



Method for the transmission of position information by a mobile device

The present invention relates to a method for the transmission of position information by a mobile device. It notably applies to the field of road,
5 motorway and urban electronic payment systems and to any other geolocalized payment system, and to devices designed to store and/or to transmit position information periodically.

In all systems for tracking a mobile device such as a vehicle or a fleet of vehicles, it is known that the vehicle periodically transmits information
10 concerning its position to a central server. The transmission period depends on the type of application which is using this information. For applications which necessitate transmitting this information very often with a low period of the order of a few seconds, or even one second, the vehicle generally transmits its position by a telecommunication means, for example of the
15 cellular network type or by satellites. The transmission of position information is generally carried out in the form of sending a data triplet relating to the latitude, longitude and altitude of the vehicle in a predetermined system of coordinates. The position information can also be transmitted in the form of a set of pseudo-distances between the mobile device and reference points, the
20 reference points being satellites in the case of the use of a GNSS (Global Navigation Satellite System) satellite navigation system. Typically, in the standardized system known by the acronym 3GPP (Third Generation Partnership Project), each item of position data is binary encoded in 32 bits which requires a data rate equal to three times 32 bits to be transmitted per
25 second and per vehicle when the position information relates to latitude, longitude and altitude and the transmission period is equal to one second.

For large fleets of vehicles, the quantity of information to be transmitted becomes very large and expensive whilst the data rates authorized by the telecommunication systems are limited. In order to
30 generalize the position reporting systems for a large number of vehicles, it is therefore essential to limit the amount of position data to be transmitted.



The purpose of the invention is to solve these problems and to propose a method for the transmission of position information reported by a mobile device whilst not having the disadvantages of the known methods and making it possible to limit the amount of position data to be transmitted.

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For this purpose, the invention relates to a method for the transmission of position information by a mobile device consisting in acquiring, on board the mobile device, position information of the mobile device from GNSS navigation signals transmitted by a satellite constellation and in transmitting the position information to a position server, characterized in that it consists:

- starting from an initial time t_0 and at successive times t_i greater than t_0 and spaced by a period T_v , in periodically measuring pseudo-distances of separation of the mobile device with respect to the satellites of the constellation,
- on the basis of the pseudo-distance measurement carried out at the initial time t_0 , in determining a first item of absolute position information of the mobile device at the initial time t_0 ,
- starting with the absolute position information at the initial time and for each measurement carried out at the successive times t_i , in determining successive items of information on the position variation of the said mobile device between two consecutive measurement times t_i and $t_i + T_v$,
- in encoding and transmitting the absolute position information and the successive items of position variation information to the position server.

Advantageously, the method furthermore consists, on the basis of the pseudo-distance measurements carried out at the successive times t_i and on the basis of the absolute position information at the initial time t_0 , in periodically determining, with a period T_a , items of absolute position of the mobile device information, the period T_a being equal to a multiple, greater than one, of the period T_v .

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According to one embodiment of the invention, the absolute position information and the position variation information transmitted to the position server by the mobile device are the pseudo-distance measurements acquired
5 by the mobile device and variations of pseudo-distance calculated on board the mobile device respectively, the successive positions of the mobile device being calculated by the position server.

According to another embodiment of the invention, the absolute
10 position information and the position variation information are respectively triplets of values corresponding to the latitude (lat), longitude (long) and altitude (alt) of the mobile device and variations of latitude (δlat), of longitude (δlong) and of altitude (δalt) of the mobile device.

15 Advantageously, the absolute position and the position variation items of information are real numbers comprising a number of successive significant figures of variable importance, and the method furthermore consists, for each item of information, in selecting the significant figures according to an estimation of their degree of importance and in transmitting a
20 reduced number of significant figures to the position server, the figures estimated to be of least importance being eliminated.

Alternatively, the absolute position information and the position variation information are real numbers comprising a number of successive
25 significant figures of variable importance, and the method furthermore consists, for each item of information, in selecting the significant figures according to an estimation of their degree of importance and in encoding and then transmitting all of the significant figures, the figures estimated to be of least importance being encoded using a number of bits lower than the
30 number of bits used for the figures having a higher degree of importance.

According to another embodiment of the invention, the method consists in transmitting an identifier of a road segment on which the mobile device is located and the absolute position and position variation items of information are curvilinear abscissas and curvilinear abscissa variations respectively of the mobile device on the road segment.

Advantageously, the road segment identifier is obtained from a vector cartographic database.

10 Advantageously, the curvilinear abscissas and the curvilinear abscissa variations are calculated and encoded on board the mobile device with a binary code provided by a Huffman table stored in a vector cartographic database, or provided by the position server.

15 The transmission of the position and position variation items of information can be carried out progressively, as they are acquired, by a cellular network mobile communication system. Alternatively, the position and position variation items of information can be stored in an on-board memory of the mobile device and transmitted globally when the mobile device passes
20 close to a terrestrial relay provided with a radio-communication system.

Other features and advantages of the invention will appear clearly in the continuation of the description given as a purely illustrative example, with reference to the appended diagrammatic drawings in which:

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- figures 1a and 1b show two diagrammatic examples of satellite systems for locating a moving object, according to the invention;
- figure 2 shows an example of a method of determining the position of a GNSS receiver in a mobile device, according to the invention;
- 30 - figure 3 is a diagram of a first example of transmission of position information, according to a first embodiment of the invention;

- figure 4 shows an example of curves giving the accuracy of a pseudo-distance measurement as a function of the signal to noise ratio, according to the invention;
- figure 5 is a diagram of an example of transmission of items of position information, according to a second embodiment of the invention;
- figure 6 is a diagram of an example of transmission of items of position information, according to a third embodiment of the invention.

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Figures 1a and 1b show two examples of satellite systems for locating a mobile device 1, for example a vehicle, according to the invention. The locating system comprises, on board the vehicle 1, a locating and broadcasting device 2 intended to carry out measurements making it possible to determine the position and/or the speed of the vehicle and to transmit these items of information to a position server 3 responsible for storing and/or using 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 a satellite constellation 5a, 5b. The measurements carried out on board the vehicle can be transmitted directly to the position server 3 which derives the position information of the vehicle from them. Alternatively, the position information of the vehicle can be calculated on board the vehicle by the GNSS receiver 4 by exploiting the signals 13a and 13b transmitted by the satellites 5a, 5b. The number of satellites must be equal to four in order to determine the four position coordinates of the vehicle in space x, y, z and in time t. The transmission of position information to the position server 3 can be carried out in real time progressively as these items of information are acquired or, alternatively, can be deferred in time.

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When the transmission of the information is carried out in real time as shown in figure 1a, the locating and broadcasting device 2 furthermore comprises a cellular network mobile communication transmitter-receiver 6,

for example of the GSM (Global System for Mobile communications), UMTS (Universal Mobile Telecommunications System) or CDMA (Code Division Multiple Access) type, connected to the GNSS receiver 4. The position information determined by the receiver 4 is then supplied to the mobile communication transmitter-receiver 6 which, according to a predetermined period depending on the application, sends the said position information to the position server 3 over a communications channel 12 and by the intermediary of a terrestrial relay such as for example a base station 7 covering a cover zone, also called a cell, in which the mobile device 1, or a road gantry, is located.

When the transmission is deferred in time, as shown in figure 1b, the items of position information acquired successively by the receiver 4 are stored in a memory 8 of this receiver 4 and transmitted simultaneously to the position server 3 by the intermediary of a local radio-communication access point such as, for example, a road gantry of the electronic payment gantry type equipped with radio-communication means. The deferring in time of the transmission of position information makes it possible to do without mobile telephony systems, which is therefore more economical.

An example of a method for determining the position of the GNSS receiver 4 is shown diagrammatically in figure 2. For the receiver 4, the method consists in determining the pseudo-distances d_1 , d_2 , d_3 separating it from at least three satellites 5a, 5b, 5c of the constellation and then in deriving the point of intersection 14 of the spheres whose centres are the positions of the satellites themselves and whose radii are provided by the pseudo-distances d_1 , d_2 , d_3 . The position of the GNSS receiver 4 corresponds to this point of intersection 14. The measurement of the pseudo-distances d_1 , d_2 , d_3 is carried out in the receiver 4 by measuring the times of arrival of radio signals constituting navigation messages coming from the satellites 5a, 5b, 5c. The essential items of information coming from each satellite via the navigation message and which the receiver must process are constituted by the time of transmission of the message and the

position of the satellite at the moment of transmission of the radio signal. The satellite transmits its ephemerides (Keplerian parameters) in its navigation message allowing the receiver 4, or the position server 3, to calculate the position of the satellite in a reference system related to the Earth. The
 5 ephemerides are constituted, 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 4, or for the position server 3, to detect the time of transmission of the message in order to derive the propagation time of the signal transmitted
 10 by the satellite and the pseudo-distance separating it from the satellite and then the radius of one of the four necessary spheres and the position of the vehicle 1.

In order to reduce the amount of information transmitted to the
 15 position server 3, the invention consists, for each moving vehicle 1, in a first step, in determining a first item of absolute position information of the vehicle at an initial time t_0 and then, in a second step, starting from the initial time t_0 , in periodically determining successive position variation of the moving vehicle items of information over the course of time between consecutive
 20 measurement times, for example t_i and $t_i + T_v$, i being an integer greater than 0. The determination of the successive position variations is carried out with a predetermined period T_v chosen as a function of the application in question. In order to ensure that the items of position information obtained from the variation values are correct and do not drift in time, the method
 25 preferably consists in periodically determining, with a period T_a equal to a multiple, greater than one, of the period T_v , items of absolute position information and, between each determination of absolute position information, in determining, with the period T_v , successive position variation of the said moving vehicle items of information. The absolute position or
 30 position variation items of information can be calculated on board the moving vehicle by the receiver 4 and then either transmitted to the position server 3 progressively as they are acquired or stored in a memory 8 of the receiver 4

and transmitted globally by the intermediary of a local radio-communication access point. Alternatively, the absolute position or position variation items of information can be calculated by the position server 3 from the pseudo-distance measurements, or respectively from the variations between
 5 consecutive pseudo-distance measurements, carried out and transmitted directly by the receiver 4 without prior processing. The pseudo-distance measurements carried out by the receiver 4 correspond to the pseudo-distances separating the vehicle from the satellites of the locating system.

In a first embodiment of the invention shown in figure 3, the absolute
 10 position items of information determined with a period of T_a , for example at the times t_0 and $t_0 + T_a$, are triplets of values corresponding to the latitude lat , longitude $long$ and altitude alt of the vehicle, and the successive position variations determined with a period T_v are triplets of values corresponding to the variations in the latitude δlat , longitude $\delta long$ and altitude δalt of the
 15 vehicle between consecutive measurement times, for example t_i and $t_i + T_v$.

The precision of the measurements carried out by the receiver 4 and the precision of the position information determined from these measurements depend on the quality of the GNSS signals received by the receiver 4 and in particular on the received signal to noise ratio, or on the
 20 noise, making it possible to calculate the position. Consequently, the measurements carried out, the absolute values corresponding to the latitude lat , longitude $long$ and altitude alt of the vehicle and the variation values corresponding to the variations in the latitude δlat , longitude $\delta long$ and altitude δalt of the vehicle between consecutive measurement times
 25 comprise a number of significant figures whose importance can vary. Advantageously, the invention furthermore consists in determining which are the most significant figures and, at the level of the binary encoding of the information to be transmitted, in allocating lesser importance to the less significant figures.

30 The importance of the significant figures can be estimated from a measurement of the signal to noise ratio carried out on each GNSS signal received and taken into account in the calculation of the position. The

relationship between the signal to noise ratio and an estimation of the pseudo-distance measurement precision is known to those skilled in the art and is obtained using the expressions described hereafter.

The overall precision of the pseudo-distance measurement depends
5 on a set of contributory factors:

- Precision σ_o related to the orbital precision of the satellites, typically of the order of 1m,
- Precision σ_c related to the precision of the satellite's clock, typically limited by the value 2m,
- 10 ▪ Precision σ_{io} related to the ionospheric crossing, typically 1m,
- Precision related to the presence of Multi-paths, σ_{MP} , of the order of 1m.
- Precision related to thermal noise: the following formula in fact makes it possible to conventionally relate the standard deviation in the measurement of pseudo-distance to the signal
15 to noise ratio:

$$\sigma_b = \sqrt{\frac{B_L d}{2C/N_0} \left(1 + \frac{2}{(2-d)C/N_0 T_{Coherent}} \right)} * T_c$$

where

- B_L represents the frequency band of the tracking loop of the
20 GNSS signal,
- d represents the spacing of the correlator called the 'Advance-Delay' between the received signal and the replica of the spread code used by the satellite involved in the pseudo-distance measurement, this replica being generated
25 locally by the receiver,
- C/N_0 represents the signal to noise ratio,
- $T_{coherent}$ represents the coherent integration time of the signal,
- T_c represents the chip duration of the GNSS signal.

The overall precision of the measurement of the pseudo-distance to a satellite k , conventionally called the UERE (User Equivalent Range Error) is then given by the expression:

$$\sigma_k = \sqrt{\sigma_b^2 + \sigma_o^2 + \sigma_c^2 + \sigma_{io}^2 + \sigma_{MP}^2}$$

5 The precision of the position of the mobile device can then be derived easily from the precision of the measurements of pseudo-distance to the satellite k σ_k by application of a geometric factor determined by the receiver and known to those skilled in the art as the Geometric Dilution of Precision, DOP.

10 $Precision = GDOP * \sigma$,

where

σ is the root mean square of the σ_k values, and

GDOP is given by:

$$GDOP = \sqrt{\text{trace}(A)}, \text{ where } A = ({}^t G G)^{-1},$$

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$$G = \begin{bmatrix} u_{1,1} & u_{1,2} & u_{1,3} & -1 \\ \vdots & \vdots & \vdots & \vdots \\ u_{k,1} & u_{k,2} & u_{k,3} & -1 \end{bmatrix}$$

$$\begin{cases} u_{k,1} = \frac{x_k - \bar{x}_{Rx}}{d_k} \\ u_{k,2} = \frac{y_k - \bar{y}_{Rx}}{d_k} \\ u_{k,3} = \frac{z_k - \bar{z}_{Rx}}{d_k} \end{cases}$$

where x_k, y_k, z_k are the coordinates of the satellite k and $\bar{x}_{Rx}, \bar{y}_{Rx}, \bar{z}_{Rx}$ are the approximate coordinates of the receiver.

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The selection of the number of significant figures in the position is therefore derived directly from the position precision thus estimated.

According to a first embodiment of the invention, the figures considered insignificant are eliminated and only the significant figures are

encoded and transmitted. According to a variant embodiment of the invention, all of the figures are encoded and transmitted but the less significant figures are encoded in fewer bits than the most significant figures. The elimination of the figures whose reliability is doubtful or their encoding
 5 using a smaller number of bits makes it possible to greatly reduce the amount of information to be stored and to be transmitted.

Typically, the precision as a function of the signal to noise ratio is given by curves shown for example in figure 4 for a conventional receiver. According to these curves, for a receiver operating at 30dBHz with a loop
 10 band of 5Hz, the measurement precision related to the thermal noise is approximately equal to $\sigma_b = 10m$. The result of this is that the overall precision of the pseudo-distance measurement is 10.3m.

This signifies that the significant figures which go beyond a precision of 10m no longer have any value regarding the informational content. This
 15 makes it possible to carry out an encoding of the latitude and the longitude in degrees with only five significant figures.

In a second embodiment of the invention, shown in figure 5, the absolute position items of information determined with a period T_a , for
 20 example at the times t_0 and $t_0 + T_a$, are two values respectively corresponding to a road segment on which the moving vehicle is located and the curvilinear abscissa corresponding to the position of the vehicle on the said road segment. The successive position variations determined, with the period T_v , between two absolute position measurements are variations of the
 25 curvilinear abscissa of the vehicle between consecutive measurement times, for example t_i and $t_i + T_v$. The identifier of the road segment on which the vehicle is located is determined by means of a vector cartographic database for example installed in the GNSS receiver 4. The vector cartographic database identifies a road segment by a point of origin and a point of arrival,
 30 which makes it possible to obtain a geometric representation of each road segment. This second embodiment of the invention makes it possible to

transmit only a single item of binary encoded position information instead of three at each measurement period T_v and to further reduce the amount of information to be transmitted to the position server 3.

In a third embodiment of the invention shown in figure 6, the
 5 curvilinear abscissas and the curvilinear abscissa variations, obtained in the example of figure 5, are calculated on board the vehicle by the receiver 4 and encoded with a binary code depending on the road segment on which the vehicle is located prior to their transmission to the position server 3. This encoding makes it possible to further compress the information transmitted to
 10 the position server. The binary code can for example be provided by the position server or by a Huffman table stored in a vector cartographic database installed in the receiver 4. In the case of an encoding provided by a Huffman table, in order to allow the decoding of the message transmitted by the receiver 4, the Huffman table is also stored in a memory of the position
 15 server 3. The transmission of the encoded information is carried out by a radio-communication means such as a terrestrial relay.

The Huffman encoding is carried out on the basis of the knowledge identifier of the road segment on which the vehicle is located and is different for each road segment. Knowledge of the road segment makes it possible to
 20 know which type of road the vehicle is located on, whether it is a departmental (minor) road, a national (main) road or a motorway, if the segment is in an urban zone or not, and the associated speed limit conditions. These items of information make it possible to determine the most probable travelling speed of the vehicle and to allocate, to this speed of
 25 highest probability, an encoding value using a minimal number of bits, the other speeds being encoded using a number of bits which becomes greater as their probability reduces.

For example, on a main road, outside of a town, there is a high probability that the vehicle is travelling, for example, at eighty kilometres per
 30 hour. If the receiver 4 transmits a curvilinear abscissa variation every second, there is a high probability that the vehicle will have travelled twenty metres between two successive measurement times. This most probable value will

therefore be encoded in binary for example by the value 1. Each time that the receiver 4 transmits the value 1, corresponding to a single bit, this means that the vehicle will have travelled about twenty metres. On the other hand, if the vehicle travels fifty metres, the receiver will send a number of bits greater
5 than one, for example three bits. Each of the distances travelled will thus be encoded by different values according to the known Huffman principle, the most probable value being encoded in the least number of bits. Each road segment corresponds to a specific Huffman encoding, for example stored in a vector cartographic database of the receiver 4 and/or stored in a memory of
10 the position server 3.

Even though the invention has been described in association with particular embodiments, it is obvious that it is in no way limited to them and that it comprises all of the technical equivalents of the described means and
15 their combinations if the latter are included in the context of the invention.

CLAIMS

1. Method for the transmission of position information by a mobile device

5 consisting in acquiring, on board the mobile device, position information of the mobile device (1) from GNSS navigation signals transmitted by a satellite constellation (5a, 5b, 5c) and in transmitting the position information to a position server (3), characterized in that it consists:

 - 10 - starting from an initial time t_0 and at successive times t_i greater than t_0 and spaced by a period T_v , in periodically measuring pseudo-distances (d_1 , d_2 , d_3) of separation of the mobile device (1) with respect to the satellites (5a, 5b, 5c) of the constellation,

- on the basis of the pseudo-distance measurement carried out at the initial time t_0 , in determining a first item of absolute position information

15 of the mobile device at the initial time t_0 ,

- starting with the absolute position information at the initial time and for each measurement carried out at the successive times t_i , in determining successive items of information on the position variation of the said mobile device (1) between two consecutive measurement times t_i and

20 $t_i + T_v$,

- in encoding and transmitting the absolute position information and the successive items of position variation information to the position server (3).

- 25 2. Method according to Claim 1, characterized in that it furthermore consists, on the basis of the pseudo-distance measurements carried out at the successive times t_i and on the basis of the absolute position information at the initial time t_0 , in periodically determining, with a period T_a , items of absolute position of the mobile device (1) information, the

30 period T_a being equal to a multiple, greater than one, of the period T_v .

3. Method according to one of Claims 1 or 2, characterized in that the absolute position information and the position variation information transmitted to the position server (3) by the mobile device (1) are the pseudo-distance measurements acquired by the mobile device (1) and variations of pseudo-distance calculated on board the mobile device (1) respectively, the successive positions of the mobile device (1) being calculated by the position server (3).
4. Method according to one of Claims 1 or 2, characterized in that the absolute position information and the position variation information are respectively triplets of values corresponding to the latitude (lat), longitude (long) and altitude (alt) of the mobile device (1) and variations of latitude (δlat), of longitude (δlong) and of altitude (δalt) of the mobile device (1).
5. Method according to Claim 4, characterized in that the absolute position and the position variation items of information are real numbers comprising a number of successive significant figures of variable importance, and in that it furthermore consists, for each item of information, in selecting the significant figures according to an estimation of their degree of importance and in transmitting a reduced number of significant figures to the position server (3), the figures estimated to be of least importance being eliminated.
6. Method according to Claim 4, characterized in that the absolute position information and the position variation information are real numbers comprising a number of successive significant figures of variable importance, and in that it furthermore consists, for each item of information, in selecting the significant figures according to an estimation of their degree of importance and in encoding and then transmitting all of the significant figures, the figures estimated to be of least importance being encoded using a number of bits lower than the

number of bits used for the figures having a higher degree of importance.

- 5 7. Method according to one of Claims 1 or 2, characterized in that it consists in furthermore transmitting an identifier of a road segment on which the mobile device (1) is located and in that the absolute position and position variation items of information are curvilinear abscissas and curvilinear abscissa variations respectively of the mobile device (1) on the road segment.
- 10 8. Method according to Claim 7, characterized in that the road segment identifier is obtained from a vector cartographic database.
- 15 9. Method according to Claim 7, characterized in that the curvilinear abscissas and the curvilinear abscissa variations are calculated and encoded on board the mobile device (1) with a binary code provided by a Huffman table stored in a vector cartographic database or provided by the position server (3).
- 20 10. Method according to any one of the preceding claims, characterized in that the transmission of the position and position variation items of information is carried out progressively, as they are acquired, by a cellular network mobile communication system.
- 25 11. Method according to any one of Claims 1 to 9, characterized in that the position and position variation items of information are stored in an on-board memory (8) of the mobile device (1) and transmitted globally when the mobile device (1) passes close to a terrestrial relay provided with a radio-communication system.