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# (54) Title: METHOD AND SYSTEM FOR DETERMINING THE TOLL DUE FOR THE USE OF A ROAD INFRASTRUCTURE

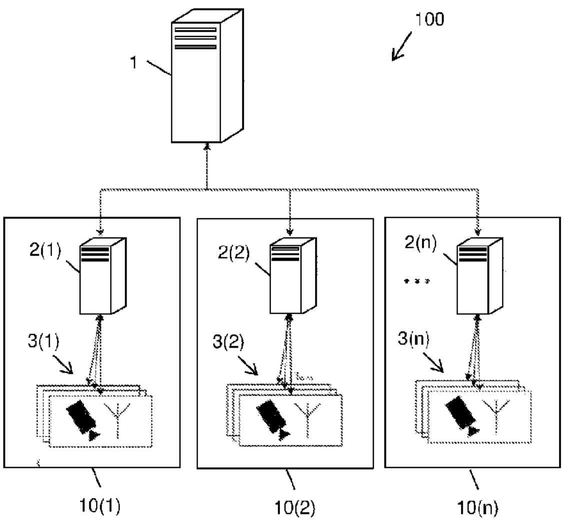


Fig. 1

(57) Abstract: A system and a method are disclosed for determining the toll due for the use of a road infrastructure by a vehicle. The system comprises a plurality of detection stations located along the road infrastructure, and a corresponding plurality of mutually connected peripheral servers. Each station is assigned to a respective peripheral server. Upon transit of the vehicle at a first detection station, this generates first transit data and dispatches them to the peripheral servers to which the detection stations located in positions following the first station are assigned. In case of transit of the vehicle at any of such positions, the corresponding station generates second transit data and forwards them to the peripheral server to which it is assigned. Upon receiving the second transit data, the latter associates it with the first transit data previously received and determines the toll due based on the first transit data and the second transit data.

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# METHOD AND SYSTEM FOR DETERMINING THE TOLL DUE FOR THE USE OF A ROAD INFRASTRUCTURE

## Technical field

The present invention relates, in general, to the field of methods and systems for the control of traffic. In particular, the present invention relates to a method and a system for determining a toll due for use of a road infrastructure by a vehicle.

## Background art

As is known, the toll consists of a payment made to an operator (public or private) for a travel over a road infrastructure, such as for example a highway or freeway, a bridge, a tunnel, etc..

The toll may be a fixed charge or may depend on the section of road infrastructure which has effectively been travelled (as in the case of freeways), or on the time spent on the infrastructure (as in the case of payment areas), or on the time at which the section of infrastructure has been travelled. In the case of a fixed charge, it suffices to record data relating to a single transit of the vehicle, for example its transit through the toll gate of the toll road infrastructure. In the case of a charge depending on the travelled section, on the time spent or on the time of travel, it is on the other hand necessary to record and to correlate with one another data relating to more transits, i.e. the transit through the entry gate, the transit through the exit gate and possibly also one or more transits through intermediate gates, if between entry gate and exit gate more alternative routes are present, for which different tolls are due.

Systems are known for determining the toll due which make use of an onboard device (OBU) located on board the vehicle, which has its own associated unique identifier OBU-id. The OBU is provided with a radiofrequency transceiver (DSRC, RFID or UHF) which, during the transit through the gate, communicates with a corresponding road side device which identifies its unique identifier. The data of the transit through the entry gate (date, time and identifier of the entry gate, toll class of the vehicle) are recorded in the same OBU which, at the time of the transit through the exit gate, transmits them to the ground device. This can thus determine the toll due and send the relevant toll payment request, typically to a provider of an electronic tolling service.

WO 2017/153823 describes a system for making a payment for access by a vehicle to a payment area, which comprises a central server in which, during an initial registration phase, the license plate number of the vehicle is stored. Near a toll gate of the payment area, a remote camera is provided which acquires one or more images of the vehicle, when the latter transits through the gate. The images are thus processed in order to identify therein the license plate number of the vehicle in transit. Once the license plate number has been received or identified, the central server verifies whether it is present in its list of users. In the affirmative, the central server determines the toll, by possibly correlating the transit with other transits of the same vehicle identified in the license number database, if the toll depends on the section travelled.

EP 1 354 306 describes an electronic tolling system comprising detection stations connected to a sub-system for processing the transit data (toll processing subsystem TTP) comprising a plurality of processors which process the transit data collected from the detection stations.

## Summary of the invention

These known systems exhibit some drawbacks.

With regard to systems that make use of radiofrequency OBU, an OBU is generally capable of storing only the data relating to its transit through the entry gate, which are then correlated with the data relating to its transit through the exit gate for the determination of the toll due, or at the most a very limited number of intermediate transits. Such systems do not therefore allow the determination of the toll due in the case where, between entry gate and exit gate, more alternative routes are present for which different charges are due.

With regard to the system described by WO 2017/153823 based on the automatic reading of the license plate number of the vehicle, this does not allow a determination of the toll due in real time, in the case where this depends on the section traveled. This is because the operation for correlation of the data relating to various transits of a same vehicle through the entry gate, the exit gate, and possible intermediate gates, is carried out by the central server, to which all the transit data recorded at the various gates of the road network are provided. The central server, depending on the computational resources that are at its disposal and on the amount of transit data that need to be processed, will thus take a certain time to correlate the various transits with one another. This does not allow the toll to be determined – and thus the payment for it to be requested and the debit of it to be notified - in real time.

Similar considerations are also valid for the system described by EP 1 354 306.

In light of the above, an object of the present invention is to provide a method and a system for determining the toll due for the use of a road infrastructure by a vehicle which solves the aforementioned drawbacks.

In particular, an object of the present invention is to provide a method and a system for determining a toll due for use of a road infrastructure by a vehicle, which allows the various transits of the vehicle to be correlated with one another substantially in real time, so as to allow the determination of the toll due substantially in real time, also in the event that the determination of the toll due requires the correlation of data relating to various transits of the vehicle.

According to embodiments of the present invention, these objects are achieved by a system for determining a toll due for use of a road infrastructure by a vehicle. The system comprises a plurality of detection stations located along the road infrastructure (at its entries, its exits and also at possible intermediate points) and a corresponding plurality of mutually connected peripheral servers; each one of the detection stations is assigned to a respective peripheral server, where “assigned” means that it is directly connected to it, and it is also typically co-located with it, so that when the detection station detects a transit and generates corresponding transit data, the peripheral server to which it is assigned receives and automatically stores the transit data in real time. When the vehicle transits at a first detection station, the latter generates first transit data and forwards them to the peripheral servers to which the detection stations located in positions following the first station along the road infrastructure in the travel direction of the vehicle are assigned. When the vehicle transits at any of such following positions, the corresponding detection station generates second transit data. The peripheral server to which this second station is assigned associates the second transit data with the first transit data previously received and, based on the mutually associated first transit data and second transit data, determines the toll due.

Advantageously, the system according to embodiments of the present invention allows the determination of the toll due substantially in real time, also when the toll due requires the correlation of data relating to various transits of the vehicle (for example, when the toll due depends on the section traveled or on the travel duration). When the first transit takes place, indeed, the relevant transit data are dispatched substantially in real time to the peripheral servers to which the detection stations located in the following positions in the travel direction of the vehicle along the road infrastructure are assigned. Therefore, when one of these detection stations detects a second transit of the vehicle and generates the associated transit data, the peripheral server to which it is assigned already has all the information needed to determine the toll due in a timely and autonomous way.

According to a first aspect, a system is provided for determining a toll due for use of a road infrastructure by a vehicle, the system comprising a plurality of detection stations located along the road infrastructure, and a corresponding plurality of mutually connected peripheral servers, each one of the detection stations being assigned to a respective peripheral server of the plurality of peripheral servers, wherein:

- a first detection station of the plurality of detection stations is configured to, upon transit of the vehicle, generate first transit data and forward the first transit data to at least one peripheral server from the plurality of peripheral servers to which a second detection station of the plurality of detection stations, located in a position following the first detection station in the travel direction of the vehicle along the road infrastructure, is assigned;
- the second detection station is configured to, in the case of a transit of the vehicle, generate second transit data and forward the second transit data to said at least one peripheral server to which it is assigned; and
- said at least one peripheral server is configured to, upon receiving the second transit data, associate them with the first transit data previously received and determine the toll due based on the first transit data and of the second transit data.

Preferably, the vehicle is associated with a set of detectable identifiers, the set of detectable identifiers being stored at said at least one peripheral server.

Preferably, the first transit data comprise a first identifier of the set of detectable identifiers detected by the first detection station, and the second transit data comprise a second identifier of the set of detectable identifiers detected by the second detection station.

Preferably, the vehicle is further associated with a unique generic identifier uniquely associated with the set of detectable identifiers and generated by a manager of the system.

Preferably, the first transit data forwarded by the first detection station to said at least one peripheral server comprise the unique generic identifier.

Optionally, the first identifier of the set of detectable identifiers detected by the first detection station may be removed from the first transit data forwarded by the first detection station to said at least one peripheral server, after the unique generic identifier has been inserted into first transit data.

Preferably, said at least one peripheral server is configured to associate the second transit data and the first transit data based on the unique generic identifier.

According to a first embodiment, the second detection station is located at an exit gate of the road infrastructure following the first detection station in the travel direction of the vehicle along the road infrastructure.

According to this first embodiment, the at least one peripheral server is configured to also receive third transit data from a third detection station of said plurality of detection stations, located between the first detection station and the exit gate, and to determine the toll due also based on the third transit data.

According to a second embodiment, the second detection station is located at an intermediate point of the road infrastructure following the first detection station in the travel direction of the vehicle along the road infrastructure.

Preferably, the second detection station is located at an intermediate point immediately following the first detection station in the travel direction of the vehicle along the road infrastructure.

Preferably, the at least one peripheral server is configured to forward the second transit data and the toll determined to at least one further peripheral server of the plurality of peripheral servers to which a third detection station of the plurality of detection stations, located at an exit gate or a further intermediate point following the second detection station in the travel direction of the vehicle along the road infrastructure, is assigned.

Preferably, the third detection station is configured to, in case of transit of the vehicle, generate third transit data and forward the third transit data to the at least one further peripheral server; and the at least one further peripheral server is configured to, upon receiving the third transit data, associate it with the second transit data received and update the amount of the toll determined based on the second transit data and the third transit data.

According to a second aspect, a method is provided for determining a toll due for use of a road infrastructure by a vehicle, the method comprising:

- at a first detection station of a plurality of detection stations located along the road infrastructure, upon transit of the vehicle, generating first transit data and forwarding the first transit data to at least one peripheral server of a plurality of mutually connected peripheral servers, each one of the detection stations being assigned to a respective peripheral server of the plurality of peripheral servers, a second detection station of the plurality of detection stations, located in a position following the first detection station in the travel direction of the vehicle the road infrastructure, being assigned to said at least one peripheral server;
- at the second detection station, in the case of a transit of the vehicle, generating second transit data and forwarding the second transit data to said at least one peripheral server; and
- at said at least one peripheral server, upon receiving the second transit

data, associating them with the received first transit data and determining the toll due based on the first transit data and of the second transit data.

According to a third aspect, a roadside device is provided for determining a toll due for use of a road infrastructure by a vehicle, said roadside device being located at a first position of the road infrastructure and comprising a peripheral server and a detection station assigned thereto, wherein:

- the peripheral server is configured to store first transit data received by a further roadside device to which it is connected, the further roadside device being located along the road infrastructure at a second position preceding the first position in the travel direction of said vehicle;
- the detection station is configured to, in case of transit of the vehicle, generate second transit data and forward the second transit data to the peripheral server; and
- the peripheral server is further configured to, upon receiving the second transit data, associate them with the first transit data previously received and determine the toll due based on the first transit data and of the second transit data.

## Brief description of the drawings

The present invention will become clearer from the following detailed description, provided by way of non-limiting example, to be read with reference to the appended drawings, wherein:

- Figure 1 schematically shows a system for determining a toll due for use of a road infrastructure by a vehicle, according to an embodiment of the present invention;
- Figure 2 schematically shows a registry record relating to a vehicle, according to an embodiment of the present invention;
- Figure 3 schematically shows an application scenario of the system

for determining a toll due for use of a road infrastructure by a vehicle, according to a first embodiment of the present invention;

- Figure 4 schematically shows an event record relating to a vehicle, according to an embodiment of the present invention;
- Figure 5 schematically shows an application scenario of the system for determining a toll due for use of a road infrastructure by a vehicle, according to a second embodiment of the present invention; and
- Figure 6 is a flow chart of the operation of a peripheral server, according to embodiments of the present invention.

## Detailed description of embodiments of the invention

Figure 1 schematically shows a system for the detection of transits of a vehicle along a road infrastructure, according to an embodiment of the present invention.

The system 100 preferably comprises a central server 1, a plurality of peripheral servers 2(1), 2(2), ... 2(n) and a corresponding plurality of detection stations 3(1), 3(2), ... 3(n).

The detection stations 3(1), 3(2), ... 3(n) are preferably distributed along the road infrastructure (for example, a freeway network), in particular at its entry gates, exit gates and, possibly, also at intermediate positions of the road infrastructure, which do not correspond either to entry gates or to exit gates. In case of intermediate detection stations, these are preferably distributed along the road infrastructure at a certain mutual distance, which depends on the granularity needed to determine the charge due, in case it depends on the travelled route and/or on the travel duration and/or the time of the travel. The detection stations 3(1), 3(2), ... 3(n) may be implemented as barriers or as gates of the 'free-flow' type.

Each detection station 3(1), 3(2), ... 3(n) is configured to detect the transit of vehicles at the gate or intermediate position at which it is located. For this purpose, each detection station 3(1), 3(2), ... 3(n) is provided with sensors that, for each vehicle in transit, detect at least one of its identifiers. These sensors may for example comprise cameras for the automatic detection of the license plate number and/or road-side radiofrequency devices for the detection of the OBU-id (for example by means of DSRC or CEN/TC 278 technology). If more lanes are present, the detection station 3(1), 3(2), ... 3(n) comprises, for each lane, a respective set of sensors for the detection of the identifier of the vehicles in transit along that lane, as schematically shown in Figure 1.

The detectable identifier may be the same for all the detection stations 3(1), 3(2), ... 3(n) (for example, the license plate number, or the OBU-id, or a *fingerprint* of the vehicle), or the detection stations 3(1), 3(2), ... 3(n) may be equipped with sensors that, for a given vehicle in transit, detect different identifiers thereof. For example, some detection stations may be equipped with sensors that detect the OBU-id of the OBU on board the vehicle, other detection stations may be equipped with sensors that detect the license plate number of the vehicle, while other detection stations may be equipped with sensors that detect the *fingerprint* of the vehicle (for example, its shape and its color). Each detection station 3(1), 3(2), ... 3(n) may be equipped with sensors for the detection of a single identifier of each vehicle in transit, or with sensors for the simultaneous detection of more identifiers of each vehicle in transit (for example, both license plate number and OBU-id).

Each detection station 3(1), 3(2), ... 3(n) is further preferably provided with a sensor (for example an induction coil and/or a laser detector) that detects the physical passage of each vehicle in transit and, in response to this, activates the sensors that detect the identifier or identifiers of the vehicle in transit.

Preferably, each detection station 3(1), 3(2), ... 3(n) is further provided with a time synchronization system, for example by means of an NTP or GPS satellite system or similar system, which allows the synchronization with respect both to the absolute time and to the time of the other detection stations of the system.

Each detection station 3(1), 3(2), ... 3(n) preferably assigned to a respective peripheral server 2(1), 2(2), ... 2(n), where "assigned to" means that it is directly connected to it so that, when the detection station 3(1), 3(2), ... 3(n) detects a transit and generates corresponding transit data, the peripheral server 2(1), 2(2), ... 2(n) connected to it receives and stores automatically and in real time these transit data. Each peripheral server 2(1), 2(2), ... 2(n) is furthermore substantially co-located with the detection station 3(1), 3(2), ... 3(n) assigned thereto. Each detection station 3(1), 3(2), ... 3(n) and the peripheral server 2(1), 2(2), ... 2(n) to which it is assigned therefore form part of a single roadside or peripheral device 10(1), 10(2), ... 10(n) located at a given position along the road infrastructure 6.

If more lanes are present, the peripheral server 2(1), 2(2), ... 2(n) may be composed of more control units, each of which stores and manages the transit data relating to the transits along a respective lane. As an alternative, the peripheral server 2(1), 2(2), ... 2(n) may comprise only one control unit (or two, if a redundant configuration is adopted) which stores and manages the transit data relating to the transits along all the lanes of the detection station 3(1), 3(2), ... 3(n).

The peripheral servers 2(1), 2(2), ... 2(n) are preferably all directly or indirectly connected together, so as to form a distributed system. The peripheral servers 2(1), 2(2), ... 2(n) are preferably also connected to the central server 1. By way of non-limiting example, the peripheral servers 2(1), 2(2), ... 2(n) may be connected together (and possibly to the central server) via a WAN (Wide Area Network), with an optical fiber backbone and optical fiber or copper distribution and backhaul network. Alternatively, the peripheral servers 2(1), 2(2), ... 2(n) may be connected together (and possibly to the central server 1) via a wireless network, for example a cellular network.

According to embodiments of the present invention, each vehicle is preferably associated with a respective registry record.

Figure 2 schematically shows a registry record 4 relating to a vehicle, according to an embodiment of the present invention.

The registry record 4 preferably comprises a set of detectable identifiers of the vehicle 40. For example, the set of detectable identifiers 40 may comprise the license plate number of the vehicle, the OBU-id of the OBU associated with the vehicle, a description of the fingerprint of the vehicle, a UHF tag, etc. Each detection station 3(1), 3(2), .... 3(n) is preferably configured for detecting at least one of the detectable identifiers 40 included in the registry record 4.

According to preferred embodiments, the registry record 4 also comprises a unique generic identifier of the vehicle 41, which is uniquely associated with the set of detectable identifiers 40. The unique generic identifier 41 is preferably an alphanumeric identifier, which for example may be generated and assigned to the vehicle by the manager of the system 100 at the time of the creation of the registry record 4. By way of example, the unique generic identifier 41 may comprise the concatenation of a unique identifier of the manager of the system 100 and of a sequential number.

Optionally, the registry record 4 may also comprise additional information 42, such as for example information useful for the determination of the toll due (motorization of the vehicle, Euroclass, number of axles, etc.).

The registry record 4 is preferably created by the manager of the system 100 based on information received from third-parties, for example from the system of a provider of an electronic tolling or electronic payment service with whom the driver of the vehicle is registered.

The registry records of the vehicles are preferably stored at each of the peripheral servers 2(1), 2(2), ... 2(n). Optionally, the registry records of the vehicles may also be stored at the central server 1. For example, the registry records may initially be created in a database at the central server 1 and successively distributed to all the peripheral servers 2(1), 2(2), ... 2(n) of the system 100.

With reference to Figure 3, the operation of the system 100 will now be described for the determination of the toll due for use of a road infrastructure 6 (for example, a freeway) by a vehicle 5, according to a first embodiment of the present invention.

The vehicle 5 preferably enters the road infrastructure 6 via one of its entry gates, at which a detection station 3(in) is located, which is assigned to a peripheral server 2(in). The detection station 3(in) preferably detects the transit of the vehicle 5, in particular it detects one of its identifiers ID(in) (for example, it detects the OBU-id of the OBU on board the vehicle 5 by using DSRC technology).

The detection station 3(in) thus preferably sends data T(in) relating to the entry transit of the vehicle 5 to the peripheral server 2(in) to which it is assigned. This entry transit data T(in) preferably comprise the detected identifier ID(in) of the vehicle 5, the toll class of the vehicle, the date and time of the transit and an identifier of the detection station 3(in) and/or of the entry gate at which it is located.

According to an advantageous embodiment, the entry gate may be provided with a barrier which is opened to allow the access of the vehicle 5 to the road infrastructure 6 only after the peripheral server 2(in) has ascertained that the vehicle 5 is amongst those registered. In order to carry out this assessment, the peripheral server 2(in) preferably verifies whether, amongst the registry records present in its memory, there is a registry record 4 that comprises the identifier ID(in) within its own set of detectable identifiers 40.

Thus, the peripheral server 2(in) preferably inserts into the entry transit data T(in) the unique generic identifier of the vehicle 5. For this purpose, the peripheral server 2(in) preferably uses the detected identifier ID(in) in order to obtain, from amongst its registry records, the one relating to the vehicle 5, i.e. the registry record 4 that comprises the identifier ID(in) within its set of detectable identifiers 40. From the registry record 4, the unique generic identifier 41 is read, which is then inserted into the entry transit data T(in). Optionally, following the insertion of the unique generic identifier 41 into the entry transit data T(in), the peripheral server 2(in) may remove the detected identifier ID(in) from the entry transit data T(in).

Preferably, the peripheral server 2(in) thus forwards the entry transit data T(in) to the other peripheral servers of the system 100, in particular to the peripheral servers to which the detection stations located at the exit gates and/or the intermediate points of the road infrastructure 6 are assigned. More preferably, the peripheral server 2(in) forwards the entry transit data T(in) not to all the aforementioned peripheral servers, but only to the peripheral servers to which the detection stations located at exit gates and/or the intermediate points that follow the entry gate in the travel direction of the vehicle 5 along the infrastructure 6, or a part of them, are assigned.

According to a first embodiment, in particular, the peripheral server 2(in) preferably forwards the entry transit data T(in) to the peripheral servers to which the detection stations located at the exit gates of the road infrastructure 6 that follow the entry gate in the direction of travel of the vehicle 5 along the infrastructure 6 are assigned. In case of a junction, the exit gates in question are all those that follow the entry gate in the travel direction of the vehicle 5, on each branch of the junction. By way of example, Figure 3 shows a single exit gate which follows the entry gate, at which exit gate the detection station 3(out) assigned to the peripheral server 2(out) is located. The peripheral server 2(out) therefore receives the entry transit data T(in).

The peripheral server 2(in) may send the entry transit data T(in) directly to the peripheral server 2(out). As an alternative, the entry transit data T(in) may first be sent to the central server 1, which stores them in its own database, identifies the peripheral servers to which the data are to be forwarded and carries out the forwarding.

Upon receiving the entry transit data T(in), the peripheral server 2(out) preferably creates an event record relating to the vehicle 5.

For this purpose, the peripheral server 2(out) preferably uses the unique generic identifier 41 of the vehicle 5 contained in the entry transit data T(in) in order to retrieve, from amongst its registry records, the one relating to the vehicle 5, i.e. the registry record 4.

Once the registry record 4 relating to the vehicle 5 has been retrieved, the peripheral server 2(out) preferably creates an event record 4′ relating to the vehicle 5, by adding to the registry record 4 at least a part of the entry transit data T(in). As shown in Figure 4, the event record 4′ preferably comprises the set of detectable identifiers 40 of the vehicle 5, the unique generic identifier 41, the additional information 42 and, for example, the date and time of the transit and the identifier of the detection station 3(in) and/or of the entry gate at which it is located, which were contained in the entry transit data T(in).

It is now assumed that, between the entry gate at which the detection station 3(in) is located and the exit gate at which the detection station 3(out) is located, two intermediate detection stations 3(int1) and 3(int2) are present, each of which is assigned to a respective peripheral server 2(int1), 2(int2).

The detection station 3(int1) preferably detects the transit of the vehicle 5, in particular it detects one of its identifiers ID(int1). It will be noted that the identifier ID(int1) is not necessarily the same as the identifier ID(in) detected by the detection station 3(in) located at the entry gate. For example, the identifier ID(in) could be the OBU-id of the OBU present on board the vehicle 5, whereas the identifier ID(int1) could be the license plate number of the vehicle 5.

The detection station 3(int1) thus preferably sends, to the peripheral server 2(int1) to which it is assigned, data T(int1) relating to the first intermediate transit of the vehicle 5. These first intermediate transit data T(int1) preferably comprise the detected identifier ID(int1) of the vehicle 5, the date and time of the transit and an identifier of the detection station 3(int1).

Thus, the peripheral server 2(int1) preferably inserts into the data of first intermediate transit T(int1) the unique generic identifier of the vehicle 5. For this purpose, the peripheral server 2(int1) preferably uses the detected identifier ID(int1) in order to retrieve, from amongst its registry records, the one relating to the vehicle 5, i.e. the registry record 4 that comprises the identifier ID(int1) within its set of identifiers 40, and from this it reads the unique generic identifier 41 which it inserts into the data of the first intermediate transit T(int1). Optionally, once the unique generic identifier 41 has been inserted into the first intermediate transit data T(int1), the peripheral server 2(int1) may remove the identifier ID(int1) from it.

The peripheral server 2(int1) thus preferably forwards the first intermediate transit data T(int1) to the peripheral servers to which the detection stations located at the exit gates that follow the intermediate detection station 3(int1) in the direction of travel of the vehicle 5 along the infrastructure 6 are assigned. The first intermediate transit data T(int1) are accordingly also sent to the peripheral server 2(out).

The peripheral server 2(int1) may send the first intermediate transit data T(int1) directly to the peripheral server 2(out). As an alternative, the entry data may be first sent to the central server 1, which stores it in its own database, identifies the peripheral servers to which the data are to be forwarded and carries out the forwarding.

Upon receiving the first intermediate transit data T(int1), the peripheral server 2(out) preferably uses the unique generic identifier 41 of the vehicle 5 contained in the first intermediate transit data T(int1) in order to obtain, from amongst its event records, the one relating to the vehicle 5. Once the event record 4′ relating to the vehicle 5 has been obtained, the peripheral server 2(out) preferably updates it, by appending at least part of the first intermediate transit data T(int1) thereto. For example, the event record 4′ may be updated by appending thereto the date and time of the first intermediate transit and the identifier of the detection station 3(int1), contained in the first intermediate transit data T(int1).

The aforementioned operations are repeated at each possible subsequent intermediate transit, such as for example the transit detected by the detection station 3(int2).

For each intermediate transit, the peripheral server 2(out) thus receives corresponding transit data, all comprising the unique generic identifier 41 of the vehicle 5. Upon receiving the data relating to each transit, the peripheral server 2(out) can then use the unique generic identifier 41 in order to retrieve the event record 4′ and update it substantially in real time with the data relating to the latest intermediate transit detected.

It is now assumed that the vehicle 5 exits from the road infrastructure 6 through one of its exit gates, for example through the exit gate at which the detection station 3(out) is located.

The detection station 3(out) preferably detects the transit of the vehicle 5, in particular it detects one of its identifiers ID(out). It will be noted that the identifier ID(out) is not necessarily the same as the identifiers ID(in), ID(int1), ID(int2) previously detected.

The detection station 3(out) thus preferably sends, to the peripheral server 2(out) to which it is assigned, data T(out) relating to the exit transit of the vehicle 5. This exit transit data T(out) preferably comprise the detected identifier ID(out) of the vehicle 5, the date and time of the transit, the toll class and an identifier of the detection station 3(out) and/or of the exit gate at which it is located.

Thus, the peripheral server 2(out) preferably uses the identifier ID(out) of the vehicle 5 contained in the exit transit data T(out) in order to retrieve, from amongst its event records, the one relating to the vehicle 5, i.e. the event record 4′ that comprises the identifier ID(out) within its set of detectable identifiers 40. Once the event record 4′ relating to the vehicle 5 has been retrieved, the peripheral server 2(out) preferably updates it, by appending thereto at least part of the exit transit data T(out). For example, the event record 4′ may be updated by appending thereto the date and time of the exit transit and the identifier of the detection station 3(out) contained in the exit transit data T(out).

The peripheral server 2(out) can then determine the toll due by the driver of the vehicle 5. For the determination of the toll due, the peripheral server 2(out) may avail itself of a locally stored tolling table, in which a respective toll due is stored for each entry gate–exit gate pair of the road infrastructure 6. If the road infrastructure 6 has a topology whereby, for a given entry gate-exit gate pair, two or more possible routes are provided for which different tolls are provided, the tolling table preferably also stores the toll due for each route. In that case, for the determination of the toll, the peripheral server 2(out) takes into account not only entry transit data and exit transit data included in the event record 4′, but also data relating to the intermediate transits.

The peripheral server 2(out) then generates a request for payment of the toll that it forwards for example to the systems of a provider of an electronic tolling service or, more generally, of an electronic payment service. This request may be transmitted through a gateway, which acts as an interface between the system 100 and the system of the provider of an electronic tolling service or, more generally, of an electronic payment service.

Advantageously, the system 100 allow the determination of the toll due substantially in real time, also when the toll due depends on the section of road infrastructure 6 which has been effectively travelled and/or on the travel duration. When the entry transit takes place, indeed, the relevant entry transit data T(in) are dispatched substantially in real time to the peripheral servers to which the detection stations located at the exit gates (or, at least, at the possible exit gates, as described above) are assigned. The same applies to the data relating to the intermediate transits, if any. Therefore, when one of these peripheral servers receives exit transit data relating to the vehicle 5 from the detection station assigned thereto, it already disposes of all the information that it needs for determining the toll due in a timely and automatic way.

The substantially autonomous distributed system of peripheral servers 2(1), 2(2), ... 2(n) is furthermore advantageously resistant with respect to possible network outages or possible outages of the central server 1. In particular, a possible fault in the central server 1 does not substantially compromise the operation of the system 100, whose peripheral servers can continue to operate and to determine the payments due as described above. On the other hand, the system 100 advantageously allows the various transits of the vehicle 5 to be correlated with one another also when these are detected with different technologies (for example, radiofrequency OBU and automatic reading of the license plate number). This is because not only one detectable identifier is associated with the vehicle 5, but rather a set of detectable identifiers 40. So, accordingly, if the detection station located at the entry gate and the detection station located at the exit gate (and the possible intermediate detection stations, if any) detect different identifiers of the vehicle (for example, one the OBU-id and the other the license plate number), these identifiers both form part of the set of detectable identifiers associated with the vehicle, and therefore the peripheral server is in any case capable of establishing that the entry transit data and the exit transit data (and the potential intermediate transit data) are related to the same vehicle and may thus be used in combination for the determination of the charge to be paid.

As described above, the intermediate detection stations are located along the road infrastructure 6 according to the granularity needed to determine the toll due, in case this depends on the route travelled and/or on the travel duration and/or on the time of travel. In case where it depends on the travel duration and/or on the time of travel, the presence of intermediate detection stations may be useful for example in case the manager of the system 100 wishes to establish the travel duration and the time of travel for each section of road infrastructure 6 travelled by the vehicle 5 (where "section" is understood to mean the segment of road infrastructure 6 included between two successive detection stations). This determination, advantageously, may for example allow the manager of the system 100 to determine, if the travel duration between entry gate and exit gate is substantially greater than a nominal travel duration, which is the section or which are the sections responsible for the anomalous delay. In the case where this section or these sections correspond for example to roadworks (and the time and date of the travel over these sections effectively corresponds to that of the presence of the roadworks), the manager of the system 100 may for example apply a discount to the toll due, as a compensation for the fact that the anomalous delay suffered by the vehicle 5 is under the responsibility of the manager itself.

According to one advantageous variant, each detection station located at an entry gate may also be provided with a ticket dispenser and a barrier. When the vehicle 5 passes through an entry gate, it stops so that the driver can withdraw the ticket, after which the barrier raises and the vehicle 5 can pass through. On the ticket, a unique code is preferably stamped, which the detection station adds to the entry transit data T(in) to be transmitted to the peripheral server to which the station is assigned. This unique code is preferably inserted into the set of detectable identifiers 40 included in the registry record 4 of the vehicle 5. For this purpose, preferably, the detection station located at the entry gate also detects one of the detectable identifiers 40 (for example, the license plate number) of the vehicle 5 and adds it to the transit data T(in). The peripheral server to which the detection station is assigned uses the license plate number in order to retrieve the registry record 4 of the vehicle 5, so as to be able to add the unique code of the ticket amongst the detectable identifiers 40 included in it. This update of the registry record 4 of the vehicle 5 is then issued to the peripheral servers to which the detection stations located at the exit gates of the infrastructure 6 (or at least at the possible exit gates) are assigned. If the detection station at one of the exit gates is equipped with a ticket reader and the driver of the vehicle 5 inserts the ticket into it at the time of the transit, the peripheral server to which this detection station is assigned will be able to identify the exit transit data T(out) relating to the vehicle 5 and append it to the correct event record on the basis of the unique code recorded on the ticket.

With reference to Figure 5, the operation will now be described of the system 100 for the determination of a toll due for use of a road infrastructure 6 (for example, a freeway) by a vehicle 5, according to a second embodiment of the present invention.

According to the second embodiment, the peripheral server 2(in) forwards the entry transit data T(in) to the peripheral servers of the system 100 to which detection stations following the detection station 3(in) in the travel direction of the vehicle 5 along the road infrastructure 6 are assigned, whether these are located at exit gates of the infrastructure 6 or at the intermediate points of the infrastructure 6. More preferably, the entry transit data T(in) are forwarded to the peripheral server to which the detection station immediately following (or to the peripheral servers to which the detection stations immediately following, in the case of several branches) the detection station 3(in) in the travel direction of the vehicle 5 along the road infrastructure 6 is assigned, whether this is an intermediate detection station or an exit detection station. For example, with reference to the scenario exemplified in Figure 5, the transit data T(in) are thus sent to the peripheral server 2(int1) and, optionally, also to the servers 2(int2) and 2(out).

According to this second embodiment, the peripheral server 2(int1) uses the entry transit data T(in) to generate its own event record relating to the vehicle 5, similar to the event record 4′ shown in Figure 4. The procedure by which the peripheral server 2(int1) generates its own event record 4′ is the same as that described above in connection with the first embodiment, therefore a detailed description of this procedure will not be repeated.

When, upon passage of the vehicle 5, the peripheral server 2(int1) receives from the detection station 3(int1) the first intermediate transit data T(int1), it preferably uses it in order to update its own event record 4′. Thus, the peripheral server 2(int1) preferably determines a partial toll P(in→int1) due for the use of the road section included between the detection station 3(in) and the detection station 3(int1), based on the data T(in) and the data T(int1). This partial toll P(in→int1) is also inserted into the first intermediate transit data T(int1), together with the data detected by the detection station 3(int1) and with the unique generic identifier 41 of the vehicle 5, which the peripheral server 2(int1) determines from its own event record 4′ relating to the vehicle 5.

Thus, according to the second embodiment, the peripheral server 2(int1) preferably forwards the first intermediate transit data T(int1) to the peripheral servers to which the detection stations which follow (more preferably the one that immediately follows, or those that immediately follow, in the case of several branches) the detection station 3(int1) in the travel direction of the vehicle 5 along the road infrastructure 6 are assigned, whether these are intermediate detection stations or exit detection stations. With reference to the exemplary scenario in Figure 5, the transit data T(int1) are then sent to at least one peripheral server 2(int2) and, optionally, also to the server 2(out).

According to this second embodiment, the peripheral server 2(int2) uses the first intermediate transit data T(int1) (and possibly also the entry transit data T(in), if it has received it from the peripheral server 2(in)), in order to generate an event record relating to the vehicle 5, similar to the event record 4′ shown in Figure 4. The procedure by which the peripheral server 2(int2) generates its own event record 4′ is similar to that described above in connection with the first embodiment, therefore a detailed description of this phase will not be repeated.

When the peripheral server 2(int2) receives from the detection station 3(int2) the second intermediate transit data T(int2), it preferably uses them to update its own event record 4′. It furthermore determines the partial toll P(in→int2) due for travelling the concatenation of the road sections included between the detection station 3(in) and the detection station 3(int2). The partial toll P(in→int2) is preferably determined by summing the partial toll P(in→int1) contained in the data of the first intermediate transit T(int1) with the toll due travelling the road section included between the detection station 3(int1) and the detection station 3(int2), that the peripheral server 2(int2) determines based on the first intermediate transit data T(int1) and second intermediate transit data (Tint2). This partial toll P(in→int2) is itself also inserted into the second intermediate transit data T(int2), together with the data detected by the detection station 3(int2) and with the unique generic identifier 41 of the vehicle 5, that the peripheral server 2(int2) determines from its event record 4′ relating to the vehicle 5.

Then, according to the second embodiment, the peripheral server 2(int2) preferably forwards the second intermediate transit data T(int2) to the peripheral servers to which the detection stations following (more preferably the one immediately following, or the ones immediately following, in case of several branches) the detection station 3(int2) in the travel direction of the vehicle 5 along the road infrastructure 6, whether these are intermediate detection stations or exit detection stations. With reference to the exemplary scenario in Figure 5, the transit data T(int2) are then sent to at least one peripheral server 2(out).

According to this second embodiment, the peripheral server 2(out) uses the entry transit data T(int2) (and possibly also the transit data T(in) and T(int1), if it has received it from the peripheral servers 2(in) and 2(int1), respectively) in order to generate an event record relating to the vehicle 5, similar to the event record 4′ shown in Figure 4. The procedure by which the peripheral server 2(out) generates its own event record 4′ is similar to that described above in connection with the first embodiment, hence a detailed description of this procedure will not be repeated.

When the peripheral server 2(out) receives the exit transit data T(out) from the detection station 3(out), it preferably uses it in order to update its own event record 4′. It furthermore determines the total toll P(in→out) due for travelling the concatenation of the road sections included between the detection station 3(in) and the detection station 3(out). The total toll P(in→out) is preferably determined by summing the partial toll P(in→int2) comprised in the second intermediate transit data T(int2) and the toll due for traveling the road section included between the detection station 3(int2) and the detection station 3(out), which the peripheral server 2(out) determines based on the second intermediate transit data T(int2) and the exit transit data T(out).

The peripheral server 2(out) then generates a request for payment of the toll, in a way similar to what was described above in connection with the first embodiment of the present invention.

The system 100 operating according to this second embodiment offers the same advantages as the first embodiment, i.e.: it allows the determination of the toll due substantially in real time, also in case the toll due depends on the section of road infrastructure 6 that has effectively been travelled and/or on the travel duration; it is resistant to the outages of the network and/or of the central server 1; it allows the various transits of the vehicle 5 to be correlated with one another also in the case in which these are detected with different technologies; and – as long as intermediate detection stations with the appropriate granularity are provided – it allows the travel duration and time of travel of each individual section to be established, and thus for example the manager of the system 100 to apply a discount on the toll due, as a compensation for potential delays suffered by the vehicle 5 and under the responsibility of the manager itself.

With reference to the flow chart in Figure 6, the operation of a peripheral server 2(i) (i=1, 2, ... n) of the system 100 will now be described, according to embodiments of the present invention.

Upon transit of the vehicle 5 (step 600), the detection station 3(i) assigned to the peripheral server 2(i) detects its identifier ID(i) (for example, the license plate number) and detects the time and date of its transit. These data are inserted into the transit data T(i) (step 601). As described above, the transit data T(i) also comprise the toll class of the vehicle, an identifier of the detection station 3(i) and/or of the entry or exit gate at which it is located and, optionally, the number printed on the ticket supplied (if it is an entry gate).

If the detection station 3(i) is part of an open system (i.e. if the toll due has a fixed charge), the peripheral server 2(i) updates the event record relating to the vehicle 5, determines the toll due and forwards the request for payment as described above (step 602). If a barrier is present, the latter is raised in order to allow the transit of the vehicle 5.

If, instead, the detection station 3(i) is part of a closed system (i.e. if the toll has a charge which depends on the section travelled over and/or on the travel duration and/or on the time of travel), in the case where this is an entry transit, the peripheral server 2(i) preferably checks whether the vehicle 5 is registered, i.e. if amongst its registry records there is one corresponding to the vehicle 5 and, in the affirmative, it raises the barrier in order to allow the transit of the vehicle 5 (step 603).

Then, the peripheral server 2(i) preferably sends the transit data T(i) to one or more of the other peripheral servers of the system 100 (step 604). As described above, according to the first embodiment, the peripheral server 2(i) forwards the transit data T(i) to the peripheral servers to which the detection stations are assigned, which are located at the exit gates of the road infrastructure 6 (preferably, only at the possible exit gates, i.e. those that follow the entry gate in the travel direction of the vehicle). According to the second embodiment, instead, the peripheral server 2(i) forwards the transit data to the peripheral servers to which the intermediate detection stations following the entry gate are assigned (preferably, only the intermediate or exit detection station immediately following the entry gate – possibly more than one, in the case of several branches).

In any case, the peripheral server 2(i) may optionally also insert into the transit data T(i) additional information for the authentication of the detected identifier ID(i).

If, instead, it is not an entry transit, the peripheral server 2(i) preferably obtains, from its own local database, the registry record or event record relating to the vehicle 5 (step 605). If an event record is present, the peripheral server 2(i) preferably determines whether it contains transit data T(i-1) relating to a preceding transit (step 606).

In the negative, the peripheral server 2(i) sends the transit data T(i) to one or more of the other peripheral servers of the system 100 (step 604), as described above.

If, instead, the peripheral server 2(i) determines that the event record relating to the vehicle 5 contains transit data T(i-1) relating to a preceding transit, optionally it may determine the toll due for traveling the preceding road section, i.e. that included between the preceding detection station 3(i-1) and the detection station 3(i), based on the transit data T(i-1) and of the transit data T(i) (step 607).

Then, if the detection station 3(i) is located at an exit gate, the peripheral server 2(i) closes the event record relating to the vehicle 5 and sends the request for payment of the toll due, as described above. If a barrier is present at the exit gate, this is raised in order to allow the transit of the vehicle 5.

If, instead, the detection station 3(i) is an intermediate detection station, the peripheral server 2(i) inserts the toll optionally calculated into the transit data T(i) and reverts to step 604, by sending the transit data T(i) to at least part of the other peripheral servers of the system 100 (step 604), as described above.

## CLAIMS

1. System (100) for determining a toll due for use of a road infrastructure (6) by a vehicle (5), said system (100) comprising a plurality of detection stations (3(1), 3(2), ... 3(n)) located along said road infrastructure (6) and a corresponding plurality of mutually connected peripheral servers (2(1), 2(2), ... 2(n)), each one (3(i)) of said detection stations being assigned to a respective peripheral server (2(i)) of said plurality of peripheral servers, wherein:
   - a first detection station (3(in)) of said plurality of detection stations is configured to, upon transit of said vehicle (5), generate first transit data (T(in)) and forward said first transit data (T(in)) to at least one peripheral server (2(out); 2(int1)) of said plurality of peripheral servers to which a second detection station (3(out); 3(int1)) of said plurality of detection stations, located in a position following said first detection station (3(in)) in the travel direction of said vehicle (5) along said road infrastructure (6), is assigned;
   - said second detection station (3(out); 3(int1)) is configured to, in case of transit of said vehicle (5), generate second transit data (T(out); T(int1)) and forward said second transit data (T(out); T(int1)) to said at least one peripheral server (2(out); 2(int1)); and
   - said at least one peripheral server (2(out); 2(int1)) is configured to, upon receiving said second transit data (T(out); T(int1)), associate them with said first transit data (T(in)) previously received and determine said toll due based on said first transit data (T(in)) and said second transit data (T(out); T(int1)).

2. System (100) according to claim 1, wherein said vehicle (5) is associated with a set of detectable identifiers (40), said set of detectable identifiers (40) being stored at said at least one peripheral server (2(out); 2(int1)).

3. System (100) according to claim 2, wherein said first transit data (T(in)) comprise a first identifier (ID(in)) of said set of detectable identifiers (40) detected by said first detection station (3(in)) and said second transit data (T(out); T(int1)) comprise a second identifier (ID(out); ID(int1)) of said set of detectable identifiers (40) detected by said second detection station (3(out); 3(int1)).

4. System (100) according to claim 3, wherein said vehicle (5) is further associated with a unique generic identifier (41) uniquely associated with said set of detectable identifiers (40) and generated by a manager of said system (100).

5. System (100) according to claim 4, wherein said first transit data (T(in)) forwarded by said first detection station (3(in)) to said at least one peripheral server (2(out); 2(int1)) comprise said unique generic identifier (41).

6. System (100) according to claim 5, wherein said first identifier (ID(in)) of said set of detectable identifiers (40) detected by said first detection station (3(in)) is removed from said first transit data (T(in)) forwarded by said first detection station (3(in)) to said at least one peripheral server (2(out); 2(int1)), after said unique generic identifier (41) has been inserted into said first transit data (T(in)).

7. System (100) according to any of claims 4 to 6, wherein said at least one peripheral server (2(out); 2(int1)) is configured to associate said second transit data (T(out); T(int1)) and said first transit data (T(in)) based on said unique generic identifier (41).

8. System (100) according to any of the preceding claims, wherein said second detection station (3(out)) is located at an exit gate of said road infrastructure (6) following said first detection station (3(in)) in the travel direction of said vehicle (5) along said road infrastructure (6).

9. System (100) according to claim 8, wherein said at least one peripheral server (2(out)) is further configured to receive third transit data (T(int1), T(int2)) from a third detection station (3(int1), 3(int2)) of said plurality of detection stations, located between said first detection station (3(in)) and said exit gate, and to determine said toll due also based on said third transit data (T(int1), T(int2)).

10. System (100) according to any of claims 1 to 7, wherein said second detection station (3(int1)) is located at an intermediate point of said road infrastructure (6) following said first detection station (3(in)) in the travel direction of said vehicle (5) along said road infrastructure (6).

11. System (100) according to claim 10, wherein said second detection station (3(int1)) is located at an intermediate point immediately following said first detection station (3(in)) in the travel direction of said vehicle (5) along said road infrastructure (6).

12. System (100) according to claim 10 or 11, wherein said at least one peripheral server (2(int1)) is configured to forward said second transit data (T(int1)) and said toll determined to at least one further peripheral server (2(int2)) of said plurality of peripheral servers to which a third detection station (3(int2)) of said plurality of detection stations, located at an exit gate or a further intermediate point following said second detection station (3(int1)) in the travel direction of said vehicle (5) along said road infrastructure (6), is assigned.

13. System (100) according to claim 12, wherein said third detection station (3(int2)) is configured to, in case of transit of said vehicle (5), generate third transit data (T(int2)) and forward said third transit data (T(int2)) to said at least one further peripheral server (2(int2)); and wherein said at least one further peripheral server (2(int2)) is configured to, upon receiving said third transit data (T(int2)),

associate them with said received second transit data (T(int1)) and update the amount of said toll determined based on said second transit data (T(int1)) and said third transit data (T(int2)).

14. Method for determining a toll due for use of a road infrastructure (6) by a vehicle (5), said method comprising:
    - at a first detection station (3(in)) of a plurality of detection stations (3(1), 3(2), ... 3(n)) located along said road infrastructure (6), upon transit of said vehicle (5), generating first transit data (T(in)) and forwarding said first transit data (T(in)) to at least one peripheral server ((2(out); 2(int1)) of a plurality of mutually connected peripheral servers (2(1), 2(2), ... 2(n)), each one (3(i)) of said detection stations (3(1), 3(2), ... 3(n)) being assigned to a respective peripheral server (2(i)) of said plurality of peripheral servers, a second detection station (3(out); 3(int1)) of said plurality of detection stations, located in a position following said first detection station (3(in)) in the travel direction of said vehicle (5) along said road infrastructure (6), being assigned to said at least one peripheral server ((2(out); 2(int1));
    - at said second detection station (3(out); 3(int1)), in case of transit of said vehicle (5), generating second transit data (T(out); T(int1)) and forwarding said second transit data (T(out)) to said at least one peripheral server (2(out); 2(int1)) to which said second detection station (3(out); 3(int1)) is assigned; and
    - at said at least one peripheral server (2(out); 2(int1)), upon receiving said second transit data (T(out); T(int1)), associating it with said first transit data (T(in)) previously received and determining said toll due based on said first transit data (T(in)) and said second transit data (T(out); T(int1)).

15. Roadside device (10(1), 10(2), ... 10(n)) for determining a toll due for use of a road infrastructure (6) by a vehicle (5), said roadside device

(10(1), 10(2), ... 10(n)) being located at a first position of said road infrastructure (6) and comprising a peripheral server (2(i)) and a detection station (3(i)) assigned thereto, wherein:

- said peripheral server (2(i)) is configured to store first transit data (T(i-1)) received from a further roadside device to which it is connected, said further roadside device being located along said road infrastructure (6) at a position preceding said first position in the travel direction of said vehicle (5);
- said detection station (3(i)) is configured to, in case of a transit of said vehicle (5), generate second transit data (T(i)) and forward said second transit data (T(i)) to said peripheral server (2(i)); and
- said peripheral server (2(i)) is further configured to, upon receiving said second transit data (T(i)), associate them with said first transit data (T(i-1)) previously received and determine said toll due based on said first transit data (T(i)) and said second transit data (T(i-1)).

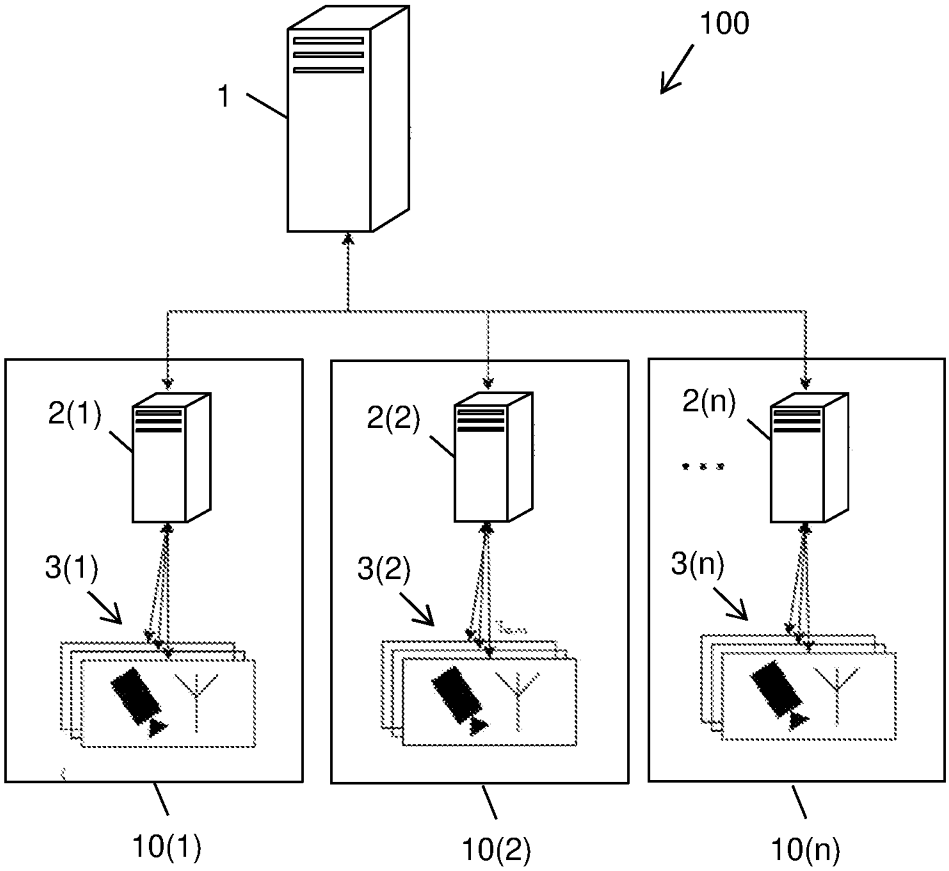
100
1
2(1)
2(2)
2(n)
3(1)
3(2)
3(n)
10(1)
10(2)
10(n)

Fig. 1

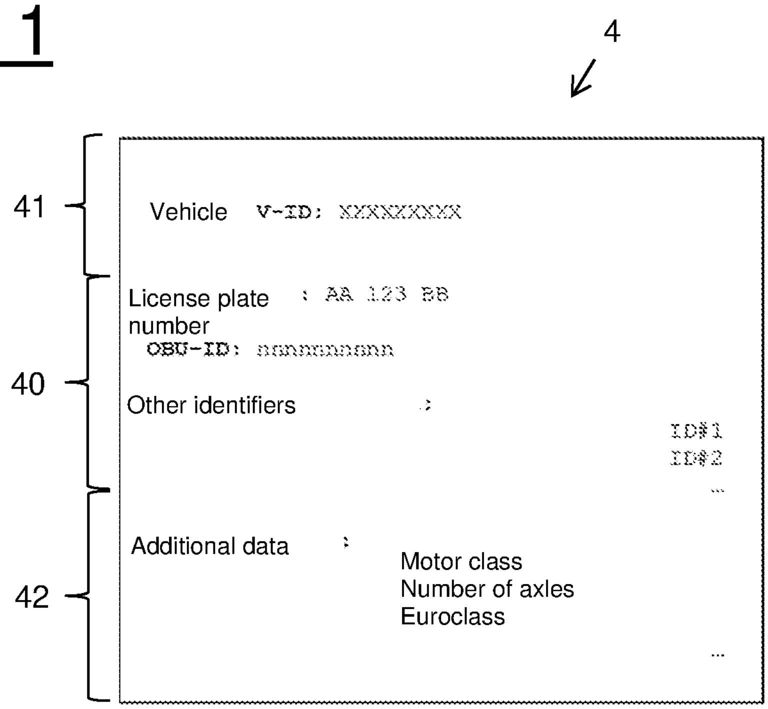
4
41
40
42
Vehicle V-ID: XXXXXXXXX
License plate number : AA 123 BB
OBU-ID: nnnnnnnnnn
Other identifiers :
ID#1
ID#2
...
Additional data :
Motor class
Number of axles
Euroclass
...

Fig. 2

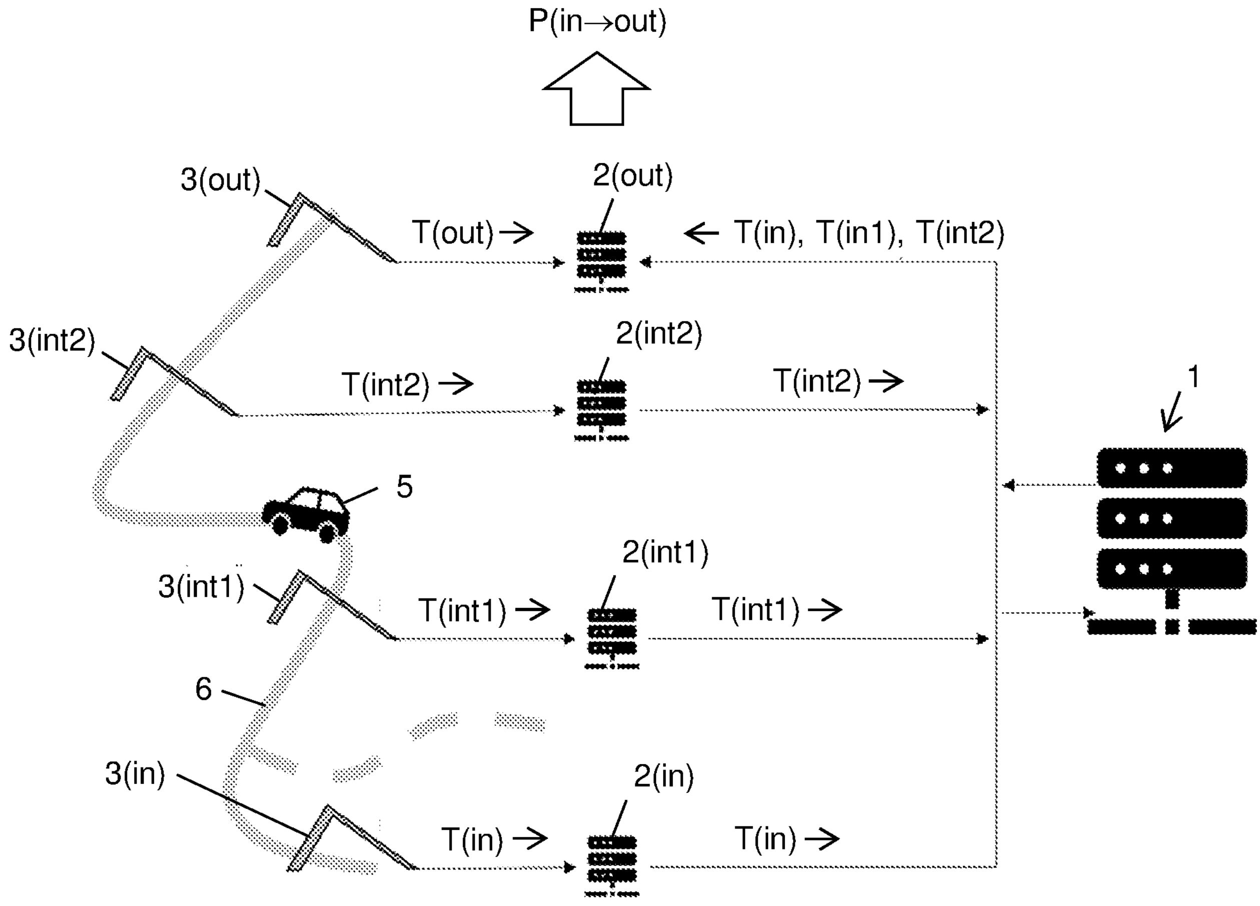
P(in→out)
3(out)
2(out)
T(out) →
← T(in), T(in1), T(int2)
3(int2)
2(int2)
T(int2) →
T(int2) →
1
5
3(int1)
2(int1)
T(int1) →
T(int1) →
6
3(in)
2(in)
T(in) →
T(in) →

Fig. 3

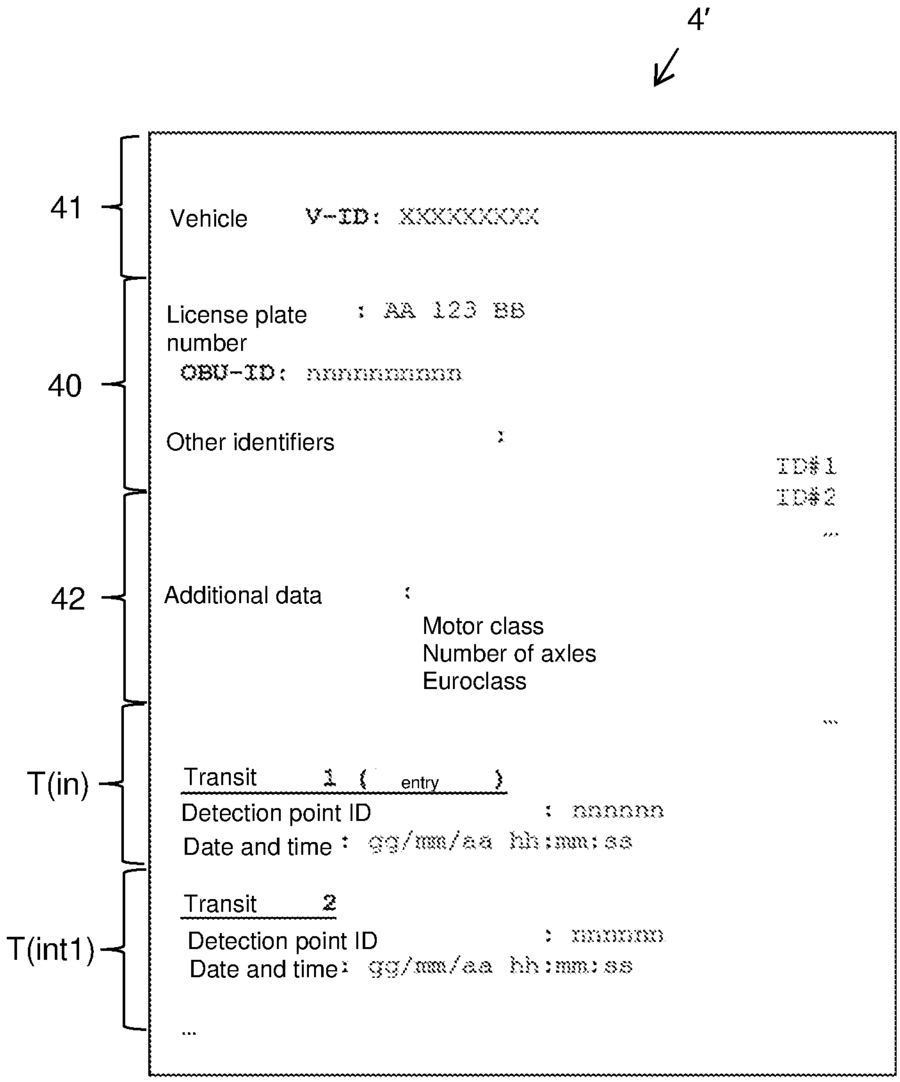
4'
41
Vehicle V-ID: XXXXXXXXX
License plate number : AA 123 BB
40
OBU-ID: nnnnnnnnnn
Other identifiers :
ID#1
ID#2
...
42
Additional data :
Motor class
Number of axles
Euroclass
...
T(in)
Transit 1 ( entry )
Detection point ID : nnnnnn
Date and time : gg/mm/aa hh:mm:ss
T(int1)
Transit 2
Detection point ID : nnnnnn
Date and time: gg/mm/aa hh:mm:ss
...

Fig. 4

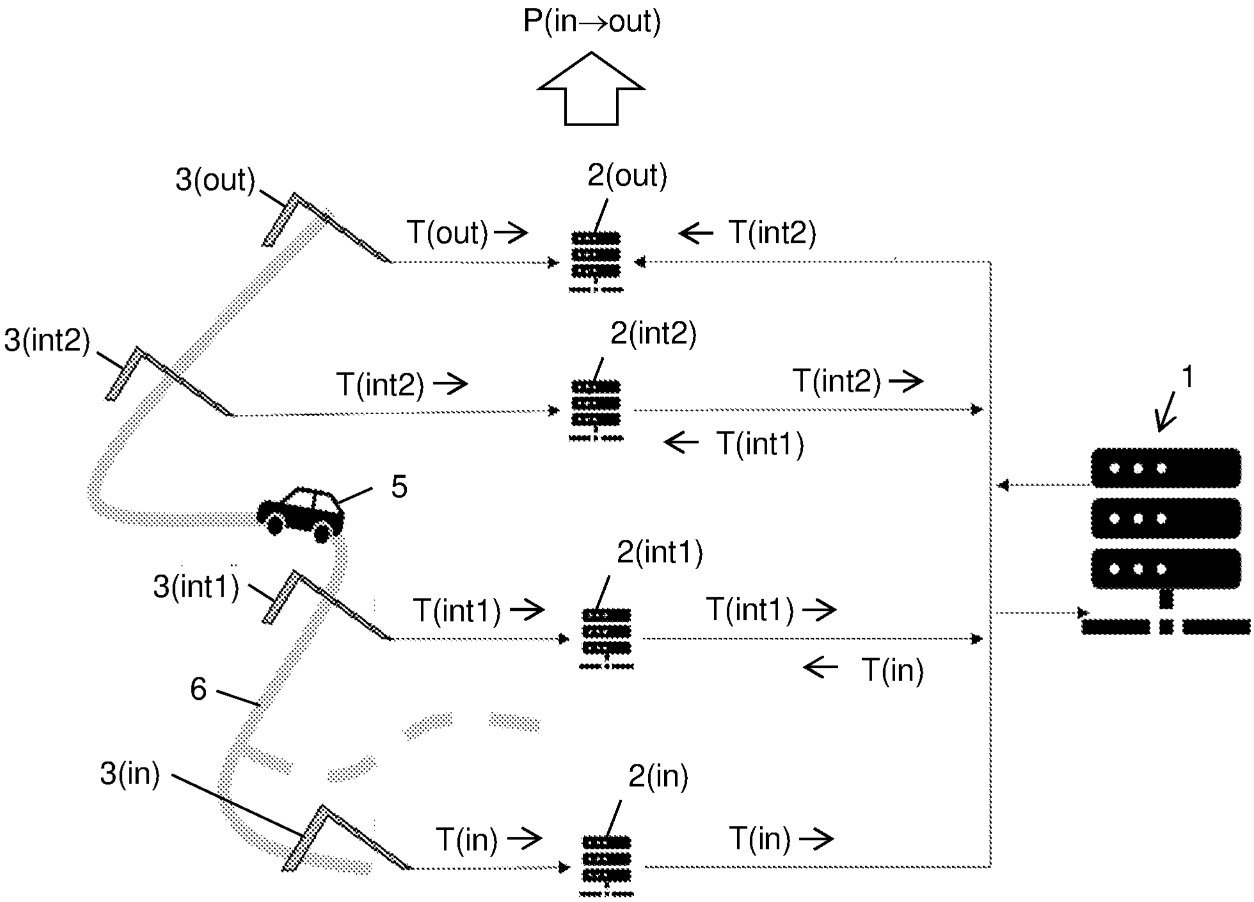
P(in→out)
3(out)
2(out)
T(out)→
← T(int2)
3(int2)
2(int2)
T(int2)→
T(int2)→
← T(int1)
1
5
3(int1)
2(int1)
T(int1)→
T(int1)→
← T(in)
6
3(in)
2(in)
T(in)→
T(in)→

Fig. 5

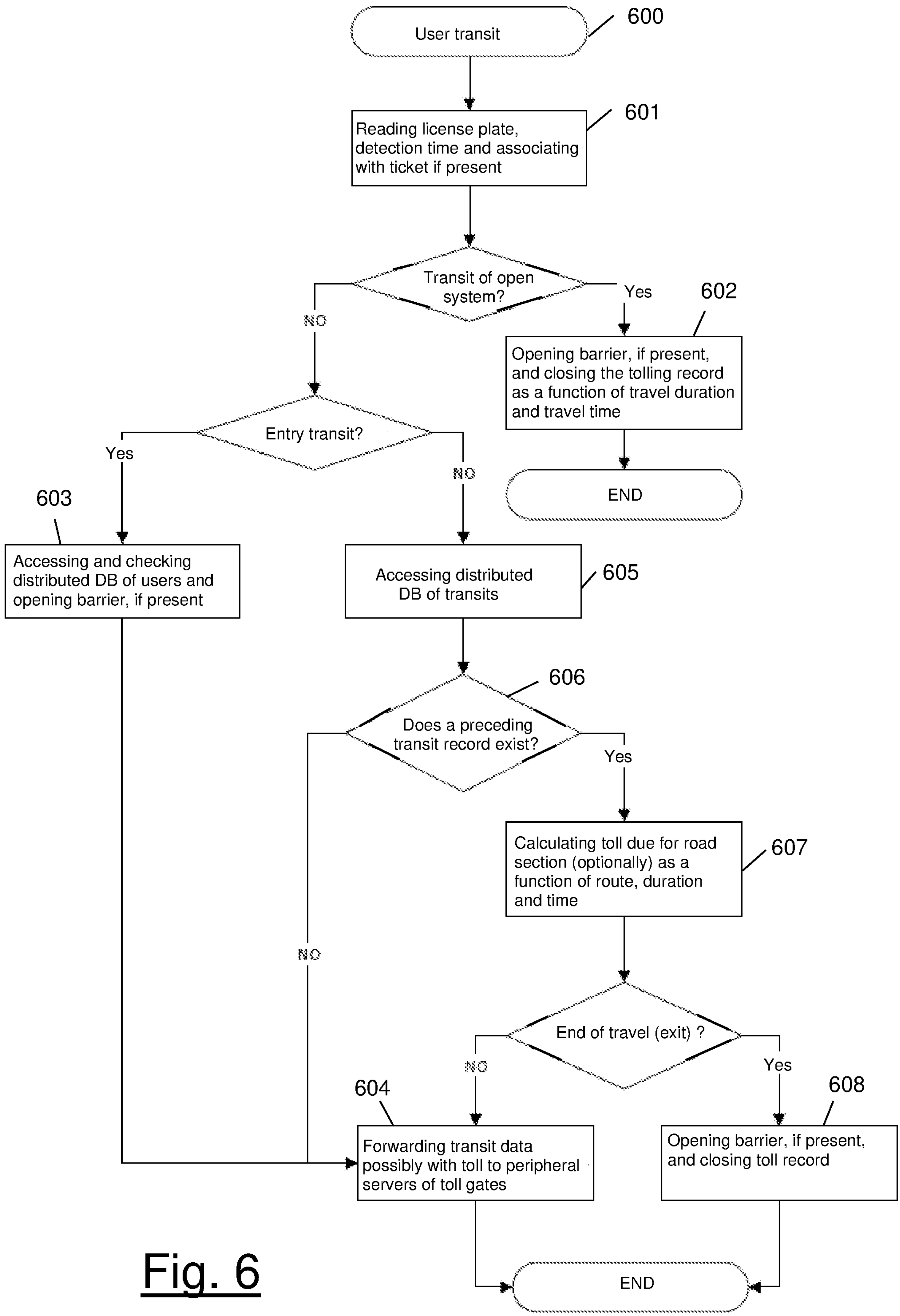
User transit
600
Reading license plate, detection time and associating with ticket if present
601
Transit of open system?
Yes
602
NO
Opening barrier, if present, and closing the tolling record as a function of travel duration and travel time
END
Entry transit?
Yes
NO
603
Accessing and checking distributed DB of users and opening barrier, if present
Accessing distributed DB of transits
605
606
Does a preceding transit record exist?
Yes
Calculating toll due for road section (optionally) as a function of route, duration and time
607
NO
End of travel (exit) ?
NO
Yes
604
608
Forwarding transit data possibly with toll to peripheral servers of toll gates
Opening barrier, if present, and closing toll record
END

Fig. 6

# INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2022/050208

**A. CLASSIFICATION OF SUBJECT MATTER**
INV. G07B15/06
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)
G07B G06Q G08G G07C H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | EP 1 354 306 A2 (RAYTHEON CO [US]) 22 October 2003 (2003-10-22) abstract; figures 1,2 paragraph [0009] paragraph [0011] - paragraph [0065] paragraph [0095] - paragraph [0120] claims 1-3 ----- | 1-15 |
| Y | EP 1 617 382 A2 (AUTOSTRADE PER L ITALIA S P A [IT]) 18 January 2006 (2006-01-18) abstract paragraph [0009] - paragraph [0040] claim 1 ----- | 1-15 |

-/--

[x] Further documents are listed in the continuation of Box C. [x] See patent family annex.

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| Name and mailing address of the ISA/ | Authorized officer |
|---|---|
| European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016 | Pañeda Fernández, J |

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
| --- | --- | --- |
| Y | EP 0 989 705 A2 (AT & T CORP [US]) 29 March 2000 (2000-03-29) abstract figures 1-5 paragraph [0018] - paragraph [0027] ----- | 1-15 |
| A | CA 2 867 173 A1 (KAPSCH TRAFFICCOM AG [AT]) 7 April 2016 (2016-04-07) abstract paragraph [0022] - paragraph [0064] figures 1-3 ----- | 1-15 |
| A | EP 3 745 089 A1 (AUTOSTRADE TECH S P A [IT]) 2 December 2020 (2020-12-02) abstract figures 1-6 paragraph [0028] - paragraph [0109] ----- | 1-15 |

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# INTERNATIONAL SEARCH REPORT

**Information on patent family members**

International application No
PCT/IB2022/050208

| Patent document cited in search report | | Publication date | Patent family member(s) | | | Publication date |
|---|---|---|---|---|---|---|
| EP 1354306 | A2 | 22-10-2003 | AT | 357717 | T | 15-04-2007 |
| | | | AU | 2002243702 | B2 | 03-03-2005 |
| | | | AU | 2002243934 | B2 | 30-06-2005 |
| | | | CA | 2434704 | A1 | 01-08-2002 |
| | | | CA | 2434963 | A1 | 01-08-2002 |
| | | | CZ | 20032279 | A3 | 14-01-2004 |
| | | | CZ | 20032292 | A3 | 14-01-2004 |
| | | | DE | 60218982 | T2 | 06-12-2007 |
| | | | EP | 1354299 | A2 | 22-10-2003 |
| | | | EP | 1354306 | A2 | 22-10-2003 |
| | | | ES | 2282395 | T3 | 16-10-2007 |
| | | | HU | 0302998 | A2 | 29-12-2003 |
| | | | HU | 0401051 | A2 | 28-09-2004 |
| | | | IL | 156674 | A | 19-08-2007 |
| | | | IL | 156675 | A | 15-05-2007 |
| | | | JP | 4291571 | B2 | 08-07-2009 |
| | | | JP | 4334870 | B2 | 30-09-2009 |
| | | | JP | 2004525445 | A | 19-08-2004 |
| | | | JP | 2004525447 | A | 19-08-2004 |
| | | | US | 2002140577 | A1 | 03-10-2002 |
| | | | US | 2002140579 | A1 | 03-10-2002 |
| | | | US | 2006056658 | A1 | 16-03-2006 |
| | | | WO | 02059838 | A2 | 01-08-2002 |
| | | | WO | 02059852 | A2 | 01-08-2002 |
| EP 1617382 | A2 | 18-01-2006 | DK | 1617382 | T3 | 29-07-2019 |
| | | | EP | 1617382 | A2 | 18-01-2006 |
| | | | ES | 2745588 | T3 | 02-03-2020 |
| | | | PL | 1617382 | T3 | 29-11-2019 |
| | | | PT | 1617382 | T | 25-07-2019 |
| | | | SI | 1617382 | T1 | 30-10-2019 |
| EP 0989705 | A2 | 29-03-2000 | CA | 2281483 | A1 | 14-03-2000 |
| | | | CN | 1250996 | A | 19-04-2000 |
| | | | DE | 69929661 | T2 | 07-12-2006 |
| | | | EP | 0989705 | A2 | 29-03-2000 |
| | | | US | 6965591 | B1 | 15-11-2005 |
| | | | US | 7590104 | B1 | 15-09-2009 |
| CA 2867173 | A1 | 07-04-2016 | CA | 2867173 | A1 | 07-04-2016 |
| | | | WO | 2016055226 | A1 | 14-04-2016 |
| EP 3745089 | A1 | 02-12-2020 | NONE | | | |