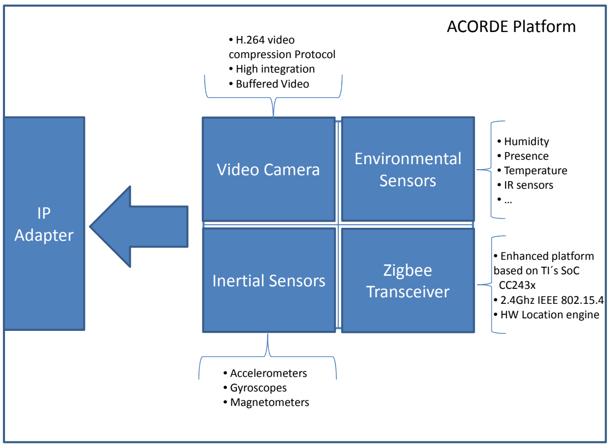


Figure 44: ACORDE Platform description

**Blocks of the Platform** Next, it is summarized the initial highlighted features of each part:

- **ZigBee Transceiver:** The core of the device will be the same of that was used in WHERE platform, but in this case, it is intended to enhance some features in order to achieve a more robust and efficient device. The ZigBee SoC is base on the CC2430 or CC2431 Texas Instruments Chip. This chip is a solution for IEEE 802.15.4 and ZigBee applications. It integrates a fully-compliant 802.15.4 transceiver with an 8051 microprocessor. The CC2431 includes also the location engine based on Received Signal Strength Indication implemented in hardware. Other features are the following ones:

  – Frequency: 2.4 GHz ISM Band
  – Bandwidth: 5 MHz is the channel spacing
  – Data rate: Nominal 250kbps.
  – Modulation: DSSS(OQPSK)
  – Peak Transmit power: -1.9dBm
  – Rx sensitivity: -92 dBm under PER=1
  – Module unit consumption below 30mA@3V, enabling a battery-powered portable mode.

  In addition to this, an enhanced functionality is intended by using the optimal bridge to link location services with the global framework or to transmit data through another deployed technology, like WiFi. This development will be a new challenge in the scope of the project. Moreover, the firmware will be improved to provide cooperative and clusters amongst terminals deployed in the network. In the picture below it is shown the new application layer colored in orange and called ZigBee Cluster Handover Management, which will be in charge of keeping the tracking between different PAN, by means of adding new capabilities such as dynamic change of channel and devices are able to update their routing and network table when they change the cluster.

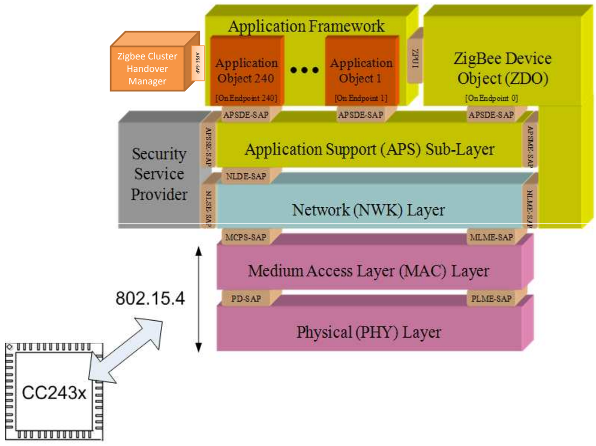


Figure 45: ACORDE ZigBee Stack

In the same way of WHERE project, ZigBee platforms will have three different types of nodes according to their function: reference, blind and dongle node. A “dongle node” just acts as Coordinator of the network and in the scope of WHERE2, also it will integrate the suitable adaptor to link with other RAT or it will be implemented in a hybrid architecture WiFi-ZigBee. A “Reference node” is a static node placed at a known position. In the scope of WHERE2, this kind of devices could be enhanced to be able to switch to low power mode when any MT is present. A “Blind node” is a node built with CC2431 which offers the location engine. In this case, “Blind-node” will be implemented as a part of MT and it will be able to calculate its position more accurately and faster, by means of reducing latency and cycle time to collect samples of those reference nodes requested. Finally, ZigBee chip will calculate the position data and this information will be transmitted with the output calculated by the inertial sensor unit.

- **Inertial sensors:** These elements are able to calculate parameters such magnitude and direction of the acceleration, orientation, the strength and/or direction of the magnetic field, etc... The devices commonly compromised are accelerometers, gyroscopes and magnetometers, whose functionality will be subject of study in the scope of WHERE2 project. On the other hand, an inertial measurement unit (IMU) combines multiple accelerometers and gyros, usually three of each, to produce a three-dimensional measurement of specific force and angular rate. The best option of each element will be researched and implemented together with ZigBee platform for improving the results in the most accurate way.

- **Environmental Sensors:** A wide range of sensors are available in the market, so one of the research actions will be the election of those more suitable to get additional and relevant information for the scope of the scenario where devices are going to be implemented. For instance, in security and safety scenario, presence, humidity, temperature, gas and smoke detector could be important to detect and avoid potential risks.

- **Security Camera:** One of the highlighted aspects in this platform could be the integration of capabilities to manage a security camera. This devices should implement a video compression protocol like H264, due to this profile defines the highest video quality with the lowest bit rate, making it especially relevant for applications such as video surveillance and security. On the other, camera should have other functionalities available such as local data storage, video analytics and remote control to offer further capabilities for controlling any situation.

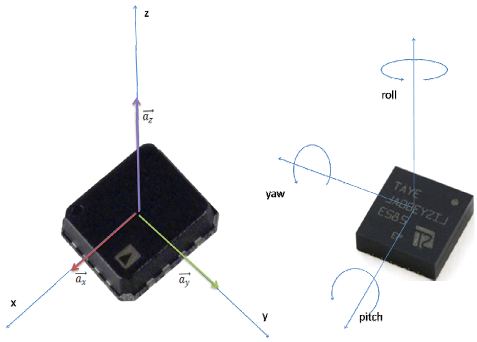


Figure 46: Inertial Sensors Example

In general, the platform requires WP2 and WP3 inputs to achieve the best cooperative location framework and communications for heterogeneous networks. In addition, it will be required a common framework where other technologies, like LTE, UWB and WiFi, can cooperate in the same context and combine broadband and peer-to-peer communication links.

### 5.5.6 DLR Platform OFDM Positioning Testbed

**OFDM Positioning Testbed - Transmitter** The transmitter (TX) equipment is schematically shown in Figure 47. It consists of two Alteral Stratix III FPGA boards. These boards generate OFDM signals, i.e., a predefined OFDM frame, which is transmitted repeatedly. Each board itself provides two synchronous TX signals with bandwidths of up to 20 MHz at an intermediate frequency (IF) of 60 MHz. These IF signals are upconverted to a carrier frequency of 2.5 GHz and transmitted at a power level of $\approx 1$ W per TX site. A further board serves two additional TX antennas. Both boards can be connected in order to achieve full TX synchronization. With this setup 3 independent Time Difference of Arrival (TDOA) values can be measured. Without the synchronization link between the boards, the TX sites are pair wise synchronous, which means that there will be 2 measurable TDOAs, one for each of the two synchronized TX pairs.

Full synchronization of the boards require cable connections between the TX boards (see Figure 47). The TX distance is also limited by cable connections from the boards to the RF front end components including the TX antenna. To overcome TX distance limitations due to cable connections, a GPS based TX synchronization is currently developed. The block diagram is shown in Figure 48. In this structure, each FPGA board serves one TX site. Therefore, the cable lengths from the FPGA hardware to the RF front end components can be kept low. Cable connections between boards are no longer required.

Figure 49 shows the TX hardware. The two boards can be connected in order to achieve full synchronous transmission from all the four TX branches. However, it is possible to skip this connection for achieving a higher TX antenna distance. In this case the signal generation is pair wise synchronous.

Figure 50 shows the TX signal spectrum at an IF of 60 MHz and a bandwidth of $\approx 18$ MHz. These signals will be upconverted to a carrier frequency of 2.5 GHz and transmitted at a power level of approximately 30 dBm per TX branch.

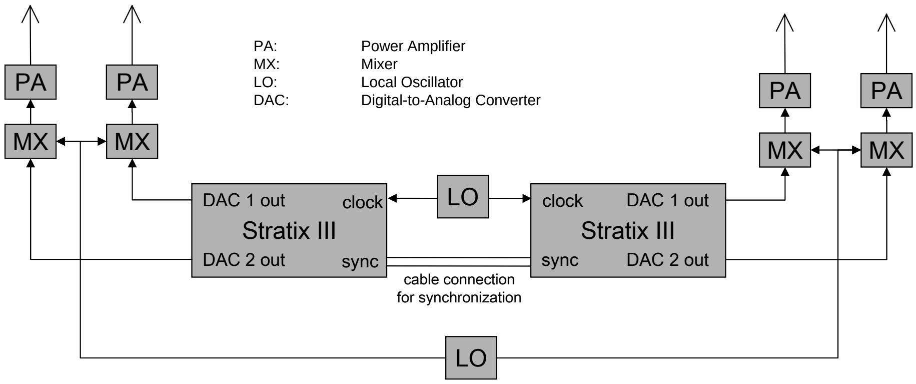


Figure 47: Block diagram of the currently available OFDM transmitter platform.

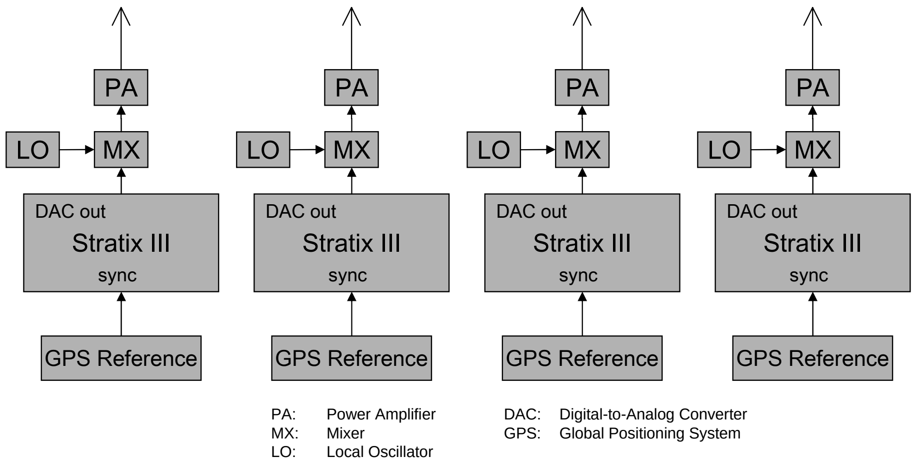


Figure 48: Block diagram of the OFDM transmitter platform, currently being developed.

**OFDM Positioning Testbed - Receiver** At the receiver side, the signals are downconverted to an IF of 60 MHz as shown in Figure 51. The IF signal is sampled at a rate of 60 Msamples/s. This undersampling is sufficient for a maximum IF signal bandwidth of 20 MHz. A PCIe connection between the main board of the PC and the FPGA card provides sufficient data throughput for sampling. The sampled signal is saved at the host PC's solid state disc (SSD). The hardware implementation on FPGA therefore contains two main parts.

1. Signal reception, sampling, downconversion into baseband and saving.
2. Timing estimation based on sampled signals.

With this approach data can on the one hand be recorded and post processed. On the other hand TDOA estimation can also be done in real time, which does not require data recording.

**RTOA Positioning Extension** Within WHERE2 an experimental system for the measurement of Round Trip Time of Arrival (RTOA) will be developed and implemented. Additionally, the OFDM TDOA positioning receiver as described previously will be cloned. This extension allows an experimental evaluation of cooperative positioning methods.

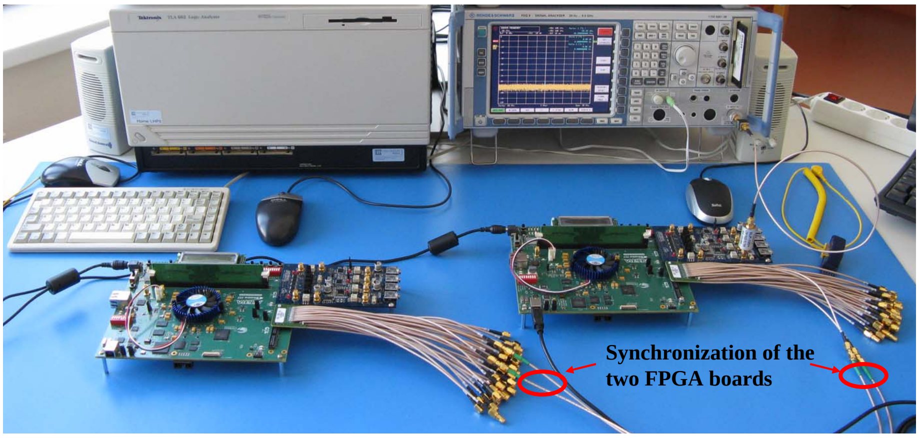


Figure 49: OFDM transmitter hardware.

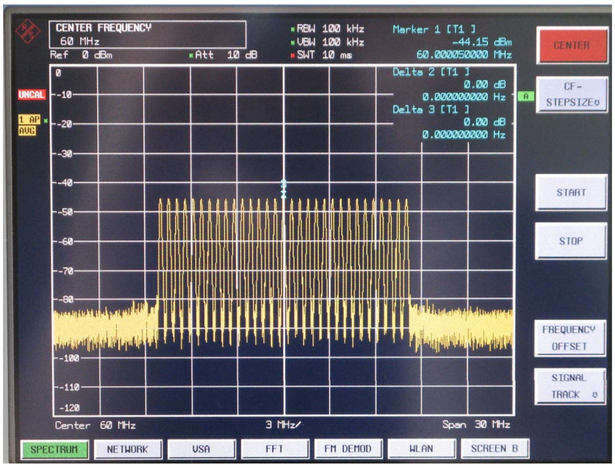


Figure 50: Transmitter OFDM spectrum.

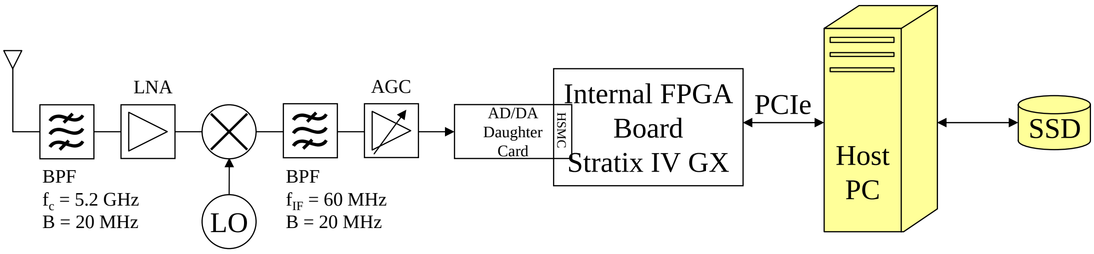


Figure 51: Block diagram of the OFDM receiver platform.

## 5.6 Description of Related FP7 Projects

In the following several projects from Call 4 and Call 5 of the ICT domain are briefly introduced and their potential connection to the WHERE2 project. One part of the discussion of the projects is linked directly to the use cases we have described in Section 2. The other part is linked to the keywords of the WHERE2 project with a focus on coordinated, cooperative and cognitive radio; femto-cells; peer-2-peer indoor-communications.

### 5.6.1 ARTIST4G: Advanced Radio Interface Technologies for 4G Systems

The ARTIST4G project aims to provide innovative research for the LTE-Advanced mobile radio generation. The key objective is to improve the ubiquitous user experience of cellular mobile radio communications systems by satisfying the following requirements:

- High spectral efficiency and user data rate across the whole coverage area
- Fairness between users
- Low cost per information bit
- Low latency

A good key performance indicator for this objective is the ratio of the cell-average over the cell-edge spectrum efficiency. This ratio will be enhanced with respect to the following guideline:

- Improve significantly the cell-average spectrum efficiency over cell-edge spectrum efficiency ratio.
- Maintain or improve the cell-average spectrum efficiency.

As ARTIST4G claims to evaluate more parameters than the current standardisation process of LTE-Advanced. The project aims to take advantages of geo-location information by taking the user behavior models into account (from static to dynamic behavior)[20]. Two interactions between ARTIST4G and WHERE2 are possible a. WP3 of WHERE2 interacts with ARTIST4G as both have a focus on improving communications based on geo-location information and b. WP2 will deliver reasonable performance assessments about the positioning performances, like accuracy and latency. The different latencies of multiple communication systems is one of the metrics that also influences the positioning performance in a heterogeneous system that we envisage in WHERE2.

### 5.6.2 ACROPOLIS: Advanced Coexistence Technologies for Radio Optimisation in Licenced and Unlicensed Spectrum

The ACROPOLIS project fosters the coexistence of multiple communication technologies that jointly operate in licensed and unlicensed spectrum. In order to enhance system performance and cater for the services and applications of the future, there is the need for cooperative and cognitive communications paradigms that support advanced coexistence technologies for radio optimisation. To account for this paradigm shift and position Europe to benefit most from it, experts in areas of cooperation and coexistence, comprising but not limited to realms such as cognitive radio, cognitive networking and flexible networking, must integrate and harmonize their agendas. Through this approach, to paraphrase a common adage, the whole will become stronger than the sum of the parts. Moreover, there is the need to produce a next generation of European researchers, with the right skills-sets to solve the challenges of optimisation for cooperative and coexisting wireless systems. The ACROPOLIS NoE is specifically designed to meet these challenges, it has a strong, interdisciplinary, joint-research agenda, fostering rapid innovation that is of the highest quality and is able to bridge the gaps in European research. Its structure allows it to react rapidly to changes in the research landscape, where integration of research activities to achieve critical mass, and spreading of excellence throughout industry, other research organisations and elsewhere, are at the very heart of its formulation and ideals. Geo-location information linked to details about the wireless communication channel, interference from licensed users, etc. is an already accepted part of the geo-location database that the FCC is publishing in the US.

### 5.6.3 ALARP: A Railway Automatic Track Warning System Based on Distributed Personal Mobile Terminals

The objective of the ALARP project is to study, design and develop an innovative more efficient Automatic Track Warning System (ATWS) to improve the safety of railway trackside workers. ALARP ATWS will able to selectively inform the trackside workers about approaching trains on the track, maintenance events on power lines and/or safety equipment in the concerned tracks that may put at risk workers safety (e.g. being hit by a train or by an electric shock) emergencies on tracks and tunnels nearby the workers (e.g. fires in a tunnel, toxic smoke, etc.), escape routes in case of emergencies, keep track of the status and localisation of the workers (and especially those at risk, not responding) and of the operating conditions of devices.

The proposed ALARP concept will be based on the following main components: the track-side train presence alert device (TPAD), able to sense an approaching train on the interested track without interfering with the signalling system, a set of distributed, low-cost, wearable, context-aware, robust, trustable and highly reliable, wireless Mobile Terminals (MTs) to inform the workers about possible approaching trains and/or other events that could put at risk their safety. The ALARP concept is under investigation as one of the WHERE2 use-cases 2.5.5.

### 5.6.4 AWISSENET: Ad-hoc Personal Area Network and WIreless Sensor SEcure NETwork

AWISSENET is a project focused on security and resilience across ad-hoc PANs and wireless sensor networks. AWISSENET motivation is to implement and validate a scalable, secure, trusted networking protocol stack, able to offer self-configuration and secure roaming of data and services over multiple administrative domains and across insecure infrastructures of heterogeneous ad-hoc and wireless tiny sensor networks. AWISSENET optimisations will be extended where applicable from networking up to the applications layer, focusing on four key principles:

- Discovery, evaluation and selection of trusted routes based on multiple security metrics and key pre-distribution methods. The overall scheme must support secure routing even with disappearing nodes, multiple levels of in-network processing and multiple layers of aggregation. Moreover to protect the secure routing information from traffic analysis attacks, the project will research utilisation of dynamic obfuscation of relationships.
- Secure Service Discovery, providing an extremely low power network-level security framework, which will protect service discovery messages inside the AWISSENET, when crossing unknown domains or when interacting with public service providers.
- Intrusion detection, intruder identification and recovery based on distributed trust to provide security against malicious attacks.
- Highly Secure sensor nodes against attacks from malicious users having actual access to the sensor nodes.

The AWISSENET project use-case is described in Section 2.5.6.

### 5.6.5 Befemto: Broadband Evolved FEMTO Networks

The aim of BefemTO is to develop evolved femto-cell technologies based on LTE-A that enable a cost-efficient provisioning of ubiquitous broadband services and support novel usage scenarios like networked, relay and mobile femto-cells.

The project targets both near-term and long-term solutions. With its strong industry consortium, the BefemTO project aims to have a real impact on the standardisation of the next generation femto-cell technologies based on LTE-A in the near term. In the long-term, the project focuses on novel concepts and usage scenarios such as self-organizing and self-optimizing femto-cell Networks, Outdoor Relay femto-cells as well as Mobile femto-cells. In WP3 of WHERE2 the focus is on femto-cells - explicitly synchronisation and inter-cell-cooperation (cooperation between femto- and macro-cells) - and the usage of geo-location information.

### 5.6.6 C-Cast: Project Context Casting

Project Context Casting (C-CAST) main objective is to evolve mobile multimedia multicasting to exploit the increasing integration of mobile devices with our everyday physical world and environment.

C-CAST is based on two main competence areas: creation of context awareness and multicasting technologies. Context information defines groups that demand the same information or service. These services are delivered efficiently by multicasting bearers. The project will research, investigate and define ways to use the situation/environment of a user (a mobile device) to initiate group communication. This environment mediated multicast may be triggered by an event or something in the physical environment offering a situation or context orientated service. C-CAST will provide an end-to-end context-aware communication framework specifically for intelligent multicast-broadcast services. It addresses three key issues:

- Development of context and group management service enablers for context representation, context assisted group management and context reasoning
- Definition of a framework to collect sensor data, distribute context information and manage efficiently context aware multiparty and multicast transport.
- Development of mechanisms for autonomous context driven content creation, adaptation and media delivery.

The main strategic objective of Context Casting is to evolve mobile multicasting to exploit the increasing integration of mobile devices with out everyday physical world and environment. The C-CAST project finished in June 2010. Nevertheless, the interactive hardware platforms and the gained knowledge of understanding how context information is used is of interest for task T3.2 that investigates the clustering of multiple mobile user terminals.

#### 5.6.7 COGEU: Conitive Radio Systems for Efficient Sharing of TV White Spaces in European Context

The COGEU project is a composite of technical, business, and regulatory/policy domains, with the objective of taking advantage of the TV digital switch-over (or analog switch-off) by developing cognitive radio systems that leverage the favorable propagation characteristics of the TVWS through the introduction and promotion of real-time secondary spectrum trading and the creation of new spectrum commons regime.

The COGEU project has a strong motivation to exploit geo-location or positioning information that is linked with the available spectrum offered by TVWS. A data base provides such information about the availability of TVWS. In the US the FCC provides such a database FCC: TV Service Contour Data Points. COGEU is one of the cognitive radio projects and focuses explicitly on TV white space.

#### 5.6.8 CHOSEN: Cooperative Hybrid Objects in Sensor Networks

CHOSEN will develop appropriate technology, including advanced configurable RF and digital baseband transceiver hardware, networking protocols with scalable Quality of Service in respect of transmission speed, robustness, security, and low-power support, and a generic collaboration middleware that abstracts from the diversity and heterogeneity provided by the layers below, and it will thereby improve the state-of-the-art in system maintenance utilizing heterogeneous wireless sensor technologies. CHOSeN has strong focus on providing practical solutions for the automotive and the aerospace application domain, which promise better, more reliable and easier to maintain products in two of the most significant European industrial domains. The key objective of the CHOSEN project matches with the key objectives of WHERE2: cooperation of hybrid objects for real devices.

#### 5.6.9 C2POWER: Cognitive Radio and Cooperative Strategies for Power Saving in Multi-standard Wireless Devices

The promise of a truly mobile experience is to have the freedom to roam around anywhere and not be bound to a single location. However, the energy required to keep mobile devices connected to the network over extended periods of time quickly dissipates. In fact, the operational time, has been identified as the number one criteria by the majority of the consumers purchasing a mobile device. Moreover, concern about exhausting battery lifetime is also one of the main reasons why users do not opt to use advanced multimedia services on their mobiles more frequently.

The perspective for the future does not look encouraging in this aspect, as one could easily expect a rise of power demand for 4G devices while the progress of battery technology is very slow. Therefore, without any new approaches for energy saving, 4G mobile users will relentlessly be searching for power outlets rather than network access, and becoming once again bound to a single location. In addition, high power dissipation means that the temperature of the small handhold devices would rise to unpleasant values for the user, and make active cooling necessary.

To avoid the foreseen 4G energy trap C2POWER project will investigate, develop and demonstrate how cognition and cooperative strategies can be extended to decrease the overall energy consumption of mobile devices while still enabling the required performance in terms of QoS. In particular, C2POWER will investigate two complementary techniques to increase power efficiency at the wireless interface of handsets: Cooperative power saving strategies between neighbouring nodes using low power short range communications, Cognitive handover mechanisms to select the Radio Access Technology which has the lowest energy demand in heterogeneous environments. As a consequence C2POWER should have impact on emerging standardization groups and will provide sufficient evidence on the technology and economics viability and its deployment. C2POWER matches the key objectives of the WHERE2 project. Especially the focus on cooperation of short-range objects with the special focus on low power consumption.

#### 5.6.10 EARTH: Energy Aware Radio and Network Technologies

Telecommunication networks and in particular mobile communications are increasingly contributing to global energy consumption. The EARTH proposal tackles the important issue of energy saving by enhancing the energy efficiency of mobile broadband systems thereby reducing $CO_2$ emissions. It is a highly ambitious and unique proposal, applying an integrated approach to investigate the energy efficiency of mobile systems. EARTH has mobilized a consortium of all major stakeholders with serious efforts committed to the development of a new generation of energy efficient products, components, deployment strategies and energy-aware network management solutions. The target of EARTH is to enhance the energy efficiency of mobile systems by a factor of at least 50% compared with the current ones. It will investigate the energy efficiency limit that is theoretically and practically achievable whilst providing high capacity and uncompromised QoS. The proposal is primarily focused on mobile cellular systems, LTE and its evolution LTE-A, where potential impact on standardization is envisaged but it will also consider 3G (UMTS/HSPA) technology for immediate impact. The tangible results of the EARTH project are:

1. Energy efficient deployment strategies
2. Energy efficient network architectures
3. New network management mechanisms, adaptive to load variations with time
4. Innovative component designs with energy efficient adaptive operating points,
5. New radio and network resource management protocols for multi-cell cooperative networking

The new techniques will be validated using sophisticated simulation tools and in a mobile network test plant. Technologies developed by EARTH will enable wireless communications systems with unprecedented energy efficiency, significant reduction in environment pollution and operating cost. EARTH plans to provide valuable and timely contributions to standardization, regulations processes and place Europe in a strong IPR position. EARTH matches some key objectives of the WHERE2 project - especially the focus on multi-cell cooperation. However, the focus of EARTH is on the network layer, which remains unclear how geo-location information is of any direct use.

### 5.6.11 EUWB: Coexisting Short Range Radio by Advanced Ultra-Wideband Radio Technology

Ultra-Wideband radio technology (UWB-RT) enables short range wireless communications with data rates ranging up to Gigabit per second as well as precise real-time location tracking inherently due to UWB's unique feature of ultra-wide radio frequency band allocation.

Widespread application of this innovative wireless technology will facilitate growth of a number of market segments  all different, but all enabled by the unique features of UWB-RT being highly scalable with regard to complexity, range, costs and throughput as well as location precision accuracy.

UWB-RT provides a minimum of interference to other electronic equipment compared to existing alternative radio solutions. Major European industry sectors are convinced of these advantages and consequently request the introduction of UWB based radio services in their areas.

Following this request, an industry-led initiative of 26 major industrial, highly regarded academic and excellent consulting partners from Europe and Israel was formed. The resulting EUWB project will effectively leverage and significantly enhance the scientific knowledge base in the advanced Ultra-Wideband Radio Technology providing sophisticated new applications enabled by UWB and highly demanded in several European key industrial sectors such as home entertainment, automotive, public transport, and mobile communications.

EUWB's key objective is to exploit the enormous potential of the innovative and disruptive radio technology embodied in Ultra-Wideband Radio Technology (UWB-RT) for key industrial sectors in Europe by innovation of cutting-edge short range radio solutions.

EUWB aims at consolidating the technical advances in scientific areas related to UWB-RT and combining them in order to define system concepts and enable the implementation of applications for envisaged four application areas:

- Heterogeneous Network
- Public Transport
- Home Environment
- Automotive

Main goals of EUWB are:

- Combining UWB-RT with advanced methods of wireless technology such as cognitive signalling, intelligent multiple antenna and multiband/ multimode concepts
- Applying R&D results to enable the introduction of advanced services and competitive next generation UWB applications
- Driving international standards and industrial initiatives (ECMA 368/369, TGUWB, IEEE 802.15.3c/4a, WiMedia, WUSB)

EUWB already cooperated with the WHERE project. The well established links from the past and the joint focus on UWB devices for positioning are a good basis for further cooperation between both projects.

### 5.6.12 FREEDOM: Femto-cell-based Network Enhancement by Interference Management and Coordination of Information for Seamless Connectivity

Currently, femto-cells and macro-cells are seen as isolated networks, competing for the resources available in the common spectrum band, at the cost of injecting interference to the whole system. FREEDOM project will face key technical and industrial concerns about the foreseen mid-term massive deployment of femto-cells by adopting a new approach based on cooperative/coordination paradigms, enabled by the limited ISP backhaul link.

The project will not disregard the approach of isolated networks because it is met when there is not enough backhaul link connecting the femto-cells and macro-cell. In order to guarantee a strong focus and efficiency, FREEDOM will focus on:

- advanced interference-aware cooperative PHY techniques,
- improvement of the control plane procedures for seamless connectivity,
- System-level and hardware feasibility evaluation of the proposed femto-based network architecture.

The FREEDOM project overlaps with the research activities in T3.1. (femto-cells and coordinated communications) 5.1.6.

#### 5.6.13 LOLA: Low-LAtency in Wireless Communications

The focus of LOLA is on access-layer technologies targeting low-latency robust and spectrally-efficient transmission in a set of emerging application scenarios. Two basic types of wireless networks are considered, namely long-range LTE-Advanced Cellular Networks and medium-range rapidly-deployable mesh networks. Research on low-latency transmission in cellular networks is focused firstly on transmission technologies in support of gaming services which will undoubtedly prove to be a strategic revenue area for operators in the years to come. Secondly, machine-to machine (M2M) applications in mobile environments using sensors connected to public infrastructure (in trains, buses, train stations, utility metering, etc.) are also considered. M2M is an application area of extremely high growth potential in the context of future LTE-Advanced networks. A primary focus of the M2M research is to provide recommendations regarding PHY/MAC procedures in support of M2M to the 3GPP standardization process. The rapidly-deployable mesh topology component addresses M2M applications such as remote control and personnel/fleet tracking envisaged for future broadband civil protection networks. This work builds upon ongoing European research in this important area. Fundamental aspects of low-latency transmission are considered in addition to validation on real-time prototypes for subset of the considered application scenarios. The cellular scenario validation is carried out using both live measurements from a test cell coupled with large-scale real-time emulation using the Openairinterface.org emulator for both high-performance gaming and M2M application. In addition, a validation testbed for low-layer (PHY/MAC) low latency procedures will be developed. The rapidly deployable wireless mesh scenario validation makes use of the real-time OpenAirInterface.org RF platform and the existing FP6 CHORIST demonstrator interconnected with commercial M2M equipment. The LOLA project uses one part of the intended hardware platforms from EURECOM in WP4. The LOLA project also envisage applications as tracking in M2M communications. This matches the key objectives in WP2.

#### 5.6.14 QUASAR: Quantitative Assessment of Secondary Spectrum Access

QUASAR aims at using secondary spectrum access either by non-cooperative(e. g . TVWS) or cooperative access. The specific objectives of QUASAR project are:

- investigating the impact of opportunistic spectrum access on primary system performance, especially as a function of primary system receiver requirements.
- moving the community from “detecting spectrum holes” to the regime of “discovering ‘real’ spectrum opportunities.”
- developing detailed methods to assess the impact of multiple secondary users.
- multi-parameter and utility based assessment of value of spectrum (opportunities).
- providing detailed roadmaps and guidelines on how to apply and analyze new opportunistic spectrum access business models.
- providing specific and reasoned proposals to go beyond the current regulatory framework and to cover the whole value-chain inspiring interaction between all stakeholders and regulators.

Geo-location information as explained in other cognitive radio projects seems a vital source. More information is not publicly available.

### 5.6.15 QOSMOS: Quality of Service and Mobility Driven Cognitive Radio Systems

The traffic on cellular wireless networks is growing rapidly due to increases in data, streamed high-bandwidth video and digital TV. The networks themselves have typically not been planned for such traffic, so that mobile operators have some difficult decisions to make if they are to maintain good user experience. Since the proportion of voice traffic as a function of the total is becoming less, the revenue generated is not in proportion with the traffic increase and the gap between traffic growth and revenue will get larger. A second factor is that European countries typically have multiple cellular operators who are no longer able to differentiate themselves on coverage. The combination of these factors is resulting in radio base-station sharing to reduce costs (for example T-Mobile and 3 in the UK and Telefonica and Vodafone pan-European collaboration to share network infrastructure in Germany, Spain, Ireland and the Czech Republic).

In parallel, a regulatory trend is that radio spectrum is moving towards technology and service neutrality where several user groups have access but are required to work out their own mechanisms to manage interference. One example of this neutrality (but still with licensed spectrum) is the central portion of the 2.5–2.7GHz band to be auctioned in the UK in 2010. Another example of neutrality, but coupled with opportunistic use of spectrum has arisen from television switching from analogue to digital in both the US and Europe. From this activity, TV 'white spaces' are increasing in the US and also spectrum is becoming available in Europe through the 'digital dividend'.

Making use of technology and service neutral spectrum opportunistically is a principal focus of QoSMOS.

Low power cognitive devices could potentially share with radar if the radar sweep can be detected and the transmission of the timed to avoid interference. This scheme would involve sharing on a dynamic temporal basis where the opportunistic user would need to have cognitive equipment that adapts to spectrum measurements.

The opportunistically obtained spectrum can be used for congestion relief during peak loads in licensed spectrum, or to enhance existing services and / or provide new services without the need for acquiring additional licensed spectrum. More generally, with the availability of opportunistic spectrum access telecommunication and digital broadcasting systems will be able to dynamically and locally vary their operating spectrum over a wide range of frequencies bands, and access the best available spectrum on a 'just-in-time' basis. This may happen either upon instruction from a cognitive base station or autonomously by devices themselves.

Good user experience at the right price is a key to the commercial success of services, and will be one of the cornerstones for the future internet, but this will require support for managed QoS and mobility.

The value chain currently in place for mobile broadband, which benefits a comparatively low number of operators and service providers, is likely to continue with LTE and IMT-A mobile services if unchallenged. Lowering the barriers to market entry for service providers, at present restricted to fixed networks, should be further extended to mobile networks. This will encourage growth of entrepreneurial service providers and supply new employment prospects. The market for vendors will expand beyond the low number of operators, on whom they are dependent for custom and are nervous about upsetting, to customers of new market entrants which will herald increasing production and faster development cycles. Qosmos is another cognitive radio project that focuses on free spectrum for 2nd user and focuses on the geo-location database technologies.

### 5.6.16 SACRA: Spectrum and Energy Efficiency Through Multi-band Cognitive Radio

SACRA addresses the implementation of a multi-band cognitive radio technology for spectral and energy-efficient broadband communications and targets, as major outcome, a proof-of-concept.

SACRA focuses on sensing the environment by using multi-band devices. Especially the distributed and advanced allocation strategies promise may offer synergies with key WHERE2 research goals. Promising research takes place in radio resource management and cooperative sensing.

### 5.6.17 SELFNET: Self-Management of Cognitive Future InterNET Elements

Self-NET aims to design, develop and validate an innovative paradigm for cognitive self-managed elements of the Future Internet. The present Internet model is based on clear separation of concerns between protocol layers, with intelligence moved to the edges, and with the existent protocol pool targeting user and control plane operations with less emphasis on management tasks.

Self-NET shall engineer the Future Internet based on **cognitive behaviour** with a high degree of autonomy, by proposing the operation of self-managed Future Internet elements around a novel feedback-control cycle. Self-NET shall embed new management capabilities into network elements in order to take advantage of the increasing knowledge that characterizes the daily operation of mobile Future Internet users. The consortium shall develop innovative cross-layer design optimisation approaches that alleviate the shortcomings and duplication of functionalities in different protocol layers of the present IP stack. Furthermore, Self-NET shall provide a **peer-to-peer** style distribution of responsibilities among self-governed elements of the Future Internet, therefore overcoming the barrier of current client-server and proxy-based models in the operation of **mobility management**, broadcast/multicast, and quality of service mechanisms.

A key objective of Self-NET is to provide a holistic architectural and validation framework that unifies networking operations and service facilities of the Future Internet. The consortium shall develop a real-world demonstrator to test the applicability, robustness, and stability of Self-NET solutions and to ensure smooth migration from present Internet mechanisms. In parallel, simulation campaigns shall verify the scalability and performance sustainability of Self-NET artefacts. Self-NET envisages the worldwide dissemination of the proposed framework to global standardization bodies, thereby maximising Europe's position in the development of the Future Internet. WHERE2 matches some key objectives of the self-net project, like cognitive and peer-to-peer radio communications.

### 5.6.18 SENSEI: Integrating the Physical with the Digital World of the Network of the Future

SENSEI (Integrating the Physical with the Digital World of the Network of the Future) is an Integrated Project in the EU's Seventh Framework Programme, in the IST (Information Society Technologies) Thematic Priority of Challenge 1: Pervasive and Trusted Network and Service Infrastructures: ICT-2007.1.1: The Network of the Future. The SENSEI project started on 1st January 2008, and is set out to run for three years. 19 partners from 11 European countries participate in the project.

In order to realise the vision of Ambient Intelligence in a future network and service environment, **heterogeneous wireless sensor and actuator networks (WS&AN)** have to be integrated into a common framework of global scale and made available to services and applications via universal service interfaces. SENSEI creates an open, business driven architecture that fundamentally addresses the scalability problems for a large number of globally distributed WS&A devices. It provides necessary network and information management services to enable reliable and accurate**context information retrieval and interaction with the physical environment**. By adding mechanisms for accounting, security, privacy and trust it enables an open and secure market space for context-awareness and real world interaction.

Tangible results of the SENSEI project are:

1. A highly scalable architectural framework with corresponding protocol solutions that enable easy plug and play integration of a large number of globally distributed WS&AN into a global system providing support for network and information management, security, privacy and trust and accounting.

2. An open service interface and corresponding semantic specification to unify the access to context information and actuation services offered by the system for services and applications.

3. Efficient WS&AN island solutions consisting of a set of cross-optimised and energy aware protocol stacks including an ultra low power multi-mode transceiver targeting 5nJ/bit.

4. Pan European test platform, enabling large scale experimental evaluation of the SENSEI results and execution of field trials - providing a tool for long term evaluation of WS&AN integration into the Future Internet.

Technology developed by SENSEI will play an essential part in transforming the existing Internet, Mobile Networks and Service Infrastructures into a Network of the Future that is capable to deal with the challenging demands of a Future Networked Society.

#### 5.6.19 TALOS: Task Aware Location Based Services for Mobile Environments

Despite the growth in the number of mobile users, the wide-spread adoption of ubiquitous wireless networks, and the ever increasing capabilities of mobile handsets, the market of mobile services is still dominated by simple infotainment services. This is especially apparent in the area of Location Based Systems, which with few exceptions (e.g. navigation), have not fulfilled its predicted commercial success in mobile environments. Some reasons here are that:

- Content offered in typical **LBS applications** is still narrow and static
- Available methods and interfaces in mobile handsets for the discovery of available content are at best insufficient (e.g. keyword type search)
- Mobile users still require a GPS module (integrated or autonomous) to utilize location based services
- Existing structured content available in several LBS applications is hard to reuse.

The scope of the project is to address the above problems to the benefit of the participating SMEs, offering them a clear S&T advantage over their competition, enabling them to deliver commercially successful location based services for mobile environments.

TALOS is a project that will provide the technological foundations for the task-aware supply of rich content in mobile LBS environments. In particular:

- the project will develop a user interface based on the principles of task computing, which provides an efficient content discovery channel for mobile users
- the project will employ approximate positioning techniques requiring no extra hardware other than their mobile phones.

Furthermore, in order to enrich the available content in mobile LBS, we will develop:

- Task annotation tools for structured content, enabling the SMEs to offer their existing content in a task-aware manner
- Spatio-temporal annotation tools for structured content
- Tools for integrating Web content

The positioning techniques investigated and proposed within the TALOS project are a very reasonable level of cooperation between both projects.

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