Wireless Hybrid Enhanced Mobile Radio Estimators – WHERE

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Abstract: Wireless communications and navigation have different constraints to cope with. On the one hand, communication systems traditionally aim at high spectral efficiency with specific requirements such as low latency and low power consumption. On the other hand, navigation is usually based on the transmission of known data signals at low data rates with fine synchronization capabilities for efficient signal acquisition and tracking. The ICT project WHERE (Wireless Hybrid Enhanced Mobile Radio Estimators) will focus on exploiting the positioning information to enhance communications -and vice versa- within heterogeneous and/or cooperative wireless systems. The paper gives an overview and outlines the upcoming goals of the FP7-ICT project WHERE. The WHERE project is an ICT STREP project involving 14 partners. It started in January 2008, for a duration of 30 months.

Keywords: FP7-ICT project, communication, navigation, hybrid data fusion

1. Introduction

Future wireless communication systems will have to enable and provide a multiplicity of services for a tremendously increasing number of mobile users. Globally, the number of wireless cellular customers is expected to surpass 50% of the population in 2009 [1]. Therefore, an efficient use of wireless communication systems is necessary to cover the increased demand on data rate. Frequency spectrum as the main and most valuable resource in wireless communications is limited. An efficient use of this resource is one of the main objectives in the development of future wireless systems. A variety of projects in European research framework programmes are aiming at figuring out and developing technologies for ubiquitous mobile and broadband network access which is mandatory for many services people will use in their everyday lives. For an efficient use of the available resources in a heterogeneous Radio Access Network (RAN) infrastructure, the availability of position information will allow a more efficient allocation of the available resources or even the prediction of required resources in a highly dynamic scenario and heavily loaded networks.

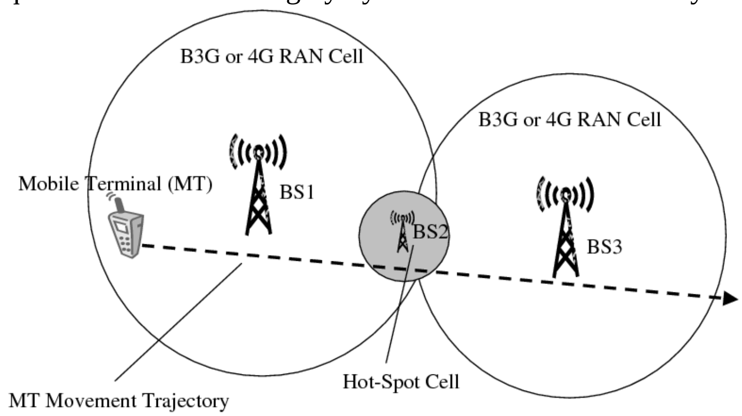

Figure 1 Location based horizontal (intra-system) or vertical (inter-system) handover.

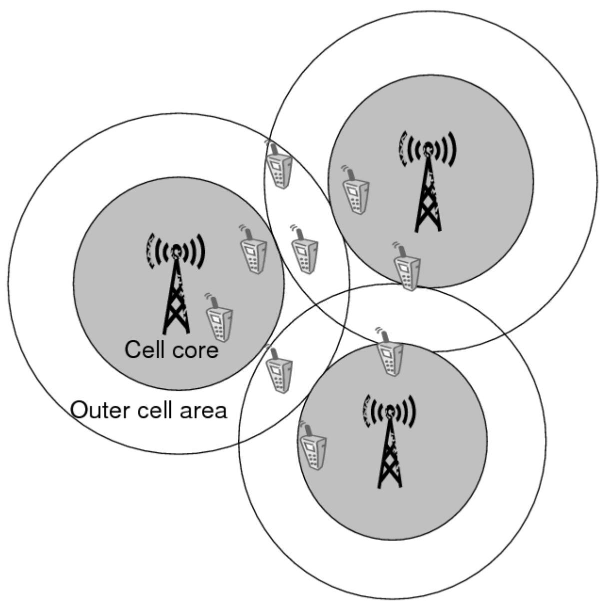

Figure 2 Cooperative spectrum allocation.

A first straightforward example for the benefit of positioning information is shown in Figure 1. As the Mobile Terminal (MT) is moving slowly along the trajectory, it will become possible to hand over to a small hot-spot cell, which locally provides significantly higher data rates than the radio access network cells do. For a high MT speed along the trajectory, the dwell time of the MT in the hot-spot cell area is so low that the effort for a handover exceeds the achievable gain in data rate. In such a case it is beneficial to remain connected to the former RAN cell (Base Station 1 (BS1)) or hand over directly to BS3. The most problematic area in mobile radio communications are the cell borders. At the cell borders the mobile terminal needs more power or more bandwidth to sustain the high data rate links. On the other hand this will increase the inter-cellular interference in the neighbouring cells as the envisaged frequency reuse factor for future mobile radio systems is 1. Therefore, very effective and adaptive radio resource management on the link and on the system layer is mandatory.

Figure 2 shows a hybrid cellular system scenario aiming to design a cooperative spectrum allocation, where in the inner circle we have a frequency reuse factor of 1 and in the outer areas cooperative radio resource management still offers high spectrum efficiency by avoiding interference, applying soft and location based handover, exploiting macro diversity techniques, etc.

Location based RAN functionalities, as motivated previously, require an accurate estimation of the MT location parameters, i.e., the position itself and even derivatives like the MT velocity including its direction. Global Navigation Satellite Systems (GNSS), such as US Global Positioning System (GPS) or the future European Galileo system, are providing position information. However, their accuracy strongly depends on the scenario. Especially in urban or even indoor environments, navigation based on GNSS becomes inaccurate or impossible, since the necessary amount of 4 directly visible satellites is not reached. As an example, Figure 3 shows an urban canyon scenario, where angle α describes the sector of direct visibility of navigation satellites (aperture angle). Figure 4 illustrates the Cumulative Distribution Functions (CDFs) of the number of directly visible navigation satellites for a fixed position of the MT in the middle of the urban canyon. The width of the street W and the height of the buildings H for this example are both equal to 30m. The analysis shows that it is almost impossible to directly receive 4 or more navigation satellites for either the European satellite navigation system Galileo or the GPS. Even the combination of both systems provides a probability of less than 30% that line-of-sight signals from at least 4 satellites can be received simultaneously in this critical scenario.

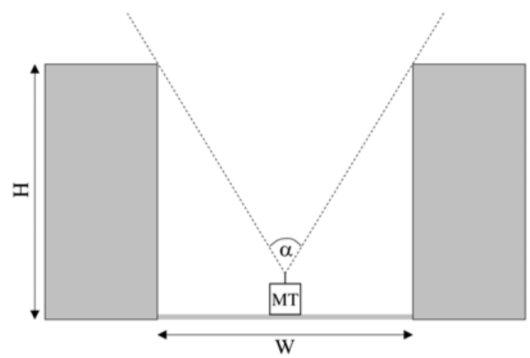

Figure 3 Urban canyon scenario.

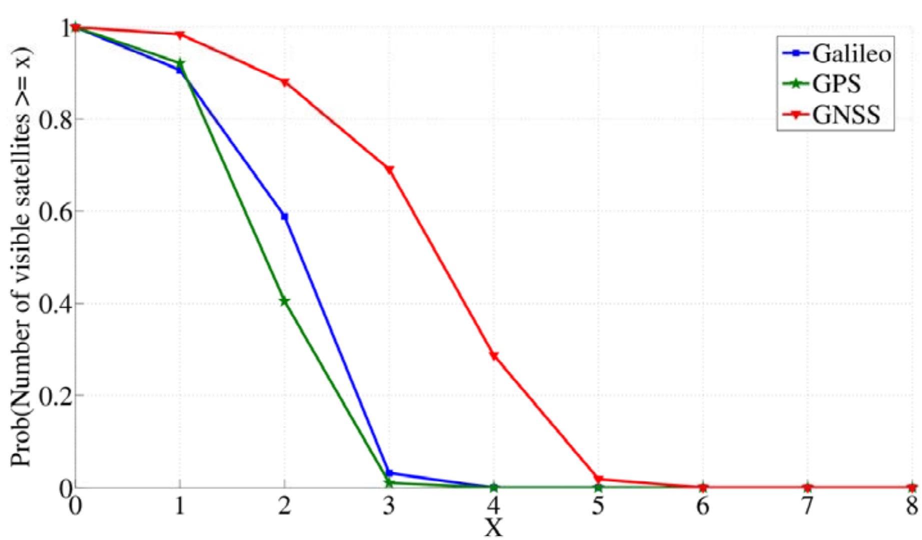

Figure 4 CDF of visible satellites in an urban canyon.

The previous examples clearly highlight the current needs for more efficient and intrinsically synergetic radiolocation/communication means in demanding environments (e.g., urban canyons or indoor). In this context, one major goal of the European FP7-ICT WHERE project is to demonstrate that the combination of various wireless systems (e.g., short-range complementing cellular systems), coupled with adapted algorithmic strategies (e.g., hybrid data fusion, fingerprinting) and proper data signalling or protocols, can enhance location accuracy, location reliability, as well as the continuity of the location service (e.g., in terms of coverage or availability). In parallel of these investigations (i.e., after delivering realistic values for achievable location accuracy and reliability), another related purpose of the project consists in putting forward advanced location based communication schemes (e.g., handover prediction, resources allocation.

2. Research Topics

In this Section, the core ideas of the project WHERE [2] are outlined. It starts with the understanding of the channel for scenarios which communication and navigation systems cope with. Hybrid and cooperative positioning topics are sketched in the following. Finally, different aspects that improve communication systems on the different ISO layers are outlined.

2.1 Channel Characterization

Understanding the channels between all participants is obviously one crucial key. Therefore, specific channel measurements will be performed to collect channel impulse responses in specific environments for different radio systems, such as LTE, WiFi and UWB based communication systems.

Relying on these measurements, one first trivial goal is to provide relevant models, and potentially emulation sources, with respect to various traditional radiolocation metrics investigated in the frame of WHERE (e.g. Time of Arrival (ToA), Time Difference of Arrival (TDoA), Received Signal Strength (RSSI), etc.) under a wide variety of scenarios. Another major stake is to create realistic data bases for fingerprinting based positioning techniques (according to which received channel profiles are interpreted as radio signatures accounting for the user position).

Mobility models will also be derived for the various addressed scenarios to cope with changing environments or spatially correlated observations (i.e., in both the fingerprinting data base and derived metrics models).

Focusing more precisely on fingerprinting approaches, these changes can be taken into account offline -to deal with more significant effects- or they can be done in real-time. The real-time changes could be the following ones:

- Evaluate the signature of the signal transmitted by the mobile at the serving base station.
- Compare the signature with the stored signatures in order to find good matches and assign probabilities to them. The comparison is usually based on minimizing a cost function.
- Choose the location for which the stored signature best matches the measured signature, i.e., the location has the highest probability to be the correct one. Resolve any ambiguity in location estimation.

The signal signature can be derived from any combination of amplitude, phase, delay, direction and polarization information of not only the direct (Line-of-sight (LoS)) but also the multipath signals. Obviously the more parameters are used the higher the accuracy of the method will be, until maybe a saturation point is reached. However, adding parameters also leads to an increase in systems complexity -by requiring more storage space and higher computational power- and in the time needed for the location to be estimated. The more detailed understanding of the channel helps to establish more accurate solutions for positioning and an enhanced and robust performance in communication systems.

2.2 Hybrid and Cooperative Positioning

The motivation for providing accurate position estimation is actually twofold. On the one hand, positioning information is also provided in scenarios, which are critical for GNSS based navigation. On the other hand, an operation of location based RAN technologies becomes more independent from GNSS. Nevertheless, the aim is to use additionally GNSS based positioning, e.g., the European satellite navigation system Galileo, for improving position estimates. This integration becomes possible by hybrid data fusion:

- Hybrid positioning techniques using both static position information and mobility/trajectory information.
- Hybrid operation of positioning and communications. This yields a WHERE approach of cooperative positioning, where several MTs provide and share their position information via communication links in order to achieve more accurate position estimation.
- Hybrid positioning techniques combining both classical positioning techniques based on measurements such as ToA, DoA, etc. and profile fingerprinting techniques. The classical techniques require a Line-of-Sight (LoS) path and hence, assume the existence of a LoS. The fingerprinting techniques can work, and work even better, in multipath, possibly non-LoS environments.
- Research multipath and non-LoS mitigation algorithms for classical positioning techniques (ToA, TDoA).
- Hybrid fingerprinting techniques using both measurement based databases and ray-tracing based databases. Ray-tracing techniques can be used to generate position dependent profile databases starting from terrain information. The accuracy of ray tracing based predictions by measurements is a key research topic.

2.3 Communications

The hybrid system approach addressed in the WHERE project encompass key innovations beyond state of the art for both communications and positioning. A joint consideration of both aspects will allow exploiting synergies among them. In the field of communications, key research topics are:

- Communication systems using multiple RANs and radio access technologies (RATs) and optimisation of that heterogeneous communications infrastructure based on positioning information of BSs and possibly RAN nodes. Examples of such RAT combinations could be cellular/WiFi or cellular/P2P. Location based protocols, developed and investigated in WHERE, will enable such heterogeneous network connectivity even if the availability of different RANs/RATs is dynamic. This leads to a more efficient use of the available radio resources through advanced location based radio resource management and handover algorithms.
- On the PHY layer technologies and procedures, which take into account positioning information, will be researched. Such approaches optimise MIMO strategies (spatial multiplexing, spatial diversity) or provide adaptive macro diversity techniques.
- Taking into account positioning information yields to a more precise prediction of channel information. This will be exploited in a joint optimisation of the PHY and MAC layer through adaptive coding/modulation and hybrid automatic repeat request (ARQ) procedures.
- Synchronisation of both the network and the MTs is improved by RAN based positioning technologies, since parts of them rely on correlation techniques to obtain ToA or TDoA measures. These technologies relate very much to MT synchronisation strategies, but provide higher accuracy.

2.4 Demonstrators

The WHERE project enhances, combines and assesses several already existing platforms (e.g. LTE, WiFi, UWB, IEEE802.11a, ZigBee) that have been developed in the frame of previous European research projects, see Figure 6. Once upgraded, these validation platforms will enable to carry out adequate evaluation trials and provide algorithmic studies with realistic signals, metrics, or models for emulation purposes. Furthermore, one ultimate goal will be to validate some of the proposed concepts in a local and global cellular mobile radio system. On this occasion, specific scenarios that suit the capabilities of today's communication and navigation units -the commercial hardware of tomorrow- will be considered to demonstrate the key idea of combining communications and navigation.

Figure 5: Current UWB and IEEE802.11a communication platforms

3. Project Organization

Figure 6 shows an overview of the project structure and work flow adopted in WHERE.

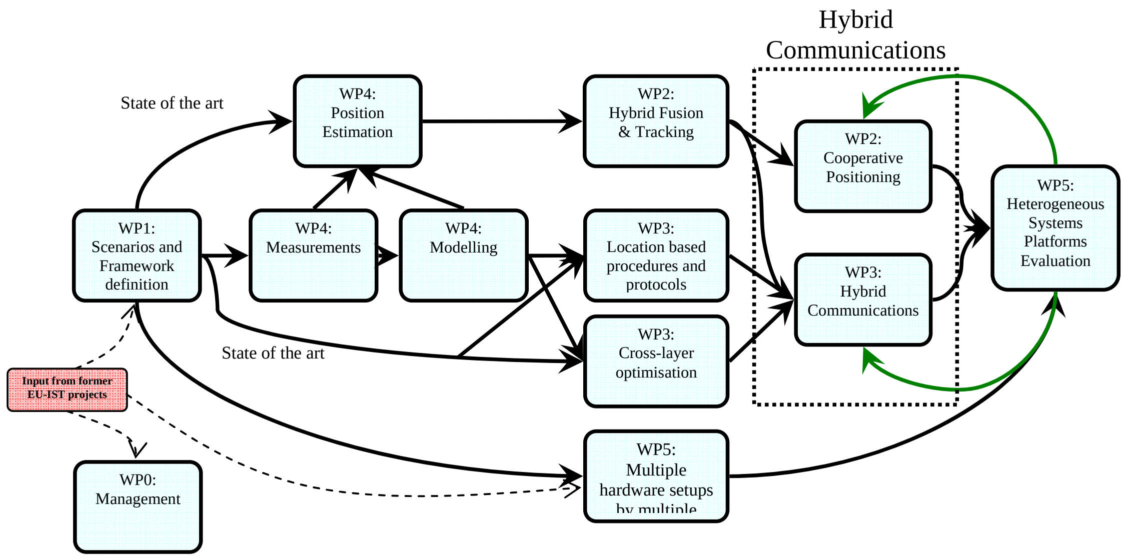

Figure 6: Overall structure and work flow in the WHERE project

4. Partners

The partners of the WHERE project are:
German Aerospace Center (DLR), Aalborg University, Advanced Communications Research & Development (ACORDE), Commissariat à L'Énergie Atomique – LETI, Institut Eurécom, Siradel, Universite de Rennes 1, Instituto Telecomunicações, Mitsubishi Electric ITE, Sigint Solutions Ltd., University of Surrey, Universidad Politecnica de Madrid, University of Alberta, City University of Hong Kong.

5. Conclusions

The paper introduces different scenarios where positioning information can aid a communication system and vice versa. These -and more- scenarios will be investigated in the FP7 project WHERE of the European Commission. The idea of this paper is to show the topics of this project to stimulate awareness in and feedback from the community in an early stage.

6. Acknowledgment

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