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Barton; Robert E. et al.

Backscatter device placement and placement calibration

Abstract

Backscatter Device (BKD) placement and placement calibration may be provided. A plurality of ambient energy sources in a Three-Dimensional (3D) space may be identified and mapped. Each of the plurality of ambient energy sources may be categorized as one of the following: a stationary and controllable ambient energy source, a stationary and uncontrollable ambient energy source, and a mobile ambient energy source. An amount of ambient energy available at each of a plurality of sub-spaces of the 3D space may be determined. The amount of ambient energy available at each of the plurality of sub-spaces may be determined by determining a first amount of ambient energy that is continuously available and a second amount of ambient energy that is likely available at each of the plurality of sub-spaces of the 3D space.

Inventors: Barton; Robert E. (Richmond, CA), Ficara; Domenico (Essertines-sur-Yverdon, CH), Choukir; Amine (Lausanne, CH), Henry; Jerome (Pittsboro, NC), Campiglio; Ugo Mario (Morges, CH)

Applicant: Cisco Technology, Inc. (San Jose, CA)

Family ID: 1000008763130

Assignee: Cisco Technology, Inc. (San Jose, CA)

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Primary Examiner: Kuntz; Curtis A

Assistant Examiner: Munion; James E

Attorney, Agent or Firm: Merchant & Gould P.C.

Background/Summary

RELATED APPLICATION (1) Under provisions of 35 U.S.C. § 119(e), Applicant claims the benefit of U.S. Provisional Application No. 63/501,796, filed May 12, 2023, which is incorporated

herein by reference.

TECHNICAL FIELD

(1) The present disclosure relates generally to processes for Backscatter Device (BKD) placement and placement calibration.

BACKGROUND

(2) In computer networking, a wireless Access Point (AP) is a networking hardware device that allows a Wi-Fi compatible client device to connect to a wired network and to other client devices. The AP usually connects to a router (directly or indirectly via a wired network) as a standalone device, but it can also be an integral component of the router itself. Several APs may also work in coordination, either through direct wired or wireless connections, or through a central system, commonly called a Wireless Local Area Network (WLAN) controller. An AP is differentiated from a hotspot, which is the physical location where Wi-Fi access to a WLAN is available.

(3) Prior to wireless networks, setting up a computer network in a business, home, or school often required running many cables through walls and ceilings in order to deliver network access to all of the network-enabled devices in the building. With the creation of the wireless AP, network users are able to add devices that access the network with few or no cables. An AP connects to a wired network, then provides radio frequency links for other radio devices to reach that wired network. Most APs support the connection of multiple wireless devices. APs are built to support a standard for sending and receiving data using these radio frequencies.

Description

BRIEF DESCRIPTION OF THE FIGURES

(1) The accompanying drawings, which are incorporated in and constitute a part of this disclosure, illustrate various embodiments of the present disclosure. In the drawings:

(2) FIG. 1 is a block diagram of an operating environment for Backscatter Device (BKD) placement;

(3) FIG. 2 is a flow chart of a method for BKD placement;

(4) FIG. 3 is a flow chart of a method for BKD placement calibration; and

(5) FIG. 4 is a block diagram of a computing device.

DETAILED DESCRIPTION

(6) Overview

(7) Backscatter Device (BKD) placement and placement calibration may be provided. A plurality of ambient energy sources in a Three-Dimensional (3D) space may be identified and mapped. Each of the plurality of ambient energy sources may be categorized as one of the following: a stationary and controllable ambient energy source, a stationary and uncontrollable ambient energy source, and a mobile ambient energy source. An amount of ambient energy available at each of a plurality of sub-spaces of the 3D space may be determined. The amount of ambient energy available at each of the plurality of sub-spaces may be determined by determining a first amount of ambient energy that is continuously available and a second amount of ambient energy that is likely available at each of the plurality of sub-spaces of the 3D space.

(8) Both the foregoing overview and the following example embodiments are examples and explanatory only and should not be considered to restrict the disclosure's scope, as described, and claimed. Furthermore, features and/or variations may be provided in addition to those described. For example, embodiments of the disclosure may be directed to various feature combinations and sub-combinations described in the example embodiments.

(9) Example Embodiments

(10) The following detailed description refers to the accompanying drawings. Wherever possible, the same reference numbers are used in the drawings and the following description to refer to the

same or similar elements. While embodiments of the disclosure may be described, modifications, adaptations, and other implementations are possible. For example, substitutions, additions, or modifications may be made to the elements illustrated in the drawings, and the methods described herein may be modified by substituting, reordering, or adding stages to the disclosed methods. Accordingly, the following detailed description does not limit the disclosure. Instead, the proper scope of the disclosure is defined by the appended claims.

(11) Ambient Power (AMP) Backscatter Devices (BKDs) may use ambient energy, for example, Radio Frequency (RF) signals, to transmit data without a power source such as a battery or a connection to electricity. BKDs may use an antenna to receive a RF signal, use the received RF signal for excitation (e.g., convert the RF signal into electricity), and use the power to modify and reflect the RF signal with data. Other network devices may receive a reflected RF signal transmitted by a BKD to process the data the BKD is sending. BKD operations may be described in documents and standards from the Institute of Electrical and Electronics Engineers (IEEE).

(12) There may be two types of BKDs: passive BKDs (pBKDs) and active BKDs (aBKDs). A pBKD may directly reflect back the energy it receives. An aBKD may include a capacitor and may thus charge until it sends its own frame. As discussed above, BKDs may be powered by ambient energy (for example, RF signals) present in the surrounding environment. A power level the BKDs receive may depend on how well BKDs may be able to receive the ambient energy from ambient energy sources in the surrounding environment. Therefore, a deployment location of a BKD may significantly influence an ability of the BKD to perform. This may especially be true for BKDs where ambient energy may be harvested and stored before being used. The disclosure, therefore, may provide processes for BKD placement and placement calibration that may enable BKDs to receive a maximum possible amount of energy thereby improving BKD's performance. In addition, the BKD placement processes disclosed here may provide backscattered BKD frames from the BKDs to have a best chance to be received by a network device.

(13) FIG. 1 is a block diagram of an operating environment **100** for BKD placement and placement calibration. Operating environment **100** may include a network **105** and a controller **110**. Network **105** may include a plurality of network devices, for example, a first Access Point (AP) **120**, a second AP **125**, a first BKD **130**, a second BKD **135**, a first station **140**, and a second station **145**. Network **105** may comprise, but is not limited to, a Wireless Local Area Network (WLAN) in a Three-Dimensional (3D) space **150**. 3D space **150** may include a plurality of sub-spaces, for example, a first sub-space **155**, a second sub-space, **160**, and a third sub-space **165**. The plurality of sub-spaces may be unit sub-spaces and may include one or more BKDs, one or more Survey Devices (SDs), and/or one or more stations. For example, first sub-space **155** may comprise first BKD **130**, a first SD **175** and a second SD **180**. Second sub-space **160** may comprise second BKD **135**. Third sub-space **165** may not comprise any BKDs or survey devices.

(14) Controller **110** may be a Wireless LAN Controller (WLC) and may provision and control network **105**. Controller **110** may be implemented by a Digital Network Architecture Center (DNAC) controller (i.e., a Software-Defined Network (SDN) controller). Controller **110**, first AP **120**, and second AP **125** may provide a WLAN. Through this WLAN, first BKD **130**, second BKD **135**, first station **140**, second station **145**, first SD **175**, and second SD **180** may be provided with access to the Internet or other cloud-based networking environments.

(15) Each first AP **120** and second AP **125** may be compatible with specification standards such as, but not limited to, the IEEE 802.11 specification standard for example. First AP **120** and second AP **125** may communicate with each other and controller **110** to conduct operations in concert to provide network coverage or Wireless Fidelity (WiFi) coverage in 3D space **150**. In addition, first AP **120** and second AP **125** may send and receive signals to provide a connection to network **105**.

(16) First BKD **130** and second BKD **135** may be devices that can utilize RF signals that first AP **120**, second AP **125**, first station **140**, second station **145**, and/or other devices transmit to generate power, modulate or otherwise modify the received signals to encode data, and reflect the modulated

signals. First BKD **130** and second BKD **135** may be user devices, Internet-of-Things (IoT) devices, sensors, and/or the like. Each of first BKD **130** and second BKD **135** may be a pBKD or an aBKD.

(17) First station **140** and second station **145** may communicate with first AP **120**, second AP **125**, first BKD **130**, second BKD **135**, first SD **175**, and second SD **180**. In accordance with example embodiments, first station **140** and second station **145** may be devices with a power source, for example, a battery or connected to electrical power. First station **140** and second station **145** may be, for example, a smart phone, a personal computer, a tablet device, a mobile device, a telephone, a remote control device, a set-top box, a digital video recorder, an IoT device, a network computer, a router, an Automated Transfer Vehicle (ATV), a drone, an Unmanned Aerial Vehicle (UAV), or other similar microcomputer-based device.

(18) First SD **175** and second SD **180** may communicate with first AP **120**, second AP **125**, first BKD **130**, second BKD **135**, first station **140**, and second station **145**. Each of first SD **175** and second SD **180** may measure an amount of ambient energy being received at its location and a source of the ambient energy. First SD **175** and second SD **180** may be placed in 3D space **150** to measure ambient energy.

(19) The elements described above of operating environment **100** (e.g., controller **110**, first AP **120**, second AP **125**, first BKD **130**, second BKD **135**, first station **140**, second station **145**, first SD **175**, and second SD **180**) may be practiced in hardware and/or in software (including firmware, resident software, micro-code, etc.) or in any other circuits or systems. The elements of operating environment **100** may be practiced in electrical circuits comprising discrete electronic elements, packaged or integrated electronic chips containing logic gates, a circuit utilizing a microprocessor, or on a single chip containing electronic elements or microprocessors. Furthermore, the elements of operating environment **100** may also be practiced using other technologies capable of performing logical operations such as, for example, AND, OR, and NOT, including but not limited to, mechanical, optical, fluidic, and quantum technologies. As described in greater detail below with respect to FIG. **4**, the elements of operating environment **100** may be practiced in a computing device **400**.

(20) FIG. **2** is a flow chart setting forth the general stages involved in a method **200** consistent with embodiments of the disclosure for BKD placement. Method **200** may be implemented using controller **110** as described in more detail above with respect to FIG. **1**. However, method **200** may be implemented using any of first AP **120**, second AP **125**, first station **140**, and second station **145** as described in more detail above with respect to FIG. **1**. Ways to implement the stages of method **200** will be described in greater detail below.

(21) Method **200** may begin at starting block **205** and proceed to stage **210** where controller **110** may identify and map a plurality of ambient energy sources in 3D space **150**. Location server **115** may perform a RF survey where a RF spectrum may be analyzed in 3D space **150** using survey devices, for example, first SD **175** and second SD **180**. In the RF survey, all RF emitters (for example, microwave sources, owned APs (that is, first AP **120** and second AP **125**), neighboring network APs, rogue APs, Bluetooth Low Energy (BLE) sources, light sources, Light Fidelity (LiFi) sources, Television (TV) signal sources, any remote controlled sources, etc.) may be identified and mapped. Non-RF sources, for example, heat sources (that is, heat pumps, space heaters, Air Conditioning (AC) systems, etc.), light sources, vibration sources, etc. may also be identified and mapped.

(22) Controller **110** may identify and map the plurality of ambient energy sources in 3D space **150** at a predetermined frequency for a certain time. For example, controller **110** may identify and map the plurality of ambient energy sources every minute or hour of the day for a few weeks or a few months, or few seasons. The mapping of the plurality of ambient energy sources may be stored in a database.

(23) After identifying and mapping the plurality of ambient energy sources in 3D space **150** at stage

210, method **200** may proceed to stage **220** where controller **110** may categorize each of the plurality of ambient energy sources as one of the following: a stationary and controllable ambient energy source, a stationary and uncontrollable ambient energy source, and a mobile ambient energy source. Stationary and controllable ambient energy sources may include LiFi sources, BLE sources, WiFi sources, and any other network devices that may be fixed at a position and controllable by controller **110**. Stationary and uncontrollable ambient energy sources may include rogue APs, rogue RF sources, daylight, etc. that may be fixed at a position but are not controllable by controller **110**. Mobile ambient energy sources may include sources that may move in and out of 3D space **150** and not controllable by controller **110**.

(24) Once having categorized each of the plurality of ambient energy sources at stage **220**, method **200** may proceed to stage **230** where controller **110** may determine an amount of ambient energy available at each of a plurality of sub-spaces of 3D space **150**. Determining the amount of ambient energy available at each of the plurality of sub-spaces may include determining a first amount of ambient energy that is continuously available and a second amount of ambient energy that is likely available at each of the plurality of sub-spaces of 3D space **150**.

(25) Controller **110**, for example, may gather the historical data including ambient energy emission pattern from the plurality of ambient energy sources of 3D space **150** over time. The historical data may be used to determine or predict the first amount of ambient energy that is continuously available at each of the plurality of sub-spaces and the second amount of ambient energy that is likely available at each of the plurality of sub-spaces of 3D space **150**. For example, a room may temporarily become full of ambient energy sources for a single transient but not predictable event. This may not mean that controller **110** may rely on such room to have that much ambient energy. However, other rooms, for example, a classroom or a movie theater may have ambient energy sources show up on a predicted schedule.

(26) With the classification of ambient energy sources, controller **110** may estimate the amount of ambient energy for each sub-space of 3D space **150** that: is continuously available (for example, from controllable and stationary ambient energy sources) and is likely to be available from transient but predictable energy sources. The amount of ambient energy that is likely to be available may be determined based on availability patterns of uncontrollable stationary ambient energy sources and mobile ambient energy sources. The availability pattern of stationary and uncontrollable ambient energy sources and mobile ambient energy sources may be determined based on historical availability patterns. The amount of ambient energy that is likely available may then be determined based on the predicted availability pattern. The predicted availability pattern may be determined using a machine learning algorithm. After controller **110** determines the amount of energy available at each of the plurality of sub-spaces of 3D space **150** at stage **230**, method **200** may terminate at end block **240**.

(27) Based on the amount of ambient energy available at each of the plurality of sub-spaces of 3D space **150**, controller **110** may create a recommendation to suggest BKD locations at macro scale in 3D space **150**. In some examples, controller **110** may provide a BKD energizing (that is, ambient energy) heatmap that may be used to determine BKD locations. The ambient energy heatmap may provide the amount of ambient energy available at different positions in 3D space **150**. The ambient energy heatmap may be used to determine optimal positions for placing BKDs.

(28) Controller **110** may provide a different ambient energy heatmap for non-RF ambient energy. For example, controller **110** may provide a vibration energy heatmap, a light energy heatmap, etc. Non-RF ambient energy heatmaps may be used to determine positions of BKDs that may use non-RF ambient energy. First BKD **130**, for example, may be placed in 3D space **150** based on the ambient energy heatmap and an energy budget of first BKD **130**. The energy budget may depend on a type and a frequency of operation of first BKD **130**. For example, first BKD **130** may need less ambient energy if it is configured to send data every minute vs when it is configured to send multiple times every second. Similarly, a BKD with a temperature sensor may need more ambient

energy than a BKD with an open/close sensor if a door associated with the open/close sensor is not operated frequently.

(29) Some BKDs may be placed freely. For example, a BKD with a smoke detector may be placed anywhere in a room or on ceiling of a room. However, placement of other BKDs may be constrained. For example, a BKD with an open/close sensor of a door may need to be placed along a frame of the door. The disclosure may provide calibration of BKD placement at constrained positions.

(30) FIG. 3 is a flow chart setting forth the general stages involved in a method **300** consistent with embodiments for BKD placement calibration. Method **300** may be implemented using controller **110** as described in more detail above with respect to FIG. 1. However, method **300** may also be implemented using any of first AP **120**, second AP **125**, first station **140**, and second station **145** as described in more detail above with respect to FIG. 1. Ways to implement the stages of method **300** will be described in greater detail below.

(31) Method **300** may begin at starting block **305** and proceed to stage **310** where controller **110** may cause a plurality of ambient energy sources of 3D space **150** to transmit charging frames for BKDs. Each of the charging frames may comprise a payload having a Media Access Control (MAC) address of transmitting ambient energy source. For example, controller **110** may trigger or instruct first AP **120**, second AP **125**, first station **140**, and second station **145** to transmit charging frames comprising the MAC address of the transmitting device.

(32) Once having instructed the plurality of ambient energy sources to transmit the charging frames at stage **310**, method **300** may proceed to stage **320** where controller **110** may receive from one or more survey devices placed at one or more positions along a sub-space of 3D space **150** an amount of ambient energy received from the charging frames of the plurality of ambient energy sources and each contributing source. For example, first SD **175** and second SD **180** may be placed around first sub-space **155** that may be a constrained sub-space for placement of first BKD **130**. Each of first SD **175** and second SD **180** may detect the charging frames transmitted by first AP **120**, second AP **125**, first station **140**, and second station **145** and determine a power or intensity of detected charging frames at its respective position.

(33) The charging frames may lose some power (referred to as a path loss) as it travels through the surrounding environment. The path loss may depend on a distance between a transmitting device and a receiving device, any obstruction along a path between the transmitting device and the receiving device, etc. Each of first SD **175** and second SD **180** may determine the amount of ambient energy received from each first AP **120**, second AP **125**, first station **140**, and second station **145** at its respective position from the charging frames and the MAC address included in the charging frames. First SD **175** and second SD **180** may send this information to controller **110**.

(34) After determining the amount of ambient energy received from the plurality of ambient energy sources and each contributing source at stage **320**, method **300** may proceed to stage **330** where controller **110** may predict the amount of ambient energy available from each contributing source at each of the one or more positions along the sub-space per predetermined time period based on the amount of ambient energy received from the plurality of ambient energy sources. For example, based on a detected signal level of the charging frames from the plurality of ambient energy sources, controller **110** may determine the path loss for each of first AP **120**, second AP **125**, first station **140**, and second station **145** to each of first SD **175** and second SD **180**. In addition, controller **110** may determine an operational activity of each of the plurality of ambient energy sources. For example, first AP **120** may send beacons 10 times per second and may reply to each first station **140** and second station **145** with an average channel utilization (CU) of 45%. A wireless video unit may be used on an average of 10% of the time during weekdays with both upstream and downstream packets. A printer may be heavily used, but its traffic may primarily be downstream with only acknowledgement packets and occasional updates for upstream.

(35) Based on the path loss and the operational activity, controller **110** may predict the amount of

ambient energy available from each contributing source at each of the one or more positions along first sub-space **155** per predetermined time period, for example, per second, per minute, per hour, etc. Once having predicted the amount of ambient energy available from each contributing source at each of the one or more positions along first sub-space **155**, method **300** may terminate at end stage **340**.

(36) A type and the ambient energy requirement or the ambient energy budget of first BKD **130** to be placed at first sub-space **155** may be known. Controller **110** may compare the ambient energy budget of first BKD **130** with the predicted amount of ambient energy available from contributing sources at each of the one or more positions around first sub-space **155**. Controller **110** then may recommend a position from the one or more positions for placement of first BKD **130** based on the comparison. For example, controller **110** may recommend first BKD **130** to be placed at a first position along first sub-space **155** where the predicted amount of ambient energy available from the contributing sources is greater than the ambient energy budget of first BKD **130**.

(37) In accordance with example embodiments, controller **110** may determine an energy gap comprising a difference between the predicted amount of ambient energy available at each of one or more positions or a preferred second position and the ambient energy budget of first BKD **130**. If the energy gap is less than zero, then controller **110** may recommend placing first BKD **130** at any of the one or more positions of first sub-space **155**. However, if the energy gap is greater than zero, controller **110** may cause at least one ambient energy source of the plurality of ambient energy sources to transmit additional charging frames to cover the energy gap. For example, controller **110** may cause one of first AP **120**, second AP **125**, first station **140**, and second station **145** to transmit additional charging frames. In some examples, controller **110** may recommend adding at least one ambient energy source in 3D space **150** to cover the gap. In another examples, controller **110** may recommend adding an energy input module to first BKD **130**. For example, if first BKD **130** is located near a window and receives sunlight, controller **110** may recommend adding a solar energy module to first BKD **130** to cover the energy gap.

(38) In some example embodiments, controller **110** may recommend moving or relocating one of first AP **120** and second AP **125** to cover the energy gap. For moving one of first AP **120** and second AP **125**, a convex optimization algorithm may be used to maintain the WiFi coverage while maximizing the ambient energy at positions where first BKD **130** and second BKD **135** are located. This may pose a dual constraint optimization problem. Convex optimizing algorithms implementing Karush-Kuhn-Tucker conditions (for example, a barrier technique, an interior point method, etc.) may be used to provide such optimization. In some examples, optimization of the ambient energy availability may result in a sub-optimal WiFi coverage or vice versa. In such cases, controller **110** may favor WiFi coverage, and then may examine if any of the plurality of ambient energy sources may be caused to send additional charging frames to cover the energy gap. For example, first AP **120** may be caused to send additional charging frames when not sending or receiving data frames. In another example, a printer in network **105** may be caused to send additional charging frames at intervals and medium power causing a moderate and localized increase of airtime utilization in an associate cell. An ambient energy source closer to first BKD **130** may be caused to send the additional charging frames provided any increase in airtime is bounded to a Channel Utilization (CU) value that is configurable.

(39) If first BKD **130** is already placed at a second position, controller **110** may determine the energy gap at the second position and recommend a remedial action to cover the gap. An iterative or a brownfield deployment approach may be employed where a number of BKDs are already deployed and a few more have to be added or a location of the ones already deployed may need to be adjusted. In such scenarios, deployed BKDs may report the ambient energy levels at their positions to controller **110** that in turn may recommend adjusting their positions based on the reported ambient energy levels. Controller **110** may also adjust RF signals emitted from controllable ambient energy sources in order to improve the ambient energy levels.

(40) In some examples, BKDs may be mounted on a moving object, for example, a vehicle. In such scenarios, controller **110** may recommend a route recommendation to the moving object that may provide a certain level of ambient energy availability for the BKDs along the recommended route. Controller **110** may also ensure that enough ambient energy is available along the recommended route based on the ambient energy requirement of the BKDs.

(41) FIG. 4 is a block diagram of a computing device **400**. As shown in FIG. 4, computing device **400** may include a processing unit **410** and a memory unit **415**. Memory unit **415** may include a software module **420** and a database **425**. While executing on processing unit **410**, software module **420** may perform, for example, processes for BKD placement and calibration described with respect to FIG. 2 and FIG. 3. Computing device **400**, for example, may provide an operating environment for controller **110**, first AP **120**, second AP **125**, first BKD **130**, second BKD **135**, first station **140**, and second station **145**, and the like. Controller **110**, first AP **120**, second AP **125**, first BKD **130**, second BKD **135**, first station **140**, and second station **145**, and the like may operate in other environments and are not limited to computing device **400**.

(42) Computing device **400** may be implemented using a Wi-Fi access point, a tablet device, a mobile device, a smart phone, a telephone, a remote control device, a set-top box, a digital video recorder, a cable modem, a personal computer, a network computer, a mainframe, a router, a switch, a server cluster, a smart TV-like device, a network storage device, a network relay device, or other similar microcomputer-based device. Computing device **400** may comprise any computer operating environment, such as hand-held devices, multiprocessor systems, microprocessor-based or programmable sender electronic devices, minicomputers, mainframe computers, and the like. Computing device **400** may also be practiced in distributed computing environments where tasks are performed by remote processing devices. The aforementioned systems and devices are examples, and computing device **400** may comprise other systems or devices.

(43) Embodiments of the disclosure, for example, may be implemented as a computer process (method), a computing system, or as an article of manufacture, such as a computer program product or computer readable media. The computer program product may be a computer storage media readable by a computer system and encoding a computer program of instructions for executing a computer process. The computer program product may also be a propagated signal on a carrier readable by a computing system and encoding a computer program of instructions for executing a computer process. Accordingly, the present disclosure may be embodied in hardware and/or in software (including firmware, resident software, micro-code, etc.). In other words, embodiments of the present disclosure may take the form of a computer program product on a computer-usable or computer-readable storage medium having computer-usable or computer-readable program code embodied in the medium for use by or in connection with an instruction execution system. A computer-usable or computer-readable medium may be any medium that can contain, store, communicate, propagate, or transport the program for use by or in connection with the instruction execution system, apparatus, or device.

(44) The computer-usable or computer-readable medium may be, for example but not limited to, an electronic, magnetic, optical, electromagnetic, infrared, or semiconductor system, apparatus, device, or propagation medium. More specific computer-readable medium examples (a non-exhaustive list), the computer-readable medium may include the following: an electrical connection having one or more wires, a portable computer diskette, a random access memory (RAM), a read-only memory (ROM), an erasable programmable read-only memory (EPROM or Flash memory), an optical fiber, and a portable compact disc read-only memory (CD-ROM). Note that the computer-usable or computer-readable medium could even be paper or another suitable medium upon which the program is printed, as the program can be electronically captured, via, for instance, optical scanning of the paper or other medium, then compiled, interpreted, or otherwise processed in a suitable manner, if necessary, and then stored in a computer memory.

(45) While certain embodiments of the disclosure have been described, other embodiments may

exist. Furthermore, although embodiments of the present disclosure have been described as being associated with data stored in memory and other storage mediums, data can also be stored on, or read from other types of computer-readable media, such as secondary storage devices, like hard disks, floppy disks, or a CD-ROM, a carrier wave from the Internet, or other forms of RAM or ROM. Further, the disclosed methods' stages may be modified in any manner, including by reordering stages and/or inserting or deleting stages, without departing from the disclosure.

(46) Furthermore, embodiments of the disclosure may be practiced in an electrical circuit comprising discrete electronic elements, packaged or integrated electronic chips containing logic gates, a circuit utilizing a microprocessor, or on a single chip containing electronic elements or microprocessors. Embodiments of the disclosure may also be practiced using other technologies capable of performing logical operations such as, for example, AND, OR, and NOT, including but not limited to, mechanical, optical, fluidic, and quantum technologies. In addition, embodiments of the disclosure may be practiced within a general purpose computer or in any other circuits or systems.

(47) Embodiments of the disclosure may be practiced via a system-on-a-chip (SOC) where each or many of the element illustrated in FIG. 1 may be integrated onto a single integrated circuit. Such an SOC device may include one or more processing units, graphics units, communications units, system virtualization units and various application functionality all of which may be integrated (or “burned”) onto the chip substrate as a single integrated circuit. When operating via an SOC, the functionality described herein with respect to embodiments of the disclosure, may be performed via application-specific logic integrated with other components of computing device **400** on the single integrated circuit (chip).

(48) Embodiments of the present disclosure, for example, are described above with reference to block diagrams and/or operational illustrations of methods, systems, and computer program products according to embodiments of the disclosure. The functions/acts noted in the blocks may occur out of the order as shown in any flowchart. For example, two blocks shown in succession may in fact be executed substantially concurrently or the blocks may sometimes be executed in the reverse order, depending upon the functionality/acts involved.

(49) While the specification includes examples, the disclosure's scope is indicated by the following claims. Furthermore, while the specification has been described in language specific to structural features and/or methodological acts, the claims are not limited to the features or acts described above. Rather, the specific features and acts described above are disclosed as example for embodiments of the disclosure.

Claims

1. A method comprising: identifying and mapping a plurality of ambient energy sources in a Three-Dimensional (3D) space; categorizing each of the plurality of ambient energy sources as one of the following: a stationary and controllable ambient energy source, a stationary and uncontrollable ambient energy source, and a mobile ambient energy source; and determining an amount of ambient energy available at each of a plurality of sub-spaces of the 3D space, wherein determining the amount of ambient energy available at each of the plurality of sub-spaces comprises: determining a first amount of ambient energy that is continuously available at each of the plurality of sub-spaces of the 3D space, and determining a second amount of ambient energy that is likely available at each of the plurality of sub-spaces of the 3D space.

2. The method of claim 1, wherein determining the first amount of ambient energy that is continuously available comprises: determining the first amount of ambient energy available from stationary and controllable ambient energy sources.

3. The method of claim 1, wherein determining the second amount of ambient energy that is likely available comprises: predicting an availability pattern of the stationary and uncontrollable ambient

energy sources and the mobile ambient energy sources based on historical availability patterns; and determining the second amount of ambient energy that is likely available based on the predicted availability pattern.

4. The method of claim 3, wherein determining the availability pattern of the stationary and uncontrollable ambient energy sources and the mobile ambient energy sources comprises determining the availability pattern of the stationary and uncontrollable ambient energy sources and the mobile ambient energy sources based on historical data of the mapping of the plurality of ambient energy sources in the 3D space.

5. The method of claim 1, further comprising: categorizing each of the plurality of ambient energy sources as one of the following: a Radio Frequency (RF) source and a non-RF source.

6. The method of claim 1, further comprising: creating a recommendation to suggest Ambient Power (AMP) Backscatter Device (BKD) device locations for a plurality of AMP BKDs in the 3D space based on the amount of ambient energy available at each of the plurality of sub-spaces of the 3D space and an ambient energy budget of each of the plurality of BKDs.

7. The method of claim 1, wherein identifying and mapping the plurality of ambient energy sources in the 3D space comprises performing a Radio Frequency (RF) survey of the 3D space to determine RF signal emitters in the 3D space.

8. The method of claim 1, wherein identifying and mapping the plurality of ambient energy sources in the 3D space comprises analyzing a Radio Frequency (RF) spectrum in the 3D space to determine RF signal emitters in the 3D space.

9. A system comprising: a memory storage; and a processing unit coupled to the memory storage, wherein the processing unit is operative to: identify and map a plurality of ambient energy sources in a Three-Dimensional (3D) space; categorize each of the plurality of ambient energy sources as one of the following: a stationary and controllable ambient energy source, a stationary and uncontrollable ambient energy source, and a mobile ambient energy source; and determine an amount of ambient energy available at each of a plurality of sub-spaces of the 3D space, wherein the processing unit being operative to determine the amount of ambient energy available at each of the plurality of sub-spaces comprises the processing unit being operative to: determine a first amount of ambient energy that is continuously available at each of the plurality of sub-spaces of the 3D space, and determine a second amount of ambient energy that is likely available at each of the plurality of sub-spaces of the 3D space.

10. The system of claim 9, wherein the processing unit being operative to determine the first amount of ambient energy that is continuously available comprises the processing unit being operative to: determine the first amount of ambient energy available from stationary and controllable ambient energy sources.

11. The system of claim 9, wherein the processing unit being operative to determine the second amount of ambient energy that is likely available comprises the processing unit being operative to: predict an availability pattern of the stationary and uncontrollable ambient energy sources and the mobile ambient energy sources based on historical availability patterns; and determine the second amount of ambient energy that is likely available based on the predicted availability pattern.

12. The system of claim 11, wherein the processing unit being operative to determine the availability pattern of the stationary and uncontrollable ambient energy sources and the mobile ambient energy sources comprises the processing unit being operative to determine the availability pattern of the stationary and uncontrollable ambient energy sources and the mobile ambient energy sources based on historical data of the mapping of the plurality of ambient energy sources in the 3D space.

13. The system of claim 9, wherein the processing unit is further operative to: categorize each of the plurality of ambient energy sources as one of the following: a Radio Frequency (RF) source and a non-RF source.

14. The system of claim 9, wherein the processing unit is further operative to: creating a

recommendation to suggest Ambient Power (AMP) Backscatter Device (BKD) device locations for a plurality of AMP BKDs in the 3D space based on the amount of ambient energy available at each of the plurality of unit sub-spaces of the 3D space and an ambient energy budget of each of the plurality of BKDs.

15. A non-transitory computer-readable medium that stores a set of instructions which when executed perform a method comprising: identifying and mapping a plurality of ambient energy sources in a Three-Dimensional (3D) space; categorizing each of the plurality of ambient energy sources as one of the following: a stationary and controllable ambient energy source, a stationary and uncontrollable ambient energy source, and a mobile ambient energy source; and determining an amount of ambient energy available at each of a plurality of sub-spaces of the 3D space, wherein determining the amount of ambient energy available at each of the plurality of sub-spaces comprises: determining a first amount of ambient energy that is continuously available at each of the plurality of sub-spaces of the 3D space, and determining a second amount of ambient energy that is likely available at each of the plurality of sub-spaces of the 3D space.

16. The non-transitory computer-readable medium of claim 15, wherein determining the first amount of ambient energy that is continuously available comprises: determining the first amount of ambient energy available from stationary and controllable ambient energy sources.

17. The non-transitory computer-readable medium of claim 15, wherein determining the second amount of ambient energy that is likely available comprises: predicting an availability pattern of the stationary and uncontrollable ambient energy sources and the mobile ambient energy sources based on historical availability patterns; and determining the second amount of ambient energy that is likely available based on the predicted availability pattern.

18. The non-transitory computer-readable medium of claim 17, wherein determining the availability pattern of the stationary and uncontrollable ambient energy sources and the mobile ambient energy sources comprises determining the availability pattern of the stationary and uncontrollable ambient energy sources and the mobile ambient energy sources based on historical data of the mapping of the plurality of ambient energy sources in the 3D space.

19. The non-transitory computer-readable medium of claim 15, further comprising: categorizing each of the plurality of ambient energy sources as one of the following: a Radio Frequency (RF) source and a non-RF source.

20. The non-transitory computer-readable medium of claim 15, further comprising: creating a recommendation to suggest Ambient Power (AMP) Backscatter Device (BKD) device locations for a plurality of AMP BKDs in the 3D space based on the amount of ambient energy available at each of the plurality of sub-spaces of the 3D space and an ambient energy budget of each of the plurality of BKDs.
