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(54) **MULTIPLE APPLICATION RUNTIMES IN A SPLIT-COMPUTE ARCHITECTURE**

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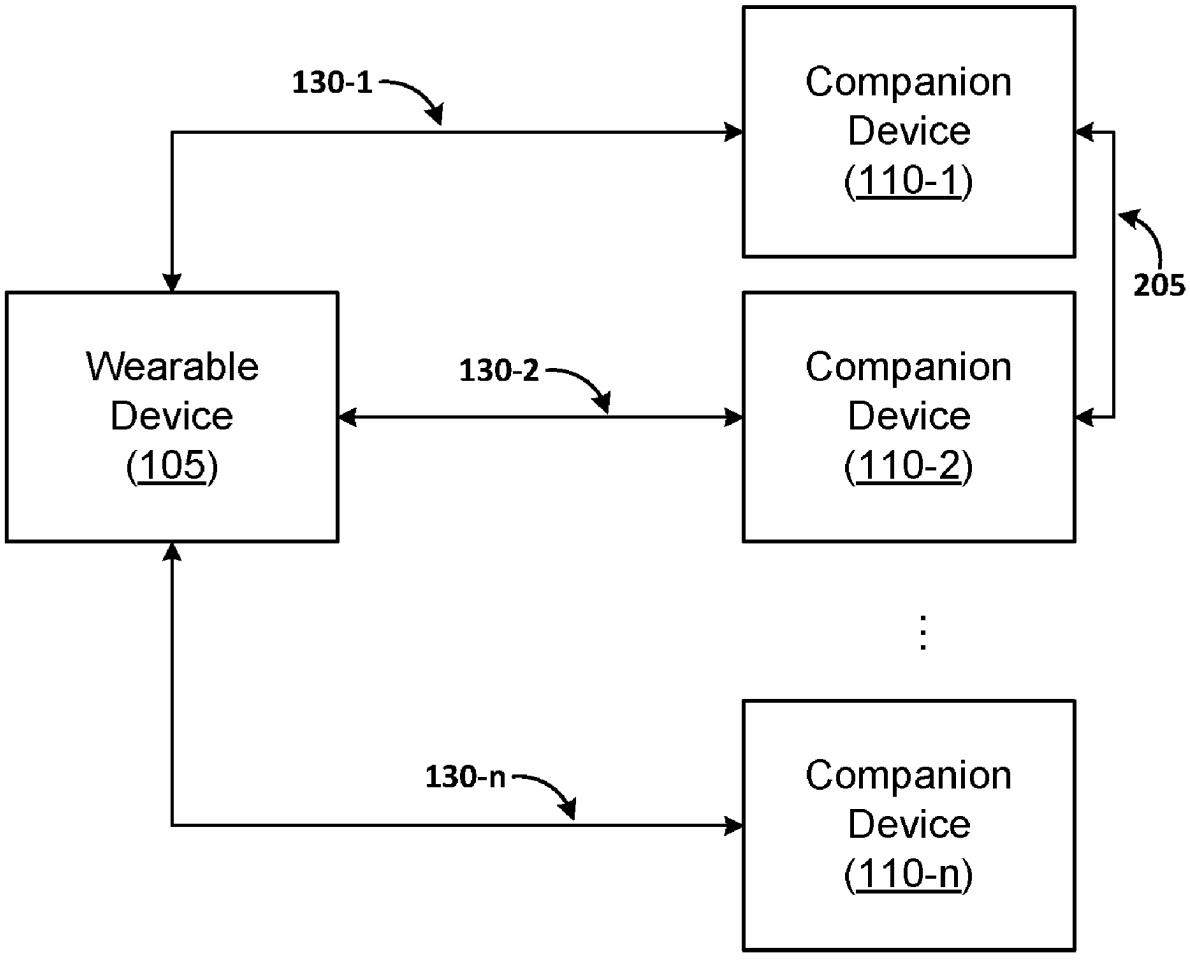
(57) **ABSTRACT**

A method including initiating a computing process on a wearable device, the computing process including a plurality of tasks, identifying a first companion device and determining that the first companion device is available to perform at least one task of the plurality of tasks, identifying a second companion device and determining that the second companion device is available to perform at least one task of the plurality of tasks, causing the first companion device to perform a first task of the plurality of tasks including communicating data generated by the wearable device to the first companion device, causing the second companion device to perform a second task of the plurality of tasks, and receiving, by the wearable device from the first companion device, a result associated with a completion of the first task and the second task.



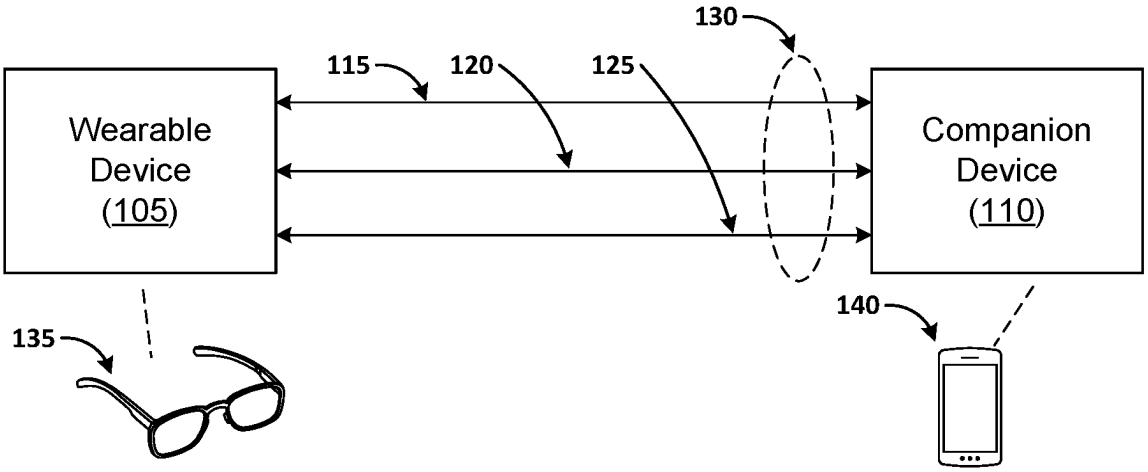

130
115
120
125
Wearable Device (105)
Companion Device (110)
135
140

FIG. 1

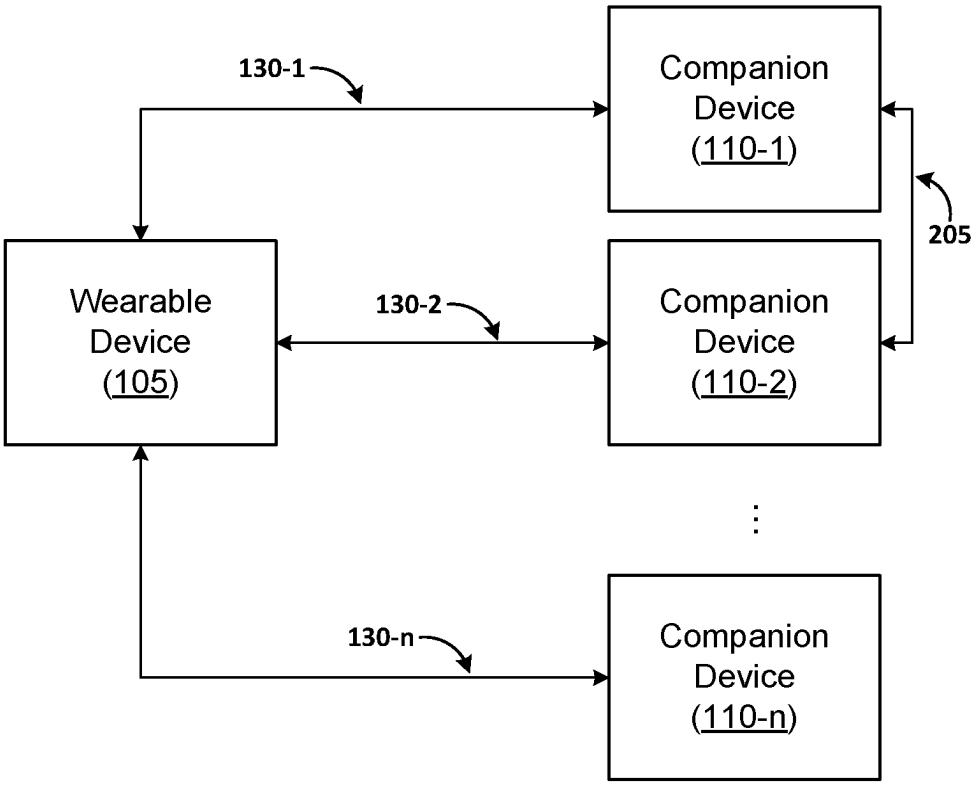

130-1
Companion Device (110-1)
205
Wearable Device (105)
130-2
Companion Device (110-2)
130-n
Companion Device (110-n)

FIG. 2

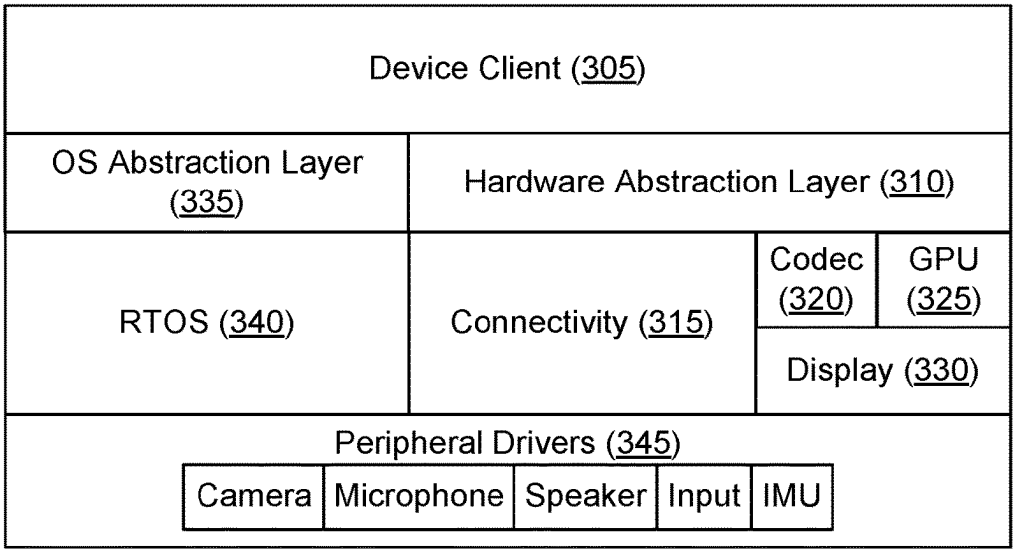

Device Client (305)
OS Abstraction Layer (335)
Hardware Abstraction Layer (310)
RTOS (340)
Connectivity (315)
Codec (320)
GPU (325)
Display (330)
Peripheral Drivers (345)
Camera
Microphone
Speaker
Input
IMU

FIG. 3

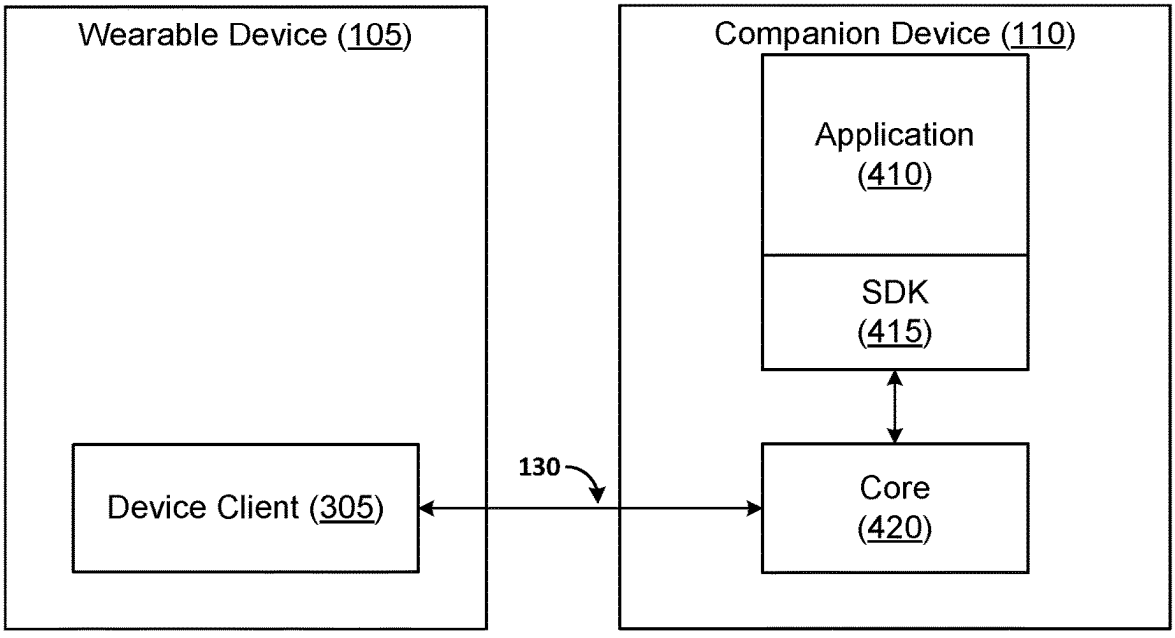

Wearable Device (105)
Companion Device (110)
Application (410)
SDK (415)
Device Client (305)
130
Core (420)

FIG. 4

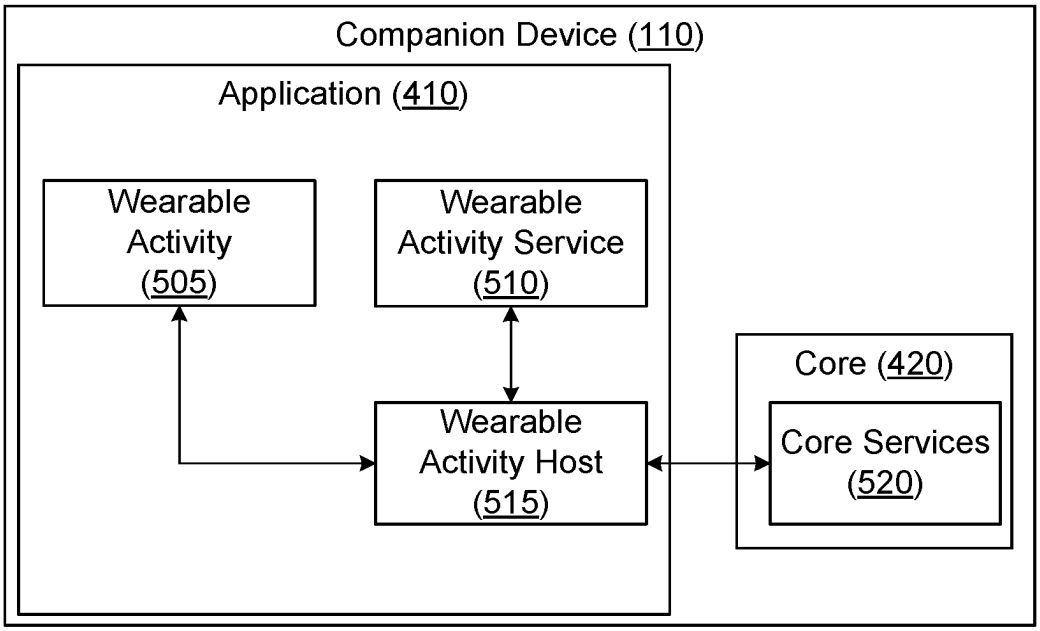

Companion Device (110)
Application (410)
Wearable Activity (505)
Wearable Activity Service (510)
Core (420)
Wearable Activity Host (515)
Core Services (520)

FIG. 5

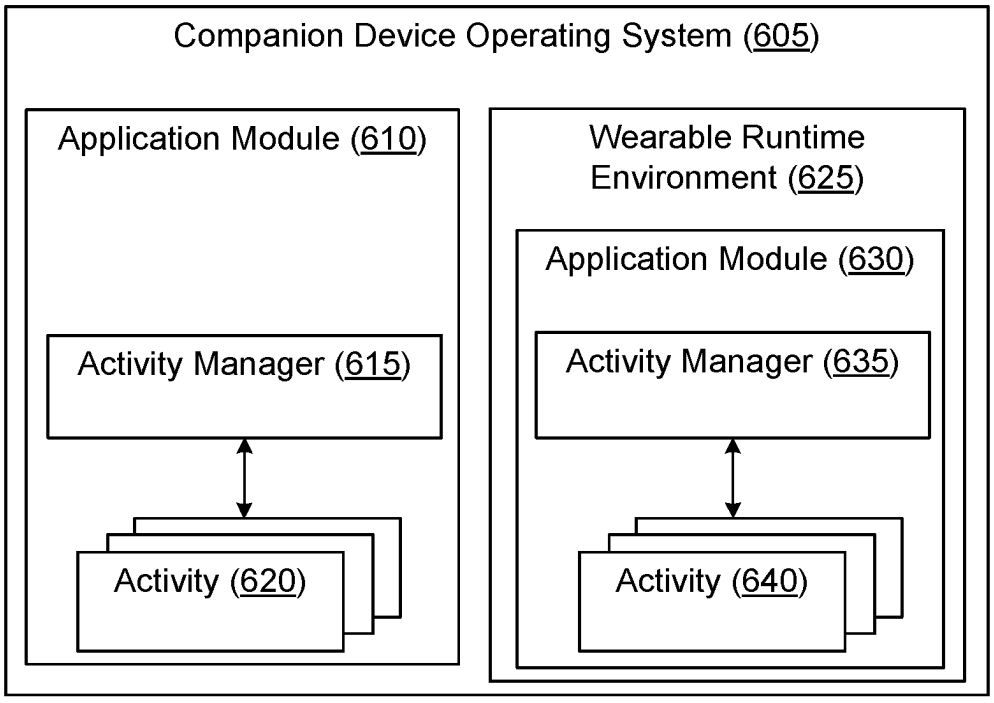

Companion Device Operating System (605)
Application Module (610)
Activity Manager (615)
Activity (620)
Wearable Runtime Environment (625)
Application Module (630)
Activity Manager (635)
Activity (640)

FIG. 6

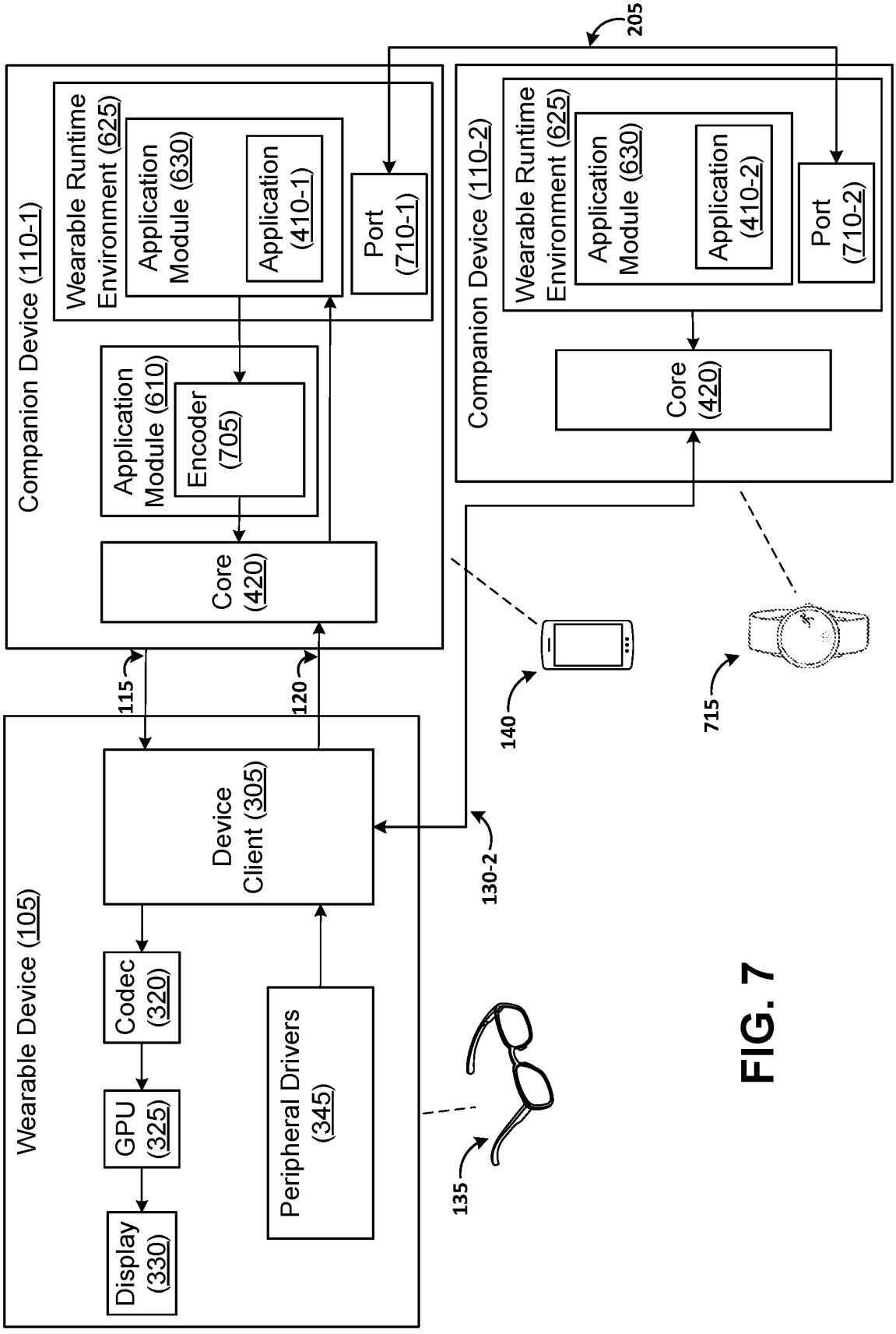

205
Companion Device (110-1)
Wearable Runtime Environment (625)
Application Module (630)
Application (410-1)
Port (710-1)
Application Module (610)
Encoder (705)
Core (420)
Companion Device (110-2)
Wearable Runtime Environment (625)
Application Module (630)
Application (410-2)
Port (710-2)
Core (420)
115
120
140
715
Wearable Device (105)
Device Client (305)
130-2
Codec (320)
GPU (325)
Display (330)
Peripheral Drivers (345)
135

FIG. 7

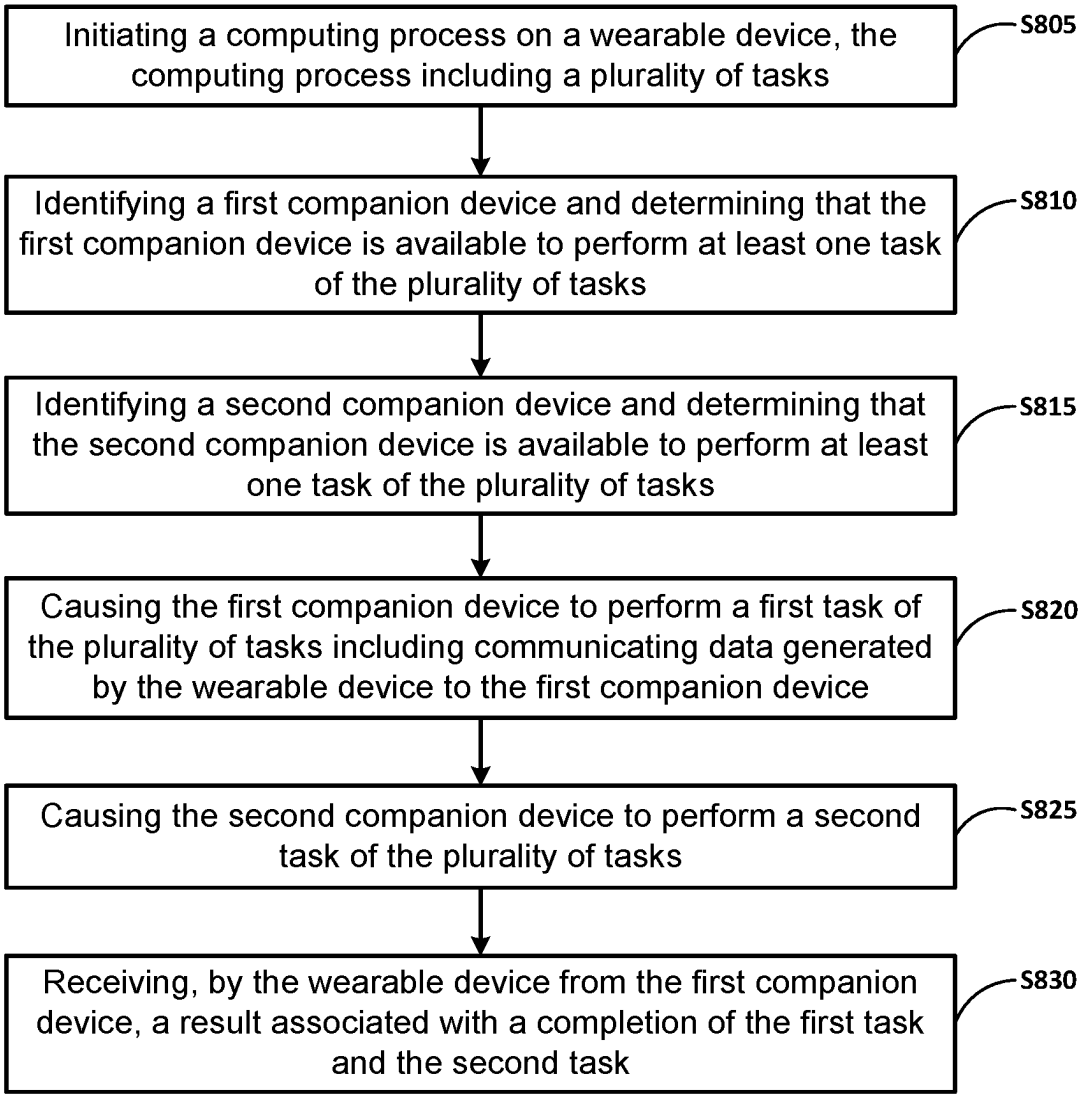

Initiating a computing process on a wearable device, the computing process including a plurality of tasks
S805
Identifying a first companion device and determining that the first companion device is available to perform at least one task of the plurality of tasks
S810
Identifying a second companion device and determining that the second companion device is available to perform at least one task of the plurality of tasks
S815
Causing the first companion device to perform a first task of the plurality of tasks including communicating data generated by the wearable device to the first companion device
S820
Causing the second companion device to perform a second task of the plurality of tasks
S825
Receiving, by the wearable device from the first companion device, a result associated with a completion of the first task and the second task
S830

FIG. 8

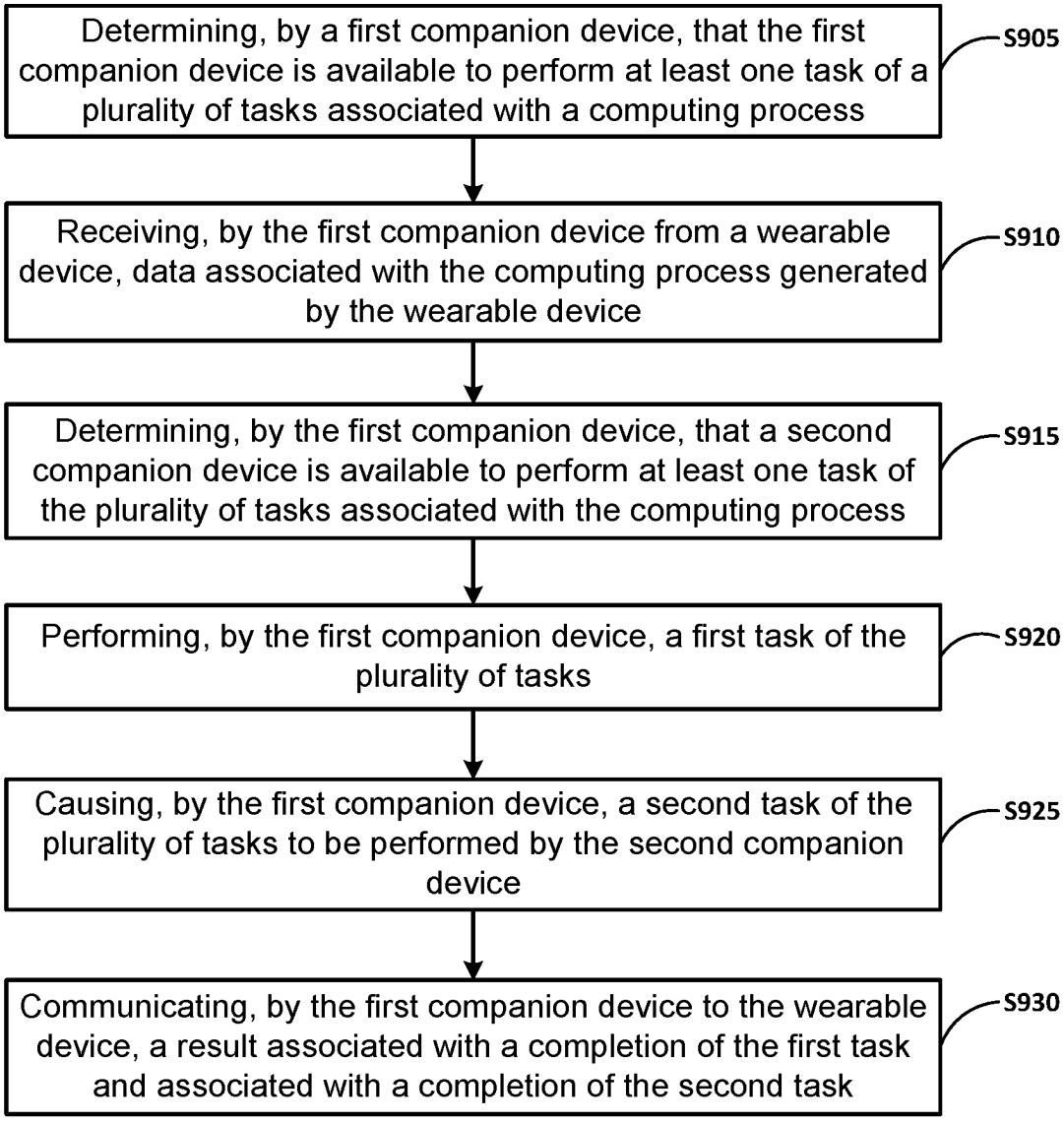

Determining, by a first companion device, that the first companion device is available to perform at least one task of a plurality of tasks associated with a computing process
S905
Receiving, by the first companion device from a wearable device, data associated with the computing process generated by the wearable device
S910
Determining, by the first companion device, that a second companion device is available to perform at least one task of the plurality of tasks associated with the computing process
S915
Performing, by the first companion device, a first task of the plurality of tasks
S920
Causing, by the first companion device, a second task of the plurality of tasks to be performed by the second companion device
S925
Communicating, by the first companion device to the wearable device, a result associated with a completion of the first task and associated with a completion of the second task
S930

FIG. 9

MULTIPLE APPLICATION RUNTIMES IN A SPLIT-COMPUTE ARCHITECTURE

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit and priority to U.S. Provisional Patent Application No. 63/363,592, filed on Apr. 26, 2022, entitled "SPLIT-COMPUTE ARCHITECTURE", the disclosure of which is incorporated by reference herein in its entirety.

[0002] This application also incorporates by reference herein the disclosures to related co-pending applications, PCT Application No. PCT/US2023/019563, filed Apr. **24**, **2023**, PCT Application No. PCT/US2023/019832, filed Apr. 25, 2023, "SPLIT-COMPUTE ARCHITECTURE", filed Apr. 26, 2023 (Attorney Docket No. 0120-497WO1), "PERIPHERAL DEVICES IN A SPLIT-COMPUTE ARCHITECTURE", filed Apr. 26, 2023 (Attorney Docket No. 0120-498WO1), "MULTIPLE APPLICATION RUNTIMES IN A SPLIT-COMPUTE ARCHITECTURE", filed Apr. 26, 2023 (Attorney Docket No. 0120-505WO1), and "MACHINE LEARNING PROCESSING OFFLOAD IN A SPLIT-COMPUTE ARCHITECTURE", filed Apr. 26, 2023 (Attorney Docket No. 0120-509WO1).

FIELD

[0003] Implementations relate to a wearable device processing architecture.

BACKGROUND

[0004] Some devices (e.g., wearable devices) can have advanced display capabilities. These devices can be challenged to fit sufficiently capable electronics into a small form factor. These issues become increasingly challenging in applications, such as accessibility, where a device might be expected to be worn for a full day.

[0005] Existing commercially available systems cannot support continuous usage scenarios. For example, wearable devices (e.g., smart glasses, smart watches, head mounted displays, and the like) are intended for intermittent engagement and are built around phone-class System-on-Chips (SoCs). These devices can provide only a few hours of battery life with a display on. In addition, thermal comfort can be an issue due to the small volume head mounted displays.

SUMMARY

[0006] Example implementations include a wearable device and a companion device using a split-compute architecture. To conserve wearable device resources, the companion device can process computing tasks that otherwise would be performed by the wearable device. The split-compute architecture facilitates the offloading of the computing tasks to the companion device. The computing tasks can be shared by at least two companion devices.

[0007] In a general aspect, a device, a system, a non-transitory computer-readable medium (having stored thereon computer executable program code which can be executed on a computer system), and/or a method can perform a process with a method including initiating a computing process on a wearable device, the computing process including a plurality of tasks, identifying a first companion device and determining that the first companion device is available to perform at least one task of the plurality of tasks, identifying a second companion device and determining that the second companion device is available to perform at least one task of the plurality of tasks, causing the first companion device to perform a first task of the plurality of tasks including communicating data generated by the wearable device to the first companion device, causing the second companion device to perform a second task of the plurality of tasks, and receiving, by the wearable device from the first companion device, a result associated with a completion of the first task and the second task.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] Example implementations will become more fully understood from the detailed description given herein below and the accompanying drawings, wherein like elements are represented by like reference numerals, which are given by way of illustration only and thus are not limiting of the example implementations.

[0009] FIG. **1** illustrates a block diagram of a high-level split-compute architecture according to an example implementation.

[0010] FIG. **2** illustrates a block diagram of the high-level split-compute architecture with a shared runtime environment according to an example implementation.

[0011] FIG. **3** illustrates a block diagram of a wearable device split-compute architecture according to an example implementation.

[0012] FIG. **4** illustrates a block diagram of a high-level split-compute architecture according to an example implementation.

[0013] FIG. **5** illustrates a block diagram of activity elements in a wearable device application according to an example implementation.

[0014] FIG. **6** illustrates a block diagram of a wearable device application in a wearable device runtime environment according to an example implementation.

[0015] FIG. **7** illustrates a block diagram of a system using a split-compute architecture according to an example implementation.

[0016] FIG. **8** is a block diagram of a method of operating a split-compute system according to an example implementation.

[0017] FIG. **9** is a block diagram of a method of operating a companion device according to an example implementation.

[0018] It should be noted that these Figures are intended to illustrate the general characteristics of methods, and/or structures utilized in certain example implementations and to supplement the written description provided below. These drawings are not, however, to scale and may not precisely reflect the precise structural or performance characteristics of any given implementation and should not be interpreted as defining or limiting the range of values or properties encompassed by example implementations. For example, the positioning of modules and/or structural elements may be reduced or exaggerated for clarity. The use of similar or identical reference numbers in the various drawings is intended to indicate the presence of a similar or identical element or feature.

DETAILED DESCRIPTION

[0019] Wearable devices can provide only a few hours of battery life with a display on. For example, computationally expensive operations such as image rendering, distortion correction, location services, and/or the like for wearable display optics may not always be possible to execute efficiently on a low-power embedded system implemented in the wearable device. Therefore, display architectures for thin-client wearable devices (e.g., smart glasses), however, can have the opportunity to reduce device onboard power and thermal footprint, by offloading computation-intensive operations (e.g., graphics operations) to a companion device (e.g., a mobile device, a smartphone, a server, and/or the like).

[0020] Some wearable devices can have implementation constraints. For example, a smart glasses implementation constraint can include (1) smart glasses should amplify key services through wearable computing. This can include supporting technologies such as AR and visual perception. For example, a smart glasses implementation constraint can include (2) smart glasses should last a full day of use on a single charge. For example, a smart glasses implementation constraint can include (3) smart glasses should look and feel like real glasses. Wearable devices can include augmented reality (AR) and virtual reality (VR) devices. Wearable devices can include smart glasses, head worn devices, and/or head mount devices. The wearable devices, head worn devices, and/or head mount devices can be AR/VR devices. Fully stand-alone wearable devices (e.g., smart glasses) solutions with mobile SoCs that have the capability to support the desired features may not meet the power and industrial design constraints listed above. On-device compute solutions that meet constraints (1), (2) and (3) may be difficult to achieve with current technologies. Current technology is limited in that stand-alone solutions with mobile system on a chip (SoC) technologies that meet the functionality requirements won't meet the power and industrial design constraints listed above.

[0021] A split-compute architecture can be used to solve the problems associated with existing wearable devices technology implementations meeting the aforementioned constraints. A split-compute architecture can be an architecture that moves an application runtime environment to a remote compute endpoint, such as a smartphone, a server, the cloud, a desktop computer, and the like, hereinafter often referred to as a companion device. In some implementations, data sources such as an inertial measurement unit (IMU) and camera sensors can be streamed from the wearable device to the companion device. In some implementations, display content can be streamed from the companion device back to the wearable device. In some implementations, content and/or data generated by a first application operating of a first companion device can be streamed from the first companion device to a second companion device. Then, a second application operating of the second companion device can generate content using the streamed content and/or data to the wearable device.

[0022] Continuing the smart glasses example, the majority of the compute and rendering does not happen on the smart glasses, therefore the split-compute architecture can allow leveraging low-power processor and/or low-power microcontroller MCU based systems. In some implementations, the split-compute architecture combined with a wearable device including an MCU can allow minimizing power usage, meeting constraints (1) and (2) and (3). With new innovation in codecs and networking, it is possible to sustain the required networking bandwidth in a low power manner. In some implementations, wearable devices can communicate with a companion device over a well-defined protocol. In some implementations, a first companion device can communicate with a second companion device over the well-defined protocol. This architecture can be platform independent.

[0023] FIG. **1** illustrates a block diagram of a high-level split-compute architecture according to an example implementation. As shown in FIG. **1**, the split-compute architecture can include a wearable device **105** and a companion device **110**. In an example implementation, the wearable device **105** can be smart glasses, an augmented reality/virtual reality headset, a head mounted display (HMD), a smart watch, a smart ring, and/or the like. As an example, FIG. **1** shows the wearable device **105** as smart glasses **135**. In an example implementation, the companion device **110** can be another wearable device, a mobile device, a smart phone, a tablet, a server, and a device including a processor and an operating system. As an example, FIG. **1** shows the companion device **110** as a smart phone **140**.

[0024] The wearable device **105** and the companion device **110** can be communicatively coupled. For example, the wearable device **105** and the companion device **110** can be communicatively coupled wired or wirelessly. In other words, the wearable device **105** and the companion device **110** can be endpoints of a two-way, wired and/or wireless, communication link. As an example, the wearable device **105** and the companion device **110** can communicate an audio stream and/or video stream over communications line **115**. As an example, the wearable device **105** and the companion device **110** can communicate data (e.g., IMU, camera, input, and/or the like) over communications line **120**. As an example, the wearable device **105** and the companion device **110** can communicate a control stream over communications line **125**. Communications line **115**, communications line **120**, and/or communications line **125** can be referred to collectively as communications line **130**. In some implementations, the communications line **130** can be bi-directional.

[0025] In some implementations, the companion device **110** can include a runtime environment the wearable device **105** can connect to. In some implementations, the wearable device **105** can stream data such as IMU and camera imagery into the runtime environment. In some implementations, the runtime environment of the companion device **110** can be configured to perform the tracking, perception and/or application rendering and deliver the output back to the wearable device **105** through a graphics application programming interface (API), such as encoded video or rendering commands. In some implementations, the runtime environment can be a code or software application and/or container executing on the companion device **110**. In some implementations, the runtime environment can be software operating on the companion device **110** at the same time as the wearable device **105** and/or during a time when the wearable device **105** and the companion device **110** are communicatively coupled. In some implementations, input is captured from the wearable device **105** and injected into (e.g., communicated to) the runtime environment of the companion device **110**.

[0026] As an example, absent the companion device **110**, a computing process would entirely be executed on the wearable device **105**. The computing process can be any computing process associated with the function of the wearable device. For example, the computing process can be a computing process configured to display content (e.g., as an image or video) on a display of the wearable device **105**. The computing process can be any computing process including at least one task (or a plurality of tasks). The at least one task can be computer instructions (e.g., code) stored on a memory of the wearable device **105** that are executed by a processor of the wearable device **105**. The at least one task can be computer instructions (e.g., code) stored on a memory of the companion device **110** that are executed by a processor of the companion device **110**.

[0027] The at least one task can be computer instructions (e.g., code) configured to generate a result. The result can be an intermediate result or output of the computing process. The result can be a completed or final result or output of the computing process. The at least one task can be instructions executed by the processor of the wearable device **105**. The at least one task can be instructions executed by the processor of the companion device **110**. In some implementations, a task(s) can be implemented as a service. A service can be, for example, a machine-to-machine interaction over a network. A service can be implemented as a background operation. For example, a service can perform network transactions, play audio, perform I/O, interact with a content provider, and/or the like from the background.

[0028] By including the companion device **110** (e.g., the runtime environment of the companion device **110**), device onboard power usage and thermal footprint can be reduced by offloading one or more tasks of the plurality of tasks to the companion device **110**. In an example implementation, the plurality of tasks can be fragmented. Fragmenting tasks can include methodically and/or randomly assigning plurality of tasks between the wearable device **105** and the companion device **110**. For example, methodically assigning plurality of tasks between the wearable device **105** and the companion device **110** can be based on resource usage. For example, if the amount of resources used to cause a task (or tasks) to be executed (noting that executing a task includes performing computer operations) on the companion device **110** is greater than executing the task (or tasks) on the wearable device **105**, then the task (or tasks) can be executed on the wearable device **105**.

[0029] For example, a task (or tasks) can include and/or use computer data (e.g., a high-resolution image captured by a camera of the wearable device **105**). If communicating the computer data uses more resources (e.g., battery resources of the wearable device **105**) than a task including processing the data by the wearable device **105**, the wearable device **105** could be assigned to complete the task. Otherwise, the companion device **110** should be assigned to complete the task. In this example implementation, both the wearable device **105** and the companion device **110** are capable of performing the task (or tasks). In some implementations, two or more companion devices may be used to complete the process including the plurality of tasks.

[0030] FIG. **2** illustrates a block diagram of the high-level split-compute architecture with a shared runtime environment according to an example implementation. As shown in FIG. **2**, the wearable device **105** is communicatively coupled to two or more companion devices **110-1**, **110-2**, . . . **110**-n via communications lines **130-1**, **130-2**, . . . **130-*n*** respectively. In some implementations, the wearable device **105** could roam between various companion devices **110-1**, **110-2**, . . . **110-*n***, selecting the companion devices **110-1**, **110-2**, . . . **110-*n*** that provides the best experience at that point in time. The wearable device **105** can connect to multiple companion devices **110-1**, **110-2**, . . . **110-*n*** runtimes simultaneously. Therefore, the wearable device **105** can connect to multiple runtime environments simultaneously.

[0031] For example, the runtime environment associated with companion device **110-1** can be configured to project content onto a display of the wearable device **105** while the runtime environment associated with companion device **110-2** can be configured to access the data sources (e.g., sensors) from the wearable device **105**, a database server, the internet, and/or the like for processing. In addition, or alternatively, the companion devices **110-1**, **110-2**, . . . **110-*n*** can be communicatively coupled (e.g., wired or wirelessly) to share resources and/or data. For example, companion device **110-1** and companion device **110-2** can be communicatively coupled enabling the runtime environment associated with companion device **110-1** to receive data from the runtime environment associated with companion device **110-2** for use when the runtime environment associated with companion device **110-2** generates images (or frames) to project content onto the display of the wearable device **105**.

[0032] For example, companion device **110-1** and companion device **110-2** can be communicatively coupled (e.g., via communications line **205**) enabling the runtime environment associated with companion device **110-2** to share processing resources with the runtime environment associated with companion device **110-1**. For example, the runtime environment associated with companion device **110-1** may be instructed to generate content (e.g., an image, a frame, a map, and/or the like) that is more efficiently generated by the runtime environment associated with companion device **110-2**. For example, companion device **110-2** may include a map database and map (e.g., image) generator. The runtime environment associated with companion device **110-1** may be instructed to generate content that includes a map. In this example, the runtime environment associated with companion device **110-1** can request a map from the runtime environment associated with companion device **110-2**.

[0033] Continuing the example above, should a determination be made that the companion device **110** is to perform the task(s), the companion device **110** (or the wearable device **105**) can determine that two or more companion devices **110** can perform the task(s). For example, the task(s) can include generating content (e.g., an image) to be displayed on the wearable device **105**. In this example, the companion device **110-1** can be configured to generate the content. However, data used to generate the content may be generated by the companion device **110-2** which is then communicated (e.g., via communications line **205**) from the companion device **110-2** to the companion device **110-1**. For example, the companion device **110-2** can be a wearable smart watch configured to sense a user heart rate. Data representing the heart rate can be communicated from the companion device **110-2** to the companion device **110-1**. Then, the companion device **110-1** can generate content using the data representing the heart rate and the content can be communicated to the wearable device **105** for display on a display of the wearable device **105**.

[0034] FIG. **3** illustrates a block diagram of a wearable device split-compute architecture according to an example implementation. As shown in FIG. **3**, the wearable device split-compute architecture can include a hardware abstraction layer (HAL) **310** block. The HAL **310** can be a layer of software configured to interface between an operating system (e.g., RTOS **340**) and a hardware device at a general or abstract level rather than at a hardware level. In some implementations, using abstraction layers can make the split-compute architecture platform independent. The HAL **310** can be called from the operating system kernel. In some implementations, the HAL **310** can be a virtual HAL. The virtual HAL can minimize interpretation latency based on the similarity in architectures of a guest and a host platform. Virtualization technique helps map the virtual resources to physical resources and use the native hardware for computations in the virtual HAL.

[0035] Accordingly, as an example, the HAL **310** can include a connectivity **315** block, a codec **320** block, a graphics processing unit (GPU) **325** block, and a display **330** block each configured to interface with a corresponding hardware device. For example, the connectivity **315** can be configured to interface between the operating system (e.g., RTOS **340**) and Bluetooth hardware, WIFI hardware, ultra-wideband (UWB) hardware, 5G hardware, and/or the like. Therefore, the wearable device split-compute architecture can be configured to utilize any connectivity hardware designed into the wearable device **105**.

[0036] For example, the codec **320** can be configured to interface between the operating system (e.g., RTOS **340**) and an encoder and/or a decoder (e.g., a hardware-based encoder and/or decoder). The codec **320** standard can be, for example, H.265, H.264, MPEG, VP9, machine learned, and/or the like. The codec **320** can be an image, video, and/or audio codec. Therefore, the wearable device split-compute architecture can be configured to utilize any codec software and/or hardware designed into the wearable device **105**. For example, the GPU **325** can be configured to interface between the operating system (e.g., RTOS **340**) and GPU hardware (e.g., a GPU ASIC). Therefore, the wearable device split-compute architecture can be configured to utilize any GPU (e.g., to render an image on a display system) designed into the wearable device **105**. For example, the display **330** can be configured to interface between the operating system (e.g., RTOS **340**) and display hardware (e.g., a wearable device display). Therefore, the wearable device split-compute architecture can be configured to utilize any display (e.g., display driver system) designed into the wearable device **105**.

[0037] As shown in FIG. **3**, the wearable device split-compute architecture can include an operating system (OS) abstraction layer (OSAL) **335**. In some implementations, using abstraction layers can make the split-compute architecture platform independent. The OSAL **335** can be configured to provide an interface to common system functions offered by the OS of the wearable device **105**. These OSAL **335** can simplify development and porting software (e.g., applications) to multiple OS and hardware platforms. In some implementations, the OSAL **335** can operate as (or similar to) an application programming interface (API). In some implementations, the OSAL **335** can be platform dependent.

[0038] The OSAL **335** can include a real-time operating system (RTOS) **340** block. The RTOS **340** can be configured to process, for example, multi-threaded applications to meet real-time deadlines. For example, the RTOS **340** can be configured to process a plurality of tasks each (or a grouping of tasks) having a maximum completion time. Although an RTOS is illustrated, any OS can be used. For example, a high-level operating system (HLOS) can be used. In a split-compute system, using tasks enables distribution of these tasks (or groups of tasks) between computing devices. For example, a content display operation for the wearable device **105** can be divided between the wearable device **105** and the companion device **110** (e.g., the runtime environment associated with companion device **110**). In other words, the wearable device **105** (and/or the companion device **110**) can be configured to (e.g., using the wearable device split-compute architecture) cause the companion device **110** to perform a portion (a task or a grouping of tasks) of a process (e.g., content display).

[0039] As shown in FIG. **3**, the wearable device split-compute architecture can include a peripheral drivers **345** block. The peripheral drivers **345** can be configured to interface between the OS and a peripheral device. For example, the wearable device **105** can include a plurality of peripheral devices including, for example, a camera(s), a microphone(s), a speaker(s), an input(s), an inertial measurement unit(s) (IMU), and/or the like. Therefore, the peripheral drivers **345** can be configured to interface between the RTOS **340** and the peripheral device(s) of the wearable device **105**.

[0040] As shown in FIG. **3**, the wearable device split-compute architecture can include a device client **305**. The device client **305** can be configured to control communication between the wearable device **105** and the companion device **110**. For example, device client **305** can be configured to generate, initialize, and control the communications line **130** and the communications over the communications line **130**. The communications line **130** can operate as, for example, a socket (e.g., a network socket, a TCP/IP network socket, and the like). A socket can be one endpoint of a two-way communication link between computer code (e.g., applications, programs, software systems, and/or the like) running on two computing devices. The socket mechanism can be configured to provide inter-process communication (IPC) by establishing named communication contact points between two endpoints and/or between two endpoints and an intermediate device (e.g., an access point (AP)). A socket can be configured to provide a bidirectional first-in first-out (FIFO) communication channel. A socket connecting to the network is created at each end of the communication. As an example, each socket can have an address (or memory location). The address (or memory location) can be, for example, an IP address and a port number. Accordingly, the device client **305** can be configured to write to and read from a socket associated with the companion device **110** (or the runtime environment associated with companion device **110**). In some implementations, the device client **305** can be platform independent.

[0041] In some implementations, a software development kit (SDK) can be associated with the wearable device **105** and the companion device **110**. The SDK can be used when developing applications for the wearable device **105** and/or the companion device **110**. The SDK can enable the implementation of the split-compute architecture. Therefore, any wearable device **105** and/or companion device **110** (regardless of the hardware and/or software platform) that includes

the split-compute architecture can use an application that was developed using the SDK. Therefore, an application does not have to be developed and ported to each hardware and/or software platform that may be used as a wearable device **105** and/or the companion device **110**. The SDK can be included (or have elements that can be included) with the application when the application is installed on the wearable device **105** and/or the companion device **110**.

[0042] FIG. **4** illustrates a high-level split-compute architecture according to an example implementation. As shown in FIG. **4**, a system can include the wearable device **105** and the companion device **110**. The split-compute architecture for the system can include a device client **305** block associated with the wearable device **105**, an application **410** block, an SDK **415** block, and a core **420** block associated with the companion device **110**. As mentioned above, the device client **305** can be configured to control communication between the wearable device **105** and the companion device **110**. The core **420** can be configured to control communication between the companion device **110** and the wearable device **105**. Accordingly, the core **420** can be configured to, at least, generate, initialize, and control the communications line **130** and the communications over the communications line **130**. The communications line **130** can operate as, for example, a socket (as described above).

[0043] In some implementations, the application **410** can include the file format for applications used on the OS that holds the application logic (e.g., the Android package kit (APK)). In some implementations, wearable device applications can link with a stub (e.g., not a complete) version of the SDK to support compile and testing services. In some implementations, at runtime, the application **410** can load the wearable device SDK **415** directly from a wearable device runtime environment. In some implementations, the SDK **415** can provide developers the application programming interface (API) used to build wearable device applications. In some implementations, an API versioning scheme allows introduction of new APIs while maintaining backwards compatibility. In some implementations, the wearable device runtime environment can be a collection of core services responsible for maintaining the wearable device execution environment. In some implementations, wearable device applications may not interact with the core services directly. In some implementations, one or more interaction may go through the SDK. In some implementations, the device client **305** can be a thin client running on the wearable device **105** hardware.

[0044] As an example, the application **410** can be configured to generate (or help generate) content for display on the wearable device **105**. For example, the application can be configured to process a task(s). For example, the application can generate the content (e.g., as an image) and communicate the content to the core **420** via the SDK **415**. Communicating the content to the core **420** via the SDK **415** can be one of the features that allows the application **410** to be developed for any hardware and/or software platform. For example, the SDK **415** can be configured to communicate with the application **410** when the application **410** is developed. The SDK **415** can also be configured to communicate with the core **420** associated with a plurality of hardware and/or software platforms. After receiving the content, the core **420** can communicate the content to the wearable device **105** via the device client **305** using, for example, a pre-established socket.

[0045] As mentioned above, in some implementations, the wearable device **105** can be configured to connect to more than one companion device **110** at a given time. In some implementations, a different companion device **110** can be configured to provide different services (e.g., using an application **410**). In some implementations, with low-latency, high-bandwidth 5G connections becoming mainstream, the companion device **110** can be configured to operate in the cloud (e.g., connecting through 5G standards).

[0046] FIG. **5** illustrates a block diagram of activity elements in a wearable device application according to an example implementation. As shown in FIG. **5**, the application **410** can include a wearable activity **505** block, a wearable activity service **510** block, and a wearable activity host **515** block, and the core **420** can include a core services **520** block.

[0047] In some example implementations, wearable device application design can resemble an activity model. Referring to FIG. **3**, the RTOS **340** can be configured to process, a task, a plurality of tasks each (or a grouping of tasks) having a maximum completion time. Therefore, each activity can be a task executed in a parallel process and having a time (or amount of time) to be completed by.

[0048] In an example implementation, activities can be executed in a service context. In some implementations, running in a service context can allow the application **410** to run concurrently with companion device **110** applications. In some implementations, the application can continue running and rendering when a companion device **110** display is off.

[0049] In some implementations, one or more application **410** can include a wearable activity service **510**. The wearable activity service **510** can be configured to expose the wearable activity **505** so that the wearable activity **505** can be instantiated by the SDK **415**. Therefore, the wearable activity **505** can be instantiated at a later point in time. From a developer's point of view, the wearable activity service **510** can be boilerplate code that does not directly relate to application **410** logic. The wearable activity **505** can be the code related to application **410** logic. In some implementations, wearable activity **505** can be managed by an activity manager and behave similarly to a standard OS activity counterpart.

[0050] In some implementations, the service binding can be used by the wearable device runtime environment to start and manage the life cycle of the application **410**. Once the activity manager binds to the service as part of a launch flow, the SDK **415** can instantiate and attach a wearable activity host **515** as, for example, a class that can be responsible for general activity state control. For example, during initialization the wearable activity host **515** can request a surface from a window manager. This surface is then used as a backing store for a virtual display that's used to render the contents of the application **410**.

[0051] FIG. **6** illustrates a block diagram of a wearable device application in a wearable device runtime environment according to an example implementation. As shown in FIG. **6**, a companion device OS **605** can simultaneously process two or more application environments. For example, the companion device OS **605** can include an application module **610**. The application module **610** can be associated with standard OS application activity. In addition, the companion device OS **605** can include an application module **630** operating in association with a wearable runtime envi-

ronment **625**. The wearable runtime environment **625** can be associated with the wearable device **105**.

[0052] An activity(s) **620**, **640** can be a single, focused task that the application can perform. For example, some applications can include a user interface (UI). Therefore, the activity(s) **620**, **640** can be configured to create a window to place the UI. The window can be a full-screen window, a floating window, embedded into other windows, a hidden window, and/or the like. The different types of windows can be associated with different activity(s) **620**, **640**. The activity (s) **620**, **640** can be configured for any task, a window is just one example.

[0053] The activity manager **615**, **635** can be configured to communicate information about, and interact with the activities **620**, **640**. The activity manager **615**, **635** can be further configured to communicate information about, and interact with tasks, threads, services and other processes.

[0054] In an example implementation, the wearable runtime environment **625** can be a virtual runtime environment. The virtual runtime environment can be configured to operate in the background of a computing device. Therefore, the wearable runtime environment **625** can be a virtual runtime environment associated with the wearable device **105** and configured to operate as a background process on the companion device **110**. In other words, the wearable runtime environment **625** can operate without a user interface shown on a display of the companion device **110**. For example, the wearable runtime environment **625** can operate in a hidden window of the companion device **110**. Therefore, a user of the companion device **110** may have no visual or I/O control of an application using the wearable runtime environment **625** if the wearable runtime environment **625** is a virtual runtime environment.

[0055] In an alternative, or additional implementation, the application **410** and/or the application module **630** can be a virtual process. The virtual process can be configured to operate in the background of a computing device. Therefore, the application **410** and/or the application module **630** can be a virtual process associated with the wearable device **105** and configured to operate as a background process on the companion device **110**. In other words, the application **410** and/or the application module **630** can operate without a user interface shown on a display of the companion device **110**. For example, the application **410** and/or the application module **630** can operate in a hidden window of the companion device **110**. Therefore, a user of the companion device **110** may have no visual or I/O control of the application **410** and/or the application module **630** if the process is a virtual runtime process.

[0056] FIG. **7** illustrates a block diagram of a system using a split-compute architecture according to an example implementation. As shown in FIG. **7**, the system includes the wearable device **105** and the companion device **110**. The wearable device **105** can include the device client **305**, the codec **320**, the GPU **325**, the display **330**, and the peripheral drivers **345**. The companion device **110-1** can include the core **420**, the application module **610** including an encoder **705**, and the application module **630** including the application **410-1**. The companion device **110-2** can include the application **410-2**. The wearable device runtime environment of the companion device **110-2** can be configured to communicate with the wearable device **105** via communications line **130** using the core **420** and the device client **305** of the companion device **110-2** and the wearable device **105** respectively. As an example, FIG. **7** shows the wearable device **105** as smart glasses **135**. As an example, FIG. **7** shows the companion device **110-1** as a smart phone **140**. As an example, FIG. **7** shows the companion device **110-2** as a smart watch **715**. In this example, the companion device **110-2** is illustrated as being communicatively coupled to the wearable device **105** via the communications line **130-2**. However, in some example implementations, the companion device **110-2** may not be communicatively coupled to the wearable device **105**. Therefore, in some implementations, the companion device **110-2** may be configured to communicate with the wearable device **105** via the companion device **110-1**.

[0057] This example implementation can be used to describe a signal flow associated with generating and displaying content on the wearable device **105** using the split-compute architecture described herein. This is just one of many possible system configurations and uses, other configurations and uses can exist and are within the scope of this disclosure.

[0058] In this example implementation, the application **410-1** can be configured to generate content for display on the wearable device **105**. The application **410-1** can be configured to generate content based on data received from the wearable device **105**. For example, the peripheral drivers **345** can sense and communicate data, as peripheral data, (e.g., IMU data) to the application module **630** via the device client **305** and the core **420** using the communications line **120**. In other words, peripheral data can be the data that is collected by and/or processed by (e.g., compressed, packaged, parsed, filtered, denoised, and/or the like) the peripheral device via the peripheral drivers **345** and packaged for communication with and use by the wearable device **105** and/or the companion device **110**. In addition, the application **410-1** can be configured to generate content based on data received from the companion device **110-2**. For example, the application **410-1** can be configured to generate content based on a number of steps, a distance, a heartrate, a blood oxygen content, and/or the like sensed by the companion device **110-2** and communicated to the companion device via communications port **710-2**, communications line **205** and communications port **710-1**.

[0059] Communications port **710-1** and communications port **710-2** are illustrated as being included in the respective wearable device runtime environment **625**. However, in an alternative (and/or additional) implementation, the communications port **710-1** and the communications port **710-2** can be included in the respective core **420**. Accordingly, the wearable device **105** can be configured to cause the companion device **110-2** to perform a task and/or the companion device **110-1** can be configured to cause the companion device **110-2** to perform the task. The task can be associated with one or more tasks being processed by application **410-1**. In some implementations, the application **410-1** and the application **410-2** can be configured to synchronize state information associated with a task(s) and/or process. In some implementations, the respective wearable device runtime environment **625** can be configured to synchronize state information associated with a task(s) and/or process. In some implementations, the respective wearable device runtime environment **625**, the application **410-1** and/or the application **410-2** can be configured to synchronize state information associated with a task(s) and/or process. State information can include information associated with and/or

resulting from, for example, preceding processes, preceding events, preceding user interactions, preceding input and/or output data, logic values, data that can cause a change in state and/or the like. The state information can be associated with the respective wearable device runtime environment **625**, the application **410-1** and/or the application **410-2**.

[0060] In some example implementations, the companion device **110-1** may not be configured to perform tasks that the companion device **110-2** can be configured to perform. In other words, Application **410-1** may not be configured to perform a task(s) that application **410-2** is configured to perform. For example, the companion device **110-1** may not be configured to sense heartrate and/or blood oxygen content, whereas the companion device **110-2** can be configured to sense heartrate and/or blood oxygen. Therefore, the application **410-2** can be configured to perform a task(s) using heartrate and/or blood oxygen content. For example, the application **410-2** can be a fitness application and the companion device **110-2** can be configured to communicate data and/or content generated by the fitness application to the companion device **110-1**. This is one of many possible implementations of using a split-compute architecture with two or more companion devices.

[0061] The application **410** can generate the content as, for example, a rendered image and/or frame. The encoder **705** can compress the image and/or frame (e.g., using the H.264 codec). The compressed image and/or frame can be communicated to the wearable device **105** via the core **420** and the device client **305** using the communications line **115**. The codec **320** can decompress the image and/or frame (e.g., using the H.264 codec). The GPU **325** can cause the image and/or frame to be displayed on the display **330**.

[0062] Example 1. FIG. **8** is a block diagram of a method of operating a split-compute system including a wearable device and a companion device communicatively coupled to the wearable device according to an example implementation. As shown in FIG. **8**, in step S**805** a computing process is initiated on the wearable device, the computing process including a plurality of tasks. For example, the computing process can be initiated by a user of the wearable device providing corresponding user input (e.g., a gesture) to the wearable device. In some implementations, the wearable device can initiate the computing process based on another computing process, based on a spatial position of the wearable device, and/or the like. In step S**810** a first companion device is determined to be available to perform at least one task of the plurality of tasks. For example, the first companion device can be identified by the wearable device as an available companion device on a list of potential available companion devices stored in a memory of the wearable device and/or the first companion device. Alternatively, the available first companion device could be any companion device in the proximity of the wearable device that can establish a connection with the wearable device via a Two-Way or Three-Way Handshake (e.g., handshaking can be bi-directional in that both the client and the host determine what capabilities each support). The available first companion device can signal to the wearable device a list of tasks that the first companion device is capable to perform, or the wearable device can be already aware of the tasks a particular type of companion device is capable to perform. In step S**815** a second companion device is determined to be available to perform at least one task of the plurality of tasks. For example, the second companion device can be identified by the wearable device and/or the first companion device as an available companion device on a list of potential available companion devices stored in a memory of the wearable device, the first companion device and/or the first companion device. Alternatively, the available second companion device could be any companion device in the proximity of the wearable device and/or the first companion device that can establish a connection with the wearable device via a Two-Way or Three-Way Handshake. The available second companion device can signal to the wearable device and/or the first companion device a list of tasks that the second companion device is capable to perform, or the wearable device and/or the first companion device can be already aware of the tasks a particular type of companion device is capable to perform. In step S**820** the first companion device performs a first task of the plurality of tasks including communicating and/or receiving data generated by the wearable device. For example, the first companion device can automatically perform the first task upon receiving a trigger, an instruction, and/or the data. In step S**825** the second companion device performs a second task of the plurality of tasks. For example, the second companion device can automatically perform the second task upon receiving a trigger, an instruction, and/or data. In step S**830** the companion device communicates and/or the wearable device receives a result associated with a completion of the first task and the second task. Here, the term result can be used to refer to the processed data.

[0063] Example 2. The method of Example 1, wherein the wearable device can be communicatively coupled to the second companion device and the wearable device is configured to cause the second companion device to perform the second task.

[0064] Example 3. The method of Example 1, wherein the first companion device can be communicatively coupled to the second companion device and the first companion device can be configured to cause the second companion device to perform the second task.

[0065] Example 4. The method of Example 1, wherein the first companion device can be communicatively coupled to the second companion device and the first companion device, and the second companion device can be configured to synchronize state information associated with the computing process.

[0066] Example 5. The method of Example 1 can further include receiving, by the first companion device from the second companion device, a result associated with a completion of the second task.

[0067] Example 6. The method of Example 1 can further include communicating, by the first companion device to the second companion device, a request to perform the first task.

[0068] Example 7. The method of Example 1, wherein the first companion device may not be configured to perform the second task.

[0069] Example 8. The method of Example 1, wherein the computing process can be initiated by the wearable device.

[0070] Example 9. The method of Example 1, wherein the computing process can be initiated by the first companion device and initiating the computing process on the wearable device can include receiving a trigger from the first companion device, by the wearable device.

[0071] Example 10. The method of Example 1, wherein the wearable device can include a first socket, the first companion device can include a second socket communi-

catively coupled to the first socket, the first companion device can include a third socket, the second companion device can include a fourth socket communicatively coupled to the third socket, causing the first companion device to perform the first task can include writing an instruction and data to the first socket, causing the first companion device to perform the first task can include reading data from the third socket, and receiving the result associated with a completion of the first task can include reading the result from the second socket. Causing a device to perform a task can include sending an instruction configured to initiate processing and/or trigger processing of a task by the device and/or another device(s).

[0072] Example 11. The method of Example 1, wherein the result can include an image and the method can further include displaying the image on a display of the wearable device.

[0073] Example 12. The method of Example 1, wherein the wearable device can be smart glasses.

[0074] Example 13. The method of Example 1, wherein the first companion device can be at least one of another wearable device, a mobile device, a smart phone, a tablet, a server, and a device including a processor and an operating system.

[0075] Example 14. The method of Example 1, wherein the second companion device can be at least one of another wearable device, a mobile device, a smart phone, a tablet, a server, and a device including a processor and an operating system.

[0076] Example 15. The method of Example 1, wherein the first companion device can include a virtual runtime environment, causing the first companion device to perform the first task can include causing the virtual runtime environment to perform the computing process, the result can be the completion of the computing process, and the method can further include completing, by the wearable device, the computing process based on the result includes rendering an image on a display of the wearable device.

[0077] Example 16. FIG. **9** is a block diagram of a method of operating a companion device according to an example implementation. As shown in FIG. **9**, in step S**905** determining, by a first companion device, that the first companion device is available to perform at least one task of a plurality of tasks associated with a computing process. In step S**910** receiving, by the first companion device from a wearable device, data associated with the computing process generated by the wearable device. In step S**915** determining, by the first companion device, that a second companion device is available to perform at least one task of the plurality of tasks associated with the computing process. In step S**920** performing, by the first companion device, a first task of the plurality of tasks. In step S**925** causing, by the first companion device, a second task of the plurality of tasks to be performed by the second companion device. In step S**930** communicating, by the first companion device to the wearable device, a result associated with a completion of the first task and associated with a completion of the second task.

[0078] Example 17. The method of Example 16, wherein the first companion device and the second companion device can be communicatively coupled.

[0079] Example 18. The method of Example 16, wherein the first companion device can be communicatively coupled to the second companion device and the first companion device can be configured to cause the second companion device to perform the second task.

[0080] Example 19. The method of Example 16, wherein the first companion device can be communicatively coupled to the second companion device, and the first companion device and the second companion device can be configured to synchronize state information associated with the computing process.

[0081] Example 20. The method of Example 16 can further include receiving, by the first companion device from the second companion device, a result associated with a completion of the second task.

[0082] Example 21. The method of Example 16 can further include communicating, by the first companion device to the second companion device, a request to perform the second task.

[0083] Example 22. The method of Example 16, wherein the first companion device may not be configured to perform the second task.

[0084] Example 23. The method of Example 16, wherein the computing process can be initiated by the first companion device and initiating the computing process on the wearable device can include communicating a trigger from the first companion device to the wearable device.

[0085] Example 24. The method of Example 16, wherein the wearable device can include a first socket, the first companion device can include a second socket communicatively coupled to the first socket, the first companion device can include a third socket, the second companion device can include a fourth socket communicatively coupled to the third socket, causing the first companion device to perform the first task can include writing an instruction and data to the first socket, causing the first companion device to perform the first task can include reading data from the third socket, and receiving the result associated with a completion of the first task can includes reading the result from the second socket.

[0086] Example 25. The method of Example 16, wherein the wearable device can be smart glasses.

[0087] Example 26. The method of Example 16, wherein the first companion device can be at least one of another wearable device, a mobile device, a smart phone, a tablet, a server, and a device including a processor and an operating system.

[0088] Example 27. The method of Example 16, wherein the second companion device can be at least one of another wearable device, a mobile device, a smart phone, a tablet, a server, and a device including a processor and an operating system.

[0089] Example 28. The method of Example 16, wherein the first companion device can include a virtual runtime environment, causing the first companion device to perform the first task can include causing the virtual runtime environment to perform the computing process, and the result can be the completion of the computing process, the method can further include completing, by the wearable device, the computing process based on the result includes rendering an image on a display of the wearable device.

[0090] Example 29. A method can include any combination of one or more of Example 1 to Example 28.

[0091] Example 30. A non-transitory computer-readable storage medium comprising instructions stored thereon that,

when executed by at least one processor, are configured to cause a computing system to perform the method of any of Examples 1-29.

[0092] Example 31. An apparatus comprising means for performing the method of any of Examples 1-29.

[0093] Example 32. An apparatus comprising at least one processor and at least one memory including computer program code, the at least one memory and the computer program code configured to, with the at least one processor, cause the apparatus at least to perform the method of any of Examples 1-29.

[0094] Example implementations can include a non-transitory computer-readable storage medium comprising instructions stored thereon that, when executed by at least one processor, are configured to cause a computing system to perform any of the methods described above. Example implementations can include an apparatus including means for performing any of the methods described above. Example implementations can include an apparatus including at least one processor and at least one memory including computer program code, the at least one memory and the computer program code configured to, with the at least one processor, cause the apparatus at least to perform any of the methods described above.

[0095] Various implementations of the systems and techniques described here can be realized in digital electronic 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.

[0096] 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" "computer-readable medium" refers to any computer program product, 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.

[0097] To provide for interaction with a user, the systems and techniques described here can be implemented on a computer having a display device (a LED (light-emitting diode), or OLED (organic LED), or LCD (liquid crystal display) monitor/screen) for displaying information to the user and 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 for 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.

[0098] The systems and techniques described here can be implemented in a computing system that includes a back end component (e.g., as a data server), or that includes a middleware component (e.g., an application server), or that includes a front end component (e.g., a client computer having a graphical user interface or a Web browser through which a user can interact with an implementation of the systems and techniques described here), or any combination of such back end, middleware, or front end components. The components of the system can be interconnected by any form or medium of digital data communication (e.g., a communication network). Examples of communication networks include a local area network ("LAN"), a wide area network ("WAN"), and the Internet.

[0099] The computing system can include clients and servers. A client and server are generally remote from each other and typically interact through a communication network. The relationship of client and server arises by virtue of computer programs running on the respective computers and having a client-server relationship to each other.

[0100] 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 specification.

[0101] In addition, the logic flows depicted in the figures do not require the particular order shown, or sequential order, to achieve desirable results. In addition, other steps may be provided, or steps may be eliminated, from the described flows, and other components may be added to, or removed from, the described systems. Accordingly, other implementations are within the scope of the following claims.

[0102] While certain features of the described implementations have been illustrated as described herein, many modifications, substitutions, changes and equivalents will now occur to those skilled in the art. It is, therefore, to be understood that the appended claims are intended to cover all such modifications and changes as fall within the scope of the implementations. It should be understood that they have been presented by way of example only, not limitation, and various changes in form and details may be made. Any portion of the apparatus and/or methods described herein may be combined in any combination, except mutually exclusive combinations. The implementations described herein can include various combinations and/or sub-combinations of the functions, components and/or features of the different implementations described.

[0103] While example implementations may include various modifications and alternative forms, implementations thereof are shown by way of example in the drawings and will herein be described in detail. It should be understood, however, that there is no intent to limit example implementations to the particular forms disclosed, but on the contrary, example implementations are to cover all modifications, equivalents, and alternatives falling within the scope of the claims. Like numbers refer to like elements throughout the description of the figures.

[0104] Some of the above example implementations are described as processes or methods depicted as flowcharts. Although the flowcharts describe the operations as sequential processes, many of the operations may be performed in parallel, concurrently or simultaneously. In addition, the

order of operations may be re-arranged. The processes may be terminated when their operations are completed, but may also have additional steps not included in the figure. The processes may correspond to methods, functions, procedures, subroutines, subprograms, etc.

[0105] Methods discussed above, some of which are illustrated by the flow charts, may be implemented by hardware, software, firmware, middleware, microcode, hardware description languages, or any combination thereof. When implemented in software, firmware, middleware or microcode, the program code or code segments to perform the necessary tasks may be stored in a machine or computer readable medium such as a storage medium. A processor(s) may perform the necessary tasks

[0106] Specific structural and functional details disclosed herein are merely representative for purposes of describing example implementations. Example implementations, however, be embodied in many alternate forms and should not be construed as limited to only the implementations set forth herein.

[0107] It will be understood that, although the terms first, second, etc. may be used herein to describe various elements, these elements should not be limited by these terms. These terms are only used to distinguish one element from another. For example, a first element could be termed a second element, and, similarly, a second element could be termed a first element, without departing from the scope of example implementations. As used herein, the term and/or includes any and all combinations of one or more of the associated listed items.

[0108] It will be understood that when an element is referred to as being connected or coupled to another element, it can be directly connected or coupled to the other element or intervening elements may be present. In contrast, when an element is referred to as being directly connected or directly coupled to another element, there are no intervening elements 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.).

[0109] The terminology used herein is for the purpose of describing particular implementations only and is not intended to be limiting of example implementations. As used herein, the singular forms a, an and the are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms comprises, comprising, includes and/or including, when used herein, specify the presence of stated features, integers, steps, operations, elements and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components and/or groups thereof.

[0110] It should also be noted that in some alternative implementations, the functions/acts noted may occur out of the order noted in the figures. For example, two figures shown in succession may in fact be executed concurrently or may sometimes be executed in the reverse order, depending upon the functionality/acts involved.

[0111] Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by one of ordinary skill in the art to which example implementations belong. It will be further understood that terms, e.g., those defined in commonly used dictionaries, should be interpreted as having a meaning that is consistent with their meaning in the context of the relevant art and will not be interpreted in an idealized or overly formal sense unless expressly so defined herein.

[0112] Portions of the above example implementations and corresponding detailed description are presented in terms of software, or algorithms and symbolic representations of operation on data bits within a computer memory. These descriptions and representations are the ones by which those of ordinary skill in the art effectively convey the substance of their work to others of ordinary skill in the art. An algorithm, as the term is used here, and as it is used generally, is conceived to be a self-consistent sequence of steps leading to a desired result. The steps are those requiring physical manipulations of physical quantities. Usually, though not necessarily, these quantities take the form of optical, electrical, or magnetic signals capable of being stored, transferred, combined, compared, and otherwise manipulated. It has proven convenient at times, principally for reasons of common usage, to refer to these signals as bits, values, elements, symbols, characters, terms, numbers, or the like.

[0113] In the above illustrative implementations, reference to acts and symbolic representations of operations (e.g., in the form of flowcharts) that may be implemented as program modules or functional processes include routines, programs, objects, components, data structures, etc., that perform particular tasks or implement particular abstract data types and may be described and/or implemented using existing hardware at existing structural elements. Such existing hardware may include one or more Central Processing Units (CPUs), digital signal processors (DSPs), application-specific-integrated-circuits, field programmable gate arrays (FPGAs) computers or the like.

[0114] It should be borne in mind, however, that all of these and similar terms are to be associated with the appropriate physical quantities and are merely convenient labels applied to these quantities. Unless specifically stated otherwise, or as is apparent from the discussion, terms such as processing or computing or calculating or determining of displaying or the like, refer to the action and processes of a computer system, or similar electronic computing device, that manipulates and transforms data represented as physical, electronic quantities within the computer system's registers and memories into other data similarly represented as physical quantities within the computer system memories or registers or other such information storage, transmission or display devices.

[0115] Note also that the software implemented aspects of the example implementations are typically encoded on some form of non-transitory program storage medium or implemented over some type of transmission medium. The program storage medium may be magnetic (e.g., a floppy disk or a hard drive) or optical (e.g., a compact disk read only memory, or CD ROM), and may be read only or random access. Similarly, the transmission medium may be twisted wire pairs, coaxial cable, optical fiber, or some other suitable transmission medium known to the art. The example implementations are not limited by these aspects of any given implementation.

[0116] Lastly, it should also be noted that whilst the accompanying claims set out particular combinations of features described herein, the scope of the present disclosure is not limited to the particular combinations hereafter claimed, but instead extends to encompass any combination

of features or implementations herein disclosed irrespective of whether or not that particular combination has been specifically enumerated in the accompanying claims at this time.

1. A method comprising:
initiating a computing process on a wearable device, the computing process including a plurality of tasks;
identifying a first companion device and determining that the first companion device is available to perform at least one task of the plurality of tasks;
identifying a second companion device and determining that the second companion device is available to perform at least one task of the plurality of tasks;
causing the first companion device to perform a first task of the plurality of tasks including communicating data generated by the wearable device to the first companion device;
causing the second companion device to perform a second task of the plurality of tasks; and
receiving, by the wearable device from the first companion device, a result associated with a completion of the first task and the second task.

2. The method of claim **1**, wherein
the wearable device is communicatively coupled to the second companion device, and
the wearable device is configured to cause the second companion device to perform the second task.

3. The method of claim **1**, wherein
the first companion device is communicatively coupled to the second companion device, and
the first companion device is configured to cause the second companion device to perform the second task.

4. The method of claim **1**, wherein
the first companion device is communicatively coupled to the second companion device, and
the first companion device and the second companion device are configured to synchronize state information associated with the computing process.

5. The method of claim **1**, further comprising:
receiving, by the first companion device from the second companion device, a result associated with a completion of the second task.

6-8. (canceled)

9. The method of claim **1**, wherein
the computing process is initiated by the first companion device, and
initiating the computing process on the wearable device includes receiving a trigger from the first companion device, by the wearable device.

10. The method of claim **1**, wherein
the wearable device includes a first socket,
the first companion device includes a second socket communicatively coupled to the first socket,
the first companion device includes a third socket,
the second companion device includes a fourth socket communicatively coupled to the third socket,
causing the first companion device to perform the first task includes writing an instruction and data to the first socket,
causing the first companion device to perform the first task includes reading data from the third socket, and
receiving the result associated with a completion of the first task includes reading the result from the second socket.

11. The method of claim **1**, wherein the result includes an image, the method further comprising displaying the image on a display of the wearable device.

12. The method of claim **1**, wherein the wearable device is smart glasses,
the first companion device is at least one of another wearable device, a mobile device, a smart phone, a tablet, a server, and a device including a processor and an operating system, and
the second companion device is at least one of another wearable device, a mobile device, a smart phone, a tablet, a server, and a device including a processor and an operating system.

13-14. (canceled)

15. The method of claim **1**, wherein
the first companion device includes a virtual runtime environment,
causing the first companion device to perform the first task includes causing the virtual runtime environment to perform the computing process, and
the result is the completion of the computing process, the method further comprising completing, by the wearable device, the computing process based on the result includes rendering an image on a display of the wearable device.

16. A system comprising:
a wearable device;
a first companion device; and
a second companion device,
the wearable device including:
a device client,
a hardware abstraction layer,
an operating system abstraction layer, and
and at least one peripheral device driver,
the first companion device including a first runtime environment associated with the wearable device,
the second companion device including a second runtime environment associated with the wearable device, and
the system configured to:
initiate a computing process on the wearable device, the computing process including a plurality of tasks;
determine that the first companion device is available to perform at least one task of the plurality of tasks;
determine that the second companion device is available to perform at least one task of the plurality of tasks;
cause the first companion device to perform a first task of the plurality of tasks including communicating data generated by the wearable device to the first companion device;
cause the second companion device to perform a second task of the plurality of tasks; and
receive, by the wearable device from the first companion device, a result associated with a completion of the first task and the second task.

17. The system of claim **16**, wherein the first companion device and the second companion device are communicatively coupled.

18. The system of claim **16**, wherein
the wearable device is communicatively coupled to the second companion device, and

the wearable device is configured to cause the second companion device to perform the second task.

19. The system of claim **16**, wherein

the first companion device is communicatively coupled to the second companion device, and

the first companion device is configured to cause the second companion device to perform the second task.

20. The system of claim **16**, wherein

the first companion device is communicatively coupled to the second companion device, and

the first companion device and the second companion device are configured to synchronize state information associated with the computing process.

21-23. (canceled)

24. The system of claim **16**, wherein the computing process is initiated by the wearable device.

25. The system of claim **16**, wherein

the computing process is initiated by the first companion device, and

initiating the computing process on the wearable device includes receiving a trigger from the first companion device, by the wearable device.

26. The system of claim **16**, wherein

the wearable device includes a first socket,

the first companion device includes a second socket communicatively coupled to the first socket,

the first companion device includes a third socket,

the second companion device includes a fourth socket communicatively coupled to the third socket,

causing the first companion device to perform the first task includes writing an instruction and data to the first socket,

causing the first companion device to perform the first task includes reading data from the third socket, and

receiving the result associated with a completion of the first task includes reading the result from the second socket.

27. The system of claim **16**, wherein the result includes an image, the system further configured to display the image on a display of the wearable device.

28. The system of claim **16**, wherein

the wearable device is smart glasses,

the first companion device is at least one of another wearable device, a mobile device, a smart phone, a tablet, a server, and a device including a processor and an operating system, and

the second companion device is at least one of another wearable device, a mobile device, a smart phone, a tablet, a server, and a device including a processor and an operating system.

29-30. (canceled)

31. The system of claim **16**, wherein

the first companion device includes a virtual runtime environment,

causing the first companion device to perform the first task includes causing the virtual runtime environment to perform the computing process, and

the result is the completion of the computing process, the system further configured to complete, by the wearable device, the computing process based on the result includes rendering an image on a display of the wearable device.

32. A method comprising:

determining, by a first companion device, that the first companion device is available to perform at least one task of a plurality of tasks associated with a computing process;

receiving, by the first companion device from a wearable device, data associated with the computing process generated by the wearable device;

determining, by the first companion device, that a second companion device is available to perform at least one task of the plurality of tasks associated with the computing process;

performing, by the first companion device, a first task of the plurality of tasks;

causing, by the first companion device, a second task of the plurality of tasks to be performed by the second companion device; and

communicating, by the first companion device to the wearable device, a result associated with a completion of the first task and associated with a completion of the second task.

33-50. (canceled)

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