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Amended claims in accordance with Rule 137(2) EPC.

(54) **VEHICLE OPERATION WITH A CENTRAL DIGITAL TRAFFIC MODEL**

(57) A method for operating a vehicle, wherein a vehicle transmits vehicle data to an edge data center being connected to a radio access network via a wireless connection being established by a communication unit of the vehicle; the edge data center updates a digital traffic model of a traffic situation involving the vehicle with the trans-

mitted vehicle data, calculates a trajectory of the vehicle based on the updated digital traffic model and transmits trajectory data of the calculated trajectory to the vehicle via the wireless connection; and the vehicle is operated according to the transmitted trajectory data, a vehicle and a computer program product.

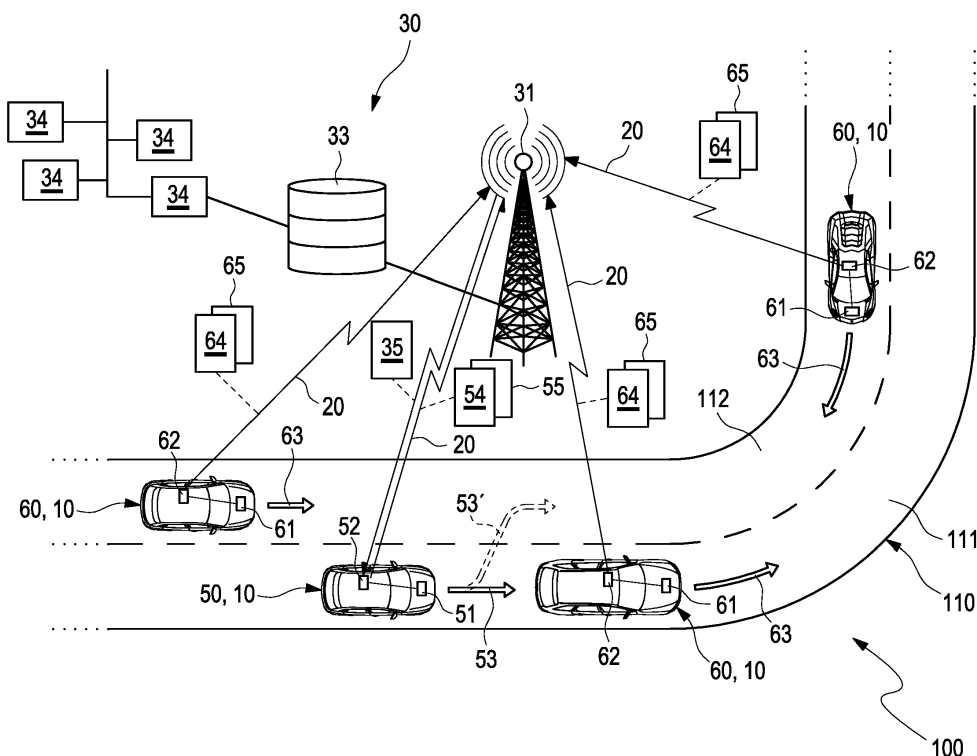


Fig. 2

Description

[0001] The invention relates to a method for operating a vehicle, wherein a vehicle transmits vehicle data to an edge data center being connected to a radio access network via a wireless connection being established by a communication unit of the vehicle; the edge data center updates a digital traffic model of a traffic situation involving the vehicle with the transmitted vehicle data, calculates a trajectory of the vehicle based on the updated digital traffic model and transmits trajectory data of the calculated trajectory to the vehicle via the wireless connection; and the vehicle is operated according to the transmitted trajectory data. The invention further relates to a vehicle and a computer program product.

[0002] Vehicles are increasingly provided with autonomous driving capabilities which at present are provided by advanced driving assistance systems (ADAS) and only cover particular operational contexts, i.e. traffic situations, of the vehicles (levels 2 and 3). However, fully autonomous vehicles (level 4) are expected to be available in the future which are operated basically without any intervention of a driver.

[0003] An autonomous driving functionality of a vehicle is based on a digital environmental model of the vehicle which is generated and continuously updated during operation of the vehicle by a control unit of the vehicle. A trajectory of the vehicle, i.e. positions and velocities of the vehicle as respective functions of time, is calculated by the control unit depending on the digital environmental model.

[0004] The digital environmental model reflects a traffic situation the vehicle is actually involved in and is updated when the traffic situation changes. When the traffic situation comprises one or more further vehicles operating in the environment of the vehicle the digital environmental model necessarily has to comprise operational data, e.g. positions, velocities, accelerations, etc. of each further vehicle being involved in the traffic situation of the vehicle. The operational data of the each further vehicle may be detected sensorially and/or received via a wireless connection from the further vehicle either immediately (vehicle-to-vehicle, V2V) or via a radio access network (vehicle-to-infrastructure-to-vehicle, V2I2V).

[0005] Vehicles provided by different manufacturers usually have different control units and use different digital environmental models due to a lack of standardization. As a consequence, the individual trajectories are calculated differently. Moreover, a traffic situation mostly involves also vehicles which are operated by a driver manually to follow an individual trajectory without a control unit even calculating it. In a complex traffic situation involving a plurality of vehicles the respective trajectories, hence, may easily conflict with each other increasing a risk of colliding and abrupt maneuvering of the vehicles. It is noted that the vehicle is understood to be a car, a motorcycle, a carry, an e-bike, a bicycle, an e-scooter, a pedestrian and the like, i.e. any item following an individ-

ual trajectory within the traffic situation.

[0006] The problem of conflicting trajectories may be solved by a stationary server centrally calculating the trajectories of the vehicles being involved in the traffic situation depending on a digital traffic model of the traffic situation. Each involved vehicle may transmit vehicle data to the stationary server via a wireless connection being established by the communication unit of the vehicle. The stationary server updates the digital traffic model with the transmitted vehicle data, calculates a trajectory of each vehicle based on the updated digital traffic model and transmits trajectory data of the calculated trajectories to the respective vehicles via the wireless connection. Each vehicle is then operated according to the transmitted trajectory data.

[0007] However, the vehicle data is received by the central server with a time offset, i.e. after a run time of a signal between the vehicle and the stationary server. Due to the time offset the digital traffic model of the stationary server is always outdated with respect to the traffic situation, i.e. the digital traffic model reflects the traffic situation the time offset ago. In other words, there is a discrepancy between the actual traffic situation and the traffic situation reflected by the digital traffic model.

[0008] Moreover, the trajectory data is received by each vehicle with another time offset, i.e. after a run time of a signal between the stationary server and the vehicle, which causing the trajectory corresponding to the received trajectory data to be even more outdated with respect to the actual traffic situation. Thus the discrepancy between the actual traffic situation and the trajectory corresponding to the received trajectory data is even larger.

[0009] The control unit of the vehicle may have to remove the discrepancy by quickly adjusting the trajectory, the quick trajectory adjustment causing the vehicle to suddenly accelerate and reducing an operational comfort of the vehicle. Eventually, even a collision with another vehicle may occur despite the quick trajectory adjustment which reduces an operational safety of the vehicle.

[0010] Hence, it would be desirable to increase the operational comfort and the operational safety of a plurality of vehicles being involved in a traffic situation.

[0011] It is, therefore, an object of the invention to suggest a method for comfortably and safely operating a vehicle in a traffic situation comprising at least one further vehicle. Further objects of the invention are a vehicle and a computer program product.

[0012] A first aspect of the invention is a method for operating a vehicle, wherein a vehicle transmits vehicle data to an edge data center being connected to a radio access network via a wireless connection being established by a communication unit of the vehicle; the edge data center updates a digital traffic model of a traffic situation involving the vehicle with the transmitted vehicle data, calculates a trajectory of the vehicle based on the updated digital traffic model and transmits trajectory data of the calculated trajectory to the vehicle via the wireless connection; and the vehicle is operated according to the

transmitted trajectory data.

[0013] In other words, the operation of the vehicle is not self-controlled but instead controlled centrally by the edge data server. The edge data center may be a server node which is immediately connected to an access node, e.g. a base station, of the radio access network, the access node providing the wireless connection to the wireless communication unit of the vehicle. The edge data center may also be a server node of the radio access network. The digital traffic model comprises operational data of the vehicle and reflects the traffic situation the vehicle is involved in. The calculated trajectory is continuously validated by the edge data center with respect to the digital traffic model in order to exclude any conflict of the trajectory with the updated digital traffic model.

[0014] According to the invention, calculating the trajectory comprises taking into account respective transmission delays of the transmitted vehicle data and the transmitted trajectory data. Taking into account the transmission delays requires a knowledge of the transmission delays and removes or at least reduces a discrepancy between the actual traffic situation and the trajectory corresponding to the transmitted trajectory data. The known transmission delay of the transmitted vehicle data allows the edge data server for updating the received vehicle data being outdated due to the transmission delay to the actual time. The known transmission delay of the transmitted trajectory data allows the edge data server for updating the transmitted trajectory data to the future reception time of the vehicle. As a consequence, the trajectory corresponding to the transmitted trajectory data better matches the actual traffic situation. Hence, a sudden acceleration for quickly adjusting the trajectory corresponding to the transmitted trajectory data is avoided or at least mitigated and a risk for colliding with the further vehicle is removed or at least reduced. Both effects result in a comfortable and safe operation of the vehicle.

[0015] In an embodiment, a further vehicle being involved in the traffic situation transmits vehicle data to the edge data center via a wireless connection being established by a communication unit of the further vehicle and the edge data center updates the digital traffic model of the traffic situation with the transmitted vehicle data of the further vehicle. The digital traffic model comprises vehicle data of one or more further vehicles, particularly each further vehicle, being involved in the traffic situation of the vehicle.

[0016] In a preferred embodiment, each transmission delay is taken into account as a maximum uplink latency or a maximum downlink latency being allocated to the wireless connection of the vehicle or the further vehicle by the radio access network. The maximum downlink latency and the maximum uplink latency indicate a maximum run time of the operational data along the wireless connections. The uplink run time and the downlink run time essentially contribute to the over all run time between transmitting the vehicle data to the edge data server and receiving the trajectory data from the edge data

server. When the edge data server knows the maximum uplink latency and the maximum downlink latency the edge data server may take into account the transmission delays precisely.

[0017] Advantageously, calculating a trajectory comprises taking into account a processing time for processing the vehicle data with the processing time being employed by at least one of the edge data center being connected to the radio access network, the vehicle and the further vehicle and/or a round trip time of the operational data between a backbone, i.e. a core, of the radio access network and the edge data center. The respective processing times of the vehicle and the further vehicles are known to the respective vehicle and may be transmitted to the edge data center as the vehicle data. The edge data center knows its own processing time for processing the vehicle data of the vehicle and the further vehicle. The edge data center may also know the round trip time between the backbone and the edge data center as the radio access network knows the round trip time and may transmit the round trip time to the edge data center. The processing times of the vehicle, each further vehicle and the edge data center and the round trip time of the radio access network complete the contributions to an overall transmission delay.

[0018] It is further preferred that the radio access network allocates a predetermined combination of a minimum data rate and/or a maximum latency for uplink and downlink, respectively, to each wireless connection of the vehicle and the further vehicle. A specification of a radio communication protocol may define a plurality of predetermined combinations of minimum data rate values and maximum latency values. The combinations may cover a range from a practical non-availability to an ideal availability of a data rate and/or latency and may prefer either the data rate or the latency between the non-availability and the ideal availability.

[0019] Each vehicle may transmit operational data and/or technical specification data as the vehicle data. The operational data may comprise a position, a velocity, an acceleration of the vehicle, navigational data and generally each data item of the digital environmental model of the vehicle. The vehicle may detect data items of the digital environmental model sensorially, i.e. by means of one or more environmental sensors of the vehicle.

[0020] The technical specification data may comprise a maximum velocity and a maximum acceleration of the vehicle. The technical specification data may comprise any data which is not immediately operational, i.e. related to the actual operation of the further vehicle. For instance, the technical specification data may comprise a maximum velocity and a maximum acceleration of the vehicle. The technical specification data of the vehicle allows the edge data center for estimating a confidence level of the updated received operational data, e.g. for judging whether the vehicle operates in a comfort zone or near an operational limit.

[0021] Additionally or alternatively, each vehicle may

transmit the vehicle data periodically and/or when a difference between the transmitted trajectory data and actual operational data of the vehicle or the further vehicle, respectively, exceeds a predetermined threshold value. A periodical transmission of the vehicle data allows the edge data server for regularly updating the digital traffic model, but may cause a constant relevant load to the radio access network, particularly in case a period time of the transmission is short. In contrast, the event-driven transmission causes little load to the radio access network, but prevents the edge data server from regularly updating the digital traffic model. It is noted that both transmissions policies may be readily combined for lengthening the period time of the transmission and reducing an average load of the radio access network.

[0022] In a further embodiment, calculating the trajectory comprises using a digital road map comprising a road segment accommodating the traffic situation and traffic data concerning the road segment accommodating the traffic situation. The digital road map may comprise high precision data. The traffic data may comprise weather data, data related to construction areas, traffic jam data and the like. The edge data center may be provided with the digital road map and the traffic data by a stationary server.

[0023] The vehicle advantageously adjusts the trajectory corresponding to the transmitted trajectory data depending on sensorially detected environmental data. In other words, the digital environmental model enables the control unit of the vehicle to reduce a difference between the trajectory data and the environmental data.

[0024] The edge data center may calculate the trajectory depending on an availability of the radio access network for the vehicle. For instance, a more conservative trajectory may be calculated in case the availability of the radio access network is at least partially poor for the traffic situation while an optimized trajectory may be calculated in case the availability of the radio access network is continuously high for the traffic situation. The more conservative trajectory may be calculated and transmitted in advance in order to anticipate a reduced availability of the radio access network.

[0025] In a preferred embodiment, the edge data center determines a confidence level of the digital traffic model and determines a length of the calculated trajectory depending on the determined confidence level. The higher the confidence level is the longer the calculated trajectory may be. The lower the confidence level is the shorter the calculated trajectory must be. The terms long and short are to be understood spatially or timely.

[0026] The edge data center may determine the confidence level depending on a redundancy of the transmitted vehicle data and/or an accuracy of a forecast of the traffic situation. Data items being consistently covered by the vehicle data of a plurality of vehicles, i.e. redundant data items, increase the confidence level of the digital traffic model. The more accurate the traffic situation may be forecast the higher the confidence level

of the digital traffic model may be determined.

[0027] In many embodiments, the vehicle is operated autonomously and automatically follows a trajectory corresponding to the transmitted trajectory data. The vehicle very precisely obeys the transmitted trajectory data due to an autonomous driving functionality of the control unit. Of course, the vehicle independently validates the trajectory corresponding to the transmitted trajectory data with respect to the digital environmental model reflecting the traffic situation the vehicle is involved in. In case an accident might occur or in case the wireless connection is temporarily unavailable, i.e. interrupted, the vehicle may ignore the transmitted trajectory, calculate a trajectory on its own and follow the calculated trajectory. Thus, the vehicle may be operated autonomously by way of exception.

[0028] In further embodiments, the vehicle is operated by a driver manually following a trajectory corresponding to the transmitted trajectory data and a warning is displayed to the driver when a difference between actual operational data of the vehicle and the transmitted trajectory data exceeds a predetermined threshold value. The trajectory and the warning may be displayed to the driver on a screen and/or by a speaker of the vehicle.

[0029] A second aspect of the invention is a vehicle, comprising a wireless communication unit and a control unit being connected to the wireless communication unit. The control unit is configured for establishing and continuously updating a digital environmental model of the vehicle and calculating a trajectory for the vehicle depending on the digital environmental model. The control unit may receive trajectory data from an edge data server of a radio access network via the wireless communication unit.

[0030] According to the invention, the control unit is configured for carrying out an inventive method. The control unit is configured for taking into account an uplink transmission delay and a downlink transmission delay being caused by a vehicle-to-infrastructure (V2I) connection with the edge data server.

[0031] A third aspect of the invention is a computer program product, comprising a computer readable storage medium storing a program code, the program code being executable by a control unit of a vehicle or an edge data center being connected to a radio access network. The computer program product may be a CD, a DVD, a USB stick and the like. The program code stored on the computer program product may be executable by the control unit of the vehicle or the edge data center immediately or after having been installed therein, respectively.

[0032] According to the invention, the program code causes the control unit or the edge data center to carry out an inventive method when being executed by a processor of the control unit or the edge data center, respectively. The vehicle and the edge data center cooperate for allowing a comfortable and safe operation for the vehicle.

[0033] It is an essential advantage of the inventive method that the vehicle is operated comfortably and safely. Sudden accelerations of the vehicle are avoided or at least mitigated. A risk for colliding with the further vehicle is removed or at least reduced.

[0034] Further advantages and configurations of the invention become apparent from the following description and the enclosed drawings.

[0035] It shall be understood that the features described previously and to be described subsequently may be used not only in the indicated combinations but also in different combinations or on their own without leaving the scope of the present invention.

[0036] The invention is described in detail by means of an exemplary embodiment and with reference to the drawings.

Fig. 1 schematically shows a structural diagram of a radio access network according to an embodiment of the invention;

Fig. 2 schematically shows a top view of a traffic situation involving a vehicle according to the invention;

[0037] Fig. 1 schematically shows a structural diagram of a radio access network 30 according to an embodiment of the invention. The radio access network 30 comprises a plurality of access nodes 31, 32 with the access node 31 being configured as a base station of a cellular communication network and the access node 32 being configured as a W-LAN router. Each access node 31, 32 supports corresponding wireless connections 20, 21, the wireless connection 20 being configured according to a standardized radio technology, i.e. LTE, 5G, a previous or a future radio technology standard and the wireless connection 21 being configured according to the standard IEEE 802.11 family.

[0038] Furthermore, the radio access network 30 comprises a plurality of edge data centers 33 and a backbone, i.e. core, having a plurality of stationary backbone nodes 34. The stationary backbone nodes 34 are not qualified in detail for avoiding any confusion as they are not essential for the invention. The radio access network 30 provides wireless connections to a plurality of user equipment devices 10, the wireless connections allowing the user equipment (UE) devices 10 to access an internet 40 which is symbolized as a cloud.

[0039] The radio access network 30 and the user equipment device 10 comprise a program code of a computer program product according to the invention. The program code is executed by a processor of a user equipment device 10 and/or by a processor of a stationary network node of the radio access network 30.

[0040] Fig. 2 schematically shows a top view of a traffic situation 100 involving a vehicle 50 according to the invention, the vehicle 50 comprising a wireless communication unit 52 and a control unit 51 being connected to

the wireless communication unit 52. The traffic situation 100 also involves three further vehicles 60 each further vehicle 60 comprising a wireless communication unit 62 and a control unit 61 being connected to the respective wireless communication unit 62. All vehicles 50, 60 are user equipment (UE) devices 10 with respect to a radio access network (RAN) 30.

[0041] The traffic situation 100 comprises a road segment 110 with a lane 111 being used by the vehicle 50 and one further vehicle 60 and an adjacent lane 112 being used by two further vehicles 60 each following a trajectory 63 and one of them approaching the vehicle 50 from behind and the other one approaching the vehicle 50 in an opposite direction. It is noted that the road segment 110 exemplarily makes a curve wherein the further vehicle 60 approaching the vehicle 50 in the opposite direction is hidden, i.e. can neither be seen by a driver of the vehicle 50 nor detected by a sensor of the vehicle 50. Furthermore, the traffic situation 100 comprises an access point 31, an edge data server 33 and a backbone having a plurality of backbone nodes 34. The edge data server 33 is connected both to the access point 31 and the backbone.

[0042] The vehicles 50, 60 and the edge data center 33 may have been configured by a computer program product. The computer program product comprises a computer readable storage medium storing a program code. The program code is executable by the control units 51, 61 of the vehicles 50, 60 or the edge data center 33 being connected to the radio access network 30, respectively, and causes the control units 51, 61 or the data edge server 33 to carry out the method described below when being executed by a processor of the control units 51, 61 or the edge data center 33, respectively.

[0043] The vehicle 50 is operated as follows. The vehicle 50 transmits vehicle data 54, 55 to an edge data center 33 being connected to the radio access network 30 via a wireless connection 20 (uplink) being established by a communication unit 52 of the vehicle 50.

[0044] The edge data center 33 updates a digital traffic model of the traffic situation 100 involving the vehicle 50 with the transmitted vehicle data 54, 55, calculates a trajectory 53, 53' of the vehicle 50 based on the updated digital traffic model and transmits trajectory data 35 of the calculated trajectory 53, 53' to the vehicle 50 via the wireless connection 20 (downlink).

[0045] The vehicle 50 is operated according to the transmitted trajectory data 35. The vehicle 50 may be operated autonomously to automatically follow the trajectory 53, 53' corresponding to the transmitted trajectory data 35. Alternatively, the vehicle 50 may be operated by a driver manually following the trajectory 53, 53' corresponding to the transmitted trajectory data 35. When a difference between actual operational data 54 of the vehicle 50 and the transmitted trajectory data 35 exceeds a predetermined threshold value a warning may be displayed to the driver. Due to the warning the driver may adjust the actual trajectory of the vehicle 50 to the trans-

mitted trajectory 53, 53'.

[0046] Calculating the trajectory 53, 53' comprises taking into account respective transmission delays of the transmitted vehicle data 54, 55 and the transmitted trajectory data 35.

[0047] The further vehicles 60 being involved in the traffic situation 100 also transmit vehicle data 64, 65 to the edge data center 33 via wireless connections 20 being established by the respective communication unit 62 of the further vehicles 60. The edge data center 33 updates the digital traffic model of the traffic situation 100 with the transmitted vehicle data 64, 65 of the further vehicles 60.

[0048] Each transmission delay may be taken into account as a maximum uplink latency or a maximum downlink latency being allocated to the wireless connections 20 of the vehicle 50 and the further vehicles 60 by the radio access network 30.

[0049] The radio access network 30 preferably allocates a predetermined combination of a minimum data rate and/or a maximum latency for uplink and downlink, respectively, to each wireless connection 20 of the vehicle 50 and the further vehicles 60.

[0050] Calculating the trajectory 53, 53' may also comprise taking into account a processing time for processing the vehicle data 54, 55, 64, 65 with the processing time being employed by at least one of the edge data center 33 being connected to the radio access network 30, the vehicle 50 and the further vehicle 60 and/or a round trip time (RTT) of the operational data between a core of the radio access network 30 and the edge data center 33.

[0051] It is preferred that each vehicle 50, 60 transmits operational data 54, 64 and/or technical specification data 55, 65 as the vehicle data 54, 55, 64, 65. The operational data 54, 64 may comprise a GPS position, a velocity and an acceleration of the vehicle 50, 60 and a digital environmental model of the vehicle 50, 60. Particularly, the digital environmental model of the vehicle 50 comprises operational data, e.g. positions, velocities, accelerations, etc. of each further vehicle 60 being involved in the traffic situation of the vehicle 50 and vice versa. The operational data of each further vehicle 60 may be detected sensorially, e.g. by an optical sensor, i.e. a camera, a radar sensor or a lidar sensor of the vehicle 50, and/or received via a wireless connection from the further vehicle 60 either immediately (vehicle-to-vehicle, V2V) or via the radio access network 30 (vehicle-to-infrastructure-to-vehicle, V2I2V).

[0052] The technical specification data may comprise a maximum velocity and a maximum acceleration of the vehicle 50, 60. Apart from that, each vehicle 50, 60 may transmit the vehicle data 54, 55, 64, 65 periodically, e.g. successively at equal time intervals, and/or when a difference between the transmitted trajectory data 35 and actual operational data of the vehicle 50 or the further vehicle 60, respectively, exceeds a predetermined threshold value, e.g. event driven.

[0053] Furthermore, calculating the trajectory 53, 53'

may comprise using a digital road map comprising the road segment 110 accommodating the traffic situation 100 and traffic data, e.g. weather data, data related to construction areas, traffic jam data and the like, concerning the road segment 110 accommodating the traffic situation 100 and being received from an external server.

[0054] The vehicle 50 preferably adjusts the trajectory 53, 53' corresponding to the transmitted trajectory data 35 depending on sensorially detected environmental data.

[0055] The edge data center 33 may calculate the trajectory 53, 53' depending on an availability of the radio access network 30 for the vehicle 50, e.g. a more conservative trajectory 53 without a lane change or at a lower speed may be calculated when the availability of the radio access network 30 is at least partially poor for the traffic situation 100 while a more optimized trajectory 53' with a lane change or at a higher speed for overtaking may be calculated when the availability of the radio access network 30 is continuously high for the traffic situation 100.

[0056] The edge data center 33 preferably determines a confidence level of the digital traffic model and determines a length of the calculated trajectory 53, 53' depending on the determined confidence level, e.g. a shorter length is determined for a lower confidence level while a longer length is determined for a higher confidence level. The edge data center 33 may determine the confidence level depending on a redundancy of the transmitted vehicle data 54, 55, 64, 65 and an accuracy of a forecast of the traffic situation 100. Data items being consistently covered by the vehicle data 54, 55, 64, 65 of a plurality of vehicles 50, 60, i.e. redundant data items, increase the confidence level of the digital traffic model.

The more accurate the traffic situation may be forecast the higher the confidence level of the digital traffic model may be determined.

Reference Numerals

[0057]

- 10 user equipment device
- 20 wireless connection
- 21 wireless connection
- 30 radio access network
- 31 access node
- 32 access node
- 33 edge data center
- 34 backbone node
- 35 trajectory data
- 40 internet
- 50 vehicle
- 51 control unit

52 wireless communication unit
 53 trajectory
 53' trajectory
 54 operational data
 55 technical specification data

60 further vehicle
 61 control unit
 62 wireless communication unit
 63 trajectory
 64 operational data
 65 technical specification data

100 traffic situation
 110 road segment
 111 lane
 112 adjacent lane

Claims

1. A method for operating a vehicle (50), wherein

- a vehicle (50) transmits vehicle data (54, 55) to an edge data center (33) being connected to a radio access network (30) via a wireless connection (20, 21) being established by a communication unit (52) of the vehicle (50);
- the edge data center (33) updates a digital traffic model of a traffic situation (100) involving the vehicle (50) with the transmitted vehicle data (54, 55), calculates a trajectory (53, 53') of the vehicle (50) based on the updated digital traffic model and transmits trajectory data (35) of the calculated trajectory (53, 53') to the vehicle (50) via the wireless connection (20, 21);
- the vehicle (50) is operated according to the transmitted trajectory data (35); and
- calculating the trajectory (53, 53') comprises taking into account respective transmission delays of the transmitted vehicle data (54, 55) and the transmitted trajectory data (35).

2. The method according to claim 1, wherein a further vehicle (60) being involved in the traffic situation (100) transmits vehicle data (64, 65) to the edge data center (33) via a wireless connection (20, 21) being established by a communication unit (62) of the further vehicle (60) and the edge data center (33) updates the digital traffic model of the traffic situation (100) with the transmitted vehicle data (64, 65) of the further vehicle (60).

3. The method according to one of claims 1 to 3, wherein each transmission delay is taken into account as a maximum uplink latency or a maximum downlink latency being allocated to the wireless connection (20, 21) of the vehicle (50) or the further vehicle (60)

by the radio access network (30).

4. The method according to one of claims 1 to 3, wherein calculating a trajectory (53, 53') comprises taking into account a processing time for processing the vehicle data (54, 55, 64, 65) with the processing time being employed by at least one of the edge data center (33) being connected to the radio access network (30), the vehicle (50) and the further vehicle (60) and/or a round trip time of the operational data between a backbone of the radio access network (30) and the edge data center (33).

5. The method according to one of claims 1 to 4, wherein the radio access network (30) allocates a predetermined combination of a minimum data rate and/or a maximum latency for uplink and downlink, respectively, to each wireless connection (20, 21) of the vehicle (50) and the further vehicle (60).

6. The method according to one of claims 1 to 5, wherein each vehicle (50, 60) transmits operational data (54, 64) and/or technical specification data (55, 65) as the vehicle data (54, 55, 64, 65) and/or transmits the vehicle data (54, 55, 64, 65) periodically and/or when a difference between the transmitted trajectory data (35) and actual operational data of the vehicle (50) or the further vehicle (60), respectively, exceeds a predetermined threshold value.

7. The method according to one of claims 1 to 6, wherein calculating the trajectory (53, 53') comprises using a digital road map comprising a road segment (110) accommodating the traffic situation (100) and traffic data concerning the road segment (110) accommodating the traffic situation (100).

8. The method according to one of claims 1 to 7, wherein the vehicle (50) adjusts the trajectory (53, 53') corresponding to the transmitted trajectory data (35) depending on sensorially detected environmental data.

9. The method according to one of claims 1 to 8, wherein the edge data center (33) calculates the trajectory (53, 53') depending on an availability of the radio access network (30) for the vehicle (50).

10. The method according to one of claims 1 to 9, wherein the edge data center (33) determines a confidence level of the digital traffic model and determines a length of the calculated trajectory (53, 53') depending on the determined confidence level.

11. The method according to claim 10, wherein the edge data center (33) determines the confidence level depending on a redundancy of the transmitted vehicle data (54, 55, 64, 65) and/or an accuracy of a forecast of the traffic situation (100).

12. The method according to one of claims 1 to 11, wherein the vehicle (50) is operated autonomously and automatically follows a trajectory (53, 53') corresponding to the transmitted trajectory data (35).
13. The method according to one of claims 1 to 11, wherein the vehicle (50) is operated manually by a driver following a trajectory (53, 53') corresponding to the transmitted trajectory data (35) and a warning is displayed to the driver when a difference between actual operational data of the vehicle (50) and the transmitted trajectory data (35) exceeds a predetermined threshold value.
14. A vehicle (50), comprising a wireless communication unit (52) and a control unit (51) being connected to the wireless communication unit (52) and being configured for carrying out a method according to one of claims 1 to 13.
15. A computer program product, comprising a computer readable storage medium storing a program code, the program code being executable by a control unit (51) of a vehicle (50) or an edge data center (33) being connected to a radio access network (30) and causing the control unit (51) or the data edge server to carry out a method according to one of claims 1 to 13 when being executed by a processor of the control unit (51) or the edge data center (33), respectively.

Amended claims in accordance with Rule 137(2) EPC.

1. A method for operating a vehicle (50), wherein
- a vehicle (50) transmits vehicle data (54, 55) to an edge data center (33) being connected to a radio access network (30) via a wireless connection (20, 21) being established by a communication unit (52) of the vehicle (50);
 - the edge data center (33) updates a digital traffic model of a traffic situation (100) involving the vehicle (50) with the transmitted vehicle data (54, 55), calculates a trajectory (53, 53') of the vehicle (50) based on the updated digital traffic model and transmits trajectory data (35) of the calculated trajectory (53, 53') to the vehicle (50) via the wireless connection (20, 21); and
 - the vehicle (50) is operated according to the transmitted trajectory data (35), **characterized in that**
 - calculating the trajectory (53, 53') comprises taking into account respective transmission delays of the transmitted vehicle data (54, 55) and the transmitted trajectory data (35) by updating the received vehicle data (54, 55) being outdated due to the transmission delay of the transmitted vehicle data (54, 55) to the actual time

and by updating the transmitted trajectory data (53) to the future reception time of the vehicle (50).

2. The method according to claim 1, wherein a further vehicle (60) being involved in the traffic situation (100) transmits vehicle data (64, 65) to the edge data center (33) via a wireless connection (20, 21) being established by a communication unit (62) of the further vehicle (60) and the edge data center (33) updates the digital traffic model of the traffic situation (100) with the transmitted vehicle data (64, 65) of the further vehicle (60).
3. The method according to one of claims 1 to 3, wherein each transmission delay is taken into account as a maximum uplink latency or a maximum downlink latency being allocated to the wireless connection (20, 21) of the vehicle (50) or the further vehicle (60) by the radio access network (30).
4. The method according to one of claims 1 to 3, wherein calculating a trajectory (53, 53') comprises taking into account a processing time for processing the vehicle data (54, 55, 64, 65) with the processing time being employed by at least one of the edge data center (33) being connected to the radio access network (30), the vehicle (50) and the further vehicle (60) and/or a round trip time of the operational data between a backbone of the radio access network (30) and the edge data center (33).
5. The method according to one of claims 1 to 4, wherein the radio access network (30) allocates a predetermined combination of a minimum data rate and/or a maximum latency for uplink and downlink, respectively, to each wireless connection (20, 21) of the vehicle (50) and the further vehicle (60).
6. The method according to one of claims 1 to 5, wherein each vehicle (50, 60) transmits operational data (54, 64) and/or technical specification data (55, 65) as the vehicle data (54, 55, 64, 65) and/or transmits the vehicle data (54, 55, 64, 65) periodically and/or when a difference between the transmitted trajectory data (35) and actual operational data of the vehicle (50) or the further vehicle (60), respectively, exceeds a predetermined threshold value.
7. The method according to one of claims 1 to 6, wherein calculating the trajectory (53, 53') comprises using a digital road map comprising a road segment (110) accommodating the traffic situation (100) and traffic data concerning the road segment (110) accommodating the traffic situation (100).
8. The method according to one of claims 1 to 7, wherein the vehicle (50) adjusts the trajectory (53, 53') cor-

responding to the transmitted trajectory data (35) depending on sensorially detected environmental data.

9. The method according to one of claims 1 to 8, wherein the edge data center (33) calculates the trajectory (53, 53') depending on an availability of the radio access network (30) for the vehicle (50). 5
10. The method according to one of claims 1 to 9, wherein the edge data center (33) determines a confidence level of the digital traffic model and determines a length of the calculated trajectory (53, 53') depending on the determined confidence level. 10
11. The method according to claim 10, wherein the edge data center (33) determines the confidence level depending on a redundancy of the transmitted vehicle data (54, 55, 64, 65) and/or an accuracy of a forecast of the traffic situation (100). 15
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12. The method according to one of claims 1 to 11, wherein the vehicle (50) is operated autonomously and automatically follows a trajectory (53, 53') corresponding to the transmitted trajectory data (35). 25
13. The method according to one of claims 1 to 11, wherein the vehicle (50) is operated manually by a driver following a trajectory (53, 53') corresponding to the transmitted trajectory data (35) and a warning is displayed to the driver when a difference between actual operational data of the vehicle (50) and the transmitted trajectory data (35) exceeds a predetermined threshold value. 30
14. A vehicle (50), comprising a wireless communication unit (52) and a control unit (51) being connected to the wireless communication unit (52) and being configured for carrying out a method according to one of claims 1 to 13. 35
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15. A computer program product, comprising a computer readable storage medium storing a program code, the program code being executable by a control unit (51) of a vehicle (50) or an edge data center (33) being connected to a radio access network (30) and causing the control unit (51) or the data edge server to carry out a method according to one of claims 1 to 13 when being executed by a processor of the control unit (51) or the edge data center (33), respectively. 45
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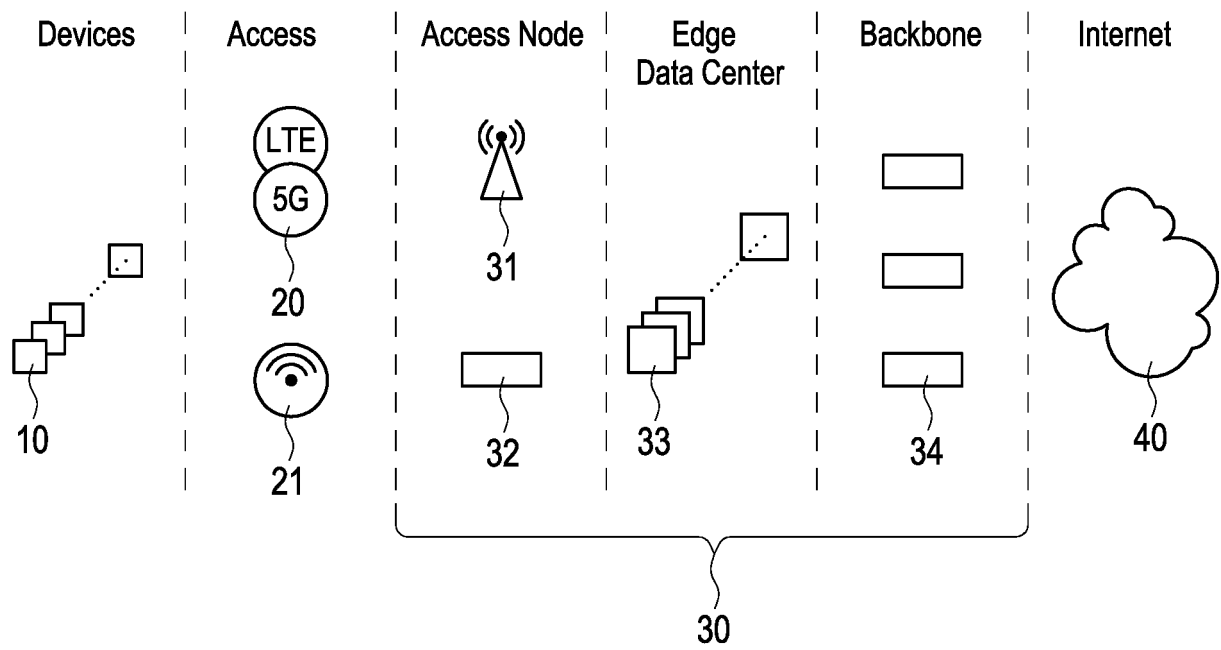


Fig. 1

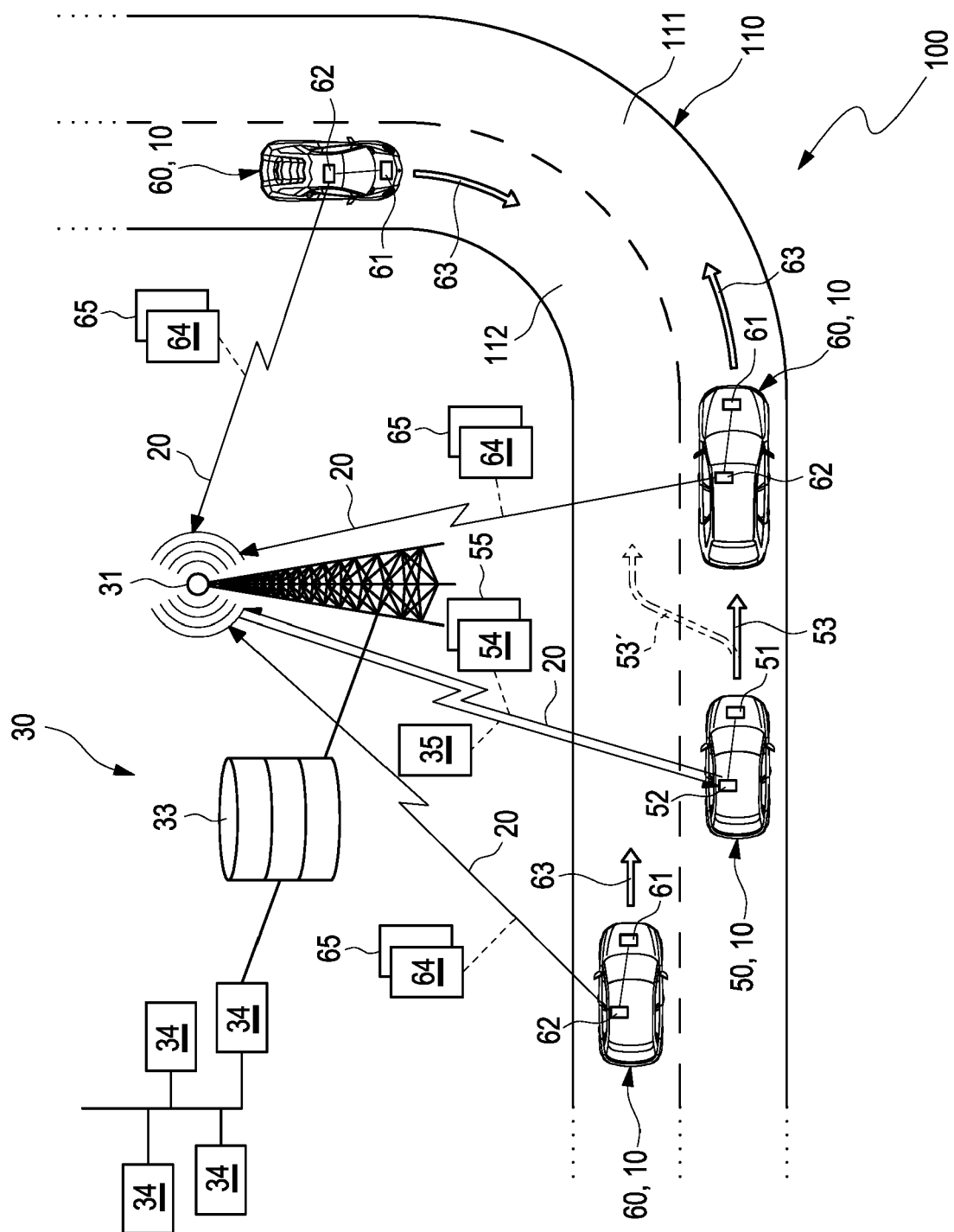


Fig. 2



EUROPEAN SEARCH REPORT

Application Number
EP 20 17 5940

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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	WO 2019/180700 A1 (LIVEU LTD [IL]) 26 September 2019 (2019-09-26) * paragraphs 13, 16, 25, 30, 34, 35, 40, 41, 44, 48, 49, 52, 55, 58, 59, 60, 62, 73, 75, 78, 84, 89, 93, 94-98, 100, 104, 105, 110, 137, 149, 160, 181; claims 1,2; figures 1-4 *	1-15	INV. G08G1/01 G08G1/0967 G08G1/0968 G08G1/16
A	US 2020/026290 A1 (LIM SUNHEE [KR]) 23 January 2020 (2020-01-23) * the whole document *	1-15	
A	US 2018/213376 A1 (PINHEIRO ANA LUCIA [US] ET AL) 26 July 2018 (2018-07-26) * the whole document *	1-15	
A	US 2017/309172 A1 (LINDER ERIC [US]) 26 October 2017 (2017-10-26) * the whole document *	1-15	
			TECHNICAL FIELDS SEARCHED (IPC)
			G05D G01C G08G H04W B60W H04L
The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
The Hague		16 October 2020	Datondji, Sokèmi
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

EPO FORM 1503 03.82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 20 17 5940

5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

16-10-2020

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2019180700 A1	26-09-2019	NONE	
US 2020026290 A1	23-01-2020	KR 20190105539 A US 2020026290 A1	17-09-2019 23-01-2020
US 2018213376 A1	26-07-2018	CN 107852763 A EP 3323270 A1 HK 1251843 A1 JP 2018527771 A US 2018213376 A1 WO 2017011039 A1	27-03-2018 23-05-2018 12-04-2019 20-09-2018 26-07-2018 19-01-2017
US 2017309172 A1	26-10-2017	CN 107305131 A EP 3299766 A1 US 2017309172 A1 US 2018211521 A1	31-10-2017 28-03-2018 26-10-2017 26-07-2018