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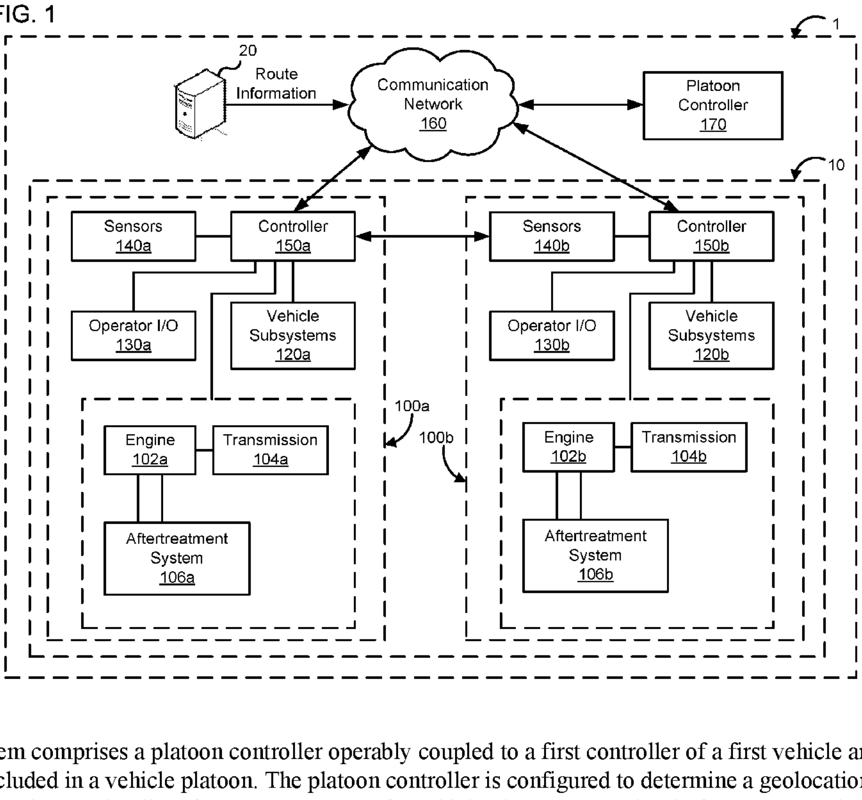
(54) Title: PREDICTIVE AND OPTIMAL VEHICLE OPERATION CONTROL IN PLATOONING OPERATIONS

FIG. 1



(57) **Abstract:** A system comprises a platoon controller operably coupled to a first controller of a first vehicle and a second controller of a second vehicle included in a vehicle platoon. The platoon controller is configured to determine a geolocation of each vehicle. The platoon controller determines a plurality of route parameters of a vehicle platoon route ahead of a current geolocation of each vehicle, and also determines an engine speed and a powertrain load of the vehicles for reducing an energy consumption based on the plurality of route parameters. Furthermore, the platoon controller instructs at least one of the first controller and the second controller to selectively adjust the engine speed and the powertrain load of the vehicles based on the geolocation of each vehicle on the vehicle platoon route.

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PREDICTIVE AND OPTIMAL VEHICLE OPERATION CONTROL IN PLATOONING OPERATIONS

Cross-Reference to Related Applications

[0001] This application claims priority to and the benefit of U.S. Provisional Application No. 62/585,109, filed November 13, 2017 and entitled "Predictive and Optimal Vehicle Operation Control in Platooning Operations," which is hereby incorporated herein by reference in its entirety.

Technical Field

[0002] The present disclosure relates generally to control systems for maximizing energy economy of vehicles operating in a vehicle platoon.

Background

[0003] Platooning is an effective approach for reducing vehicle drag on vehicles. Such vehicles can include vehicles powered by internal combustion (IC) engines (e.g., diesel, gasoline, natural gas, ethanol, biodiesel or dual fuel vehicles), hybrid vehicles or electric powered vehicles. Platooning allows two vehicles to follow each other very closely (e.g., having a distance therebetween which is less than or equal to one vehicle length) with vehicle to vehicle communication, such that the drag on the following vehicle is reduced by the lead vehicle. This results in significant reduction in fuel consumption. Generally, the distance between two vehicles operating in platoon formation is less than 1 vehicle length. Drafting is another similar concept but the distance between the two vehicles is between 1-2 vehicle lengths or greater. Platooning provides much more favorable results during operation on flat long routes. However, road grade, changing traffic patterns, changes in speed limit, etc. can impact the fuel savings in conventional platooning operation. For example, in conventional platooning operation in which the focus is on maintaining a predetermined distance between the lead and the following vehicle/s, road grade or other changes on the vehicle platoon route often cause the following vehicle to accelerate rapidly, or use hard braking to maintain the distance from the lead vehicle, which adversely affects fuel economy.

Summary

[0004] Embodiments described herein relate generally to systems and methods for reducing energy consumption of vehicles included in a vehicle platoon, and in particular to a platoon controller in communication with each of a plurality of vehicles included in the vehicle platoon through a communication network such as the cloud. The platoon controller is operable to analyze a route information of a route of the vehicles in the vehicle platoon, and control an engine speed and/or a powertrain load (or torque) of the each of the vehicles in the vehicle platoon independently, so as to minimize energy consumption of each of the plurality of vehicles in the vehicle platoon, thereby maximizing an energy economy of the entire platoon.

[0005] In some embodiments, a system comprises a platoon controller operably coupled to a first controller of a first vehicle and a second controller of a second vehicle included in a vehicle platoon. The platoon controller is configured to determine a geolocation of each of the first vehicle and the second vehicle. The platoon controller determines a plurality of route parameters of a vehicle platoon route ahead of a current geolocation of the first vehicle and the second vehicle. The platoon controller also determines at least one of an engine speed or a powertrain load of the first vehicle and the second vehicle for reducing an energy consumption of each of the first vehicle and the second vehicle on the platoon route based on the plurality of route parameters. The platoon controller instructs at least one of the first controller or the second controller to selectively adjust the engine speed and the powertrain load of the first vehicle and the second vehicle, respectively based on the geolocation thereof on the vehicle platoon route.

[0006] In some embodiments, a method comprises determining a geolocation of each of a first vehicle and a second vehicle included in a vehicle platoon and traveling on a vehicle platoon route. A plurality of route parameters of the vehicle platoon route ahead of a current geolocation of the first vehicle and the second vehicle are determined. At least one of an engine speed or a powertrain load of the first vehicle and the second vehicle for reducing an energy consumption of each of the first vehicle and the second vehicle on the platoon route based on the plurality of route parameters is determined. The engine speed and the powertrain load of the first vehicle and the second vehicle are adjusted based on the geolocation of the first vehicle and the second vehicle, respectively on the vehicle platoon route.

[0007] In some embodiments, a non-transitory computer-readable media having processor-readable instructions stored thereon, such that when executed by a processor of a platoon controller operably coupled to a first controller of a first vehicle and a second controller of a second vehicle included in a vehicle platoon, causes the platoon controller to perform operations comprising: determining a geolocation of each of the first vehicle and the second vehicle; determining a plurality of route parameters of a vehicle platoon route ahead of a current geolocation of the first vehicle and the second vehicle; determining at least one of an engine speed or a powertrain load of the first vehicle and the second vehicle for reducing an energy consumption of each of the first vehicle and the second vehicle on the platoon route based on the plurality of route parameters; and instructing at least one of the first controller or the second controller to selectively adjust the engine speed and the powertrain load of the first vehicle and the second vehicle, respectively based on the geolocation of the first vehicle and the second vehicle on the vehicle platoon route.

[0008] It should be appreciated that all combinations of the foregoing concepts and additional concepts discussed in greater detail below (provided such concepts are not mutually inconsistent) are contemplated as being part of the subject matter disclosed herein. In particular, all combinations of claimed subject matter appearing at the end of this disclosure are contemplated as being part of the subject matter disclosed herein.

Brief Description of Drawings

[0009] The foregoing and other features of the present disclosure will become more fully apparent from the following description and appended claims taken in conjunction with the accompanying drawings. Understanding that these drawings depict only several implementations in accordance with the disclosure and are therefore not to be considered limiting of its scope, the disclosure will be described with additional specificity and detail through use of the accompanying drawings.

[0010] FIG. 1 is a schematic illustration of a system comprising a vehicle platoon and a platoon controller, according to an embodiment.

[0011] FIG. 2 is a schematic illustration showing the determination of route information of a vehicle platoon route by the platoon controller of FIG. 1 and determining a predictive horizon of an engine speed and a powertrain load of each vehicle included in the vehicle platoon of FIG. 1 corresponding to a maximum energy economy of each vehicle at each geolocation on the vehicle platoon route included in the predictive horizon.

[0012] FIG. 3 is a schematic block diagram of the platoon controller of FIG. 1, according to an embodiment.

[0013] FIG. 4 is a schematic flow diagram of a method of determining a plurality of route parameters of a vehicle platoon route of a plurality of vehicles included in a vehicle platoon, and predictively adjusting at least an engine speed and powertrain load of each vehicle included in the vehicle platoon so as to minimize energy consumption, according to an embodiment.

[0014] FIG. 5 is a schematic block diagram of a computing device which may be used as the controller of the vehicles shown in FIGS. 1, and/or 3.

[0015] Reference is made to the accompanying drawings throughout the following detailed description. In the drawings, similar symbols typically identify similar components unless context dictates otherwise. The illustrative implementations described in the detailed description, drawings, and claims are not meant to be limiting. Other implementations may be utilized, and other changes may be made, without departing from the spirit or scope of the subject matter presented here. It will be readily understood that the aspects of the present disclosure, as generally described herein and illustrated in the figures, can be arranged, substituted, combined, and designed in a wide variety of different configurations, all of which are explicitly contemplated and made part of this disclosure.

Detailed Description

[0016] Embodiments described herein relate generally to systems and methods for reducing energy consumption of vehicles included in a vehicle platoon, and in particular to a platoon controller in communication with each of a plurality of vehicles included in the vehicle platoon through a communication network such as the cloud. The platoon controller is operable to analyze a route information of a route of the vehicles in the vehicle platoon, and control an engine speed and/or a powertrain load (or torque) of the each of the vehicles in the vehicle platoon independently, so as to reduce energy consumption of each of the plurality of vehicles in the vehicle platoon, thereby maximizing or at least improving an energy economy of the entire platoon of vehicles.

[0017] In conventional platooning operation in which the focus is on maintaining a predetermined distance between the lead and the following vehicle/s, road grade or other changes on the vehicle platoon route often cause the following vehicle to accelerate rapidly, or use hard braking to maintain the distance from the lead vehicle, which adversely affects energy economy (e.g., fuel economy). For example, during downhill operation, with conventional powertrain control, when the lead vehicle gets close to downhill operation, the predictive cruise control reduces the speed of the lead vehicle. The predictive cruise control then increases the cruise speed reference over the hill to save vehicle kinetic energy. However, conventional platooning operations are configured only to maintain the distant between the lead vehicle and the following vehicle. The following vehicle has to lower its speed far from the downhill operation and then accelerate to reach the lead vehicle. This increases energy consumption (e.g., fuel consumption or battery power consumption) and reduces the benefits of platooning, for example, by more than 50%.

[0018] Similarly, when the lead vehicle in a vehicle platoon encounters a steep uphill, the lead vehicle may experience a large increase in speed followed by change of a gear (e.g., downshift of a transmission of the lead vehicle). This may result in an increase in the distance or gap between the two vehicles. The following vehicle may have to significantly increase its speed so as to maintain the gap, and once the desired gap is achieved, it may strongly brake. This behavior also negatively impacts the energy economy.

[0019] Various embodiments of the systems and methods described herein may provide benefits including, for example: (1) using a central platoon controller to control operation of each vehicle in a vehicle platoon; (2) determining look ahead information of a plurality of route parameters of a vehicle route including road grade, traffic lights, traffic signs, traffic patterns, weather patterns such as wind or rain, etc. to predict optimal speed for each vehicle and distance therebetween for maximizing energy economy; and (3) predict and independently adjust at least an engine speed and powertrain load of each vehicle in a vehicle platoon so as to maximize energy economy of each vehicle included in the vehicle platoon, and thereby the entire vehicle platoon.

[0020] FIG. 1 is a schematic illustration of a system 1 including a vehicle platoon 10 and a platoon controller 170, according to an embodiment. As shown in FIG. 1, the vehicle platoon 10 includes a first vehicle 100a and a second vehicle 100b (collectively referred to herein as “the vehicles 100”). In other embodiments, the vehicle platoon 10 may include any number of vehicles, for example 3, 4, 5, 10 or even more. The first vehicle 100a is the lead vehicle and the second vehicle 100b follows the first vehicle 100a, for example at a predetermined distance therefrom so as to reduce a drag on the second vehicle 100b and maximize energy economy.

[0021] As shown in FIG. 1, the first vehicle 100a and the second vehicle 100b generally include first vehicle subsystems 120a and second vehicle subsystems 120b (collectively referred to herein as “the vehicle subsystems 120”), a first operator input/output (I/O) 130a and a second vehicle I/O 130b (collectively referred to herein as “the operator I/O 130”), a first sensor 140a and a second sensor 140b ((collectively referred to herein as “the sensors 140”), and a first controller 150a and a second controller 150b (collectively referred to herein as “the controllers 150”), respectively. Furthermore, the first vehicle 100a and the second vehicle 100b comprise a first powertrain and a second powertrain including a first engine 102a and second engine 102b (collectively referred to herein as “the engines 102”), and a first transmission 104a and a second transmission 104b (collectively referred to herein as “the transmissions 104”). In some embodiments, in which the engines 102 include diesel engines, the first vehicle 100a and the second vehicle 100b may also include a first aftertreatment system 106a and a second aftertreatment system 106b (collectively referred to herein as “the aftertreatment systems 106”), respectively.

[0022] In the example depicted, the engines 102 are diesel engines and energy economy and energy consumption imply fuel economy and fuel consumption, respectively. However, in other embodiments, the engines 102 may be another type of IC engine, such as a gasoline engine, a natural gas engine, a dual fuel engine, an ethanol engine, and/or a biodiesel engine, or a fuel cell. In still other embodiments, the vehicles 100 may comprise a hybrid vehicle or an electric vehicle. In such embodiments, the engines 102 may comprise a motor (e.g., a DC motor) and the vehicles 100 may include batteries to power the vehicles 100. In such embodiments, maximizing energy economy implies minimizing energy consumption of the batteries. The vehicles 100 may be an on-road or an off-road vehicle including, but not limited to, line-haul trucks, mid-range trucks (e.g., pick-up truck), cars (e.g., sedans, hatchbacks, coupes, etc.), buses, vans, refuse vehicles, delivery trucks, and any other type of vehicle. Thus, the present disclosure is applicable with a wide variety of implementations.

[0023] Similarly, the transmissions 104 may be structured as any type of transmission, such as a continuous variable transmission, a manual transmission, an automatic transmission, an automatic-manual transmission, a dual clutch transmission, and so on. Accordingly, as transmissions vary from geared to continuous configurations (e.g., continuous variable transmission), the transmissions 104 may include a variety of settings (gears, for a geared transmission) that affect different output speeds based on an input speed received thereby.

[0024] The controllers 150 are operably coupled to the components of the corresponding vehicle 100 using any type and any number of wired or wireless connections. For example, a wired connection may include a serial cable, a fiber optic cable, a CAT5 cable, or any other form of wired connection. Wireless connections may include the Internet, Wi-Fi, cellular, radio, Bluetooth, ZigBee, etc. In one embodiment, a controller area network (CAN) bus provides the exchange of signals, information, and/or data. The CAN bus includes any number of wired and wireless connections. Because the controllers 150 are communicably coupled to the systems and components of the corresponding vehicle 100 of FIG. 1, the controllers 150 are structured to receive data regarding one or more of the components shown in FIG. 1. For example, the data may include operation data regarding the operating conditions of the engines 102, the transmissions 104, and/or other components (e.g., a battery system, a motor, a generator, a regenerative braking system, an engine, etc.) acquired by one or more sensors, such as sensors 140 or the vehicle subsystems 120. As another example, the data may include an input from operator I/O device 130. The controllers 150 may determine how to control the engines 102 and the transmissions 104 based on the operation data, or based on input from the platoon controller 170, as described herein. In some embodiments, the controllers 150 may include the computing device 630, as described in detail herein with respect to FIG. 5.

[0025] As mentioned above, in this example, the engines 102 are a diesel engine. Additionally and in this embodiment, a first aftertreatment system 106a and a second aftertreatment system 106b is operatively coupled to each of the first engine 102a and the second engine 102b, respectively and configured to reduce constituents of an exhaust gas passing therethrough (e.g., nitrogen oxide (NOx), sulfur oxide (SOx), carbon monoxide (CO), particulate matter, ammonia, etc.). The aftertreatment systems 106 may comprise, for example a selective catalytic reduction (SCR) catalyst, a diesel oxidation catalyst (DOC), a diesel particulate filter (DPF), a diesel exhaust fluid (DEF) doser with a supply of diesel exhaust fluid, a plurality of sensors for monitoring the aftertreatment systems 106 (e.g., a nitrogen oxide (NOx) sensor, temperature sensors, etc.), and/or still other components.

[0026] The vehicle subsystems 120 may include one or more electrically-powered accessories and/or engine-drive accessories. Electrically-powered accessories may receive power from an energy storage device included in the vehicles 100 to facilitate operation thereof. Being electrically-powered, the accessories may be able to be driven largely independent of the engines 102 of the vehicles 100 (e.g., not driven off of a belt coupled to the engines 102). The electrically-powered accessories may include, but are not limited to, air compressors (e.g., for pneumatic devices, etc.), air conditioning systems, power steering pumps, engine coolant pumps, fans, and/or any other electrically-powered vehicle accessories.

[0027] The operator I/O device 130 may enable an operator of the vehicle 100 (or passenger or manufacturing, service, or maintenance personnel) to communicate with the vehicles 100 and the controllers 150. By way of example, the operator I/O device 130 may include, but is not limited to, an interactive display, a touchscreen device, one or more buttons and switches, voice command receivers, and the like. In one embodiment, the operator I/O device 130 includes a brake pedal or a brake lever, an accelerator pedal, and/or an accelerator throttle.

[0028] The sensors 140 may include sensors positioned and/or structured to monitor operating characteristics of various components of the vehicle 100. For example, the sensors 140 may include a sensor structured to facilitate monitoring of a state of charge ("SOC") of a battery, a state of health ("SOH") of a battery, and/or the engines 102. The sensors 140 may additionally or alternatively include a geolocation sensor structured to determine a geolocation of each of the vehicles 100. The sensors 140 may additionally or alternatively include a speed sensor structured to facilitate monitoring the speed of the vehicle 100. The sensors 140 may additionally or alternatively include road grade monitoring, traffic monitoring and/or weather monitoring sensor.

[0029] The platoon controller 170 is communicatively coupled to each of the first controller 150a of the first vehicle 100a and the second controller 150b of the second vehicle 100b included in the vehicle platoon 10, via a communication network 120, for example a cloud communication network. The communication network 120 may include any suitable Local Area Network (LAN) or Wide Area Network (WAN). For example, the communication network 120 can be supported by Frequency Division Multiple Access (FDMA), Time Division Multiple Access (TDMA), Code Division Multiple Access (CDMA) (particularly, Evolution-Data Optimized (EVDO)), Universal Mobile Telecommunications Systems (UMTS) (particularly, Time Division Synchronous CDMA (TD-SCDMA or TDS) Wideband Code Division Multiple Access (WCDMA), Long Term Evolution (LTE), evolved Multimedia Broadcast Multicast Services (eMBMS), High-Speed Downlink Packet Access (HSDPA), and the like), Universal Terrestrial Radio Access (UTRA), Global System for Mobile Communications (GSM), Code Division Multiple Access 1x Radio Transmission Technology (1x), General Packet Radio Service (GPRS), Personal Communications Service (PCS), 802.11X, ZigBee, Bluetooth, Wi-Fi, any suitable wired network, combination thereof, and/or the like. The communication network 120 is structured to permit the exchange of data, values, instructions, messages, and the like between the platoon controller 170 and the controllers 150.

[0030] Referring to FIGS. 1-2, the platoon controller 170 is configured to determine a geolocation of each of the first vehicle 100a and the second vehicle 100b. For example, the vehicle subsystems 120 may include global positioning system (GPS) configured to determine a geolocation of the vehicles 100. The controllers 150 may communicate the geolocation of the corresponding vehicles 100 to the platoon controller 170 via the communication network 120, and the platoon controller 170. The platoon controller 170 may determine and update the geolocation of each of the first vehicle 100a and the second vehicle 100b in real time.

[0031] The platoon controller 170 determines a plurality of route parameters or a vehicle platoon route ahead of a current geolocation of the first vehicle100a and the second vehicle 100b. For example, the platoon controller 170 may be communicatively coupled to an external notification system 20, for example a map system (e.g., GOOGLE MAPS®, APPLE MAPS, WAZE®, etc.), a news service (e.g., CNN®, FOX®, ABC®, CBS®, etc.), a weather reporting system (e.g., the WEATHER CHANNEL®, local or global weather reporting services, etc.), or any combination thereof via the communication network 120. The platoon controller 170 may receive route information from the external notification system 20 and determine, the plurality of route parameters therefrom.

[0032] As shown in FIG. 2, the plurality of route parameters may comprise a static route parameter, which includes a route parameter that only changes spatially but not temporally. These may include, for example a road grade, a speed limit, traffic signs, etc. In other embodiments, the plurality of route parameters may additionally or alternatively include a dynamic route parameter, that is a route parameter which may change spatially as well as temporary. Such route parameters may include, for example traffic flow, surrounding vehicle information, traffic lights, weather patterns, emergency vehicle information, etc. In various embodiments, the platoon controller 170 may determine the plurality of route parameters over a fixed distance on the vehicle platoon route ahead of the current geolocation of the first vehicle 100a (e.g., 1 mile, 2 miles, 3 miles, 5 miles, 10 miles or any other suitable distance or combination thereof). In other embodiments, the platoon controller 170 may determine the plurality of route parameters over a predetermined travel time from a current geolocation of the first vehicle 100a (e.g., 5 minutes, 10 minutes, 15 minutes, 30 minutes, 1 hour, 2 hour or any other travel time or a combination thereof).

[0033] The platoon controller 170 is configured to determine at least one of an engine speed and a powertrain load of the first vehicle 100a and the second vehicle 100b for minimizing an energy consumption of each of the first vehicle 100a and the second vehicle 100b on the platoon route based on the plurality of route parameters. The platoon controller 170 may determine the engine speed and the powertrain load over a predetermined prediction horizon as shown in FIG. 2. For example, the platoon controller 170 may determine the optimal engine speed and/or powertrain load for an operating parameter of each of the first vehicle 100a and the second vehicle 100b at each location over a predetermined distance on the vehicle route ahead of a current geolocation (e.g., 1 mile, 2 miles, 3 miles, 5 miles, 10 miles or any other suitable distance or combination thereof) of the vehicles 100. Said another way, the platoon controller 170 determines what the optimal engine speed and/or powertrain load of each of the vehicles 100 should be to maximize energy economy (i.e., the operating parameter) of the vehicle platoon 10 at any given location ahead of the current geolocation of the vehicles 100 up to a predetermined distance.

[0034] Expanding further, unexpected changes in the route, for example steep uphill or downhill grade on the route, speed limit changes, traffic lights, traffic pattern changes or congestion, wind, rain, emergency vehicle passage or criminal activity may cause the first vehicle 100a to make sudden changes in engine speed and powertrain load or torque. In conventional systems, the following vehicle is only configured to maintain a predetermined distance from the lead vehicle to minimize energy consumption and maximize energy economy. Sudden changes in engine speed of the lead vehicle, for example when going uphill or downhill, experiencing traffic congestion, traffic lights, dangerous weather conditions causes the following vehicle to apply sudden braking or acceleration so as to maintain the predetermined distance which decreases energy economy.

[0035] The platoon controller 170 however, determines the engine speed and the powertrain load for each of the first vehicle 100a and the second vehicle 100b based on the plurality of route parameters (e.g., dependent on a vehicle mass of the vehicles 100) over the prediction horizon, as shown in FIG. 2. In other words, the platoon controller 170 predictively determines the engine speed and the powertrain load for each of the vehicles 100 which may cause each of the vehicle 100 in the vehicle platoon 10 to have maximum energy economy at any segment of the route based on their current geolocation, instead of solely relying on maintain a predetermined distance between them. This may provide optimal energy economy for each of the vehicles 100 and, thereby an optimal energy economy for the vehicle platoon 10. For example, the vehicles 100 operating in the vehicle platoon 10 may have an energy economy which is greater than 25% relative to an energy economy of vehicles operating in a vehicle platoon that does not employ the platoon controller 170.

[0036] As described herein, the term “maximum energy economy” implies that the energy economy of the vehicle 100, for example a fuel economy or a battery discharge rate at any vehicle speed is at least 90% of a theoretical maximum energy economy, for example 10-30 mpg (e.g., 10, 12, 15, 17, 19, 21, 23, 25, 27 or 30 mpg inclusive of all ranges and values therebetween) or 30 – 70 miles per gallon equivalent (mpge) for electrified vehicles (e.g., 30, 35, 40, 45, 50, 55, 60, 65 or 70 mpge inclusive of all ranges and values therebetween) determined to be achievable by the vehicle 100 (e.g., via EPA fuel economy tests) at the corresponding vehicle speed under normal operating conditions. As described herein, the term “optimal energy economy” implies a theoretical optimal energy economy achievable by the vehicle 100 when operating in platoon formation at any location of the vehicle route based on the plurality of route parameters and a distance between the vehicles 100 as determined by the platoon controller 170. The optimal energy economy may be within 30% of the theoretical maximum energy economy of the vehicles 100.

[0037] The platoon controller 170 instructs each of the first controller 150a and the second controller 150b to selectively adjust the engine speed and the powertrain load of the first vehicle 100a and the second vehicle 100b, respectively based on the geolocation thereof on the vehicle platoon route. For example, the platoon controller 170 may determine that there is a steep downhill on the route ahead. The platoon controller 170 may instruct the first controller 150a to reduce an engine speed and the powertrain load of the first vehicle 100a before approaching the steep downhill. Furthermore, the platoon controller 170 may also instruct the second controller 150b to reduce an engine speed and powertrain load of the second vehicle 100b predictively, instead of in response to the first vehicle 100a braking. In this manner, sudden braking or acceleration of the vehicles 100 is avoided which may adversely impact the energy economy of the vehicle platoon 10.

[0038] In some embodiments, the platoon controller 170 may determine the engine speed and powertrain load for the optimal energy economy of the first vehicle 100a based on the plurality of route parameters of the vehicle platoon route ahead of the current geolocation of the first vehicle 100a, and communicate them to the first controller 150a. The first controller 150a may predictively adjust an engine speed and powertrain load of the first vehicle 100a so as to avoid sudden acceleration or braking. The second controller 150b of the second vehicle 100b may then adjust the engine speed and powertrain load of the second vehicle 100b, for example responsive to a communication from the first controller 150a, or based on a distance from the first vehicle 100a. In particular embodiments, the platoon controller 170 may be configured to instruct the second controller 150b to adjust the engine speed and/or powertrain load of the second vehicle 100b so as to maintain the predetermined distance between the first vehicle 100a and second vehicle 100b.

[0039] In various embodiments, the platoon controller 170 determines the engine speed and powertrain load for the optimal energy economy of the second vehicle 100b based on the plurality of route parameters of the vehicle platoon route ahead of the current geolocation of the first vehicle 100a, and communicate them to the second controller 150b. The second controller 150b of the second vehicle 100b may then adjust the engine speed and powertrain load of the second vehicle 100b predictively based on anticipated operation of the leading first vehicle 100a. In particular embodiments, the second controller 150b may also communicate with the first controller 150a, for example to provide instructions to the first controller 150a to adjust the engine speed and powertrain load of the first vehicle 100a based on the plurality of route parameters ahead of the current geolocation of the first vehicle 100a.

[0040] In some embodiments as previously described, the engines 102 of the vehicles 100 may comprise diesel engines having the aftertreatment systems 106 fluidly coupled thereto. In such embodiments, the platoon controller 170 may be configured to determine an aftertreatment system temperature and/or a reductant insertion rate of the aftertreatment systems 106 so as to minimize NOx emissions based on the plurality of route parameters. For example, the aftertreatment systems 106 may include an SCR system structured to reduce constituents of an exhaust gas (e.g., NOx gases) in the presence of a reductant (e.g., urea, an aqueous urea solution, a diesel exhaust fluid or ammonia gas).

[0041] The aftertreatment system temperature and reductant insertion rate for optimal operation of the aftertreatment systems 106 depend upon the exhaust flow rate of the exhaust gas produced by the engines 102 and an amount of NOx therein, which is dependent on the engine speed and/or powertrain load. In other words, the aftertreatment system temperatures and/or reductant insertion rates for maintaining an optimal catalytic conversion efficiency of the aftertreatment systems 106 may depend on the aftertreatment system temperature and reductant insertion rate corresponding to a particular engine speed and powertrain load. The platoon controller 170 may therefore instruct at least one of the first controller 150a and the second controller 150b to adjust the aftertreatment system temperature and/or the reductant insertion rate of the first aftertreatment system 106a and/or the second aftertreatment system 106b based on the geolocation of the first vehicle 100a and the second vehicle 100b on the vehicle platoon route. For example, if the platoon controller 170 determines that the first vehicle 100a will be moving into a transient/acceleration mode of operation from a fuel cut mode of operation as determined from the plurality of route parameters on the vehicle platoon route ahead of the first vehicle 100a, the platoon controller 170 may instruct the first aftertreatment system 106a to increase the aftertreatment system temperature and/or reductant insertion rate to reduce future spike in NOx emissions. Similarly, the platoon controller 170 may also instruct the second aftertreatment system 106b to increase the temperature and/or reductant insertion rate.

[0042] In particular embodiments, the platoon controller 170 may be further configured to instruct each of the first controller 150a and the second controller 150b to dynamically adjust a route of the first vehicle 100a and the second vehicle 100b based on the plurality of route parameters so as to minimize energy consumption of each of the first vehicle 100a and the second vehicle 100b. For example, the platoon controller 170 may determine that an alternate vehicle platoon route may provide the optimal energy economy and instruct the controllers 150 adjust the vehicle route of the vehicles 100 to the alternate vehicle route.

[0043] In various embodiments, the platoon controller 170 may comprise an electronic control unit configured to receive various signals from the controllers 150 of the vehicles 100 and communicate instructions thereto for controlling the engine speed and powertrain load thereof for optimal fuel efficiency. As shown in FIG. 3, the platoon controller 170 includes a processing circuit 171 having a processor 172 and a memory 173, a geolocation circuit 174, a vehicle speed circuit 176, a route information circuit 178, and a communications interface 190. The platoon controller 170 also includes a response management circuitry 180 having an acceleration circuit 182, a deceleration circuit 184, a transmission circuit 186 and an aftertreatment management circuit 188.

[0044] The processor 172 may comprise a microprocessor, programmable logic controller (PLC) chip, an ASIC chip, or any other suitable processor. The processor 172 is in communication with the memory 173 (e.g., a non-transitory computer-readable media) and configured to execute instructions, algorithms, commands, or otherwise programs stored in the memory 173. The memory 173 may comprise any of the memory and/or storage components discussed herein. For example, memory 173 may comprise a RAM and/or cache of processor 172. The memory 173 may also comprise one or more storage devices (e.g., hard drives, flash drives, computer readable media, etc.) either local or remote to the platoon controller 170. The memory 173 is configured to store look up tables, algorithms, or instructions.

[0045] In one configuration, the geolocation circuit 174, the vehicle speed circuit 176, and the response management circuitry 180 are embodied as machine or computer-readable media (e.g., stored in the memory 173) that is executable by a processor, such as the processor 172. As described herein and amongst other uses, the machine-readable media (e.g., the memory 173) facilitates performance of certain operations to enable reception and transmission of data. For example, the machine-readable media may provide an instruction (e.g., command, etc.) to, e.g., acquire data. In this regard, the machine-readable media may include programmable logic that defines the frequency of acquisition of the data (or, transmission of the data). Thus, the computer readable media may include code, which may be written in any programming language including, but not limited to, Java or the like and any conventional procedural programming languages, such as the "C" programming language or similar programming languages. The computer readable program code may be executed on one processor or multiple remote processors. In the latter scenario, the remote processors may be connected to each other through any type of network (e.g., CAN bus, etc.).

[0046] In another configuration the geolocation circuit 174, the vehicle speed circuit 176, the route information circuit 178 and the response management circuitry 180 are embodied as hardware units, such as electronic control units. As such, the geolocation circuit 174, the vehicle speed circuit 176, the route information circuit 178 and the response management circuitry 180 may be embodied as one or more circuitry components including, but not limited to, processing circuitry, network interfaces, peripheral devices, input devices, output devices, sensors, etc. In some embodiments, the geolocation circuit 174, the vehicle speed circuit 176, and the response management circuitry 180 may take the form of one or more analog circuits, electronic circuits (e.g., integrated circuits (IC), discrete circuits, system on a chip (SOCs) circuits, microcontrollers, etc.), telecommunication circuits, hybrid circuits, and any other type of “circuit.” In this regard, the geolocation circuit 174, the vehicle speed circuit 176, the route information circuit 178 and the response management circuitry 180 may include any type of component for accomplishing or facilitating achievement of the operations described herein. For example, a circuit as described herein may include one or more transistors, logic gates (e.g., NAND, AND, NOR, OR, XOR, NOT, XNOR, etc.), resistors, multiplexers, registers, capacitors, inductors, diodes, wiring, and so on.

[0047] Thus, the geolocation circuit 174, the vehicle speed circuit 176, the route information circuit 178 and/or the response management circuitry 180 may also include programmable hardware devices such as field programmable gate arrays, programmable array logic, programmable logic devices or the like. In this regard the geolocation circuit 174, the vehicle speed circuit 176, the route information circuit 178 and the response management circuitry 180 may include one or more memory devices for storing instructions that are executable by the processor(s) of the geolocation circuit 174, the vehicle speed circuit 176, the route information circuit 178 and the response management circuitry 180. The one or more memory devices and processor(s) may have the same definition as provided below with respect to the memory 173 and the processor 172.

[0048] In the example shown, the platoon controller 170 includes the processing circuit 171 having the processor 172 and the memory 173. The processing circuit 171 may be structured or configured to execute or implement the instructions, commands, and/or control processes described herein with respect the geolocation circuit 174, the vehicle speed circuit 176, the route information circuit 178 and the response management circuitry 180. Thus, the depicted configuration represents the aforementioned arrangement where the geolocation circuit 174, the vehicle speed circuit 176, the route information circuit 178 and the response management circuitry 180 are embodied as machine or computer-readable media. However, as mentioned above, this illustration is not meant to be limiting as the present disclosure contemplates other embodiments such as the aforementioned embodiment where the geolocation circuit 174, the vehicle speed circuit 176, the route information circuit 178 and the response management circuitry 180, or at least one circuit of the geolocation circuit 174, the vehicle speed circuit 176, the route information circuit 178 and the response management circuitry 180 are configured as a hardware unit. All such combinations and variations are intended to fall within the scope of the present disclosure.

[0049] The processor 172 may be implemented as one or more general-purpose processors, an application specific integrated circuit (ASIC), one or more field programmable gate arrays (FPGAs), a digital signal processor (DSP), a group of processing components, or other suitable electronic processing components. In some embodiments, the one or more processors may be shared by multiple circuits (e.g., the geolocation circuit 174, the vehicle speed circuit 176, the route information circuit 178 and the response management circuitry 180 may comprise or otherwise share the same processor which, in some example embodiments, may execute instructions stored, or otherwise accessed, via different areas of memory). Alternatively or additionally, the one or more processors may be structured to perform or otherwise execute certain operations independent of one or more co-processors. In other example embodiments, two or more processors may be coupled via a bus to enable independent, parallel, pipelined, or multi-threaded instruction execution. All such variations are intended to fall within the scope of the present disclosure. The memory 173 (e.g., RAM, ROM, Flash Memory, hard disk storage, etc.) may store data and/or computer code for facilitating the various processes described herein. The memory 173 may be communicably connected to the processor 172 to provide computer code or instructions to the processor 172 for executing at least some of the processes described herein. Moreover, the memory 173 may be or include tangible, non-transient volatile memory or non-volatile memory. Accordingly, the memory 173 may include database components, object code components, script components, or any other type of information structure for supporting the various activities and information structures described herein.

[0050] The communications interface 190 may include wireless interfaces (e.g., jacks, antennas, transmitters, receivers, transceivers, wire terminals, etc.) for conducting data communications with various systems, devices, or networks. For example, the communications interface 190 may include an Ethernet card and port for sending and receiving data via an Ethernet-based communications network and/or a Wi-Fi transceiver for communicating with the controllers 150 of the vehicles 100 via the communication network 120. The communications interface 190 may be structured to communicate via local area networks or wide area networks (e.g., the Internet, etc.) and may use a variety of communications protocols (e.g., IP, LON, Bluetooth, ZigBee, radio, cellular, near field communication, etc.).

[0051] The geolocation circuit 174 is structured to receive geolocation data (e.g., physical location of the vehicles 100 on the vehicle platoon route), for example from the controllers 150, which is indicative of the geolocation of the vehicles 100. The geolocation circuit 174 may thereby facilitate determining the current geolocation of each of the first vehicle 100a and the second vehicle 100b on the vehicle platoon route. The geolocation data may be received in real time such that the platoon controller 170 continuously or sequentially determines and updates the geolocation of the vehicles 100.

[0052] The vehicle speed circuit 176 is structured to receive vehicle speed data from the controllers 150 and determine the respective vehicle speed of the first vehicle 100a and the second vehicle 100b. For example, the sensors 140 may include speed sensors structured to acquire speed data of the vehicles 100 which may be communicated to the controllers 150. The vehicle speed circuit 176 of the platoon controller 170 may receive the vehicle speed data from the controllers 150, for example, via the communication network 120, and interpret the vehicle speed data so as to determine the vehicle speed of the vehicles 100 therefrom. In some embodiments, the vehicle speed data may include information corresponding to the engine speed and powertrain transmission load of the vehicles 100. The vehicle speed circuit 176 may be configured to determine a current engine speed and powertrain load of the engines 102 at the current geolocation of the vehicles 100.

[0053] The route information circuit 178 is structured to receive route information from the external notification system 20 and determine a plurality of route parameters of the vehicle platoon route ahead of the first vehicle 100a and the second vehicle 100b. For example, the route information circuit 178 may determine a plurality of static route parameters such as a road function class (e.g., freeway/interstate, arterial roads, toll collectors, local roads, unclassified roads, etc.), a speed limit, road grades, road slope, road curvature, bridges, fuel stations, number of lanes, road surface condition and/or traffic signs, and/or dynamic route parameters such as traffic flow, surrounding vehicle information, traffic lights, weather patterns, and/or emergency vehicle information, which will be encountered by the vehicles 100 ahead of their current geolocation. In various embodiments, the route information circuit 178 may determine the plurality of route parameters over a fixed distance (e.g., the prediction horizon as shown in FIG. 2) on the vehicle platoon route ahead of the current geolocation of the first vehicle 100a (e.g., 1 mile, 2 miles, 3 miles, 5 miles, 10 miles or any other suitable distance or combination thereof). In other embodiments, the route information circuit 178 may determine the plurality of route parameters over a predetermined travel time from a current geolocation of the first vehicle 100a (e.g., 5 minutes, 10 minutes, 15 minutes, 30 minutes, 1 hour, 2 hour or any other travel time or a combination thereof).

[0054] The response management circuitry 180 is structure to receive an indication of the geolocation of the vehicles 100 (e.g., from the geolocation circuit 174), the indication of vehicle speed, engine speed and/or powertrain load of the vehicles 100 (e.g., from the vehicle speed circuit 176), and/or the plurality of route parameters (e.g., from the route information circuit 178). The response management circuitry 180 is further structured to determine the engine speed and powertrain load of the first vehicle 100a and the second vehicle 100b so as to reduce or minimize an energy consumption of each of the first vehicle 100a and the second vehicle 100b such that the vehicle platoon 10 has an optimal energy economy corresponding to the plurality of route parameters at a particular geolocation.

[0055] Furthermore, the response management circuitry 180 is structured to instruct the first controller 150a and the second controller 150b to selectively adjust the engine speed and/or the powertrain load of each of the first vehicle 100a and the second vehicle 100b based on the geolocation thereof on the vehicle platoon route, so as to reduce or minimize energy consumption and optimize energy economy for each of the first vehicle 100a and the second vehicle 100b.

[0056] Expanding further, the acceleration circuit 182 may be structured to instruct the controllers 150 to accelerate the vehicles 100 based on the plurality of route parameters. For example, the route information circuit 178 may determine that an incline is present on the vehicle route ahead of the current geolocation of the vehicles 100, or a stretch of flat road with minimal traffic which may require the first vehicle 100a and thereafter, the second vehicle 100b to accelerate (e.g., to maintain the predetermined distance therebetween). The acceleration circuit 182 may instruct the first vehicle 100a and/or the second vehicle 100b via their respective controllers 150 to increase an engine speed thereof. Predictive increase of the engine speed of the vehicles 100 may allow the vehicles 100 to gradually increase their respective engine speeds in anticipation of the changes in route parameters ahead on the vehicle platoon route, and prevent sudden acceleration, which may reduce energy economy.

[0057] The deceleration circuit 184 may be structured to instruct the controllers 150 to reduce a vehicle speed of the vehicles 100 based on the plurality of route parameters, for example via a braking operation. For example, the route information circuit 178 may determine that a slope is present on the vehicle route ahead of the current geolocation of the vehicles 100, a traffic jam, an accident, road construction and/or any other parameter which may require deceleration of the first vehicle 100a and thereafter, the second vehicle 100b (e.g., to maintain the predetermined distance therebetween). The deceleration circuit 184 may instruct the first vehicle 100a and/or the second vehicle 100b via their respectively controllers 150 to decrease an engine speed thereof. Predictive decrease of the engine speed of the vehicles 100 may allow the vehicles 100 to gradually decrease their respective engine speeds in anticipation of the changes in route parameters on the vehicle platoon route, and prevent hard braking, which may reduce energy economy.

[0058] The transmission circuit 186 may be structured to instruct the controllers 150 to adjust a powertrain load or torque by adjusting the transmissions 104, for example changing a gear of the transmissions 104 of the respective vehicles 100. For example, the route information circuit 178 may determine that an incline is present on the vehicle route ahead of the current geolocation of the vehicles 100. The transmission circuit 186 may instruct the first vehicle 100a and the second vehicle 100b via their respective controllers 150 to downshift a gear of their respective transmissions 104, so as to increase a powertrain load or torque, for example in advance of experiencing the incline.

[0059] Furthermore, the aftertreatment management circuit 188 may be structured to instruct the controllers 150 to adjust an aftertreatment system temperature and/or reductant insertion rate of the aftertreatment systems 106. For example, the route information circuit 178 may determine that an incline is present on the vehicle route ahead of the current geolocation of the vehicles 100. The aftertreatment management circuit 188 may instruct the aftertreatment systems 106 of the vehicles 100 to predictively increase an aftertreatment system temperature and/or reductant insertion rate in anticipation of a spike in NOx emission by the vehicles 100 due to acceleration on encountering the incline, thereby reducing any future NOx spike.

[0060] FIG. 4 is a schematic flow diagram of an example method 200 for optimizing energy economy of a first vehicle (e.g., the first vehicle 100a) and a second vehicle (e.g., the second vehicle 100b) included in a vehicle platoon (e.g., the vehicle platoon 10).

While described as including the first vehicle and the second vehicle, the operations of the method 200 are applicable to any number of vehicles that may be included in the vehicle platoon. As such the operations of the method 200 may be implemented with the first vehicle 100a, the second vehicle 100b and the platoon controller 170, and are therefore described with respect to FIGS. 1-3.

[0061] The geolocation circuit 174 determines a geolocation of the first vehicle 100a and the second vehicle 100b, at 202. For example, the geolocation circuit 174 of the platoon controller 170 is structured to receive geolocation information of the first vehicle 100a and the second vehicle 100b from their respective controllers 150 and determine a real time geolocation of the vehicles 100 therefrom.

[0062] In some embodiments, the vehicle speed circuit 176 determines at least one of a vehicle speed, an engine speed, and/or powertrain load of the first vehicle 100a and the second vehicle 100b, at 204. For example, the vehicle speed circuit 176 may receive vehicle speed, engine speed and/or powertrain load information from the first vehicle 100a and the second vehicle 100b via their respective controllers 150, and determine the vehicle speed, the engine speed and/or the powertrain load of the vehicles 100 at a current geolocation of the vehicles 100 on the vehicle route.

[0063] The route information circuit 178 determines a plurality of route parameters of the vehicle platoon route, at 206. For example the route information circuit 178 may receive route information from the external notification system 20, and determine the plurality of route parameters therefrom, as previously described herein. The response management circuitry 180 determines an engine speed and/or a powertrain load of the first vehicle 100a and the second vehicle 100b so as to reduce or minimize energy consumption on the vehicle route ahead of the current geolocation of the first vehicle 100a and the second vehicle 100b, at 208. For example, the response management circuitry 180 analyzes the plurality of route parameters as previously described herein, so as to determine the engine speed and the powertrain load that will minimize energy consumption (i.e., maximize energy economy) on the vehicle platoon route ahead of the current geolocation of the first vehicle 100a and the second vehicle 100b.

[0064] The response management circuitry 180 adjusts at least one of an engine speed and a powertrain load of the first vehicle 100a and the second vehicle 100b, at 210. For example, the acceleration circuit 182 may increase an engine speed, the deceleration circuit 184 may decrease an engine speed and/or the transmission circuit 186 may up shift or downshift the transmissions 104 so as to adjust the engine speed and/or the powertrain load based on the plurality of route parameters.

[0065] In some embodiments, the response management circuitry 180 may also determine an aftertreatment temperature and/or a reductant insertion rate to minimize emissions of the first vehicle 100a and the second vehicle 100b based on the plurality of route parameter, at 212. For example, the first vehicle 100a and the second vehicle 100b may include diesel powered vehicles including the aftertreatment systems 106. The response management circuitry 180 may determine the aftertreatment system temperature and/or reductant insertion rate for reducing any future spikes in NOx gases on the vehicle route ahead of the current geolocation of the first vehicle 100a and the second vehicle 100b. The aftertreatment management circuit 188 may instruct the first controller 150a and the second controller 150b to adjust the aftertreatment system temperature and/or reductant insertion rate of the first aftertreatment system 106a and the second aftertreatment system 106b, at 214.

[0066] In some embodiments, the controllers 150 described herein can comprise a computing device including a system computer of the vehicles 100. For example, FIG. 5 is a block diagram of a computing device 630 in accordance with an illustrative implementation. The computing device 630 comprise a bus 632 or other communication component for communicating information. The computing device 630 can also comprise one or more processors 634 or processing circuits coupled to the bus 632 for processing information.

[0067] The computing device 630 also comprises main memory 636, such as a random access memory (RAM) or other dynamic storage device, coupled to the bus 632 for storing information and instructions to be executed by the processor 634. Main memory 636 can also be used for storing position information, temporary variables, or other intermediate information during execution of instructions by the processor 634. The computing device

630 may further comprise ROM 638 or other static storage device coupled to the bus 632 for storing static information and instructions for the processor 634. A storage device 640, such as a solid-state device, magnetic disk or optical disk, is coupled to the bus 632 for persistently storing information and instructions.

[0068] The computing device 630 may be coupled via the bus 632 to a display 644, such as a liquid crystal display or active matrix display, for displaying information to a user. An input device 642, such as a keyboard or alphanumeric pad, may be coupled to the bus 632 for communicating information and command selections to the processor 634. In another implementation, the input device 642 has a touch screen display 644.

[0069] According to various implementations, the processes and methods described herein can be implemented by the computing device 630 in response to the processor 634 executing an arrangement of instructions contained in main memory 636 (e.g., the operations of the method 200). Such instructions can be read into main memory 636 from another non-transitory computer-readable medium, such as the storage device 640. Execution of the arrangement of instructions contained in main memory 636 causes the computing device 630 to perform the illustrative processes described herein. One or more processors in a multi-processing arrangement may also be employed to execute the instructions contained in main memory 636. In alternative implementations, hard-wired circuitry may be used in place of or in combination with software instructions to effect illustrative implementations. Thus, implementations are not limited to any specific combination of hardware and software.

[0070] Although an example computing device has been described in FIG. 5, implementations described in this specification can be implemented in other types of digital electronic, or in computer software, firmware, or hardware, including the structures disclosed in this specification and their structural equivalents, or in combinations of one or more of them.

[0071] Implementations described in this specification can be implemented in digital electronic, or in computer software, firmware, or hardware, including the structures disclosed in this specification and their structural equivalents, or in combinations of one or more of them. The implementations described in this specification can be implemented as one or more computer programs (i.e., one or more circuitries of computer program instructions) encoded on one or more computer storage media for execution by, or to control the operation of, data processing apparatus. A computer storage medium comprises a non-transitory computer readable medium and can be, or be included in, a computer-readable storage device, a computer-readable storage substrate, a random or serial access memory array or device, or a combination of one or more of them. Moreover, while a computer storage medium is not a propagated signal, a computer storage medium can be a source or destination of computer program instructions encoded in an artificially-generated propagated signal. The computer storage medium can also be, or be included in, one or more separate components or media (e.g., multiple disks, or other storage devices). Accordingly, the computer storage medium is both tangible and non-transitory.

[0072] The operations described in this specification can be performed by a data processing apparatus on data stored on one or more computer-readable storage devices or received from other sources. The term “data processing apparatus” or “computing device” encompasses all kinds of apparatus, devices, and machines for processing data, including, by way of example, a programmable processor, a computer, a system on a chip, or multiple ones, or combinations of the foregoing. The apparatus can comprise special purpose logic, e.g., an FPGA (field programmable gate array) or an ASIC (application-specific integrated circuit). In addition to hardware, the apparatus can also comprise code that creates an execution environment for the computer program in question (e.g., code that constitutes processor firmware, a protocol stack, a database management system, an operating system, a cross-platform runtime environment, a virtual machine, or a combination of one or more of them). The apparatus and execution environment can realize various different computing model infrastructures, such as web services, distributed computing and grid computing infrastructures.

[0073] A computer program (also known as a program, software, software application, script, or code) can be written in any form of programming language, including compiled or interpreted languages, declarative or procedural languages, and it can be deployed in any form, including as a stand-alone program or as a circuitry, component, subroutine, object, or other unit suitable for use in a computing environment. A computer program may, but need not, correspond to a file in a file system. A program can be stored in a portion of a file that holds other programs or data (e.g., one or more scripts stored in a markup language document), in a single file dedicated to the program in question, or in multiple coordinated files (e.g., files that store one or more circuitries, sub-programs, or portions of code). A computer program can be deployed to be executed on one computer, on multiple computers that are located at one site, or distributed across multiple sites and interconnected by a communication network.

[0074] Processors suitable for the execution of a computer program comprise, by way of example, both general and special purpose microprocessors and any one or more processors of any kind of digital computer. Generally, a processor will receive instructions and data from a read-only memory or a random access memory or both. The essential elements of a computer are a processor for performing actions in accordance with instructions and one or more memory devices for storing instructions and data. Generally, a computer will also comprise, or be operatively coupled to receive data from or transfer data to, or both, one or more mass storage devices for storing data (e.g., magnetic, magneto-optical disks, or optical disks). However, a computer need not have such devices. Devices suitable for storing computer program instructions and data comprise all forms of non-volatile memory, media and memory devices, including, by way of example, semiconductor memory devices (e.g., EPROM, EEPROM, and flash memory devices); and magnetic disks (e.g., internal hard disks or removable disks. The processor and the memory can be supplemented by, or incorporated in, special purpose logic.

[0075] It should be noted that the term “example” as used herein to describe various embodiments is intended to indicate that such embodiments are possible examples, representations, and/or illustrations of possible embodiments (and such term is not intended to connote that such embodiments are necessarily extraordinary or superlative examples).

[0076] The terms “coupled,” “connected” and the like as used herein mean the joining of two members directly or indirectly to one another. Such joining may be stationary (e.g., permanent) or moveable (e.g., removable or releasable). Such joining may be achieved with the two members or the two members and any additional intermediate members being integrally formed as a single unitary body with one another or with the two members or the two members and any additional intermediate members being attached to one another.

[0077] It is important to note that the construction and arrangement of the various exemplary embodiments are illustrative only. Although only a few embodiments have been described in detail in this disclosure, those skilled in the art who review this disclosure will readily appreciate that many modifications are possible (e.g., variations in sizes, dimensions, structures, shapes and proportions of the various elements; values of parameters, mounting arrangements; use of materials, colors, orientations, etc.) without materially departing from the novel teachings and advantages of the subject matter described herein. Additionally, it should be understood that features from one embodiment disclosed herein may be combined with features of other embodiments disclosed herein as one of ordinary skill in the art would understand. Other substitutions, modifications, changes, and omissions may also be made in the design, operating conditions, and arrangement of the various exemplary embodiments without departing from the scope of the present embodiments.

[0078] While this specification contains many specific implementation details, these should not be construed as limitations on the scope of any embodiments or of what may be claimed, but rather as descriptions of features specific to particular implementations of particular embodiments. Certain features described in this specification in the context of separate implementations can also be implemented in combination in a single implementation. Conversely, various features described in the context of a single implementation can also be implemented in multiple implementations separately or in any suitable subcombination. Moreover, although features may be described above as acting in certain combinations and even initially claimed as such, one or more features from a claimed combination can in some cases be excised from the combination, and the claimed combination may be directed to a subcombination or variation of a subcombination.

WHAT IS CLAIMED IS:

1. A system, comprising:

a platoon controller operably coupled to a first controller of a first vehicle and a second controller of a second vehicle included in a vehicle platoon, the platoon controller configured to:

determine a geolocation of each of the first vehicle and the second vehicle,

determine a plurality of route parameters of a vehicle platoon route ahead of a current geolocation of the first vehicle and the second vehicle,

determine at least one of an engine speed or a powertrain load of the first vehicle and the second vehicle for reducing an energy consumption of each of the first vehicle and the second vehicle on the platoon route based on the plurality of route parameters, and

instruct at least one of the first controller or the second controller to selectively adjust the engine speed and the powertrain load of the first vehicle and the second vehicle, respectively based on the geolocation of the first vehicle and the second vehicle on the vehicle platoon route.

2. The system of claim 1, wherein the platoon controller is configured to instruct the second controller to adjust the engine speed thereof so as to maintain a predetermined distance between the second vehicle and the first vehicle.

3. The system of claim 1, wherein the plurality of route parameters comprise a static route parameter, the static route parameter comprising at least one of a road grade, a speed limit and traffic signs.

4. The system of claim 1, wherein the plurality of route parameters comprise a dynamic route parameter, the dynamic route parameter comprising at least one of a traffic flow, surrounding vehicle information, traffic lights, weather patterns, and emergency vehicle information.

5. The system of claim 1, wherein at least one of the first vehicle and the second vehicle comprise an aftertreatment system, and wherein the platoon controller is further configured to:

determine at least one of an aftertreatment system temperature and a reductant insertion rate of the aftertreatment system so as to minimize NOx emissions based on the plurality of route parameters; and

instruct at least one of the first controller and the second controller to adjust at least one of the aftertreatment system temperature and a reductant insertion rate based on the geolocation of the first vehicle and the second vehicle on the vehicle platoon route.

6. The system of claim 1, wherein the platoon controller is further configured to instruct each of the first controller and the second controller to dynamically adjust a route of the first vehicle and the second vehicle based on the plurality of route parameters so as to minimize energy consumption of each of the first vehicle and the second vehicle.

7. The system of claim 1, further comprising a communication network communicatively coupling the platoon controller to the first controller and the second controller.

8. The system of claim 7, wherein the communication network comprises a cloud communication network.

9. The system of claim 1, wherein the platoon controller is configured to determine the plurality of route parameters over a predetermined distance on the vehicle platoon route ahead of the current geolocation of the first vehicle.

10. The system of claim 1, wherein the platoon controller is configured to determine the plurality of route parameters over a predetermined travel time on the vehicle platoon route ahead of the current geolocation of the first vehicle.

11. The system of claim 1, wherein the controller is configured to provide instructions for adjusting the engine speed and the powertrain load of the second vehicle to the first

controller, the first controller configured to communicate with the second controller to provide the instructions thereto.

12. A method, comprising:

determining a geolocation of each of a first vehicle and a second vehicle included in a vehicle platoon and traveling on a vehicle platoon route;

determining a plurality of route parameters of the vehicle platoon route ahead of a current geolocation of the first vehicle and the second vehicle;

determining at least one of an engine speed or a powertrain load of the first vehicle and the second vehicle for reducing an energy consumption of each of the first vehicle and the second vehicle on the platoon route based on the plurality of route parameters; and

selectively adjusting the engine speed and the powertrain load of the first vehicle and the second vehicle based on the geolocation of the first vehicle and the second vehicle, respectively on the vehicle platoon route.

13. The method of claim 12, adjusting the engine speed of the second vehicle so as to maintain a predetermined distance between the second vehicle and the first vehicle.

14. The method of claim 12, wherein the plurality of route parameters comprise a static route parameter, the static route parameter comprising at least one of a road grade, a speed limit and traffic signs.

15. The method of claim 12, wherein the plurality of route parameters comprise a dynamic route parameter, the dynamic route parameter comprising at least one of a traffic flow, surrounding vehicle information, traffic lights, weather patterns, and emergency vehicle information.

16. The method of claim 12, wherein at least one of the first vehicle and the second vehicle comprise an aftertreatment system, and wherein the method further comprises:

determining at least one of an aftertreatment system temperature and a reductant insertion rate of the aftertreatment system included in each of the first vehicle and the second vehicle so as to minimize NOx emissions based on the plurality of route parameters; and

adjusting at least one of the aftertreatment system temperature and a reductant insertion rate based on the geolocation of the first vehicle and the second vehicle on the vehicle platoon route.

17. The method of claim 12, further comprising dynamically adjusting a route of the first vehicle and the second vehicle based on the plurality of route parameters so as to minimize energy consumption of each of the first vehicle and the second vehicle.

18. A non-transitory computer-readable media having processor-readable instructions stored thereon, such that when executed by a processor of a platoon controller operably coupled to a first controller of a first vehicle and a second controller of a second vehicle included in a vehicle platoon, causes the platoon controller to perform operations, the operations comprising:

determining a geolocation of each of the first vehicle and the second vehicle;

determining a plurality of route parameters of a vehicle platoon route ahead of a current geolocation of the first vehicle and the second vehicle;

determining at least one of an engine speed or a powertrain load of the first vehicle and the second vehicle for reducing an energy consumption of each of the first vehicle and the second vehicle on the platoon route based on the plurality of route parameters; and

instructing at least one of the first controller or the second controller to selectively adjust the engine speed and the powertrain load of the first vehicle and the second vehicle, respectively based on the geolocation of the first vehicle and the second vehicle on the vehicle platoon route.

19. The non-transitory computer-readable media of claim 18, wherein at least one of the first vehicle and the second vehicle comprise an aftertreatment system, and wherein the operations further comprise:

determining at least one of an aftertreatment system temperature and a reductant insertion rate of the aftertreatment system so as to minimize NOx emissions based on the plurality of route parameters; and instructing at least one of the first controller and the second controller to adjust at least one of the aftertreatment system temperature and a reductant insertion rate based on the geolocation of the first vehicle and the second vehicle on the vehicle platoon route.

20. The non-transitory computer-readable media of claim 18, wherein the operations further comprise instructing each of the first controller and the second controller to dynamically adjust a route of the first vehicle and the second vehicle based on the plurality of route parameters so as to minimize energy consumption of each of the first vehicle and the second vehicle.

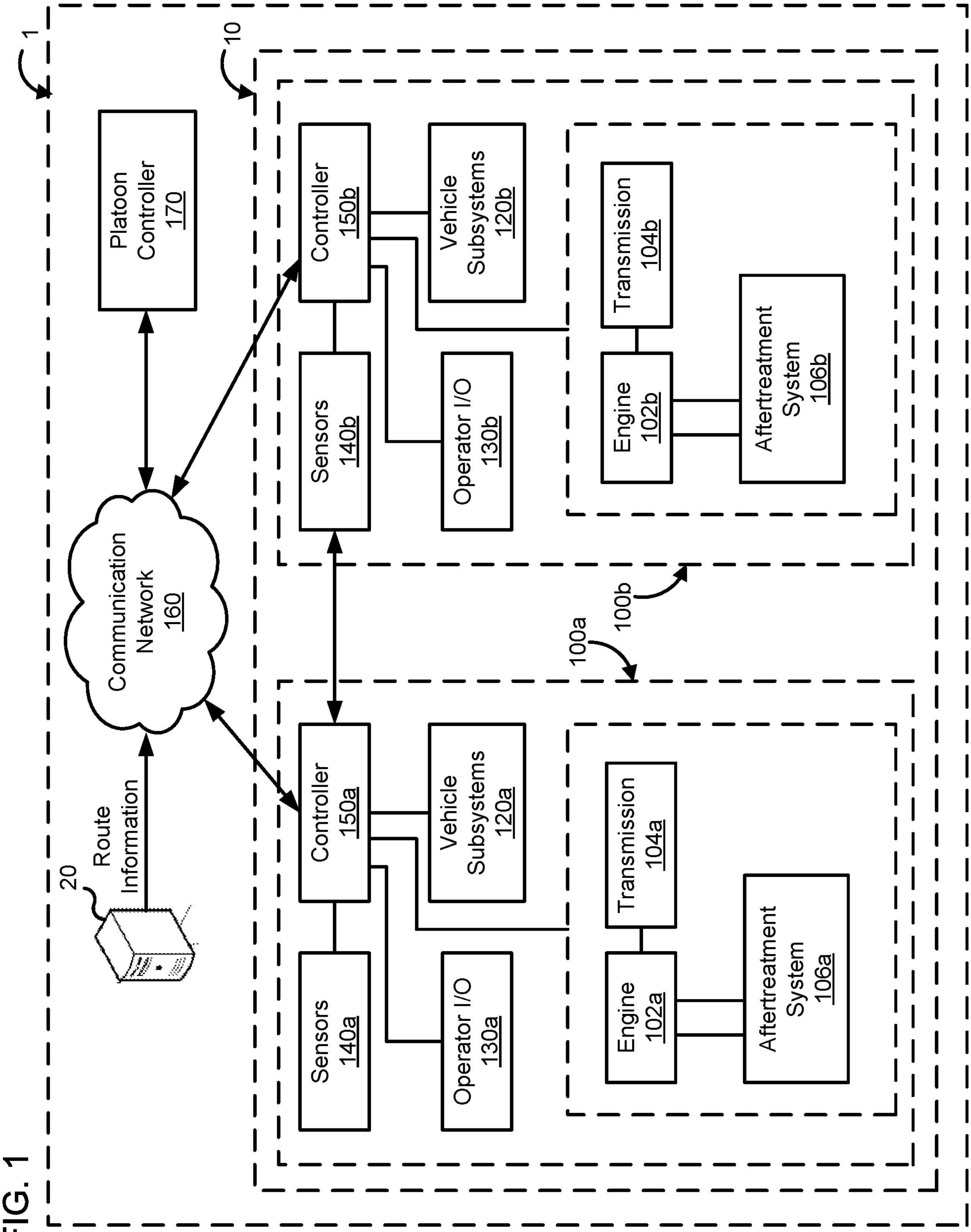

1
10
Platoon Controller 170
Communication Network 160
20
Route Information
Controller 150b
Vehicle Subsystems 120b
Sensors 140b
Operator I/O 130b
Transmission 104b
Engine 102b
Aftertreatment System 106b
100b
100a
Controller 150a
Vehicle Subsystems 120a
Sensors 140a
Operator I/O 130a
Transmission 104a
Engine 102a
Aftertreatment System 106a

FIG. 1

FIG. 2

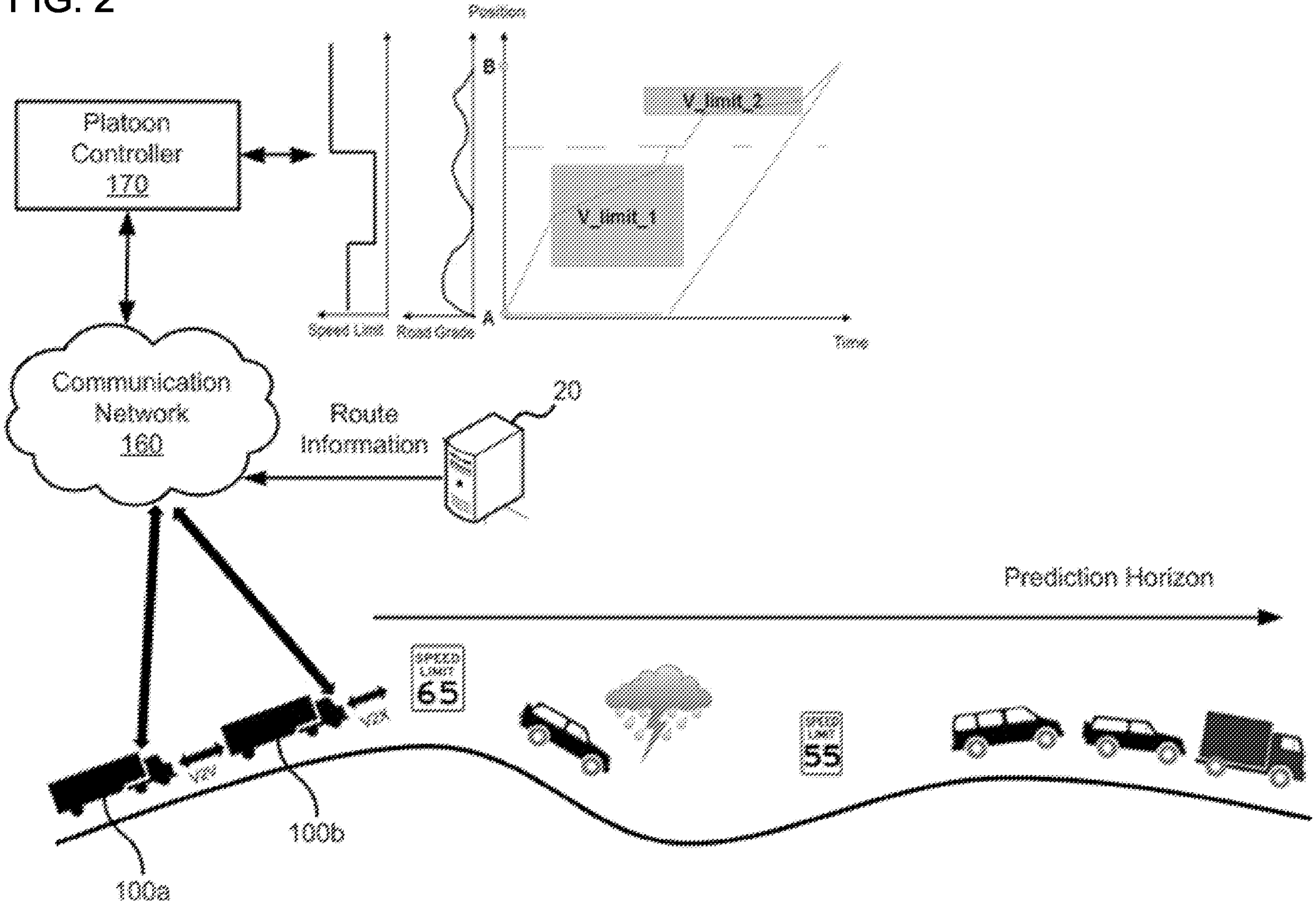

Platoon Controller 170
Position
B
V_limit_2
V_limit_1
Speed Limit
Road Grade
A
Time
Communication Network 160
Route Information
20
Prediction Horizon
SPEED LIMIT 65
SPEED LIMIT 55
V2V
V2X
100b
100a

FIG. 3

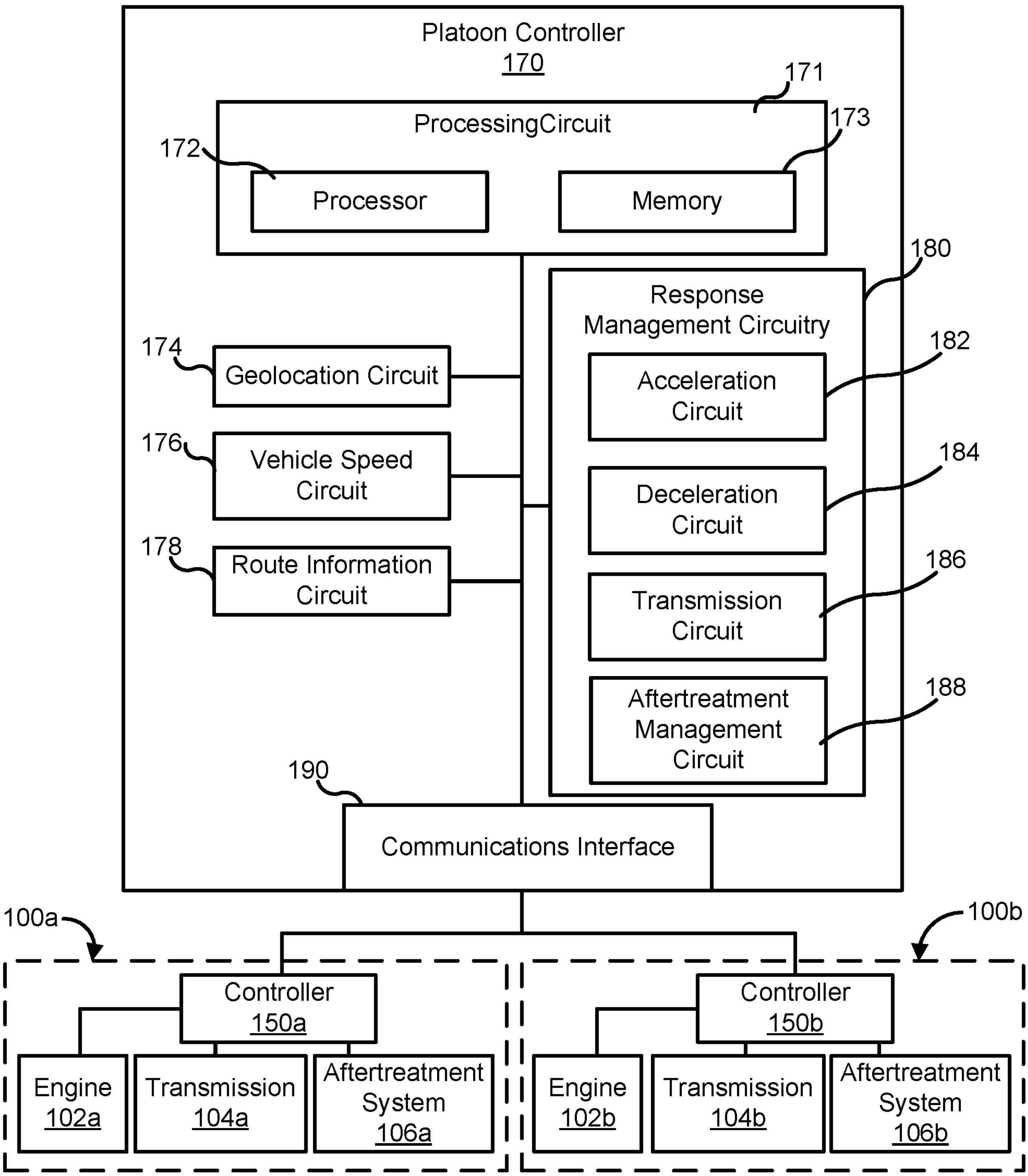

Platoon Controller
170
171
ProcessingCircuit
172
173
Processor
Memory
180
Response
Management Circuitry
174
Geolocation Circuit
182
Acceleration
Circuit
176
Vehicle Speed
Circuit
184
Deceleration
Circuit
178
Route Information
Circuit
186
Transmission
Circuit
188
Aftertreatment
Management
Circuit
190
Communications Interface
100a
100b
Controller
150a
Controller
150b
Engine
102a
Transmission
104a
Aftertreatment
System
106a
Engine
102b
Transmission
104b
Aftertreatment
System
106b

FIG. 4

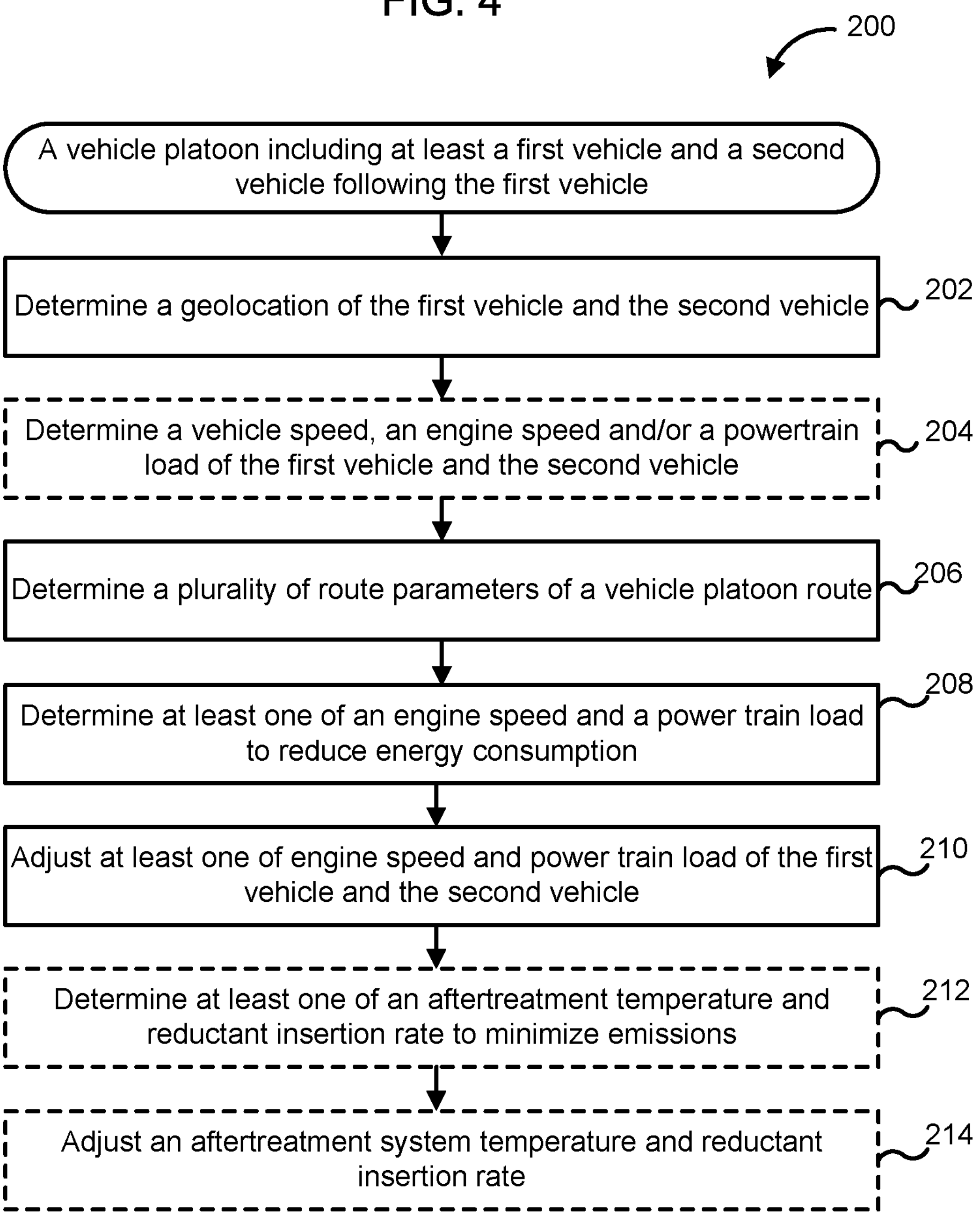
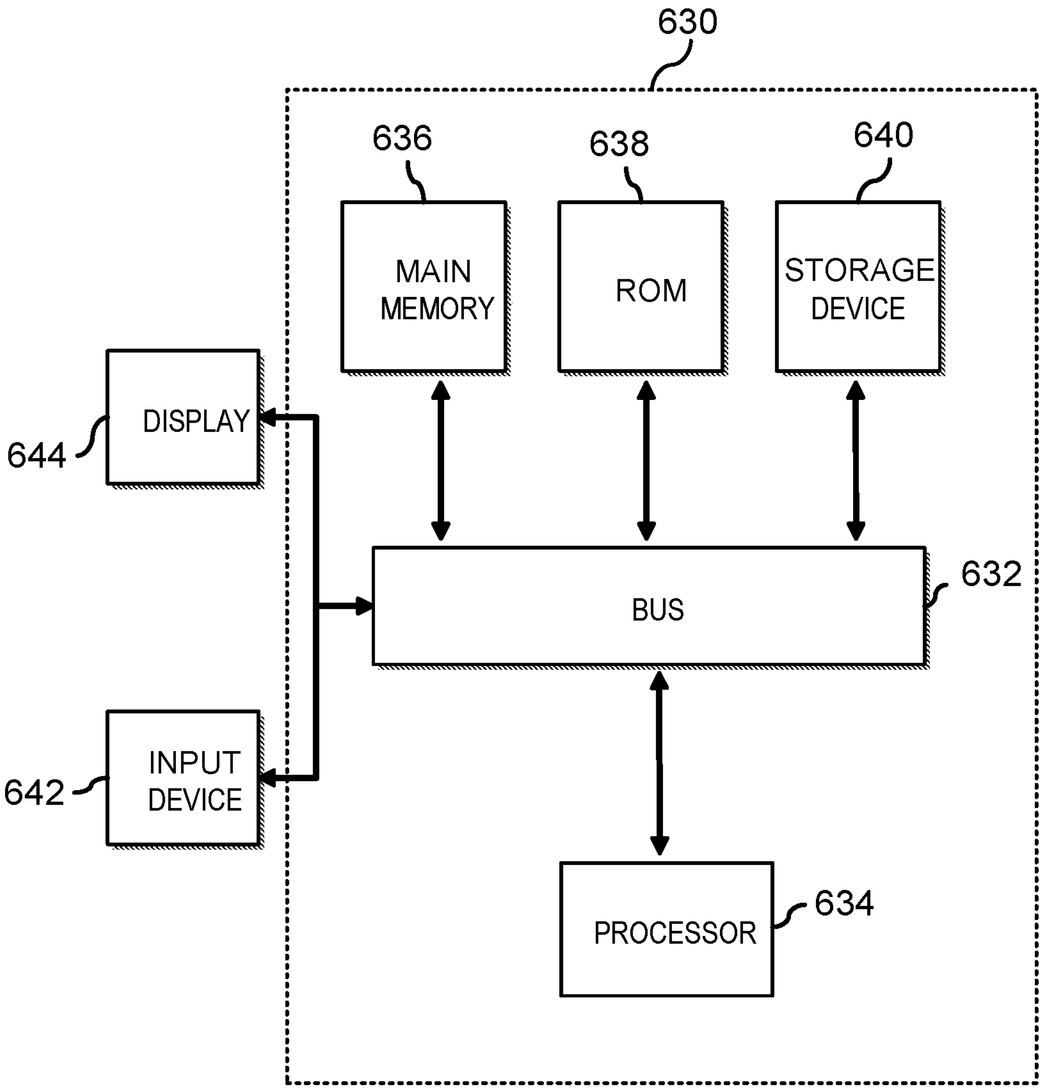

200
A vehicle platoon including at least a first vehicle and a second vehicle following the first vehicle
Determine a geolocation of the first vehicle and the second vehicle
202
Determine a vehicle speed, an engine speed and/or a powertrain load of the first vehicle and the second vehicle
204
Determine a plurality of route parameters of a vehicle platoon route
206
Determine at least one of an engine speed and a power train load to reduce energy consumption
208
Adjust at least one of engine speed and power train load of the first vehicle and the second vehicle
210
Determine at least one of an aftertreatment temperature and reductant insertion rate to minimize emissions
212
Adjust an aftertreatment system temperature and reductant insertion rate
214

FIG. 5


630
636
MAIN MEMORY
638
ROM
640
STORAGE DEVICE
644
DISPLAY
BUS
632
642
INPUT DEVICE
PROCESSOR
634

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2018/059740

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - B60W 30/18; G01C 21/34; G05D 1/02; G06F 19/00; G08G 1/00 (2018.01)
CPC - B60W 30/165; B60W 30/18; B60W 40/076; B60W 40/13; B60W 2530/10; B60W 2530/16; B60W 2550/12; G01C 21/34; G01C 21/3469; G05D 1/0088; G05D 2201/0213 (2018.08)

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)
See Search History document

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
USPC - 701/23; 701/25; 701/70 (keyword delimited)

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US 9,182,764 B1 (CUMMINS, INC.) 10 November 2015 (10.11.2015) entire document	1-4, 6-15, 17, 18, 20 --- 5, 16, 19
Y	US 2017/0101913 A1 (CUMMINS EMISSION SOLUTIONS INC.) 13 April 2017 (13.04.2017) entire document	5, 16, 19
A	US 2016/0082964 A1 (CUMMINS INC.) 24 March 2016 (24.03.2016) entire document	1-20
A	US 2015/0241226 A1 (FORD GLOBAL TECHNOLOGIES, LLC) 27 August 2015 (27.08.2015) entire document	1-20
A	US 2010/0256852 A1 (MUDALIGE) 07 October 2010 (07.10.2010) entire document	1-20
A	US 2017/0186327 A1 (OZYEGIN UNIVERSITESI et al) 29 June 2017 (29.06.2017) entire document	1-20

☐ Further documents are listed in the continuation of Box C.   ☐ See patent family annex.

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be of particular relevance		
"E"	earlier application or patent but published on or after the international filing date	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed	"&"	document member of the same patent family

Date of the actual completion of the international search 07 January 2019	Date of mailing of the international search report 22 JAN 2019
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, VA 22313-1450 Facsimile No. 571-273-8300	Authorized officer Blaine R. Copenheaver PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774