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Overview of mobile localization techniques and performances of a novel fingerprinting-based method

Aperçu des techniques de localisation de mobiles et performances d'une nouvelle méthode basée sur l'identification d'empreintes

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ABSTRACT

Mobile localization techniques in outdoor environment have been widely studied. In this paper, we consider a specific application related to search and rescue activities or electronic surveillance in urban areas. In this case, the localization must be of high accuracy, on the order of 10 m, despite other constraints related, among others, to non-line-of-sight conditions and non-cooperation with other nearby mobiles or cellular base stations. A brief survey of RF-based localization techniques shows that none of them fully satisfy the desired specifications. A novel approach combining fingerprinting and polarization diversity is then described, its performance being assessed from on-site measurements.

RÉSUMÉ

Dans cet article, on envisage une application spécifique des techniques de localisation radiofréquences pour la surveillance ou la recherche de personnes en environnement urbain. La localisation doit être faite avec une précision importante, de l'ordre de 10 m, en dépit de contraintes liées aux conditions de non-visibilité directe et de non-coopération avec d'autres mobiles. Une revue de l'état de l'art des techniques de localisation montrant qu'aucune d'entre elles ne satisfaisait les spécifications souhaitées, une approche innovante, combinant identification d'empreintes et diversité de polarisation, est proposée. Les performances sont évaluées à partir de simulations et de mesures in situ.

0. Introduction

Accurate localization of mobile phone users in outdoor environment has received considerable attention during this last decade and a wide range of commercial software or applications providing information services to customers has been de-

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veloped. Among these applications, let us mention the automatic localization of emergency callers in distress, dialing 911 in North America, to improve the efficiency of rescue services. For example, the U.S. Federal Communications Commission (FCC) requires from the wireless service providers that the accuracy for such localization, based for example on cell identification and triangulation technology, must be within 50 to 300 m. To improve this accuracy, one solution proposed by the Canadian Radio-television and Telecommunication Commission (CRTC) is that the Global Positioning System (GPS) caller's location available in his cell phone, called Mobile Station (MS) in the following, would be automatically transmitted with the emergency call.

In this paper, we treat a special case of surveillance of people potentially dangerous for our society, which is an important item dealing with the security of citizens. Hence, the localization of their mobiles can be an additional tool to the existing techniques used by the teams during surveillance missions. The localization accuracy must be on the order of 10 m despite other constraints related, among others, to the fact that MS is in an urban or suburban environment. The signals between MS and the cellular network base stations (BS) will thus suffer from strong multipath effects, while the probability to be in Non-Line Of Sight (NLOS) scenario is also high. The GPS option cannot be chosen since one can easily imagine that a dangerous individual has disabled the tracking GPS capability of his phone; otherwise he uses a cell phone not having GPS. Note that the same problem occurs to precisely locate not such individuals but an injured person in case he is incapacitated to give a call and whose cell phone has no GPS availability.

The first step of this study was to make an overview of the most relevant techniques already described in the literature and which could be applied, as least in their basic principles, to our application. This is briefly summarized in Section 1 where advantages/disadvantages as well as performances of different techniques are discussed. Since it appears that in NLOS conditions, the aimed accuracy can be reached only with a very large number of BS and with the cooperation of nearby MSs, which is not possible for surveillance applications, a new technique based on a fingerprinting approach has been proposed.

The starting assumption is that the MS was roughly estimated within a hundred-meter radius area with the GSM cell identification approach or any other means. Thus one or a few dedicated receiving stations (RS) can be deployed in this area to detect and process signals sent by the MS without the knowledge of the MS's owner. This can be done owing to an improved and modified version of International Mobile Subscriber Identity (IMSI) catchers, whose description is out of the scope of this paper, acting as a "false" BS, able to force the MS to send messages which will be received by RS. As a result, in such a configuration, MS and RS are not synchronized and the localization is made without the cooperation of possible other nearby cellular phones knowing their positions or of the BSs of the cellular network.

The principle of the method already described in [1] is briefly recalled in Section 2. An improvement of the localization algorithm is proposed by introducing polarization diversity at RS to take into account that the orientation of the MS antenna is unknown. In Section 3, we will focus on experimental results, in order to extract statistics on localization accuracy in real conditions. This is an important concern for the final assessment of a localization method. Indeed, for an urban scenario, characteristics of the propagation paths deduced from simulation or from measurements may sometimes strongly differ, impacting the estimation of the method reliability.

1. Survey of RF-based localization techniques

Most RF ground-based localization techniques rely on the signals transmitted by the MS and received by BSs (or by anchor nodes). For each MS-BS radio link, specific characteristics or signatures as RSS (Received Signal Strength), TOA (Time Of Arrival), TDOA (Time Difference Of Arrival), AOA (Angle Of Arrival), PDP (Power-Delay Profile), are extracted from received signals and used by a dedicated localization algorithm to obtain an estimate of the MS position. Hence, the accuracy and robustness of the procedure is tightly bound to given system parameters and environment in which the MS has to be localized. For example, system parameters include the bandwidth of the signals, the deployment or not of antenna arrays for the MS and/or BS, the number of snapshots collected over time, while the environment is divided into 2 classes: Line Of Sight (LOS) or NLOS. The survey described below does not pretend to be exhaustive, the idea being to extract from the literature a few papers describing techniques having possible application to our localization problem. Generally, localization techniques are split into two categories [2]: geometrical and non-geometrical techniques.

1.1. Geometrical techniques

For this first category, the position is estimated by compiling one or more channel characteristics (AOA, TOA, or RSS) into a geometric output. Equations relating the unknown position of the MS with the known positions of the BSs are derived and solved to estimate the MS position. Optimization routines such as the Least Squares algorithm (LS) are often used as a metric to minimize the estimation error. One could mention:

- The TOA method [3] which requires a perfect synchronization between the MS and BSs, a large bandwidth to obtain a time delay resolution small enough for the desired localization accuracy. Also, the algorithm implicitly needs the knowledge of the LOS TOA. We note this is not always possible and in particular for urban and indoor environments where the MS-BSs links are in NLOS. The NLOS condition adds a positive delay bias to the real TOA and can introduce severe localization errors if it is not corrected or removed with specific treatments as reported in [4,5].