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Ultra-wideband power usage optimization

Abstract

A computing device may determine, via ultra-wideband ranging, that the computing device is proximate to a second computing device paired with the computing device. The computing device may determine that the second computing device is abie to perform ultra-wideband ranging with a particular set of one or more devices. The computing device may, in response to determining that the computing device is proximate to the second computing device and that the second computing device is able to perform ultra-wideband ranging with the particular set of one or more devices, set an ultra-wideband component of the computing device to a power-saving mode.

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Background/Summary

BACKGROUND

(1) Ultra-wideband is a short-range radio-frequency technology for wireless communication that enables computing devices to accurately identify the relative locations of the computing devices to other devices in their immediate vicinity. Computing devices that support ultra-wideband technology may periodically perform ultra-wideband ranging to determine distances of the computing devices to other ultra-wideband-enabled devices and/or to determine the angle of arrival of ultra-wideband signals between the computing devices and other ultra-wideband-enabled devices.

SUMMARY

(2) In general, techniques of this disclosure are directed to optimizing the use of ultra-wideband by computing devices in ways to reduce the amount of power consumed to perform ultra-wideband ranging. A user may use both a first computing device and a second computing device that each periodically performs ultra-wideband ranging. When the first computing device performs ultra-wideband ranging, the first computing device may determine whether the second computing device is proximate to the first computing device. If the first computing device determines that the second computing device is proximate to the first computing device, the first computing device may determine whether the associated second device's ultra-wideband ranging capabilities can be used to accurately determine the proximity of the user to other ultra-wideband-enabled devices. If the first computing device determines that the associated second device's ultra-wideband ranging

capabilities can be used to accurately determine the proximity of the user to other ultra-wideband-enabled devices, the first computing device may reduce the frequency with which the first computing device performs ultra-wideband ranging. By reducing the frequency with which the first computing device performs ultra-wideband ranging, the first computing device may reduce the amount of power consumed during operation while still being able to accurately determine the proximity of the user of the first computing device and the second computing device to other ultra-wideband-enabled devices.

(3) In some aspects, the techniques described herein relate to a method including: determining, by a first computing device and via ultra-wideband ranging, that the first computing device is proximate to a second computing device paired with the first computing device; determining, by the first computing device, that the second computing device is able to perform ultra-wideband ranging with a particular set of one or more devices, and in response to determining that the first computing device is proximate to the second computing device and that the second computing device is able to perform ultra-wideband ranging with the particular set of one or more devices, setting, by the first computing device, an ultra-wideband component of the first computing device to a power-saving mode.

(4) In some aspects, the techniques described herein relate to a computing device that includes: a memory; an ultra-wideband component; an ultra-wideband communication component; and one or more processors communicably coupled to the memory and the ultra-wideband component and configured to: determine, via ultra-wideband ranging, that the computing device is proximate to a second computing device paired with the computing device; determine that the second computing device is able to perform ultra-wideband ranging with a particular set of one or more devices; and in response to determining that the computing device is proximate to the second computing device and that the second computing device is able to perform ultra-wideband ranging with the particular set of one or more devices, set the ultra-wideband component of the computing device to a power-saving mode.

(5) In some aspects, the techniques described herein relate to a computer-readable storage medium storing instructions that, when executed, cause one or more processors of a computing device to: determine, via ultra-wideband ranging, that the computing device is proximate to a second computing device paired with the computing device; determine that the second computing device is able to perform ultra-wideband ranging with a particular set of one or more devices; and in response to determining that the computing device is proximate to the second computing device and that the second computing device is able to perform ultra-wideband ranging with the particular set of one or more devices, set an ultra-wideband component of the computing device to a power-saving mode.

(6) In some aspects, the techniques described herein relate to an apparatus that includes: means for determining, via ultra-wideband ranging, that the computing device is proximate to a second computing device paired with the computing device; means for determining that the second computing device is able to perform ultra-wideband ranging with a particular set of one or more devices; and means for, in response to determining that the computing device is proximate to the second computing device and that the second computing device is able to perform ultra-wideband ranging with the particular set of one or more devices, setting an ultra-wideband component of the apparatus to a power-saving mode.

(7) The details of one or more examples are set forth in the accompanying drawings and the description below. Other features, objects, and advantages of the disclosure will be apparent from the description and drawings, and from the claims.

Description

BRIEF DESCRIPTION OF DRAWINGS

(1) FIG. **1** is a conceptual diagram illustrating environment in which computing devices perform ultra-wideband ranging, in accordance with one or more aspects of the present disclosure.

(2) FIG. **2** is a block diagram illustrating further details of a computing device that performs ultra-wideband ranging, in accordance with one or more aspects of the present disclosure.

(3) FIG. **3** is a flow diagram illustrating an example technique for ultra-wideband optimization, in accordance with aspects of the present disclosure.

(4) FIG. **4** is a flow diagram illustrating example operations of a computing device that performs ultra-wideband ranging, in accordance with one or more aspects of the present disclosure.

DETAILED DESCRIPTION

(5) In general, techniques of this disclosure are directed to optimizing the use of ultra-wideband by computing devices in ways to reduce the amount of power consumed to perform ultra-wideband ranging. A user may carry, wear, or otherwise use a computing device that performs ultra-wideband ranging to periodically determine the distance between the computing device and other ultra-wideband-enabled devices.

(6) The user may use the computing device to perform ultra-wideband ranging with other devices to enable the other devices to detect when the computing device is proximate to the other devices. For example, the user may use the computing device to perform ultra-wideband ranging with an access control system, such as a keyless entry system of a vehicle, so that the computing device may act as a digital key for the vehicle. As the user moves towards a vehicle having a keyless entry system, the user's computing device may perform ultra-wideband ranging with the keyless entry system, so that the keyless entry system may determine the distance of the user of the computing device from the vehicle. When the keyless entry system detects that the user of the computing device is proximate to the vehicle, the keyless entry system may automatically unlock the doors of vehicle.

(7) Increasingly, people may carry, wear, or otherwise use multiple mobile computing devices that each performs ultra-wideband ranging to determine the distances of each of the mobile computing devices to other ultra-wideband-enabled devices. For example, a user may carry a smart phone that performs ultra-wideband ranging while also wearing a wearable device (e.g., a smart watch) that also performs ultra-wideband ranging.

(8) If multiple computing devices, such as both a smart phone and a smart watch are being carried by, worn by, or attached to a single user, the results (e.g., the determined distances to other ultra-wideband-enabled devices) of performing ultra-wideband ranging by each of the computing devices may be very similar to each due to the proximity of the computing devices to each other. As such, it may sometimes be redundant for each of the computing devices being carried by, worn by, or attached to a single user to frequently perform ultra-wideband ranging.

(9) Different computing devices may have different ultra-wideband ranging characteristics. For example, a smart phone may have a greater ultra-wideband range compared with a wearable device. Further, because a wearable device typically has a much smaller battery than a smart phone, performing ultra-wideband ranging may consume a larger percentage of the battery life of a wearable device compared with a smart phone. As such, when a user uses both a wearable device and a smart phone that each performs ultra-wideband ranging, the redundant performance of ultra-wideband ranging by both the wearable device and the smart phone may unnecessarily drain the battery life of the wearable device at a faster rate compared with the smart phone.

(10) In accordance with aspects of the present disclosure, when a first computing device that is being used by a user performs ultra-wideband ranging, the first computing device may determine whether a second computing device that performs ultra-wideband ranging and that is paired to the first computing device is proximate to the first computing device. For example, the first computing device may be a wearable device such as a smart watch and the second computing device may be a

mobile computing device such as a smart phone or a laptop computer, where the first computing device and the second computing device are used by the same user.

(11) If the first computing device determines that the second computing device is proximate to the first computing device, the first computing device may determine whether the second computing device's ultra-wideband ranging capabilities can accurately determine the proximity of the user of the first computing device and the second computing device to other ultra-wideband-enabled devices. If the first computing device determines that the second computing device's ultra-wideband ranging capabilities can accurately determine the proximity of the user of the first computing device and the second computing device to other ultra-wideband-enabled devices, the first computing device may set its ultra-wideband component to a power saving mode, thereby reducing battery usage of the first computing device and prolonging the battery life of the first computing device.

(12) FIG. **1** is a conceptual diagram illustrating environment in which computing devices perform ultra-wideband ranging, in accordance with one or more aspects of the present disclosure. As shown in FIG. **1**, environment **100** includes computing devices **102** and **110** and ultra-wideband (UWB)-enabled devices **120**A-**120**E ("UWB-enabled devices **120**"). Computing devices **102** and **110** and UWB-enabled devices **120** may each be configured to perform ultra-wideband ranging to determine the relative distance to other computing devices within ultra-wideband communications range. In some examples, each of computing devices **102** and **110** and UWB-enabled devices **120** may perform ultra-wideband ranging according to an ultra-wideband communications protocol, such as the Institute of Electrical and Electronics Engineers (IEEE) 802.15.4 protocol, to transmit data across a wide bandwidth, such as bandwidths greater than about 499 megahertz (MHz).

(13) When a pair of computing devices communicate via an ultra-wideband communications protocol, such as the IEEE 802.15.4 protocol, to perform ultra-wideband ranging, the pair of computing devices may exchange timestamped messages via ultra-wideband communications. Each computing device in the pair of computing devices may use the time of flight of the messages to determine the physical distance between the pair of devices and/or an angle between the pair of devices (e.g., an angle of arrival of incoming radio-frequency signals).

(14) Computing device **110** may be a mobile computing device, such as a mobile phone (e.g., a smartphone), a laptop computer, a tablet computer, a wearable computing device, a personal digital assistant (PDA), or any other mobile computing device. Computing device **110** includes ultra-wideband (UWB) component **118** and communication module **114**. UWB component **118** may include hardware, such as circuitry, antenna(s), and the like for handling wireless communications, such as radio-frequency communications, using ultra-wideband communications protocols, such as the IEEE 802.15.4 protocol, to transmit data across a wide bandwidth, such as bandwidths greater than about 499 megahertz (MHz).

(15) UWB component **118** may be configured to periodically perform ultra-wideband ranging to determine location information associated with computing device **110** using ultra-wideband communications. Specifically, UWB component **118** may be configured to perform ultra-wideband ranging to determine one or more devices (e.g., computing device **102**, one or more of devices **120**, etc.) that are within ultra-wideband communications range of computing device **110**, which may be the one or more devices with which UWB component **118** is able to exchange messages via ultra-wideband communications. By exchanging messages via ultra-wideband communications with the one or more devices within ultra-wideband communications range with computing device **110**, UWB component **118** may be able to determine the distance between computing device **110** and each of one or more computing device that are within ultra-wideband communications range of computing device **110**, and may enable each respective computing device of the one or more computing device that are within ultra-wideband communications range of computing device **110** to determine the distance between computing device **110** and the respective computing device.

(16) UWB component **118** may periodically perform ultra-wideband ranging to determine location

information associated with computing device **110**, such as every second, every five seconds, every thirty seconds, every minute, and the like. Communication module **114** may be software that executes at computing device **110** to control the operations of UWB component **118**. For example, communication module **114** may execute to control how frequently UWB component **118** performs ultra-wideband ranging, such as by decreasing how frequently UWB component **118** performs ultra-wideband ranging, increasing how frequently UWB component **118** performs ultra-wideband ranging, and the like.

(17) Computing device **102** may be a mobile computing device, such as a mobile phone (e.g., a smartphone), a laptop computer, a tablet computer, a personal digital assistant (PDA), or any other mobile computing device. In some examples, computing device **102** may be a wearable computing device such as a computerized watch (e.g., a smartwatch), a computerized fitness band/tracker, computerized eyewear, computerized headwear, a computerized glove, or any other type of mobile computing device that can attach to and be worn on a person's body or clothing.

(18) In some of the examples where computing device **102** is a wearable computing device, computing device **102** may include attachment component **106** and electrical housing **105**. Housing **105** of computing device **102** includes a physical portion of a wearable computing device that houses a combination of hardware, software, firmware, and/or other electrical components of computing device **102**. For example, FIG. **1** shows that within housing **105**, computing device **102** may include communication module **104** and UWB component **108**. Housing **105** may also include other hardware components and/or software modules not shown in FIG. **1**, such as one or more processors, memories, operating systems, applications, and the like.

(19) Attachment component **106** may include a physical portion of a wearable computing device that comes in contact with a body (e.g., tissue, muscle, skin, hair, clothing, etc.) of a user when the user is wearing computing device **102** (though, in some examples, portions of housing **105** may also come in contact with the body of the user). For example, in cases where computing device **102** is a watch, attachment component **106** may be a watch band that fits around a user's wrist and comes in contact with the skin of the user. In examples where computing device **102** is eyewear or headwear, attachment component **106** may be a portion of the frame of the eyewear or headwear that fits around a user's head, and when computing device **102** is a glove, attachment component **106** may be the material of the glove that conforms to the fingers and hand of the user. In some examples, computing device **102** can be grasped and held from housing **105** and/or attachment component **106**.

(20) Computing device **102** includes ultra-wideband (UWB) component **108** and communication module **104**. UWB component **108** may include hardware, such as circuitry, antenna(s), and the like for handling wireless communications, such as radio-frequency communications, using ultra-wideband communications protocols, such as the IEEE 802.15.4 protocol, to transmit data across a wide bandwidth, such as bandwidths greater than about 499 megahertz (MHz).

(21) UWB component **108** may be configured to periodically perform ultra-wideband ranging to determine location information associated with computing device **102** using ultra-wideband communications. Specifically, UWB component **108** may be configured to perform ultra-wideband ranging to determine one or more devices (e.g., computing device **102**, one or more of devices **120**, etc.) that are within ultra-wideband communications range of computing device **102**, which may be the one or more devices with which UWB component **108** is able to exchange messages via ultra-wideband communications. By exchanging messages via ultra-wideband communications with the one or more devices within ultra-wideband communications range with computing device **102**, UWB component **108** may be able to determine the distance between computing device **102** and each of one or more computing device that are within ultra-wideband communications range of computing device **102**, and may enable each respective computing device of the one or more computing device that are within ultra-wideband communications range of computing device **102** to determine the distance between computing device **102** and the respective computing device.

(22) UWB component **108** may periodically perform ultra-wideband ranging to determine location information associated with computing device **102**, such as every second, every five seconds, every thirty seconds, every minute, and the like. Communication module **104** may be software that executes at computing device **102** to control the operations of UWB component **108**. For example, communication module **104** may execute to control how frequently UWB component **108** performs ultra-wideband ranging, such as by decreasing how frequently UWB component **108** performs ultra-wideband ranging, increasing how frequently UWB component **108** performs ultra-wideband ranging, and the like.

(23) Ultra-wideband-enabled devices ("UWB-enabled devices") **120** may include any computing devices configured to communicate, via an ultra-wideband protocol such as via the IEEE 802.15.4 protocol, with computing devices **102** and/or **110** as computing devices **102** and/or **110** performs ultra-wideband ranging. UWB-enabled devices **120** may meet the technical specifications put out by the FiRa Consortium and/or the Car Connectivity Consortium. Examples of devices **120** may include smart home devices, vehicle keyless entry systems, point of sale terminals, UWB tags, UWB anchors, proximity sensing devices, computing devices, and the like.

(24) A UWB-enabled device that communicates via ultra-wideband communications with a computing device may be able to determine, based on the communications, the distance of the computing device from the UWB-enabled device. For example, when a computing device (e.g., computing device **102** or computing device **110**) within ultra-wideband range of an UWB-enabled device (e.g., any one of UWB-enabled devices **120**) performs ultra-wideband ranging, the UWB-enabled device may exchange timestamped messages via ultra-wideband communications with the computing device, and may determine the time of flight of the messages to determine the physical distance and/or an angle between the UWB-enabled device and the computing device.

(25) As such, each UWB-enabled device of UWB-enabled devices **120**A may exchange messages via ultra-wideband communications with each computing device within ultra-wideband communications range to determine, based on the messages, the distance of each computing device from the UWB-enabled device. For example, if UWB-enabled device **120**A communicates via ultra-wideband communications with computing device **102** as computing device **102** performs ultra-wideband ranging, both computing device **102** and UWB-enabled device **120**A may be able to determine, based on the ultra-wideband communications, the distance between computing device **102** and UWB-enabled device **120**A.

(26) A UWB-enabled device may therefore be able to detect, based on ultra-wideband communications with other computing devices, computing devices that are proximate (e.g., within a specified distance) to the UWB-enabled device, and may, in response to detecting that a computing device is proximate to the UWB-enabled device, perform one or more actions. For example, if UWB-enabled device **120**A is a keyless entry system for a vehicle, and if computing device **102** acts as a digital key fob for the vehicle, UWB-enabled device **120**A may be able to determine, via ultra-wideband communications, the physical distance between computing device **102** and UWB-enabled device **120**A (e.g., based on the time of flight of messages exchanged between computing device **102** and UWB-enabled device **120**A) in order to determine whether computing device **102** is proximate (e.g., within a specified distance) to the vehicle. When UWB-enabled device **120**A determines, based on ultra-wideband communications, the computing device **102** is proximate to the vehicle, UWB-enabled device **120**A may unlock one or more doors of the vehicle, thereby using ultra-wideband communications to perform keyless entry of the vehicle.

(27) In some examples, UWB-enabled devices may be paired with one or more computing devices. Each computing device paired with an UWB-enabled device may be a computing device that is recognized by the UWB-enabled device as an authorized or known computing device that may enable the UWB-enabled device to, in response to determining that the paired computing device is proximate to the UWB-enabled device, perform one or more actions.

(28) For example, if computing device **102** that acts as a digital car key is paired with UWB-

enabled device **120**A that is a keyless entry system of a vehicle, pairing computing device **102** with UWB-enabled device **120**A may enable computing device to act as a digital car key for UWB-enabled device **120**A. Thus, UWB-enabled device **120**A may, in response to determining that computing device **102** is proximate (e.g., within one meter) to UWB-enabled device **120**A, unlock one or more doors of the vehicle. Similarly, if UWB-enabled device **120**A determines that a computing device that is not paired with UWB-enabled device **120**A is proximate to UWB-enabled device **120**A, UWB-enabled device **120**A may refrain from unlocking one or more doors of the vehicle.

(29) In the example of FIG. **1**, computing device **110** may be paired with, tethered to, or otherwise associated with computing device **102**, so that computing devices **102** and **110** are communicatively coupled. In some examples, computing device **102** may pair with or be tethered to computing device **110** to act as a companion device to computing device **110**. For example, if computing device **102** is a wearable computing device, such as a smart watch, and if computing device **110** is a smartphone, computing device **102** may pair with computing device **110** to act as a companion device to computing device **110**. In some examples, computing devices **102** and **110** may be paired with each other when computing devices **102** and **110** are associated with the same user and/or same user account.

(30) In examples where computing devices **102** and **110** are both used by the same user, the user of computing devices **102** and **110** may wear, attach, and/or carry computing devices **102** and **110** so the computing devices **102** and **110** are with the user. For example, if computing device **102** is a wearable computing device, such as a smartwatch, and if computing device **110** is a smartphone, the user may wear computing device **102** on their body, such as by attaching computing device **102** via attachment component **106** to the user's body or clothing, while also carrying or holding computing device **102** in a pocket, a handbag, with the user's hand, etc.

(31) As the user travels around with both computing devices **102** and **110**, computing device **102** and computing device **110** may both continue to periodically perform ultra-wideband ranging to communicate with one or more of UWB-enabled devices **120** within ultra-wideband communications range of computing devices **102** and **110** to enable one or more of UWB-enabled devices **120** to determine whether computing devices **102** and/or **110** are proximate to the one or more UWB-enabled devices.

(32) However, if the user wears, holds, and/or carries both computing device **102** and **110**, it may be redundant for both computing devices **102** and **110** to periodically perform ultra-wideband ranging because computing devices **102** and **110** are likely to be very close in distance (e.g., within less than a meter) from each other. That is, if one of computing devices **102** and **110** is proximate to a UWB-enabled device, then the other one of computing devices **102** and **110** is likely to also be proximate to the UWB-enabled device.

(33) In examples where the computing device is a mobile computing device powered by a battery, how frequently the computing device performs ultra-wideband ranging may affect the computing device's battery life Specifically, decreasing the frequency with which the computing device performs ultra-wideband ranging may decrease power consumption and increase battery life. In examples where computing device **102** is a wearable device, such as a smartwatch and where computing device **110** is a smartphone, computing device **102** may have a much smaller battery than computing device **110**. Thus, performing ultra-wideband ranging may have a greater impact on computing device **102**'s battery life compared with computing device **110**'s battery life.

(34) In accordance with aspects of the present disclosure, because it may be redundant for both computing devices **102** and **110** to periodically perform ultra-wideband ranging, computing device **102** may, in certain instances, decrease the frequency with which computing device **102** performs ultra-wideband ranging based on determining whether computing device **110**'s ultra-wideband ranging capabilities can be used to accurately determine the proximity of the user of computing devices **102** and **110** to UWB-enabled devices. If computing device **102** determines that computing

device **110**'s ultra-wideband ranging capabilities can be used to accurately determine the proximity of the user of computing devices **102** and **110** to UWB-enabled devices, computing device **102** may reduce the frequency with which computing device **102** performs ultra-wideband ranging, thereby reducing the power usage of UWB component **108** and extending computing device **102**'s battery life.

(35) As part of determining whether computing device **110**'s ultra-wideband ranging capabilities can be used to accurately determine the proximity of the user of computing devices **102** and **110** to UWB-enabled devices **120**, computing device **102** may determine whether computing device **110** that includes UWB component **118** is proximate to computing device **102**. For example, computing device **102** may determine that computing device **110** is proximate to computing device **102** if computing device **110** is less than one meter, less than half a meter, and the like from computing device **102**.

(36) Computing device **102** may determine whether computing device **110** is proximate to computing device **102** using any suitable ranging or proximity detection technique. In one example, computing device **102** may determine whether computing device **110** is proximate to computing device **102** by using UWB component **108** to perform ultra-wideband ranging. That is, computing device **102** may use UWB component **108** to exchange messages with UWB component **118** of computing device **110** via ultra-wideband communications to determine the distance of computing device **110** from computing device **102** based on the time of flight of the messages.

(37) In certain instances, even if computing device **110** is proximate to computing device **102**, computing device **110**'s ultra-wideband ranging capabilities may nevertheless fail to accurately determine the proximity of the user of computing devices **102** and **110** to UWB-enabled devices **120**. In examples where computing device **102** is a smart watch and computing device **110** is a smart phone, the UWB antenna of computing device **102** may be weaker than the UWB antenna of computing device **110** by about 10 decibels (dBs). However, when computing device **102** is worn on the wrist of the user while computing device **110** is being carried in a back pocket of the user's trousers, the body absorption of computing device **110**'s ultra-wideband signals may significantly attenuate ultra-wideband signals from computing device **110**, such as by decreasing the gain of the UWB antenna of computing device **110** by 20-25 dBs, thereby potentially causing computing device **110** to have significantly worse ultra-wideband ranging performance than computing device **102**.

(38) As such, computing device **102** may, in response to determining that computing device **110** is proximate to computing device **102**, determine whether computing device **110** is able to accurately determine the proximity of the user of computing devices **102** and **110** to UWB-enabled devices **120**. Specifically, computing device **102** may select a particular set of one or more UWB-enabled devices and may, in response to determining that computing device **110** is proximate to computing device **102**, determine whether computing device **110** is able to perform ultra-wideband ranging with the particular set of one or more devices.

(39) In some examples, the particular set of one or more devices may be every device paired with both computing device **102** and computing device **110**. That is, computing device **102** may determine if computing device **110** is able to perform ultra-wideband ranging to send and receive messages via ultra-wideband communications with every device paired with both computing device **102** and computing device **110**. For example, if UWB-enabled devices **120**A-**120**C are paired with both computing devices **102** and **110**, computing device **102** may determine if computing device **110** is able to perform ultra-wideband ranging to send and receive messages via ultra-wideband communications with each of UWB-enabled devices **120**A-**120**C. If computing device **102** determines that computing device **110** is able to perform ultra-wideband ranging to send and receive messages via ultra-wideband communications with each of UWB-enabled devices **120**A-**120**C, computing device **102** may determine that computing device **110**'s ultra-wideband ranging capabilities can be used to accurately determine the proximity of the user of computing

devices **102** and **110** to UWB-enabled devices **120**.

(40) Computing device **110** may send, to computing device **102**, an indication of one or more UWB-enabled devices with which computing device **110** is able to send and receive messages via performance of ultra-wideband ranging, and computing device **102** may determine whether the one or more UWB-enabled devices with which computing device **110** is able to send and receive messages via performance of ultra-wideband ranging matches all of the UWB-enabled devices paired with both computing device **102** and computing device **110**. If computing device **102** determines that the one or more UWB-enabled devices with which computing device **102** is able to send and receive messages via performance of ultra-wideband ranging matches all of the UWB-enabled devices paired with both computing device **102** and computing device **110**, computing device **102** may determine that computing device **110**'s ultra-wideband ranging capabilities can be used to accurately determine the proximity of the user of computing devices **102** and **110** to UWB-enabled devices **120**.

(41) In some examples, the particular set of one or more devices may be the one or more devices with which computing device **102** is able to perform ultra-wideband ranging. That is, computing device **102** may determine if computing device **110** is able to perform ultra-wideband ranging to send and receive messages via ultra-wideband communications with every device with which computing device **102** is able to perform ultra-wideband ranging.

(42) For example, if computing device **102** is able to perform ultra-wideband ranging to send and receive messages via ultra-wideband communications with UWB-enabled devices **120**A and **120**B, computing device **102** may determine if computing device **110** is able to perform ultra-wideband ranging to send and receive messages via ultra-wideband communications with UWB-enabled devices **120**A and **120**B. If computing device **102** determines that computing device **110** is able to perform ultra-wideband ranging to send and receive messages via ultra-wideband communications with each of UWB-enabled devices **120**A and **120**B, computing device **102** may determine that computing device **110**'s ultra-wideband ranging capabilities can be used to accurately determine the proximity of the user of computing devices **102** and **110** to UWB-enabled devices **120**.

(43) Computing device **110** may send, to computing device **102**, an indication of one or more UWB-enabled devices with which computing device **110** is able to send and receive messages via performance of ultra-wideband ranging, and computing device **102** may determine whether the one or more UWB-enabled devices with which computing device **110** is able to send and receive messages via performance of ultra-wideband ranging matches the one or more UWB-enabled devices with which computing device **102** is able to send and receive messages via performance of ultra-wideband ranging. If computing device **102** determines that the one or more UWB-enabled devices with which computing device **110** is able to send and receive messages via performance of ultra-wideband ranging matches the one or more UWB-enabled devices with which computing device **102** is able to send and receive messages via performance of ultra-wideband ranging, computing device **102** may determine that computing device **110**'s ultra-wideband ranging capabilities can be used to accurately determine the proximity of the user of computing devices **102** and **110** to UWB-enabled devices **120**.

(44) Computing device **102** may, in response to determining that computing device **110**'s ultra-wideband ranging capabilities can be used to accurately determine the proximity of the user of computing devices **102** and **110** to UWB-enabled devices **120**, set UWB component **108** to a power-saving mode. In some examples, computing device **102** setting UWB component **108** to a power-saving mode includes decreasing the frequency with which UWB component **108** performs ultra-wideband ranging. For example, if UWB component **108** is performing ultra-wideband ranging at a frequency of once every five seconds, once every seven seconds, and the like, computing device **102** may decrease the frequency with which UWB component **108** performs ultra-wideband ranging to once every thirty seconds, once every minute, and the like. By decreasing the frequency with which UWB component **108** performs ultra-wideband ranging,

computing device **102** may therefore, in some examples, perform ultra-wideband ranging less frequently than computing device **110**.

(45) When UWB component **108** is set to the power-saving mode, UWB **108** may continue to periodically perform ultra-wideband ranging to send and receive messages with one or more of UWB-enabled devices **120** at the decreased frequency. As part of periodically performing ultra-wideband ranging while UWB component **108** is in the power-saving mode, computing device **102** may periodically determine whether computing device **110** is proximate to computing device **102**, such as via ultra-wideband ranging as described above, or via any other suitable proximity detection techniques (e.g., via Bluetooth).

(46) If computing device **102** determines that computing device **110** is no longer proximate to computing device **102**, computing device **102** may set UWB component **108** to a normal operating mode, thereby exiting the power-saving mode. In some examples, computing device **102** setting UWB component **108** to a normal operating mode includes increasing the frequency with which UWB component **108** performs ultra-wideband ranging from the frequency with which UWB component **108** performed ultra-wideband ranging while in the power-saving mode. For example, if UWB component **108** is performing ultra-wideband ranging in the power-saving mode at a frequency of once every thirty seconds, once every minute, and the like, computing device **102** may increase the frequency with which UWB component **108** performs ultra-wideband ranging to once every five seconds, once every ten seconds, and the like.

(47) While UWB component **108** is in the power-saving mode, if computing device **102** determines that computing device **110** is proximate to computing device **102**, computing device **102** may determine whether computing device **110**'s ultra-wideband ranging capabilities can be used to accurately determine the proximity of the user of computing devices **102** and **110** to UWB-enabled devices **120**, as described above.

(48) Computing device **110** is able to perform ultra-wideband ranging with a particular set of one or more devices, as described above. If computing device **102** determines that computing device **110**'s ultra-wideband ranging capabilities can be used to accurately determine the proximity of the user of computing devices **102** and **110** to UWB-enabled devices **120**, computing device **102** may enable UWB component **108** to remain in the power-saving mode. If computing device **102** determines that computing device **110**'s ultra-wideband ranging capabilities cannot be used to accurately determine the proximity of the user of computing devices **102** and **110** to UWB-enabled devices **120**, computing device **102** may set UWB component **108** to a normal operating mode, as described above.

(49) FIG. **2** is a block diagram illustrating further details of a computing device **200** that performs ultra-wideband ranging, in accordance with one or more aspects of the present disclosure. Computing device **200** of FIG. **2** is described below as an example of computing device **200** illustrated in FIG. **1**. FIG. **2** illustrates only one particular example of computing device **200**, and many other examples of computing device **200** may be used in other instances and may include a subset of the components included in example computing device **200** or may include additional components not shown in FIG. **2**.

(50) As shown in the example of FIG. **2**, computing device **200** includes one or more processors **240**, one or more input components **242**, one or more communication units **244**, one or more output components **246**, and one or more storage components **248**. Input components **242** include sensor components **214**. Storage components **248** of computing device **200** also include communication module **204**, application modules **224**, and physical devices information store **228**.

(51) Communication channels **250** may interconnect each of the components **240**, **242**, **244**, **246**, **248**, and **214** for inter-component communications (physically, communicatively, and/or operatively). In some examples, communication channels **250** may include a system bus, a network connection, an inter-process communication data structure, or any other method for communicating data.

(52) One or more input components **242** of computing device **200** may receive input. Examples of input are tactile, audio, and video input. Input components **242** of computing device **200**, in one example, includes a presence-sensitive display, touch-sensitive screen, mouse, keyboard, voice responsive system, video camera, microphone or any other type of device for detecting input from a human or machine.

(53) One or more input components **242** include one or more sensor components **214**. Numerous examples of sensor components **214** exist and include any input component configured to obtain environmental information about the circumstances surrounding computing device **200** and/or physiological information that defines the activity state and/or physical well-being of a user of computing device **200**. In some examples, a sensor component may be an input component that obtains physical position, movement, and/or location information of computing device **200**. For instance, sensor components **214** may include one or more location sensors (GPS components, Wi-Fi components, cellular components), one or more temperature sensors, one or more motion sensors (e.g., multi-axial accelerometers, gyros), one or more pressure sensors (e.g., barometer), one or more ambient light sensors, and one or more other sensors (e.g., microphone, camera, infrared proximity sensor, hygrometer, and the like). Other sensors may include a heart rate sensor, magnetometer, glucose sensor, hygrometer sensor, olfactory sensor, compass sensor, step counter sensor, to name a few other non-limiting examples.

(54) One or more output components **246** of computing device **200** may generate output. Examples of output are tactile, audio, and video output. Output components **246** of computing device **200**, in one example, includes a presence-sensitive display, sound card, video graphics adapter card, speaker, a liquid crystal display (LCD), or any other type of device for generating output to a human or machine.

(55) One or more communication units **244** of computing device **200** may communicate with external devices via one or more wired and/or wireless networks by transmitting and/or receiving network signals on the one or more networks. Examples of one or more communication units **244** include a network interface card (e.g., such as 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 one or more communication units **244** may include short wave radios, cellular data radios, wireless network radios, as well as universal serial bus (USB) controllers.

(56) One or more processors **240** may implement functionality and/or execute instructions within computing device **200**. For example, one or more processors **240** on computing device **200** may receive and execute instructions stored by storage components **248** that execute the functionality of modules **204** and **224**. The instructions executed by one or more processors **240** may cause computing device **200** to store information within storage components **248** during program execution. Examples of one or more processors **240** include application processors, display controllers, sensor hubs, and any other hardware configured to function as a processing unit. One or more processors **240** may execute instructions of modules **204** and **224** to cause one or more output components **246** to render portions of content of display data as one of user interface screen shots at one or more output components **246**. That is, modules **204** and **224** may be operable by one or more processors **240** to perform various actions or functions of computing device **200**.

(57) One or more storage components **248** within computing device **200** may store information for processing during operation of computing device **200** (e.g., computing device **200** may store data accessed by modules **204** and **224** during execution at computing device **200**). In some examples, storage component **248** is a temporary memory, meaning that a primary purpose of storage component **248** is not long-term storage. Storage components **248** on computing device **200** may be configured for short-term storage of information as volatile memory and therefore not retain stored contents if powered off. Examples of volatile memories include random access memories (RAM), dynamic random access memories (DRAM), static random access memories (SRAM), and other

forms of volatile memories known in the art.

(58) Storage components **248**, in some examples, also include one or more computer-readable storage media. Storage components **248** may be configured to store larger amounts of information than volatile memory. Storage components **248** may further be configured for long-term storage of information as non-volatile memory space and retain information after power on/off cycles. Examples of non-volatile memories include magnetic hard discs, optical discs, floppy discs, flash memories, or forms of electrically programmable memories (EPROM) or electrically erasable and programmable (EEPROM) memories. Storage components **248** may store program instructions and/or information (e.g., data) associated with modules **204** and **224** as well as devices information store **228**.

(59) Application modules **224** represent all the various individual applications and services executing at computing device **200**. A user of computing device **200** may interact with an interface (e.g., a graphical user interface) associated with one or more application modules **224** to cause computing device **200** to perform a function. Numerous examples of application modules **224** may exist and include a digital car key application, a smart home application, a fitness application, a calendar application, a personal assistant or prediction engine, a search application, a map or navigation application, a transportation service application (e.g., a bus or train tracking application), a social media application, a game application, an e-mail application, a messaging application, an Internet browser application, or any and all other applications that may execute at computing device **200**.

(60) In FIG. **2**, communication module **204** may execute at one or more processors **240** to control the operations of UWB component **208**. For example, communication module **204** may execute at one or more processors **240** to control the frequency with which UWB component **208** performs ultra-wideband ranging, including increasing the frequency with which UWB component **208** performs wideband ranging, decreasing the frequency with which UWB component **208** performs wideband ranging, and/or otherwise setting the frequency with which UWB component **208** performs wideband ranging.

(61) Communication module **204** may execute at one or more processors **240** to determine whether to change the frequency with which UWB component **208** performs ultra-wideband ranging based at least in part on determining whether another computing device having ultra-wideband ranging capabilities that is paired to computing device **202** and that is used by the same user as computing device **202** can be used to accurately determine the proximity of the user of computing device **202** to UWB-enabled devices. For example, if computing device **202** is an example of computing device **102** of FIG. **1**, communication module **204** may determine whether computing device **110** of FIG. **1** can be used to accurately determine the proximity of the user of computing devices **102** and **110** to UWB-enabled devices.

(62) Each time UWB component **208** performs ultra-wideband ranging, computing device **202** may receive information that communication module **204** may use to determine the one or more devices within ultra-wideband range of computing device **202** and the distance between computing device **202** and each of the one or more devices. Such one or more devices within ultra-wideband range of computing device **202** may be devices that are able to exchange messages with computing device **202** via an ultra-wideband protocol, such as the IEEE 802.15.4 protocol. For example, UWB component **208** may exchange timestamped messages with each of the one or more devices.

(63) The messages may indicate, for example, the identity of each of the one or more devices. Communication module **204** may use the identity of each of the one or more devices indicated in the messages received by UWB component **208** to determine whether one of the devices within ultra-wideband range of computing device **202** is a paired device (referred herein as a "paired device"). For example, communication module **204** may compare the identity of each of the one or more devices with the identity of the paired device that is stored in devices information store **228**. If communication module **204** determines that none of the one or more devices within ultra-

wideband range of UWB component **208** is a paired device, communication module **204** may refrain from changing the frequency with which UWB component **208** performs ultra-wideband ranging.

(64) Communication module **204** may use the time of flight of the messages exchanged between UWB component **208** and each of the one or more devices within ultra-wideband range of UWB component **208** to determine the physical distances and/or angles of arrival between computing device **202** and each of the one or more devices. As such, if communication module **204** determines that the one or more devices within ultra-wideband range of UWB component **208** includes a paired device, communication module **204** may determine the distance between computing device **202** and the paired device.

(65) Specifically, communication module **204** may determine if the paired device is proximate to computing device **202**. Communication module **204** may determine that the paired device is proximate to computing device **202** is proximate to computing device **202** if the distance between computing device **202** and the paired device is within (e.g., less than or equal to) a proximity threshold. Examples of such a proximity threshold may be one meter, half of a meter, twenty centimeters, and the like. If communication module **204** determines that the paired device is not proximate to computing device **202**, communication module **204** may refrain from changing the frequency with which UWB component **208** performs ultra-wideband ranging.

(66) If communication module **204** determines that the paired device is proximate to computing device **202**, communication module **204** may determine whether the paired device is able to accurately determine the proximity of the user of computing device **202** to UWB-enabled devices **120**. Specifically, communication module **204** may select a particular set of one or more UWB-enabled devices and may, in response to determining that the paired device is proximate to computing device **202**, determine whether the paired device is able to perform ultra-wideband ranging with the particular set of one or more devices selected by communication module **204**.

(67) In some examples, the particular set of one or more devices may be every device paired, via ultra-wideband communications, with both computing device **202** and the paired device. That is, computing device **102** may determine if the paired device is able to perform ultra-wideband ranging to send and receive messages via ultra-wideband communications with every device paired with both computing device **202** and the paired device.

(68) For example, devices information store **228** may store the identity of every device paired, via ultra-wideband communications, with both computing device **202** and the paired device. Computing device **202** may receive, from the paired device, indications of the identity of every device within ultra-wideband range of the paired device, as determined during the most recent performance of ultra-wideband ranging by the paired device. Computing device **202** may therefore compare the identity of every device within ultra-wideband range of the paired device with the identity of every device paired, via ultra-wideband communications, with both computing device **202** and the paired device stored in devices information store **228** to determine whether the paired device is able to perform ultra-wideband ranging to send and receive messages via ultra-wideband communications with every device paired with both computing device **202** and the paired device.

(69) In some examples, computing device **202** may receive the identity of every device within ultra-wideband range of the paired device when computing device **202** communicates with the paired device during ultra-wideband ranging. In some examples, computing device **202** may receive the identity of every device within ultra-wideband range of the paired device when computing device **202** communicates with the paired device using a communication protocol over than ultra-wideband ranging, such as Bluetooth Low Energy or Wi-Fi.

(70) If communication module **204** determines that the paired device is not able to perform ultra-wideband ranging to send and receive messages via ultra-wideband communications with every device paired with both computing device **202** and the paired device, communication module **204** may determine that the paired device is unable to accurately determine the proximity of the user of

computing device **202** to UWB-enabled devices, and may refrain from changing the frequency with which UWB component **208** performs ultra-wideband ranging. If communication module **204** determines that the paired device is able to perform ultra-wideband ranging to send and receive messages via ultra-wideband communications with every device paired with both computing device **202** and the paired device, communication module **204** may determine that the paired device is able to accurately determine the proximity of the user of computing device **202** to UWB-enabled devices.

(71) In some examples, the particular set of one or more devices may be every device that is within ultra-wideband range of UWB component **208**. That is, computing device **202** may determine if the paired device is able to perform ultra-wideband ranging to send and receive messages via ultra-wideband communications with every device within ultra-wideband range of UWB component **208**.

(72) Computing device **202** may therefore compare the identity of every device within ultra-wideband range of the paired device with the identity of every device that is within ultra-wideband range of UWB component **208**, as determined by the most recent ultra-wideband ranging performed by UWB component **208**, to determine whether the paired device is able to perform ultra-wideband ranging to send and receive messages via ultra-wideband communications with every device that is currently within ultra-wideband range of UWB component **208**.

(73) If computing device **202** determines that he paired device is able to perform ultra-wideband ranging to send and receive messages via ultra-wideband communications with every device that is within ultra-wideband range of UWB component **208**, communication module **204** may determine that the paired device is unable to accurately determine the proximity of the user of computing device **202** to UWB-enabled devices, and may refrain from changing the frequency with which UWB component **208** performs ultra-wideband ranging. If communication module **204** determines that the paired device is able to perform ultra-wideband ranging to send and receive messages via ultra-wideband communications with every device that is within ultra-wideband range of UWB component **208**, communication module **204** may determine that the paired device is able to accurately determine the proximity of the user of computing device **202** to UWB-enabled devices.

(74) If communication module **204** determines that the paired device is able to accurately determine the proximity of the user of computing device **202** to UWB-enabled devices, communication module **204** may set UWB component **208** to a power-saving mode. In some examples, communication module **204** setting UWB component **208** to a power-saving mode includes decreasing the frequency with which UWB component **208** performs ultra-wideband ranging. For example, if UWB component **208** is performing ultra-wideband ranging at a frequency of once every five seconds, once every seven seconds, and the like, communication module **204** may decrease the frequency with which UWB component **108** performs ultra-wideband ranging to once every thirty seconds, once every minute, and the like. By decreasing the frequency with which UWB component **208** performs ultra-wideband ranging, computing device **202** may therefore, in some examples, perform ultra-wideband ranging less frequently than the paired device.

(75) When UWB component **208** is set to the power-saving mode, UWB **208** may continue to periodically perform ultra-wideband ranging to send and receive messages with one or more UWB-enabled devices within ultra-wideband range at the decreased frequency. As part of periodically performing ultra-wideband ranging while UWB component **208** is in the power-saving mode, communication module **204** may determine whether the paired device is proximate to computing device **202**, as described above.

(76) If communication module **204** determines that the paired device is no longer proximate to computing device **202**, communication module **204** may set UWB component **208** to a normal operating mode, thereby exiting the power-saving mode. In some examples, communication module **204** setting UWB component **208** to a normal operating mode includes increasing the frequency with which UWB component **208** performs ultra-wideband ranging from the frequency

with which UWB component **208** performed ultra-wideband ranging while in the power-saving mode. For example, if UWB component **208** is performing ultra-wideband ranging in the power-saving mode at a frequency of once every thirty seconds, once every minute, and the like, communication module **204** may increase the frequency with which UWB component **208** performs ultra-wideband ranging to once every five seconds, once every ten seconds, and the like.

(77) While UWB component **208** is in the power-saving mode, if communication module **204** determines that the paired device is proximate to computing device **202**, communication module **204** may determine whether the paired device's ultra-wideband ranging capabilities can be used to accurately determine the proximity of the user of computing device **202** to UWB-enabled devices, as described above.

(78) If computing device determines that the paired device's ultra-wideband ranging capabilities can be used to accurately determine the proximity of the user of computing device **202** to UWB-enabled devices, communication module **204** may enable UWB component **208** to remain in the power-saving mode. If computing device determines that the paired device's ultra-wideband ranging capabilities cannot be used to accurately determine the proximity of the user of computing device **202** to UWB-enabled devices, communication module **204** may set UWB component **208** to a normal operating mode, as described above.

(79) In some examples, communication module **204** may use additional or alternative techniques to change the frequency with which UWB component **208** performs ultra-wideband ranging. In some examples, communication module **204** may perform activity recognition to recognize the physical activity being performed by the user of computing device **202** and may change the frequency with which UWB component **208** performs ultra-wideband ranging based on the physical activity being performed by the user.

(80) For example, communication module **204** may use data generated by one or more sensor components **214** to determine whether the user is moving (e.g., walking, running, riding in a vehicle, etc.) or whether the user is not moving (e.g., sitting, standing, etc.). If the user is not moving, then it may be unnecessary to determine whether the user is moving towards a UWB-enabled device. As such, if communication module **204** determines that the user is not moving, communication module **204** may set UWB component **208** to a power saving mode. Similarly, if communication module **204** determines that the user is moving, communication module **204** may set UWB component **208** to a normal operating mode

(81) FIG. **3** is a flow diagram illustrating an example technique for ultra-wideband optimization, in accordance with aspects of the present disclosure. For purposes of illustration only, the example operations are described below within the context of FIG. **1**, where computing device **102** is a wearable device that can be tethered to computing device **110**. When computing device **102** is a wearable device, computing device **102** may be worn or otherwise attached to the user of computing device **102** and may be in an unlocked state.

(82) As shown in FIG. **3**, computing device **102** may determine whether computing device **102** is connected to computing device **110** (**302**). Computing device **102** may be connected to computing device **110** if computing device **102** is tethered to computing device **110** or otherwise communicably coupled to computing device **110** via wireless communications, such as via ultra-wideband, Bluetooth, Bluetooth Low Energy, Wi-Fi, and the like. If computing device **102** determines that computing device **102** is not connected to computing device **110**, computing device **102** may perform ultra-wideband ranging via UWB component **108** as normal (**312**).

(83) If computing device **102** determines that computing device **102** is connected to computing device **110**, computing device **102** may, as part of periodically performing ultra-wideband ranging with UWB-enabled devices **120** using UWB component **108**, periodically perform ultra-wideband ranging with computing device **110** to determine the distance between computing devices **102** and **110** (**304**). Computing device **102** may determine, based on the distance between computing devices **102** and **110**, whether computing device **102** is proximate to computing device **110** (**306**).

(84) If computing device **102** determines that computing device **102** is not proximate to computing device **110**, computing device **102** may perform ultra-wideband ranging via UWB component **108** as normal (**312**). If computing device determines that computing device **102** is proximate to computing device **110**, computing device **102** may determine whether computing device **110** can, when performing ultra-wideband ranging, communicate, via ultra-wideband communications, with all UWB-enabled devices that are paired with both computing devices **102** and **110** or whether computing device **110** can, when performing ultra-wideband ranging, communicate, via ultra-wideband communications, with all UWB-enabled devices with which computing device **102** is able to communicate via ultra-wideband communications (**308**).

(85) If computing device **102** determines that computing device **110** is not able to communicate, via ultra-wideband communications, with all UWB-enabled devices that are paired with both computing devices **102** and **110** and that computing device **110** is not able to communicate, via ultra-wideband communications, with all UWB-enabled devices with which computing device **102** is able to communicate via ultra-wideband communications, computing device **102** may perform ultra-wideband ranging via UWB component **108** as normal (**312**). If computing device **102** determines that computing device **110** is able to communicate, via ultra-wideband communications, with all UWB-enabled devices that are paired with both computing devices **102** and **110** or that computing device **110** is able to communicate, via ultra-wideband communications, with all UWB-enabled devices with which computing device **102** is able to communicate via ultra-wideband communications, computing device **102** may set UWB component **108** to a power-saving mode, thereby decreasing the frequency with which UWB component **108** periodically performs ultra-wideband ranging (**310**). Computing device **102** may therefore return to periodically performing ultra-wideband ranging with UWB-enabled devices **120** using UWB component **108**, including periodically perform ultra-wideband ranging with computing device **110** to determine the distance between computing devices **102** and **110** (**304**).

(86) FIG. **4** is a flow diagram illustrating example operations of a computing device that performs ultra-wideband ranging, in accordance with one or more aspects of the present disclosure. For purposes of illustration only, the example operations are described below within the context of computing device **110** of FIG. **1**.

(87) As shown in FIG. **4**, a first computing device **102** may determine, via ultra-wideband ranging and with or without determining the angel of arrival, that the first computing device **102** is proximate to a second computing device **110** paired with the first computing device **102** (**402**). The first computing device **102** may determine that the second computing device **110** is able to perform ultra-wideband ranging with a particular set of one or more devices (**404**). The first computing device **102** may, in response to determining that the first computing device **102** is proximate to the second computing device **110** and that the second computing device **110** is able to perform ultra-wideband ranging with the particular set of one or more devices, set an ultra-wideband component **108** of the first computing device **102** to a power-saving mode (**406**).

(88) In some examples, the particular set of one or more devices comprises all ultra-wideband-enabled devices that are paired with both the first computing device **102** and the second computing device **110**. In some examples, the particular set of one or more devices comprises all ultra-wideband-enabled devices with which the first computing device **102** is able to perform ultra-wideband ranging.

(89) In some examples, the first computing device **102** may, in response to setting the ultra-wideband component **108** to the power-saving mode, determine, via ultra-wideband ranging, that the first computing device **102** is no longer proximate to the second computing device **110**. The first computing device **102** may, in response to determining that the first computing device **102** is no longer proximate to the second computing device **110**, set the ultra-wideband component **108** to a normal operating mode for performing ultra-wideband ranging.

(90) In some examples, first computing device **102** may, in response to setting the ultra-wideband

component to the power-saving mode, determine, by the first computing device **102** and via ultra-wideband ranging, that the first computing device **102** is still proximate to the second computing device **110** and that the second computing device **110** is not able to perform ultra-wideband ranging with the particular set of one or more devices. The first computing device **102** may, in response to determining that the second computing device **110** is not able to perform ultra-wideband ranging with the particular set of one or more devices, set the ultra-wideband component **108** to a normal operating mode for performing ultra-wideband ranging.

(91) In some examples, to set the ultra-wideband component **108** to the power-saving mode, the first computing device **102** may decrease a frequency with which the ultra-wideband component **108** performs ultra-wideband ranging. In some examples, to the ultra-wideband component to the normal operating mode, the first computing device **102** may increase a frequency with which the ultra-wideband component performs for performing ultra-wideband ranging.

(92) In some examples, to determine that the first computing device **102** is proximate to the second computing device **110**, computing device **102** may periodically determine, using the ultra-wideband component **108**, a respective physical distance between the first computing device **102** and each of one or more ultra-wideband-enabled devices that are within ultra-wideband range of the first computing device **102**.

(93) In some examples, computing device **102** may recognize a physical activity being performed by a user associated with the first computing device **102** and the second computing device **110**. Computing device may, in response to recognizing the physical activity being performed by the user associated with the first computing device **102** and the second computing device **110**, change a frequency with which the ultra-wideband component **108** performs ultra-wideband ranging.

(94) In some examples, the first computing device **102** comprises a wearable device and wherein the second computing device comprises a smart phone.

(95) This disclosure includes the following examples.

(96) Example 1: A method includes determining, by a first computing device and via ultra-wideband ranging, that the first computing device is proximate to a second computing device paired with the first computing device; determining, by the first computing device, that the second computing device is able to perform ultra-wideband ranging with a particular set of one or more devices; and in response to determining that the first computing device is proximate to the second computing device and that the second computing device is able to perform ultra-wideband ranging with the particular set of one or more devices, setting, by the first computing device, an ultra-wideband component of the first computing device to a power-saving mode.

(97) Example 2: The method of example 1, wherein the particular set of one or more devices comprises all ultra-wideband-enabled devices that are paired with both the first computing device and the second computing device.

(98) Example 3: The method of example 1, wherein the particular set of one or more devices comprises all ultra-wideband-enabled devices with which the first computing device is able to perform ultra-wideband ranging.

(99) Example 4: The method of any of examples 1-3, further includes in response to setting the ultra-wideband component to the power-saving mode, determining, by the first computing device and via ultra-wideband ranging, that the first computing device is no longer proximate to the second computing device; and in response to determining that the first computing device is no longer proximate to the second computing device, setting, by the first computing device, the ultra-wideband component to a normal operating mode for performing ultra-wideband ranging.

(100) Example 5: The method of any of examples 1-3, further includes in response to setting the ultra-wideband component to the power-saving mode, determining, by the first computing device and via ultra-wideband ranging, that the first computing device is still proximate to the second computing device and that the second computing device is not able to perform ultra-wideband ranging with the particular set of one or more devices; and in response to determining that the

second computing device is not able to perform ultra-wideband ranging with the particular set of one or more devices, setting, by the first computing device, the ultra-wideband component to a normal operating mode for performing ultra-wideband ranging.

(101) Example 6: The method of any of examples 1-5, wherein setting the ultra-wideband component to the power-saving mode further comprises: decreasing, by the first computing device, a frequency with which the ultra-wideband component performs ultra-wideband ranging.

(102) Example 7: The method of any of examples 4-6, wherein setting the ultra-wideband component to the normal operating mode further comprises: increasing, by the first computing device, a frequency with which the ultra-wideband component performs for performing ultra-wideband ranging.

(103) Example 8: The method of any of examples 1-7, wherein determining that the first computing device is proximate to the second computing device further comprises: periodically determining, by the first computing device and using the ultra-wideband component, a respective physical distance between the first computing device and each of one or more ultra-wideband-enabled devices that are within ultra-wideband range of the first computing device.

(104) Example 9: The method of any of examples 1-8, further includes recognizing, by the first computing device, a physical activity being performed by a user associated with the first computing device and the second computing device; and in response to recognizing the physical activity being performed by the user associated with the first computing device and the second computing device, changing, by the first computing device, a frequency with which the ultra-wideband component performs ultra-wideband ranging.

(105) Example 10: The method of any of examples 1-9, wherein the first computing device comprises a wearable device and wherein the second computing device comprises a smart phone.

(106) Example 11: A computing device includes: a memory; an ultra-wideband component; an ultra-wideband communication component; and one or more processors communicably coupled to the memory and the ultra-wideband component and configured to: determine, via ultra-wideband ranging, that the computing device is proximate to a second computing device paired with the computing device; determine that the second computing device is able to perform ultra-wideband ranging with a particular set of one or more devices; and in response to determining that the computing device is proximate to the second computing device and that the second computing device is able to perform ultra-wideband ranging with the particular set of one or more devices, set the ultra-wideband component of the first computing device to a power-saving mode.

(107) Example 12: The computing device of example 11, wherein the particular set of one or more devices comprises all ultra-wideband-enabled devices that are paired with both the computing device and the second computing device.

(108) Example 13: The computing device of example 11, wherein the particular set of one or more devices comprises all ultra-wideband-enabled devices with which the computing device is able to perform ultra-wideband ranging.

(109) Example 14: The computing device of any of examples 11-13, wherein the one or more processors are further configured to: in response to setting the ultra-wideband component to the power-saving mode, determine, via ultra-wideband ranging, that the computing device is no longer proximate to the second computing device; and in response to determining that the computing device is no longer proximate to the second computing device, set the ultra-wideband component to a normal operating mode for performing ultra-wideband ranging.

(110) Example 15: The computing device of any of examples 11-13, wherein the one or more processors are further configured to: in response to setting the ultra-wideband component to the power-saving mode, determine, via ultra-wideband ranging, that the computing device is still proximate to the second computing device and that the second computing device is not able to perform ultra-wideband ranging with the particular set of one or more devices; and in response to determining that the second computing device is not able to perform ultra-wideband ranging with

the particular set of one or more devices, set the ultra-wideband component to a normal operating mode for performing ultra-wideband ranging.

(111) Example 16: The computing device of any of examples 11-15, wherein to set the ultra-wideband component to the power-saving mode, the one or more processors are further configured to: decrease a frequency with which the ultra-wideband component performs ultra-wideband ranging.

(112) Example 17: The computing device of any of examples 14-16, wherein to set the ultra-wideband component to the normal operating mode, the one or more processors are further configured to: increase a frequency with which the ultra-wideband component performs for performing ultra-wideband ranging.

(113) Example 18: The computing device of any of examples 11-17, wherein to determine that the computing device is proximate to the second computing device, the one or more processors are further configured to: periodically determine, using the ultra-wideband component, a respective physical distance between the computing device and each of one or more ultra-wideband-enabled devices that are within ultra-wideband range of the computing device.

(114) Example 19: The computing device of any of examples 11-18, wherein the one or more processors are further configured to: recognize a physical activity being performed by a user associated with the computing device and the second computing device; and in response to recognizing the physical activity being performed by the user associated with the computing device and the second computing device, change a frequency with which the ultra-wideband component performs ultra-wideband ranging.

(115) Example 20: A computer-readable storage medium storing instructions that, when executed, cause one or more processors of a computing device to: determine, via ultra-wideband ranging, that the computing device is proximate to a second computing device paired with the computing device; determine that the second computing device is able to perform ultra-wideband ranging with a particular set of one or more devices; and in response to determining that the computing device is proximate to the second computing device and that the second computing device is able to perform ultra-wideband ranging with the particular set of one or more devices, set an ultra-wideband component of the first computing device to a power-saving mode.

(116) In one or more examples, the functions described may be implemented in hardware, software, firmware, or any combination thereof. If implemented in software, the functions may be stored on or transmitted over, as one or more instructions or code, a computer-readable medium and executed by a hardware-based processing unit. Computer-readable media may include computer-readable storage media, which corresponds to a tangible medium such as data storage media, or communication media including any medium that facilitates transfer of a computer program from one place to another, e.g., according to a communication protocol. In this manner, computer-readable media generally may correspond to (1) tangible computer-readable storage media, which is non-transitory or (2) a communication medium such as a signal or carrier wave. Data storage media may be any available media that can be accessed by one or more computers or one or more processors to retrieve instructions, code and/or data structures for implementation of the techniques described in this disclosure. A computer program product may include a computer-readable medium.

(117) By way of example, and not limitation, such computer-readable storage media can comprise RAM, ROM, EEPROM, CD-ROM or other optical disk storage, magnetic disk storage, or other magnetic storage devices, flash memory, or any other medium that can be used to store desired program code in the form of instructions or data structures and that can be accessed by a computer. Also, any connection is properly termed a computer-readable medium. For example, if instructions are transmitted from a website, server, or other remote source using a coaxial cable, fiber optic cable, twisted pair, digital subscriber line (DSL), or wireless technologies such as infrared, radio, and microwave, then the coaxial cable, fiber optic cable, twisted pair, DSL, or wireless

technologies such as infrared, radio, and microwave are included in the definition of medium. It should be understood, however, that computer-readable storage media and data storage media do not include connections, carrier waves, signals, or other transient media, but are instead directed to non-transient, tangible storage media. Disk and disc, as used, includes compact disc (CD), laser disc, optical disc, digital versatile disc (DVD), floppy disk and Blu-ray disc, where disks usually reproduce data magnetically, while discs reproduce data optically with lasers. Combinations of the above should also be included within the scope of computer-readable media.

(118) Instructions may be executed by one or more processors, such as one or more digital signal processors (DSPs), general purpose microprocessors, application specific integrated circuits (ASICs), field programmable logic arrays (FPGAs), or other equivalent integrated or discrete logic circuitry. Accordingly, the term "processor," as used may refer to any of the foregoing structure or any other structure suitable for implementation of the techniques described. In addition, in some aspects, the functionality described may be provided within dedicated hardware and/or software modules. Also, the techniques could be fully implemented in one or more circuits or logic elements.

(119) The techniques of this disclosure may be implemented in a wide variety of devices or apparatuses, including a wireless handset, an integrated circuit (IC) or a set of ICs (e.g., a chip set). Various components, modules, or units are described in this disclosure to emphasize functional aspects of devices configured to perform the disclosed techniques, but do not necessarily require realization by different hardware units. Rather, as described above, various units may be combined in a hardware unit or provided by a collection of interoperative hardware units, including one or more processors as described above, in conjunction with suitable software and/or firmware.

(120) It is to be recognized that depending on the embodiment, certain acts or events of any of the methods described herein can be performed in a different sequence, may be added, merged, or left out altogether (e.g., not all described acts or events are necessary for the practice of the method). Moreover, in certain embodiments, acts or events may be performed concurrently, e.g., through multi-threaded processing, interrupt processing, or multiple processors, rather than sequentially.

(121) In some examples, a computer-readable storage medium includes a non-transitory medium. In some examples, the term "non-transitory" indicates that the storage medium is not embodied in a carrier wave or a propagated signal. In certain examples, a non-transitory storage medium may store data that can, over time, change (e.g., in RAM or cache). Although certain examples are described as outputting various information for display, techniques of the disclosure may output such information in other forms, such as audio, holographical, or haptic forms, to name only a few examples, in accordance with techniques of the disclosure.

(122) Various examples have been described. These and other examples are within the scope of the following claims.

Claims

1. A method comprising: determining, by a first computing device and via ultra-wideband ranging, that the first computing device is proximate to a second computing device paired with the first computing device; determining, by the first computing device, that the second computing device is able to perform ultra-wideband ranging with a particular set of one or more devices; in response to determining that the first computing device is proximate to the second computing device and that the second computing device is able to perform ultra-wideband ranging with the particular set of one or more devices, setting, by the first computing device, an ultra-wideband component of the first computing device to a power-saving mode; after setting the ultra-wideband component to the power-saving mode, determining, by the first computing device and via ultra-wideband ranging, that the first computing device is still proximate to the second computing device and that the second computing device is not able to perform ultra-wideband ranging with the particular set of

one or more devices; and in response to determining that the second computing device is not able to perform ultra-wideband ranging with the particular set of one or more devices, setting, by the first computing device, the ultra-wideband component to a normal operating mode for performing ultra-wideband ranging.

2. The method of claim 1, wherein the particular set of one or more devices comprises all ultra-wideband-enabled devices that are paired with both the first computing device and the second computing device.

3. The method of claim 1, wherein the particular set of one or more devices comprises all ultra-wideband-enabled devices with which the first computing device is able to perform ultra-wideband ranging.

4. The method of claim 1, further comprising: in response to setting the ultra-wideband component to the power-saving mode, determining, by the first computing device and via ultra-wideband ranging, that the first computing device is no longer proximate to the second computing device; and in response to determining that the first computing device is no longer proximate to the second computing device, setting, by the first computing device, the ultra-wideband component to a normal operating mode for performing ultra-wideband ranging.

5. The method of claim 1, wherein setting the ultra-wideband component to the power-saving mode further comprises: decreasing, by the first computing device, a frequency with which the ultra-wideband component performs ultra-wideband ranging.

6. The method of claim 4, wherein setting the ultra-wideband component to the normal operating mode further comprises: increasing, by the first computing device, a frequency with which the ultra-wideband component performs ultra-wideband ranging.

7. The method of any of claim 1, wherein determining that the first computing device is proximate to the second computing device further comprises: periodically determining, by the first computing device and using the ultra-wideband component, a respective physical distance between the first computing device and each of one or more ultra-wideband-enabled devices that are within ultra-wideband range of the first computing device.

8. The method of claim 1, further comprising: recognizing, by the first computing device, a physical activity being performed by a user associated with the first computing device and the second computing device; and in response to recognizing the physical activity being performed by the user associated with the first computing device and the second computing device, changing, by the first computing device, a frequency with which the ultra-wideband component performs ultra-wideband ranging.

9. The method of claim 1, wherein the first computing device comprises a wearable device and wherein the second computing device comprises a smart phone.

10. A computing device includes: a memory; an ultra-wideband component; an ultra-wideband communication component; and one or more processors communicably coupled to the memory and the ultra-wideband component and configured to: determine, via ultra-wideband ranging, that the computing device is proximate to a second computing device paired with the computing device; determine that the second computing device is able to perform ultra-wideband ranging with a particular set of one or more devices; in response to determining that the computing device is proximate to the second computing device and that the second computing device is able to perform ultra-wideband ranging with the particular set of one or more devices, set the ultra-wideband component of the computing device to a power-saving mode; after setting the ultra-wideband component to the power-saving mode, determine, via ultra-wideband ranging, that the computing device is still proximate to the second computing device and that the second computing device is not able to perform ultra-wideband ranging with the particular set of one or more devices; and in response to determining that the second computing device is not able to perform ultra-wideband ranging with the particular set of one or more devices, set the ultra-wideband component to a normal operating mode for performing ultra-wideband ranging.

11. The computing device of claim 10, wherein the particular set of one or more devices comprises all ultra-wideband-enabled devices that are paired with both the computing device and the second computing device.

12. The computing device of claim 10, wherein the particular set of one or more devices comprises all ultra-wideband-enabled devices with which the computing device is able to perform ultra-wideband ranging.

13. The computing device of claim 10, wherein the one or more processors are further configured to: in response to setting the ultra-wideband component to the power-saving mode, determine, via ultra-wideband ranging, that the computing device is no longer proximate to the second computing device; and in response to determining that the computing device is no longer proximate to the second computing device, set the ultra-wideband component to a normal operating mode for performing ultra-wideband ranging.

14. The computing device of claim 10, wherein to set the ultra-wideband component to the power-saving mode, the one or more processors are further configured to: decrease a frequency with which the ultra-wideband component performs ultra-wideband ranging.

15. The computing device of any of claim 13, wherein to set the ultra-wideband component to the normal operating mode, the one or more processors are further configured to: increase a frequency with which the ultra-wideband component performs ultra-wideband ranging.

16. The computing device of claim 10, wherein to determine that the computing device is proximate to the second computing device, the one or more processors are further configured to: periodically determine, using the ultra-wideband component, a respective physical distance between the computing device and each of one or more ultra-wideband-enabled devices that are within ultra-wideband range of the computing device.

17. The computing device of claim 16, wherein the one or more processors are further configured to: recognize a physical activity being performed by a user associated with the computing device and the second computing device; and in response to recognizing the physical activity being performed by the user associated with the computing device and the second computing device, change a frequency with which the ultra-wideband component performs ultra-wideband ranging.

18. A non-transitory computer-readable storage medium storing instructions that, when executed, cause one or more processors of a computing device to: determine, via ultra-wideband ranging, that the computing device is proximate to a second computing device paired with the computing device; determine that the second computing device is able to perform ultra-wideband ranging with a particular set of one or more devices; in response to determining that the computing device is proximate to the second computing device and that the second computing device is able to perform ultra-wideband ranging with the particular set of one or more devices, set an ultra-wideband component of the computing device to a power-saving mode; after setting the ultra-wideband component to the power-saving mode, determine, via ultra-wideband ranging, that the computing device is still proximate to the second computing device and that the second computing device is not able to perform ultra-wideband ranging with the particular set of one or more devices; and in response to determining that the second computing device is not able to perform ultra-wideband ranging with the particular set of one or more devices, set the ultra-wideband component to a normal operating mode for performing ultra-wideband ranging.