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Lei et al.

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(54) **ADAPTIVELY SELECTING NETWORK APN FOR VEHICLE APPLICATION REMOTE COMPUTING DEMAND**

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G01S 5/02	(2010.01)
H04W 4/02	(2018.01)
H04W 4/44	(2018.01)
H04W 8/18	(2009.01)

(52) **U.S. Cl.**
CPC ***H04W 4/44*** (2018.02); ***H04W 8/183*** (2013.01); ***H04W 64/00*** (2013.01)

(58) **Field of Classification Search**
CPC H04W 4/44; H04W 8/183; H04W 64/00
See application file for complete search history.

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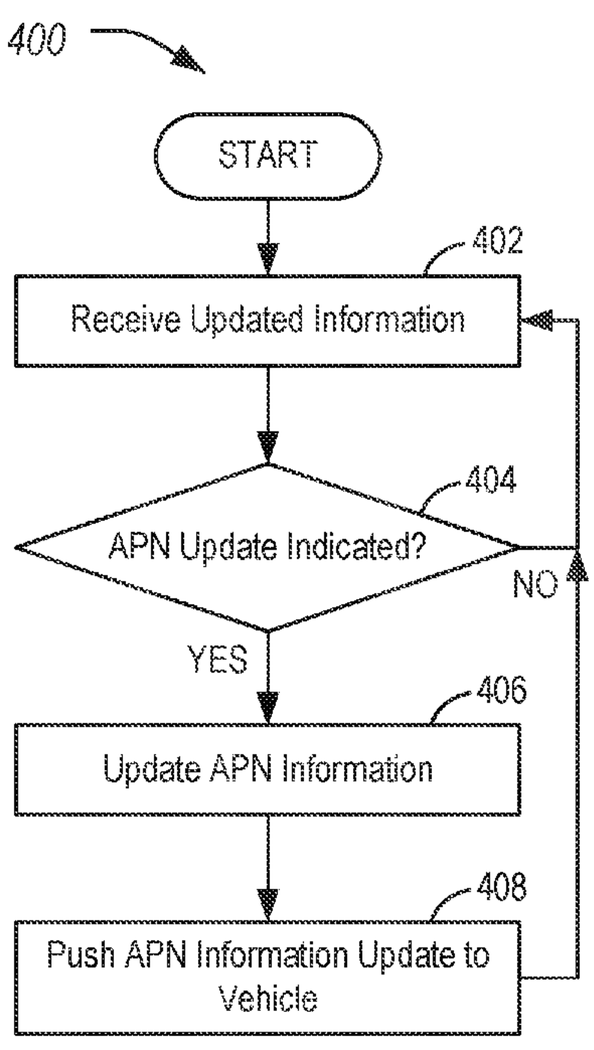
(57) **ABSTRACT**

Managing vehicle application usage of computing resources is provided. A request for computing resources of a communications network is received from a vehicle application installed to a vehicle. An access point name (APN) is assigned to the vehicle application based on an application identifier corresponding to the vehicle application by accessing stored APN information including a mapping of application identifiers to corresponding APNs. The computing resources are accessed by the vehicle application connecting to the communications network using the APN.

17 Claims, 4 Drawing Sheets



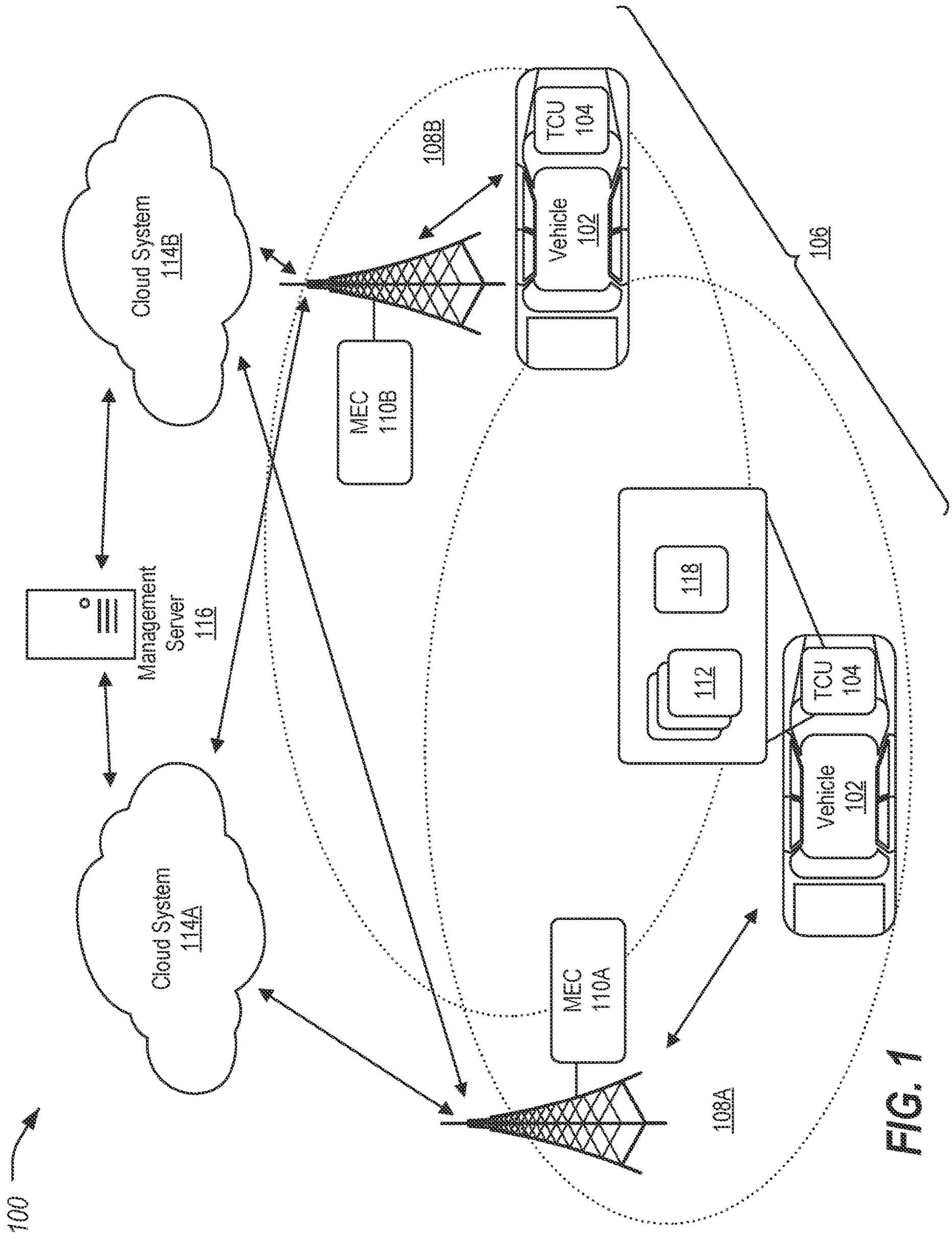

Cloud System
114B
Management
Server
116
Cloud System
114A
108B
MEC
110B
TCU
104
Vehicle
102
106
118
112
TCU
104
Vehicle
102
MEC
110A
108A
100

FIG. 1

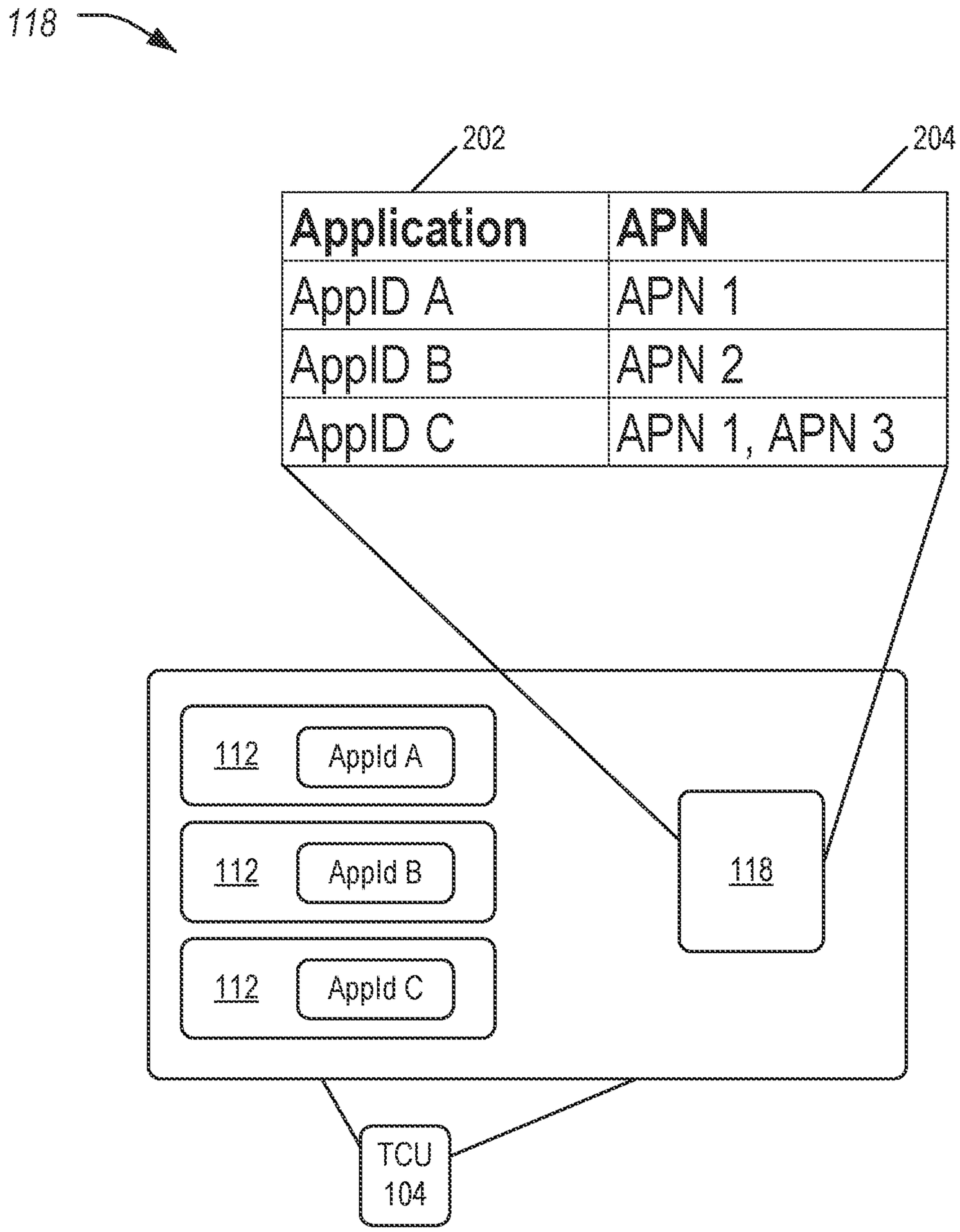

118
202
204
Application
APN
AppID A
APN 1
AppID B
APN 2
AppID C
APN 1, APN 3
112
AppId A
112
AppId B
112
AppId C
118
TCU
104

FIG. 2

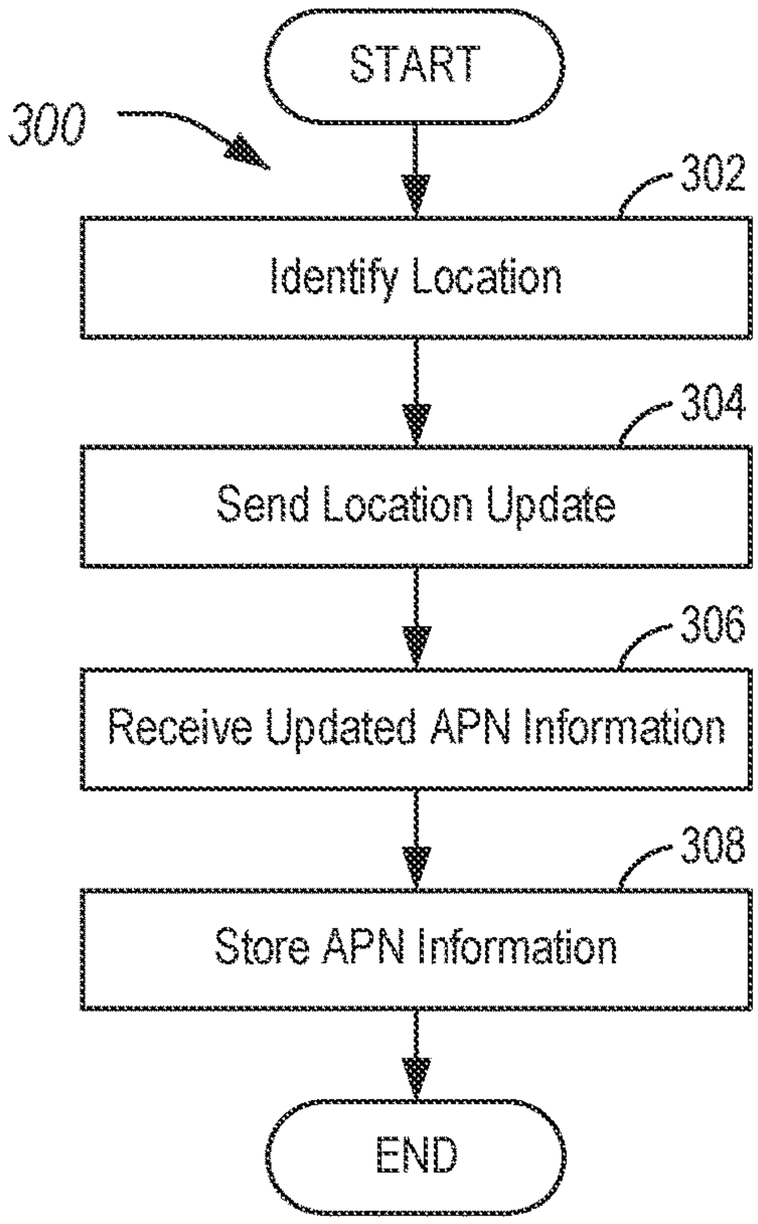


FIG. 3

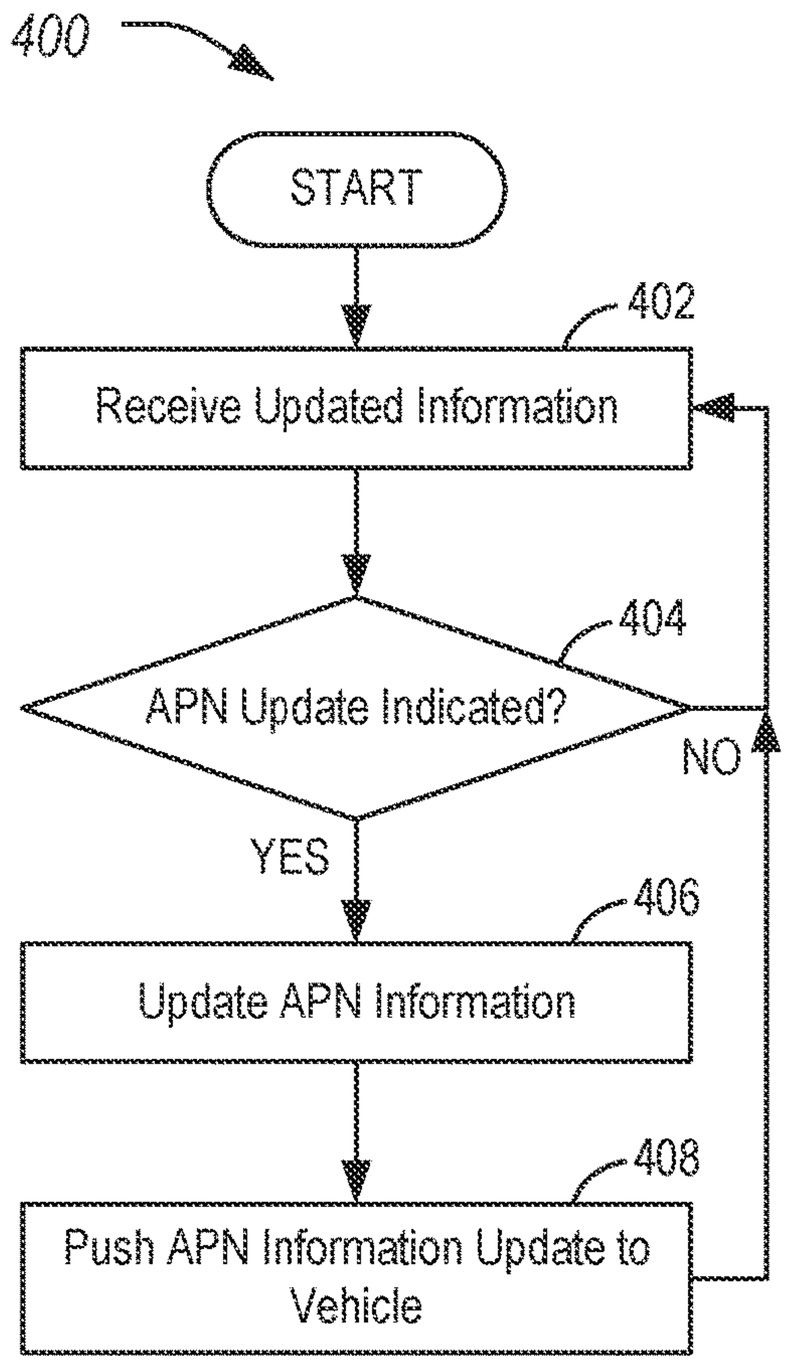


FIG. 4

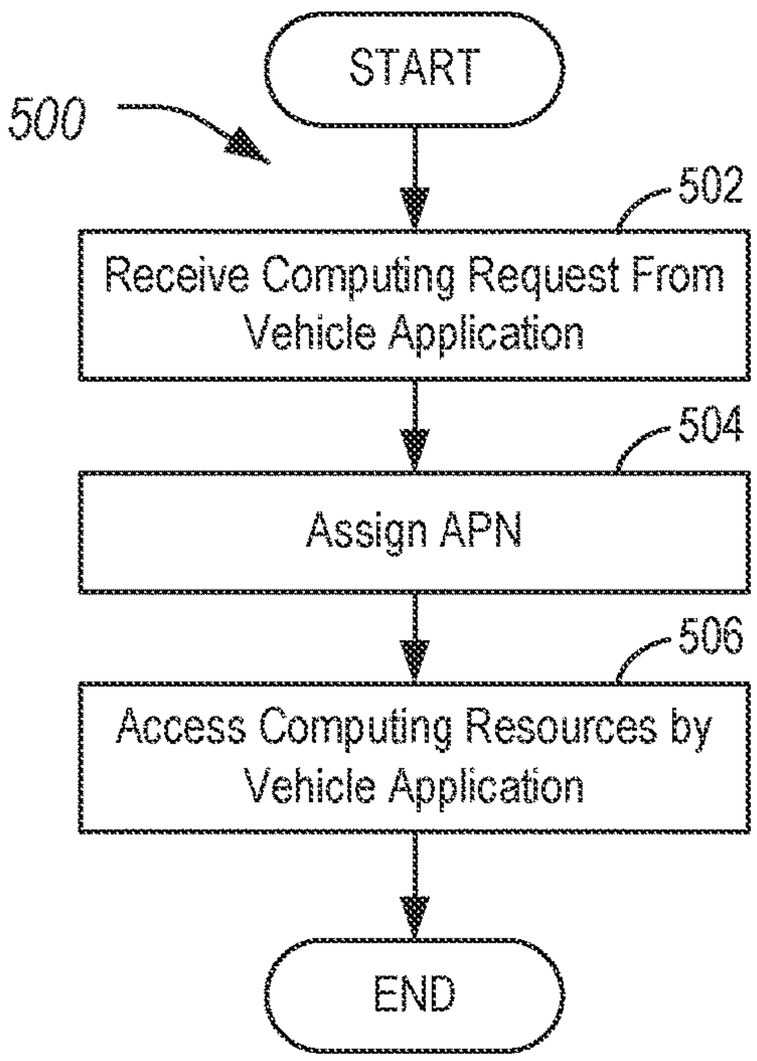


FIG. 5

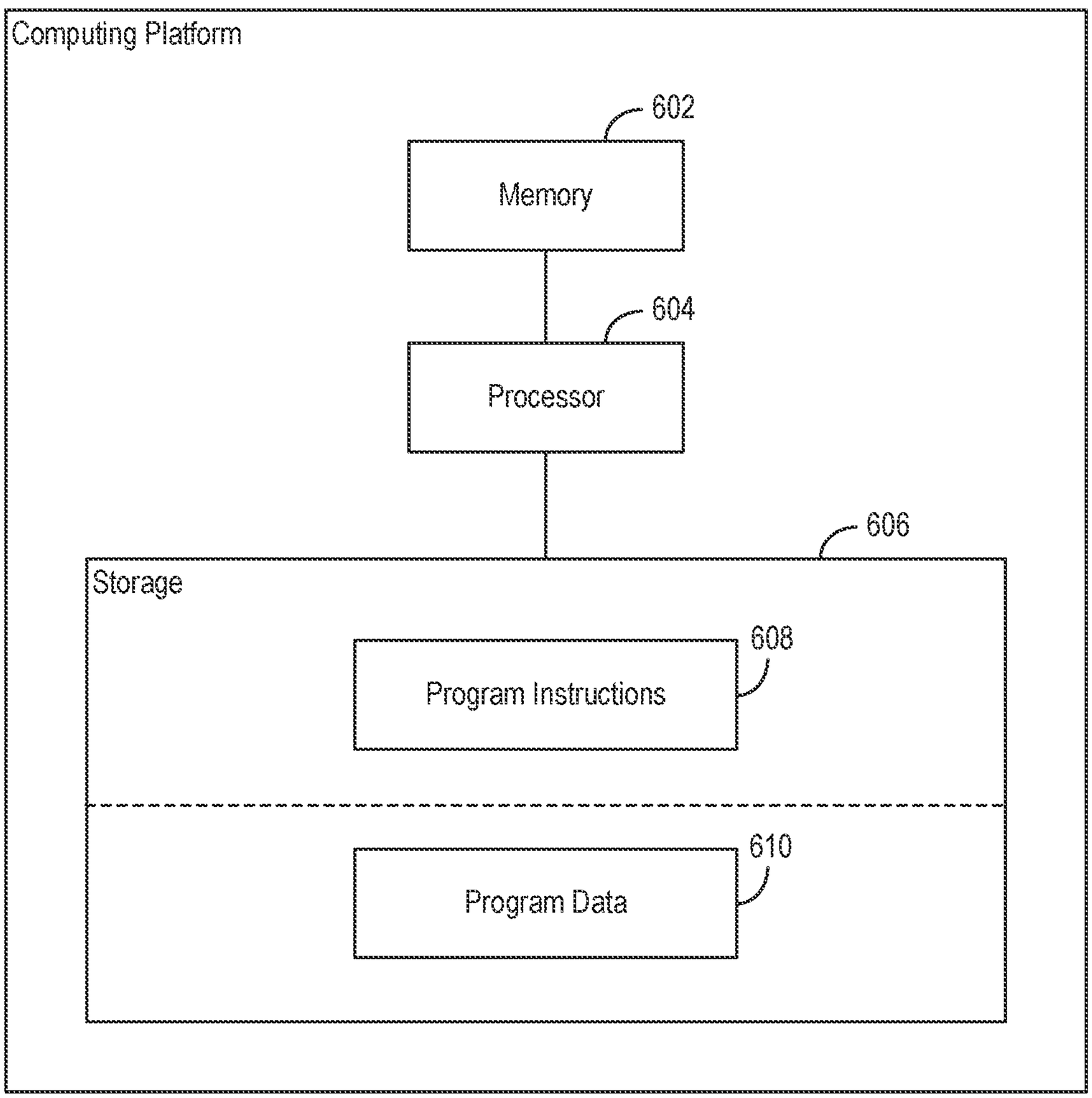

600
Computing Platform
602
Memory
604
Processor
606
Storage
608
Program Instructions
610
Program Data

FIG. 6

ADAPTIVELY SELECTING NETWORK APN FOR VEHICLE APPLICATION REMOTE COMPUTING DEMAND

TECHNICAL FIELD

Aspects of the present disclosure generally relate to adaptively selecting network access point name (APN) for vehicle application remote computing demand.

BACKGROUND

An APN may refer to a gateway between a network to which a vehicle is attached and a greater network such as the public Internet. A vehicle making a data connection may be configured with an APN to present to a carrier. The carrier may utilize the APN identifier to connect the vehicle to network resources in accordance with the parameters associated with the APN.

SUMMARY

In one or more illustrative examples, a system for managing vehicle application usage of computing resources is provided. The system includes one or more vehicle controllers of a vehicle programmed to receive a request for computing resources of a communications network from a vehicle application installed to the vehicle; assign an APN to the vehicle application based on an application identifier corresponding to the vehicle application by accessing stored APN information including a mapping of application identifiers to corresponding APNs; and access the computing resources by the vehicle application connecting to the communications network using the APN.

In one or more illustrative examples, a system for managing vehicle application usage of computing resources is provided. The system includes a management server programmed to receive updated information with respect to performance of computing resources of a plurality of multi-access edge computing devices (MECs) and/or cloud systems accessible to vehicle applications over a communications network; generate APN information mapping of application identifiers of the vehicle applications to corresponding APNs; and push the APN information to vehicles to allow the vehicles to assign APNs to the vehicle applications based on application identifiers corresponding to the vehicle applications.

In one or more illustrative examples, a method for managing vehicle application usage of computing resources is provided. A request for computing resources of a communications network is received from a vehicle application installed to a vehicle. An APN is assigned to the vehicle application based on an application identifier corresponding to the vehicle application by accessing stored APN information including a mapping of application identifiers to corresponding APNs. The computing resources are accessed by the vehicle application connecting to the communications network using the APN.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates an example system utilizing a management server for managing vehicle application usage of MECs and cloud systems;

FIG. **2** illustrates an example of APN information for an example set of vehicle applications;

FIG. **3** illustrates an example process for the vehicle to receive updated APN information from the management server;

FIG. **4** illustrates an example process for the management server providing dynamic APN information to the vehicle to allow the vehicle to provide services of the communications network to the vehicle applications;

FIG. **5** illustrates an example process for the vehicle utilizing the APN information to provide services of the communications network to the vehicle applications; and

FIG. **6** illustrates an example computing device for managing vehicle application usage of MECs and cloud systems.

DETAILED DESCRIPTION

Embodiments of the present disclosure are described herein. It is to be understood, however, that the disclosed embodiments are merely examples and other embodiments can take various and alternative forms. The figures are not necessarily to scale; some features could be exaggerated or minimized to show details of particular components. Therefore, specific structural and functional details disclosed herein are not to be interpreted as limiting, but merely as a representative basis for teaching one skilled in the art to variously employ the embodiments. As those of ordinary skill in the art will understand, various features illustrated and described with reference to any one of the figures can be combined with features illustrated in one or more other figures to produce embodiments that are not explicitly illustrated or described. The combinations of features illustrated provide representative embodiments for typical applications. Various combinations and modifications of the features consistent with the teachings of this disclosure, however, could be desired for particular applications.

MECs and traditional cloud servers may be used to assist vehicle applications for remote computing. A vehicle may include a telematics control unit (TCU) subscriber identity module (SIM) configured to use a single network APN for vehicle applications that utilize remote computing assistance. The vehicle applications may have various network demands. For instance, some applications may require broadband access, some applications desire a low latency connection, and some applications may require high computing assistance. However, a single APN to a single MEC or cloud may be unable to meet requirements for various vehicles applications.

An improved MEC system may be configured to program the TCU SIM of the vehicle with multiple APNs. These APNs may direct the vehicle's network traffic to different MECs or cloud servers based on various factors. Each MEC server or cloud may have its own abilities, such as low latency, high computing power, broadband, etc. Based on different vehicle application demands and vehicle current location, the TCU may selectively use different APNs to meet the application requirements. The MEC server may be used for local computing with low latency, while traditional cloud server can be far away with non-critical latency computing. There can be multiple MECs and/or cloud servers with different computing capabilities. Or there may be MECs with the same capabilities to provide redundancy. Based on the vehicle location, the TCU may update to utilize the latest MECs and cloud capabilities so that it can provide appropriate APN to the applications in real-time. The original equipment manufacturer (OEM) or other manager may also reduce the quantity of MECs instances based on requirements (e.g., during night) to save cost, thus the TCU

may also be able to assign multiple applications to a single APN. Further aspects of the disclosure are discussed in detail herein.

FIG. **1** illustrates an example system **100** utilizing a management server **116** for managing vehicle application **112** usage of MECs **110** and cloud systems **114**. Vehicles **102** of the system **100** may include TCUs **104** configured to communicate with service areas **108** of the system **100**. The TCUs **104** may be configured to execute various vehicle applications **112**, where the vehicle applications **112** may have varying requirements. As shown, the system **100** includes a communications network **106** that defines two service areas **108** (**108**A and **108**B), where each service area **108** includes a corresponding MEC **110**. This is simply an example, and communications networks **106** having greater quantities of service areas **108** and MECs **110** are contemplated. The system **100** also includes a plurality of cloud systems **114** configured to communicate with the communications infrastructure in the service areas **108**. The management server **116** may configured to communicate with the cloud systems **114**.

The vehicle **102** may include various types of automobile, crossover utility vehicle (CUV), sport utility vehicle (SUV), truck, recreational vehicle (RV), boat, plane or other mobile machine for transporting people or goods. In many cases, the vehicle **102** may be powered by an internal combustion engine. As another possibility, the vehicle **102** may be a battery electric vehicle (BEV) powered by one or more electric motors. As a further possibility, the vehicle **102** may be a hybrid electric vehicle powered by both an internal combustion engine and one or more electric motors, such as a series hybrid electric vehicle, a parallel hybrid electrical vehicle, or a parallel/series hybrid electric vehicle. As the type and configuration of vehicle **102** may vary, the capabilities of the vehicle **102** may correspondingly vary. As some other possibilities, vehicles **102** may have different capabilities with respect to passenger capacity, towing ability and capacity, and storage volume. For title, inventory, and other purposes, vehicles **102** may be associated with unique identifiers, such as vehicle identification numbers (VINs).

The vehicle **102** may include a plurality of controllers configured to perform and manage various vehicle **102** functions under the power of the vehicle battery and/or drivetrain. As some non-limiting vehicle controller examples: a powertrain controller may be configured to provide control of engine operating components (e.g., idle control components, fuel delivery components, emissions control components, etc.) and for monitoring status of such engine operating components (e.g., status of engine codes); a body controller may be configured to manage various power control functions such as exterior lighting, interior lighting, keyless entry, remote start, and point of access status verification (e.g., closure status of the hood, doors and/or trunk of the vehicle **102**); a radio transceiver controller may be configured to communicate with key fobs, mobile devices, or other local vehicle **102** devices; an autonomous controller may be configured to provide commands to control the powertrain, steering, or other aspects of the vehicle **102**; a climate control management controller may be configured to provide control of heating and cooling system components (e.g., compressor clutch, blower fan, temperature sensors, etc.); a global navigation satellite system (GNSS) controller may be configured to provide vehicle location information; and a human-machine interface (HMI) controller may be configured to receive user input via various buttons or other controls, as well as provide vehicle status information to a driver, such as fuel level information, engine operating temperature information, and current location of the vehicle **102**. The vehicle **102** may also be configured to power other devices external to the vehicle using the vehicle battery and/or drivetrain.

The vehicle bus may include various methods of communication available between the vehicle controllers, as well as between the TCU **104** and the vehicle controllers. As some non-limiting examples, a vehicle bus may include one or more of a vehicle controller area network (CAN), an Ethernet network, and a media-oriented system transfer (MOST) network. Further aspects of the layout and number of vehicle buses are discussed in further detail below. The TCU **104** may include network hardware configured to facilitate communication between the vehicle controllers and with other devices of the system **100**. For example, the TCU **104** may include or otherwise access a cellular modem configured to facilitate communication with other vehicles **102** or with infrastructure. The TCU **104** may, accordingly, be configured to communicate over various protocols, such as with a communication network over a network protocol (such as Uu). The TCU **104** may, additionally, be configured to communicate over a broadcast peer-to-peer protocol (such as PC5), to facilitate cellular vehicle-to-everything (C-V2X) communications with devices such as other vehicles **102**. It should be noted that these protocols are merely examples, and different peer-to-peer and/or cellular technologies may be used.

The communications network **106** may include one or more interconnected communication networks such as the Internet, a cable television distribution network, a satellite link network, a local area network, and a telephone network, as some non-limiting examples. The TCU **104** may include network hardware configured to facilitate communication between the vehicle **102** and other devices of the system **100**. For example, the TCU **104** may include or otherwise access a cellular modem configured to facilitate communication with the communications network **106**.

The communications network **106** may include one or more service areas **108** including networking and computing resources. In an example, the service areas **108** may include antennas configured to wirelessly communicate with the wireless transceivers of the devices of the system **100**. In another example, the service areas **108** may include one or more MECs **110** configured to provide computing resources to the service areas **108**. As the MECs **110** are located at the periphery of the communications network **106**, the MECs **110** may be able to handle computing tasks local to the devices in communication with the communications network **106**, without the transmission of data through the communications network **106**.

The vehicle applications **112** may include programs to perform various functions utilizing the network and/or compute services of the communications network **106**. As some examples, the vehicle applications **112** may include programs to provide directions, stream media, track weather conditions, track fleet location, monitor health of the vehicle **102**, etc. As the functions of the vehicle applications **112** vary, the network and computing requirements for the vehicle applications **112** may also vary. For instance, some vehicle applications **112** may require broadband access, some vehicle applications **112** desire a low latency connection, and some vehicle applications **112** may require high computing assistance.

The cloud systems **114** may include additional computing resources that may be available to the service areas **108**. However, the cloud systems **114** may be further in network

distance from the vehicles **102** as compared to the relative local nature of the MECs **110**. In some instances the cloud systems **114** may be accessed by the vehicle applications **112** over the public Internet. The MECs **110** may also be location-based, for example, the MEC **110**A may be assigned to a first metropolitan area, while the MEC **110**B may be assigned to a second, different metropolitan area. The cloud systems **114** may have even bigger coverage, for example, cloud systems **114**A for the West coast, while cloud systems **114**B for the East coast.

The management server **116** may be a networked computing device configured to control the configuration of the system **100**. In an example, the management server **116** may be operated by a manufacturer of the vehicles **102**. In another example, the management server **116** may be operated by a fleet manager of the vehicles **102**.

The TCU **104** may additionally maintain APN information **118** for use in connecting the vehicle applications **112** to the communications network **106**. The APN information **118** may include, for example, a mapping of identifiers of the vehicle applications **112** to a corresponding APN to be used to connect the vehicle application **112** to the communications network **106**. Each APN may point to a MEC **110** and/or to a cloud system **114** with computing capabilities corresponding to the vehicle application **112**, for example, low latency, high reliability, high computing, broadband, etc.

In an example, the APN information **118** may be installed to the TCUs **104** of the vehicles **102** at manufacture. In another example, the APN information **118** may be downloaded to the TCUs **104** of the vehicles **102** from the management server **116**. The APN information **118** may be maintained to a SIM of the TCU **104** for instance.

FIG. **2** illustrates an example of APN information **118** for an example set of vehicle applications **112**. As shown, the APN information **118** includes application identifiers **202** of three applications, where each of the application identifiers **202** is associated with one or more APNs **204** that the TCU **104** may use to connect to the communications network **106** for use by the vehicle application **112**. Each vehicle application **112** may embed or otherwise be associated with a corresponding unique application identifier **202**. When the vehicle application **112** is run, this application identifier **202** may be extracted, and compared to the entries in the APN information **118** to identify the proper APN **204** (or set of APNs **204**) to use. For instance, the vehicle application **112** having AppID A may utilize APN **1**, the vehicle application **112** having AppID B may utilize APN **2**, and the vehicle application **112** having AppID B may utilize APNs **1** or **3**.

FIG. **3** illustrates an example process **300** for the vehicle **102** to receive updated APN information **118** from the management server **116**. In an example, the process **300** may be performed by one of the vehicles **102** in the context of the system **100**.

At operation **302**, the vehicle **102** identifies the location of the vehicle **102**. In an example, the vehicle **102** may utilize GNSS functionality of a controller of the vehicle **102** to determine the vehicle **102** location. In another example, the vehicle **102** may utilize its network location on the communications network **106** to determine the vehicle **102** location, such as via a lookup of geolocation information to internet protocol (IP) or other network address.

At operation **304**, the vehicle **102** sends a location update to the management server **116**. In an example, the vehicle **102** sends the location identified at operation **302** in a message over the communications network **106**. The management server **116** may accordingly receive the information indicating the location of the vehicle **102**.

At operation **306**, the vehicle **102** receives updated APN information **118** from the management server **116**. In an example, the management server **116** may utilize the updated location of the vehicle **102** to provide an update on which APNs **204** should be used for the vehicle applications **112** based on the updated location of the vehicle **102**. Further aspects of the updated APN information **118** are discussed with respect to the process **400**.

At operation **308**, the vehicle **102** stores the APN information **118** for later use. In an example, the APN information **118** is stored to a storage of the TCU **104**. In another example the APN information **118** is stored to the SIM of the TCU **104** corresponding to the communications network **106**. After operation **308**, the process **300** ends.

FIG. **4** illustrates an example process **400** for the management server **116** providing dynamic APN information **118** to the vehicle **102** to allow the vehicle **102** to provide services of the communications network **106** to the vehicle applications **112**.

At operation **402**, the management server **116** receives updated information for use in determining the mapping of APNs **204** to vehicle applications **112**. In an example, the updated information may include a change in the location of the vehicle **102**, a change in the time of day, a change in the day of the week, an update to the requirements of the vehicle application **112** (e.g., based on a update to the vehicle application **112** or its configuration), updated information with respect to the capabilities of the APNs **204**, updated information with respect to available resources of the MECs **110**, updated information with respect to available resources of the cloud systems **114**, updated information with respect to available communication resources of the communications networks **106**, etc. The updated information regarding the location of the vehicles **102** may be received to the management server **116** in accordance with the process **300**. In another example, the location of the vehicles **102** may be inferred by the management server **116** based on the network addresses of the messages being sent or received to the vehicles **102**.

At operation **404**, the management server **116** determines whether an update of the APN information **118** is indicated. In an example, the management server **116** may be configured to update the APN **204** assignment to the application identifiers **202** of the vehicle applications **112** based factors indicated by the updated information. In another example, the management server **116** may additionally or alternately be configured to periodically update the APN information **118**. If the received information indicates a change should be made, or the periodic update time has been reached, control passes to operation **406**. If not, control returns to operation **402**.

At operation **406**, the management server **116** updates the APN information **118**. In an example, the management server **116** may update the mapping of application identifiers **202** to APNs **204** to better fulfill the requirements of the vehicle applications **112**. In an example, the management server **116** may match the requirements of the vehicle applications **112** to the capabilities of the APNs **204** to compose the APN information **118**.

At operation **408**, the management server **116** pushes the updated APN information **118** to the vehicles **102**. The updated APN information **118** may be received to the vehicles **102** as discussed with respect to the process **300**. After operation **408**, control returns to operation **402**.

It should be noted that variations on the process **400** are possible. In another example, the vehicle **102** may perform the operations of the process **400** locally to determine the best APNs **204** to use, without the services of the management server **116**.

FIG. **5** illustrates an example process **500** for the vehicle **102** utilizing the APN information **118** to provide services of the communications network **106** to the vehicle applications **112**. In an example, the process **500** may be performed by one of the vehicles **102** in the context of the system **100**.

At operation **502**, the vehicle **102** receives a computing request from a vehicle application **112**. In an example, the computing request may be for processing to be performed by a MEC **110** or cloud system **114**. In another example, the computing request may be for network usage of the communications network **106**, such as a download or upload. In yet another example, the computing request may be the startup or activation of the vehicle application **112**.

At operation **504**, the vehicle **102** assigns an APN **204** to the vehicle application **112**. In an example, as shown in FIG. **2**, the TCU **104** may identify the application identifier **202** of the vehicle application **112** and may look up the corresponding APN **204** for the application identifier **202** in the APN information **118**.

At operation **506**, the vehicle **102** provides the vehicle application **112** with access to the computing resources via the APN **204**. These resources may include, for example, network communication over the communications network **106**, computing resources of the MEC **110**, computing resources of the cloud system **114**, etc. After operation **506**, the process **500** ends.

It should be noted that the approach described above for one vehicle application **112** may be used concurrently for more than one vehicle application **112** having different requirements. The vehicle **102** may have more than one vehicle application **112** running, where each vehicle application **112** may have different remote computing needs, e.g., different requirements with respect to latency, computing, broadband, etc. For instance, a first vehicle application **112** may perform intersection traffic dynamics and user detection/notification from the MEC **110**. This first vehicle application **112** may require a low latency connection. A second vehicle application **112** may perform a dynamic traffic map build, or a fast route calculation and may require greater computing resources. A third vehicle application **112** may perform video sharing/streaming and may require a broadband connection. The vehicle application **112** may send the computing request to the TCU **104**. The TCU **104** may assign the APN **204** that meets the demands of the vehicle application **112** to the vehicle application **112**. In some examples, the APN information **118** may specify different APNs **204** based on current vehicle **102** location, and the TCU **104** may select the APN **204** corresponding to the current location of the vehicle **102**.

The OEM, fleet manager, or other management server **116** maintainer may run more MEC **110** instances during peak times and fewer instances during off peak times to save resources. Thus, some APNs **204** may only be available at peak times. Thus, the APN information **118** may assign different APNs **204** for a vehicle application **112** based on the time period. The APN information **118** may also assign the same APN **204** to multiple vehicle application **112**. Thus, each vehicle application **112** may not necessarily require its own APN **204**. The APN information **118** may also include multiple APNs **204** for a single vehicle application **112** to provide for redundancy.

The management server **116** and/or the TCUs **104** may send requests to the MECs **110** and/or the cloud systems **114** to receive updates with respect to availability of the MECs **110** and/or the cloud systems **114**. Based on the network computing load, the MECs **110** and cloud systems **114** may also send feedback to the vehicles **102** to indicate to the vehicles **102** the real-time available computing capabilities, for example, processing time has increased (e.g., by 20%), computing power is degraded, broadband is degraded (e.g., now only 30 Mbps is available), low latency is back to normal (as 30 ms), broadband is back to normal (as 100 Mbps), etc.

The TCU **104** may receive the feedback and may also measure the latency from the requests sent from the vehicle **102** to the MECs **110** and/or the cloud systems **114**. Thus, TCU **104** may have the latest capability data for the MECs **110** and/or the cloud systems **114**. As a result, the TCU **104** may assign an appropriate APN **204** to meet the vehicle application **112** demands. Utilizing the adaptive network APN **204** selection, overall vehicle application **112** performance may be improved.

In some implementations, the TCU **104** may include dual SIM or more SIMS to support dual or more network operators. Thus, in such an example there may be more flexibility for vehicle applications **112** to use different APN **204** across multiple communications networks **106**.

As another possibility, the management server **116** may set a high priority APN **204** to all vehicles **102** in a region to force all vehicle applications **112** to use that high priority APN **204**. In this case, the TCU **104** may take the high priority APN **204** and ignore the requirements specified by the vehicle application **112**. This may be useful when the management server **116** has special requirements for a given timeframe, such as priority use of other resources or outages of various network components. Of course, the management server **116** may remove the high priority APN **204** by a further update once the special requirements are no longer relevant. For instance, the management server **116** may send updated APN information **118** to all the vehicles **102** in the region. Or the high priority APN **204** may be specified by the APN information **118** with a time limit, for example, only during the night from 10:00 pm~5:00 am.

FIG. **6** illustrates an example computing device **600** for managing vehicle application **112** usage of MEC **110** and cloud systems **114**. Devices discussed herein, such as the vehicles **102** and the management server **116** may include devices such as the computing device **600**. Likewise, the operations performed herein, such as those of the processes **300** and **400**, may be implemented with such a computing device **600**. The computing device **600** may include memory **602**, processor **604**, and non-volatile storage **606**. The processor **604** may include one or more devices selected from high-performance computing (HPC) systems including high-performance cores, microprocessors, micro-controllers, digital signal processors, microcomputers, central processing units, field programmable gate arrays, programmable logic devices, state machines, logic circuits, analog circuits, digital circuits, or any other devices that manipulate signals (analog or digital) based on computer-executable instructions residing in memory **602**. The memory **602** may include a single memory device or a number of memory devices including, but not limited to, random access memory (RAM), volatile memory, non-volatile memory, static random-access memory (SRAM), dynamic random access memory (DRAM), flash memory, cache memory, or any other device capable of storing information. The non-volatile storage **606** may include one or more persistent data

storage devices such as a hard drive, optical drive, tape drive, non-volatile solid-state device, cloud storage or any other device capable of persistently storing information.

The processor **604** may be configured to read into memory **602** and execute computer-executable instructions residing in program instructions **608** of the non-volatile storage **606** and embodying algorithms and/or methodologies of one or more embodiments. The program instructions **608** may include operating systems and applications. The program instructions **608** may be compiled or interpreted from computer programs created using a variety of programming languages and/or technologies, including, without limitation, and either alone or in combination, Java, C, C++, C #, Objective C, Fortran, Pascal, Java Script, Python, and Perl.

Upon execution by the processor **604**, the computer-executable instructions of the program instructions **608** may cause the computing device **600** to implement one or more of the algorithms and/or methodologies disclosed herein. The non-volatile storage **606** may also include data **610** supporting the functions, features, and processes of the one or more embodiments described herein.

The processes, methods, or algorithms disclosed herein can be deliverable to/implemented by a processing device, controller, or computer, which can include any existing programmable electronic control unit or dedicated electronic control unit. Similarly, the processes, methods, or algorithms can be stored as data and instructions executable by a controller or computer in many forms including, but not limited to, information permanently stored on non-writable storage media such as read-only memory (ROM) devices and information alterably stored on writeable storage media such as floppy disks, magnetic tapes, compact discs (CDs), RAM devices, and other magnetic and optical media. The processes, methods, or algorithms can also be implemented in a software executable object. Alternatively, the processes, methods, or algorithms can be embodied in whole or in part using suitable hardware components, such as Application Specific Integrated Circuits (ASICs), Field-Programmable Gate Arrays (FPGAs), state machines, controllers or other hardware components or devices, or a combination of hardware, software and firmware components.

While exemplary embodiments are described above, it is not intended that these embodiments describe all possible forms encompassed by the claims. The words used in the specification are words of description rather than limitation, and it is understood that various changes can be made without departing from the spirit and scope of the disclosure. As previously described, the features of various embodiments can be combined to form further embodiments of the invention that may not be explicitly described or illustrated. While various embodiments could have been described as providing advantages or being preferred over other embodiments or prior art implementations with respect to one or more desired characteristics, those of ordinary skill in the art recognize that one or more features or characteristics can be compromised to achieve desired overall system attributes, which depend on the specific application and implementation. These attributes can include, but are not limited to strength, durability, life cycle, marketability, appearance, packaging, size, serviceability, weight, manufacturability, ease of assembly, etc. As such, to the extent any embodiments are described as less desirable than other embodiments or prior art implementations with respect to one or more characteristics, these embodiments are not outside the scope of the disclosure and can be desirable for particular applications.

With regard to the processes, systems, methods, heuristics, etc. described herein, it should be understood that, although the steps of such processes, etc. have been described as occurring according to a certain ordered sequence, such processes could be practiced with the described steps performed in an order other than the order described herein. It further should be understood that certain steps could be performed simultaneously, that other steps could be added, or that certain steps described herein could be omitted. In other words, the descriptions of processes herein are provided for the purpose of illustrating certain embodiments, and should in no way be construed so as to limit the claims.

Accordingly, it is to be understood that the above description is intended to be illustrative and not restrictive. Many embodiments and applications other than the examples provided would be apparent upon reading the above description. The scope should be determined, not with reference to the above description, but should instead be determined with reference to the appended claims, along with the full scope of equivalents to which such claims are entitled. It is anticipated and intended that future developments will occur in the technologies discussed herein, and that the disclosed systems and methods will be incorporated into such future embodiments. In sum, it should be understood that the application is capable of modification and variation.

All terms used in the claims are intended to be given their broadest reasonable constructions and their ordinary meanings as understood by those knowledgeable in the technologies described herein unless an explicit indication to the contrary in made herein. In particular, use of the singular articles such as "a," "the," "said," etc. should be read to recite one or more of the indicated elements unless a claim recites an explicit limitation to the contrary.

The abstract of the disclosure is provided to allow the reader to quickly ascertain the nature of the technical disclosure. It is submitted with the understanding that it will not be used to interpret or limit the scope or meaning of the claims. In addition, in the foregoing Detailed Description, it can be seen that various features are grouped together in various embodiments for the purpose of streamlining the disclosure. This method of disclosure is not to be interpreted as reflecting an intention that the claimed embodiments require more features than are expressly recited in each claim. Rather, as the following claims reflect, inventive subject matter lies in less than all features of a single disclosed embodiment. Thus, the following claims are hereby incorporated into the Detailed Description, with each claim standing on its own as a separately claimed subject matter.

While exemplary embodiments are described above, it is not intended that these embodiments describe all possible forms of the invention. Rather, the words used in the specification are words of description rather than limitation, and it is understood that various changes may be made without departing from the spirit and scope of the invention. Additionally, the features of various implementing embodiments may be combined to form further embodiments of the invention.

What is claimed is:

1. A system for managing vehicle application usage of computing resources, comprising:

one or more vehicle controllers of a vehicle programmed to:

receive a request for computing resources of a communications network from a vehicle application installed to the vehicle;

receive APN information from a management server;

assign an access point name (APN) to the vehicle application based on an application identifier corresponding to the vehicle application by accessing the APN information including a mapping of application identifiers to corresponding APNs;

access the computing resources by the vehicle application connecting to the communications network using the APN;

send an updated location of the vehicle to the management server;

receive updated APN information from the management server, the updated APN information including an updated mapping of the application identifiers to the corresponding APNs; and

update the stored APN information to include the updated APN information.

2. The system of claim **1**, wherein the request for the computing resources is startup or activation of the vehicle application.

3. The system of claim **1**, where in the APN information is stored to a subscriber identity module (SIM) of the vehicle.

4. The system of claim **1**, wherein the APN is configured to allow the vehicle application access to one or more predefined multi-access edge computing (MEC) devices and/or cloud systems.

5. The system of claim **1**, wherein the APN is configured to allow the vehicle application access to network resources with a defined throughput and/or latency.

6. The A system for managing vehicle application usage of computing resources, comprising:

one or more vehicle controllers of a vehicle programmed to:

receive a request for computing resources of a communications network from a vehicle application installed to the vehicle;

assign an access point name (APN) to the vehicle application based on an application identifier corresponding to the vehicle application by accessing stored APN information including a mapping of one of the application identifiers to a first APN for a first vehicle location and a second APN for a second vehicle location;

determine a current location of the vehicle;

assign the first APN to the vehicle application responsive to the current location matching the first vehicle location; and

assign the second APN to the vehicle application responsive to the current location matching the second vehicle location.

7. A system for managing vehicle application usage of computing resources, comprising:

a management server programmed to:

receive updated information with respect to performance of computing resources of a plurality of MECs and/or cloud systems accessible to vehicle applications over a communication network;

generate an APN information mapping of application identifiers of the vehicle applications to corresponding APNs; and

push the APN information to vehicles to allow the vehicles to assign APNs to the vehicle applications based on application identifiers corresponding to the vehicle applications.

8. The system of claim **7**, wherein the management server is further programmed to generate and push the APN information periodically.

9. The system of claim **7**, wherein the management server is further programmed to generate and push the APN information responsive to receipt of updated information with respect to the performance of computing resources.

10. The system of claim **7**, wherein the updated information with respect to the performance of the computing resources includes a change in location of the vehicles.

11. The system of claim **7**, wherein the updated information with respect to the performance of the computing resources includes a change in time of day and/or day of week.

12. The system of claim **7**, wherein the updated information with respect to the performance of the computing resources includes an update to requirements of the vehicle applications.

13. The system of claim **7**, wherein the updated information with respect to the performance of the computing resources includes a change in available resources of the MECs, updated information with respect to available resources of the cloud systems, and/or updated information with respect to available communication resources of the communication network.

14. A method for managing vehicle application usage of computing resources, comprising:

receiving a request for computing resources of a communication network from a vehicle application installed to a vehicle;

assigning an access point name (APN) to the vehicle application based on an application identifier corresponding to the vehicle application by accessing stored APN information including a mapping of application identifiers to corresponding APNs;

accessing the computing resources by the vehicle application connecting to the communication network using the APN;

sending an updated location of the vehicle to a management server;

receiving updated APN information from the management server, the updated APN information including an updated mapping of the application identifiers to the corresponding APNs; and

updating the stored APN information to include the updated APN information.

15. A method for managing vehicle application usage of computing resources, comprising:

receiving a request for computing resources of a communication network from a vehicle application installed to a vehicle;

assigning an access point name (APN) to the vehicle application based on an application identifier corresponding to the vehicle application by accessing stored APN information including a mapping of application identifiers to corresponding APNs;

accessing the computing resources by the vehicle application connecting to the communication network using the APN;

receiving, by a management server, updated information with respect to performance of computing resources of a plurality of MECs and/or cloud systems accessible to vehicle applications over the communication network;

generating updated APN information based on the updated information; and

pushing the updated APN information to the vehicle.

16. The method of claim 15, further comprising generating and pushing the updated APN information responsive to receipt of the updated information with respect to the performance of computing resources.

17. The method of claim 16, wherein the updated information includes an updated location of the vehicle.

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