

Method for detecting fraud in the transmission of position indications by a mobile device

The present invention relates to a method for detecting fraud in the transmission
5 of position indications by a mobile device. It applies notably to the field of systems for the remote collection of road, motorway and urban toll payments and to any other geolocated payment device.

To determine the position of a vehicle, the known devices for remote collection of toll
payments use either signalling gantries strategically sited along roads subject to a toll,
10 or a locating device onboard the vehicle periodically transmitting its position determined by a GNSS (Global Navigation Satellite System) satellite positioning system, for example of GPS (Global Positioning System) or Galileo type.

A satellite positioning system is very suitable for implementing the remote collection of road, motorway and also urban toll payments but the reliability of
15 the position indication that it delivers depends solely on an indication sent by a GNSS receiver onboard the vehicle and the reliability of the billing carried out by a position server depends directly on this position indication. Except there exist numerous sources of positioning error that may impair the validity of the position indications uploaded to the position server by a locating device. A positioning error may be due to
20 a technical problem regarding the reception of the GNSS signals, such as for example a defect of the receiver or a defect of the indications transmitted by the satellite constellation used. The error may also originate from the deliberate use of a decoy by the owner of the vehicle in order to transmit indications corresponding to a different place from the place where the vehicle is actually situated and thus evade taxes, the

decoy being able to use for example a programming of a predefined trajectory not subject to taxes or a generator of false GNSS signals similar to real signals.

A first known solution making it possible to detect and to eliminate a defect in one or more GNSS signals and to detect a partial defect of the GNSS receiver, on one
5 or more reception channels consists in using, within the GNSS receiver, an algorithm known by the name RAIM (Receiver Autonomous Integrity Monitoring).

A second known solution consists in analysing at the level of the position server, the evolution of the dated position indications which are uploaded by the locating device. An error or defect is then detected and processed as soon as a position becomes
10 inconsistent with respect to previous positions and when it causes a geographical jump to appear between two successive position indications that is much greater than the difference in position that the assumed dynamics of the vehicle can permit.

However, these two known solutions make it possible to solve the problem of integrity due to a non-intentional defect but in no case do they make it possible to detect
15 arbitrary intentional deception.

The aim of the invention is to solve these problems and to propose a method for detecting fraud in the transmission of position indications by a mobile device not exhibiting the drawbacks of the known solutions and making it possible to effectively
20 validate the position indications in any circumstance, whether they take the form of coordinates or else of measurements making it possible to deduce therefrom the coordinates of the mobile device.

1. For this purpose, the invention relates to a method for detecting fraud in the transmission of position indications by a mobile device, the position indications
25 being acquired by the mobile device on the basis of GNSS navigation signals

transmitted by a constellation of satellites and being sent to a position server by way of a cellular mobile communication network, consisting, for each position indication acquired on the basis of the reception of a navigation signal, in acquiring a communication signal transmitted by the cellular network, in
5 comparing temporal indications contained in the navigation signal received and temporal indications contained in the communication signal received and in deducing therefrom whether the position indication is exact or erroneous, the said method being characterized in that the said temporal indications contained in the navigation signal received and in the communication signal received are instants
10 of transmission of the said signals dated by the satellite, respectively the cellular network, in a time scale synchronized with an absolute time scale and instants of reception of the said signals measured by the mobile device.

Advantageously, the comparison of the temporal indications contained in the
15 navigation and communication signals consists in calculating the absolute value of the difference between the gap separating the instants of transmission and of reception of the navigation signal and the gap separating the instants of transmission and of reception of the communication signal.

20 Advantageously, the method can furthermore consist in choosing a threshold value taking account of an estimation of the maximum propagation time for the various signals and in verifying whether the result of the comparison is below the threshold value so as to validate the position indication.

Advantageously, the method can consist, at one and the same instant of measurement, in acquiring several position indications for the mobile device on the basis of navigation signals originating from several different satellites, in comparing the temporal indications contained in each navigation signal received with the temporal indications contained in the communication signal received, and in validating the position of the mobile device if for each of the indications acquired, the result of the comparison with the threshold is positive.

Advantageously, the method can furthermore consist in deciding that there is fraud if a position indication is erroneous.

Other features and advantages of the invention will be clearly apparent in the subsequent description given by way of purely illustrative and nonlimiting example, with reference to the appended schematic drawings which represent:

- Figure 1: an exemplary system for locating a mobile device, such as a vehicle, by satellite, according to the invention;
- Figure 2: An exemplary procedure for determining the position of a GNSS receiver in a mobile device, according to the invention;
- Figure 3: an exemplary schematic diagram illustrating the various steps of the method, according to the invention.

Figure 1 represents an exemplary system for locating a mobile device 1, for example a vehicle, by satellite. The locating system comprises, aboard the mobile device 1, a locating and broadcasting device 2 intended to determine the position and/or the

speed of the vehicle and to transmit these location indications to a position server 3 charged with storing them and/or utilizing them. The locating and broadcasting device 2 comprises a receiver 4 of GNSS (Global Navigation Satellite System) navigation signals such as a GPS (Global Positioning System) or Galileo receiver, transmitted by
5 a constellation of satellites 5a, 5b and a cellular network mobile communication transceiver 6, for example of GSM (Global System for Mobile communications), UMTS (Universal Mobile Telecommunications System), or CDMA (Code Division Multiple Access) type. The position indications are calculated by the GNSS receiver 4 by utilizing signals 13a and 13b transmitted by the satellites 5a, 5b. The number of
10 satellites must be at least equal to four so as to determine the four position coordinates of the vehicle in space x,y,z and in time t . This position indication is then provided to the mobile communication transceiver 6 which in accordance with a sequencing dependent on the application, the sequencing possibly being limited to follow a predetermined periodicity, dispatches the said position indication to the position server
15 3 through a communication channel 12 and by way of a base station 7a covering a zone of coverage, also called a cell, in which the mobile device 1 is situated.

An exemplary procedure for determining the position of the GNSS receiver 4 is represented schematically in Figure 2. The procedure consists as regards the receiver 4 in determining the pseudo-distances $d1$, $d2$, $d3$ separating it from at least three
20 satellites 5a, 5b, 5c of the constellation and then in deducing therefrom the point of intersection 14 of the spheres whose centre is demarcated by the position of the satellite itself and whose radius is provided by the pseudo-distances $d1$, $d2$, $d3$. The position of the GNSS receiver 4 corresponds to this point of intersection 14. The measurement of the pseudo-distances $d1$, $d2$, $d3$ is carried out in the receiver 4 by
25 logging the time of arrival of radio electrical signals constituting a navigation message

originating from the satellites 5a, 5b, 5c. The essential indications originating from each satellite via the navigation message and which must be processed by the receiver consist of the date of transmission of the message and the position of the satellite at the moment of the transmission of the radio electrical signal. The satellite transmits its
5 ephemerides (Keplerian parameters) in its navigation message, allowing the receiver 4 to calculate the position of the satellite in a frame of reference tied to the Earth. The ephemerides consist in the case of a GPS signal of 16 parameters repeated every 30 seconds in the navigation message.

The position of the satellite having been obtained, it remains for the receiver to detect
10 the time of transmission of the message so as to deduce the propagation time of the signal transmitted by the satellite and the distance separating it from the satellite, and then the radius of one of the 4 necessary spheres, and the position of the vehicle 1.

The procedure for transmitting the position indications to the position server 3 is carried out by a cellular network communication technique.

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The schematic diagram of Figure 3, represents the various steps of the method for detecting fraud in the transmission of the position indications. This method consists in detecting, in the mobile device, at the level of the locating and broadcasting device 2, the inconsistency between the measurements carried out by the receiver 4 of GNSS
20 navigation signals and the real trajectory followed by the vehicle on the basis of a comparison of the temporal indications contained in the navigation signals received by the receiver 4 and of the temporal indications contained in the communication signals received by the communication transceiver 6.

Indeed, all the satellites belonging to the navigation system and the cellular
25 communication network are mutually synchronized with a universal absolute time

reference, for example of UTC (Coordinated Universal Time) type, to within a millisecond. The times that are dispatched in the signals which they transmit respectively to the navigation receiver or to the communication receiver are therefore mutually synchronized and may be considered to be absolute times.

5 The locating and broadcasting device 2 comprises an arbitrary internal clock which is not synchronized with the clock of the satellites and which delivers its own inherent time scale, common to the receiver 4 and to the communication transceiver 6, with a lower precision than that of the absolute time scale. The times measured by the clock which is common to the two receivers 4, 6 have a precision of the order of a few
10 milliseconds to 10ms. These precisions are sufficient since the measurement errors are much smaller than the propagation time of the navigation signals which is of the order of 100ms to 150ms for a satellite in geostationary orbit.

 According to the invention, the method comprises a first step 40 in which a navigation signal 30 transmitted by a satellite is received 32, aboard the mobile device
15 1, by the navigation receiver 4. The receiver 4 carries out a measurement 33 of the pseudo-distance separating it from the satellite and the instant of reception T_r of the signal and then detects, in the signal received, the instant T_{sat} of the start of its transmission, dated by the satellite. The locating and broadcasting device 2 calculates the gap between the instant of transmission T_{sat} of the navigation signal dated by the
20 satellite and the instant of reception T_r of the navigation signal measured by the receiver 4. This gap corresponds to an estimation of the propagation time between the satellite and the receiver 4 but comprises an offset with respect to the real time of propagation of the signal, this offset corresponding to the difference in synchronization between the absolute time scale of the satellites and the time scale of the locating and
25 broadcasting device 2. On the basis of the estimation of the propagation time, the

locating and broadcasting device 2 deduces a value of pseudo-distance between the satellite and the mobile device 1.

In the same step 40, a communication signal 31 transmitted by a base station 7a of the cellular network is received 34, aboard the mobile device 1, by the communication transceiver 6. The locating and broadcasting device 2 detects the instant of transmission of the communication signal dated by the base station, measures the instant of reception of the communication signal and calculates the difference Δ_{com} between the instant of reception and the instant of transmission of the said communication signal. The gap separating the instants of transmission and of reception of the communication signal corresponds to the propagation time of the communication signal to which is added an offset corresponding to the difference in synchronization between the time scale of the cellular communication network and the time scale of the locating and broadcasting device 2. As the distance separating the mobile device from a base station 7a of the cellular network is very small, for example of the order of a few tens of kilometres, relative to the distance between the mobile device 1 and a satellite, for example 96000 km for a geostationary satellite, the propagation time of the communication signal, for example of the order of 0.1ms, is negligible compared with all the other measured times. The gap separating the instants of transmission and of reception Δ_{com} of the communication signal is therefore substantially equal to the difference in synchronization between the time scale of the cellular communication network and the time scale of the locating and broadcasting device 2.

The method thereafter consists, in a step 41, in comparing the propagation time measurements obtained on the one hand, on the basis of the navigation signals and on the other hand, on the basis of the communication signals. For this purpose, the

method consists in calculating the difference, in absolute value, between the gap $T_r - T_{\text{sat}}$ separating the instants of transmission and of reception of the navigation signal and the gap Δt_{com} separating the instants of transmission and of reception of the communication signal. Next in a step 42, the method consists in comparing the difference between the two gaps with a previously chosen threshold value, the threshold value being chosen by taking account of an estimation of the maximum propagation time for the various signals and probable measurement errors. If the difference between the two gaps is below the threshold value, the pseudo-distance measurement carried out by the navigation receiver is validated 43, in the converse case, it is invalidated 44.

The time of propagation of the signals between a satellite and a navigation receiver is less than 150ms. The gap separating the instant of measurement T_r at the level of the navigation receiver and the instant of transmission T_{sat} is therefore less than a second. A threshold value of between 200ms and 2s can therefore be chosen. For example, a threshold value equal to a second may be chosen as initial value to distinguish whether the position measurement carried out by the navigation receiver 4 is likely to be exact or whether it is erroneous. The threshold value may optionally be adjusted, subsequently, as a function of the measurement errors actually noted during operation.

The determination of the position of the mobile device 1 requiring several measurements of pseudo-distances with respect to several satellites of a constellation of satellites, the various steps of the method are repeated for each of the pseudo-distance measurements. The position measurement is validated only if for each of the corresponding pseudo-distance measurements, the result of the comparison with the threshold is positive. The successive position values are sent to the position server 3

accompanied by the result of the corresponding comparison. The position server 3 takes the decision about the presence of possible fraud.

Steps 41, 42 of comparing with a threshold and step 43 of validating or step 44 of invalidating the position measurements are preferably carried out aboard the mobile
5 device 1, but this is not obligatory. These steps could also be carried out at the level of the position server 3. For this purpose, it would be necessary to send all the time measurements carried out by the navigation receiver 4 and by the communication transceiver 6 to the position server.

10 Although the invention has been described in conjunction with a particular embodiment, it is quite obvious that it is in no way limited thereto and that it comprises all the technical equivalents of the means described as well as their combinations if the latter come within the scope of the invention.

CLAIMS

1. Method for detecting fraud in the transmission of position indications by a mobile
5 device (1), the position indications being acquired by the mobile device (1) on the
basis of GNSS navigation signals (30) transmitted by a constellation of satellites
(5a to 5c) and being sent to a position server (3) by way of a cellular mobile
communication network (7a, 12), consisting, for each position indication acquired
(33) on the basis of the reception of a navigation signal (30), in acquiring a
10 communication signal (31) transmitted by the cellular network, in comparing (41)
temporal indications contained in the navigation signal (30) received and temporal
indications contained in the communication signal (31) received and in deducing
therefrom whether the position indication (33) is exact (43) or erroneous (44), the
said method being characterized in that the said temporal indications contained in
15 the navigation signal (30) received and in the communication signal (31) received
are instants of transmission of the said signals dated by the satellite, respectively
the cellular network, in a time scale synchronized with an absolute time scale and
instants of reception of the said signals measured by the mobile device (1), wherein
the comparison (41) of the temporal indications contained in the navigation and
20 communication signals consists in calculating the absolute value of the difference
between the gap ($T_r - T_{\text{sat}}$) separating the instants of transmission (T_{sat}) and of
reception (T_r) of the navigation signal (30) and the gap (Δ_{com}) separating the
instants of transmission and of reception of the communication signal (31).
- 25 2. Method according to Claim 1, characterized in that it furthermore consists in
choosing a threshold value taking account of an estimation of the maximum

propagation time for the various signals and in verifying (42) whether the result of the comparison (41) is below the threshold value so as to validate (43) the position indication (33).

- 5 3. Method according to Claim 2, characterized in that it consists, at one and the same instant of measurement, in acquiring several position indications for the mobile device (1) on the basis of navigation signals originating from several different satellites (5a, 5b), in comparing the temporal indications contained in each navigation signal received with the temporal indications contained in the
10 communication signal (31) received, and in validating the position of the mobile device if for each of the indications acquired, the result of the comparison with the threshold is positive.
4. Method according to one of the preceding claims, characterized in that it
15 furthermore consists in deciding that there is fraud if a position indication is erroneous (44).