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(54) **SYSTEM AND METHOD FOR DEVICE INTEROPERABILITY AND SYNCHRONIZATION**

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See application file for complete search history.

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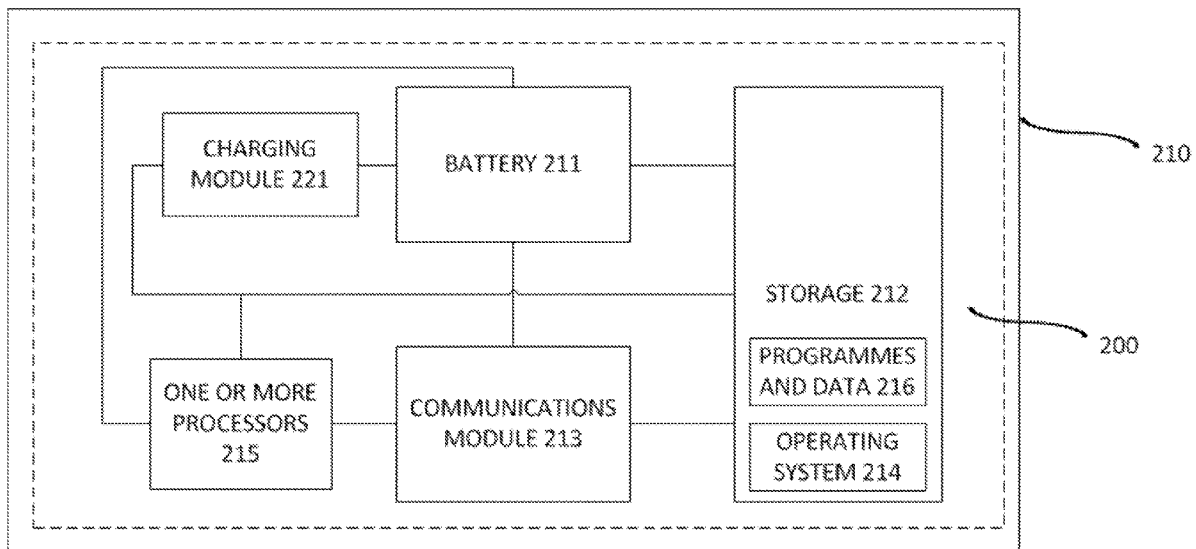
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(57) **ABSTRACT**

What is disclosed is a device interoperability system for one or more user devices associated with a user, wherein said one or more user devices comprises a first user device, said device interoperability system comprising a communications module, wherein a first connection is established between said first user device and said communications module; storage associated with said device interoperability system and coupled to said communications module, wherein said storage stores an operating system, one or more programs, and data associated with the user, further wherein said operating system is booted by said first user device via said first connection; and one or more processors to support said device interoperability system.

**30 Claims, 11 Drawing Sheets**



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*H04L 29/06* (2006.01)
- (52) **U.S. Cl.**  
CPC ..... *G06F 9/4411* (2013.01); *G06F 9/455*  
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(2013.01)

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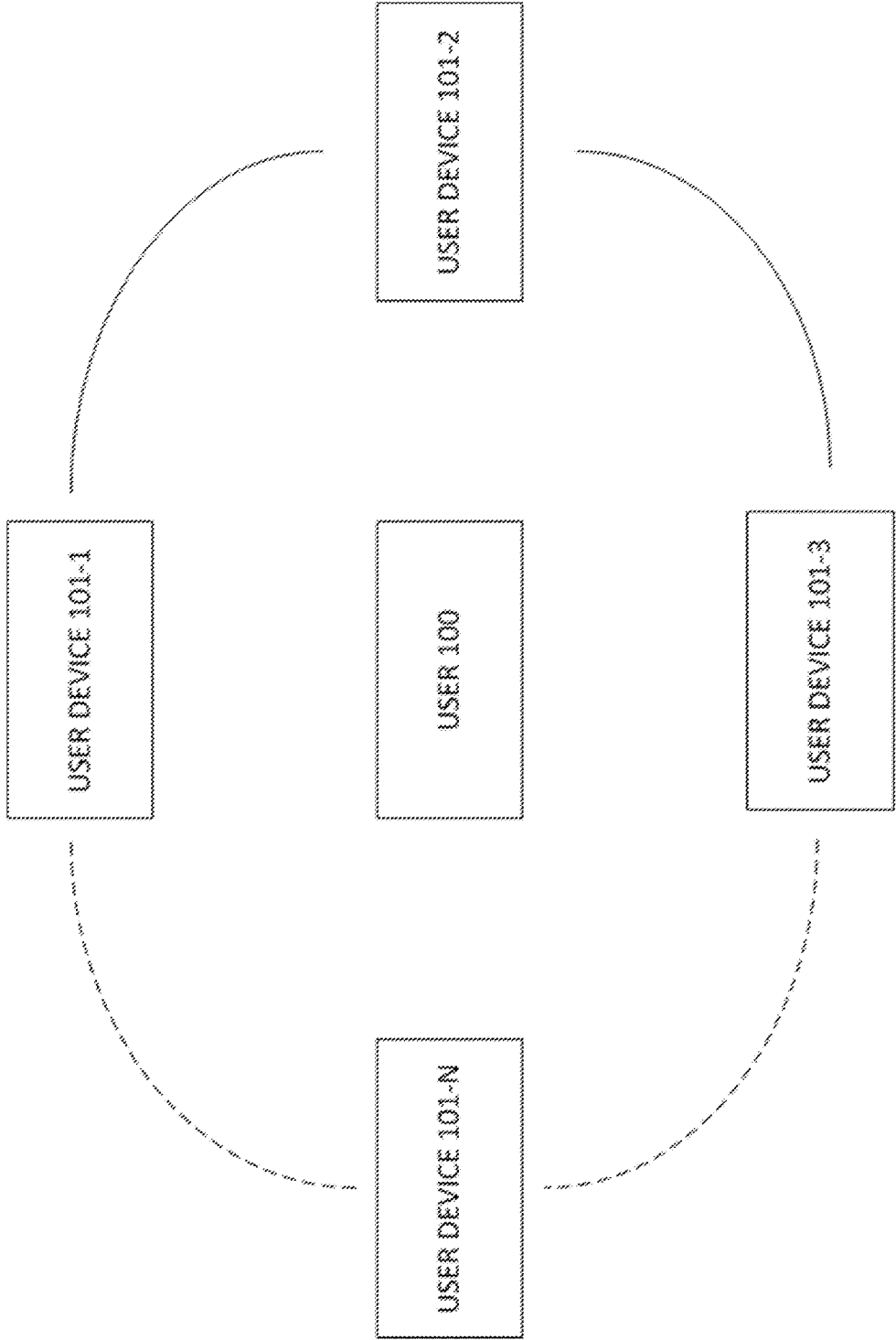


FIG. 1

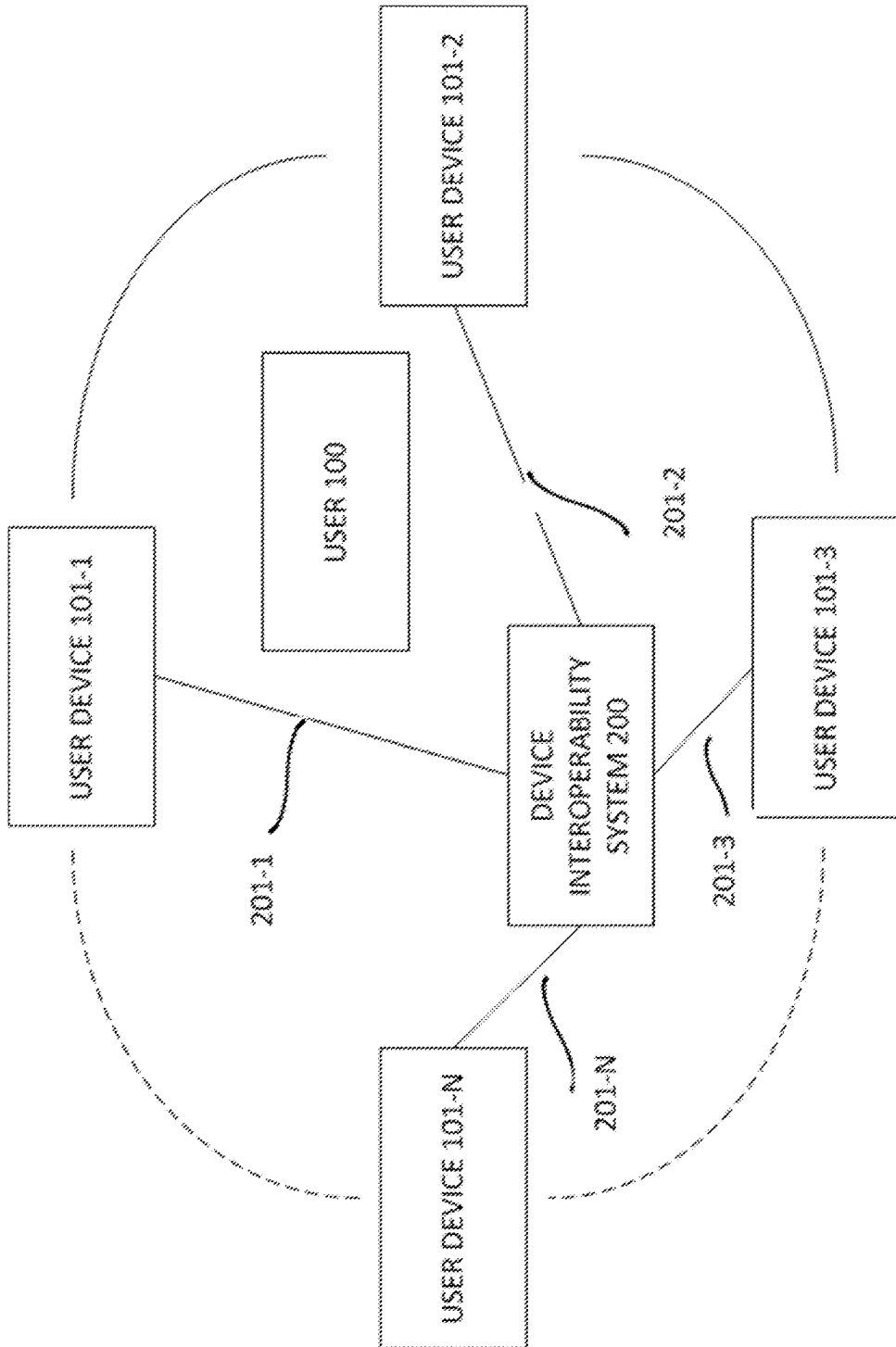


FIG. 2A

FIG. 2B

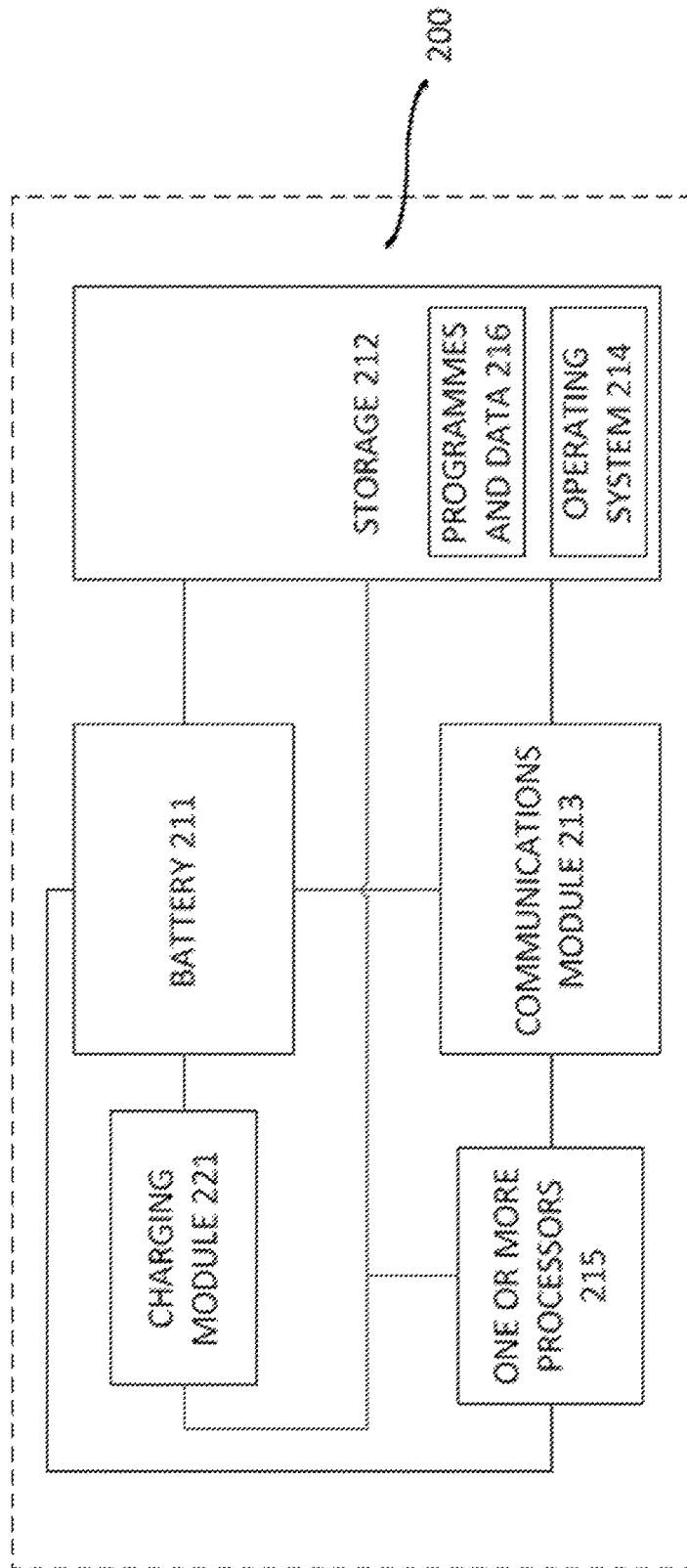
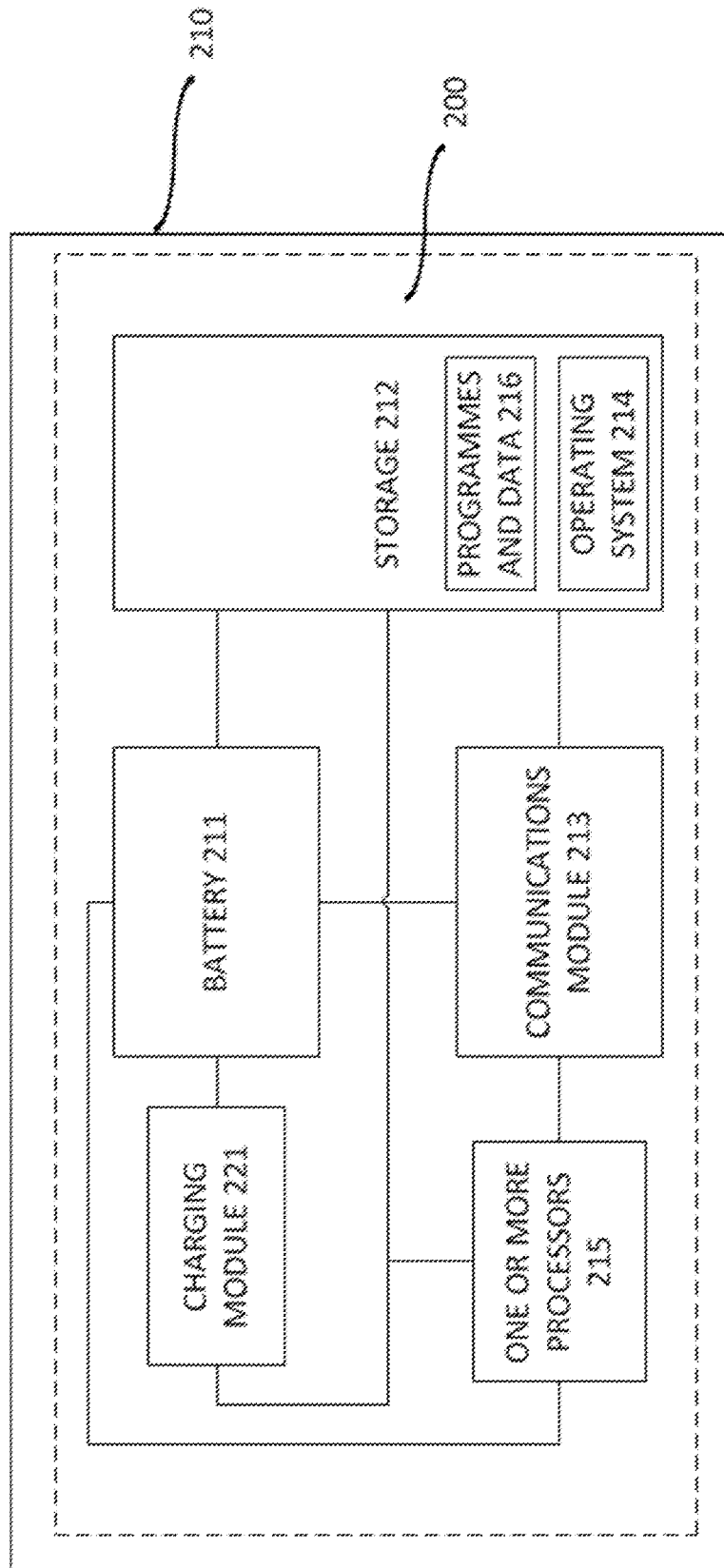


FIG. 2C



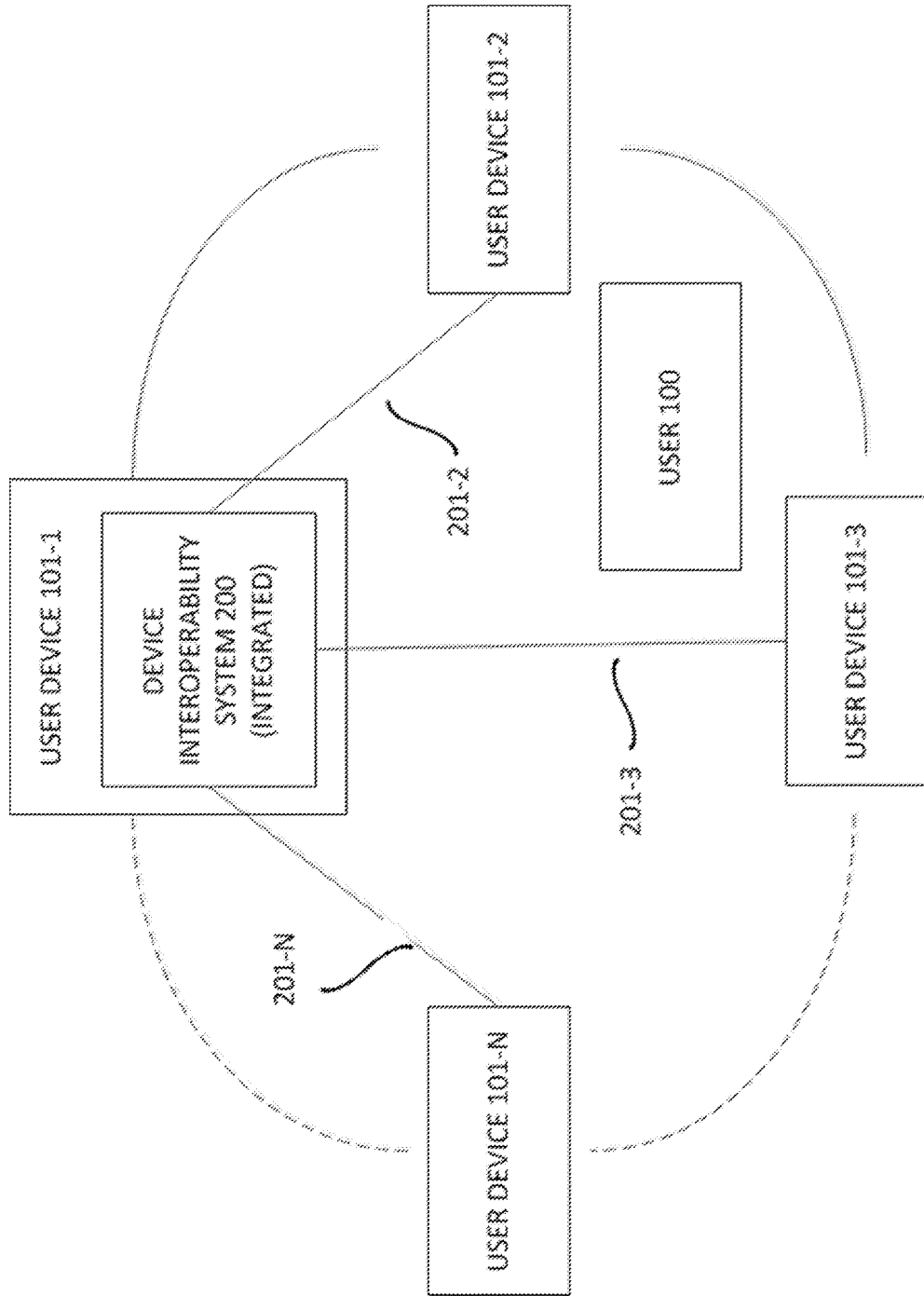


FIG. 2D

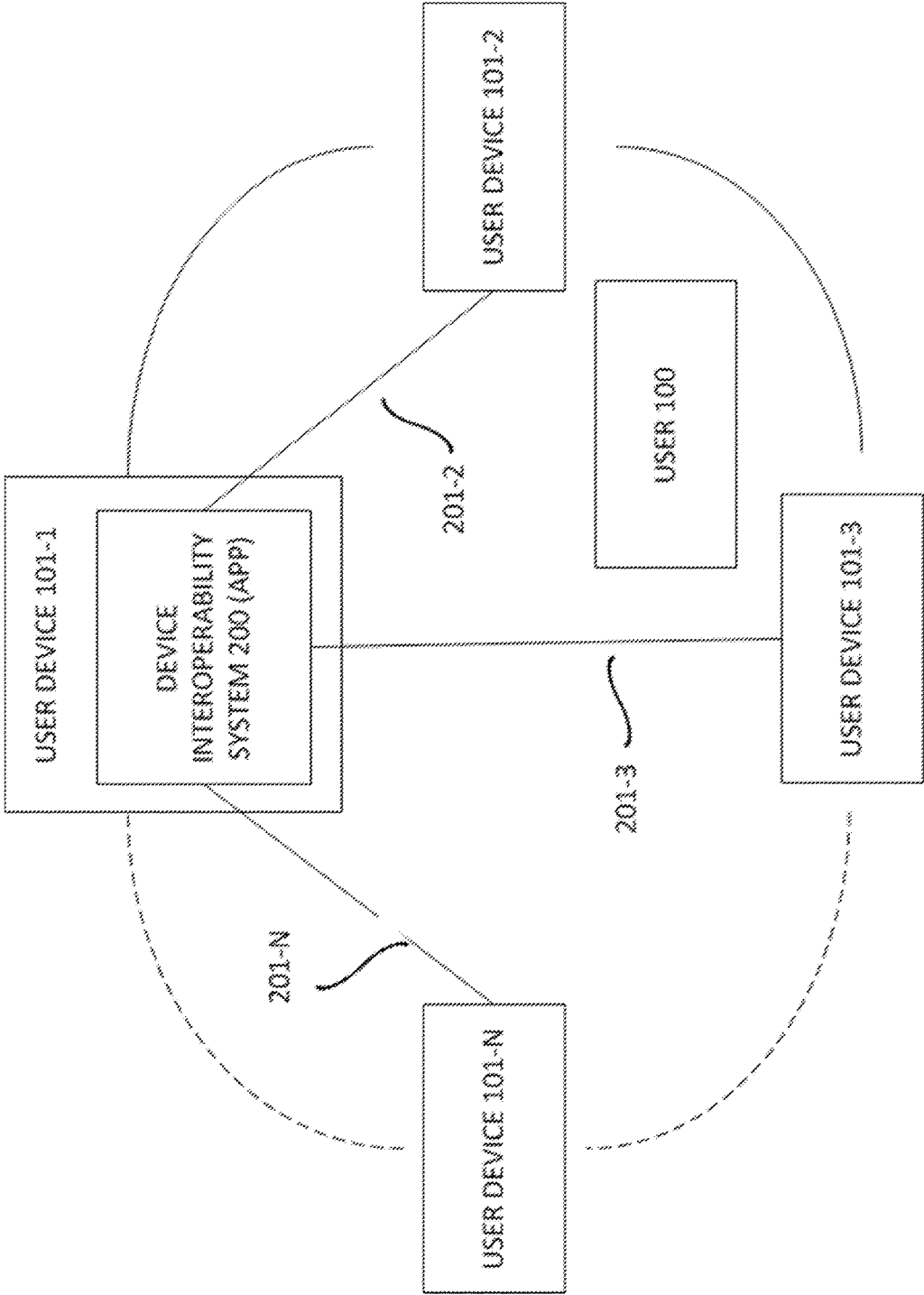
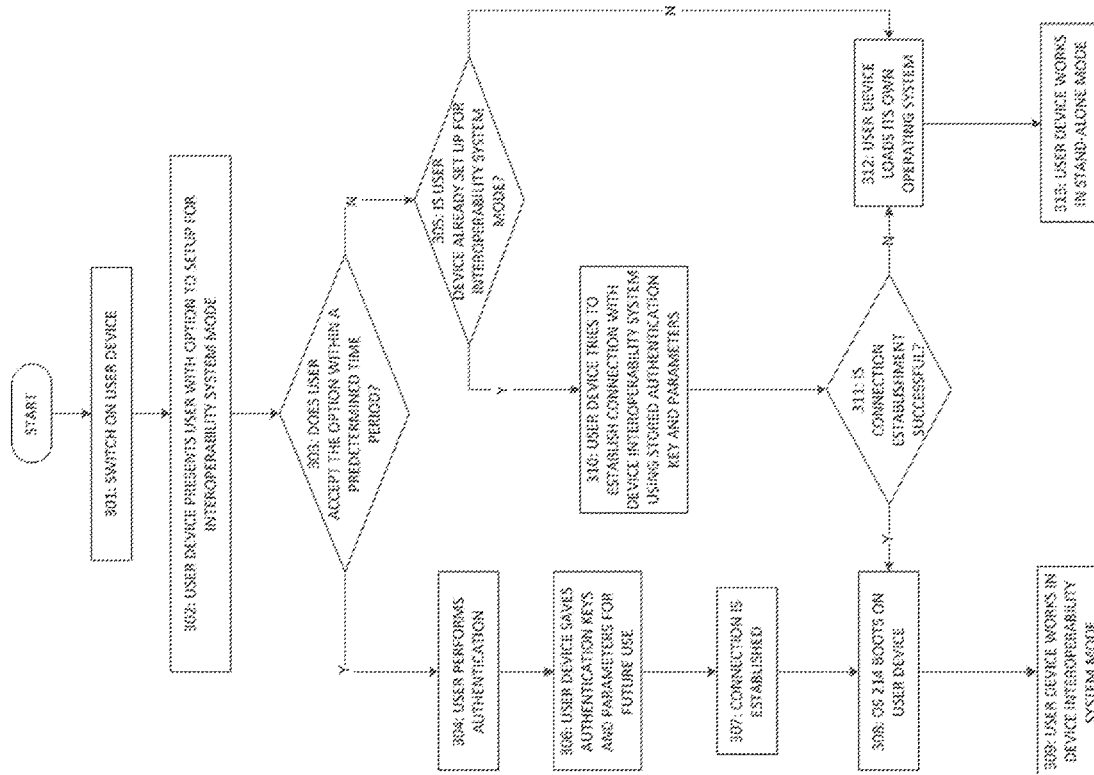


FIG. 2E



FIG. 3A



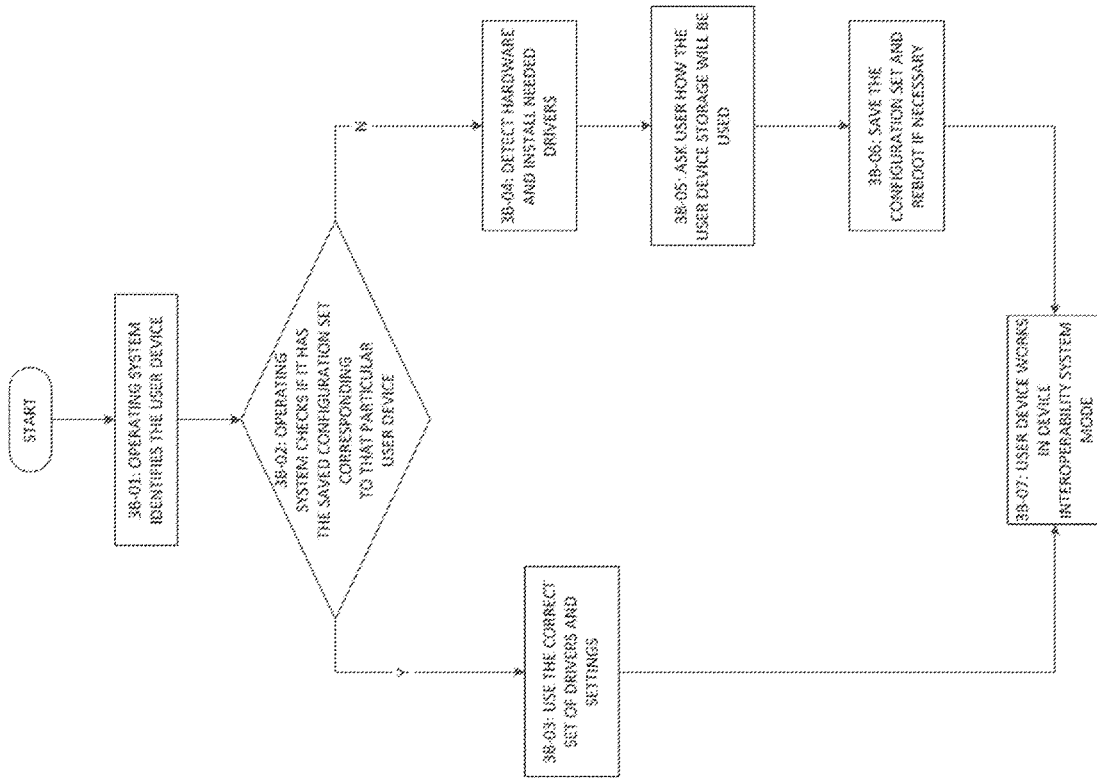


FIG. 3B

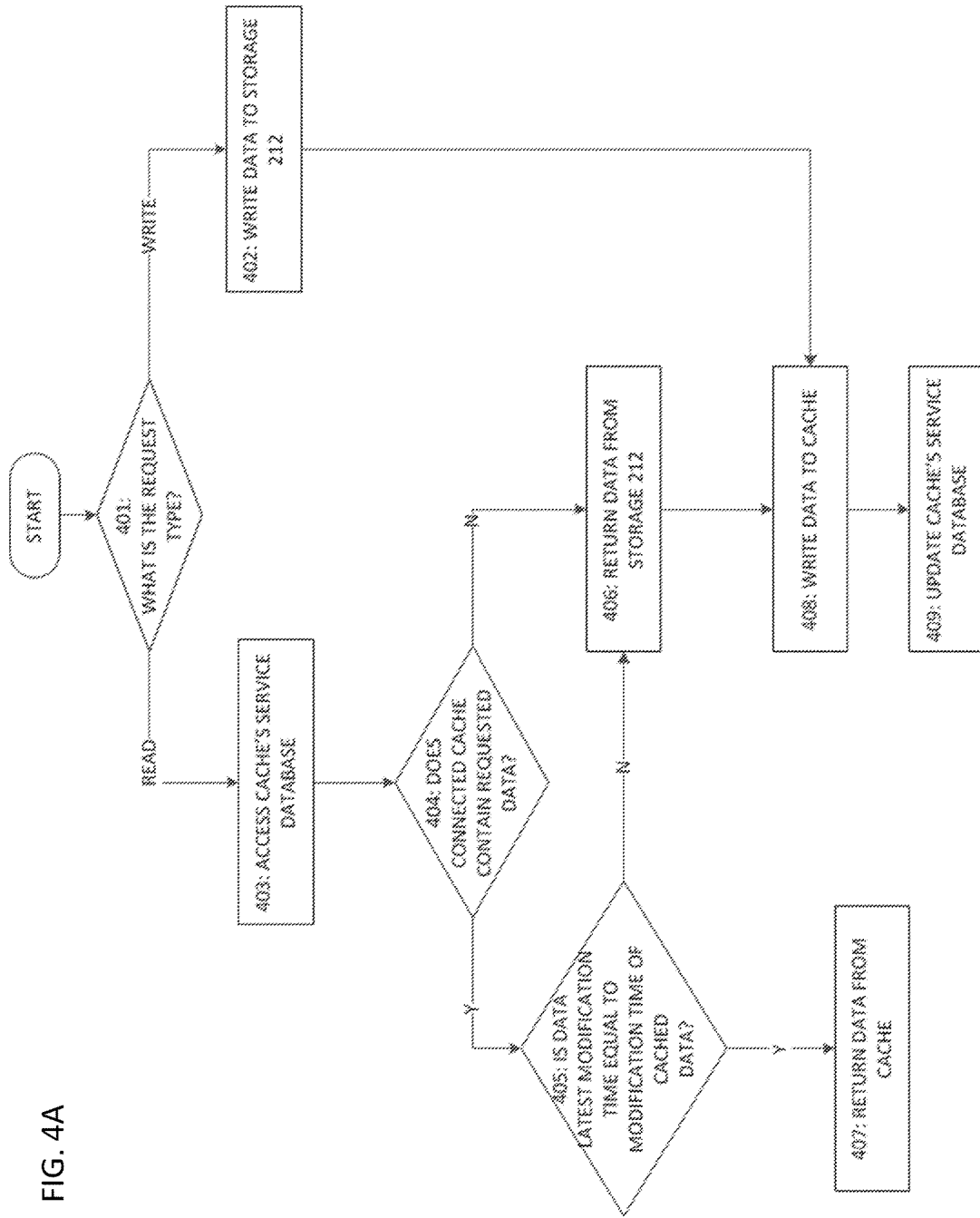


FIG. 4A

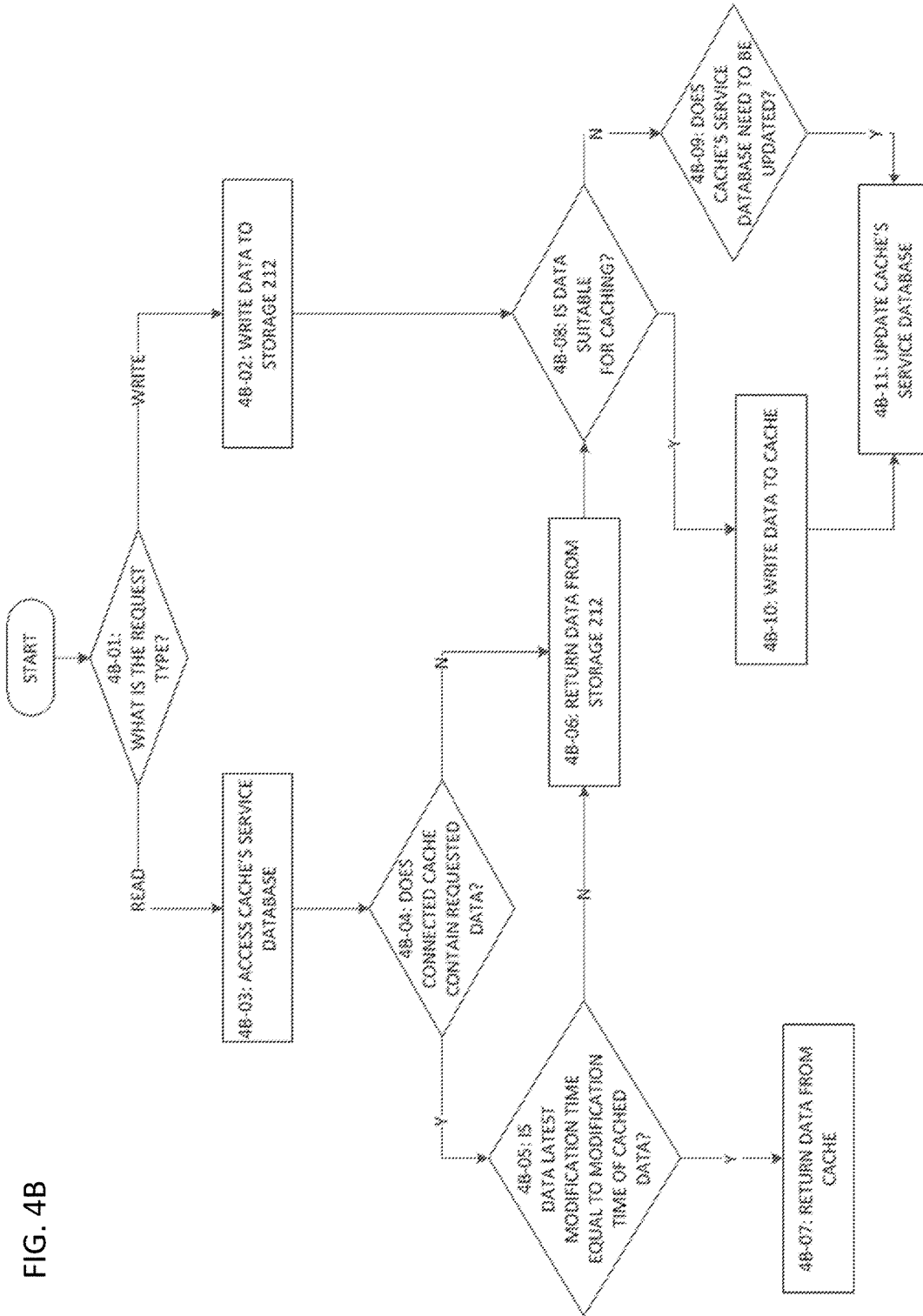
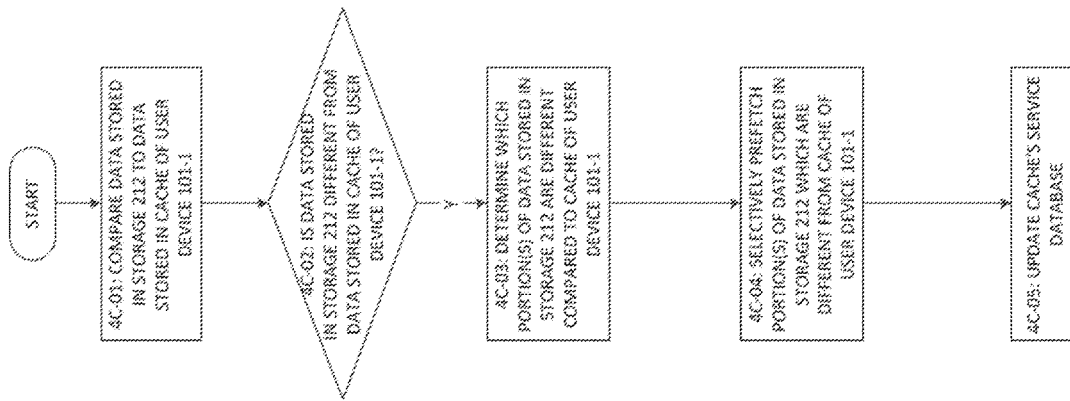


FIG. 4B

FIG. 4C



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## SYSTEM AND METHOD FOR DEVICE INTEROPERABILITY AND SYNCHRONIZATION

### CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of and priority to U.S. Provisional Patent Application No. 62/413,169, filed on Oct. 26, 2016, which is incorporated herein by reference in its respective entirety.

### FIELD OF THE INVENTION

The present disclosure relates to device interoperability for user devices.

### BRIEF SUMMARY

A device interoperability system for one or more user devices associated with a user, wherein said one or more user devices comprises a first user device, said device interoperability system comprising a communications module, wherein a first connection is established between said first user device and said communications module; storage associated with said device interoperability system and coupled to said communications module, wherein said storage stores an operating system, one or more programs, and data associated with the user, further wherein said operating system is booted by said first user device via said first connection; and one or more processors to support said device interoperability system.

A method for device interoperability for one or more user devices associated with a user, said one or more user devices comprising a first user device; said method comprising establishing a first connection between said first user device and a device interoperability system via a communications module within the a device interoperability system; storing, using storage within the device interoperability system, an operating system, one or more programs, and data associated with the user; and booting said operating system by said first user device via said first connection.

The foregoing and additional aspects and embodiments of the present disclosure will be apparent to those of ordinary skill in the art in view of the detailed description of various embodiments and/or aspects, which is made with reference to the drawings, a brief description of which is provided next.

### BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other advantages of the disclosure will become apparent upon reading the following detailed description and upon reference to the drawings.

FIG. 1 illustrates a situation for a user with one or more user devices.

FIG. 2A illustrates an example of a device interoperability system working in conjunction with the user devices.

FIG. 2B illustrates an example architecture for the device interoperability system.

FIG. 2C illustrates an example of a gadget to run the device interoperability system.

FIG. 2D shows an example where the device interoperability system is integrated into a user device.

FIG. 2E shows an example where the device interoperability system runs as an application on a user device.

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FIG. 3A shows an example algorithm for user device switchability between “stand-alone” and “interoperability system” modes.

FIG. 3B shows an example algorithm for switching the operating system between different hardware configurations on booting.

FIG. 4A shows an example embodiment of a caching operation.

FIG. 4B illustrates an example embodiment of caching where additional checks are performed before writing data to the cache.

FIG. 4C shows an example embodiment of prefetching to a cache.

While the present disclosure is susceptible to various modifications and alternative forms, specific embodiments or implementations have been shown by way of example in the drawings and will be described in detail herein. It should be understood, however, that the disclosure is not intended to be limited to the particular forms disclosed. Rather, the disclosure is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of an invention as defined by the appended claims.

### DETAILED DESCRIPTION

The number of devices owned or operated by a person has grown tremendously. Typically, a person has a plurality of computing devices, such as:

- Smartphones,
- Tablets,
- Desktops,
- Laptops,
- Game consoles,
- Smart watches/bands, and
- Smart glasses.

In addition, many other devices and items have become “smart”, that is, their computing capabilities and processing power have increased, and they have been network enabled. These include, for example:

- Vehicles such as cars and trucks,
- Television (TV) sets,
- Kitchen appliances such as refrigerators and microwave ovens,
- Cameras,
- Fitness devices such as FitBit®,
- Medical devices such as blood pressure monitors and heart rate monitors,
- Air-conditioning systems, and
- Smart home systems.

Furthermore the “Internet of Things” (IoT) has also grown tremendously. The IoT refers to networks of consumer and industrial devices interconnected with each other and with other computing devices.

All of this means that the number of devices which have computing and network capability, and are associated with a particular user, is growing rapidly.

FIG. 1 illustrates this situation. In FIG. 1, user devices 101-1 to 101-N comprise the devices associated with user 100. These include, for example, the electronic computing devices and the other devices and items mentioned above.

Given the situation shown in FIG. 1, users such as user 100 face many different challenges. Firstly, documents and data from different devices need to be synchronized with each other. Typically this is performed using, for example:

- Portable data storage devices such as Universal Serial Bus (USB) flash drives, and removable hard drives, and
- Network or “cloud”-based techniques.

These techniques of document and data synchronization have deficiencies. Cloud connectivity may not always be present. When it is, connectivity may be intermittent or slow. Privacy may also be an issue with cloud-based techniques.

Secondly, synchronization may be imperfect or incomplete due to each computing device and consumer item running different operating systems (OSes) and different platforms. Referring to FIG. 1, user device 101-1 to 101-N have their own processing and memory capabilities and may run different OSes, platforms and software. As a consequence, the user is forced to get used to different environments on different devices and also to repeat the same tasks for several devices, for example, installing applications, customizing settings or performing service tasks like software updates or antivirus scanning. Compatibility may also be an issue. As an example, if user 100 edits a file first with user device 101-1 and then with user device 101-2, that file may end up being corrupted as a result due to the different versions of the editing software installed on user device 101-1 and 101-2.

It is therefore necessary to address these deficiencies in device synchronization in order to ensure continued growth and adoption of “smart” technology; and interoperability of these user devices.

The remainder of this specification details a system and a method for device interoperability to address the above problems. An example architecture of such a device interoperability system 200 is shown in FIGS. 2A and 2B. In FIG. 2A, one or more connections 201-1, 201-2, 201-3 to 201-N between device interoperability system 200 and one or more user devices 101-1, 101-2, 101-3 to 101-N are established as needed. In one embodiment, the one or more user devices 101-1, 101-2, 101-3 to 101-N initiate the establishment of the connection. In another embodiment, the device interoperability system 200 initiates the establishment of the connection.

Device interoperability system 200 comprises several components necessary for its functioning. An illustration of one embodiment of device interoperability system 200 is shown in FIG. 2B. As shown in FIG. 2B, device interoperability system 200 comprises battery 211, battery charging module 221, storage 212, one or more processors 215 and communications module 213.

The one or more processors 215 perform the functions of supporting the other elements of device interoperability system 200. This includes, for example:

- maintaining interconnection between the elements of device interoperability system 200,
- maintaining overall security of device interoperability system 200, and
- service functions necessary for the operation of device interoperability system 200.

Communications module 213 participates in the establishment of the one or more connections 201-1 to 201-N. Communications module 213 also works to maintain the one or more connections 201-1 to 201-N to the one or more user devices 101-1 to 101-N. Communications module 213 also works to perform operations necessary to secure connections 201-1 to 201-N. These include, for example, encryption and access operations. In one embodiment, communications module 213 also manages and optimizes power consumption related to one or more connections 201-1 to 201-N. For example, communications module 213 adjusts the transmission powers used for the one or more connections 201-1 to 201-N based on distances from user devices such as user device 101-1.

Battery 211 supplies power for the operation of device interoperability system 200. Charging module 221 enables charging of battery 211 using an external power source. In one embodiment, charging module 221 enables wireless charging.

As shown in FIG. 2B, storage 212 is coupled to communications module 213 and is used to store OS 214, programs and data 216 which are necessary for the functioning of device interoperability system 200. For example, user preferences, applications and user documents and data may also be stored on storage 212. The functioning of OS 214 will be discussed in detail below. In one embodiment, storage 212 is built using energy-efficient storage technology such as SSD (Solid State Drive) or embedded MultiMedia Controller (eMMC) flash memory technology. In one embodiment, the information stored in storage 212 is encrypted. This reduces the risk of a malicious party obtaining access to the stored information. In one embodiment, the Advanced Encryption Standard (AES) is used for encryption.

Referring to FIGS. 2A and 2B, connection 201-1 between device interoperability system 200 and user device 101-1 is established before the native user device 101-1 OS loads. Once connection 201-1 is established with user device 101-1, OS 214 boots and runs from storage 212 on user device 101-1. Then, user device 101-1 is able to access data and program code stored on storage 212 as required. The program code of OS 214 and installed applications is run on the user device which device interoperability system 200 is connected to, and uses the processing capabilities of this user device for its operation. For example, referring to FIG. 2A, if device interoperability system 200 is connected to user device 101-1, then the program code is run on user device 101-1 using the processing power and memory of user device 101-1 as needed. The establishment of connection 201-1 and subsequent booting of OS 214 is performed in a variety of ways, as will be detailed below.

In one embodiment, at least one of the connections 201-1 to 201-N is a direct connection. This direct connection can be, for example, a direct wireless connection.

In some embodiments, user device 101-1 comprises firmware that provides the ability to support booting from device interoperability system 200 via a direct wireless connection. For example, in one embodiment, user device 101-1 comprises a Basic Input Output System (BIOS) or Unified Extensible Firmware Interface (UEFI) which supports the Media Agnostic USB specification. This allows the user device 101-1 to use the USB protocol over the direct wireless connection to facilitate the booting of OS 214 on the user device 101-1 and data transfer between device interoperability system 200 and user device 101-1.

In some embodiments, user device 101-1 does not comprise firmware that provides the ability to support booting from device interoperability system 200 via a direct wireless connection. Then it is necessary to use an intermediary. For example, in one embodiment, the device interoperability system 200 is coupled wirelessly to a miniature USB dongle plugged into a USB port on user device 101-1. Then the miniature USB dongle will simulate a USB flash drive connected to user device 101-1. Then when user device 101-1 is switched on, the direct wireless connection is established between the miniature USB dongle and device interoperability system 200. Then OS 214 is booted on the user device 101-1 from the storage 212 as though it is an ordinary USB flash drive connected to the USB port. In one embodiment, the user must change the BIOS or UEFI settings for user device 101-1 so that user device 101-1 will boot from the device interoperability system 200.

In another embodiment, the direct connection is a direct wired connection. In a further embodiment, the at least one direct wired connection includes, for example, a USB connection. In further embodiments, the direct wired connection is a connection facilitated via docking. In yet another embodiment, at least one of the connections **201-1** to **201-N** are direct wireless and at least one of the connections **201-1** to **201-N** are direct wired.

When connection **201-1** between user device **101-1** and device interoperability system **200** is facilitated via docking, further embodiments are also possible. In one embodiment, both the device where device interoperability system **200** is installed, and user device **101-1** have direct docking capabilities including, for example, docking ports. Then, device interoperability system **200** interacts with the user device **101-1** via these direct docking capabilities. In yet another embodiment, the device where device interoperability system **200** is installed is coupled to a docking station which is connected to user device **101-1**. In a further embodiment, when the docking station is connected to user device **101-1** by, for example, USB cable, the user device **101-1** will recognize the docking station with the device where device interoperability system **200** is installed as a connected external USB drive. In one embodiment, the user must change the BIOS or UEFI settings for user device **101-1** so that user device **101-1** will boot from the USB connected device. In a further embodiment, the docking station provides charging for the device where device interoperability system **200** is installed.

While the above describes situations where connections **201-1** to **201-N** are direct connections between two devices, one of skill in the art would know that it is possible to use indirect connections as well. In another embodiment, at least one of the connections **201-1** to **201-N** are indirect connections. These indirect connections include, for example, one or more of:

- connections facilitated via a Local Area Network (LAN),
- or
- connections facilitated via a cloud-based service.

In a further embodiment, when at least two of the described above types of connection are available, the choice between connection types is performed automatically for at least one of the connections **201-1** to **201-N**. In one embodiment, the choice is based on the following factors:

- connection speed,
- connection latency,
- data transmission costs,
- user preferences.

In a further embodiment, when the connectivity is lost, either a different type of direct or indirect connection is automatically selected.

In a further embodiment, the at least one connection is secured. The securing is performed by, for example:

- Encryption using techniques such as Wi-Fi Protected Access (WPA2), and
- Requiring access authentication on both endpoints of a connection when the connection is first established.

This is performed using, for example passwords and techniques such as near field communication (NFC) or Wi-Fi Protected Setup (WPS)-like algorithms.

In embodiments where the at least one connection is secured, before establishing the connection authentication is performed at the end points, that is, between device interoperability system **200** and user device **101-1**.

Device interoperability system **200** can be implemented in a variety of ways. In one embodiment, device interoperability system **200** is implemented using a separate gadget, such

as gadget **210** as shown in FIG. 2C. Then, the one or more connections **201-1** to **201-N** are established with gadget **210**.

In another embodiment, device interoperability system **200** is installed via integration into one of user devices **101-1** to **101-N**. For example, as shown in FIG. 2D, device interoperability system **200** is integrated into user device **101-1**. This is achieved by, for example, implementing device interoperability system **200** as a firmware module of user device **101-1**. Then, device interoperability system **200** uses one or more of the battery, storage, communications module, processors and other capabilities of user device **101-1** in a similar fashion to the above-described use of battery **211**, storage **212**, one or more processors **215** and communications module **213** for its operation. OS **214** is stored within the storage of user device **101-1**. Then the user device **101-1** runs OS **214** instead of its native OS. When, as shown in FIG. 2D, at least one of connections **201-2** to **201-N** are established between user device **101-1** and at least one of the other devices **101-2** to **101-N**, device interoperability system **200** enables the connected user device to:

- boot OS **214** which is stored in the storage of user device **101-1**, and
- use programs and data **216** which are stored in the storage of user device **101-1**.

In a further embodiment, some hardware components of the user device **101-1** with integrated device interoperability system **200** are recognized and used by the OS **214** as connected external devices, when OS **214** runs on a different device which is connected to user device **101-1**. For example, in the case where user device **101-1** is a smartphone: When OS **214** runs on user device **101-2** which is connected to user device **101-1**, the hardware components of user device **101-1** such as the microphone, sensors, mobile telecommunications module and display are used by OS **214** as external devices.

In yet another embodiment, device interoperability system **200** is implemented as an installed application or an “app” which runs on one of user devices **101-1** to **101-N**, for example user device **101-1**. For example, as shown in FIG. 2E, device interoperability system **200** runs as an app on user device **101-1**. Then device interoperability system **200** uses one or more of the battery, storage, communications module, processors and other capabilities of user device **101-1** for its operation, similar to the integrated case described above and in FIG. 2D. Similar to as described above, when a connection is established with a user device, device interoperability system **200** gives the connected user device the ability to boot OS **214** which is stored in the storage of user device **101-1**. In another embodiment, in case the app is not able to provide the required level of access to data stored on storage **212** of user device **101-1** which is used to boot OS **214** on user device **101-2**, the interoperability system **200** also includes a separate image of either a copy of the OS **214**, or some of its components.

This image is used on its own or in conjunction with user device **101-1** OS’s components stored on storage of user device **101-1** to boot the OS on user device **101-2**. Similar to the cases described above, in a further embodiment, some hardware components of the user device **101-1** are recognized and used by the OS **214** as connected external devices, when OS **214** runs on a different device which is connected to user device **101-1**.

In some of the embodiments where device interoperability system **200** is installed via integration into user device **101-1** or as an app on user device **101-1**, as part of communications module **213**, an external wireless adapter is added to user



device **101-1** to provide additional communications capabilities not available on user device **101-1**, so as to improve performance and/or energy efficiency. This external wireless adapter works with, for example, an integrated controller which is already present on user device **101-1**. Then, the communications module **213** comprises the integrated controller and the external wireless adapter of user device **101-1**. For example, a USB wireless adapter based on WiGig or Li-Fi communication technology is plugged into a USB port of user device **101-1**. This plugged in wireless adapter will interact with an integrated USB controller already present on user device **101-1**. Then, the communications module **213** comprises this integrated USB controller and plugged in USB wireless adapter. These added components provide additional communication technology which is not initially available on user device **101-1** to improve performance and/or energy efficiency.

An example of the operation of device interoperability system **200** will be detailed below with reference to a user device, specifically user device **101-1**. The descriptions below are applicable to a variety of situations including, for example:

device interoperability system **200** installed on a gadget such as gadget **210**;

device interoperability system **200** is installed via integration into one of user devices different from user device **101-1**, for example user devices **101-2** to **101-N**; and

device interoperability system **200** is installed as an app on one of user devices different from user device **101-1**, for example user devices **101-2** to **101-N**.

Additionally, there is a need to determine if user device **101-1** will operate in either “stand-alone” or “device interoperability system” mode. In stand-alone mode, the user device **101-1** runs its native OS. In interoperability system mode, the user device **101-1** is connected to device interoperability system **200** and runs OS **214**. In a further embodiment, the user device **101-1** is switchable between stand-alone and interoperability system modes.

An example algorithm for switching between stand-alone and interoperability system modes comprising:

establishment of connection **201-1** in the embodiments where connection **201-1** is a secured connection, subsequent booting of the appropriate OS depending on whether stand-alone or interoperability modes is used, is provided in FIG. **3A**.

In FIG. **3A**, in step **301**, user device **101-1** is switched on. In step **302**, prior to establishing connection **201-1**, user device **101-1** presents the user with the option of setting up for interoperability system mode.

If the user accepts the option of setting up for interoperability system mode within a predetermined period in step **303**, then in step **304** the user performs authentication. In one embodiment, in step **304** the user enters a unique string, password or passphrase specific to the device interoperability system **200**. In another embodiment, in step **304** the user enters a login name and a password specific to the OS **214**. In yet another embodiment, the user uses login details from another social media site, or web mail site, for example, Facebook®, LinkedIn®, Twitter®, Google®, Gmail®, or others. Additional steps are also possible for authentication. In another embodiment, the user is additionally asked to recognize a combination of letters, numbers and symbols in an image and enter the combination into a box. An example of such a test is the Completely Automated Public Turing test to tell Computers and Humans Apart (CAPTCHA) test. In another embodiment, the user is asked a security question,

to which the user only knows the answer. In yet another embodiment, the user may be asked additional personal information, such as date of birth and home address. In another embodiment, the user is asked to take a picture of himself/herself and the device interoperability system **200** will match the image to a pre-stored image. In yet another embodiment other biometric measures such as fingerprints scanning are used. The authentication data is used as a pre-shared key and authentication/encryption keys for encrypted connection are built.

In step **306**, the user device saves the authentication/encryption keys and connection parameters for future use.

In step **307**, connection **201-1** is established.

In step **308**, OS **214** boots on user device **101-1**.

In step **309**, the user device **101-1** works in device interoperability system mode.

If the user does not accept the option of setting up for interoperability system mode in step **303**, then in step **305**, user device **101-1** determines if it is already set up for interoperability system mode. If in step **305** the user device **101-1** is already set up, then in step **310** the user device tries to establish a connection with device interoperability system **200** using the stored authentication keys and parameters.

Following on from step **310**, if the connection establishment is successful in step **311** then the OS **214** boots on user device **101-1** (step **308**), and the user device **101-1** works in device interoperability system mode (step **309**).

If the connection is unsuccessful in step **311**, then user device **101-1** loads its own OS in step **312**. In step **313**, the user device **101-1** works in stand-alone mode.

If in step **305** the user device is not already set up, then the user device **101-1** loads its own OS (step **312**) and works in stand-alone mode (step **313**).

In one embodiment, in order to improve speed of operation and to reduce the amount of data transmitted through a connection such as connection **201-1**, the swap file or swap partition of OS **214** is placed on the storage of the user device **101-1**.

In one embodiment, in order to improve speed of operation, caching is performed by, for example, setting aside a portion of the storage of the connected user device for a cache. In one embodiment, when OS **214** is booted, it will determine if there is a cache on the connected user device. Caching operations will be discussed in detail further below.

In one embodiment, at least some portion of the local storage of a user device connected to device interoperability system **200** is used by OS **214** to store data intended for use only on this particular device. An example is where user device **101-1** is a desktop used by user **100** specifically for running high resource demand applications such as video games. Then, some of the data necessary for running the high resource demand application is stored on the local storage of user device **101-1** instead of storage **212**. In a further embodiment, the portion of the user device **101-1** storage which is to be used is recognized by OS **214** as a connected additional drive and presented accordingly.

In one embodiment, a portion of the local storage space of a user device connected to device interoperability system **200** is used by OS **214** to perform a backup of at least some of the data stored in storage **212**. The amount of data which is backed up depends on the available capacity of the local storage of the user device. In a further embodiment, the backup is performed using a plurality of user devices. That is, data is backed up from storage **212** to a portion of each local storage space corresponding to each of the plurality of user devices.

In a further embodiment, at least some of the data which is stored on the storage of user device **101-1** for either caching, swapping, expanding storage, backups or any combination of these purposes is placed in one or more partitions set up on the storage of user device **101-1**. In another embodiment, the data which is stored on the storage of user device **101-1** for either caching, expanding storage, backups or any combination of these purposes is placed in one or more file-containers created in an existing partition of user device **101-1**. This eliminates the need for repartitioning or erasing any data from the storage of user device **101-1**.

In a further embodiment, the data which is stored on the storage of user device **101-1** for either caching, swapping, expanding storage, backups or any combination of these purposes is encrypted. The decryption keys are stored and managed by OS **214** thus preventing unauthorized access to the data.

In one embodiment, the OS **214** is able to switch between different hardware configurations during booting, such as in step **308** of FIG. **3A**. An example algorithm for switching between different hardware configurations is provided in FIG. **3B**.

When the OS **214** is booted on a user device such as user device **101-1**, then in step **3B-01** OS **214** identifies the user device. In step **3B-02**, OS **214** determines whether it has stored the configuration set corresponding to the identified user device in storage **212**. If yes, then in step **3B-03** OS **214** uses the correct set of drivers and setting for the identified user device. The user device then works in device interoperability system mode in step **3B-07**.

If in step **3B-02** OS **214** is unable to find the configuration set corresponding to the identified user device in storage **212**, then in step **3B-04** OS **214** will detect all hardware on this user device and install needed drivers automatically.

In step **3B-05**, OS **214** prompts the user to enter one or more answers to one or more questions to determine how the user device storage will be used for the functioning of OS **214**. Example questions include:

- will the user device storage be used for caching?
- will the user device storage be used for backups?
- will the user device storage be used to provide additional storage space for OS **214** for its use?
- how much space will be reserved for specified above purposes?

In step **3B-06**, OS **214** will save the configuration set and reboot if necessary, before proceeding to work in device interoperability system mode in step **3B-07**.

As mentioned previously, example embodiments of caching operations are discussed in detail below with reference to FIGS. **4A**, **4B** and **4C**.

FIG. **4A** shows an example flow when a received read or write operation request is processed by OS **214**. In this example OS **214** is stored on the device where device interoperability system **200** is installed. This device is connected to user device **101-1**. Also, a cache has been set up on user device **101-1**.

In step **401**, the request type is determined by OS **214**.

If the request is determined to be for a read operation, then in step **403** the OS **214** determines if the cache contains the requested data. In one embodiment, OS **214** accesses the cache service database to determine if the cache set up on user device **101-1** contains the requested data. The cache service database describes modification times of the versions of the files stored in at least one of the caches of the user devices **101-1** to **101-N**, and modification times of the original versions of those files stored in the storage **212**. Determination if the cache contains the requested data is

performed by comparison of those modification times. The cache service database is stored in storage **212**.

Table 1 shows an example of a cache service database:

TABLE 1

Example of Cache Service Database				
File [1C-01]	Storage 212 [1C-02]	Cache #1 [1C-03]	Cache #2 [1C-04]	...
C:\path1\file1 [1R-01]	dd/mm/yy HH:MM:SS [1R-01, 1C-02]	dd/mm/yy HH:MM:SS [1R-01, 1C-03]	dd/mm/yy HH:MM:SS [1R-01, 1C-04]	
C:\path2\file2 [1R-02]	dd/mm/yy HH:MM:SS [1R-02, 1C-02]	n/a [1R-02, 1C-03]	dd/mm/yy HH:MM:SS [1R-02, 1C-04]	
...				

In Table 1, column 1C-01 represents the files. Each file corresponds to a separate row of Table 1. With reference to Table 1, file 1 is assigned to row 1R-01, file 2 is assigned to row 1R-02 and so on.

Column 1C-02 of Table 1 represents the modification times of the original versions of those files stored in the storage **212** and in at least one of the caches on the user devices **101-1** to **101-N**. Then, referring to Table 1:

Cell [1R-01, 1C-02] represents the modification time of the original version of file 1 in storage **212**,

Cell [1R-02, 1C-02] represents the modification time of the original version of file 2 in storage **212**,

Columns 1C-03 and 1C-04 represent the modification times of the versions of the file in the respective caches. For example, column 1C-03 corresponds to the cache 1 stored on user device **101-1**, 1C-04 corresponds to cache 2 stored on user device **101-2**, and so on. Then:

Cell [1R-01, 1C-03] represents the modification time of the version of file 1 in cache 1,

Cell [1R-01, 1C-04] represents the modification time of the version of file 1 in cache 2,

Cell [1R-02, 1C-03] represents the modification time of the version of file 2 in cache 1, and

Cell [1R-02, 1C-04] represents the modification time of the version of file 2 in cache 2.

There are a variety of formats which can be used to represent the times in the cache service database. One example format is a two-digit representation of day/month/year followed by hour:minute:second or "dd/mm/yy HH:MM:SS".

There is a variety of other information which can be also included in the cache service database. For example, the cache service database can also include file sizes and checksums for data integrity checks.

In another embodiment the cache service database is based on file checksums instead of file modification times. Then, the cache service database describes checksums of the versions of the files stored in at least one of the caches of the user devices **101-1** to **101-N**, and checksums of the original versions of those files stored in the storage **212**. Determination if the cache contains the requested data is performed by comparison of those checksums.

If the data cannot be found on the cache in step **404**, or the data on the cache has a modification time which is different from the modification time of the corresponding data on storage **212** (step **405**), or the checksums are different; then OS **214** retrieves the data from storage **212** (step **406**). In step **408**, the retrieved data is then written into the cache, so that subsequent data read operations are performed using the cache. This also has the advantage of reducing the power

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consumption of the device where device interoperability system **200** is installed, as data does not have to be transmitted from this device to user device **101-1** via connection **201-1**. In step **409**, the cache service database is also updated.

If, in step **404** the data is found on the cache, and the data on the cache matches the corresponding data on storage **212** (step **405**); then in step **407** the data is read from the cache.

In a further embodiment, if the request type is determined to be a write operation in step **401**, then in step **402** OS **214** performs a data write operation. In one embodiment, this data write operation is performed in write-through mode. Then, following from the OS **214** writing the data to storage **212** via connection **201-1** in step **402**, OS **214** also writes data to the user device **101-1** cache in step **408**. In step **409**, the cache service database is also updated.

In another embodiment, one or more additional checks are performed to determine whether the data should be written to the cache. FIG. **4B** illustrates an example of an embodiment. Steps **4B-01** to **4B-07** are similar to steps **401-407** in FIG. **4A**. In step **4B-08**, additional checks are used to determine if the data is suitable for caching. Examples of the factors which are examined to determine if the data is suitable for caching include:

- Maximum capacity of the cache,
- Utilization of the cache capacity,
- Size of data item,
- Usage frequency of data item,
- Time expiration of data item,
- Currently running applications,
- Previously collected data usage patterns, and
- Device type of user device **101-1**.

If the data is determined to be suitable for caching in step **4B-08**, then in step **4B-10** the data is written to the cache and in step **4B-11** the cache service database is updated.

In one embodiment, the OS **214** performs additional cache servicing functions, for example:

- cache defragmentation, or
- deletion of less cache-suitable data to free up space.

Then, the above described factors used in step **4B-08** are used to optimize the performance of these additional cache servicing functions as well.

In a further embodiment, if the data is determined to not be suitable for caching in step **4B-08**, then in step **4B-09** an additional check to determine the necessity of updating of the cache service database is performed. For example, if the data is determined not to reside in any cache of any user device, then it is unnecessary to update the cache service database.

In one embodiment, when user device **101-1** runs OS **214**, data is prefetched from storage **212** and used to update the user device **101-1** cache. That is, data is fetched from storage **212** and transmitted to the user device **101-1** cache in readiness for future use.

FIG. **4C** shows an example embodiment of prefetching. In step **4C-01**, data stored in storage **212** is compared by the OS **214** to the data stored in the user device **101-1** cache. The OS **214** performs the data comparison by comparing the information from the cache service database corresponding to user device **101-1**, to the information stored in file system of the storage **212**.

If the data stored in the connected cache is determined not to match the data stored in storage **212** in step **4C-02**, then in step **4C-03** the OS **214** determines which of the one or more portions of data stored in storage **212** are different compared to the data on the user device **101-1** cache.

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In a further embodiment, in step **4C-04**, OS **214** selectively prefetches one or more portions of data stored in storage **212** which are different from the data stored in the cache of user device **101-1**.

The selection and prioritization of data depends on several factors:

- Connection of the device where device interoperability system **200** is installed to a power source,
- Charge level of battery **211**,
- Total capacity of battery **211**,
- Current utilization of connection **201-1**,
- Current user activity,
- Current hardware utilization of user device **101-1**
- Maximum capacity of the connected cache,
- Utilization of the cache capacity,
- Size of data portion,
- Usage frequency of data item,
- Time expiration of data item,
- Currently running applications,
- Previously collected data usage patterns, and
- Device type of user device **101-1**.

Then in step **4C-05**, the cache service database is updated accordingly based on the data stored in the user device **101-1** cache.

In one embodiment, security measures are used so as to reduce the risk of a malicious party gaining access to device interoperability system **200**. For example, in one embodiment access to device interoperability system **200** is secured using biometric measures such as fingerprints scanning or facial recognition.

In one embodiment, the OS **214** is able to pause its operation if the connection **201-1** is lost, and resume operation immediately when the connection is reestablished.

In one embodiment, OS **214** includes one or more kernels corresponding to one or more architectures. For example, OS **214** includes kernels for the x86 and ARM architectures. Then depending on the architecture of the connected user device, the appropriate kernel is used automatically. This behavior is completely transparent for the user.

In one embodiment, a graphical user interface (GUI) is generated on user device **101-1** to enable the user to interact and interface with user device **101-1** including OS **214**. In one embodiment, the OS **214** automatically optimizes and adapts the GUI according to the following factors:

- physical form-factor of the user device **101-1**. For example, what type of device is user device **101-1**? Is it a laptop, tablet, TV set, game console or integrated in-car system?
- number and size of screens associated with the user device **101-1**;
- screen resolution; and
- input methods. For example, is the input device a keyboard and mouse, touchscreen, infrared remote control or gamepad?

Examples of GUI optimizations and adaptations include:

- adjusting the size and placement of GUI control elements such as buttons and checkboxes;
- adjusting the size and placement of windows;
- enabling or disabling specific text input methods such as on-screen keyboard or voice text input;
- enabling or disabling GUI parts for device-specific features such as controls for in-car air conditioning system.

In one embodiment, OS **214** is only able to work on one connected user device at a time. An example is when OS **214** is running on user device **101-1**. Then, to work on a different user device such as user device **101-2** after establishing

connection **201-2**, in one embodiment OS **214** must be shut down on user device **101-1**, then booted on user device **101-2**. In another embodiment, OS **214** operation on user device **101-1** is first paused. Then OS **214** is either booted or, if it was previously paused, resumed on user device **101-2**.

In another embodiment, OS **214** is able to work with a plurality of user devices such as, for example, user devices **101-1**, **101-2** and **101-3**. In order to enable this, in an embodiment communications module **213** is able to establish and simultaneously maintain connections **201-1**, **201-2** and **201-3** with user devices **101-1**, **101-2** and **101-3** respectively. Then, user devices **101-1**, **101-2** and **101-3** are simultaneously connected to the device interoperability system **200** and each one of these user devices runs its instance of OS **214** in parallel with each other. In one embodiment, the transmission capacity of communications module **213** is balanced between connections **201-1**, **201-2** and **201-3** according to the current utilization of each connection.

In a further embodiment, different instances of OS **214** which are simultaneously running on user devices **101-1**, **101-2** and **101-3** use the distributed lock management approach to coordinate concurrent access to the storage **212**. For example, the lock managers of all three instances of OS **214** which are running on the user devices **101-1**, **101-2** and **101-3**, use the same lock database which is distributed among these instances by means of device interoperability system **200** and connections **201-1**, **201-2** and **201-3**.

In one embodiment, the interoperability system **200** is used by the different instances of OS **214** which are simultaneously running on different user devices to exchange some details about their current status. This, for example, includes:

- number and device types of simultaneously working user devices,
- status of important OS service functions, for example, an OS update process,
- current user activity, and
- currently running applications.

This data is used by every running instance of OS **214** to coordinate and optimize its service functions. For example, when three instances of OS **214** are running on user devices **101-1**, **101-2** and **101-3**, coordination is performed to ensure that the OS update process is not running simultaneously on all three devices. In a further embodiment, this data is used to prioritize the balancing of the transmission capacity of communications module **213** between established connections **201-1** to **201-3**. For example, a higher priority is given to that user device which user **100** currently uses.

In yet another embodiment, the OS **214** supports migration of running applications between OS instances running on different user devices. With reference to the example above, OS **214** supports the ability to move a currently running application from user device **101-2** to user device **101-3**. After the migration, the application continues to have access to any previously opened files. In a further embodiment, the data described previously is used to present more details to a user if the user opts to migrate applications and the connections **201-2** and **201-3** are used to facilitate the migration process.

The use of device interoperability system **200** offers several other advantages. In some embodiments, device interoperability system **200** is used in conjunction with cloud-based data synchronization capabilities. For example, if cloud-based services are used for synchronization of data between different user devices, device interoperability system **200** reduces the necessity for user devices to connect to the cloud to perform data synchronization. Instead, the user

devices use data from storage **212**. This reduces the utilization of the cloud connection with the user devices. Furthermore, in some embodiments, the device interoperability system **200** ensures data availability in case cloud connectivity is lost or not available, as the user devices can retrieve data from storage **212**. In some embodiments, intelligent approaches to ensuring availability of data which is most likely to be relevant to a user are employed. These include, for example, approaches based on:

Temporal locality: Data which was most recently used on a user device is stored on storage **212** as it is likely that the user device will use this data again in the near future.

Spatial locality: Data sets which occupy memory locations close to recently used data are stored on storage **212** as it is likely that the user device will use these data sets in the near future.

Branch locality: In cases where there are multiple possible outcomes from conditional branching instructions, then data related to each of these outcomes are stored on storage **212** as it is likely that the user device will use this data.

Probabilistic analysis of user interactions with user devices: For example, if there is a high probability that a user will use one or more data sets either in conjunction with or after using a particular program, then these data sets are stored on storage **212**.

In some embodiments, some user data is stored on storage **212** but not within the cloud. This capability is useful if, for example, users want to keep control of sensitive data.

The use of device interoperability system **200** also offers advantages for IoT-enabled user devices. Similar to as with cloud-based services, device interoperability system **200** reduces the need to connect to the cloud to perform data synchronization. Furthermore it reduces the difficulty of having to maintain separate cloud credentials and device settings for user devices.

Although the algorithms described above including those with reference to the foregoing flow charts have been described separately, it should be understood that any two or more of the algorithms disclosed herein can be combined in any combination. Any of the methods, algorithms, implementations, or procedures described herein can include machine-readable instructions for execution by: (a) a processor, (b) a controller, and/or (c) any other suitable processing device. Any algorithm, software, or method disclosed herein can be embodied in software stored on a non-transitory tangible medium such as, for example, a flash memory, a CD-ROM, a floppy disk, a hard drive, a digital versatile disk (DVD), or other memory devices, but persons of ordinary skill in the art will readily appreciate that the entire algorithm and/or parts thereof could alternatively be executed by a device other than a controller and/or embodied in firmware or dedicated hardware in a well known manner (e.g., it may be implemented by an application specific integrated circuit (ASIC), a programmable logic device (PLD), a field programmable logic device (FPLD), discrete logic, etc.). Also, some or all of the machine-readable instructions represented in any flowchart depicted herein can be implemented manually as opposed to automatically by a controller, processor, or similar computing device or machine. Further, although specific algorithms are described with reference to flowcharts depicted herein, persons of ordinary skill in the art will readily appreciate that many other methods of implementing the example machine readable instructions may alternatively be used. For example, the order of execution of the blocks may be

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changed, and/or some of the blocks described may be changed, eliminated, or combined.

It should be noted that the algorithms illustrated and discussed herein as having various modules which perform particular functions and interact with one another. It should be understood that these modules are merely segregated based on their function for the sake of description and represent computer hardware and/or executable software code which is stored on a computer-readable medium for execution on appropriate computing hardware. The various functions of the different modules and units can be combined or segregated as hardware and/or software stored on a non-transitory computer-readable medium as above as modules in any manner, and can be used separately or in combination.

While particular implementations and applications of the present disclosure have been illustrated and described, it is to be understood that the present disclosure is not limited to the precise construction and compositions disclosed herein and that various modifications, changes, and variations can be apparent from the foregoing descriptions without departing from the spirit and scope of an invention as defined in the appended claims.

What is claimed is:

1. A device interoperability system for one or more user devices associated with a user, wherein said one or more user devices comprises a first user device  
said device interoperability system comprising  
a communications module,  
wherein a first connection is established between said first user device and said communications module;  
storage coupled to said communications module,  
wherein said storage stores  
an operating system,  
one or more programs, and  
data associated with the user,  
further wherein said operating system is booted at said first user device via said first connection,  
said operating system runs on said first user device, and  
the operating system uses one or more processing capabilities of  
the first user device for operation;  
one or more processors to support said device interoperability system;  
a battery to power said device interoperability system;  
a charging module to charge said battery; and  
said device interoperability system is installed on a gadget.
2. The system of claim 1, wherein said first user device operates in either an interoperability system mode or a stand-alone mode.
3. The system of claim 1, wherein said one or more user devices further comprises a set of user devices comprising one or more user devices different from said first user device;  
a set of connections comprising one or more connections different from said first connection are established between said set of user devices and said communications module; and  
said operating system is booted by said set of user devices via said set of connections.
4. The system of claim 3, wherein said communications module simultaneously maintains said set of connections with said set of user devices; and

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each of a plurality of instances of said operating system runs on each of said set of user devices and said first user device.

5. The system of claim 1, wherein said first connection is based on one of  
a direct wireless connection,  
a direct wired connection, or  
docking.
6. The system of claim 1, wherein said first user device comprises a first user device storage; and  
said first user device storage is used for at least one of  
swapping, backing up data or caching.
7. The system of claim 1, wherein said operating system includes one or more kernels corresponding to one or more architectures.
8. The system of claim 1, further wherein said one or more user devices comprises a second user device;  
said operating system stores  
a first configuration set corresponding to the first user device, and  
a second configuration set corresponding to the second user device; and  
said operating system uses either said first configuration set or said second configuration set depending on whether said operating system is booted on said first user device or said second user device.
9. A device interoperability system for one or more user devices associated with a user, wherein said one or more user devices comprises a first user device and a second user device;  
said device interoperability system comprising  
a communications module, wherein a first connection is established between said first user device and said communications module,  
storage coupled to said communications module,  
wherein said storage stores  
an operating system,  
one or more programs, and  
data associated with the user,  
further wherein said operating system is booted at said first user device via said first connection, said operating system runs on said first user device, and the operating system uses one or more processing capabilities of the first user device for operation; and  
said device interoperability system is installed via integration into said second user device.
10. The system of claim 9, wherein  
said second user device has an integrated controller and an added external wireless adapter; and  
said communications module comprises the integrated controller and the added external wireless adapter.
11. The system of claim 9, wherein said first user device operates in either an interoperability system mode or a stand-alone mode.
12. The system of claim 9, wherein said one or more user devices further comprises a set of user devices comprising one or more user devices different from said first user device and said second user device;  
a set of connections comprising one or more connections different from said first connection are established between said set of user devices and said communications module; and  
said operating system is booted by said set of user devices via said set of connections.

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- 13. The system of claim 12, wherein said communications module simultaneously maintains said set of connections with said set of user devices; and  
 each of a plurality of instances of said operating system runs on each of said set of user devices and said first user device. 5
- 14. The system of claim 9, wherein said first connection is based on one of  
 a direct wireless connection,  
 a direct wired connection, or  
 docking. 10
- 15. The system of claim 9, wherein said first user device comprises a first user device storage; and  
 said first user device storage is used for at least one of swapping, backing up data or caching. 15
- 16. The system of claim 9, wherein said operating system includes one or more kernels corresponding to one or more architectures.
- 17. The system of claim 9, wherein a first and a second instance of said operating system runs on said first and second user device respectively. 20
- 18. The system of claim 9, further wherein said operating system stores  
 a first configuration set corresponding to the first user device, and  
 a second configuration set corresponding to the second user device; and  
 said operating system uses either said first configuration set or said second configuration set depending on whether said operating system is booted on said first user device or said second user device. 25 30
- 19. The system of claim 9, further comprising changing firmware of said first user device.
- 20. A method for device interoperability for one or more user devices associated with a user,  
 said one or more user devices comprising a first user device and a second user device;  
 said method comprising  
 establishing a first connection between said first user device and a communications module within a device interoperability system implemented using an installed application on said second user device;  
 storing, using a storage within the device interoperability system,  
 an operating system,  
 one or more programs, and  
 data associated with the user; and  
 booting said operating system at said first user device via said first connection,  
 further wherein  
 said operating system runs on said first user device, and  
 the operating system uses one or more processing capabilities of the first user device for operation. 35 40 45 50

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- 21. The method of claim 20, wherein  
 said second user device has an integrated controller and an added external wireless adapter; and  
 said communications module comprises the integrated controller and the added external wireless adapter.
- 22. The method of claim 20, wherein said first user device operates in either an interoperability system mode or a stand-alone mode.
- 23. The method of claim 20, wherein said one or more user devices further comprises a set of user devices comprising one or more user devices different from said first user device and said second user device;  
 a set of connections comprising one or more connections different from said first connection are established between said set of user devices and said communications module; and  
 said operating system is booted by said set of user devices via said set of connections.
- 24. The method of claim 23, wherein said communications module simultaneously maintains said set of connections with said set of user devices; and  
 each of a plurality of instances of said operating system runs on each of said set of user devices and said first user device.
- 25. The method of claim 20, wherein said first connection is based on one of  
 a direct wireless connection,  
 a direct wired connection, or  
 docking.
- 26. The method of claim 20, wherein said first user device comprises a first user device storage; and  
 said first user device storage is used for at least one of swapping, backing up data or caching.
- 27. The method of claim 20, wherein said operating system includes one or more kernels corresponding to one or more architectures.
- 28. The method of claim 20, wherein a first and a second instance of said operating system runs on said first and second user device respectively.
- 29. The method of claim 20, further comprising  
 storing, by said operating system, a first configuration set corresponding to the first user device, and a second configuration set corresponding to the second user device; and  
 said operating system uses either said first configuration set or said second configuration set depending on whether said first user device or said second user device is used to boot said operating system.
- 30. The method of claim 20, further comprising changing firmware of said first user device.

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