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Shkedi

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(54) **SIGNAL COMPARISON-BASED LOCATION DETERMINING METHOD**

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This patent is subject to a terminal disclaimer.

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(63) Continuation of application No. 13/448,309, filed on Apr. 16, 2012, now Pat. No. 8,594,698, which is a

(Continued)

(51) **Int. Cl.**

H04W 24/00	(2009.01)
H04W 4/02	(2018.01)
G01S 5/02	(2010.01)

(52) **U.S. Cl.**

CPC ***H04W 4/023*** (2013.01); ***G01S 5/0252*** (2013.01)

(58) **Field of Classification Search**

CPC .. H04W 4/02; H04W 64/00; H04L 29/08657; H04L 29/08108; H04L 29/08936;

(Continued)

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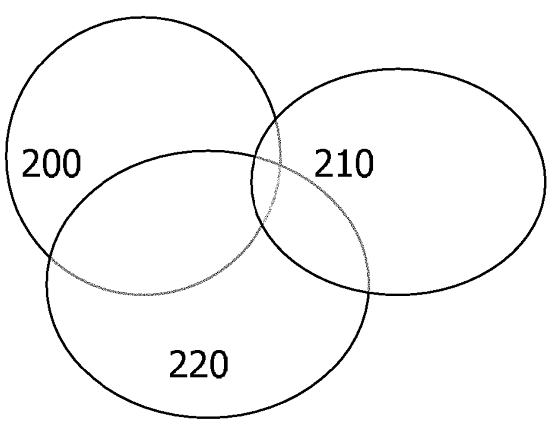
(57) **ABSTRACT**

At least one portable RF communications device in conjunction with at least two fixed-location service-area antenna stations respectively capable of RF communication with the at least one device performs the steps of: (I) using a portable device at a selected location to measure RF communications signals from the plurality of local fixed-location service-area antenna stations and electronically storing at least two of the respective reception signal strength measurements; and (II) monitoring a portable device location by causing the device to measure reception signal strength associated with local fixed-location service-area antenna stations signals, and to electronically compare these measurements with the stored at least two measurements.

28 Claims, 1 Drawing Sheet



Related U.S. Application Data

continuation of application No. 12/720,362, filed on Mar. 9, 2010, now Pat. No. 8,170,583, which is a continuation of application No. 11/533,238, filed on Sep. 19, 2006, now Pat. No. 7,706,811.

(58) **Field of Classification Search**
CPC G01S 5/0252; G01S 5/02; G01S 5/14; H04M 1/72572; G01C 21/20
USPC 455/404.2, 432.1, 436, 437, 440, 441, 455/452.2, 456.1, 456.2, 513
See application file for complete search history.

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A Survey and Taxonomy of Location Systems for Ubiquitous Computing—by Jeffrey Hightower and Gaetano Borriello (Technical Report UW-CSE Jan. 8, 2003).
SpotON: An Indoor 3D Location Sensing Technology Based on RF Signal Strength-by Jeffrey Hightower and Gaetano Borriello—(UW CSE Technical Report #2000-02-02, Feb. 18, 2002).

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Figure 1

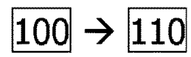

Figure 2

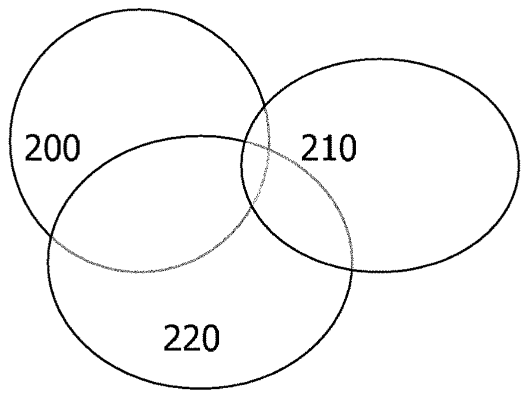

Figure 3

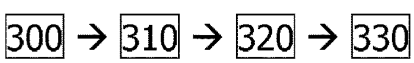

Figure 4

Figure 5

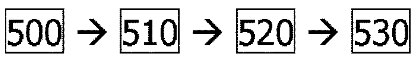

Figure 6

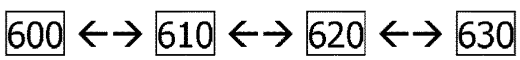

Figure 7

SIGNAL COMPARISON-BASED LOCATION DETERMINING METHOD

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation of Ser. No. 13/448,309, filed Apr. 16, 2012, now U.S. Pat. No. 8,594,698, which is a continuation of application Ser. No. 12/720,362, filed Mar. 9, 2010, now U.S. Pat. No. 8,170,583, which is a continuation of application Ser. No. 11/533,238, filed Sep. 19, 2006, now U.S. Pat. No. 7,706,811. The disclosures of said applications and their entire file wrappers (included all prior art references cited therewith) are hereby specifically incorporated herein by reference in their entirety as if set forth fully herein.

TECHNICAL FIELD

The present invention generally relates to methods for determining the location of a mobile telephone, or of a mobile communications device. More specifically, the present invention relates to a method for determining the location of a mobile telephone, wherein the mobile telephone is preferably capable of performing measurements of signal characteristics deriving from signals being received from mobile telephone service area antennas, of performing calculations related thereto, and of storing these measurements and/or calculation results.

BACKGROUND ART

Simply stated, there is a longstanding problem of providing high accuracy location data for mobile devices, such as mobile telephones. In the most critical aspect, the problem is to maintain user privacy of precise location data of the mobile telephone user. Nevertheless, there also remains a need in the art for simple straightforward improvements in determining the precise location of mobile devices; especially in poor signal-reception locations such as in dense multi-story urban centers. Furthermore, there is a need in the art for providing an elevation component to location data, so as to locate a device in a multi-story structure.

Motorola, Inc., Overview of 2G LCS Technologies and Standards (3GPP TSG SA2 LCS Workshop LCS-010019—London, UK, 11-12 Jan. 2001)—discusses why locating mobile phones becomes a hot topic in telecommunications industry, and what technologies are being studied and standardized.

Y. Zhao, "Mobile Phone Location Determination and Its Impact on Intelligent Transportation Systems," IEEE Transactions on Intelligent Transportation Systems, vol. 1, no. 1, pp. 55-64, March 2000.—provides more information on different location technologies and related location services.

There are many location-determining methods used to determine the location of a cell phone. These methods differ in the level of accuracy they provide as well as their implementation. In general these methods could be divided into methods that involve the cellular network participation and those that don't (handset based only).

Methods that involve the cellular network participation include:

Cell-ID
TDOA—Time Difference Of Arrival
TOA—Time Of Arrival
AOA—Angel Of Arrival
EOTD—Enhanced Observed Time Difference
A-FLT—Advanced Forward Link Trilateration
A-GPS—Assisted GPS (Global Positioning System)

Methods that rely solely on the handset to determine its position:

GPS—Global Positioning System

Expect Cell-ID where the location of the handset is simply determined to be within the area of the cell, where the cell's base station location is known and the accuracy depends on the size of the cell (accuracy of anywhere between 100 meter and 3,000 meters) all other methods require different levels of calculations either by the network or the handset or both.

A substantially similar field where virtually the same class of location based need arise is in the area of ubiquitous computing. Essentially, with respect to location based applications, the primary difference between the mobile telephony and ubiquitous computing relates to privacy—since the mobile telephone user might prefer not to allow his location to be monitored, while privacy is a non-issue for a ubiquitous computer attached to a box in a large warehouse or to a piece of luggage in an airport customs clearance center or to a semi-assembled component in a multifaceted manufacturing facility or to a semiautonomous vehicle in a recreation center, etc.

A Survey and Taxonomy of Location Systems for Ubiquitous Computing—by Jeffrey Hightower and Gaetano Borriello (Technical Report UW-CSE 01-08-03)—"Emerging mobile computing applications often need to know where things are physically located. To meet this need, many different location systems and technologies have been developed. In this paper we present the basic techniques used for location-sensing, describe a taxonomy of location systems, present a survey of research and commercial location systems that define the field, show how the taxonomy can be used to evaluate location-sensing systems, and offer suggestions for future research. It is our hope that this paper is a useful reference for researchers and location-aware application builders alike for understanding and evaluating the many options in this domain."

SpotON: An Indoor 3D Location Sensing Technology Based on RF Signal Strength—by Jeffrey Hightower and Gaetano Borriello—(UW CSE Technical Report #2000-02-02) "Providing a reliable technology and architecture for determining the location of real world objects and people will undoubtedly enable applications, customization, and inference not currently possible. This paper documents the creation of SpotON, a new tagging technology for three dimensional location sensing based on radio signal strength analysis. Although there are many aspects to the topic of location sensing and several of them will be briefly discussed, this paper is primarily concerned with the hardware and embedded system development of such a system."

For many mobile telephone location based services, constant calculation of a user's handset location is required. For example, if a user asked to receive food coupons whenever he enters a specific area or to be informed if a child carrying a cell phone left a certain perimeter around the house, or if the user asked for a group call to his cell phone and home phone every time that he is at home; in order to give him the option to answer calls to his cell phone on his landline.

From a network perspective, in an anticipated emerging world where Location Based Services (LBS) are expected to be widely used and of those services many require constant monitoring of a user's cell phone location, those methods will require the networks to have a lot of infrastructure dedicated to the determination of handsets' locations.

From a privacy perspective, having the cellular network constantly monitor a user's location is problematic to many people. For example, the user asked to receive coupons for merchandise on sale when he is in the shopping area next to his home. However, that same user is troubled by a prospect that, in order for the coupons to be sent, the user's location must be constantly monitored so as to find out when he enters the shopping area.

Obviously the privacy problem could be solved by having the cell phone itself monitor its position, and activate an application when the cell phone concludes that the user has entered the shopping area, etc. This class of solution is also amenable for adaptation to ubiquitous computing situations—since it simply makes the location monitoring logic part of a distributed computing architecture.

Having the cell phone monitor its position will also significantly reduce the infrastructure required by the cellular network to determine the location of handsets. This is also true in ubiquitous computing applications.

Currently a cell phone can determine its geographical location by using a GPS receiver. The challenges with using a GPS in a handset—is that GPS require significant calculations that takes time, up to several minutes; it is difficult to get GPS signals in dense urban areas; and GPS does not distinguish between different elevations at the same location. Thus, in our shopping area example, GPS would not distinguish between entering a large department store from entering a shopping center plaza in a floor below or entering a professional service office in a floor above.

A-GPS (Assisted-GPS), which is intended to reduce the time it takes to determine a location as well as possibly calculate the location in the network in order to reduce the complexity required from the cell phone, once again requires the network.

Using Cell-ID by the cell phone is limited as a cell area location resolution is not good enough for most location based applications. On the ubiquitous computing side, division of large areas into micro-cells presents a substantially similar location accuracy threshold.

There are, of course, numerous patents that have contributed to progress in this art—especially in the field of cellular telephones—most especially since there is an ongoing attempt to reach compliance with regulations calling for instant automatic location reporting for cellular telephone users requesting emergency services (police, ambulance, fire department, etc.).

U.S. Pat. No. 7,057,556—Method And Apparatus For Geolocating A Wireless Communications Device—"The time difference of arrival for a signal received at two or more receiving sites as transmitted from a wireless communications device, is determined by a frequency domain technique. The constituent frequencies of the signals received at the two or more receiving sites are determined, including the phase, or a value representative of the phase, of each frequency component. The phase values for the same frequency are subtracted to yield a phase difference values as a function of frequency. The slope of the function represents the time difference of arrival for the wireless communications device signal as received at the two receiving sites. To determine the mobile location based on the determined time difference of arrival values, a seed or initial location is first assumed for the wireless communications device and the distance difference of arrival (the time difference of arrival multiplied by the speed of light) is calculated. The calculated time difference of arrival is then used to adjust the distance difference of arrival by continuously iterating the position of the wireless communications device until the calculated distance of arrival and the calculated time difference of arrival (as multiplied by the speed of light) are within a predetermined margin."

U.S. Pat. No. 7,050,786—Method And Apparatus For Locating A Wireless Device—"Disclosed is a method and apparatus for locating a wireless device especially useful for locating a cellular telephone making a call from an unknown location. The call may be a request for emergency assistance, or for location-based commercial services, for example. Various embodiments may optionally include a mobile location component, a cellular telephone enabled to chirp-on-demand, and/or an interferometer link. A mobile location component may include a directional antenna. The directional antenna may be mounted on an antenna boom on top of an emergency vehicle, for example. The mobile location component may alternately or additionally comprise a hand-held unit. System elements may cooperate to generate a situation awareness map or other display. The mobile location component may be moved in the general direction of a first location calculation associated with a first circular error of probability. After being moved in the general direction, the mobile location component may cooperate with other elements to determine a second location calculation associated with a second circular error of probability. Second and subsequent location calculations are of increasing precision, enabling an emergency vehicle or attendant to zero in on a cellular telephone."

U.S. Pat. No. 6,972,717—Method And Apparatus For Enhanced 911 Location Using Power Control In A Wireless System—"A method of locating a mobile telephone includes steps of receiving, transmitting, increasing and determining. In the receiving step, a first base station receives a call from a mobile telephone, the call including a dialed number and a TDMA signal. In the transmitting step, the base station transmits a control message to the mobile telephone when the dialed number meets a predetermined criterion, such as being 911. The control message instructs the mobile telephone to transmit the TDMA signal at a maximum power. In the increasing step, the mobile telephone increases the TDMA signal to maximum power in response to the control message. Then in the determining step, location information for the mobile telephone is determined based on at least one characteristic of the TDMA signal received at at-least one of the first base station and other base stations. In an alternate embodiment, the method is practiced in a mobile telephone and the power level is automatically increased in response to the dialed number meeting a predetermined criterion."

U.S. Pat. No. 6,674,403—Position Detection And Location Tracking In A Wireless Network—"A system and method for performing real-time position detection and motion tracking of mobile communications devices moving about in a defined space comprised of a plurality of locales is provided. A plurality of access points are disposed about the space to provide an interface between mobile devices and a network having functionality and data available or accessible there-from. Knowledge of adjacency of locales may be used to better determine the location of the mobile device as it transitions between locales and feedback may be provided to monitor the status and configuration of the access points."

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