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AUDIO ROUTING BETWEEN MULTIPLE DEVICES BASED ON PRIORITIZED ACTIVITIES

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ABSTRACT

A system including two or more computing devices (e.g., a smartphone, a laptop computer, a tablet computer, a portable gaming device, etc.) and an audio output device (e.g., speakers, headphones, earphones, earbuds, etc.) may implement an audio switching module enabling the audio output device to intelligently switch audio routing based on prioritized activities. For instance, the audio output device may initially reproduce a soundfield based on an audio signal output during a first activity occurring at a first computing device (e.g., video playback via execution of a video playback application). A second activity may concurrently occur at a second computing device (e.g., receipt of a phone call via background execution of a phone call application). Responsive to the audio switching module determining that the second activity is of a higher priority than the first activity, the audio output device may automatically switch (e.g., without any user input) the audio routing such that the audio signal from the second computing device (instead of the audio signal from the first computing device) is routed to the audio output device for output.

DESCRIPTION

FIG. 1 below is a conceptual diagram illustrating a system 10 including a number of different computing devices 100A-100N (collectively, “computing devices 100) and an audio

output device 102. As shown in FIG. 1, computing devices 100 may communicate with audio output device 102 via network 104.

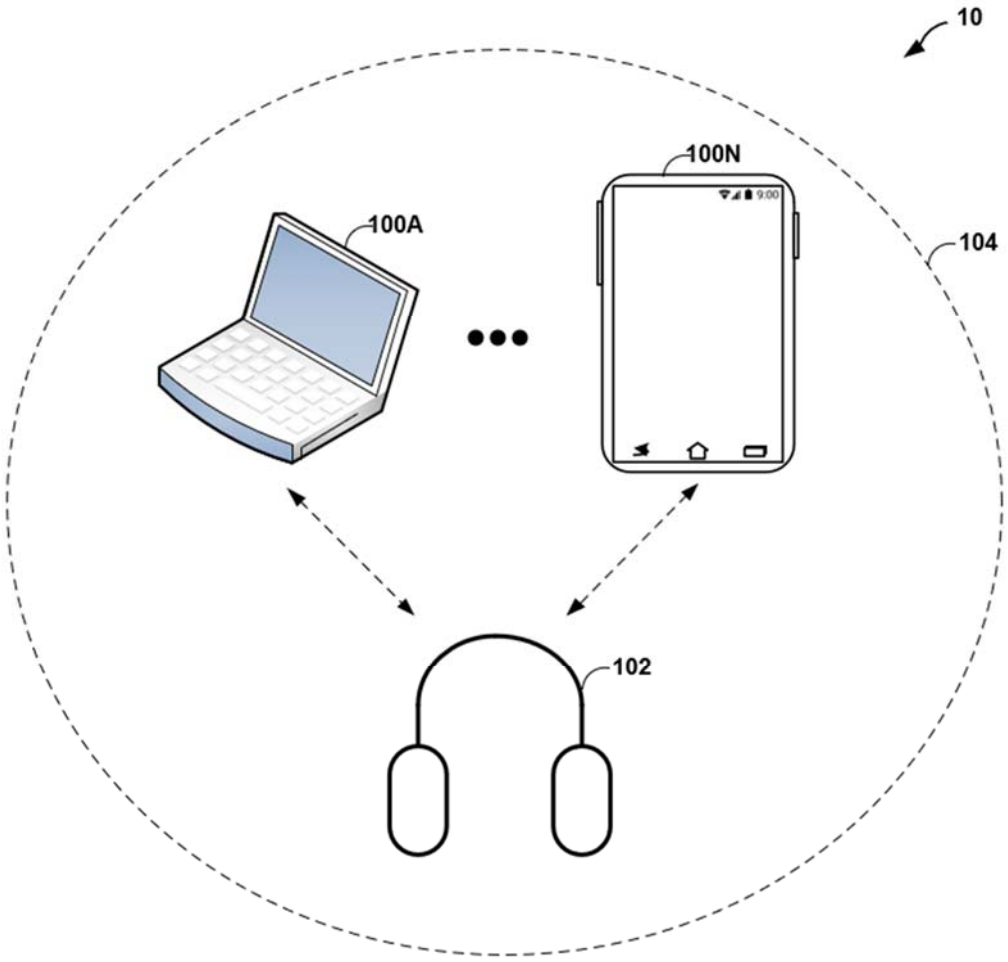

FIG. 1

Computing devices 100 may include any mobile or non-mobile computing device. For example, computing devices 100 may include a mobile phone, a smartphone, a personal digital assistant (PDA), a desktop computer, a laptop computer, a tablet computer, a portable gaming device, a portable media player, an e-book reader, a watch (including a so-called “smartwatch”), an add-on device (such as a casting device), smart glasses, a gaming controller, mixed-reality (XR) headset (which includes virtual reality (VR) headsets, augmented reality (AR) headsets, and the like), smart speakers, smart televisions, etc.

Audio output device 102 may include any device that reproduces a soundfield based on one or more audio signals. For example, audio output device 102 may include speakers (including devices in which speakers are integrated, such as a smartphone, a laptop computer, smart glasses, XR headsets, etc.), headphones, earphones, earbuds, etc. In general, audio output device 102 may be configured to connect to a variety of source devices, including computing devices 100. For instance, audio output device 102 may connect to an audio amplifier, a radio, a CD player, a portable media player, mobile phone, a smartphone, a video game console, a desktop computer, a laptop computer, a tablet computer, or any other type of computing device listed above, etc.

As noted above, computing devices 100 may communicate with audio output device 102 via network 104. For instance, computing devices 100 may wirelessly transmit audio signals via network 104 to audio output device 102, whereupon audio output device 102 reproduces a soundfield based on the audio signals. In some examples, network 104 may include a personal area network (PAN), such as a Bluetooth® network (including various versions or, in other words, profiles of Bluetooth®, such as Bluetooth Low Energy (BLE)). Additionally or alternatively, network 104 may include a local-area network (LAN), a wide-area network (WAN) (e.g., the Internet), an enterprise network, a cellular network, a telephone network, a Metropolitan area network (e.g., WiFi®, WAN, worldwide interoperability for microwave access (WiMAX), etc.), an ultrawideband network, one or more other types of networks, or a combination of two or more different types of networks (e.g., a combination of a PAN and the Internet).

A user who owns computing devices 100 may connect audio output device 102 to computing devices 100 (e.g., via a process referred to as pairing in the context of Bluetooth®) to

enable audio output device 102 to reproduce a soundfield based on audio signals from computing devices 100. However, in general, audio output device 102 may reproduce a soundfield based on the audio signal from only one of computing devices 100 at any given time. This may be true even if audio output device 102 can simultaneously connect with two or more of computing devices 100. As a result, a user who wishes to switch the audio signal being routed to audio output device 102 for output may need to provide user inputs (e.g., to change settings of computing devices 100 and/or audio output device 102), which can be time-consuming and inconvenient.

For example, audio output device 102 may be concurrently connected (e.g., via network 104, which may be BLE) to computing device 100A (shown as a laptop in the example of FIG. 1) and computing device 100N (shown as a smartphone in the example of FIG. 1). A user may initially be using audio output device 102 to reproduce a soundfield based on an audio signal output during a first activity occurring at computing device 100A (e.g., video playback via execution of a video playback application). A second activity may concurrently occur at computing device 100N (e.g., receipt of a phone call via background execution of a phone call application). In turn, the user may need to provide user inputs to manually switch the audio signal being routed to audio output device 102 from computing device 100A to computing device 100N. This interaction can be awkward and annoying, especially if performed frequently.

In accordance with techniques of this disclosure, system 10 may implement an audio switching module enabling audio output device 102 to intelligently switch audio routing based on prioritized activities. For instance, audio output device 102 may reproduce a soundfield based on an audio signal output during a first activity occurring at computing device 100A (e.g., video playback via execution of a video playback application). A second activity may concurrently

occur at computing device 100N (e.g., receipt of a phone call via background execution of a phone call application). Responsive to system 10 (e.g., at least one of computing device 100A or computing device 100N) determining that the second activity is of a higher priority than the first activity, audio output device 102 may automatically switch (e.g., without any user input) the audio routing such that the audio signal from computing device 100N (instead of the audio signal from computing device 100A) is routed to audio output device 102 for output.

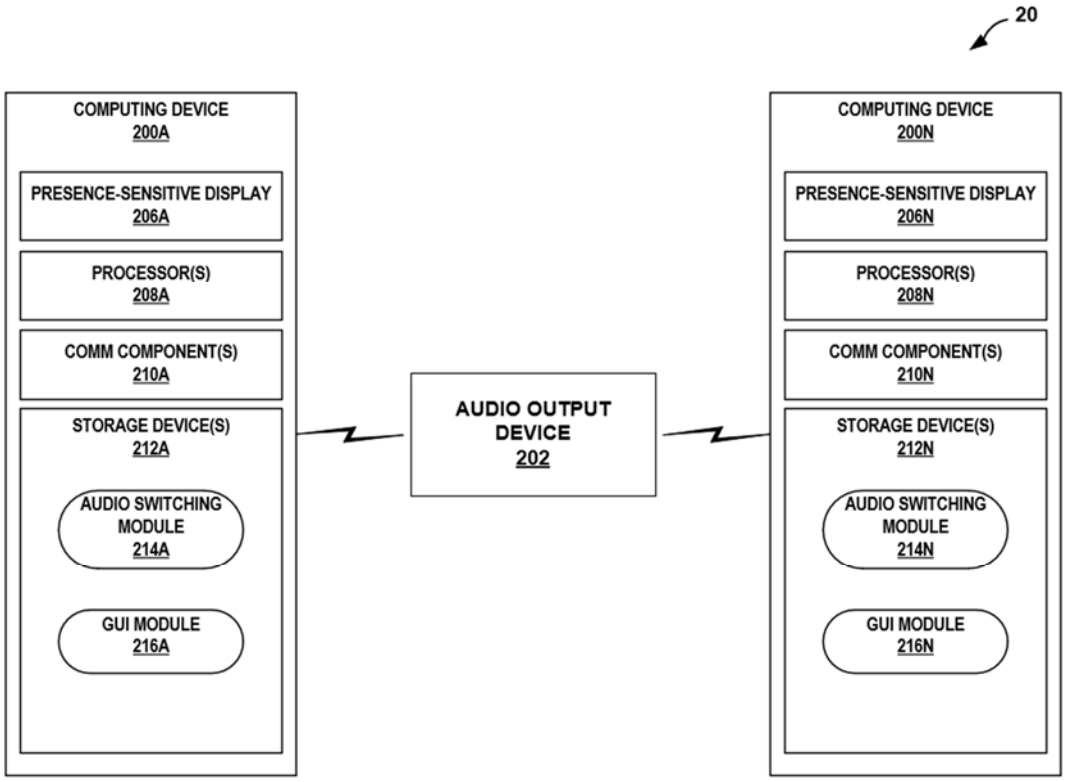

FIG. 2

FIG. 2 above is a conceptual diagram illustrating a system 20 including a computing device 200A, computing device 200N, and an audio output device 202. System 20 is described as an example of system 10 illustrated in FIG. 1. System 20 may include additional computing devices but only two are shown in FIG. 2 and described herein for ease of explanation. In the

example of FIG. 2, computing device 200A and computing device 200N are substantially similar such that the description of one may apply equally to the other.

As shown in FIG. 2, computing device 200A includes a presence-sensitive display 206A, one or more processors 208A, one or more communication components 210A ("COMM components 210A"), and one or more storage devices 212A. Storage devices 212A may include an audio switching module 214A and a graphical user interface module 216A ("GUI module 216A").

Presence-sensitive display 206A of computing device 200A may be a presence-sensitive display that functions as an input device and as an output device. For example, presence-sensitive display 206A may function as an input device using a presence-sensitive input component, such as a resistive touchscreen, a surface acoustic wave touchscreen, a capacitive touchscreen, a projective capacitance touchscreen, a pressure sensitive screen, an acoustic pulse recognition touchscreen, or another presence-sensitive display technology. Additionally, presence-sensitive display 206A may function as an output (e.g., display) device using any of one or more display components, such as a liquid crystal display (LCD), dot matrix display, light emitting diode (LED) display, microLED display, organic light-emitting diode (OLED) display, e-ink, active-matrix organic light-emitting diode (AMOLED) display, or similar monochrome or color display capable of outputting visible information to a user of computing device 200A.

Processors 208A may implement functionality and/or execute instructions associated with computing device 200A. Examples of processors 208A may include one or more of an application specific integrated circuit (ASIC), a field programmable gate array (FPGA), an application processor, a display controller, an auxiliary processor, a central processing unit

(CPU), a graphics processing unit (GPU), one or more sensor hubs, and any other hardware configure to function as a processor, a processing unit, or a processing device.

Computing device 200A may include COMM components 210A. COMM components 210A may receive and transmit various types of information via a network (e.g., network 104). Examples of COMM components 210A include a network interface card (e.g., an Ethernet card), an optical transceiver, a radio frequency transceiver, a GPS receiver, or any other type of device that can send and/or receive information. Other examples of COMM components 210A may include short wave radios (e.g., near field communication (NFC), Bluetooth® (including BLE), GPS, 3G, 4G, 5G, WiFi®, radios found in mobile devices as well as Universal Serial Bus (USB) controllers, etc.

Storage devices 212A may include one or more computer-readable storage media. For example, storage devices 212A may be configured for long-term, as well as short-term storage of information, such as instructions, data, or other information used by computing device 200A. In some examples, storage devices 212A may include non-volatile storage elements. Examples of such non-volatile storage elements include magnetic hard discs, optical discs, solid state discs, and/or the like. In other examples, in place of, or in addition to the non-volatile storage elements, storage devices 212A may include one or more so-called “temporary” memory devices, meaning that a primary purpose of these devices may not be long-term data storage. For example, the devices may comprise volatile memory devices, meaning that the devices may not maintain stored contents when the devices are not receiving power. Examples of volatile memory devices include random-access memories (RAM), dynamic random-access memories (DRAM), static random-access memories (SRAM), etc.

In some examples, computing devices connecting to audio output device 202 may each include an audio switching module. For example, as shown in FIG. 2, computing device 200A and computing device 200N include audio switching module 214A and audio switching module 214N, respectively. In addition to facilitating audio switching in accordance with techniques of this disclosure, the audio switching modules may cause a computing device (e.g., computing device 200N) to connect (if not already connected) to audio output device 202 in response to system 20 switching to the audio signal from that computing device such that simultaneously maintaining multiple connections between the computing devices and audio output device 202 is not required. In these examples, system 20 may implement audio switching in accordance with table 1 below.

Table 1

SWITCHING RULES WHEN EACH COMPUTING DEVICE INCLUDES AUDIO SWITCHING MODULE		
Activity on First Device (e.g., Computing Device 200A)	**Higher Priority Activity on Second Device (e.g., Computing Device 200N) that will Cause Switching**	**What Happens to First Device (e.g., Computing Device 200A) upon Switch**
Ongoing phone or video call	N/A	N/A
Watching a video or listening to music	• Incoming phone call or user-initiated phone call • Assistant response • Alarm is triggered • Video, music, or other media is initiated by user	Media is paused; audio routing for audio output device is switched to second device (e.g., computing device 200N)
Playing a game	• Incoming phone call or user-initiated phone call • Assistant response • Alarm is triggered • Video, music, or other media • Game is initiated by user	audio routing for audio output device is switched to second device (e.g., computing device 200N)

Audio output device is connected with no active audio or audio output device is disconnected from nearby computing devices	• Incoming phone call or user-initiated phone call • Assistant response • Alarm is triggered • Video, music, or other media • Game is initiated by user	audio routing for audio output device is switched to second device (e.g., computing device 200N)

As indicated by table 1, an ongoing phone or video call may be considered the highest priority activity such that no activity occurring at another computing device can cause audio routing to switch. Accordingly, if a user is using computing device 200A for an ongoing video call, system 20 (e.g., via audio switching modules 214A and/or 214N) may not switch the audio signal being routed to audio output device 202 from computing device 200A to computing device 200N irrespective of the activity occurring at computing device 200N.

However, if a lower priority activity is occurring at computing device 200A, system 20 may switch the audio signal being routed to audio output device 202 from computing device 200A to computing device 200N in response to a higher priority activity occurring at computing device 200N. For example, if a user is using computing device 200A to watch a video and computing device 200N receives a phone call, system 20 may determine that the phone call is a higher priority activity than the video and switch the audio signal being routed to audio output device 202 from computing device 200A to computing device 200N.

System 20 may determine the priority of activities based on the respective applications executing at computing device 200A and computing device 200N. In some examples, audio switching module 214A may obtain information from an operating system (OS) of computing device 200A to identify a first application associated with a first activity occurring at computing device 200A. Similarly, audio switching module 214N may obtain information from an OS of

computing device 200N to identify a second application associated with a second activity occurring at computing device 200N.

Based on the application type of the first application, audio switching module 214A may determine a priority of the first activity associated with the first application. Likewise, based on the application type of the second application, audio switching module 214N may determine a priority of the second activity associated with the second application. In some examples, audio switching module 214A and audio switching module 214B may determine the priorities of the activities by querying a repository storing information mapping priority and application type.

Responsive to determining the priorities of the first activity and the second activity, audio switching module 214A and audio switching module 214B may transmit (e.g., via network 104, which may be a local network, such as BLE) the priorities to each other. Responsive to audio switching module 214A and/or audio switching module 214B determining that the priority of the second activity is higher than the priority of the first activity, system 20 may switch the audio signal being routed to audio output device 202 from computing device 200A to computing device 200N.In some examples, system 20 may transmit the priorities to each of computing devices 200 associated with the same user account. For instance, audio switching module 214A may transmit the priority of the first activity to computing devices 200B-200N, and audio switching module 214B may transmit the priority of the second activity to computing devices 200A and 200C-N. Other audio switching modules executed by other computing devices associated with the same user account may operate in a similar fashion. In this way, the techniques of this disclosure may facilitate audio routing between a potentially large number of computing devices owned by a user based on prioritized activities.

When system 20 switches the audio signal being routed to audio output device 202 from computing device 200A to computing device 200N, computing device 200A may (attempt to) automatically pause the activity occurring at computing device 200A. In some examples, computing device 200A may automatically resume the activity occurring at computing device 200A (e.g., upon cessation of the higher priority activity occurring at computing device 200N).

While system 20 is primarily described herein as switching the audio signal being routed to audio output device 202 from computing device 200A to computing device 200N, the reverse is also possible. In this respect, system 20 may switch between any of the computing devices and in any direction. Moreover, while the audio switching modules are primarily described herein as being included in the computing devices, audio output device 202 may also include an audio switching module that at least partially performs the techniques of this disclosure.

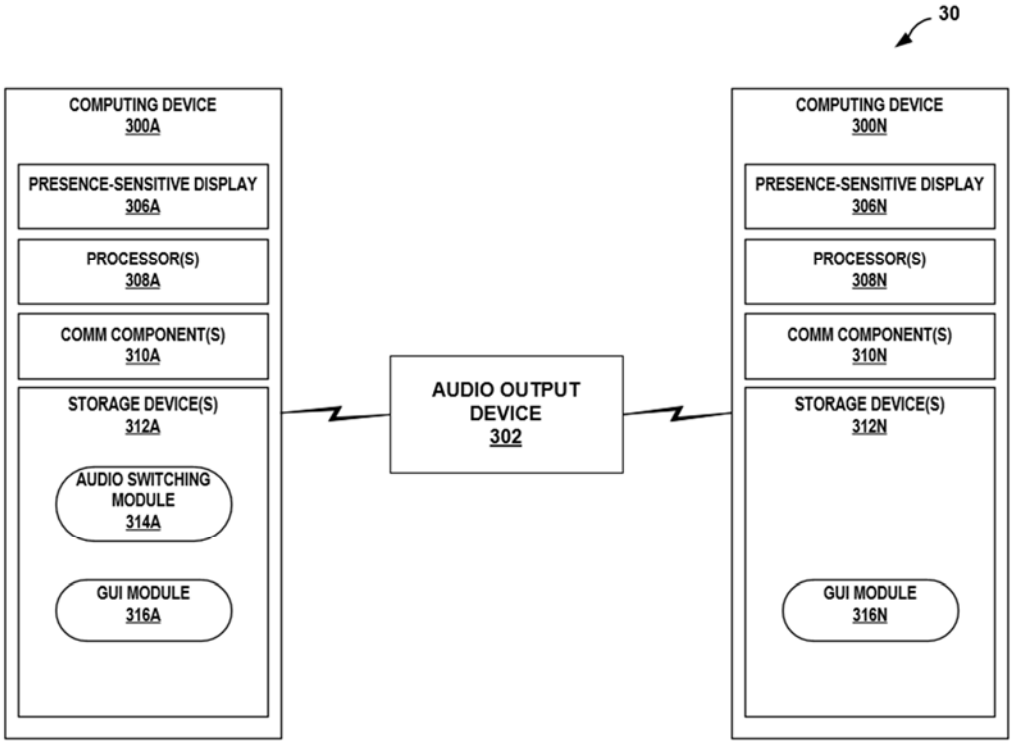

FIG. 3

FIG. 3 above is a conceptual diagram illustrating a system 30 including a computing device 300A, computing device 300N, and an audio output device 302. System 30 is substantially similar to system 20 except for any differences described herein.

In some examples, one or more of the computing devices connecting to audio output device 202 may not include an audio switching module. For example, as shown in FIG. 3, computing device 300A includes an audio switching module 314A, but computing device 300N does not include an audio switching module. Additionally, audio output device 302 may be configured to simultaneously connect to multiple devices (e.g., by using Bluetooth multipoint). In such examples, system 30 may implement audio switching in accordance with table 2 below.

Table 2

SWITCHING RULES WHEN ONE OR MORE OF COMPUTING DEVICES SIMULTANEOUSLY CONNECTED TO AUDIO OUTPUT DEVICE DO NOT INCLUDE AUDIO SWITCHING MODULE		
Activity on First Device (e.g., Computing Device 300A)	**Higher Priority Activity on Second Device (e.g., Computing Device 300N) that will Cause Switching**	**What Happens to First Device (e.g., Computing Device 300A) upon Switch**
Ongoing phone or video call	N/A	N/A
Watching a video, listening to music, or playing a game (e.g., an Advanced Audio Distribution Profile (A2DP) activity)	• Incoming phone call (e.g., hands-free profile (HFP)) or user-initiated phone call	• Active audio is switched to second device so the first device is no longer a source of active audio
Watching a video, listening to music, or playing a game (e.g., A2DP activity)	• Any A2DP activity	• Media on first continues and active audio is not switched to second device • Video/Music on second device pauses • Game audio should not be heard
Audio output device is connected to both devices with no active audio	• Any HFP or A2DP activity (including notifications)	• Active audio is switched to second device so the first device is no longer a source of active audio

As indicated by table 2, an ongoing phone or video call may still be considered the highest priority activity such that no activity occurring at another computing device can cause audio routing to switch. However, if a lower priority activity (e.g., watching a video) is occurring at computing device 300A, system 30 may switch the audio signal being routed to audio output device 302 from computing device 300A to computing device 300N in response to a higher priority activity (e.g., an A2DP activity) occurring at computing device 300N.

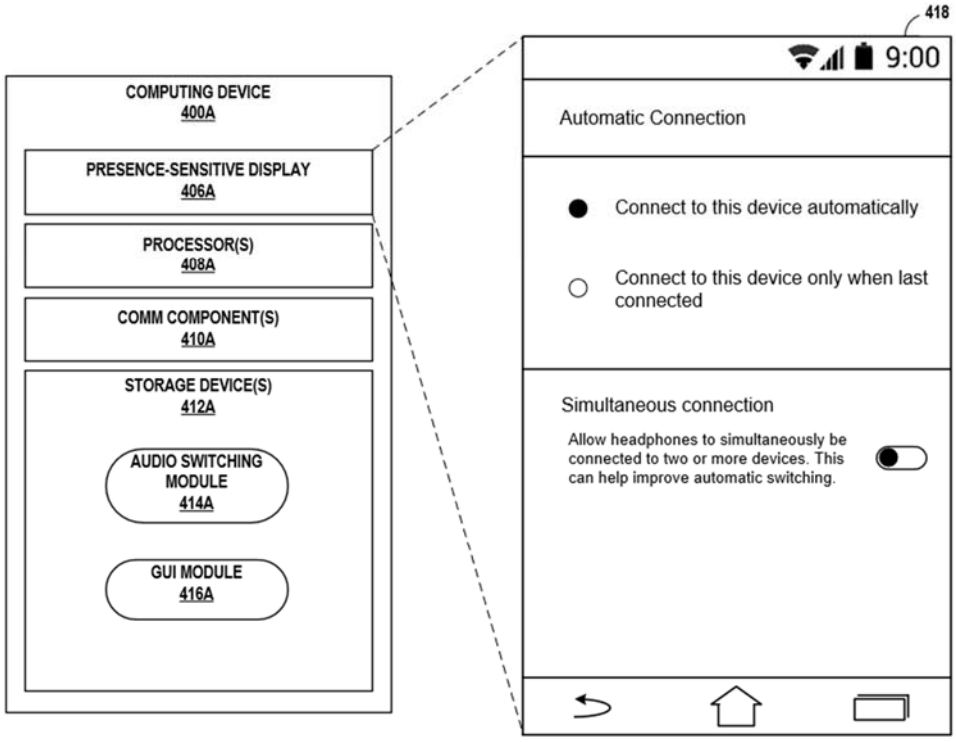

FIG. 4

FIG. 4 above is a conceptual diagram illustrating a computing device 400A. Computing device 400A may be substantially similar to computing device 200A. As shown in FIG. 4, computing device 400A includes a GUI module 416A. GUI module 416A may display a GUI 418 of settings for an audio switching module 414A. Example settings may include enabling automatic connection, simultaneous connection, etc. For instance, a user may enable an audio output device (e.g., audio output device 202) to connect to computing device 400A automatically or only when last connected. Furthermore, the user may enable simultaneous connection (e.g., allowing audio output device 202 to simultaneously be connected to two or more computing devices), which may improve automatic switching.

It is noted that the techniques of this disclosure may be combined with any other suitable technique or combination of techniques. As one example, the techniques of this disclosure may

be combined with the techniques described "HUAWEI FreeBuds Pro Know-how [Vol. 4] Connecting with Two Devices Simultaneously," Huawei Inc., November 23, 2020. In another example, the techniques of this disclosure may be combined with the techniques described in "Connecting the earphones to two devices simultaneously," Huawei Inc., October 26, 2021. In yet another example, the techniques of this disclosure may be combined with the techniques described in "Wireless noise canceling stereo headset WH-1000XM4," Sony, October 26, 2021. In yet another example, the techniques of this disclosure may be combined with the techniques described in "Switch your AirPods to another device," Apple, October 25, 2021. In yet another example, the techniques of this disclosure may be combined with the techniques described in "Switch AirPods between iPhone and other devices," Apple, October 25, 2021. In yet another example, the techniques of this disclosure may be combined with the techniques described in Tim Hardwick, "AirPods: How to automatically switch between devices," Macrumors, September 28, 2021. In yet another example, the techniques of this disclosure may be combined with the techniques described in PCT Patent Application Publication No. 2020/262927A1.