US 20250258706A1

(19) United States
(12) Patent Application Publication
Vemuri et al.

(10) Pub. No.: US 2025/0258706 A1
(43) Pub. Date: Aug. 14, 2025

(54) MATTER COMPUTE ARCHITECTURE WITH SMART DISCOVERY AND OPPORTUNISTIC ALLOCATION OF IOT DEVICE RESOURCES

(71) Applicant: **GM Global Technology Operations LLC**, Detroit, MI (US)

(72) Inventors: **Venkata Naga Siva Vikas Vemuri**, Farmington Hills, MI (US); **Lakshmi V. Thanayankizil**, Troy, MI (US); **John Sergakis**, Bloomfield Hills, MI (US); **Andrew J. MacDonald**, Grosse Pointe Park, MI (US)

(73) Assignee: **GM Global Technology Operations LLC**, Detroit, MI (US)

(21) Appl. No.: **18/437,371**

(22) Filed: **Feb. 9, 2024**

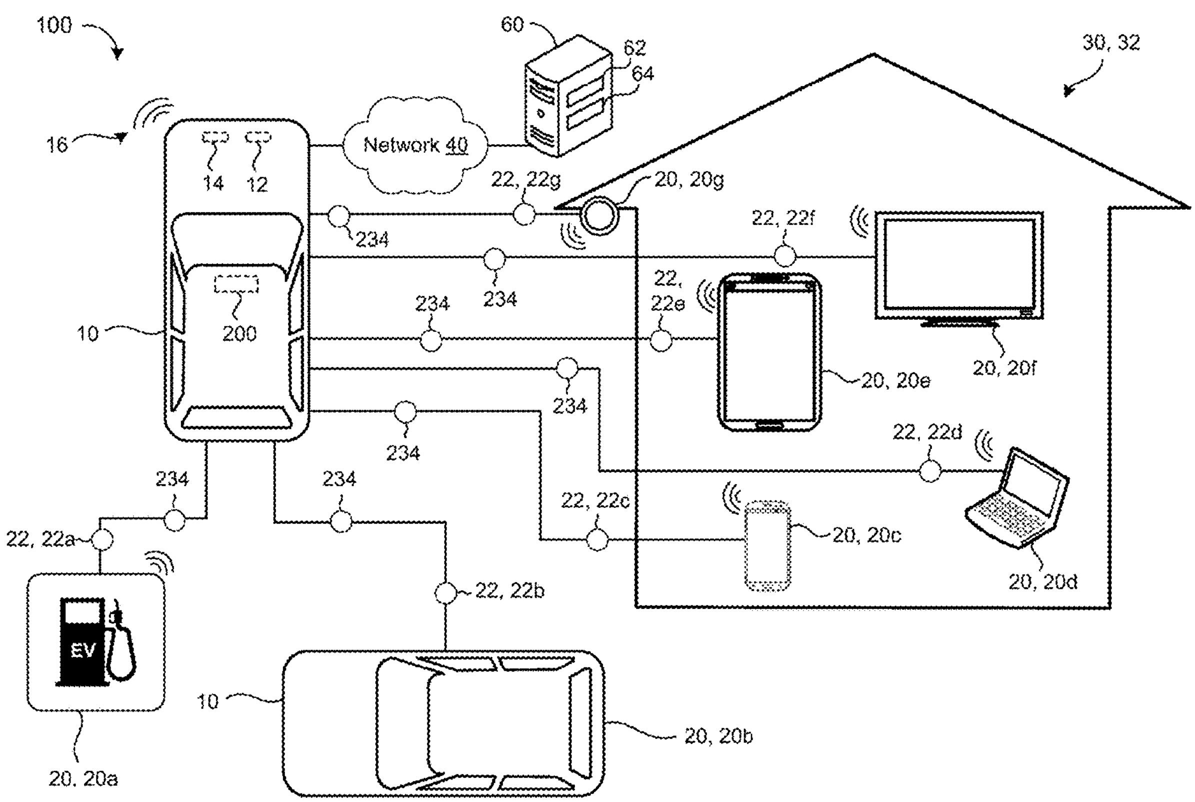
Publication Classification

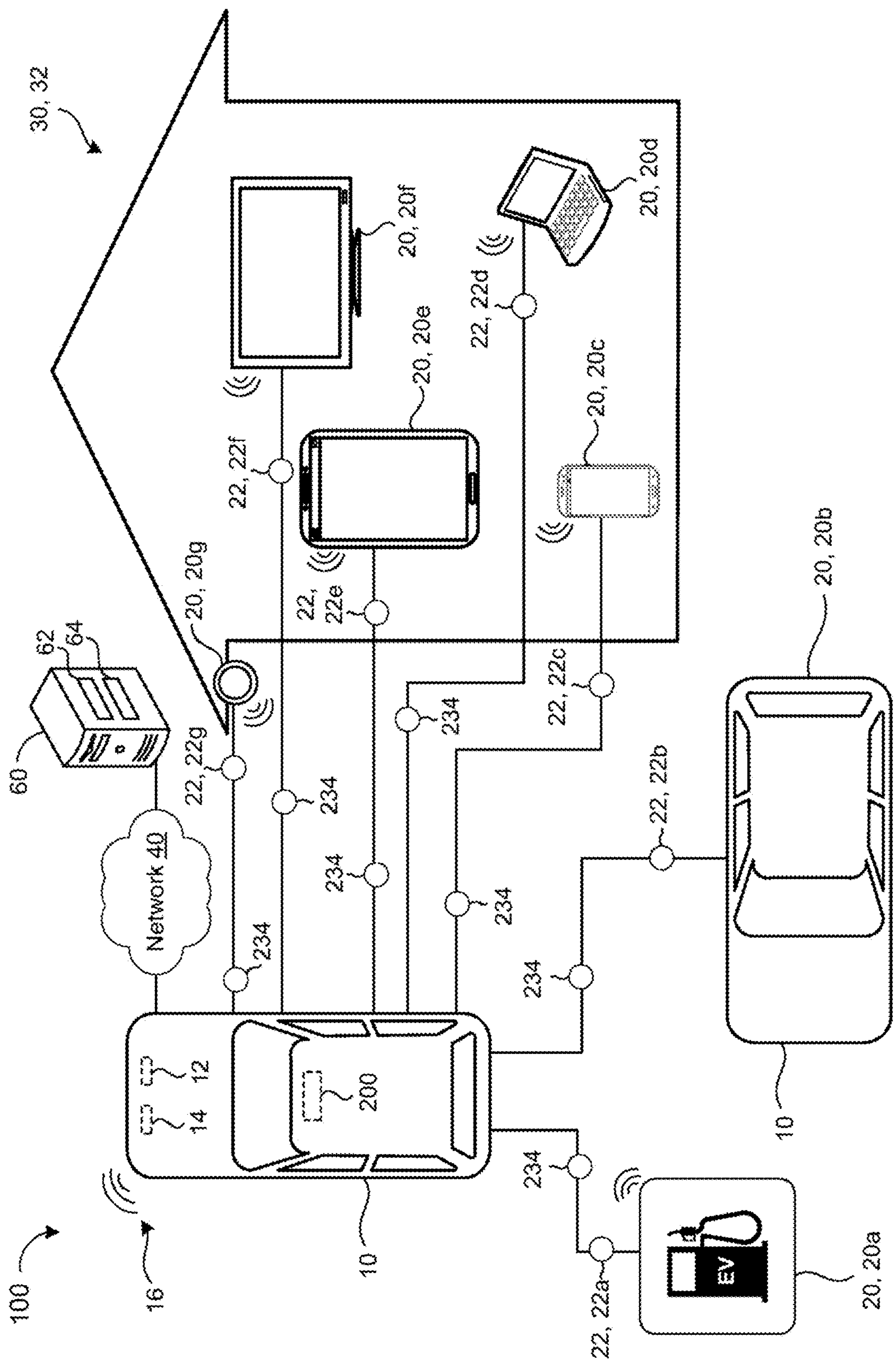
(51) Int. Cl.
G06F 9/50 (2006.01)

(52) U.S. Cl.
CPC *G06F 9/5027* (2013.01)

(57) ABSTRACT

A method for a Matter compute architecture with smart discovery and opportunistic allocation of IoT device resources includes obtaining a device identifier for each of a plurality of devices within an ecosystem of a vehicle, each device identifier including resource capabilities and resource needs of the device. For each device, the method also includes validating the device based on the obtained device identifier, and classifying the device based on the resource capabilities and the resource needs of the device. The method also includes generating a device controller matrix by identifying an ecosystem resource requirement for the plurality of devices, predicting an ecosystem resource availability for the plurality of devices, and prioritizing the resource capabilities and the resource needs of each device based on the ecosystem resource requirement and the ecosystem resource availability.





100
16
10
14
12
200
234
22, 22a
20, 20a
EV
Network 40
60
62
64
30, 32
20, 20g
22, 22g
22, 22f
20, 20f
22, 22e
20, 20e
22, 22d
20, 20d
22, 22c
20, 20c
22, 22b
20, 20b

FIG. 1

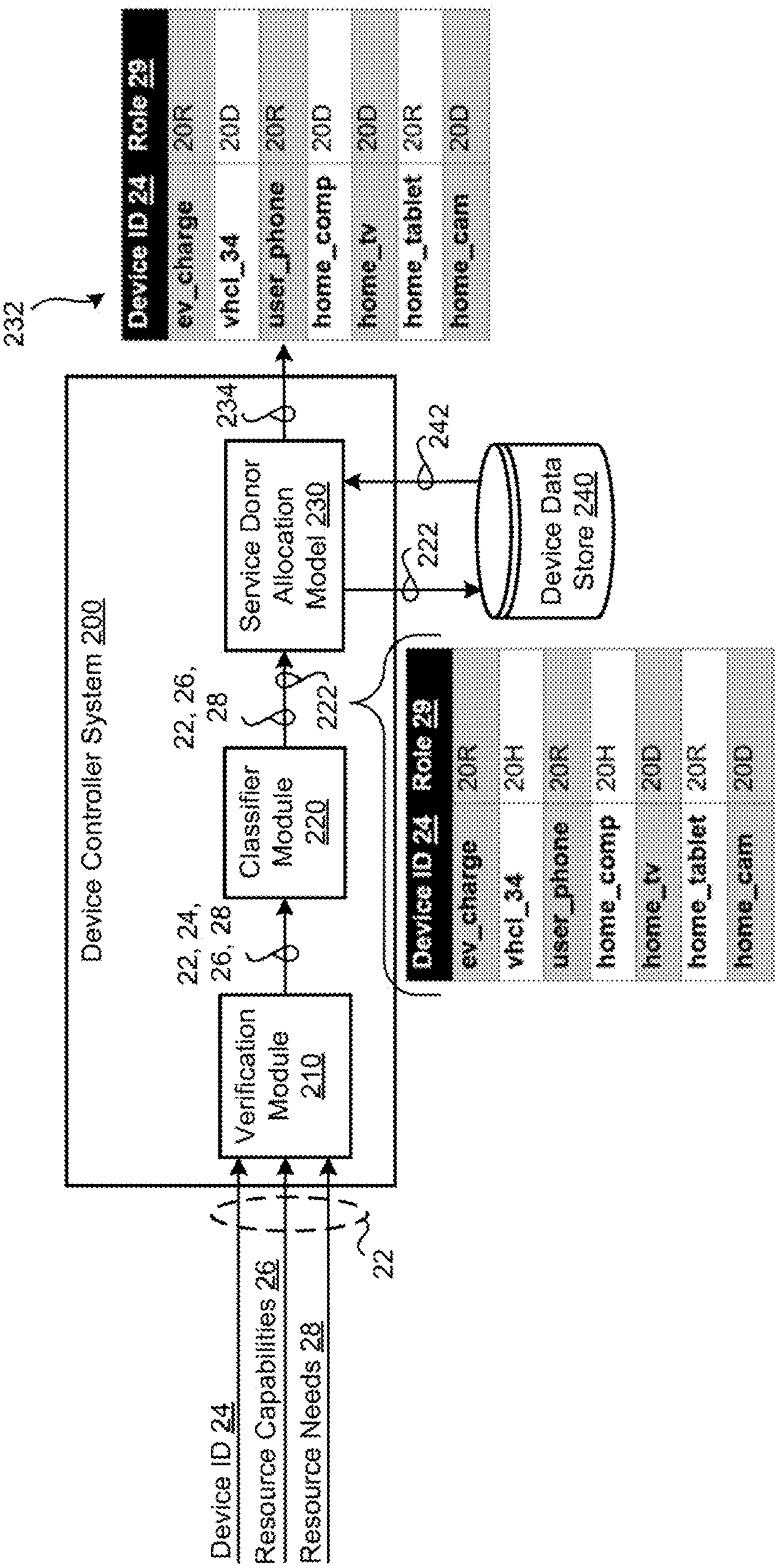
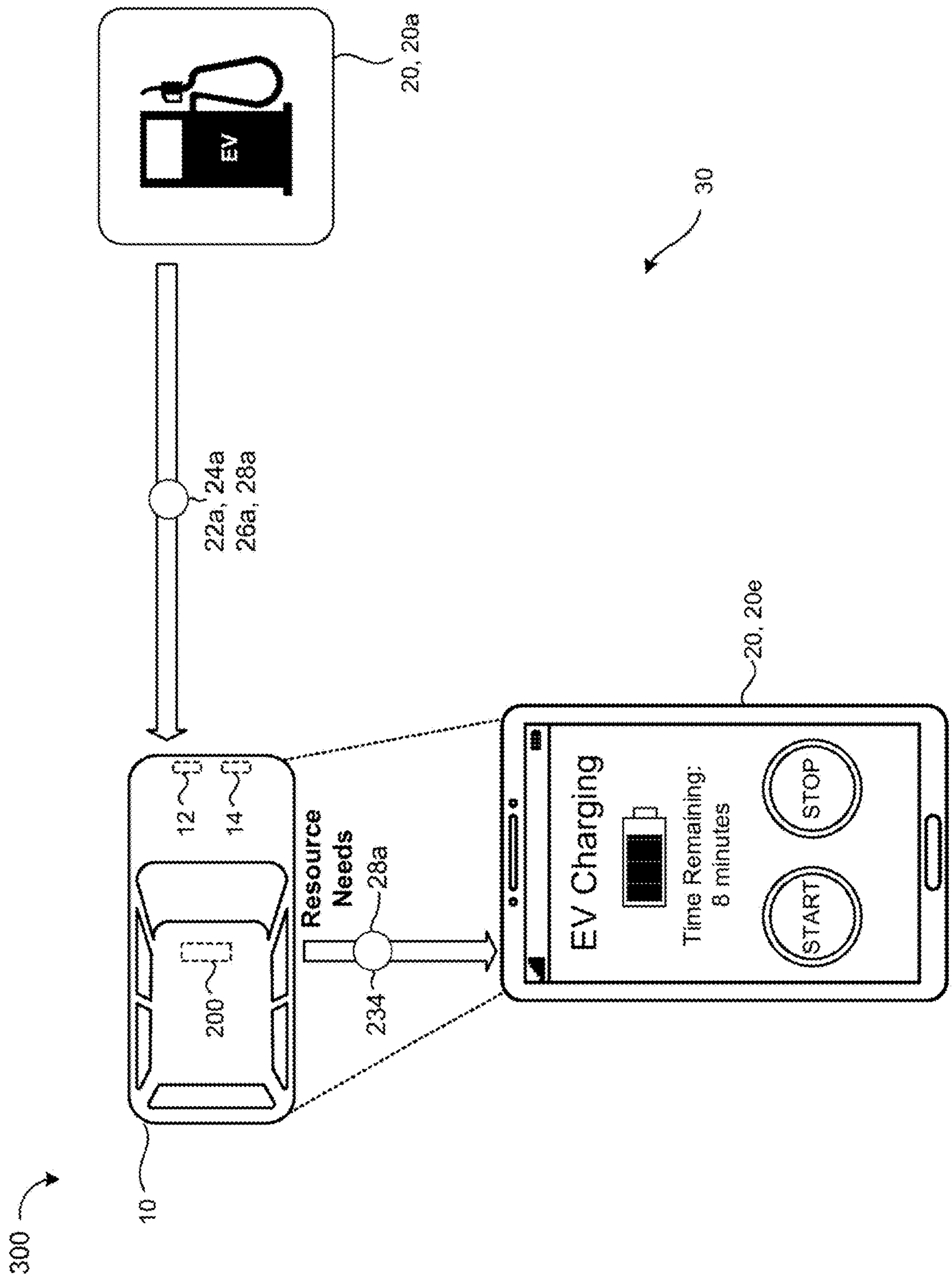

Device ID 24
Resource Capabilities 26
Resource Needs 28
22
Device Controller System 200
Verification Module 210
22, 24, 26, 28
Classifier Module 220
22, 26, 28
222
Service Donor Allocation Model 230
234
232
242
222
Device Data Store 240
Device ID 24 Role 29
ev_charge 20R
vhcl_34 20H
user_phone 20R
home_comp 20H
home_tv 20D
home_tablet 20R
home_cam 20D
Device ID 24 Role 29
ev_charge 20R
vhcl_34 20D
user_phone 20R
home_comp 20D
home_tv 20D
home_tablet 20R
home_cam 20D

FIG. 2



300
10
200
12
14
Resource
Needs
28a
234
20, 20a
EV
22a, 24a
26a, 28a
30
20, 20e
EV Charging
Time Remaining:
8 minutes
START
STOP

FIG. 3

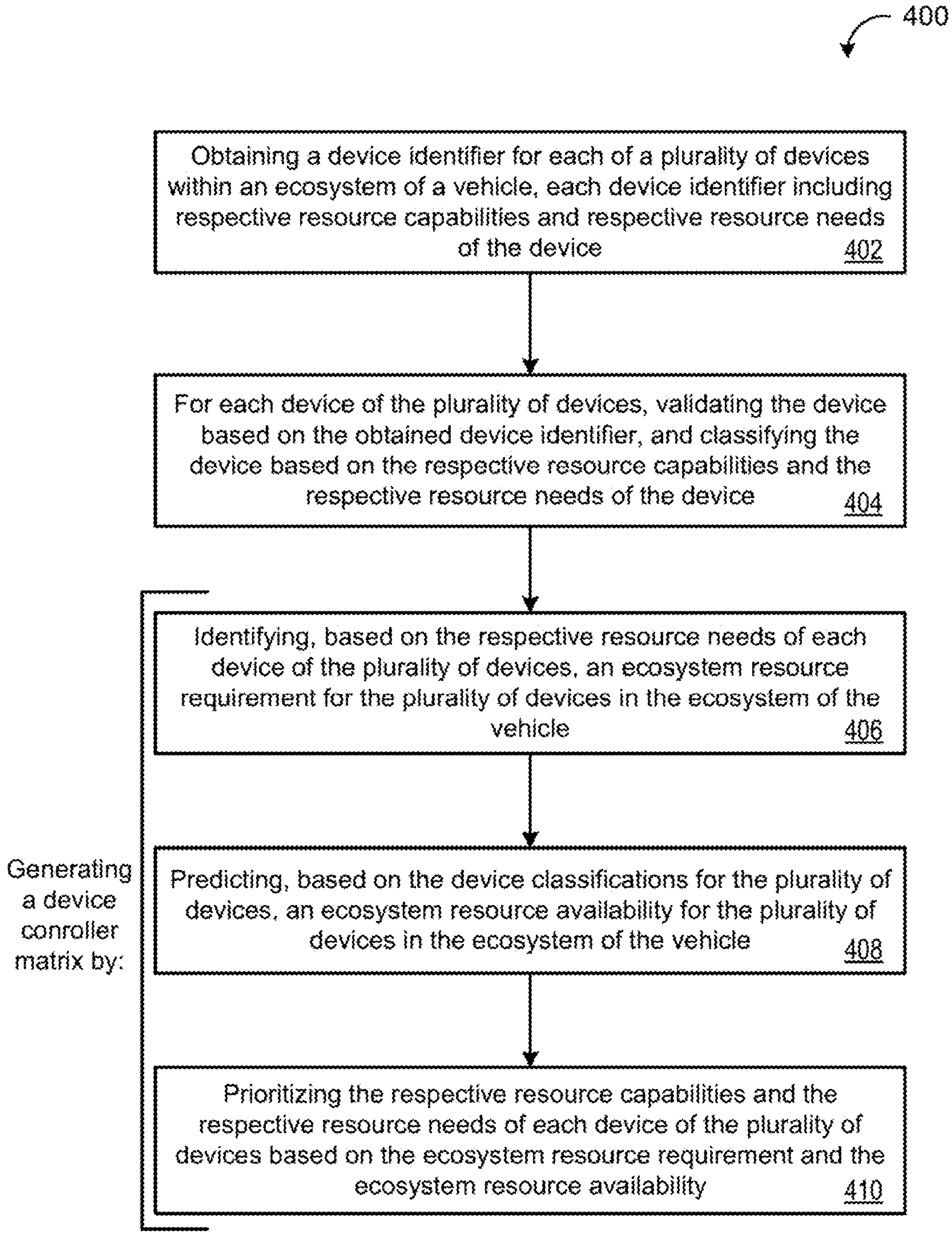

400
Obtaining a device identifier for each of a plurality of devices within an ecosystem of a vehicle, each device identifier including respective resource capabilities and respective resource needs of the device
402
For each device of the plurality of devices, validating the device based on the obtained device identifier, and classifying the device based on the respective resource capabilities and the respective resource needs of the device
404
Generating a device conroller matrix by:
Identifying, based on the respective resource needs of each device of the plurality of devices, an ecosystem resource requirement for the plurality of devices in the ecosystem of the vehicle
406
Predicting, based on the device classifications for the plurality of devices, an ecosystem resource availability for the plurality of devices in the ecosystem of the vehicle
408
Prioritizing the respective resource capabilities and the respective resource needs of each device of the plurality of devices based on the ecosystem resource requirement and the ecosystem resource availability
410

FIG. 4

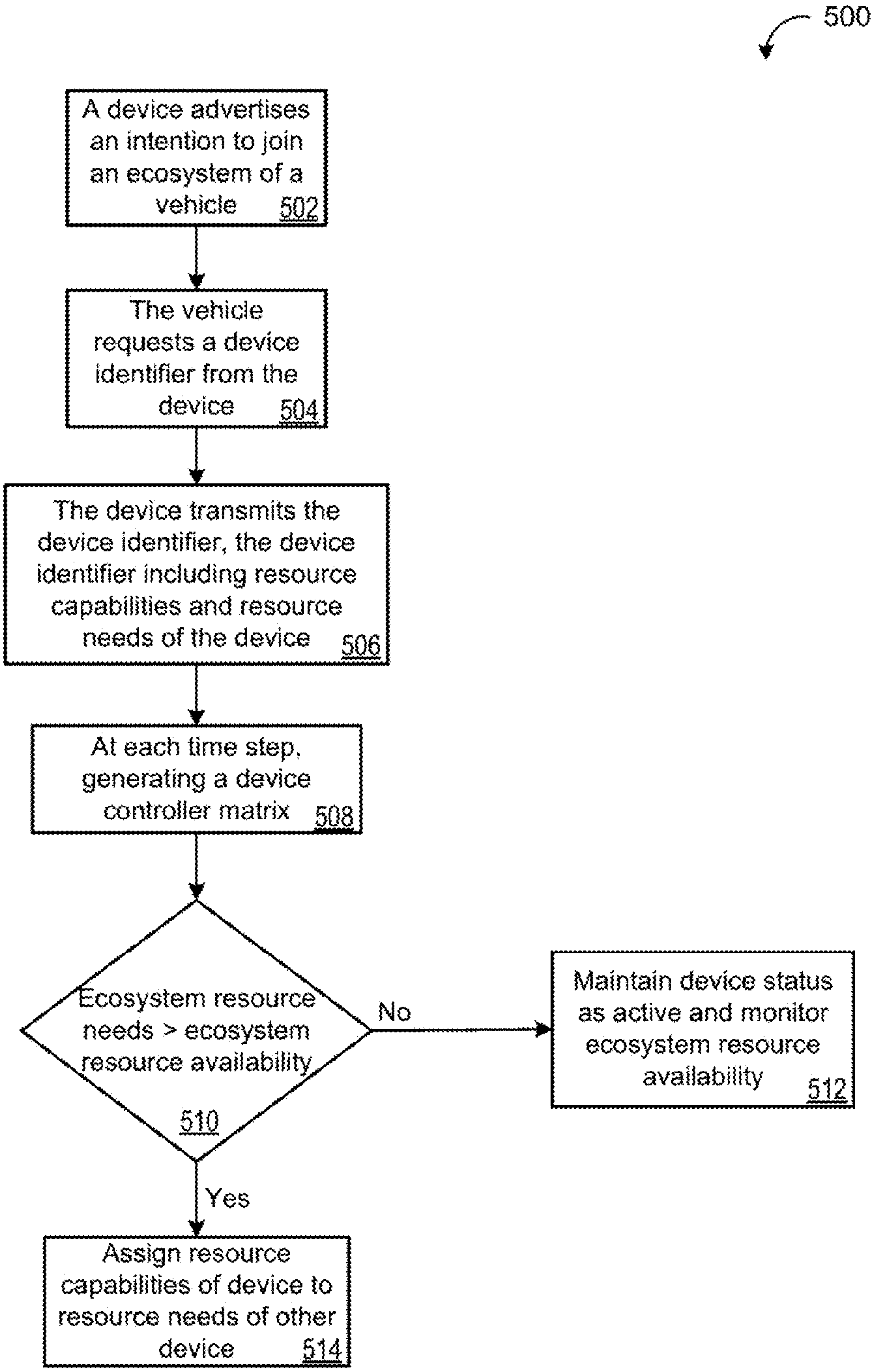

500
A device advertises an intention to join an ecosystem of a vehicle 502
The vehicle requests a device identifier from the device 504
The device transmits the device identifier, the device identifier including resource capabilities and resource needs of the device 506
At each time step, generating a device controller matrix 508
Ecosystem resource needs > ecosystem resource availability 510
No
Maintain device status as active and monitor ecosystem resource availability 512
Yes
Assign resource capabilities of device to resource needs of other device 514

FIG. 5

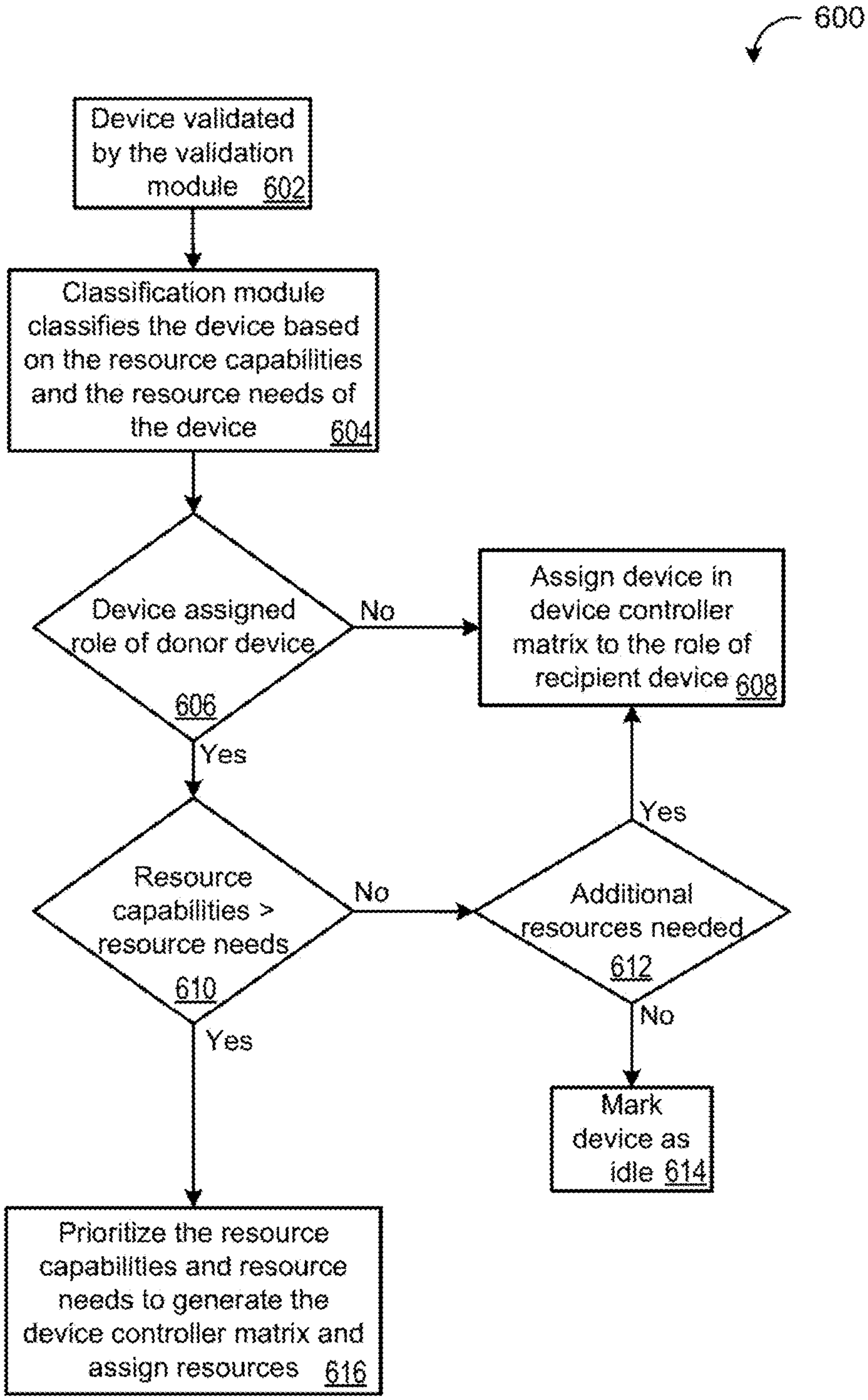

600
Device validated by the validation module 602
Classification module classifies the device based on the resource capabilities and the resource needs of the device 604
Device assigned role of donor device 606
No
Assign device in device controller matrix to the role of recipient device 608
Yes
Resource capabilities > resource needs 610
No
Additional resources needed 612
Yes
No
Yes
Mark device as idle 614
Prioritize the resource capabilities and resource needs to generate the device controller matrix and assign resources 616

FIG. 6

MATTER COMPUTE ARCHITECTURE WITH SMART DISCOVERY AND OPPORTUNISTIC ALLOCATION OF IOT DEVICE RESOURCES

INTRODUCTION

[0001] The information provided in this section is for the purpose of generally presenting the context of the disclosure. Work of the presently named inventors, to the extent it is described in this section, as well as aspects of the description that may not otherwise qualify as prior art at the time of filing, are neither expressly nor impliedly admitted as prior art against the present disclosure.

[0002] The present disclosure relates generally to a matter compute architecture with smart discovery and opportunist allocation of internet of things (IoT) device resources. By virtue of its inherent mobility, a modern vehicle is in dynamic communication with IoT devices that enter and exit an ecosystem of the vehicle depending on a location of the vehicle relative to the IoT devices. While these IoT devices may opt into the ecosystem of the vehicle, not all of these IoT devices may use the same communication link (i.e., communication fabric) to communicate with the vehicle. As such, IoT devices may not be able to see or communicate with IoT devices in different fabrics.

SUMMARY

[0003] One aspect of the disclosure provides a computer-implemented method for a matter compute architecture with smart discovery and opportunistic allocation of IoT device resources that when executed on data processing hardware causes the data processing hardware to perform operations that include obtaining a device identifier for each of a plurality of devices within an ecosystem of a vehicle. Each device identifier includes respective resource capabilities and respective resource needs of the device. For each device of the plurality of devices, the operations also include validating the device based on the obtained device identifier, and classifying the device based on the respective resource capabilities and the respective resource needs of the device. The operations also include generating a device controller matrix by identifying, based on the respective resource needs of each device of the plurality of devices, an ecosystem resource requirement for the plurality of devices in the ecosystem of the vehicle, predicting, based on the device classifications for the plurality of devices, an ecosystem resource availability for the plurality of devices in the ecosystem of the vehicle, and prioritizing the respective resource capabilities and the respective resource needs of each device of the plurality of devices based on the ecosystem resource requirement and the ecosystem resource availability.

[0004] Implementations of the disclosure may include one or more of the following optional features. In some implementations, classifying each device of the plurality of devices based on the respective resource capabilities and the respective resource needs of the device further includes assigning a role to each device of the plurality of devices. In these implementations, the assigned role of each device of the plurality of devices may include one of a donor device, a recipient device, or a hybrid device. Here, generating the device controller matrix may further include reassigning a hybrid device as one of a donor device or a recipient device based on the ecosystem resource requirement and the ecosystem resource availability.

[0005] In some examples, classifying each device of the plurality of devices based on the respective resource capabilities and the respective resource needs of the device includes assigning a role to the device. Here, prioritizing the respective resource capabilities and the respective resource needs of each device of the plurality of devices includes identifying a first device of the plurality of devices having respective resource capabilities that exceed respective resource needs. In these examples, generating the device controller matrix may further include updating the device classification of the first device by reassigning the role of the first device to a donor device role, assigning the respective resource capabilities of the first device that exceed the respective resource needs of the first device to a second device having a recipient device role.

[0006] In some implementations, classifying each device of the plurality of devices based on the respective resource capabilities and the respective resource needs of the device includes assigning a role to the device. Here, prioritizing the respective resource capabilities and the respective resource needs of each device of the plurality of devices includes identifying a first device of the plurality of devices having respective resource needs that exceed respective resource capabilities. In these examples, generating the device controller matrix may further include updating the device classification of the first device by reassigning the role of the first device to a recipient device role, and assigning the respective resource capabilities of a second device having a donor device role to the first device.

[0007] In some implementations, generating the device controller matrix is further based on a device presence pattern. In some examples, a first device of the plurality of devices includes a first communication protocol, and a second device of the plurality of devices includes a second communication protocol. Here, the first device and the second device are in communication through the ecosystem of the vehicle.

[0008] Another aspect of the disclosure provides a system for a matter compute architecture with smart discovery and opportunistic allocation of IoT device resources that includes data processing hardware and memory hardware in communication with the data processing hardware. The memory hardware stores instructions that when executed by the data processing hardware cause the data processing hardware to perform operations that include obtaining a device identifier for each of a plurality of devices within an ecosystem of a vehicle. Each device identifier includes respective resource capabilities and respective resource needs of the device. For each device of the plurality of devices, the operations also include validating the device based on the obtained device identifier, and classifying the device based on the respective resource capabilities and the respective resource needs of the device. The operations also include generating a device controller matrix by identifying, based on the respective resource needs of each device of the plurality of devices, an ecosystem resource requirement for the plurality of devices in the ecosystem of the vehicle, predicting, based on the device classifications for the plurality of devices, an ecosystem resource availability for the plurality of devices in the ecosystem of the vehicle, and prioritizing the respective resource capabilities and the respective resource needs of each device of the plurality of devices based on the ecosystem resource requirement and the ecosystem resource availability.

[0009] This aspect may include one or more of the following optional features. In some implementations, classifying each device of the plurality of devices based on the respective resource capabilities and the respective resource needs of the device further includes assigning a role to each device of the plurality of devices. In these implementations, the assigned role of each device of the plurality of devices may include one of a donor device, a recipient device, or a hybrid device. Here, generating the device controller matrix may further include reassigning a hybrid device as one of a donor device or a recipient device based on the ecosystem resource requirement and the ecosystem resource availability.

[0010] In some examples, classifying each device of the plurality of devices based on the respective resource capabilities and the respective resource needs of the device includes assigning a role to the device. Here, prioritizing the respective resource capabilities and the respective resource needs of each device of the plurality of devices includes identifying a first device of the plurality of devices having respective resource capabilities that exceed respective resource needs. In these examples, generating the device controller matrix may further include updating the device classification of the first device by reassigning the role of the first device to a donor device role, assigning the respective resource capabilities of the first device that exceed the respective resource needs of the first device to a second device having a recipient device role.

[0011] In some implementations, classifying each device of the plurality of devices based on the respective resource capabilities and the respective resource needs of the device includes assigning a role to the device. Here, prioritizing the respective resource capabilities and the respective resource needs of each device of the plurality of devices includes identifying a first device of the plurality of devices having respective resource needs that exceed respective resource capabilities. In these examples, generating the device controller matrix may further include updating the device classification of the first device by reassigning the role of the first device to a recipient device role, and assigning the respective resource capabilities of a second device having a donor device role to the first device.

[0012] In some implementations, generating the device controller matrix is further based on a device presence pattern. In some examples, a first device of the plurality of devices includes a first communication protocol, and a second device of the plurality of devices includes a second communication protocol. Here, the first device and the second device are in communication through the ecosystem of the vehicle.

[0013] The details of one or more implementations of the disclosure are set forth in the accompanying drawings and the description below. Other aspects, features, and advantages will be apparent from the description and drawings, and from the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] The drawings described herein are for illustrative purposes only of selected configurations and are not intended to limit the scope of the present disclosure.

[0015] FIG. **1** is a schematic view of an example system for a matter compute architecture with smart discovery and opportunistic allocation.

[0016] FIG. **2** is a schematic view of example components of the system of FIG. **1**.

[0017] FIG. **3** is a schematic view of an example recipient device in communication with an example recipient device through a device controller system of a vehicle.

[0018] FIG. **4** is a flowchart of an example arrangement of operations for a method of a matter compute architecture with smart discovery and opportunistic allocation.

[0019] FIG. **5** is a flowchart of an example arrangement of operations for a method of a matter compute architecture with smart discovery and opportunistic allocation.

[0020] FIG. **6** is a flowchart of an example arrangement of operations for a method of classifying a device in a matter compute architecture.

[0021] Corresponding reference numerals indicate corresponding parts throughout the drawings.

DETAILED DESCRIPTION

[0022] Example configurations will now be described more fully with reference to the accompanying drawings. Example configurations are provided so that this disclosure will be thorough, and will fully convey the scope of the disclosure to those of ordinary skill in the art. Specific details are set forth such as examples of specific components, devices, and methods, to provide a thorough understanding of configurations of the present disclosure. It will be apparent to those of ordinary skill in the art that specific details need not be employed, that example configurations may be embodied in many different forms, and that the specific details and the example configurations should not be construed to limit the scope of the disclosure.

[0023] The terminology used herein is for the purpose of describing particular exemplary configurations only and is not intended to be limiting. As used herein, the singular articles “a,” “an,” and “the” may be intended to include the plural forms as well, unless the context clearly indicates otherwise. The terms “comprises,” “comprising,” “including,” and “having,” are inclusive and therefore specify the presence of features, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, steps, operations, elements, components, and/or groups thereof. The method steps, processes, and operations described herein are not to be construed as necessarily requiring their performance in the particular order discussed or illustrated, unless specifically identified as an order of performance. Additional or alternative steps may be employed.

[0024] When an element or layer is referred to as being “on,” “engaged to,” “connected to,” “attached to,” or “coupled to” another element or layer, it may be directly on, engaged, connected, attached, or coupled to the other element or layer, or intervening elements or layers may be present. In contrast, when an element is referred to as being “directly on,” “directly engaged to,” “directly connected to,” “directly attached to,” or “directly coupled to” another element or layer, there may be no intervening elements or layers present. Other words used to describe the relationship between elements should be interpreted in a like fashion (e.g., “between” versus “directly between,” “adjacent” versus “directly adjacent,” etc.). As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items.

[0025] The terms "first," "second," "third," etc. may be used herein to describe various elements, components, regions, layers and/or sections. These elements, components, regions, layers and/or sections should not be limited by these terms. These terms may be only used to distinguish one element, component, region, layer or section from another region, layer or section. Terms such as "first," "second," and other numerical terms do not imply a sequence or order unless clearly indicated by the context. Thus, a first element, component, region, layer or section discussed below could be termed a second element, component, region, layer or section without departing from the teachings of the example configurations.

[0026] In this application, including the definitions below, the term "module" may be replaced with the term "circuit." The term "module" may refer to, be part of, or include an Application Specific Integrated Circuit (ASIC); a digital, analog, or mixed analog/digital discrete circuit; a digital, analog, or mixed analog/digital integrated circuit; a combinational logic circuit; a field programmable gate array (FPGA); a processor (shared, dedicated, or group) that executes code; memory (shared, dedicated, or group) that stores code executed by a processor; other suitable hardware components that provide the described functionality; or a combination of some or all of the above, such as in a system-on-chip.

[0027] The term "code," as used above, may include software, firmware, and/or microcode, and may refer to programs, routines, functions, classes, and/or objects. The term "shared processor" encompasses a single processor that executes some or all code from multiple modules. The term "group processor" encompasses a processor that, in combination with additional processors, executes some or all code from one or more modules. The term "shared memory" encompasses a single memory that stores some or all code from multiple modules. The term "group memory" encompasses a memory that, in combination with additional memories, stores some or all code from one or more modules. The term "memory" may be a subset of the term "computer-readable medium." The term "computer-readable medium" does not encompass transitory electrical and electromagnetic signals propagating through a medium, and may therefore be considered tangible and non-transitory memory. Non-limiting examples of a non-transitory memory include a tangible computer readable medium including a nonvolatile memory, magnetic storage, and optical storage.

[0028] The apparatuses and methods described in this application may be partially or fully implemented by one or more computer programs executed by one or more processors. The computer programs include processor-executable instructions that are stored on at least one non-transitory tangible computer readable medium. The computer programs may also include and/or rely on stored data.

[0029] A software application (i.e., a software resource) may refer to computer software that causes a computing device to perform a task. In some examples, a software application may be referred to as an "application," an "app," or a "program." Example applications include, but are not limited to, system diagnostic applications, system management applications, system maintenance applications, word processing applications, spreadsheet applications, messaging applications, media streaming applications, social networking applications, and gaming applications.

[0030] The non-transitory memory may be physical devices used to store programs (e.g., sequences of instructions) or data (e.g., program state information) on a temporary or permanent basis for use by a computing device. The non-transitory memory may be volatile and/or non-volatile addressable semiconductor memory. Examples of non-volatile memory include, but are not limited to, flash memory and read-only memory (ROM)/programmable read-only memory (PROM)/erasable programmable read-only memory (EPROM)/electronically erasable programmable read-only memory (EEPROM) (e.g., typically used for firmware, such as boot programs). Examples of volatile memory include, but are not limited to, random access memory (RAM), dynamic random access memory (DRAM), static random access memory (SRAM), phase change memory (PCM) as well as disks or tapes.

[0031] These computer programs (also known as programs, software, software applications or code) include machine instructions for a programmable processor, and can be implemented in a high-level procedural and/or object-oriented programming language, and/or in assembly/machine language. As used herein, the terms "machine-readable medium" and "computer-readable medium" refer to any computer program product, non-transitory computer readable medium, apparatus and/or device (e.g., magnetic discs, optical disks, memory, Programmable Logic Devices (PLDs)) used to provide machine instructions and/or data to a programmable processor, including a machine-readable medium that receives machine instructions as a machine-readable signal. The term "machine-readable signal" refers to any signal used to provide machine instructions and/or data to a programmable processor.

[0032] Various implementations of the systems and techniques described herein can be realized in digital electronic and/or optical circuitry, integrated circuitry, specially designed ASICS (application specific integrated circuits), computer hardware, firmware, software, and/or combinations thereof. These various implementations can include implementation in one or more computer programs that are executable and/or interpretable on a programmable system including at least one programmable processor, which may be special or general purpose, coupled to receive data and instructions from, and to transmit data and instructions to, a storage system, at least one input device, and at least one output device.

[0033] The processes and logic flows described in this specification can be performed by one or more programmable processors, also referred to as data processing hardware, executing one or more computer programs to perform functions by operating on input data and generating output. The processes and logic flows can also be performed by special purpose logic circuitry, e.g., an FPGA (field programmable gate array) or an ASIC (application specific integrated circuit). Processors suitable for the execution of a computer program include, by way of example, both general and special purpose microprocessors, and any one or more processors of any kind of digital computer. Generally, a processor will receive instructions and data from a read only memory or a random access memory or both. The essential elements of a computer are a processor for performing instructions and one or more memory devices for storing instructions and data. Generally, a computer will also include, or be operatively coupled to receive data from or transfer data to, or both, one or more mass storage devices for storing data, e.g., magnetic, magneto optical disks, or optical disks. However, a computer need not have such devices. Computer readable media suitable for storing computer program instructions and data include all forms of non-volatile memory, media and memory devices, including by way of example semiconductor memory devices, e.g., EPROM, EEPROM, and flash memory devices; magnetic disks, e.g., internal hard disks or removable disks; magneto optical disks; and CD ROM and DVD-ROM disks. The processor and the memory can be supplemented by, or incorporated in, special purpose logic circuitry.

[0034] To provide for interaction with a user, one or more aspects of the disclosure can be implemented on a computer having a display device, e.g., a CRT (cathode ray tube), LCD (liquid crystal display) monitor, or touch screen for displaying information to the user and optionally a keyboard and a pointing device, e.g., a mouse or a trackball, by which the user can provide input to the computer. Other kinds of devices can be used to provide interaction with a user as well; for example, feedback provided to the user can be any form of sensory feedback, e.g., visual feedback, auditory feedback, or tactile feedback; and input from the user can be received in any form, including acoustic, speech, or tactile input. In addition, a computer can interact with a user by sending documents to and receiving documents from a device that is used by the user; for example, by sending web pages to a web browser on a user's client device in response to requests received from the web browser.

[0035] FIG. **1** illustrates an example system **100** including a device controller system **200** executing a service donor allocation model **230**. The device controller system **200** includes a vehicle **10** in communication with a plurality of internet of things (IoT) devices **20**, **20***a-n* (also referred to as devices **20**) within an ecosystem **30** of the vehicle **10** via a vehicle network **16**. The ecosystem **30** may include any devices **20** within an environment **32** (i.e., a network range **32**) of the vehicle network **16**. The vehicle network **16** may include a wireless local area network (WLAN) that facilitates communication and interoperability among the vehicle **10** and the devices **20** within the environment **32** of the vehicle **10**. In the example shown, the devices **20** within the environment **30** have all opted into the ecosystem **30** of the vehicle **10**, and, as such, are in communication with the vehicle **10** via the device controller system **200**. In particular, the devices **20** are located around the vehicle **10** and include an electric vehicle (EV) charging station **20***a*, a guest vehicle **20***b*, a cellular device **20***c*, a personal computer **20***d*, a tablet **20***e*, a television (TV) **20***f*, and a camera system **20***g*. The device controller system **200** may communicate with each of the devices **20** in the ecosystem **30** via wireless or wired communications technologies and/or protocols. Thus, the vehicle network **16** can include Wireless Fidelity (WiFi®) (e.g., IEEE 802.11), Low-Rate Wireless Personal Area Networks (e.g., IEEE 802.15.4), worldwide interoperability for microwave access (WiMAX), 3G, 4G, Long Term Evolution (LTE), 5G, digital subscriber line (DSL), Bluetooth®, Near Field Communication (NFC), or any other wireless standards, or Ethernet (e.g., IEEE 802.3). The vehicle **10** may additionally include one or more access points (AP) (not shown) configured to facilitate wireless communication between the vehicle **10** and one or more of the devices **20**, **20***a-g*.

[0036] Additionally, each device **20** may communicate with other devices **20** within the same communication fabric/cluster as the device **20**. For example, the devices **20***c*-**20***g* in FIG. **1** are shown as part of a premises of a user, where the devices **20***c*-**20***g* may be in communication with one another via a first communication fabric (e.g., a home area network (HAN)), while the devices **20***a*, **20***b*, may not be a part of the first communication fabric, and instead may communicate with the vehicle **10** via a second communication fabric that is different from the first communication fabric. Consequently, the devices **20***b*-**20***g* can only communicate with the devices **20***a*, **20***b* via the vehicle **10** (i.e., executing the device controller system **200**).

[0037] In the examples shown, the device controller system **200** is implemented within the vehicle **10**. However, the device controller system **200** can be implemented on other computing devices (e.g., computing devices in communication with the vehicle **10**), such as, without limitation, a smart phone, tablet, smart display, desktop/laptop, smart watch, smart appliance, or smart glasses/headset. The vehicle **10** includes data processing hardware **12** and memory hardware **14** storing instructions that when executed on the data processing hardware **12** cause the data processing hardware **14** to perform operations. In addition to the vehicle network **16**, the vehicle **10** is in communication with a remote system **60** via a network **40**. The remote system **60** (e.g., server, cloud computing environment) also includes data processing hardware **62** and memory hardware **64** storing instructions that when executed on the data processing hardware **62** cause the data processing hardware **62** to perform operations. In some examples, execution of the device controller system **200** is shared across the vehicle **10** and the remote system **60**. As described in greater detail below with reference to FIGS. **2** and **3**, the device controller system **200** executing on the vehicle **10** and/or the remote system **60** executes a verification module **210**, a classifier module **220**, and a service donor allocation model **230**, and is configured to intelligently discover devices **20** that dynamically join and leave the vehicle network **16**, where the device controller system **200** opportunistically allocates resources **26**, **28** of the devices **20** based on predictions of near-future resource availability to reduce cost and increase efficiency, thereby improving utilization of the devices **20**. Notably, because the device controller system **200** of the vehicle **10** is communication agnostic (i.e., it communicates via a common application programming interface (API)), it operates to integrate/facilitate communication between devices **20** that are otherwise unaware of devices **20** outside of their own communication fabrics.

[0038] The device controller system **200** can be implemented on any computing device that is capable of communication with the devices **20**. While the device controller system **200** is included within the vehicle **10** in the example shown, the device controller system **200** may also be included in, without limitation, a smart phone, a smart watch, a laptop, a desktop, or a smart display. When a device **20** opts into the ecosystem **30** (e.g., by a user of the device **20** during a communication association process with the vehicle **10**), it may thereafter be discoverable by the device controller system **200** of the vehicle **10** any time that the device **20** is within range (e.g., the environment **32**) of the vehicle **10**.

[0039] In some implementations, the vehicle **10** executes the device controller system **200** (including the service donor allocation model **230**) that initiates communication with each device **20** such that each device **20** (i.e., a device **20** with a role **29** of a donor device **29**D) of the plurality of devices **20** is controllable by the device controller system **200** to perform available actions (i.e., via the resource capabilities **26**) requested by a different device **20** (i.e., a device **20** with the role **29** of a recipient device **29**R). In the example shown, the device controller system **200** obtains the device identifier **22** for each of the plurality of devices **20** within the ecosystem **30** of the vehicle **10**. In some implementations, the vehicle **10** intelligently discovers the device **20** when it enters the ecosystem **30** of the vehicle **10** and generates a request for the device identifier **22** that prompts the device **20** to share its device identifier **22**. In other implementations, when a device **20** enters the ecosystem **30**, the device **20** may advertise its intent to join the ecosystem **30**, thereby prompting the vehicle **10** to request the device identifier **22** of the device **20**.

[0040] Each device identifier **22** may include a respective device identity (ID) **24** including a unique identifier of the device **20**, respective resource capabilities **26** of the device **20**, and respective resource needs **28** of the device **20**. The device identifier **22** may include a fabric certificate communicating the device ID **24**, respective resource capabilities **26**, and respective resource needs **28** of the device **20**, where the device controller system **200** (via a common API) understands/translates the fabric certificate to integrate the device **20** with the other devices **20** within the ecosystem **30**. The resource capabilities **26** include the intrinsic resource capabilities of the device **20**, such as, the energy capability/capacity of the device **20**, the available storage of the device **20**, the computing cost of the device **20**, the processing performance (e.g., MIPS) of the device **20**, any communication fabrics of the device **20**, an estimation of the amount of time the device **20** will be underutilized (e.g., how long the device **20** will have available resource capabilities **26**), an estimation of the amount of time the device **10** will be in the ecosystem **30** of the vehicle **10**, as well as standard services such as displays, cameras, and sensors operated by the device **20**. The resource needs **28** may include the dynamic usage of the device **20** (e.g., its baseline operations), as well as any capability needs that the device **20** may have that exceed the resource capabilities **26** of the device **20**. For example, a device **20** that does not include a graphical user interface may have a resource need **28** for a graphical user interface when to display information to a user of the device **20**.

[0041] With reference to FIGS. **1** and **2**. the device controller system **200** includes the verification module **210**. the classifier module **220**. the service donor allocation model **230**. and a device data store **240**. The verification module **210** is configured to receive the obtained device identifier **22** and. based on the device identifier **22** (e.g., the device ID **24**), validate the device **20**. For example, the vehicle **10** may validate the device **20** by checking the device ID **24** against a list of known devices **20** that have opted into the ecosystem **30** of the device controller system **200**. If the verification module **210** determines that the device **20** is not a valid device. it may block the device **20** from the ecosystem **30** of the vehicle **10**.

[0042] If the verification module **210** validates the device **20**, the classification module **220**) is configured to classify the device **20** based on the device ID **24**, the resource capabilities **24**. and the resource needs **28** of the device **20**, and output device classifications **222** for the plurality of devices **20**. For example. the classification module **220** may assign a role **29** to each device **20** of the plurality of devices **20**. The roles **29** assigned by the classification module include a donor device **20**D. a recipient device **20**R. and a hybrid device **20**H. The donor devices **20**D may be devices **20** that include resource capabilities **26** that exceed the resource needs **28** of the donor device **20**D. Conversely. the recipient devices **20**R may be devices **20** that include resource needs **28** that exceed the resource capabilities **26** of the recipient device **20**R. Put another way, donor devices **20**D may be devices **20** that are currently underutilized. while recipient devices **20**R may be devices **20** that currently lack the resource capabilities **26** necessary to optimally operate. Notably. a device role **29** may be assigned based on a particular service performed by the device **20**. For example, when the device **20** is a smart thermostat. it can serve as a donor device **20**D for weather application information. but cannot serve as a donor device **20**D for imaging. Instead. if the smart thermostat needed imaging services. it may be assigned the role **29** of a recipient device **20**R for imaging services. The hybrid devices **20**H may be devices **20** that may either serve as a donor device **20**D or a recipient device **20**R depending on the optimal utilization of the capabilities **26** and needs **28** in the ecosystem **30** at any given moment.

[0043] With continued reference to FIG. **2**. after the classifier module **220** outputs the device classifications **222** for the plurality of devices **20**. the service donor allocation model **230** may receive the device classifications **222** including each device identifier **22** having the respective resource capabilities **26** and the respective resource needs **28**. and generate a device controller matrix **232**. In particular, the service donor allocation model **230** predicts, based on the respective resource needs **28** of each device **20** of the plurality of devices **20**. an ecosystem resource need **224** for the plurality of devices **20** in the ecosystem **30** of the vehicle **10**. Here, the service donor allocation model **230** predicts the ecosystem resource need **224** based on the existing resource needs **28** of the devices **20**.

[0044] The service donor allocation model **230** further predicts, based on the device classifications **222** and the respective resource capabilities **26** of each device **20**, an ecosystem resource availability **226** for the plurality of devices **20** in the ecosystem **30** of the vehicle **10**. The ecosystem resource availability **226** indicates an estimation of a near-future (e.g., one second, five seconds, five minutes, etc.,) resource availability of the devices **20** within the ecosystem **30** of the vehicle **10** and is based on the dynamic usage of each device **20** communicated in the device identifier **22**, as well as historical data **242** of the behavior of the devices **20**. For example, the service donor allocation model **230** accesses a device data store **240**) that records/stores historical data **242** that includes historically received device identifiers **22** including device IDs **24**, resource capabilities **26**, and resource needs **28**, device classifications **222**, and ecosystem resource needs **224** and ecosystem resource availabilities **226** for previous states of the ecosystem **30**. Additionally, previous device controller matrixes **232** may be stored in the device data store **240**. The historical records of the device data store **240** may be stored on the memory hardware **14** of the vehicle **10** and/or the memory hardware **64** of the remote server **60**. Here, when predicting the ecosystem resource availability **226** for the plurality of devices **20**, the service donor allocation model **230** may estimate, based on the historical data **242** stored in the device data store **240**, an average amount of time that a device **20** is within the ecosystem **30**, how often the device **20** is within the ecosystem **30**, a device presence pattern indicating how often and how long the device **20** is within the ecosystem **30**, and/or patterns in the respective capabilities **26** of the device **20** while in the ecosystem **30**. For example, the device data store **240**) may include historical data indicating a presence pattern of the guest vehicle **20***b* that the guest vehicle **20***b* enters the ecosystem **30** for four (4) hours every week day (i.e., Monday-Friday). In this example, the ecosystem resource availability **226** predicted by the service donor allocation model **230** may include the respective capabilities **26***b* of the guest vehicle **20***b* as a predicted available resource for other devices **20** in the ecosystem **30** of the vehicle **10**. The service donor allocation model **230** may give priority to the respective capabilities **26***b* of the guest vehicle **20***b* based on a confidence level of the presence pattern of the guest vehicle **20***b*.

[0045] With the ecosystem resource needs **224** and the ecosystem resource availabilities **226**, the service donor allocation model **230** then prioritizes the respective resource capabilities **26** and the respective resource needs **28** of each device **20** of the plurality of devices **20** to generate the device controller matrix **232**. In some implementations, the service donor allocation model **230** only updates the device controller matrix **232** from a previous time step when the ecosystem resource needs **224** meets or exceeds a minimum threshold (e.g., the ecosystem resource capabilities **226**, or 90% of the ecosystem resource capabilities **226**) of resource usage in the ecosystem **30** of the vehicle **10**. Put another way, when the ecosystem resource needs **224** are less than the ecosystem resource availability **226**, the service donor allocator model **230** may maintain a current device controller matrix **232** and continue to monitor the ecosystem resource needs **224** until the ecosystem resource needs are equal to or exceed the minimum threshold Additionally, the service donor allocation model **230** may generate one or more resource assignments **234** for each of the devices **20** that are assigned to offer resources (i.e., are donor devices **20**D), and communicate the resource assignments **234** to the respective devices **20** within the environment. In prioritizing the respective resource capabilities **26** and the respective resource needs **28**, the service donor allocation model **230**) may optimize the mix of device roles **29** based on the dynamically changing needs (i.e., as devices **20** join and leave) of the ecosystem **30** of the vehicle **10**. For example, the service donor allocation model **230** may reassign the role **29** of a hybrid device **20**H to one of the role of a donor device **20**D and the role of a recipient device **20**R based on one of the ecosystem resource needs **224** and the ecosystem resource availabilities **226**. As shown in FIG. **2**, while the device classifications **222** initially included the device ID **24** of vhcl_**34** (e.g., guest vehicle **20***b*) and the device ID **24** of home_comp as assigned to the role of a hybrid device **20**H, the service donor allocation model **230** re-assigns the roles **29** when generating the device controller matrix **232** to the role **29** of a donor device **20**D.

[0046] In some implementations, after the classifier module **220** has assigned a role **29** to each device **20**, the service donor allocation model **230** may modify/update the assigned role **29** when it prioritizes the respective resource capabilities **26** and the respective resource needs **28** of each device **20** of the plurality of devices **20**. For example, when prioritizing the respective resource capabilities **26** and the respective resource needs **28** of each device **20**, the service donor allocation model **230** may identify a first device **20** of the plurality of devices **20** that has respective resource capabilities **26** that exceed the respective resource needs **24** of the device **20**. For example, the first device **20** may be the guest vehicle **20***b* that is parked and not in use, and, as such, is not currently using its own resource capabilities **26**. Here, when generating the device controller matrix **232**, the service donor allocation model **230** updates the device classification **222** of the guest vehicle **20***b* by reassigning the role **29** of the guest vehicle **20***b* to the role **29** of a donor device **20**D. Thereafter, the service donor allocation model **230** may send resource assignments **234** to the guest vehicle **20***b* to perform using its underutilized resource capabilities **26**.

[0047] Conversely, when prioritizing the respective resource capabilities **26** and the respective resource needs **28** of each device **20**, the service donor allocation model **230** may identify a second device **20** of the plurality of devices **20** that has respective resource needs **28** that exceed the respective resource capabilities **26** of the second device **20**. For example, the second device **20** may be the camera system **20***g* mounted to an exterior surface of the residence of FIG. **1**, but, by virtue of its location, cannot capture image data outside of its field-of-view. However, in situations where the camera system **20***g* needs additional fields-of-view (i.e., for security of the residence), it may benefit from any imaging devices within the ecosystem **30**. Here, when generating the device controller matrix **232**, the service donor allocation model **230** updates the device classification **222** of the camera system **20***g* by reassigning the role **29** of the camera system **20***g* to the role **29** of a recipient device **20**R. Thereafter, the service donor allocation model **230** may send resource assignments **234** to a device **20** (e.g., the guest vehicle **20***b* having imaging resources) assigned a donor role **20**D within the ecosystem **30** that is capable of fulfilling the resource needs **28***g* of the camera system **20***g*.

[0048] With reference to FIG. **3**, a system **300** including the vehicle **10** is shown with the EV charger **20***a* and the tablet **20***e* within the ecosystem **30** of the vehicle **10**. Here, the tablet **20***e* is disposed within the vehicle **10**, and the EV charger **20***a* does not have a screen for displaying information. When the device controller system **200** obtains the device identifier **22** of the EV charger **20***a* (e.g., when the EV charger **20***a* enters the range of the vehicle network **16**), the device controller system **200** may classify the EV charger **20***a* under the role of a recipient device **20**R for the capabilities of displaying data. Put differently, because the EV charger **20***a* does not include a screen, the device controller system **200** may identify and validate the EV charger **20***a* as a device that may benefit from available resource capabilities **26** for displaying data from an available device **20** within the ecosystem **30** of the vehicle **10** that includes a screen. Here, when the service donor allocation model **230** generates the device controller matrix **232** it may identify that the tablet **20***e* is not currently using its respective capability **26** of displaying data. In other words, the displaying data capability **26** of the tablet **20***e* is currently underutilized within the ecosystem **30**. The vehicle **10** may then assign the tablet **20***e* to display the data from the EV charger **20***a* so that a passenger of the vehicle **10** may be apprised of the charging status of the vehicle.

[0049] FIG. **4** includes a flowchart of an example arrangement of operations for a method **400** for a matter compute architecture with smart discovery and opportunistic allocation of IoT device resources. Data processing hardware (e.g., data processing hardware **12**, **62** of FIG. **1**) may execute instructions stored on memory hardware (e.g., memory hardware **14**, **64** of FIG. **1**) to perform the example arrangement of operations for the method **400**. At operation **402**, the method **400** includes obtaining a device identifier **22** for each of a plurality of devices **20** within an ecosystem **30** of a vehicle **10**. Each device identifier **22** includes respective resource capabilities **26** and respective resource needs **28** of the device **20**.

[0050] For each device **20** of the plurality of devices **20**, the method **400** also includes, at operation **404**, validating the device **20** based on the obtained device identifier **22**, and classifying the device **20** based on the respective resource capabilities **26** and the respective resource needs **28** of the device **20**. At operation **406**, the method **400** also includes generating a device controller matrix **232** by identifying, based on the respective resource needs **28** of each device **20** of the plurality of devices **20**, an ecosystem resource requirement **224** of the plurality of devices **20** in the ecosystem **30** of the vehicle **10**. The method **400** further includes, at operation **408**, predicting, based on the device classifications **222** for the plurality of devices **20**, an ecosystem resource availability **226** for the plurality of devices **20** in the ecosystem **30** of the vehicle **10**. The method **400** also includes, at operation **410**, prioritizing the respective resource capabilities **26** and the respective resource needs **28** of each device **20** of the plurality of the plurality of devices **20** based on the ecosystem resource requirement **224** and the ecosystem resource availability **226**.

[0051] FIG. **5** includes a flowchart of an example arrangement of operations for a method **500** for the device controller **200** to intelligently discover devices **20** within an ecosystem **30** of a vehicle and opportunistically allocate unused or underutilized capabilities **26** of the devices **20**. Data processing hardware (e.g., data processing hardware **12**, **62** of FIG. **1**) may execute instructions stored on memory hardware (e.g., memory hardware **14**, **64** of FIG. **1**) to perform the example arrangement of operations for the method **500**. At operation **502**, the method **500** includes a device **20** advertising an intention to join an ecosystem **30** of a vehicle **10**. The device **20** may advertise its intention by opting into the ecosystem **30** of the vehicle **10**. For example, when the device **20** is within communication range (e.g., within a range of a vehicle network **16**) of the vehicle **10**, it may prompt a user of the device **20** to opt into the ecosystem **30** of the vehicle **10**. In other examples, the device **20** may automatically advertise its intention to join the ecosystem **30** when it is within communication range of the vehicle **10**.

[0052] At operation **504**, the method **500** also includes the vehicle **10** (e.g., via the device controller system **200**), requesting a device identifier **22** from the device **20**. For example, the device identifier **22** may include a communication certificate. At operation **506**, the operations **500** also include the device **20** transmitting the device identifier **22**. Here, the device identifier **22** includes resource capabilities **26** (e.g., the computing capacity) and resource needs **28** (e.g., computational needs) of the device **20**. The device identifier **22** may further include a device ID **24** of the device **20**. At each time step, the method **500** also includes, at operation **508**, generating a device controller matrix **232**. Here, at operation **510**, a service donor allocation model **230** of the device controller system **200** determines whether the identified ecosystem resource needs **224** exceed the predicted near-future ecosystem resources **226**. Put another way, the service donor allocation model **230** determines whether the identified ecosystem resource needs **224** are less than a minimum threshold of resource usage of the ecosystem **30** such that no further optimization is necessary. If the ecosystem resource needs **224** do not exceed the predicted near-future ecosystem resources **226**, the method **500** proceeds to operation **512**, where the service donor allocation model **230** maintains the device **20** in the device controller matrix **232** with an active status, and continues to monitor the ecosystem resource availability **224**. If the ecosystem resource needs **224** do exceed the predicted near-future ecosystem resources **226**, the method **500** proceeds from the operation **510** to the operation **514**, where the service donor allocation model **230** assigns, in the device controller matrix **232**, the resource capabilities **26** of the device **20** to the resource needs **28** of another device **20** that is also in the ecosystem **30** of the vehicle **10**.

[0053] FIG. **6** includes a flowchart of an example arrangement of operations for a method **600** for of classifying a device **20** in a matter compute architecture by updating a device classification **222** in a device controller matrix **232**. Data processing hardware (e.g., data processing hardware **12**, **62** of FIG. **1**) may execute instructions stored on memory hardware (e.g., memory hardware **14**, **64** of FIG. **1**) to perform the example arrangement of operations for the method **600**. At operation **602**, the method **600** includes validating the device **20** using a validation module **210**. At operation **604**, the method **600** also includes classifying, using a classification module **220**, the device **20** based on the resource capabilities **26** and the resource needs **28** of the device **20**.

[0054] At operation **606**, the method **600** includes determining whether the device **20** is assigned a role **29** of a donor device **20**D. If the device **20** not assigned the role **29** of the donor device **20**D, the method **600** proceeds to operation **608** of assigning the device **20** in the device controller matrix **232** to the role **29** of a recipient device **20**R. If the device **20** is assigned the role **29** of the donor device **20**D, the method **600** proceeds to operation **610**, which includes determining whether the resource capabilities **26** of the device **20** exceed the resource needs **28** of the device **20**. If, at operation **610**, the resource capabilities **26** of the device **20** do not exceed (i.e., are equal to or less than) the resource needs **28** of the device **20**, the method **600** proceeds to operation **612**, which determines whether the device **20** needs additional resource capabilities **26**. If the device **20** needs additional resource capabilities **26**, the method **600** returns to operation **608**, and assigns (i.e., reassigns) the device **20** in the device controller matrix **232** to the role **29** of a recipient device **20**R.

[0055] At operation **612**. if the device **20** does not need additional resource capabilities **26**, the method **600** proceeds to operation **614**, where the service donor allocation model **230** may update the device controller matrix **232** to include an idle status. If, at operation **610**, the resource capabilities **26** of the device **20** exceed the resource needs **28** of the device **20** (i.e., the device **20** includes unused or underutilized resource capabilities **26**), the method **600** proceeds to operation **616**, which includes prioritizing the resource capabilities **26** and the resource needs **28** of the device **20** to generate the device controller matrix **232**, and generating one or more resource assignments **234** that assign the respective resource needs **28** of another device **20** to the resource capabilities **28** of the device **20**.

[0056] A number of implementations have been described. Nevertheless, it will be understood that various modifications may be made without departing from the spirit and scope of the disclosure. Accordingly, other implementations are within the scope of the following claims.

[0057] The foregoing description has been provided for purposes of illustration and description. It is not intended to be exhaustive or to limit the disclosure. Individual elements or features of a particular configuration are generally not limited to that particular configuration, but, where applicable, are interchangeable and can be used in a selected configuration, even if not specifically shown or described. The same may also be varied in many ways. Such variations are not to be regarded as a departure from the disclosure, and all such modifications are intended to be included within the scope of the disclosure.

What is claimed is:

1. A computer-implemented method when executed on data processing hardware causes the data processing hardware to perform operations comprising:

obtaining a device identifier for each of a plurality of devices within an ecosystem of a vehicle, each device identifier including respective resource capabilities and respective resource needs of the device;

for each device of the plurality of devices:

validating the device based on the obtained device identifier; and

classifying the device based on the respective resource capabilities and the respective resource needs of the device; and

generating a device controller matrix by:

identifying, based on the respective resource needs of each device of the plurality of devices, an ecosystem resource requirement for the plurality of devices in the ecosystem of the vehicle;

predicting, based on the device classifications for the plurality of devices, an ecosystem resource availability for the plurality of devices in the ecosystem of the vehicle; and

prioritizing the respective resource capabilities and the respective resource needs of each device of the plurality of devices based on the ecosystem resource requirement and the ecosystem resource availability.

2. The method of claim **1**, wherein classifying each device of the plurality of devices based on the respective resource capabilities and the respective resource needs of the device further comprises assigning a role to each device of the plurality of devices.

3. The method of claim **2**, wherein the assigned role of each device of the plurality of devices includes one of a donor device, a recipient device, or a hybrid device.

4. The method of claim **3**, wherein generating the device controller matrix further includes reassigning a hybrid device as one of a donor device or a recipient device based on the ecosystem resource requirement and the ecosystem resource availability.

5. The method of claim **1**, wherein classifying each device of the plurality of devices based on the respective resource capabilities and the respective resource needs of the device includes assigning a role to the device; and

wherein prioritizing the respective resource capabilities and the respective resource needs of each device of the plurality of devices comprises identifying a first device of the plurality of devices having respective resource capabilities that exceed respective resource needs.

6. The method of claim **5**, wherein generating the device controller matrix further comprises:

updating the device classification of the first device by reassigning the role of the first device to a donor device role; and

assigning the respective resource capabilities of the first device that exceed the respective resource needs of the first device to a second device having a recipient device role.

7. The method of claim **1**, wherein classifying each device of the plurality of devices based on the respective resource capabilities and the respective resource needs of the device includes assigning a role to the device; and

wherein prioritizing the respective resource capabilities and the respective resource needs of each device of the plurality of devices comprises identifying a first device of the plurality of devices having respective resource needs that exceed respective resource capabilities.

8. The method of claim **7**, wherein generating the device controller matrix further comprises:

updating the device classification of the first device by reassigning the role of the first device to a recipient device role; and

assigning the respective resource capabilities of a second device having a donor device role to the first device.

9. The method of claim **1**, wherein the generating the device controller matrix is further based on a device presence pattern.

10. The method of claim **1**, wherein a first device of the plurality of devices includes a first communication protocol, and a second device of the plurality of devices includes a second communication protocol, the first device and the second device in communication through the ecosystem of the vehicle.

11. A system comprising:

data processing hardware; and

memory hardware in communication with the data processing hardware, the memory hardware storing instructions that when executed on the data processing hardware cause the data processing hardware to perform operations comprising:

obtaining a device identifier for each of a plurality of devices within an ecosystem of a vehicle, each device identifier including respective resource capabilities and respective resource needs of the device;

for each device of the plurality of devices:

validating the device based on the obtained device identifier; and

classifying the device based on the respective resource capabilities and the respective resource needs of the device; and

generating a device controller matrix by:

identifying, based on the respective resource needs of each device of the plurality of devices, an ecosystem resource requirement for the plurality of devices in the ecosystem of the vehicle;

predicting, based on the device classifications for the plurality of devices, an ecosystem resource availability for the plurality of devices in the ecosystem of the vehicle; and

prioritizing the respective resource capabilities and the respective resource needs of each device of the plurality of devices based on the ecosystem resource requirement and the ecosystem resource availability.

12. The system of claim **11**, wherein classifying each device of the plurality of devices based on the respective resource capabilities and the respective resource needs of the device further comprises assigning a role to each device of the plurality of devices.

13. The system of claim **12**, wherein the assigned role of each device of the plurality of devices includes one of a donor device, a recipient device, or a hybrid device.

14. The system of claim **13**, wherein generating the device controller matrix further includes reassigning a hybrid device as one of a donor device or a recipient device based on the ecosystem resource requirement and the ecosystem resource availability.

15. The system of claim **11**, wherein classifying each device of the plurality of devices based on the respective resource capabilities and the respective resource needs of the device includes assigning a role to the device; and

wherein prioritizing the respective resource capabilities and the respective resource needs of each device of the plurality of devices comprises identifying a first device of the plurality of devices having respective resource capabilities that exceed respective resource needs.

16. The system of claim **15**, wherein generating the device controller matrix further comprises:

updating the device classification of the first device by reassigning the role of the first device to a donor device role; and

assigning the respective resource capabilities of the first device that exceed the respective resource needs of the first device to a second device having a recipient device role.

17. The system of claim **11**, wherein classifying each device of the plurality of devices based on the respective resource capabilities and the respective resource needs of the device includes assigning a role to the device; and

wherein prioritizing the respective resource capabilities and the respective resource needs of each device of the plurality of devices comprises identifying a first device of the plurality of devices having respective resource needs that exceed respective resource capabilities.

18. The system of claim **17**, wherein generating the device controller matrix further comprises:

updating the device classification of the first device by reassigning the role of the first device to a recipient device role; and

assigning the respective resource capabilities of a second device having a donor device role to the first device.

19. The system of claim **11**, wherein the generating the device controller matrix is further based on a device presence pattern.

20. The system of claim **11**, wherein a first device of the plurality of devices includes a first communication protocol, and a second device of the plurality of devices includes a second communication protocol, the first device and the second device in communication through the ecosystem of the vehicle.

* * * * *