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(54) **ROAD TOLL SYSTEM, ON-BOARD UNIT AND METHOD FOR OPERATING AN ON-BOARD UNIT**

(57) An on-board unit (2) is configured to determine its position on a map based on signals received from a satellite system (1) when the on-board unit (2) is in an operating mode. The map designates at least tolling zones (5) and/or non-tolling zones (6). The on-board unit (2) remains in the operating mode when it is detected that the on-board unit (2) is in a tolling zone (5). The shortest distance to the closest tolling zone entry and/or the estimated time needed to arrive at the closest tolling zone entry is determined when it is detected that the on-board unit (2) is in a non-tolling zone (6). The on-board unit (2) changes from the operating mode into a low power mode when the determined distance is longer than a predefined distance and/or the estimated time is longer than a predefined time, and changes at least partially from the low power mode into the operating mode after a predefined time has elapsed.

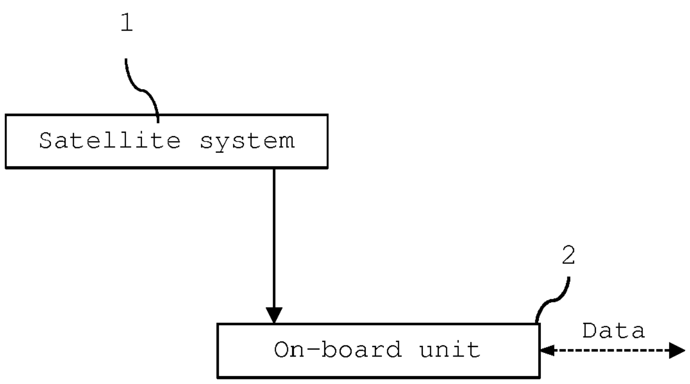

FIG 1

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Description

[0001] The current invention refers to a road toll system, an on-board unit and a method for operating an on-board unit, particularly an on-board unit in a road toll system.

[0002] In many countries all over the world there are toll roads (also known as turnpike or tollway), for which a fee (or toll) is assessed for passage. Different systems for collecting the toll are known. For example, toll booths or toll plazas where the user may pay the toll may be positioned at entry or exit points of the toll road.

[0003] It is, however, often annoying for the driver to stop at a toll booth, especially when there is a lot of traffic and the waiting time is long. Therefore, electronic road toll systems are known. In electronic road toll systems a unit (so called on-board unit) which may be a GNSS unit (GNSS = Global Navigation Satellite System) is installed in the vehicle. A GNSS unit is a satellite navigation system which allows to determine the position of the vehicle. Satellite navigation systems use a version of triangulation to locate a user through calculations involving information from a number of satellites. Known GNSS systems are GPS (Global Positioning System) or Galileo, for example. An electronic road toll system is known from publication US 2010/0060484 A1, for example.

[0004] While the vehicle is on a toll road (or in a tolling zone), the on-board unit acquires data concerning the vehicle position. The data is processed and stored within the on-board unit and/or transmitted for billing via a data channel.

[0005] When the vehicle leaves a toll road the on-board unit still acquires data concerning the vehicle position, in order to verify that the vehicle is on non-toll roads (or in a non-tolling zone). This data, however, is only used to determine the current position and is discarded afterwards, until the vehicle again enters a toll road.

[0006] As the on-board unit is always in use, irrespective of the vehicle being on a toll road or not, its power efficiency is low and the lifetime of the on-board unit's components may be reduced. If a battery is used to power the on-board unit's components, battery lifetime is short.

[0007] The problem to be solved by the current invention is therefore to provide a road toll system, an on-board unit and a method for operating an on-board unit in a road toll system which overcome the above-mentioned disadvantages.

[0008] This problem is solved by an on-board unit according to claim 1, a method according to claim 10 and a road toll system according to claim 11. Configurations and further developments of the invention are subject of the dependent claims.

[0009] An on-board unit is configured to determine its position on a map based on signals received from a satellite system when the on-board unit is in an operating mode, the map designating tolling zones and/or non-tolling zones. The on-board unit remains in the operating mode when it is detected that the on-board unit is in a tolling zone and it determines the shortest distance to the closest tolling zone entry and/or the estimated time needed to arrive at the closest tolling zone entry when it is detected that the on-board unit is in a non-tolling zone. The on-board unit changes from the operating mode into a low power mode when the determined distance is longer than a predefined distance and/or the estimated time is longer than a predefined time, and it changes at least partially from the low power mode into the operating mode after a predefined time has elapsed.

[0010] In this way, power may be saved when the on-board unit is in the low power mode. Further, the lifetime of the components of the on-board unit may be increased.

[0011] The shortest distance may be an air-line distance or a distance determined based on existing roads, for example. If the map only designates tolling zones, no information about existing non-toll roads may be available. If information about non-toll roads is included in the map, a distance that is determined based on existing roads may be more accurate.

[0012] The satellite system may comprise at least four satellites and the on-board unit may further be configured to receive signals of at least four satellites of the satellite system at the same time when the on-board unit is in an operating mode, each of the signals comprising information about the time of transmission and/or the position of the respective satellite at the time of transmission. The on-board unit may determine its position when it receives the signals of at least four satellites at the same time. A computation of the position may be based on the position of each satellite.

[0013] The predefined time may correspond to the estimated time needed to arrive at the closest tolling zone entry, so that the probability that the on-board unit wakes up when it is still in a non-tolling zone is high. It may be avoided that the on-board unit travels undetected in a tolling zone for a long time.

[0014] The on-board unit may be installed in a vehicle to detect if the vehicle is driving on a toll road or a non-toll road. The on-board unit may be put in a low power mode when the vehicle is driving on non-toll roads. Especially within vehicles, it's crucial to reduce the power consumption of the components.

[0015] The on-board unit may comprise a processor configured to determine the position of the on-board-unit. The processor may change from the low power mode into the operating mode after a predefined time has elapsed. The on-board unit may comprise further components that are not needed to determine the position of the on-board unit. Such components may be kept in the low power mode while the processor determines the position to save even more power. Other components may change from the low power mode to the operating mode only when the processor detects that the on-board unit is going to enter a tolling zone or is already in a tolling zone.

[0016] The on-board unit may further comprise a memory configured to store at least one map designating tolling zones and/or non-tolling zones. Information concerning the tolling zones and/or non-tolling zones on the map may then be easily updated. The memory may further be configured to store data representing the position of the on-board unit when the on-board unit is in the operating mode. The data may then be stored for a certain time before it is read out. It is not always possible to read out data in real time.

[0017] A method for operating an on-board unit comprises determining the position of the on-board unit on a map based on signals received from a satellite system when the on-board unit is in an operating mode, the map designating tolling zones and/or non-tolling zones. The method further comprises keeping the on-board unit in the operating mode when the on-board unit is detected in a tolling zone, and determining the shortest distance to the closest tolling zone entry and/or the estimated time needed to arrive at the closest tolling zone entry when the on-board unit is detected to be in a non-tolling zone. The on-board unit is transferred from the operating mode into a low power mode, when the determined distance is longer than a predefined distance and/or the estimated time is longer than a predefined time and is transferred at least partially from the low power mode into the operating mode after a predefined time has elapsed.

[0018] A road toll system comprises a satellite system and an on-board unit. The on-board unit is configured to receive signals from the satellite system and determine its own position based on these signals within a map when the on-board unit is in an operating mode, the map designating tolling zones and/or non-tolling zones. The on-board unit remains in the operating mode when it is detected that the on-board unit is in a tolling zone. The shortest distance to the closest tolling zone entry and/or the estimated time needed to arrive at the closest tolling zone entry is estimated when it is detected that the on-board unit is in a non-tolling zone. The on-board unit changes from the operating mode into a low power mode when the determined distance is longer than a predefined distance and/or the estimated time is longer than a predefined time and changes at least partially from the low power mode into the operating mode after a predefined time has elapsed.

[0019] The satellite system may comprise at least four satellites, wherein each satellite is configured to transmit signals, the signals comprising information about the time of transmission and/or the position of the respective satellite at the time of transmission. The on-board unit may be configured to receive signals of at least four satellites of the satellite system at the same time when the on-board unit is in an operating mode and determine its own position based on these signals. The position may usually only be detected when at least four signals of different satellites are received at the same time. If the on-board unit receives less than four signals at the same time, a determination of its position is usually not possible.

[0020] Examples are now explained with reference to the drawings. In the drawings the same reference characters denote like features.

Figure 1 illustrates in a block diagram an example of a road toll system according to the present invention,

Figure 2 illustrates in a block diagram a further example of a road toll system according to the present invention,

Figure 3 illustrates in a block diagram a further example of a road toll system according to the present invention,

Figure 4 illustrates in a block diagram a further example of a road toll system according to the present invention,

Figure 5 schematically illustrates a road network including toll roads and non-toll roads,

Figure 6 illustrates in a flow chart an example of a method for operating an on-board unit according to the present invention, and

Figure 7 illustrates in a flow chart a further example of a method for operating an on-board unit according to the present invention.

[0021] Figure 1 illustrates a road toll system including a satellite system 1 and an on-board unit 2. The on-board unit 2 may be installed in a vehicle, for example. The satellite system 1 may be a global navigation network system, for example, and may include at least four satellites (not shown). The satellites are configured to continually transmit signals, the signals including the time of transmission and the position of the respective satellite at the time of transmission. When the on-board unit 2 receives the signals of at least four satellites at the same time, it may determine its own position. Data representing the position of the on-board unit 2 may then be linked to vehicle specific data (e.g. vehicle type). Such data may then be further processed and transmitted for billing. Billing may be based on a distance travelled, the time spent in a tolling zone, the location of the on-board unit 2 within the tolling zone and vehicle characteristics, for example. The on-board unit 2 may cyclically check if its current position is within a tolling zone or not.

[0022] The on-board unit 2 may include a processor 21. The processor 21 may receive signals transmitted from the satellites of the satellite system 1. The processor 21 may further process these signals, determine the position of the on-board unit 2 and may store data relating to the position of the on-board unit 2. A map or a plurality of maps may be stored in the processor 21, for example. A map in this context may be a complex and accurate map, including features of a certain area as well as information about tolling zones (e.g. size, position, etc.)

and/or non-tolling zones in this area. It may, however, also be a simple map, which only gives basic information about the location of control points and/or borders of tolling zones in a certain area, but no or only few features of the area. When the position of the on-board unit 2 is determined, the position may be matched with the map(s). In this way it may be determined, whether the on-board unit 2 is in a tolling zone or a non-tolling zone. If the map only designates information about tolling zones in a certain area, it may be assumed that the on-board unit 2 is in a non-tolling zone when it is detected that the on-board unit 2 is not in a tolling zone.

[0023] If it is detected that the on-board unit 2 is in a non-tolling zone, the data concerning the position of the on-board unit 2 may be discarded, as no billing is required. It is not necessary to store data in this case, which saves memory space. If it is detected that the on-board unit 2 is in a tolling zone, the processor 21 may store and further process the data. The data may also be transmitted for further billing. For this, the on-board unit 2 may be coupled to a mobile communication network 3. The data may be transmitted to the mobile communication network 3 via a wireless data channel, for example. In this case, it is not required that the vehicle in which the on-board unit 2 is installed, return to a billing station to read out the data. The on-board unit 2 may include a mobile communication network module 23. The mobile communication network module 23 may transmit data to the mobile communication network 3 whenever a data connection is available. This is, however, only an example. Data may also be read out via any other wireless or wired connection. The data may be transmitted to any suitable read-out device. From the read-out device (mobile communication network 3 in Figure 2) the data may be transmitted to a back office 4 for billing.

[0024] The data may be transmitted in regular intervals. For example, the data may be transmitted at the end of each day. This is, however, only an example. Data may also be transmitted more or less regularly. In some cases the memory within the processor 21 may not have enough capacity to store all data that needs to be stored. Therefore, the on-board unit 2 may include an extended memory 22. This extended memory 22 is, however, optional.

[0025] The processor 21 may include a receiver 211 in order to receive signals from the satellite system 1, as is shown in Figure 3. The processor 21 may further include a memory 213. In the memory 213, the maps with information on tolling zones and/or non-tolling zones may be stored, for example. A tolling zone may be defined as a map of positioning coordinates or as a collection of control points, for example. A processing unit 212 may process the received signals and, based on the maps and further information, determine whether the on-board unit 2 is in a tolling zone or not. Processed data may then be stored in the memory 213. It is, however, also possible that receiver 211 and memory 213 are not integrated in the processor 21. The receiver 211 and the memory 213 may also be external devices of the processor 21, as is shown in Figure 4.

[0026] In known on-board units 2, most or all of the components are in an operating state whenever the ignition of the vehicle in which the on-board unit 2 is installed is switched on. The power consumption of the on-board unit 2 is therefore relatively high. According to the present invention, the on-board unit 2 is transferred into a low power mode in order to reduce the power consumption if certain conditions arise. If the vehicle is in a non-tolling zone, no data needs to be stored as no billing is required. The on-board unit 2 only receives signals from the satellite system 1, confirms that the on-board unit 2 is still in a non-tolling zone and then discards the data.

[0027] Figure 5 schematically illustrates an example of a road system (map) including toll roads (tolling zones) 5 and non-toll roads (non-tolling zones) 6. In general, there are more non-toll roads 6 than toll roads 5. A vehicle may therefore drive on non-toll roads 6 for a great amount of time. According to the present invention, the on-board unit 2 may be transferred into a low power mode when it is determined that the on-board unit 2 is in a non-tolling zone 6. When the on-board unit 2 leaves a tolling zone 5, the shortest distance to the closest tolling zone entry is determined. Further, the time required to reach that closest tolling zone entry may be determined. This time may be calculated based on the distance to the closest tolling zone and a maximum theoretical speed of the vehicle. The on-board unit 2 may then be put into a low power mode for a time that corresponds to the determined time. A timer 24 may be set to wake up the on-board unit 2 after the determined time has elapsed. The timer 24 is integrated in the on-board unit 2 and may be an external component of the processor 21, as is shown in Figure 3. This is, however, only an example. The timer 24 may also be integrated in the processor 21.

[0028] The shortest distance to the closest tolling zone entry may be determined based on information about existing non-toll roads 6, for example, if such information is included in the map. If the map only includes information about tolling zones (e.g. position of entries, size of tolling zone, etc.) the shortest distance may as well be an air-line distance and existing roads may be disregarded.

[0029] In general, when a vehicle exits a tolling zone 5, the closest entry is at the same location at which the vehicle just left the tolling zone 5. The time that would be needed to get to this closest entry would therefore be relatively short. It may not be advantageous to transfer the on-board unit 2 into a low power mode for only a very short time. Therefore, the on-board unit 2 may be transferred to the low power mode only when the distance to the closest entry and/or the time needed to get there is longer than a predefined value.

[0030] When the on-board unit 2 is transferred into the low power mode, a timer may be set in order to wake up the on-board unit 2 after a certain time has elapsed. The time set by the timer may correspond to the time that is needed to get to the closest entry. In this way it may be ascertained that the on-board unit 2 wakes up before it enters a tolling zone 5 again. When the on-board unit 2 changes from the low power mode back to the operating mode, it again determines its position. If it is close to or in a tolling zone, it stays in the operating mode and processes the data as has been explained above. If it is still in a non-tolling zone, it again determines the distance and time needed to reach the closest entry. If the distance to the closest entry is longer than a predefined distance or the time needed to get to the closest entry is longer than a predefined time, the on-board unit 2 may be transferred into the low power mode again for a predefined time.

[0031] Referring to Figure 5, the on-board unit 2 may first be in a tolling zone 5 at a position A, travelling along the road. As long as it is detected to be in the tolling zone 5, the data concerning the on-board unit's 2 position are matched with the maps stored in the on-board unit 2 and data is stored in the on-board unit 2. When the on-board unit 2 is detected at position B, for example, it is outside the tolling zone. It therefore determines the distance (time) to the closest tolling zone entry. Initially, this is still the entry located at position B, for example. The distance (time) might at first be too short in order to transfer the on-board unit 2 to the low power mode. As the on-board unit 2 moves along the non-toll road 6, the distance to position B becomes greater. When it reaches position B', the entry at position C may be the closest entry. As has been explained before, the distance may be an air-line distance x or a distance y on existing roads, for example. If the distance (time) is great enough, the on-board unit 2 is transferred to the low power mode. The timer is set to the time that is assumed to be needed to reach position C. The on-board unit 2 will then wake up after this preset time.

[0032] If, at wake up, the on-board unit 2 is detected at position C, it is close to the entry of the tolling zone 5. It will then stay in the operating mode. If, at wake up, the on-board unit 2 is detected at position C', it is still in the non-tolling zone 6. It may therefore determine which is the closest entry (which may be the entry at position D) as well as the distance (time) to this closest entry. The on-board unit 2 may return to the low power mode if the distance (time) is greater than a predefined value.

[0033] The method is further illustrated by means of Figure 6. In a first step, the on-board unit 2 is in an operating mode (step 601). It may then be determined whether the on-board unit 2 is in a tolling zone (step 602). If it is detected to be in a tolling zone, the on-board unit 2 may remain in the operating mode. If the on-board unit 2 is not detected to be in a tolling zone, the distance and time to the closest tolling point (closest entry to a tolling zone) may be determined (step 603) . It may then be checked whether the distance (time) is greater than a predefined value (step 604). If the distance is less than a predefined distance and/or the time is less than a predetermined time, the on-board unit 2 remains in the operating mode. If the distance is equal or greater than a predefined distance and/or the time is equal or greater than a predetermined time, the on-board unit 2 may change to the low power mode (step 605). The on-board unit 2 may wake up from the low power mode after a preset wake-up time (step 606). The on-board unit 2 then returns to step 602, determines its position and whether it is in a tolling zone or not.

[0034] When the on-board unit 2 wakes up from the low power mode all modules within the on-board unit 2 may be powered again. It is, however, also possible that in a first step not all modules are powered. Initially it is possible to power only those modules in the on-board unit 2 that are needed to determine the position. This is illustrated in Figure 7. In step 706 only those modules of the on-board unit 2 return from low power mode that are needed to determine the position. Only when the on-board unit 2 is detected in a tolling zone, does the whole unit 2 return to operating mode. In this way even more energy may be saved.

Claims

1. On-board unit (2) configured to
determine its position on a map based on signals received from a satellite system (1) when the on-board unit (2) is in an operating mode, the map at least designating tolling zones (5) and/or non-tolling zones (6);
remain in the operating mode when it is detected that the on-board unit (2) is in a tolling zone (5);
determine the shortest distance to the closest tolling zone entry and/or the estimated time needed to arrive at the closest tolling zone entry when it is detected that the on-board unit (2) is in a non-tolling zone (6);
change from the operating mode into a low power mode when the determined distance is longer than a predefined distance and/or the estimated time is longer than a predefined time; and
change at least partially from the low power mode into the operating mode after a predefined time has elapsed.

2. On-board unit (2) according to claim 1, wherein the shortest distance is an air-line distance (x) or a distance (y) determined based on existing roads.

3. On-board unit (2) according to claim 1 or 2, wherein the satellite system (2) comprises at least four satellites and the on-board unit (2) is further configured to receive signals of at least four satellites of the satellite system (1) at the same time when the on-board unit (2) is in an operating mode, each of the signals comprising information about the time of transmission and/or the position of the respective satellite at the time of transmission.

4. On-board unit (2) according to one of claims 1 to 3, wherein the predefined time corresponds to the estimated time needed to arrive at the closest tolling zone entry.

5. On-board unit (2) according to one of claims 1 to 4, wherein the on-board unit (2) is installed in a vehicle.

6. On-board unit (2) according to one of the preceding claims, comprising a processor (21) configured to determine the position of the on-board-unit (2).

7. On-board unit (2) according to claim 6, wherein the processor (21) changes from the low power mode into the operating mode after a predefined time has elapsed.

8. On-board unit (2) according to one of the preceding claims, further comprising a memory (213) configured to store at least one map designating tolling zones and/or non-tolling zones.

9. On-board unit (2) according to claim 8, wherein the memory (213) is further configured to store data representing the position of the on-board unit (2) when the on-board unit (2) is in the operating mode.

10. Method for operating an on-board unit (2), the method comprises:

determining the position of the on-board unit (2) on a map based on signals received from a satellite system (1) when the on-board unit (2) is in an operating mode, the map at least designating tolling zones (5) and/or non-tolling zones (6);
keeping the on-board unit (2) in the operating mode, when the on-board unit (2) is detected in a tolling zone (5);
determining the shortest distance to the closest tolling zone entry and/or the estimated time needed to arrive at the closest tolling zone entry, when the on-board unit (2) is detected to be in a non-tolling zone (6);
transfer the on-board unit (2) from the operating mode into a low power mode when the determined distance is longer than a predefined distance and/or the estimated time is longer than a predefined time; and
transfer the on-board unit (2) at least partially from the low power mode into the operating mode after a predefined time has elapsed.

11. Road toll system comprising:

a satellite system (1); and
an on-board unit (2) configured to receive signals from the satellite system (1) and determine its own position based on these signals on a map when the on-board unit (2) is in an operating mode, the map at least comprising tolling zones (5) and/or non-tolling zones (6);
remain in the operating mode when it is detected that the on-board unit (2) is in a tolling zone (5);
determine the shortest distance to the closest tolling zone entry and/or the estimated time needed to arrive at the closest tolling zone entry when it is detected that the on-board unit (2) is in a non-tolling zone (6);
change from the operating mode into a low power mode when the determined distance is longer than a predefined distance and/or the estimated time is longer than a predefined time; and
change at least partially from the low power mode into the operating mode after a predefined time has elapsed.

12. Road toll system according to claim 11, wherein the satellite system (1) comprises at least four satellites, wherein each satellite is configured to transmit signals, the signals comprising information about the time of transmission and/or the position of the respective satellite at the time of transmission.

13. Road toll system according to claim 12, wherein the on-board unit (2) is configured to receive signals of at least four satellites of the satellite system (1) at the same time when the on-board unit (2) is in an operating mode and determine its own position based on these signals.

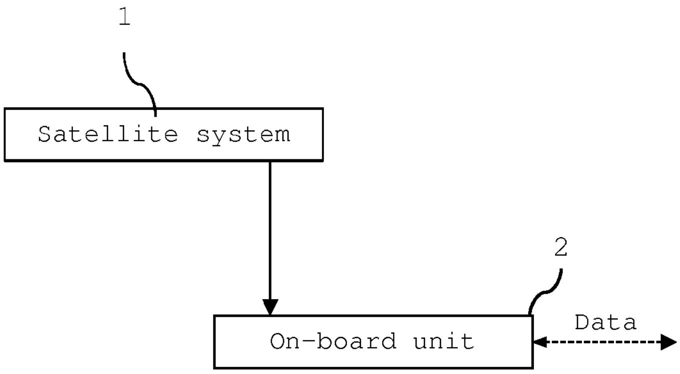
1
Satellite system
2
On-board unit
Data

FIG 1

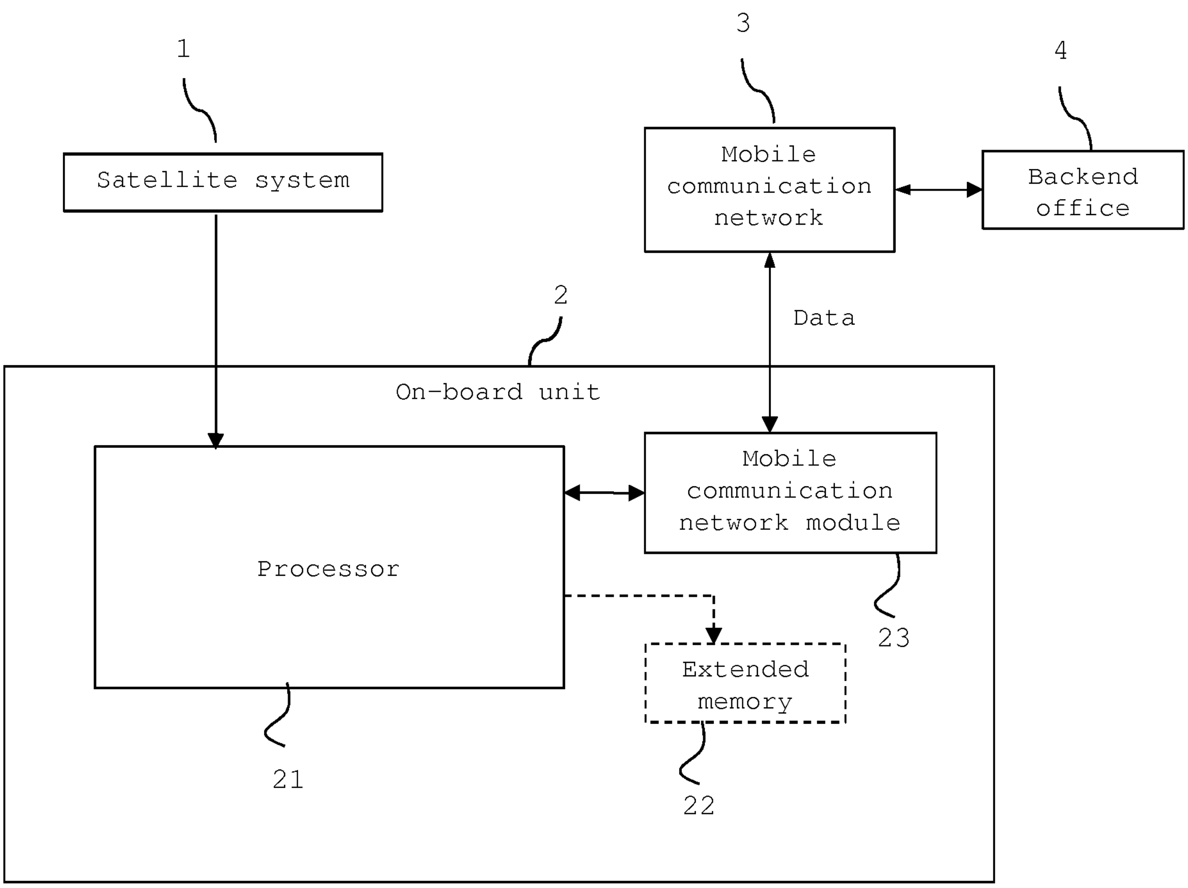
1
Satellite system
3
Mobile communication network
4
Backend office
2
Data
On-board unit
Processor
Mobile communication network module
Extended memory
21
22
23

FIG 2

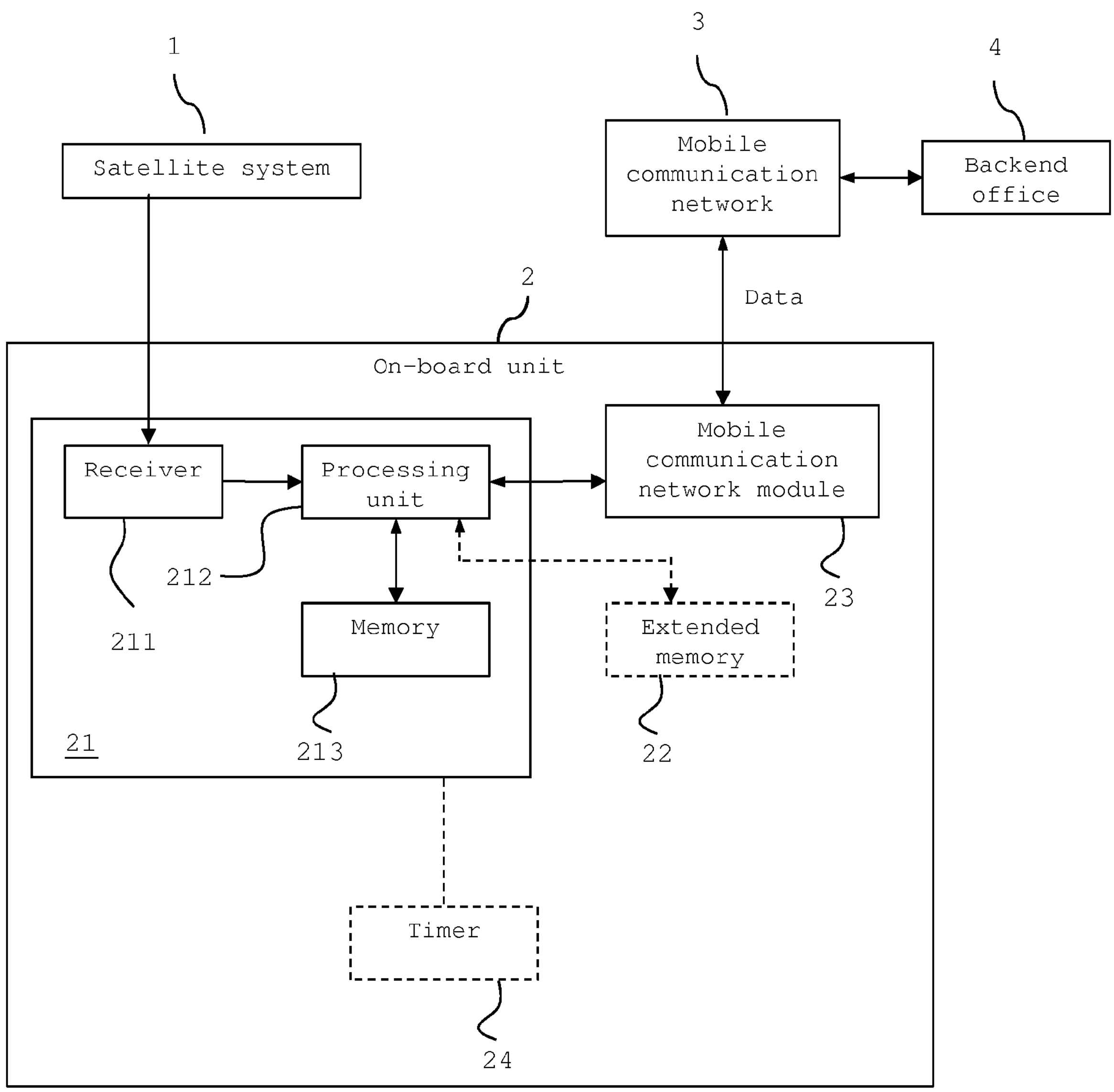
1
3
4
Satellite system
Mobile communication network
Backend office
2
Data
On-board unit
Receiver
Processing unit
Mobile communication network module
212
211
Memory
Extended memory
23
21
213
22
Timer
24

FIG 3

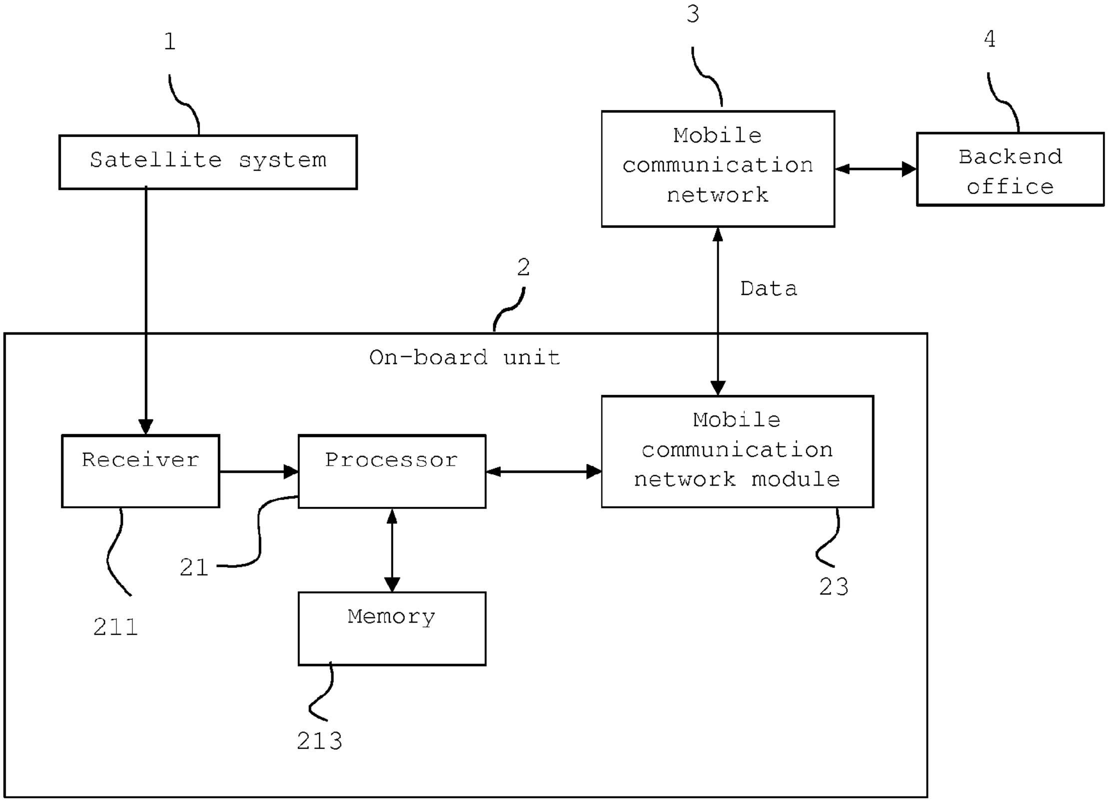
1
Satellite system
3
Mobile communication network
4
Backend office
2
Data
On-board unit
Receiver
Processor
Mobile communication network module
21
211
Memory
23
213

FIG 4

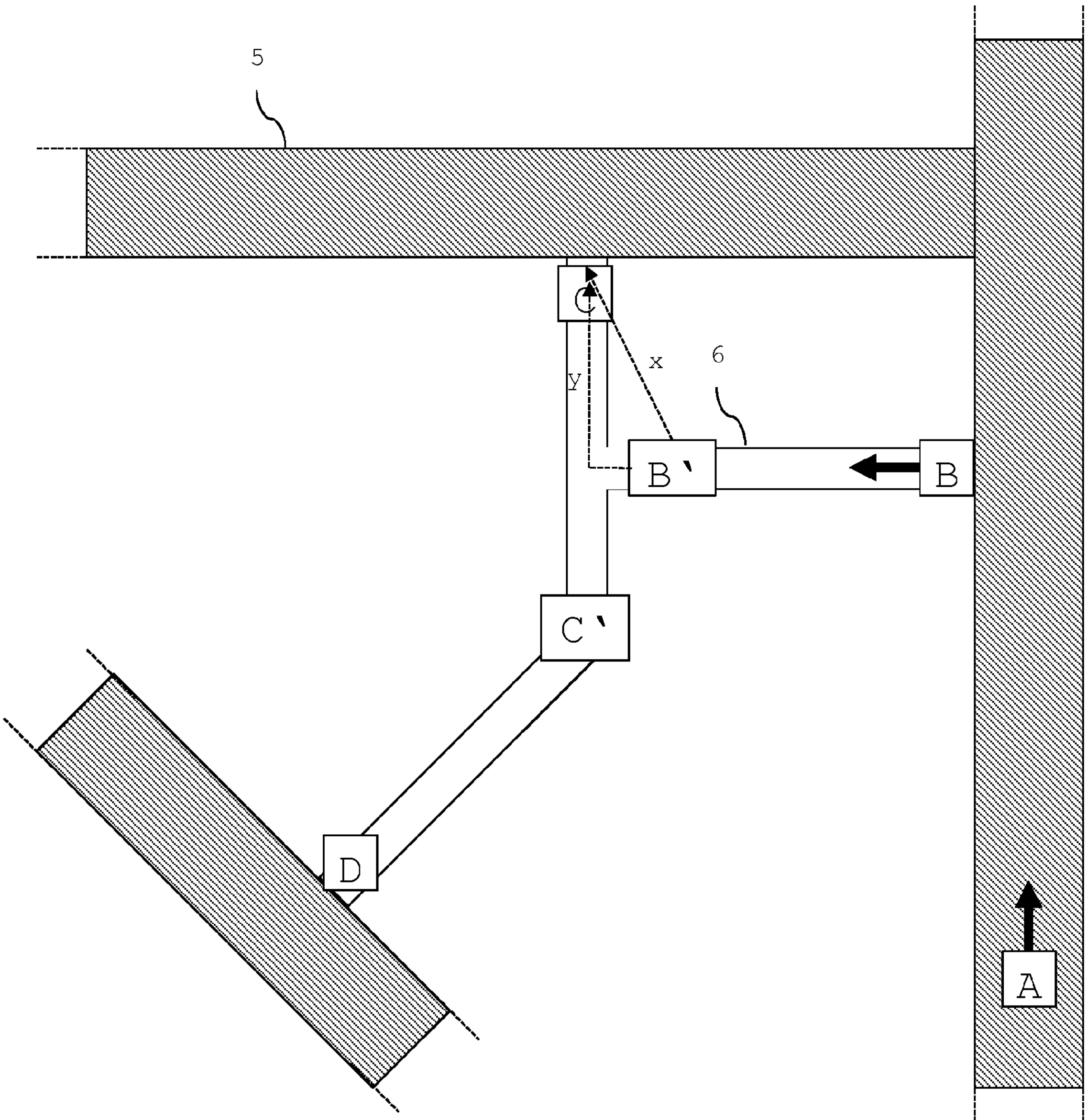

FIG 5

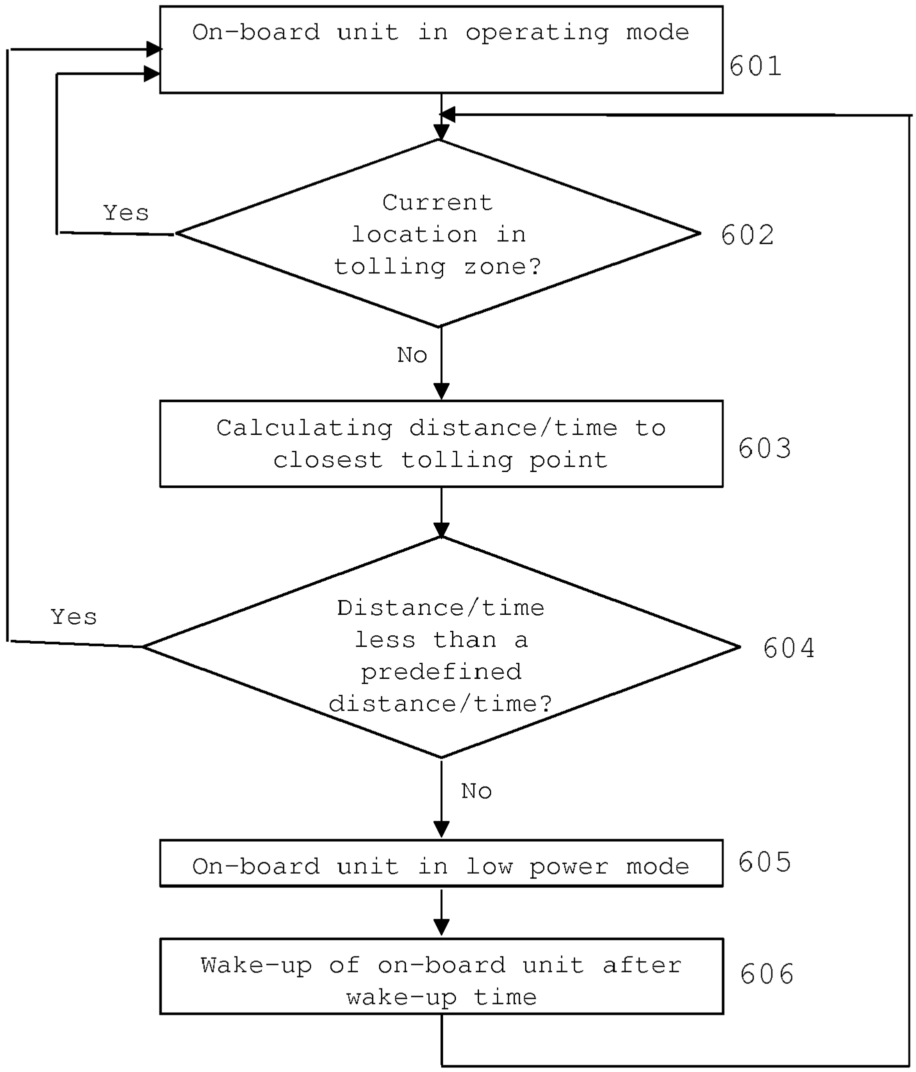
On-board unit in operating mode
601
Current location in tolling zone?
602
Yes
No
Calculating distance/time to closest tolling point
603
Distance/time less than a predefined distance/time?
604
Yes
No
On-board unit in low power mode
605
Wake-up of on-board unit after wake-up time
606

FIG 6

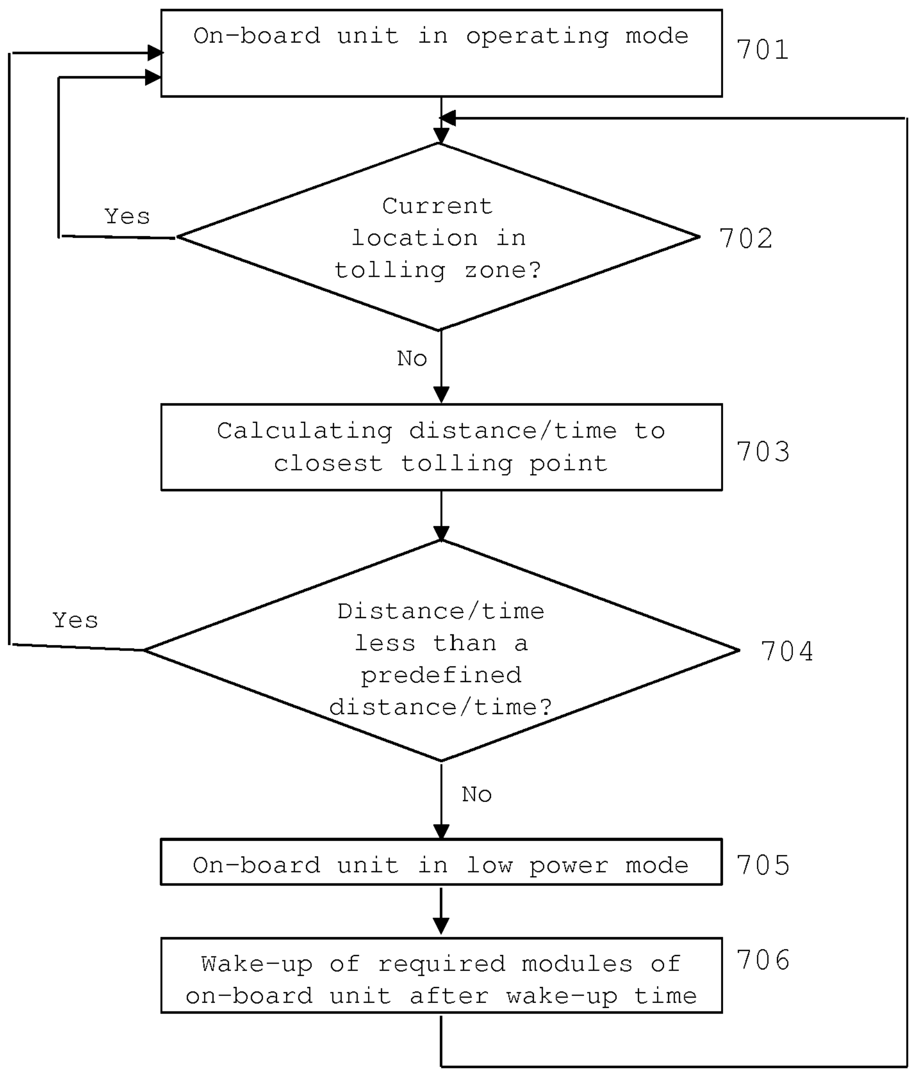
On-board unit in operating mode
701
Yes
Current location in tolling zone?
702
No
Calculating distance/time to closest tolling point
703
Yes
Distance/time less than a predefined distance/time?
704
No
On-board unit in low power mode
705
Wake-up of required modules of on-board unit after wake-up time
706

FIG 7

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EUROPEAN SEARCH REPORT

Application Number
EP 15 46 5510

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	EP 2 230 644 A1 (CS SYSTEMES D INFORMATIONS [FR]) 22 September 2010 (2010-09-22) * abstract * * paragraph [0005] - paragraph [0007] * * paragraph [0010] * * paragraph [0016] * * paragraph [0021] - paragraph [0033] * * figures * -----	1-13	INV. G07B15/06
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A	EP 1 089 088 A2 (MATSUSHITA ELECTRIC IND CO LTD [JP]) 4 April 2001 (2001-04-04) * paragraph [0037] - paragraph [0038] * * paragraph [0044] - paragraph [0048] * -----	1-13	TECHNICAL FIELDS SEARCHED (IPC)
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The present search report has been drawn up for all claims

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Place of search	Date of completion of the search	Examiner
The Hague	22 September 2015	Van der Haegen, D

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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