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METHOD TO INCREASE NAVIGATION LOCATION ACCURACY WITH A TARGET ENDPOINT

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ABSTRACT

A system is described that enables a computing device A (e.g., portable device or mobile device) to more accurately determine the location of the computing device relative to a computing device B (e.g., user equipment or handheld device) by using Bluetooth® low energy (BLE) signals. Computing device A may first generate a key (e.g., a random identifier string or a unique key) and push the key to a server. Computing device B may retrieve the key from the server. Once both devices have the key, computing device A may use GPS to find an approximate location of computing device B. As computing device A gets closer to computing device B, computing device A may begin broadcasting the key using BLE signals. If computing device B determines that the key received via BLE signals matches the key that was published to the server, computing device A may utilize received signal strength indication (RSSI) data to determine the current distance between computing device A and computing device B. Further, computing device A may determine a direction of computing device B relative to computing device A by calculating the angle of incidence. In this way, computing device A may more accurately determine the location of computing device A relative to computing device B.

DESCRIPTION

GPS tracking is a common feature for computing devices. However, existing computing devices with GPS alone are typically accurate to only within 10 meters radius under the open sky and may not be able to determine a location or may have very poor location accuracy when the computing device is located indoors, which may make it difficult to locate computing devices. As such, it would be desirable to improve the accuracy of the determined location of computing devices including the location of the computing devices relative to other computing devices. Techniques are described that enable a computing device to more accurately determine the location of a computing device relative to a target endpoint.

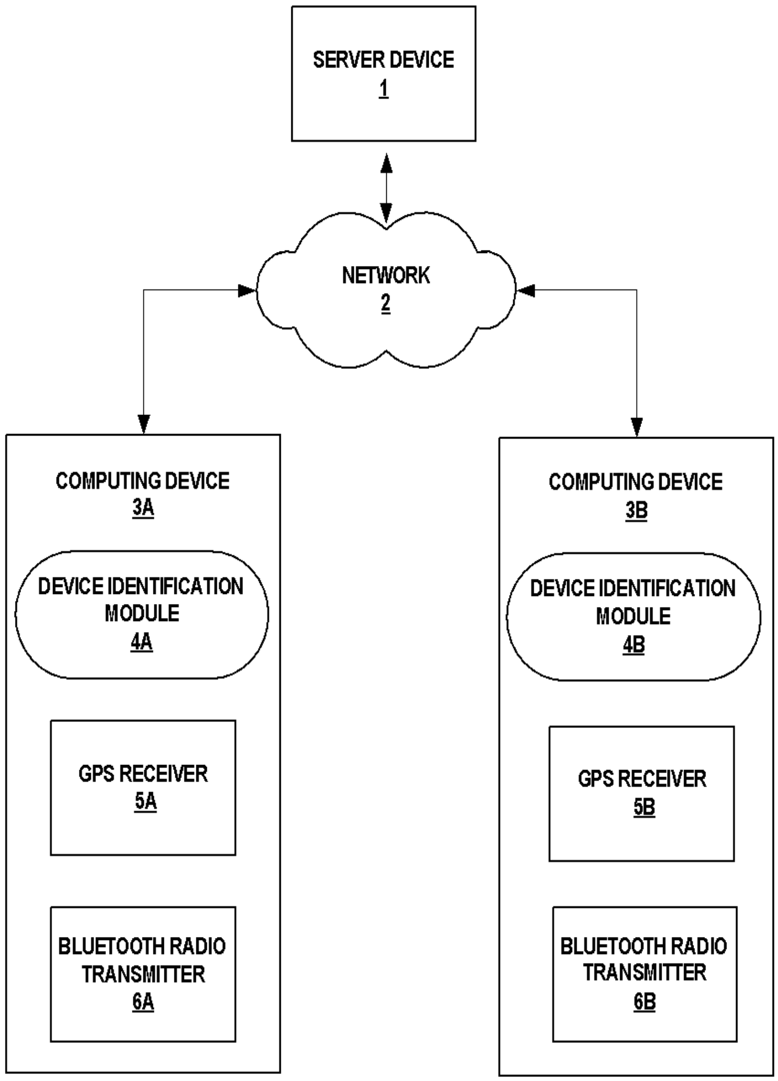

FIG. 1

As one example, a user may want to find a friend who is associated with a computing device. For example, the user may be in possession of computing device 3A of FIG. 1 and the friend may be in possession of computing device 3B of FIG. 1. Computing devices 3A and 3B may include, or otherwise be included in a mobile device (e.g., smart phone, tablet computer, laptop computer, computerized watch, computerized eyewear, computerized gloves), a personal computer, a smart television, a personal digital assistant, a portable gaming system, a media player, a mobile television platform, an automobile navigation and/or entertainment system, a vehicle (e.g., automobile, aircraft, navigable watercraft) and/or cockpit display, a home or other smart appliance and/or related device (e.g., interconnectable appliance/device via Internet of Things), or any other type of wearable or non-wearable, mobile or non-mobile computing device, and the computing system may or may not include a display device.

Both the user and the friend may provide explicit consent to exchange location information. For example, computing device 3A may output a request for authorization to share location information with the friend and computing device 3B may output a request for authorization to share location information with the user. That is, before any location information is exchanged between computing devices 3A and 3B, computing devices 3A and 3B may provide each of the users of computing devices 3A and 3B with an opportunity to accept or reject the collection and/or use of the computing device information associated with computing devices 3A and 3B (e.g., information about a user’s current location, current speed, current time, etc.).

After both the user and the friend have consented to exchanging location information, computing devices 3A and 3B may each generate a key that uniquely identifies the respective one of computing devices 3A and 3B and exchange the keys using network 3 and server device 1. Computing devices 3A and 3B may include device identification modules that generate keys that uniquely identify each device. Device identification modules 4A and 4B (collectively, device identification modules 4) may perform the operations described herein using hardware, hardware and software, hardware and firmware, or a mixture of hardware, software, and firmware residing in and/or executing at one of the computing devices 3A and 3B, respectively. The device identification modules 4 may include a software application. In such examples, device identification modules 4 may be a native application or a web-based application. Native applications may be provided by a first-party developer or by a third-party developer and may be pre-installed or downloaded via an application market.

In the example of Figure 1, computing device 3A may communicatively couple to computing device 3B via network 2. For example, computing devices 3A and 3B may each send a key to server device 1 via network 2 and retrieve the key for the other of computing devices 3A and 3B from server 1. Network 2 represents a combination of any one or more public or private communication networks, for instance, television broadcast networks, cable or satellite networks, cellular networks, Wi-Fi networks, broadband networks, and/or other type of network for transmitting data (e.g., telecommunications and/or media data) between various computing devices, systems, and other communications and media equipment.

At some point after exchanging keys, the user of computing device 3A may wish to find computing device 3B (and the friend who has computing device 3B). Computing device 3A may display a graphical user interface for finding computing device 3B. Responsive to the user requesting the location of computing device 3B, computing device 3A may send a request for the current location of computing device 3B to computing device 3B. Computing device 3B may determine a current location of computing device 3B using GPS receiver 4B. Similarly, computing device 3A may determine an initial position of computing device 3A using GPS receiver 4A.

After receiving the location of computing device 3B, computing device 3A may display information about the location of computing device 3B, such as the current location of computing device 3B, directions to navigate to device 3B, distance between computing devices 3A and 3B, etc. For example, computing device 3A may display a map that shows the location of both computing devices 3A and 3B. Computing device 3A may periodically refresh the location of both computing devices 3A and 3B and display the updated location information.

Once computing devices 3A and 3B are within a threshold distance of each other (e.g., 200 meters, 100 meters, 50 meters, 10 meters, etc.), computing devices 3A and 3B may begin advertising their own key information using Bluetooth® radios 6A and 6B, respectively, which may operate in accordance with the BLE standard. For example, computing device 3A may output an advertisement packet that includes the key that uniquely identifies computing device 3A and that was shared with computing device 3B. Similarly, computing device 3B may output an advertisement packet that includes the key that uniquely identifies computing device 3B and that was shared with computing device 3A.

When computing devices 3A and 3B are close enough to each other, computing device 3A may detect the advertisement packet being output by computing device 3B and may compare the key included in the advertisement packet to the key previously shared by computing device 3B. If the keys match, computing device 3A determines that the detected BLE signal is from computing device 3B and may determine a more precise location of computing device 3B relative to computing device 3A.

Computing device 3A may determine the received signal strength indicator (RSSI) for the BLE signal received from computing device 3B. Using the RSSI data, computing device 3A may calculate a distance between computing device 3A and 3B.

In addition to calculating the distance between computing devices 3A and 3B, computing device 3A may determine a direction of computing device 3B relative to computing device 3A.

In order to determine the direction of computing device 3B relative to computing device 3A, at least one of the computing devices 3A and 3B must have an antenna array with at least two antennas. If only one of the computing devices 3A and 3B has an antenna array with at least two antennas (e.g., computing device 3B), the one of computing devices 3A and 3B may update the other of computing devices 3A and 3B (e.g., computing device 3A updates computing device 3B) with direction information via the server. If both computing device 3A and 3B have antenna arrays with at least two antennas, computing devices 3A and 3B may determine the angle of incidence and the direction of the other one of computing devices 3A and 3B without using the server as an intermediary.

For example, computing device 3A may calculate the angle of incidence to determine the direction of computing device 3B. Figure 2, below, shows an example BLE signal being detected by antennas 1 and 2. The angle of incidence may be computed using the distance between antennas 1 and 2 and the signal's phase when it arrives at multiple antenna elements. Due to the difference in propagation distances from the signal source to individual receive antennas, each antenna observes a different phase shift of the signal. For example, as shown in Figure 2, if the incident signals are assumed to propagate in parallel through space, then the phase observed by the two receive antennas, $\Phi A1$ and $\Phi A2$, can be represented as a function of the angle of incidence θ and the distance separating the antennas d:

$$\Phi A1 - \Phi A2 = (2\pi d \sin \theta)/ \lambda \quad (1)$$

where λ is the wavelength. Therefore, one only needs to know the phase difference in the antenna array to estimate the incidence angle. The phase difference $\Phi A1 - \Phi A2$ may be computed as:

$$\Phi A1 - \Phi A2 = d \sin \theta = \alpha \qquad (2)$$

Based on equations (1) and (2), the angle of incidence θ may be calculated as:

$\theta = \sin^{-1} (\lambda \alpha / 2\pi d)$

In this way, computing device 3A may dynamically determine the direction of computing device 3B and the current distance between computing devices 3A and 3B.

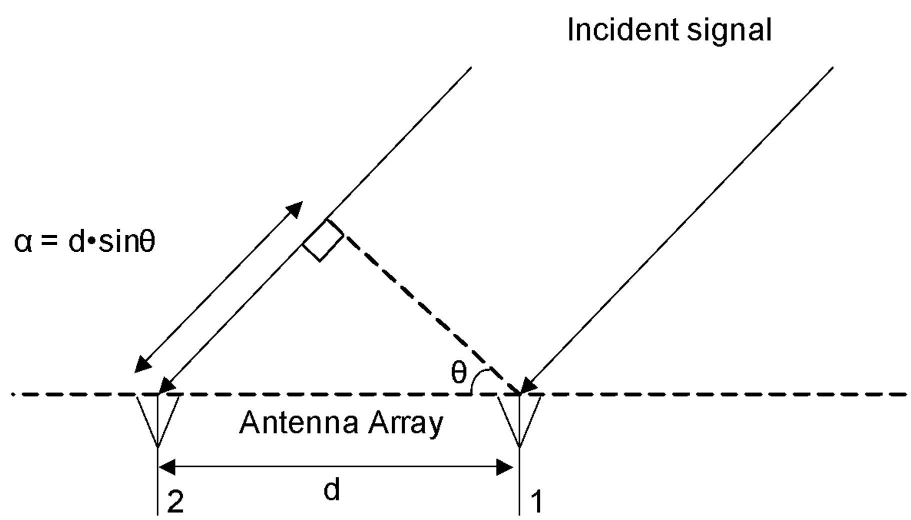

FIG. 2

Computing device 3A may periodically refresh the distance and direction calculations. Further, computing device 3A may provide a graphical user interface showing a location of computing device 3B and may include a suggested route to computing device 3B. In one example, computing device 3A may display a map to guide the user to a friend who has computing device 3B and provide the estimated time of arrival to computing device 3B via a wireless network connection.

In another example, a user may find a misplaced computing device using BLE signals when the misplaced computing device does not have a network connection. For example, computing device 3A and 3B may be paired to each other using Bluetooth®. Once paired and connected, computing devices 3A and 3B may periodically update and exchange unique keys.

For example, a user may later be unable to find computing device 3B. The user may use computing device 3A to aid in finding computing device 3B by, for example, activating a find my device functionality on computing device 3A, which causes computing device 3A to begin listening for the advertisement package from computing device 3B. As the user moves around a location (e.g., inside the user's house), computing device 3A may move within BLE range of computing device 3B and may receive the advertisement package that includes the unique key for computing device 3B. Computing device 3A may use RSSI data for the BLE signal for the advertisement package to determine the current distance between computing devices 3A and 3B, and may calculate the angle of incidence to determine the direction of computing device 3B as discussed above.

In instances where computing devices 3A and 3B are on different planes (e.g., different floors within the user's house), computing device 3A may use the specific antenna locations of the antennas within computing device 3A and the orientation of computing device 3A to determine the vertical direction of computing device 3B relative to computing device 3A. For example, computing device 3A may use the different RSSI strengths for the BLE signal detected by each of the antennas as well as the particular orientation of the device (and, thus, the antennas relative to each other) to determine the horizontal and vertical direction of computing device 3B. Computing device 3A may display a graphical user interface to direct the user towards the misplaced computing device 3B. In this way, computing device 3A may dynamically determine the direction of the misplaced computing device 3B in three-dimensional space as well as the current distance between computing devices 3A and 3B.

It is noted that the techniques of this disclosure may be combined with any other suitable technique or combination of techniques. As one example, the techniques of this disclosure may be combined with the techniques described in US Patent Application Publication 2014/0145881A1. As another example, the techniques of this disclosure may be combined with the techniques described in US Patent Application Publication 2016/0248506A1.