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(54) **COMPUTING SYSTEM IMPLEMENTING TRAFFIC MODELING USING SENSOR VIEW DATA FROM SELF-DRIVING VEHICLES**

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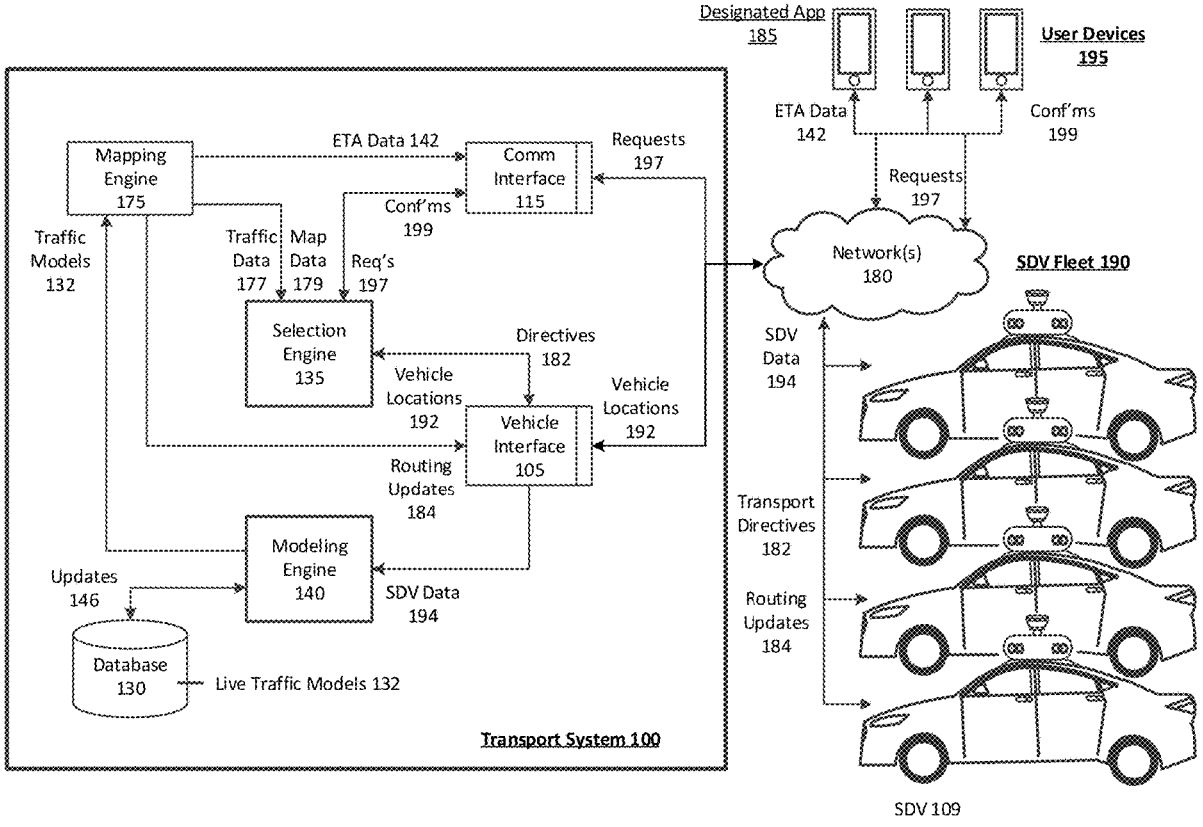
(57) **ABSTRACT**

A computing system can receive sensor view data from each self-driving vehicle (SDV) in a fleet of SDVs operating throughout a given region. The system may further determine, based on the sensor view data, a set of properties of one or more vehicles external to the SDV. Based on the set of properties of the one or more vehicles, the system can generate traffic models for the given region and generate map data for users that indicate traffic flow for at least part of the given region.



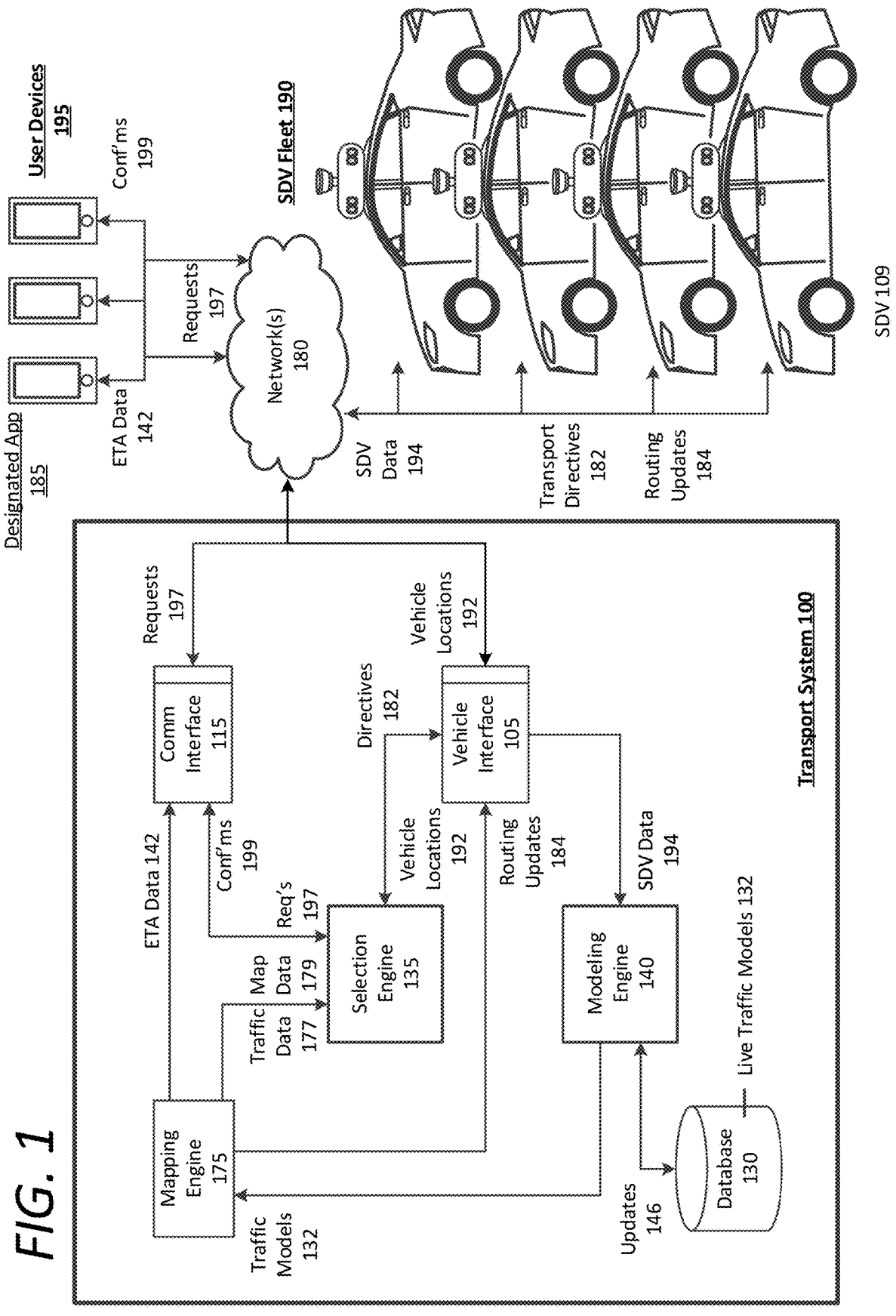


FIG. 1
Transport System 100
Designated App 185
User Devices 195
ETA Data 142
Conf'ms 199
Requests 197
Network(s) 180
SDV Fleet 190
SDV 109
SDV Data 194
Transport Directives 182
Routing Updates 184
Comm Interface 115
Vehicle Interface 105
Mapping Engine 175
Selection Engine 135
Modeling Engine 140
Database 130
Map Data 179
Traffic Data 177
Req's 197
Vehicle Locations 192
Directives 182
Traffic Models 132
Live Traffic Models 132
Updates 146

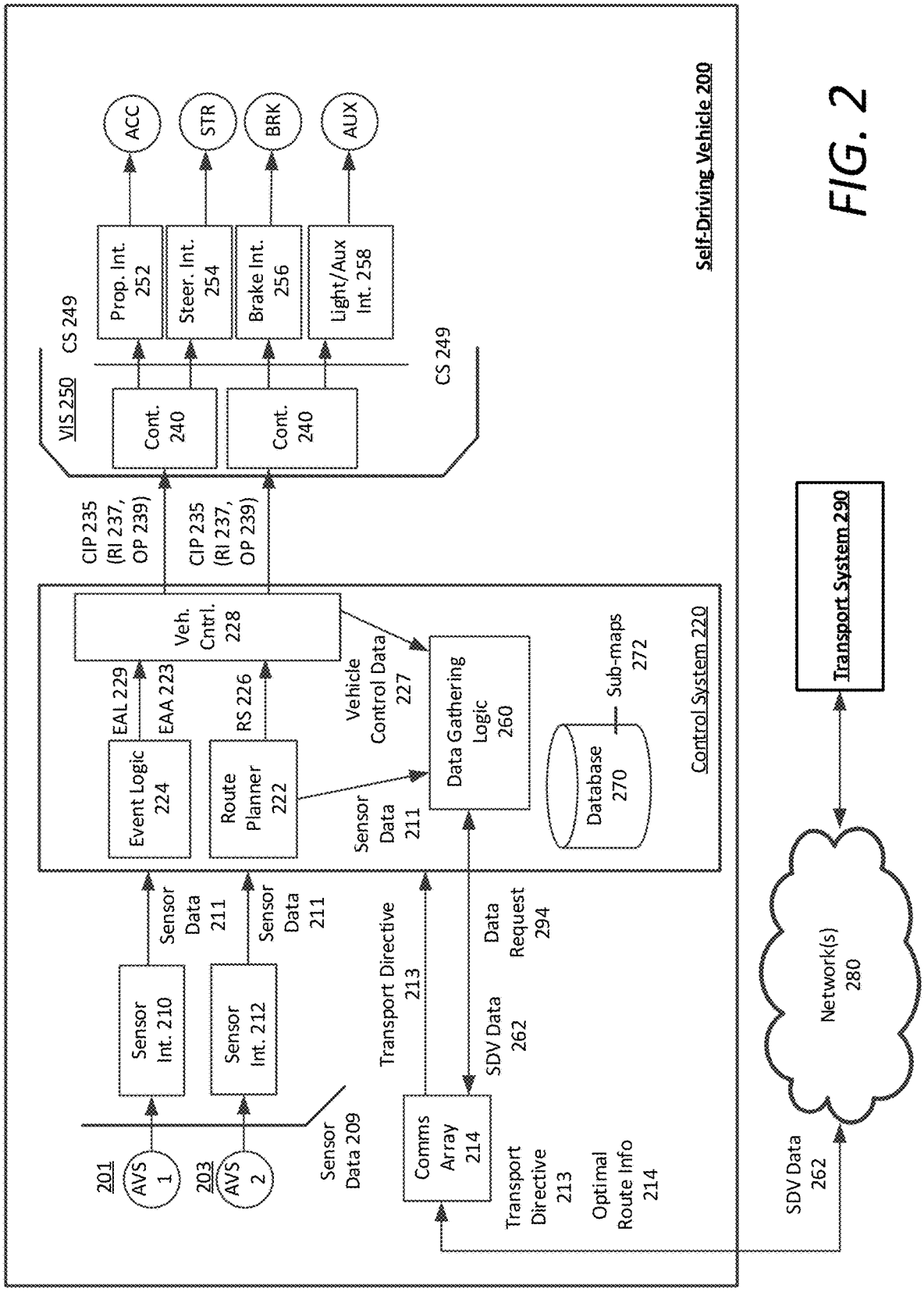

Self-Driving Vehicle 200
Control System 220
VIS 250
CS 249
CS 249
Prop. Int. 252
Steer. Int. 254
Brake Int. 256
Light/Aux Int. 258
ACC
STR
BRK
AUX
Cont. 240
Cont. 240
CIP 235 (RI 237, OP 239)
CIP 235 (RI 237, OP 239)
Veh. Cntrl. 228
EAL 229
EAA 223
RS 226
Vehicle Control Data 227
Event Logic 224
Route Planner 222
Data Gathering Logic 260
Database 270
Sub-maps 272
Sensor Data 211
Sensor Data 211
Sensor Data 211
Transport Directive 213
SDV Data 262
Data Request 294
Sensor Int. 210
Sensor Int. 212
201
AVS 1
203
AVS 2
Sensor Data 209
Comms Array 214
Transport Directive 213
Optimal Route Info 214
SDV Data 262
Network(s) 280
Transport System 290

FIG. 2

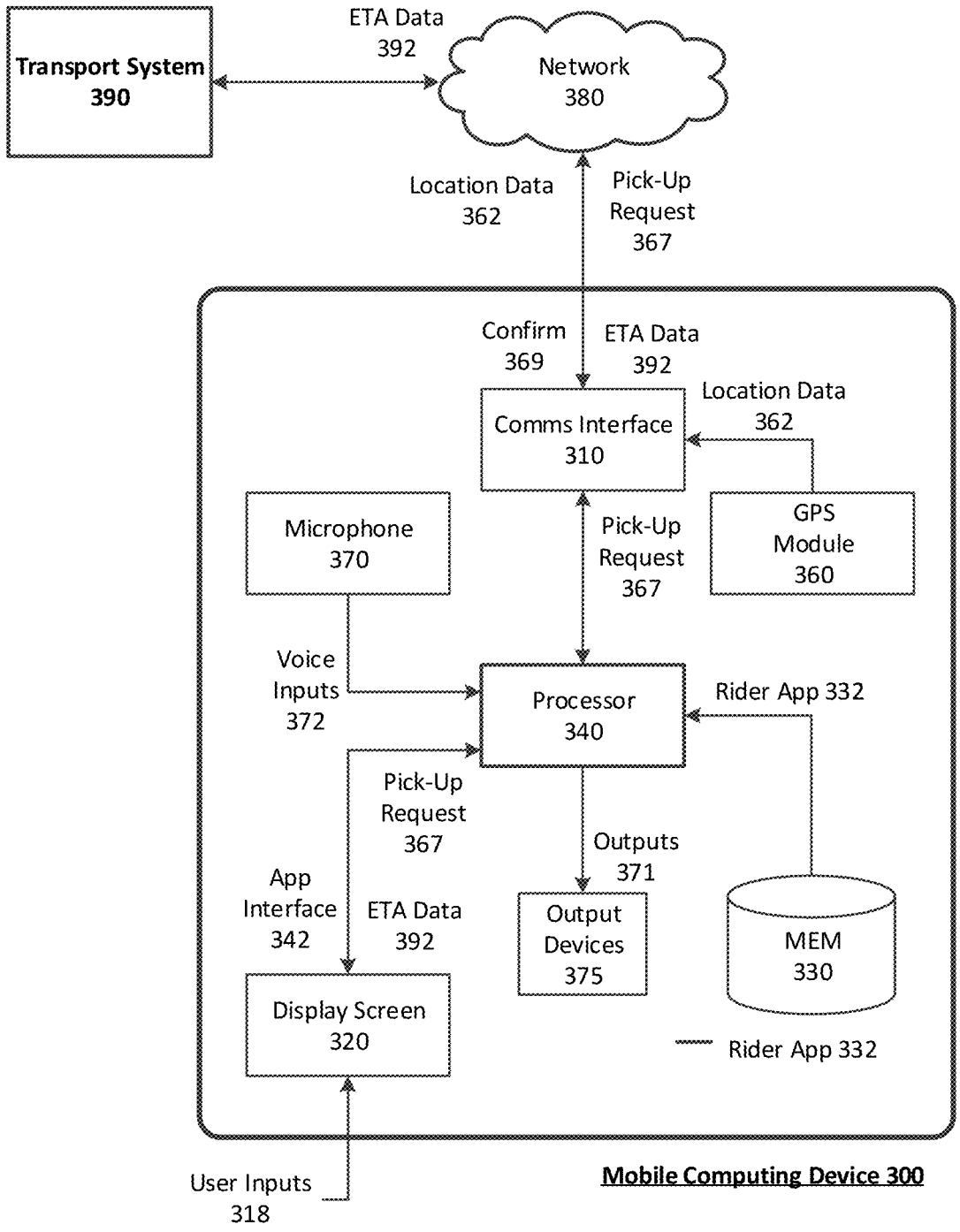

Transport System
390
ETA Data
392
Network
380
Location Data
362
Pick-Up
Request
367
Confirm
369
ETA Data
392
Comms Interface
310
Location Data
362
Microphone
370
Pick-Up
Request
367
GPS
Module
360
Voice
Inputs
372
Processor
340
Rider App 332
Pick-Up
Request
367
Outputs
371
App
Interface
342
ETA Data
392
Output
Devices
375
MEM
330
Display Screen
320
Rider App 332
User Inputs
318
Mobile Computing Device 300

FIG. 3

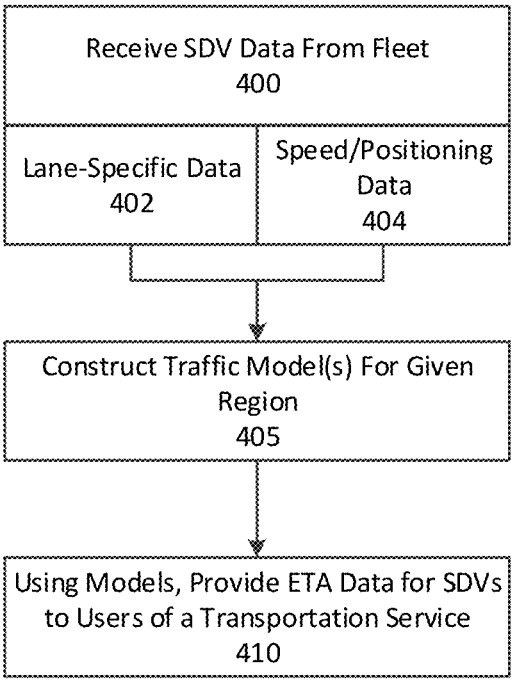

Receive SDV Data From Fleet
400
Lane-Specific Data
402
Speed/Positioning Data
404
Construct Traffic Model(s) For Given Region
405
Using Models, Provide ETA Data for SDVs to Users of a Transportation Service
410

FIG. 4A

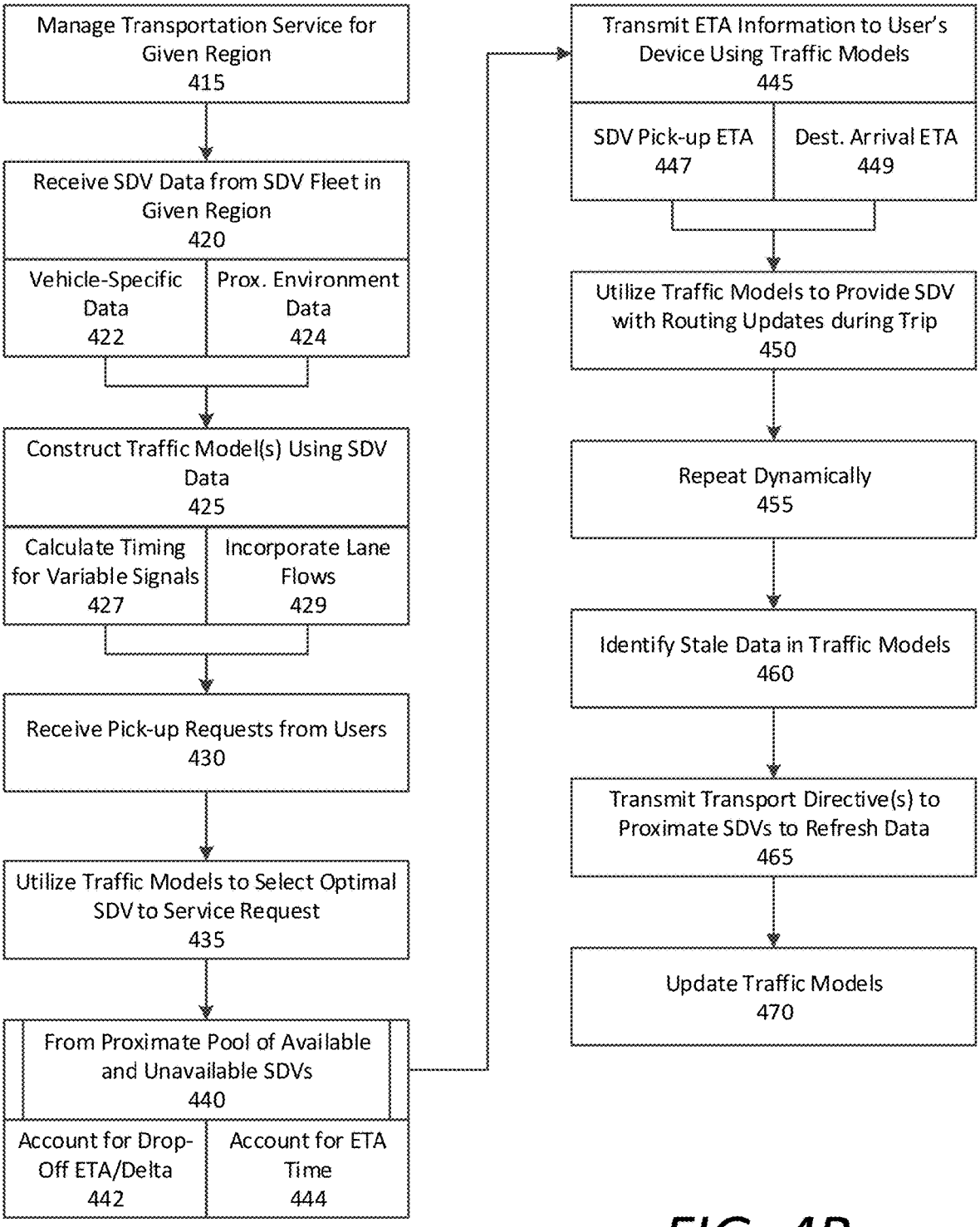

Manage Transportation Service for Given Region
415
Receive SDV Data from SDV Fleet in Given Region
420
Vehicle-Specific Data
422
Prox. Environment Data
424
Construct Traffic Model(s) Using SDV Data
425
Calculate Timing for Variable Signals
427
Incorporate Lane Flows
429
Receive Pick-up Requests from Users
430
Utilize Traffic Models to Select Optimal SDV to Service Request
435
From Proximate Pool of Available and Unavailable SDVs
440
Account for Drop-Off ETA/Delta
442
Account for ETA Time
444
Transmit ETA Information to User's Device Using Traffic Models
445
SDV Pick-up ETA
447
Dest. Arrival ETA
449
Utilize Traffic Models to Provide SDV with Routing Updates during Trip
450
Repeat Dynamically
455
Identify Stale Data in Traffic Models
460
Transmit Transport Directive(s) to Proximate SDVs to Refresh Data
465
Update Traffic Models
470

FIG. 4B

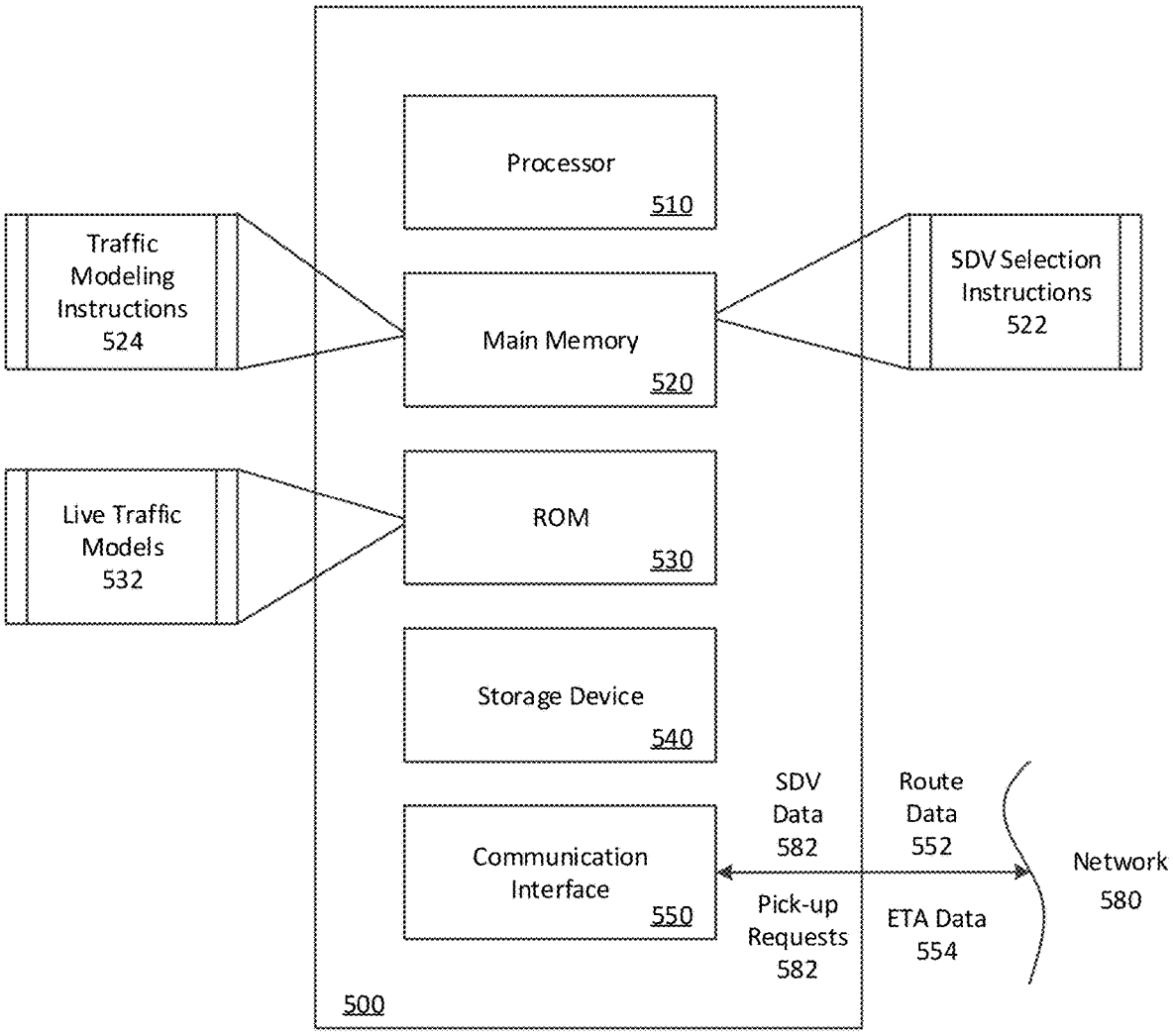

Processor
510
Traffic Modeling Instructions 524
Main Memory
520
SDV Selection Instructions 522
Live Traffic Models 532
ROM
530
Storage Device
540
SDV Data 582
Route Data 552
Communication Interface
550
Network
580
Pick-up Requests 582
ETA Data 554
500

FIG. 5

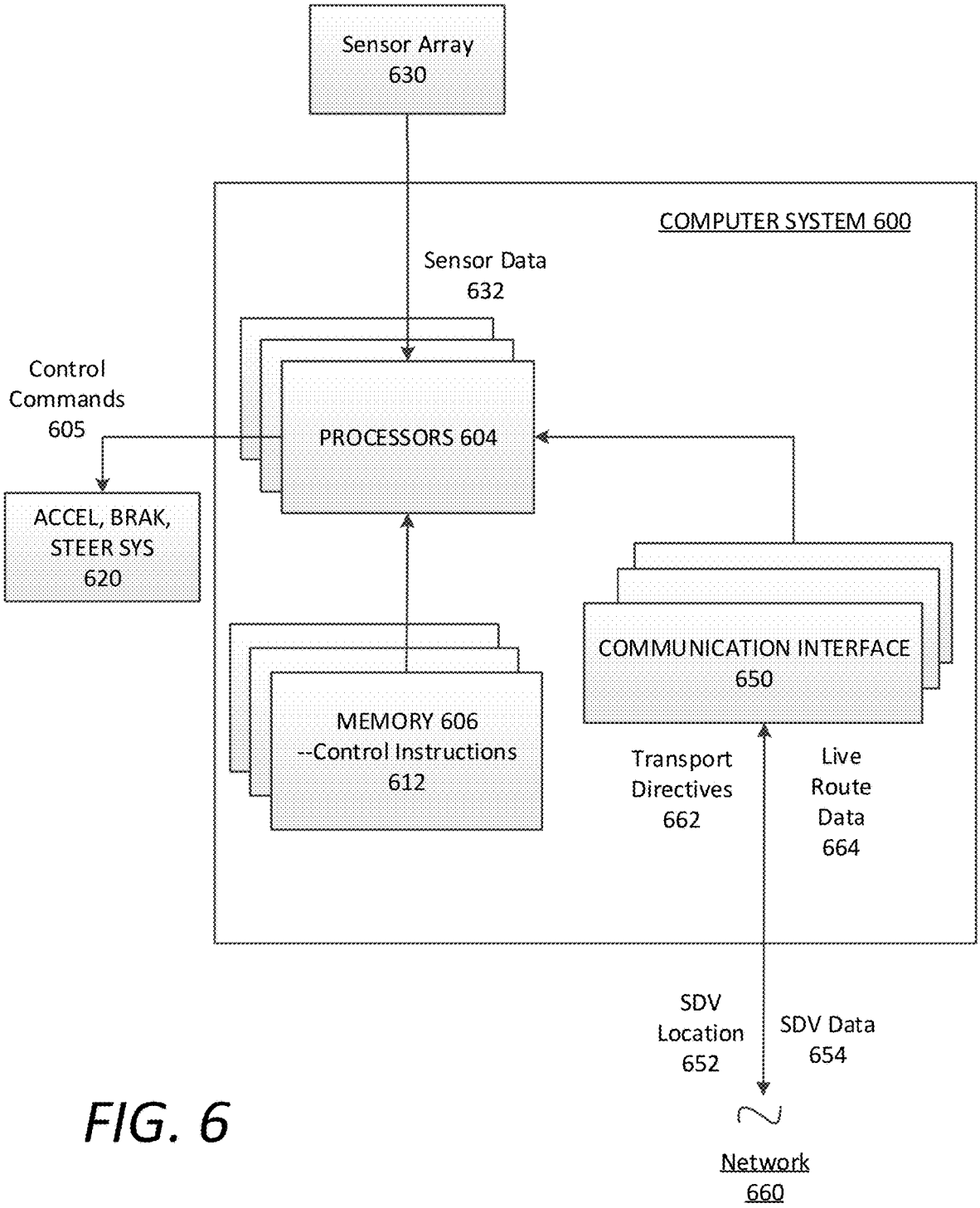

Sensor Array
630
COMPUTER SYSTEM 600
Sensor Data
632
Control
Commands
605
PROCESSORS 604
ACCEL, BRAK,
STEER SYS
620
COMMUNICATION INTERFACE
650
MEMORY 606
--Control Instructions
612
Transport
Directives
662
Live
Route
Data
664
SDV
Location
652
SDV Data
654
Network
660

FIG. 6

COMPUTING SYSTEM IMPLEMENTING TRAFFIC MODELING USING SENSOR VIEW DATA FROM SELF-DRIVING VEHICLES

CROSS REFERENCE TO RELATED APPLICATION

[0001] This application is a continuation of U.S. patent application Ser. No. 15/610,068, filed on May 31, 2017, which claims the benefit of priority to U.S. Provisional Application No. 62/345,289, filed on Jun. 3, 2016; is the aforementioned applications being hereby incorporated by reference in their respective entireties.

BACKGROUND

[0002] Traffic and mapping resources typically utilize global positioning system (GPS) data from mobile devices of drivers and passengers of vehicles traveling throughout a given region. The accuracy of GPS data may provide general information corresponding to traffic and estimated time of arrival (ETA) data when, for example, a driver has inputted a destination on a mapping resource of a mobile computing device. However, the accuracy of ETA information can be diminished due to dynamic changes in road and traffic conditions occurring in real-time, and may be significantly different from actual arrival times.

[0003] Self-driving vehicle (SDV) technology can require continuous sensor data processing of a physical surrounding environment in order to enable the SDV to autonomously operate on public roads in typical traffic conditions. Certain SDVs utilize camera sensors (e.g., single cameras or stereoscopic cameras) that implement image processing and/or active ranging systems (e.g., radar and/or LIDAR systems) in order to continuously survey the surrounding environment of the SDV to detect and avoid any potential hazards while obeying traffic laws and signals.

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] The disclosure herein is illustrated by way of example, and not by way of limitation, in the figures of the accompanying drawings in which like reference numerals refer to similar elements, and in which:

[0005] FIG. **1** is a block diagram illustrating an example transport system in communication with user devices and a fleet of transport vehicles, as described herein;

[0006] FIG. **2** is a block diagram illustrating an example AV or SDV implementing a control system, as described herein;

[0007] FIG. **3** is a block diagram illustrating an example mobile computing device executing a designated application for a transport arrangement service, as described herein.

[0008] FIGS. **4**A and **4**B are flow charts describing example methods of traffic modeling and data distribution, according to examples described herein;

[0009] FIG. **5** is a block diagram illustrating a computer system upon which examples described herein may be implemented; and

[0010] FIG. **6** is a block diagram illustrating a computing system for an AV or SDV upon which examples described herein may be implemented.

DETAILED DESCRIPTION

[0011] A transport system is disclosed herein that can leverage vehicle data from a fleet of SDVs traveling throughout a given region in order to construct dynamical traffic models that can provide lane-specific traffic information for the given region. Utilizing the dynamically constructed traffic models, the transport system can provide improved travel time estimations or estimated time of arrival (ETA) data, corresponding to one or more of the fleet of SDVs, to a number of users in the given region. According to some aspects, the vehicle data comprises lane specific data indicating a current lane of a road on which the respective SDV travels. Furthermore, in certain aspects, the vehicle data can further include dynamic speed data for the respective SDV. Accordingly, in one example, the transport system can dynamically construct the traffic model for the given region in real time based on changes in the dynamic speed data for the fleet of SDVs.

[0012] Additionally, the transport system can dynamically construct the traffic model by incorporating the lane specific data to indicate traffic flows for individual lanes of multi-lane intersections throughout the given region. Further still, the transport system can dynamically construct the traffic model by calculating timing data for individual traffic signals throughout the given region based on the traffic flows for the individual lanes. Accordingly, the calculated timing data can correspond to variable traffic signals in the given region, enabling the transport system to precisely determine, in real time, timing information for the signal states (e.g., red, yellow, green) for each lane in each direction of the intersection corresponding to the traffic signal.

[0013] According to one or more examples, the vehicle data receive from the fleet of SDVs can include location data that indicates a current location of each respective SDV in the fleet. Furthermore, in some aspects, the transport system can provide the ETA data on an interactive map for the given region via an executing rider application on mobile computing devices of the users. The interactive map can enable users to input a pick-up location on the interactive map and view ETA data for one or more proximate SDVs in the fleet in relation to the inputted pick-up location. Furthermore, the interactive map can indicate the dynamic locations of the proximate SDVs, and the ETA data for the SDV(s) (e.g., a most proximate SDV) can be based on the dynamically constructed traffic models.

[0014] In certain implementations, the transport system can receive a pick-up request from a requesting user based on an inputted location on the interactive map, and select an SDV, from one or more proximate SDVs in relation to the inputted pick-up location, to service the pick-up request. The transport system can then transmit confirmation information to a mobile computing device of the requesting user, where the confirmation information can identify the selected SDV and ETA information for the selected SDV to arrive at the pick-up location. According to examples described herein, the ETA information provided on the requesting user's mobile computing device can be based on the dynamically constructed traffic model.

[0015] Additionally or alternatively, the transport system can transmit lane specific route information to a selected SDV to cause the selected SDV to autonomously drive to the pick-up location and a destination corresponding to the pick-up request. In certain implementations, the lane specific route information can indicate a most optimal path through

traffic based on the dynamically constructed traffic model. Furthermore, in one aspect, the transport system can dynamically determine the lane specific route information as the SDV travels to the pick-up location and the destination. Thus, the transport system can also manage a transportation arrangement service utilizing the fleet of SDVs to service pick-up requests submitted by any of the users in the given region. As described herein, the fleet of SDVs can comprise on the order of hundreds, thousands, tens of thousands, or even hundreds of thousands operating throughout the given region.

[0016] According to examples described herein, based on the pick-up location, the transport system can identify a pool of available and unavailable SDVs that are proximate to the pick-up location. As used herein, an "available SDV" is an SDV that is in a standby mode, or otherwise not currently transporting a user. An "unavailable SDV" is an SDV that is currently transporting a user to a drop-off destination, upon which the unavailable SDV becomes available. The transport system can utilize the dynamically constructed traffic model to select, from the proximate available and unavailable SDVs, an optimal SDV to service the pick-up request for the requesting user. In one example, the transport system can select the optimal SDV by executing an optimization operation using the dynamically constructed traffic model to determine that the optimal SDV has a lowest ETA to the pick-up location. Thus, the optimization operation can account for drop-off time deltas for the unavailable SDVs as well as projected, lane specific route optimizations to the pick-up locations for each of the SDVs in the pool.

[0017] Still further, examples herein recognize that dynamically constructed traffic models may include inaccurate or stale data in certain areas of the region when SDVs are not traveling through such areas. In one example, the transport system can identify such stale vehicle data in the dynamically constructed traffic models. For example, the stale data can indicate that no SDVs in the fleet have traveled along a particular road for a predetermined period of time (e.g., ten minutes). In response to identifying the stale vehicle data, the transport system can transmit a transport directive to at least one of the fleet of SDVs, instructing the SDV(s) to drive through the particular area to provide refreshed vehicle data in order to update the dynamically constructed traffic model for the particular area.

[0018] Among other benefits, the examples described herein achieve a technical effect of improving ETA information for SDVs as well as optimizing SDV selection for servicing pick-up requests and optimizing route data for a fleet of SDVs. In generating a dynamic traffic model utilizing lane-specific surface data from the fleet of SDVs, the transport system can not only bolster accuracy and efficiency with respect to ETA information and SDV selection, but can also improve overall traffic in the given region by making route information more granular (e.g., lane-specific).

[0019] As used herein, a computing device refers to devices corresponding to desktop computers, cellular devices or smartphones, personal digital assistants (PDAs), laptop computers, tablet devices, virtual reality (VR) and/or augmented reality (AR) devices, wearable computing devices, television (IP Television), etc., that can provide network connectivity and processing resources for communicating with the system over a network. A computing device can also correspond to custom hardware, in-vehicle devices, or on-board computers, etc. The computing device can also operate a designated application configured to communicate with the network service.

[0020] One or more examples described herein provide that methods, techniques, and actions performed by a computing device are performed programmatically, or as a computer-implemented method. Programmatically, as used herein, means through the use of code or computer-executable instructions. These instructions can be stored in one or more memory resources of the computing device. A programmatically performed step may or may not be automatic.

[0021] One or more examples described herein can be implemented using programmatic modules, engines, or components. A programmatic module, engine, or component can include a program, a sub-routine, a portion of a program, or a software component or a hardware component capable of performing one or more stated tasks or functions. As used herein, a module or component can exist on a hardware component independently of other modules or components. Alternatively, a module or component can be a shared element or process of other modules, programs or machines.

[0022] Some examples described herein can generally require the use of computing devices, including processing and memory resources. For example, one or more examples described herein may be implemented, in whole or in part, on computing devices such as servers, desktop computers, cellular or smartphones, personal digital assistants (e.g., PDAs), laptop computers, printers, digital picture frames, network equipment (e.g., routers) and tablet devices. Memory, processing, and network resources may all be used in connection with the establishment, use, or performance of any example described herein (including with the performance of any method or with the implementation of any system).

[0023] Furthermore, one or more examples described herein may be implemented through the use of instructions that are executable by one or more processors. These instructions may be carried on a computer-readable medium. Machines shown or described with figures below provide examples of processing resources and computer-readable mediums on which instructions for implementing examples disclosed herein can be carried and/or executed. In particular, the numerous machines shown with examples of the invention include processors and various forms of memory for holding data and instructions. Examples of computer-readable mediums include permanent memory storage devices, such as hard drives on personal computers or servers. Other examples of computer storage mediums include portable storage units, such as CD or DVD units, flash memory (such as those carried on smartphones, multifunctional devices or tablets), and magnetic memory. Computers, terminals, network enabled devices (e.g., mobile devices, such as cell phones) are all examples of machines and devices that utilize processors, memory, and instructions stored on computer-readable mediums. Additionally, examples may be implemented in the form of computer-programs, or a computer usable carrier medium capable of carrying such a program.

[0024] Numerous examples are referenced herein in context of an autonomous vehicle (AV) or self-driving vehicle (SDV). An AV or SDV refers to any vehicle which is operated in a state of automation with respect to steering and propulsion. Different levels of autonomy may exist with respect to AVs and SDVs. For example, some vehicles may enable automation in limited scenarios, such as on high-

ways, provided that drivers are present in the vehicle. More advanced AVs and SDVs can drive without any human assistance from within or external to the vehicle.

[0025] System Description

[0026] FIG. **1** is a block diagram illustrating an example transport system in communication with user devices and a fleet of transport vehicles, as described herein. The transport system **100** can include a communications interface **115** to communicate with the user devices **195** and the fleet of self-driving vehicles (SDVs) **190** over a number of networks **180**. In addition or in variations, the transport system **100** can communicate with human drivers operating transport vehicles, via the drivers' mobile devices or on-board computer systems, to facilitate transportation in accordance with a transportation arrangement service managed by the transport system **100**. In many examples, the transport system **100** can provide the transportation arrangement service to link requesting users with transport vehicles and/or AVs or SDVs in the fleet **190** managed by the transport system **100**. Such vehicles in the fleet **190** may be managed directly by the transport system **100**, or vehicles owned by third-party entities that are available to service pick-up requests **197**. A designated application **185** corresponding to the transportation arrangement service can be executed on the user devices **195**. A requesting user can provide an input on a user device **195** to transmit a pick-up request **197** to the transport system **100**. The pick-up request **197** can be received by the communications interface **115** and sent to a selection engine **135**, which can match the requesting user with a proximate transport vehicle, in relation to a pick-up location, from the fleet of available vehicles **190**.

[0027] In one or more examples, the pick-up request **197** can include a pick-up location where a selected SDV **109** can rendezvous with the requesting user. The fleet of SDVs **190** can be dispersed throughout a given region (e.g., a city or metropolitan area) and transmit vehicle location data **192** to a vehicle interface **105** of the transport system **100**. The vehicle interface **105** can transmit the vehicle locations **192** to the selection engine **135** in order to enable the selection engine **135** to determine candidate vehicles that can readily service the pick-up request **197**.

[0028] According to examples described herein, the transport system **100** can include a modeling engine **140** that processes SDV data **194** from the SDV fleet **190** to construct live traffic models **132**. In one aspect, the live traffic models **132** can be continuously constructed and stored in a database **130** of the transport system **100**. As SDV data **194** is received, the modeling engine **140** can generate updates for the live traffic models **132** in order to maintain accuracy. In order to resolve the deficiencies in current mapping systems or application, the SDV data **194** can comprise real-time surface data from the sensor systems (e.g., LIDAR and/or camera systems) that can provide the modeling engine **140** with a real-time sensor view of the traffic and road conditions throughout the given area. Additionally, the SDV data **194** can include real-time speed data from the SDVs in the fleet **190** (e.g., from the vehicles' odometer) as well as the location data **192** from, for example, on-board GPS resources of the SDVs **190**. Additionally or alternatively, the SDV data **194** can comprise fine granular localization and pose information of the SDVs in the fleet.

[0029] As provided herein, each SDV **109** in the fleet **190** can perform localization and pose operations in order to determine a precise position and orientation with respect to the SDV's surrounding environment (e.g., on the order of centimeters). Such positioning determinations can be greater than an order of magnitude more accurate than GPS-based systems. In performing localization, each SDV **109** can utilize previously recorded surface maps—or sub-maps—of the given region to dynamically compare with sensor data (e.g., LIDAR and/or stereoscopic camera data) from the SDV **109**. Such sub-maps can be recorded by certain SDVs **109** in the fleet **190**, and can be processed by the transport system **100** for use in all of the SDVs in the fleet **190**. Thus, utilizing the sub-maps the SDVs **109** can each continuously perform precise positioning and determine its orientation with respect to the sub-maps (i.e., localization and pose). This allows the SDVs **109** to operate within the lanes of public roads, stop on the correct markers at intersections, and/or correlate position with a mapping or routing resource to autonomously drive to respective destinations.

[0030] The received SDV data **194** can include such precise positioning information from the SDVs **109**, and the modeling engine **140** can utilize such information to construct the lane-specific traffic models **132** in real time. Accordingly, not only do the traffic models **132** include general directional traffic and ETA information—such as in current mapping systems—the traffic models **132** further include more granular traffic flows for each lane of multi-lane roads. Furthermore, due to the precise nature of the traffic models **132** the modeling engine **140** can further determine real-time traffic signal states (e.g., red versus green) for intersections throughout the given region based on the lane flows. Thus, the modeling engine **140** can further include current timing information for both standard and variably timed traffic signals in the traffic models **132** in order to further bolster the accuracy.

[0031] In further implementations, the SDV data **194** can include data indicating other vehicles external to the SDV. For example, the SDV data **194** can comprise image data from one or more cameras of the SDV, and/or LIDAR data from a LIDAR system of the SDV. In various examples, the modeling engine **140** can determine a set of properties of the other vehicles external to the SDV, such as a relative velocity, lane-specific traffic density, whether the vehicles are accelerating, braking, or turning, any vehicle incidents (e.g., a traffic accident), and the like. As described herein, the modeling engine **140** further construct the traffic models **132** based on the set of properties of the other vehicles identified in the SDV data **194**.

[0032] The modeling engine **140** can continuously receive the SDV data **194** from the fleet of SDVs **190** as they operate throughout the given region. Thus, the modeling engine **140** can further provide continuous or near-continuous updates **146** to the traffic models **132** in order to maintain accuracy. According to some examples, the transport system **100** can include mapping engine **175**. In certain implementations, the mapping engine **175** can provide the selection engine **135** with map data **179** and/or traffic data **177**, which the selection engine **135** can utilize to make vehicle selections. For example, the selection engine **135** can identify a pick-up location in a pick-up request **197**, receive SDV locations **192** of SDVs in the fleet **190** that are proximate to the pick-up location, and utilize the map data **179** and traffic data **177** to select an optimal SDV **109** to service the pick-up request **197**.

[0033] According to examples herein, the mapping engine **175** can bolster accuracy in the traffic data **177** by utilizing

the dynamically constructed traffic models **132** in the database **130**. Thus, the traffic data **177** can be based on the live traffic models **132** constructed by the modeling engine **132**. The selection engine **135** can utilize the traffic data **177** to accurately estimate arrival times for each proximate SDV in relation to the pick-up location. The selection engine **135** may then rely on these estimated arrival times to make a selection (e.g., select an SDV **109** having the shortest estimated arrival time to the pick-up location). Accordingly, the selection of an SDV **109** to service a pick-up request may also be based on the dynamically constructed traffic models **132**.

[0034] Furthermore, utilizing the live traffic models **132** the mapping engine **175** can provide improved ETA data **142** for user devices **195**, so that requesting users can readily identify, with increased precision, improved ETAs for one or more proximate SDVs in the fleet **190**. The ETA data **142** can be provided via a mapping feature through the designated application **185** on the user devices **195**, and can also include virtual representations of the proximate vehicles. For example, a user can input a location (e.g., a current location or pick-up location) on the mapping feature, and the designated application **185** can show live representations of proximate SDVs **109** traveling on the map, with ETA data **142** for one or more of the SDVs **109** (e.g., a physically or temporally nearest SDV). Still further, in many implementations, when a SDV **109** is selected to service a particular pick-up request **197**, the mapping engine **175** can provide the user device **195** corresponding to the pick-up request with the ETA data **142** of the selected SDV **109**—where the ETA data **142** is based on the live traffic models **132** constructed by the modeling engine **140**.

[0035] Additionally, as the selected SDV **109** operates throughout the given region, the SDV **109** can follow a route generated either locally on a mapping resource of the SDV **109**, or by way of the mapping engine **175** of the transport system **100**. This high level route can comprise an optimal surface street route to a destination based on current traffic conditions at the time of determination (e.g., when the SDV **109** picks up the user for transport to a destination, or when the SDV **109** receives a transport directive **182** to head to a pick-up location). According to some examples, the mapping engine **175** of the transport system **100** can provide the SDV **109** with mid-level routing updates **184** that enable the SDV **109** to perform mid-level tasks such as changing lanes or temporarily diverging from the current route in order to condense travel time. For example, the mapping engine **175** can identify upcoming, lane-specific traffic for the SDV **109**. The traffic information can indicate that a particular lane is moving faster or more optimally than the other lanes. As such, the mapping engine **175** can provide a routing update **184** to the SDV **109** to make one or more lane changes or to make a quick detour to most efficiently get through or avoid a particular pocket of traffic (e.g., at a crowded intersection).

[0036] On a broader scale, the transport system **100** can provide such mid-level routing updates **184** to each of the fleet of SDVs **190** as they travel throughout the given region. The collective effect of such mid-level routing updates **184** can be to homogenize traffic flows through traffic pockets in the given region. Furthermore, because the modeling engine **140** can utilize highly accurate, real time data from the SDVs themselves, the time between a user's submission of a pick-up request **197** and being picked up by an optimal SDV **109** can be minimized. Still further, because the mapping engine **175** can utilize the live traffic models **132** to provide mid-level routing updates **184**, the travel time between the pick-up location and the destination can also be minimized. On a large scale (e.g., a citywide scale), the collective time saved for users of the transportation service can be quite significant. Also, due to the accuracy of the traffic models **132**, a user can be provided with ETA data **142** indicating an improved estimated time of arrival for a selected SDV **109** to rendezvous with the user and an improved estimated travel time to the destination. Thus, not only are waiting time and travel time minimized, but also the error in the time estimations provided to the user. Furthermore, because the traffic models **132** may be a significant improvement one current ETA, routing, and mapping technology, the transport system **100** can provide such traffic models **132** to third-parties, such as mapping and routing resources for human-driven vehicles. Alternatively, the transport system **100** can provide such mapping and routing resources—utilizing the dynamically constructed traffic models—directly to user devices **195** via the designated application **185** or via an alternate mapping application for use by the users when they drive throughout the given region.

[0037] FIG. **2** is a block diagram illustrating an example AV or SDV implementing a control system, as described herein. In an example of FIG. **2**, a control system **220** can autonomously operate the SDV **200** in a given geographic region for a variety of purposes, including transport services (e.g., transport of humans, delivery services, etc.). In examples described, an autonomously driven vehicle can operate without human control. For example, in the context of automobiles, an autonomously driven vehicle can steer, accelerate, shift, brake, and operate lighting components. Some variations also recognize that an autonomous-capable vehicle can be operated either autonomously or manually.

[0038] According to some examples, the control system **220** can utilize specific sensor resources in order to intelligently operate the vehicle **200** in most common driving situations. For example, the control system **220** can operate the vehicle **200** by autonomously operating the steering, accelerating, and braking systems of the vehicle **200** as the vehicle progresses to a destination. The control system **220** can perform vehicle control actions (e.g., braking, steering, accelerating) and route planning using sensor information, as well as other inputs (e.g., transmissions from remote or local human operators, network communication from other vehicles, etc.).

[0039] In an example of FIG. **2**, the control system **220** includes a computer or processing system which operates to process sensor data that is obtained on the vehicle **200** with respect to a road segment upon which the vehicle **200** operates. The sensor data can be used to determine actions which are to be performed by the vehicle **200** in order for the vehicle **200** to continue on a route to a destination. In some variations, the control system **220** can include other functionality, such as wireless communication capabilities, to send and/or receive wireless communications with one or more remote sources. In controlling the vehicle **200**, the control system **220** can issue instructions and data, shown as commands **235**, which programmatically control various electromechanical interfaces of the vehicle **200**. The commands **235** can serve to control operational aspects of the vehicle **200**, including propulsion, braking, steering, and auxiliary behavior (e.g., turning lights on).

[0040] The SDV **200** can be equipped with multiple types of sensors **201**, **203** which can combine to provide a computerized perception of the space and the physical environment surrounding the vehicle **200**. Likewise, the control system **220** can operate within the SDV **200** to receive sensor data **211** from the collection of sensors **201**, **203**, and to control various electromechanical interfaces for operating the vehicle **200** on roadways.

[0041] In more detail, the sensors **201**, **203** operate to collectively obtain a complete sensor view of the vehicle **200**, and further to obtain situational information proximate to the vehicle **200**, including any potential hazards proximate to the vehicle **200**. By way of example, the sensors **201**, **203** can include multiple sets of cameras sensors **201** (video cameras, stereoscopic pairs of cameras or depth perception cameras, long range cameras), remote detection sensors **203** such as provided by radar or LIDAR, proximity or touch sensors, and/or sonar sensors (not shown).

[0042] Each of the sensors **201**, **203** can communicate with the control system **220** utilizing a corresponding sensor interface **210**, **212**. Each of the sensor interfaces **210**, **212** can include, for example, hardware and/or other logical components which are coupled or otherwise provided with the respective sensor. For example, the sensors **201**, **203** can include a video camera and/or stereoscopic camera set which continually generates image data of the physical environment of the vehicle **200**. As an addition or alternative, the sensor interfaces **210**, **212** can include a dedicated processing resource, such as provided with a field programmable gate array ("FPGA") which can, for example, receive and/or process raw image data from the camera sensor.

[0043] In some examples, the sensor interfaces **210**, **212** can include logic, such as provided with hardware and/or programming, to process sensor data **209** from a respective sensor **201**, **203**. The processed sensor data **209** can be outputted as sensor data **211**. As an addition or variation, the control system **220** can also include logic for processing raw or pre-processed sensor data **209**.

[0044] According to one implementation, the vehicle interface subsystem **250** can include or control multiple interfaces to control mechanisms of the vehicle **200**. The vehicle interface subsystem **250** can include a propulsion interface **252** to electrically (or through programming) control a propulsion component (e.g., an accelerator actuator), a steering interface **254** for a steering mechanism, a braking interface **256** for a braking component, and a lighting/auxiliary interface **258** for exterior lights of the vehicle **200**. According to implementations described herein, control signals **249** can further be transmitted to a component interface **255** of the vehicle interface subsystem **250** to control various components and/or accommodation features **266** of the SDV **200** based on, for example, a physical impairment of the user. The vehicle interface subsystem **250** and/or the control system **220** can further include one or more controllers **240** which can receive commands **233**, **235** from the control system **220**. The commands **235** can include route information **237** and operational parameters **239**—which specify an operational state of the vehicle **200** (e.g., desired speed and pose, acceleration, etc.). The commands can further include accommodation commands **233** to cause the controller **240** to configure a number of adjustable components of the SDV **200** via the component interface **255**.

[0045] The controller(s) **240** can generate control signals **249** in response to receiving the commands **233**, **235** for one or more of the vehicle interfaces **252**, **254**, **255**, **256**, **258**. The controllers **240** can use the commands **235** as input to control propulsion, steering, braking, and/or other vehicle behavior while the SDV **200** follows a current route. Thus, while the vehicle **200** actively drives along the current route, the controller(s) **240** can continuously adjust and alter the movement of the vehicle **200** in response to receiving a corresponding set of commands **235** from the control system **220**. Absent events or conditions which affect the confidence of the vehicle **220** in safely progressing along the route, the control system **220** can generate additional commands **235** from which the controller(s) **240** can generate various vehicle control signals **249** for the different interfaces of the vehicle interface subsystem **250**.

[0046] According to examples, the commands **235** can specify actions to be performed by the vehicle **200**. The actions can correlate to one or multiple vehicle control mechanisms (e.g., steering mechanism, brakes, etc.). The commands **235** can specify the actions, along with attributes such as magnitude, duration, directionality, or other operational characteristics of the vehicle **200**. By way of example, the commands **235** generated from the control system **220** can specify a relative location of a road segment which the SDV **200** is to occupy while in motion (e.g., changing lanes, moving into a center divider or towards shoulder, turning the vehicle, etc.). As other examples, the commands **235** can specify a speed, a change in acceleration (or deceleration) from braking or accelerating, a turning action, or a state change of exterior lighting or other components. The controllers **240** can translate the commands **235** into control signals **249** for a corresponding interface of the vehicle interface subsystem **250**. The control signals **249** can take the form of electrical signals which correlate to the specified vehicle action by virtue of electrical characteristics that have attributes for magnitude, duration, frequency or pulse, or other electrical characteristics.

[0047] In an example of FIG. **2**, the control system **220** can include a route planner **222**, event logic **224**, and vehicle control logic **228**. The vehicle control logic **228** can convert alerts of event logic **224** ("event alert **229**") into commands **235** that specify a set of vehicle actions. Furthermore, in operating the acceleration, braking, and steering systems of the SDV **200**, the control system **220** can include a database **270** that stores previously recorded and processed sub-maps **272** of the given. As described herein, the sub-maps **272** can comprise processed or normalized surface data that enables the control system **220** to compare with the sensor data **211** in order to identify any potential hazards.

[0048] Additionally, the route planner **222** can select one or more route segments **226** that collectively form a path of travel for the SDV **200** when the vehicle **200** is on a current trip (e.g., servicing a pick-up request). In one implementation, the route planner **222** can specify route segments **226** of a planned vehicle path which defines turn by turn directions for the vehicle **200** at any given time during the trip. The route planner **222** may utilize the sensor interface **212** to receive GPS information as sensor data **211**. The vehicle control **228** can process route updates from the route planner **222** as commands **235** to progress along a path or route using default driving rules and actions (e.g., moderate steering and speed).

[0049] In examples described herein, the route planner **22** can receive optimal route information **214** over the network **280** from the transport system **290** based on constructed traffic models described herein. According to such examples, the optimal route information **214** can include real-time granular information regarding not only a high level route to take, but which lane the SDV **200** should presently select, whether the SDV **200** should take a detour or alternative path (e.g., to avoid a crowded intersection), and other immediate or upcoming actions that can optimize arrival times. Accordingly, in addition to generating a high level route from a current location to a destination, the route planner **222** can utilize the optimal route information **214** from the transport system **290** to mid-level route decisions.

[0050] As an example, the control system **220** can receive a transport directive **213** indicating a pick-up location to rendezvous with a requesting user. The control system **220** can accept the directive **213** and utilize the route planner **222** autonomously drive to the pick-up location along a high level route decided by the route planner **222**. After rendezvousing with the requesting user, the control system **220** can autonomously operate the acceleration, braking, and steering systems **252**, **254**, **256** to transport the requesting user to a selected destination along a high level route selected by the route planner **222**. On a more granular level, or a mid-level, as the control system **220** drives the SDV **200**, the control system can receive optimal route information **214** from the transport system **290** indicating road details to further optimize the trip. For example, the optimal route information **214** can indicate an upcoming back-up in traffic, and can further indicate that the right lane is currently moving faster than the left lane.

[0051] The control system **220** can utilize the optima route information **214** from the transport system **290** to perform mid-level actions, such as selecting a faster traffic lane on a freeway, or a more optimal lane to get through an intersection. The control system's **220** responses to the optimal route information **214** may not affect the high level route selected by the route planner **222**, but can rather enable the control system **220** to arrive at a particular destination as quickly as possible given the traffic conditions experienced along the way. In certain variations, the optimal route information **214** can cause the route planner **222** to identify an alternate path within the overall route (e.g., taking a side street or making a turn one intersection prior to that indicated by the high level route). Thus, by utilizing the dynamically constructed traffic models, the transport system **290** can further aid the SDV **200** in optimizing travel times to pick-up locations and destinations. Furthermore, at the same time, the SDV **200** can provide the transport system **290** with SDV data **262** as feedback for constructing the traffic models, as described below.

[0052] In certain implementations, the event logic **224** can trigger low level responses to detected events. A detected event can correspond to a roadway condition or obstacle which, when detected, poses a potential hazard or threat of collision to the vehicle **200**. By way of example, a detected event can include an object in the road segment, heavy traffic ahead, and/or wetness or other environmental conditions on the road segment. The event logic **224** can use sensor data **211** from cameras, LIDAR, radar, sonar, or various other image or sensor component sets in order to detect the presence of such events as described. For example, the event logic **224** can detect potholes, debris, objects projected to be on a collision trajectory, and the like. Thus, the event logic **224** can detect events which enable the control system **220** to make evasive actions or plan for any potential hazards.

[0053] When events are detected, the event logic **224** can signal an event alert **229** that can classify the event and indicates the type of avoidance action to be performed. Additionally, the control system **220** can determine whether an event corresponds to a potential incident with a human driven vehicle, a pedestrian, or other human entity external to the SDV **200**. In turn, the vehicle control **228** can determine a low level response based on a score or classification of the event. Such response can correspond to an event avoidance action **223**, or an action that the vehicle **200** can perform to maneuver the vehicle **200** based on the detected event and its score or classification. By way of example, the vehicle response can include a slight or sharp vehicle maneuver for avoidance using a steering control mechanism and/or braking component. The event avoidance action **223** can be signaled through the commands **235** for controllers **240** of the vehicle interface subsystem **250**.

[0054] When an anticipated dynamic object of a particular class does in fact move into position of likely collision or interference, some examples provide that event logic **224** can signal the event alert **229** to cause the vehicle control **228** to generate commands **235** that correspond to an event avoidance action **223**. For example, in the event of an incident in the path of the vehicle **200**, the event logic **224** can signal the event alert **229** to avoid a collision. The event alert **229** can indicate (i) a classification of the event (e.g., "serious" and/or "immediate"), (ii) information about the event, such as the type of object that generated the event alert **229**, and/or information indicating a type of action the vehicle **200** should take (e.g., location of object relative to path of vehicle, size or type of object, etc.).

[0055] According to examples described herein, SDV **200** can include a communications array **214** to communicate over one or more networks **280** with a backend, transport system **290**, such as the transport system **100** described with respect to FIG. **1**. In some aspects, when the SDV **200** is selected to service a pick-up request, the communications array **214** can receive a transport directive **213** from the transport system **290** to service the pick-up request and drive to a pick-up location to rendezvous with the requesting user. In such aspects, the transport directive **213** can be transmitted to the control system **220** in order to autonomously drive the SDV **200** to the pick-up location.

[0056] According to examples described herein, the SDV **200** can further include data gathering logic **260** that can facilitate the transport system **290** in generating the dynamic traffic models. In one example, the transport system **290** can transmit a data request **294** to the SDV **200**, which can be processed by the data gathering logic **260** in order to generate SDV data **262** to be transmitted back to the transport system **290** in response. In variations, the control system **220** can periodically or continuously transmit the SDV data **262** to the transport system **290** automatically or based on a predetermined protocol.

[0057] The SDV data **262** can comprise raw or processed sensor data **211** from the SDV's sensors **201**, **203**, and/or vehicle control data **227**, which can indicate the SDV's speed, orientation, location. Thus, the SDV data **262** can include vehicle specific data that includes information directly concerning the SDV **200**, and can further include sensor view data from the SDV's **200** sensors (e.g., LiDAR

or stereo-camera sensor systems) that can indicate road and traffic conditions in lanes proximate to the SDV **200**. In some examples, the SDV data **262** can provide the transport system **290** with information indicating traffic flow in an opposite direct to the SDV's **200**. Thus, the collective SDV data submitted to the transport system **290** from SDVs operating throughout the given region can enable the transport system **290** to construct highly accurate, real-time traffic models. In constructing such models, the transport system **290** can manage the mid-level routing for the SDV fleet by providing those SDVs with optimal route information that can collectively homogenize traffic such that ETA information is highly accurate for users of the transport service that are awaiting a ride, or that are en route to a destination in a servicing SDV.

[0058] FIG. **3** is a block diagram illustrating an example mobile computing device executing a designated application for a transport arrangement service, as described herein. The mobile computing device **300** can store a designated application (e.g., a rider app **332**) in a local memory **330**. In response to a user input **318**, the rider app **332** can be executed by a processor **340**, which can cause an app interface **342** to be generated on a display screen **320** of the mobile computing device **330**. The app interface **342** can enable the user to, for example, check current price levels and availability for the transportation arrangement service. In various implementations, the app interface **342** can further enable the user to select from multiple ride services, such as a carpooling service, a regular rider service, a professional rider service, a van transport service, a luxurious ride service, and the like. The app interface **342** can further display an interactive map that enables the user to input a pick-up location, view ETA information of nearby available drivers, confirm a pick-up request **367**, and the like.

[0059] The user can generate a pick-up request **367** via user inputs **318** provided on the app interface **342**. For example, the user can select a pick-up location, view the various service types and estimated pricing, and select a particular service for transportation to an inputted destination. In certain implementations, current location data **362** from a GPS module **360** of the mobile computing device **300** can be transmitted to the transport system **390** to set the pick-up location. In many examples, the user can also input the destination prior to pick-up. The processor **340** can transmit the pick-up request **367** via a communications interface **310** to the backend transport system **390** over a network **380**. In response, the mobile computing device **300** can receive a confirmation **369** from the transport system **390** indicating the selected SDV that will service the pick-up request **367** and rendezvous with the user at the pick-up location.

[0060] In certain implementations, the mobile computing device **300** can further include a microphone **370** to enable the user to provide voice inputs **372** to further interact with the rider application **332**. For example, instead of provide user inputs **318** on the display screen **320**, certain commands can be provided via voice input **372** (e.g., pick-up requests **367**, confirmations, cancelations, postponements, etc.). Additionally, the mobile computing device **300** can include one or more output devices **375** that can provide outputs **371** and/or feedback based on user interactions and responses through the rider application **332**. Such outputs **371** can include haptic and/or audio feedback (e.g., voice feedback) generated by the rider application **332**, such as ride update information, tonal responses, alerts, and the like.

[0061] According to examples, the mobile computing device **300** can receive ETA data **392** from the transport system **390** based on the dynamically constructed traffic models described herein. Current ETA information for mapping, routing, and traffic resources may utilize GPS information (e.g., location data **362** from the GPS resources of users' mobile devices). Examples described herein can significantly improve the ETA data **392** based on the constructed models utilizing real-time, lane-specific SDV data, which can further be utilized by the transport system **390** in mid-level routing of the SDVs, as described herein. This can further bolster ETA predictability and provide users of the service with highly accurate ETA information relating to arrival times for pick-up and overall trip time to a destination.

[0062] In one example, the ETA data **392** can include estimated arrival times for a plurality of SDVs that are proximate to the user's current location. For example, the app interface **342** can include a mapping feature with real-time virtual representations of SDVs traveling on the mapping feature. The ETA data **392** can include an estimated arrival time for each of the SDVs on the map (e.g., on a miniature window next to the SDV's displayed virtual representation). Additionally or alternatively, the ETA data **392** can include an estimated arrival time of an SDV selected to service a pick-up request **367** submitted by the user. In further examples, the ETA data **392** can include an estimated arrival time to a destination once the user has been pick-up by the selected SDV.

[0063] Methodology

[0064] FIGS. **4**A and **4**B are flow charts describing example methods of traffic modeling and data distribution, according to examples described herein. In the below descriptions of FIGS. **4**A and **4**B, reference may be made to reference characters representing like features shown and described with respect to FIGS. **1**-**3**. Furthermore, the below methods described with respect to FIGS. **4**A and **4**B may be performed by an example transport system **100** as described with respect to FIG. **1**. Referring to FIG. **4**A, the transport system **100** can receive SDV data **194** from a fleet of SDVs **190** traveling throughout a given region (**400**). In certain implementations described herein, the fleet of SDVs **190** can be managed by the transport system **100** in connection with a transportation arrangement service in which the transport system **100** receives pick-up requests **197** from user devices **195** and selects individual SDVs **109** to service those requests **197** by rendezvousing with the requesting user at a pick-up location and autonomously transporting the user to an inputted destination. In one aspect, the SDV data **194** can include lane-specific data corresponding to the traffic flow of the road lane on which the SDV **109** is currently traveling (**402**). Additionally, the SDV data **194** can include vehicle specific data, such as speed information, position and/or location of the SDV **109** in the given region, and direction of travel (**404**). Further still, the SDV data **194** can include sensor view information (e.g., stereo camera data) indicating the surrounding environment of the SDV **109**, such as the proximate lanes, opposite traffic, other entities (e.g., other vehicles), and intersection traffic information.

[0065] According to some examples, the transport system **100** can construct traffic models **132** for the given region based on the SDV data **194** collectively received from the

fleet of SDVs **190** (**405**). Such traffic models **132** can include data indicating real-time traffic flows for individual lanes throughout the given region. In various examples, the transport system **100** can construct the traffic models **132** in real-time, o periodically (e.g., every few seconds). Furthermore, the traffic models **132** can be local to specific intersections or other traffic hotspots, or can be constructed for an entire region. Using these dynamically or periodically constructed traffic models **132**, provide estimated time of arrival (ETA) data **142** for one or more SDVs to users of the transportation arrangement service (**410**). Such ETA data **142** can indicate an estimated arrival time for a selected SDV **109** to pick-up the user, an estimated arrival time at a destination, and/or a plurality of estimated arrival times for any number of proximate SDVs in relation to the user's current location.

[0066] Referring to FIG. **4**B, the transport system **100** can, in general, manage a transportation service by receiving pick-up requests **197** from users via a designated application **185** executing on the user's mobile devices **195** and selecting optimal SDVs **109** in a fleet **190** to service those pick-up requests **197** (**415**). In order to make routing through traffic more efficient and optimize timing for users, the transport system **100** can receive SDV data **194** from the SDV fleet **190** as each SDV **109** operates throughout the given region (**420**). In many examples, the SDV data **194** can include vehicle-specific data, such as the vehicle's location in the given region, its orientation, speed, a current lane on which the vehicle travels, and the like. Additionally, the SDV data **194** can include data indicating the proximate environment of the vehicle (e.g., raw or processed sensor view data **111**), such as the traffic conditions in the lane(s) adjacent to the vehicle or on an opposite side of the road (**424**). For example, the proximate environment of the SDV **109** can indicate a number of other vehicles external to the SDV **109**. The transport system **100** can determine a set of properties of the other vehicles (e.g., speed, brake lights, relative velocity to the SDV **109**, traffic density, etc.) and utilize this et of properties to construct the traffic models **132**. In one example, the transport system **100** can extrapolate lane-specific traffic conditions on lanes external to the vehicle's travel lane, including opposing traffic, by factoring the vehicle's speed versus sensor view data **111** from the vehicle that indicates the other vehicles' speeds.

[0067] According to examples described herein, the transport system **100** may then construct one or more traffic model(s) **132** for the given region using the SDV data **194** from the fleet (**425**). In constructing the traffic model(s) **132**, the transport system **100** can calculate timing for traffic signals, such as fixed or variably timed traffic signals (**427**), and incorporate individual lane flows in the traffic model(s) (**429**). In one example, the transport system **100** can construct smaller scale individual traffic models **132** that cover a particular traffic pocket, such as an area surrounding an intersection with heavy traffic, or bottlenecks on freeways. Such the transport system can utilize such individual models to, for example, manage routing for SDVs through such traffic pockets or areas (e.g., selecting lanes or alternative routes to bypass the traffic area). Furthermore, the transport system **100** can provide ETA data **142** for users of the transport service via the designated application **185**. For example, prior to transmitting a pick-up request **197**, the users can be provided with improved ETA data **142** for a number of vehicles proximate to the user's current location or a potential pick-up location.

[0068] In many implementations, the transport system **100** can receive pick-up requests **197** from user of the transportation service (**430**). As described, the pick-up requests **197** can include a pick-up location. For each pick-up request **197**, the transport system **100** can utilize the traffic model(s) **132** to select an optimal SDV **109** to service the pick-up request **197** (**435**). For example, the transport system **100** can identify a pool of proximate SDVs in relation to the pick-up location (**440**). In one aspect, the transport system **100** can only identify available SDVs, such as those that are not currently transporting a user to a destination. In variations, the transport system **100** can identify all available and unavailable SDVs proximate to the pick-up location.

[0069] For the unavailable SDVs, the transport system **100** can determine a first ETA to a drop-off destination, account for an averaged drop-off time delta (e.g., ten or fifteen seconds)—changing the status of the SDV from unavailable to available—and determine a second ETA for the SDV to arrive at the pick-up location (**442**). Thus, the transport system **100** can estimate the overall time for such unavailable SDVs to arrive at the pick-up location based on the constructed traffic models **132**. Using these overall time estimates for the unavailable SDVs, and the normal ETAs using the traffic models for the available SDVs (**444**), the transport system **100** can select an optimal SDV **109** from the proximate pool of SDVs to service the pick-up request (**435**). Thus, in certain situations, the optimal SDV **109** selected by the transport system **100** may be unavailable at the time of selection, but still determined to arrive at the pick-up location prior to any other proximate SDVs in the pool based on the constructed traffic models **132**.

[0070] In certain aspects, the transport system **100** can transmit ETA data **142** to the requesting user corresponding to the selected SDV **109** (**445**). For example, while the user is awaiting pick-up, the transport system **100** can provide the requesting user with ETA data **142** for when the selected SDV **109** is to rendezvous with the requesting user (**447**). This ETA data **142** can include the calculated overall time if the SDV **109** first needs to make a drop-off. Furthermore, once the SDV **109** has rendezvoused with the requesting user, the transport system **100** can provide the user with ETA data **142** corresponding to an arrival time to the destination (**449**). Still further, the transport system **100** can utilize the traffic models to provide the SDV with routing information or updates **184** during the trip (**450**). Such routing information or updates **184** can enable or cause the SDV **109** to perform mid-level actions such as selecting a lane, bypassing traffic pockets by using a detour or alternative route, and the like. Furthermore, the transport system **100** can provide such routing updates **184** to the SDV **109** throughout the course of the whole trip, generating such updates **184** can transmitting them to the SDV **109** dynamically, or whenever an upcoming traffic pocket or area is identified in the constructed traffic models **132** along the SDV's **109** route (**455**).

[0071] In certain implementations, the transport system **100** can identify stale data in the dynamically constructed traffic models **132** (**460**). For example, the transport system **100** can determine that SDVs have not driven through a certain area in the given region for a certain amount of time (e.g., five or ten minutes), which can indicate that the traffic model for that area is unreliable. In accordance with certain

examples, the transport system **100** can transmit transport directive **182** to SDVs in the fleet that are proximate to such areas in order to provide refreshed SDV data **194** (**465**). Such transport directives **182** can cause SDVs to be rerouted from current routes, or can utilize available SDVs that are on standby to provide the refresh SDV data **194**. Accordingly, as the SDV data **194** is received, the transport system **100** can dynamically update the constructed traffic models **132** (**470**).

[0072] Hardware Diagrams

[0073] FIG. **5** is a block diagram that illustrates a computer system upon which examples described herein may be implemented. A computer system **500** can be implemented on, for example, a server or combination of servers. For example, the computer system **500** may be implemented as part of a network service for providing transportation services. In the context of FIG. **1**, the transport system **100** may be implemented using a computer system **500** such as described by FIG. **5**. The transport system **100** may also be implemented using a combination of multiple computer systems as described in connection with FIG. **5**.

[0074] In one implementation, the computer system **500** includes processing resources **510**, a main memory **520**, a read-only memory (ROM) **530**, a storage device **540**, and a communication interface **550**. The computer system **500** includes at least one processor **510** for processing information stored in the main memory **520**, such as provided by a random access memory (RAM) or other dynamic storage device, for storing information and instructions which are executable by the processor **510**. The main memory **520** also may be used for storing temporary variables or other intermediate information during execution of instructions to be executed by the processor **510**. The computer system **500** may also include the ROM **530** or other static storage device for storing static information and instructions for the processor **510**. A storage device **540**, such as a magnetic disk or optical disk, is provided for storing information and instructions.

[0075] The communication interface **550** enables the computer system **500** to communicate with one or more networks **580** (e.g., cellular network) through use of the network link (wireless or wired). Using the network link, the computer system **500** can communicate with one or more computing devices, one or more servers, driver devices, and/or a fleet of SDVs **190**. In accordance with examples, the computer system **500** receives pick-up requests **584** from mobile computing devices of individual users. The executable instructions stored in the memory **530** can include traffic modeling instructions **524**, which the processor **510** can execute to construct live traffic models **532** for the given region. The communication interface **550** can receive SDV data **582**, comprising lane-specific and granular positioning and speed information from the fleet of SDVs. The processor **510** can utilize the SDV data **582** to dynamically construct the live traffic models **532**, as described herein.

[0076] The main memory **520** can also store SDV selection instructions **522**, which the processor **510** executes to perform an optimization operation to identify a most optimal vehicle to service a pick-up request **584**. In performing the optimization, the processor **510** can receive SDV data **582** corresponding to SDVs proximate to the pick-up location indicated in the pick-up request **584**, account for estimated drop-off time deltas for unavailable proximate SDVs, and utilize the constructed traffic models **532** to determine a most optimal SDV with a shortest ETA to the pick-up location.

[0077] The processor **510** is configured with software and/or other logic to perform one or more processes, steps and other functions described with implementations, such as described by FIGS. **1** through **6**, and elsewhere in the present application.

[0078] FIG. **6** is a block diagram illustrating a computer system upon which example SDV processing systems described herein may be implemented. The computer system **600** can be implemented using one or more processors **604**, and one or more memory resources **606**. In the context of FIG. **2**, the control system **220** can be implemented using one or more components of the computer system **600** shown in FIG. **6**.

[0079] According to some examples, the computer system **600** may be implemented within an autonomous vehicle or self-driving vehicle with software and hardware resources such as described with examples of FIG. **2**. In an example shown, the computer system **600** can be distributed spatially into various regions of the SDV, with various aspects integrated with other components of the SDV itself. For example, the processors **604** and/or memory resources **606** can be provided in the trunk of the SDV. The various processing resources **604** of the computer system **600** can also execute control instructions **612** using microprocessors or integrated circuits. In some examples, the control instructions **612** can be executed by the processing resources **604** or using field-programmable gate arrays (FPGAs).

[0080] In an example of FIG. **6**, the computer system **600** can include a communication interface **650** that can enable communications over one or more networks **660** with a backend transport system, such as those examples described with respect to FIG. **1**. In one implementation, the communication interface **650** can also provide a data bus or other local links to electro-mechanical interfaces of the vehicle, such as wireless or wired links to and from the SDV control system **220**, and can provide a network link to a transport system over one or more networks **660**.

[0081] The memory resources **606** can include, for example, main memory, a read-only memory (ROM), storage device, and cache resources. The main memory of memory resources **606** can include random access memory (RAM) or other dynamic storage device, for storing information and instructions which are executable by the processors **604**. The processors **604** can execute instructions for processing information stored with the main memory of the memory resources **606**. The main memory **606** can also store temporary variables or other intermediate information which can be used during execution of instructions by one or more of the processors **604**. The memory resources **606** can also include ROM or other static storage device for storing static information and instructions for one or more of the processors **604**. The memory resources **606** can also include other forms of memory devices and components, such as a magnetic disk or optical disk, for purpose of storing information and instructions for use by one or more of the processors **604**.

[0082] According to some examples, the memory **606** may store a set of software instructions including, for example, control instructions **612**. The control instructions **612** may be executed by one or more of the processors **604** in order to implement functionality such as described with respect to the SDVs herein. The computer system **600** can communi-

cate, periodically or continuously, SDV location data **652** and/or SDV data **654**—which can include positioning, speed, direction, and/or sensor view data—to the transport system over the network **660**. As described herein, the transport system can construct granular traffic models for the given region through which the SDV operates.

[0083] In certain examples, the computer system **600** can receive transport directives **662** via the communication interface **650** and network **660** from a transport system. As described herein, the transport directives **662** can include a request to provide transportation for a requesting user, and can include data corresponding to a pick-up location. In executing the control instructions **612**, the processing resources **604** can identify the pick-up location and destination (after pick-up), and generate control commands **605** to autonomously operate the acceleration, braking, and steering systems **620** of the SDV. In operating the acceleration, braking, and steering system **620**, the processors **604** can process sensor data **632** from the sensor array **630** of the SDV to continuously analyze the surrounding environment in order to avoid any potential hazards.

[0084] Furthermore, the processors **604** operate the acceleration, braking, and steering systems **620** along a current route, either determined locally via a mapping resource, or via information from a remote source. In one aspect, the communications interface **650** can receive live route data **664** from the transport system over the network processors **604** can

[0085] While examples of FIGS. **3**, **5**, and **6** provide for computing systems for implementing aspects described, some or all of the functionality described with respect to one computing system of FIGS. **3**, **5**, and **6** may be performed by one or more other computing systems described with respect to FIGS. **3**, **5**, and **6**.

[0086] It is contemplated for examples described herein to extend to individual elements and concepts described herein, independently of other concepts, ideas or systems, as well as for examples to include combinations of elements recited anywhere in this application. Although examples are described in detail herein with reference to the accompanying drawings, it is to be understood that the concepts are not limited to those precise examples. As such, many modifications and variations will be apparent to practitioners skilled in this art. Accordingly, it is intended that the scope of the concepts be defined by the following claims and their equivalents. Furthermore, it is contemplated that a particular feature described either individually or as part of an example can be combined with other individually described features, or parts of other examples, even if the other features and examples make no mentioned of the particular feature. Thus, the absence of describing combinations should not preclude claiming rights to such combinations.

What is claimed is:

1. A computing system implementing traffic modeling, the computing system comprising:

a network communication interface communicating, over one or more networks, with (i) a fleet of self-driving vehicles (SDVs) operating throughout a given region, and (ii) computing devices of users;

one or more processors; and

one or more memory resources storing instructions that, when executed by the one or more processors, cause the computing system to:

receive, over the one or more networks, sensor view data from each respective SDV in the fleet of SDVs, the sensor view data indicating a surrounding environment of the respective SDV;

determine, from the sensor view data, a set of properties of one or more vehicles external to each SDV in the fleet;

based on the set of properties of the one or more vehicles external to each SDV in the fleet, generate one or more traffic models for the given region to indicate traffic flow for at least part of the given region; and

utilizing the one or more traffic models, generate map data for the computing devices of the users, the map data indicating the traffic flow for the at least part of the given region.

2. The computing system of claim **1**, wherein the executed instructions cause the computing system to provide estimated time of arrival (ETA) information for the users in conjunction with the map data.

3. The computing system of claim **2**, wherein the executed instructions cause the computing system to provide the map data and the ETA data to the users via a designated application executing on the computing devices of the users.

4. The computing system of claim **3**, wherein the designated application enables a particular user to input a location on an interactive map interface and view the traffic flow and an ETA of the particular user to the inputted location on the interactive map interface.

5. The computing system of claim **1**, wherein the sensor view data from each respective SDV indicates a current lane of a road on which the respective SDV travels and one or more additional lanes in the surrounding environment of the respective SDV, and wherein the set of properties of the one or more vehicles includes a speed of each of the one or more vehicles.

6. The computing system of claim **1**, wherein the executed instructions further cause the computing system to generate the one or more traffic models by determining timing data for individual traffic signals throughout the given region based on the traffic flows.

7. The computing system of claim **1**, wherein the executed instructions further cause the computing system to:

receive, over the one or more networks, a transport request from a computing device of a requesting user, the transport request including a pick-up location and a destination location;

select an SDV, from one or more proximate SDVs in relation to a current location of the requesting user, to service the pick-up request; and

transmit, over the one or more networks, confirmation information to the computing device of the requesting user, the confirmation information identifying the selected SDV and ETA data corresponding to the selected SDV arriving at the pick-up location, the ETA data being based on the one or more traffic models.

8. A non-transitory computing readable medium storing instructions that, when executed by one or more processors of a computing system, cause the computing system to:

communicate, over one or more networks, with (i) a fleet of self-driving vehicles (SDVs) operating throughout a given region, and (ii) computing devices of users;

receive, over the one or more networks, sensor view data from each respective SDV in the fleet of SDVs, the sensor view data indicating a surrounding environment of the respective SDV;

determine, from the sensor view data, a set of properties of one or more vehicles external to each SDV in the fleet;

based on the set of properties of the one or more vehicles external to each SDV in the fleet, generate one or more traffic models for the given region to indicate traffic flow for at least part of the given region; and

utilizing the one or more traffic models, generate map data for the computing devices of the users, the map data indicating the traffic flow for the at least part of the given region.

9. The non-transitory computing readable medium of claim **8**, wherein the executed instructions cause the computing system to provide estimated time of arrival (ETA) information for the users in conjunction with the map data.

10. The non-transitory computing readable medium of claim **9**, wherein the executed instructions cause the computing system to provide the map data and the ETA data to the users via a designated application executing on the computing devices of the users.

11. The non-transitory computing readable medium of claim **10**, wherein the designated application enables a particular user to input a location on an interactive map interface and view the traffic flow and an ETA of the particular user to the inputted location on the interactive map interface.

12. The non-transitory computing readable medium of claim **8**, wherein the sensor view data from each respective SDV indicates a current lane of a road on which the respective SDV travels and one or more additional lanes in the surrounding environment of the respective SDV, and wherein the set of properties of the one or more vehicles includes a speed of each of the one or more vehicles.

13. The non-transitory computing readable medium of claim **8**, wherein the executed instructions further cause the computing system to generate the one or more traffic models by determining timing data for individual traffic signals throughout the given region based on the traffic flows.

14. The non-transitory computing readable medium of claim **8**, wherein the executed instructions further cause the computing system to:

receive, over the one or more networks, a pick-up request from a computing device of a requesting user, the pick-up request corresponding to an inputted pick-up location on the interactive map;

select an SDV, from one or more proximate SDVs in relation to a current location of the requesting user, to service the pick-up request; and

transmit confirmation information to the mobile computing device of the requesting user, the confirmation information identifying the selected SDV and ETA data corresponding to the selected SDV arriving at the pick-up location, the ETA data being based on the one or more traffic models.

15. A computer-executed method of implementing traffic modeling, the method being performed by one or more processors and comprising:

communicating, over one or more networks, with (i) a fleet of self-driving vehicles (SDVs) operating throughout a given region, and (ii) computing devices of users;

receiving, over the one or more networks, sensor view data from each respective SDV in the fleet of SDVs, the sensor view data indicating a surrounding environment of the respective SDV;

determining, from the sensor view data, a set of properties of one or more vehicles external to each SDV in the fleet;

based on the set of properties of the one or more vehicles external to each SDV in the fleet, generating one or more traffic models for the given region to indicate traffic flow for at least part of the given region; and

utilizing the one or more traffic models, generating map data for the computing devices of the users, the map data indicating the traffic flow for the at least part of the given region.

16. The method of claim **15**, wherein the one or more processors provide estimated time of arrival (ETA) information for the users in conjunction with the map data.

17. The method of claim **16**, wherein the one or more processors provide the map data and the ETA data to the users via a designated application executing on the computing devices of the users.

18. The method of claim **17**, wherein the designated application enables a particular user to input a location on an interactive map interface and view the traffic flow and an ETA of the particular user to the inputted location on the interactive map interface.

19. The method of claim **15**, wherein the sensor view data from each respective SDV indicates a current lane of a road on which the respective SDV travels and one or more additional lanes in the surrounding environment of the respective SDV, and wherein the set of properties of the one or more vehicles includes a speed of each of the one or more vehicles.

20. The method of claim **15**, wherein the one or more processors generate the one or more traffic models by determining timing data for individual traffic signals throughout the given region based on the traffic flows.

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