

US Patent & Trademark Office

Patent Public Search | Text View

United States Patent Application Publication

20250266969

Kind Code

A1

Publication Date

August 21, 2025

Inventor(s)

Brouillette; Patrick A.

Hub Station with Channel Switching Feature

Abstract

In one aspect, an example method includes monitoring, by a hub station, a first channel activity level associated with a first channel of a plurality of channels within a particular frequency range. The hub station communicates with a low-energy device using the first channel. The method includes determining that the first channel activity level satisfies a threshold activity level and switching to a second channel of the plurality of channels to communicate with the low-energy device. The method includes notifying the low-energy device that the hub station switched to the second channel by sending an acknowledgement message to the low-energy device on the second channel in response to receiving a message from the low-energy device on the second channel. The message is sent to the hub station on the second channel after at least one unsuccessful attempt to send the message to the hub station on the first channel.

Inventors: Brouillette; Patrick A. (Tempe, AZ)

Applicant: Roku, Inc. (San Jose, CA)

Family ID: 1000008578097

Appl. No.: 19/200299

Filed: May 06, 2025

Related U.S. Application Data

parent US continuation 18597489 20240306 parent-grant-document US 12323364 child US 19200299

parent US continuation 18363550 20230801 parent-grant-document US 11956175 child US 18597489

Publication Classification

Int. Cl.: H04L5/00 (20060101); H04L43/0876 (20220101)

U.S. Cl.:

CPC **H04L5/0064** (20130101); **H04L5/0055** (20130101); **H04L5/0096** (20130101);
H04L43/0876 (20130101);

Background/Summary

RELATED DISCLOSURE [0001] This application is a continuation of U.S. patent application Ser. No. 18/597,489 filed Mar. 6, 2024, which is a continuation of U.S. patent application Ser. No. 18/363,550 filed Aug. 1, 2023, both of which are hereby incorporated by reference herein in their entirety.

USAGE AND TERMINOLOGY

[0002] In this disclosure, unless otherwise specified and/or unless the particular context clearly dictates otherwise, the terms “a” or “an” mean at least one, and the term “the” means the at least one.

SUMMARY

[0003] In one aspect, an example method is disclosed. The method includes monitoring, by a hub station, a first channel activity level associated with a first channel of a plurality of channels within a particular frequency range. The hub station communicates with a low-energy device using the first channel. The method also includes determining, by the hub station, that the first channel activity level satisfies a threshold activity level. The method also includes switching, by the hub station, to a second channel of the plurality of channels to communicate with the low-energy device, at least in part, in response to determining that the first channel activity level satisfies the threshold activity level. The method also includes notifying the low-energy device that the hub station switched to the second channel by sending an acknowledgement message to the low-energy device on the second channel in response to receiving a message from the low-energy device on the second channel. The message is sent to the hub station on the second channel after at least one unsuccessful attempt to send the message to the hub station on the first channel.

[0004] In another aspect, an example hub station is disclosed. The hub station includes a memory and a processor coupled to the memory. The processor is configured to monitor a first channel activity level associated with a first channel of a plurality of channels within a particular frequency range. The hub station communicates with a low-energy device using the first channel. The processor is also configured to determine that the first channel activity level satisfies a threshold activity level. The processor is also configured to switch to a second channel of the plurality of channels to communicate with the low-energy device, at least in part, in response to determining that the first channel activity level satisfies the threshold activity level. The processor is also configured to notify the low-energy device that the hub station switched to the second channel by sending an acknowledgement message to the low-energy device on the second channel in response to receiving a message from the low-energy device on the second channel. The message is sent to the hub station on the second channel after at least one unsuccessful attempt to send the message to the hub station on the first channel.

[0005] In another aspect, an example non-transitory computer-readable medium is disclosed. The computer-readable medium has stored thereon instructions that, upon execution by a processor within a hub station, cause the processor to perform operations. The operations include monitoring a first channel activity level associated with a first channel of a plurality of channels within a particular frequency range. The hub station communicates with a low-energy device using the first channel. The operations also include determining that the first channel activity level satisfies a threshold activity level. The operations also include switching to a second channel of the plurality

of channels to communicate with the low-energy device, at least in part, in response to determining that the first channel activity level satisfies the threshold activity level. The operations also include notifying the low-energy device that the hub station switched to the second channel by sending an acknowledgement message to the low-energy device on the second channel in response to receiving a message from the low-energy device on the second channel. The message is sent to the hub station on the second channel after at least one unsuccessful attempt to send the message to the hub station on the first channel.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] FIG. 1 is a simplified block diagram of an example communication system in which various described principles can be implemented.

[0007] FIG. 2 is a simplified block diagram of an example computing system in which various described principles can be implemented.

[0008] FIG. 3 depicts diagrams of example radio transmission energy levels on different channels.

[0009] FIG. 4 is a flow chart of an example method.

[0010] FIG. 5 is a flow chart of another example method.

[0011] FIG. 6 is a flow chart of another example method.

[0012] FIG. 7 is a flow chart of another example method.

DETAILED DESCRIPTION

I. Overview

[0013] A hub station can communicate with a plurality of low-energy devices using channels (e.g., frequencies) within a particular frequency range. For example, when the hub station and a particular low-energy device are tuned to a first channel within the particular frequency range, the hub station can send data to the particular low-energy device over the first channel, and the hub station can receive data from the particular low-energy device over the first channel.

[0014] If a transmission energy level associated with the first channel is relatively high, possibly indicating a relatively large amount of jamming activity, the hub station can switch to a second channel within the particular frequency range. To illustrate, the hub station can monitor the transmission energy level on each channel within the particular frequency range. In response to a determination that second channel has a lower transmission energy level than the transmission energy level associated with the first channel, the hub station can tune a transceiver (e.g., a radio) to the second channel. After the hub station switches to the second channel, the particular low-energy device is not immediately notified of the switch. Thus, the particular low-energy device remains tuned to the first channel.

[0015] In response to an event (e.g., a wake-up event) at the particular low-energy device, the particular low-energy device can attempt to send a message to the hub station over the first channel. To illustrate, if the particular low-energy device is a motion sensor, in response to detecting motion, the particular low-energy device can attempt to send the message (indicating the detected motion) to the hub station over the first channel. However, because the hub station switched to the second channel, the hub station does not receive the message from the particular low-energy device and does not send an acknowledgment message to the particular low-energy device over the first channel.

[0016] After one or more unsuccessful attempts to send the message to the hub station over the first channel, the particular low-energy device can switch to another channel. As used herein, an “unsuccessful attempt” to send the message occurs when an acknowledgment message is not received in response to sending the message. If the particular low-energy device switches to the second channel and sends the message to the hub station over the second channel, the hub station

sends an acknowledgment message to the particular low-energy device. Upon receiving the acknowledgment message, the particular low-energy device is put on notice that the hub station has switched to the second channel. As a result, the particular low-energy device uses the second channel to send all message to the hub station until another attempt to send a message is unsuccessful, indicating that the hub station has again switched channels.

[0017] The techniques described herein can help reduce power consumption at the particular low-energy device. For example, the particular low-energy device can remain in a low-energy mode for prolonged periods of time (e.g., until the occurrence of a wake-up event) because the particular low-energy device does not have to “listen” on the first channel for the switching notification messages from the hub station. By waiting until the occurrence of a wake-up event to “find” the hub station, the particular low-energy device can remain in a low-energy mode for prolonged periods of time, thus conserving battery power.

[0018] Below, particular embodiments are described herein with reference to the drawings. In the description, common features are designated by common reference numbers throughout the drawings. In some figures, multiple instances of a particular type of feature are used. Although these features are physically and/or logically distinct, the same reference number is used for each, and the different instances are distinguished by addition of a letter to the reference number. When the features as a group or a type are referred to herein (e.g., when no particular one of the features is being referenced), the reference number is used without a distinguishing letter. However, when one particular feature of multiple features of the same type is referred to herein, the reference number is used with the distinguishing letter. For example, referring to FIG. 1, multiple channels are illustrated and associated with reference numbers **106A**, **106B**, etc. When referring to a particular one of these channels, such as the channel **106A**, the distinguishing letter “A” is used. However, when referring to any arbitrary one of these channels or to these channels as a group, the reference number **106** is used without a distinguishing letter.

II. Example Communication System

[0019] FIG. 1 is a block diagram of an example communication system **100**. The communication system **100** includes a hub station **102** and a plurality of low-energy devices **104**. For example, the communication system **100** includes a low-energy device **104A** and a low-energy device **104B**. Although two low-energy devices **104** are illustrated in FIG. 1, in other implementations, the communication system **100** can include additional (or fewer) low-energy devices. For example, in one implementation, the communication system **100** can include a single low-energy device **104**, such as the low-energy device **104A**. However, in another implementation, the communication system **100** can include five low-energy devices **104**.

[0020] The hub station **102** corresponds to a central transmitting and receiving device of a network. For example, the hub station **102** can be associated with a plurality of peripheral devices, such as the low-energy devices **104**, within a particular network. Data transmitted from the peripheral devices in the particular network is typically transmitted to the hub station **102**. In some implementations, the hub station **102** can serve as a gateway device for peripheral devices to communicate with other peripheral devices or with a device outside of the particular network.

[0021] The hub station **102** includes a processor **110**, a memory **112** coupled to the processor **110**, a transceiver **114** coupled to the processor **110**, and a transceiver **116** coupled to the processor **110**. Although transceivers **114**, **116** are depicted, in some implementations, one or more of the transceivers **114**, **116** can be replaced with a separate receiver and a transmitter. The memory **112** can correspond to a non-transitory computer-readable medium that stores instructions **113** executable by the processor **110** to perform the operations described herein.

[0022] Each transceiver **114**, **116** in the hub station **102** can be tuned to a different frequency (e.g., a different channel). To illustrate, the transceiver **114** can be tuned to communicate data using a channel within a first frequency range (e.g., a lower frequency range), and the transceiver **116** can be tuned to communicate data using a channel within a second frequency range (e.g., a higher

frequency range). As a non-limiting example, the transceiver **114** can be tuned to send and receive data (e.g., data packets) using a frequency channel below 1 Gigahertz (GHz), and the transceiver **116** can be tuned to send and receive data using a frequency channel associated with an Institute of Electrical and Electronics Engineers (IEEE) 802.11 (“Wifi”) protocol. Thus, the hub station **102** can include at least two radios (e.g., a first radio for the transceiver **114** and a second radio for the transceiver **116**) to communicate data over different frequency ranges. According to one implementation, the transceiver **114** can be tuned to send and receive data using a 900 Megahertz (MHz) frequency and/or frequencies relatively close to 900 MHz. It should be understood that the above frequency ranges for the transceiver **114** are merely for illustrative purposes and should not be construed as limiting. The techniques described herein can be applied to the transceiver **114** if the transceiver **114** is tuned to send and receive data using frequencies range above 1 GHz, as well. [0023] The hub station **102** can communicate with the low-energy devices **104** using channels **106** (e.g., frequency channels) within a particular frequency range. As used herein, the “particular frequency range” can span from 900 MHz to 1 GHz; however, it should be understood that in other implementations, the particular frequency range can include frequencies above 1 GHz and/or frequencies below 900 MHz. In the illustration of FIG. 1, the transceiver **114** of the hub station **102** can be tuned to communicate with the low-energy devices **104** using a channel **106A**, a channel **106B**, or a channel **106C**. According to one implementation, the channel **106A** can correspond to a primary channel that has a higher compatibility rating, associated with communications between the hub station **102** and the low-energy devices **104**, than the other channels **106B**, **106C**. Although three channels **106A**, **106B**, **106C** are illustrated in FIG. 1, in other implementations, the system **100** can include additional channels **106**.

[0024] The processor **110** includes a channel activity monitor **120**, a channel activity processing unit **122**, a channel evaluation unit **124**, a channel selector **126**, and a message generator **128**. In some implementations, one or more components **120**, **122**, **124**, **126**, **128** of the processor **110** can be implemented using dedicated circuitry, such as an application-specific integrated circuit (ASIC) or a field-programmable gate array (FPGA) device. In some implementations, operations associated with one or more components **120**, **122**, **124**, **126**, **128** of the processor **110** can be performed by executing the instructions **113** stored in the memory **112**. In some implementations, two or more of the components **120**, **122**, **124**, **126**, **128** of the processor **110** can be integrated into a single component. As a non-limiting example, the channel activity monitor **120** and the channel activity processing unit **122** can be integrated into a single component (e.g., a single unit or module).

[0025] The techniques described herein enable the hub station **102** to monitor activity (e.g., jamming activity or noise) on the channels **106** and select a particular channel **106** for communication with the low-energy devices **104** based on the activity. For example, at a given point in time, the transceiver **114** can be tuned to communicate with the low-energy devices **104** using the primary channel **106A**. While tuned to communicate with the low-energy devices **104** using the channel **106A**, the transceiver **114** can switch frequencies every clock period to enable the processor **110** to monitor channel activity levels **130** associated with each channel **106**. Based on the channel activity levels **130** associated with the each channel **106**, the processor **110** can select a channel **106** for communicating with the low-energy devices **104**. For example, based on the channel activity levels **130** associated with each channel **106**, the processor **110** can select to remain on the primary channel **106A** or select to switch to one of the secondary channels **106B**, **106C**.

[0026] To illustrate, the channel activity monitor **120** can be configured to monitor a channel activity level **130A** associated with the channel **106A**, a channel activity level **130B** associated with the channel **106B**, and a channel activity level **130C** associated with the channel **106C**. As a non-limiting example, each clock period can correspond to one second. During a first interval (e.g., a fifty millisecond (ms) interval) of a clock period, the transceiver **114** can switch to the channel

106B, and the channel activity monitor **120** can monitor (e.g., measure) the channel activity level **130A** associated with the channel **106A** during the first interval. During a second interval of the clock period, the transceiver **114** can switch to the channel **106C**, and the channel activity monitor **120** can monitor the channel activity level **130B** associated with the channel **106B** during the second interval. During a third interval of the clock period, the transceiver **114** can switch back to the channel **106A**, and the channel activity monitor **120** can monitor the channel activity level **130A** associated with the channel **106A** during the third interval. The remaining portion of the clock period can be used to communicate with the low-energy devices **104** using the active (e.g., currently selected) channel **106** (e.g., the channel **106A**).

[0027] It should be understood that the duration of the clock period and the duration of the intervals are merely for illustrative purposes and should not be construed as limiting. In other implementations, the clock period can have a longer or shorter duration. Additionally, in other implementations, the time intervals for monitoring channel activity levels **130** on each channel **106** can have a longer or shorter duration than the 50 ms duration described above. In some implementations, the first interval, the second interval, and the third interval can be consecutive time intervals within the clock period. In other implementations, the first interval, the second interval, and the third interval can be non-consecutive time intervals within the clock period such that the transceiver **114** can communicate with the low-energy devices **104** using the active channel **106** between the intervals for monitoring channel activity levels **130**. In these implementations, the transceiver **114** can be configured to switch back to the active channel **106A** after monitoring the channel activity level **130** on a non-active channel **106**.

[0028] The hub station **102** can be configured to monitor a channel activity level **130** for a single channel at any given point in time. For example, if the hub station **102** monitors the channel activity level **130A** associated with the channel **106A**, the channel activity levels **130B**, **130C** associated with the other channels **106B**, **106C** are unmonitored by the hub station **102**.

[0029] In some implementations, the channel activity level **130A** can correspond to a radio transmission (Tx) energy **132A** on the channel **106A**, the channel activity level **130B** can correspond to a radio transmission energy **132B** on the channel **106B**, and the channel activity level **130C** can correspond to a radio transmission energy **132C** on the channel **106C**. The radio transmission energy **132** for a particular channel **106** can be based on transmission activity on the channel **106**. To illustrate, if data is transmitted on a particular channel **106**, a magnitude of the radio transmission energy **132** for the particular channel **106** increases. Thus, the radio transmission energy **132** for a particular channel **106** correlates to jamming activity on the channel **106**.

Monitoring the radio transmission energy **132** on each channel **106** is described in greater detail with respect to FIG. 3.

[0030] In some implementations, the channel activity processing unit **122** can be configured to determine a moving average of channel activity levels **134** on each channel **106**. For example, at a particular instance of time, data can be transmitted on an otherwise relatively “quiet” channel. By determining the moving average of channel activity levels **134** on each channel **106**, the processor **110** can determine whether there is substantially continuous jamming activity on the channel or whether there was isolated activity on an otherwise quiet channel.

[0031] To illustrate, the channel activity processing unit **122** can determine (e.g., compute) a channel activity level moving average **134A** for the channel **106A**, a channel activity level moving average **134B** for the channel **106B**, and a channel activity level moving average **134C** for the channel **106C**. In some implementations, the channel activity level moving averages **134** can be based on channel activity level **130** measurements for five consecutive clock cycles. For example, to determine the channel activity moving average **134A** for the channel **106A**, the channel activity processing unit **122** can determine an average of the last five channel activity level **130A** measurements associated with the channel **106A**. Determining the channel activity level moving average **134** is described in greater detail below with respect to FIG. 3. It should be understood that

basing the channel activity level moving average **134** on the last five channel activity level **130** measurements is merely one example on how to determine the channel activity level moving average **134**. In other implementations, the channel activity level moving average **134** can be based on a different number of consecutive channel activity level **130** measurements or can be based on non-consecutive channel activity level **130** measurements.

[0032] In some implementations, the channel activity level moving average **134** for a particular channel **106** can correspond to a weighted moving average. For example, when determining the channel activity level moving average **134**, a most current channel activity level **130** measurement can be assigned a first weight, a second most current channel activity level **130** measurement can be assigned a second weight, a third most current channel activity level **130** measurement can be assigned a third weight etc. In these implementations, the first weight is greater than the second weight, the second weight is greater than the third weight, etc. Thus, in these implementations, the channel activity level moving average **134** is more indicative of the recent channel activity level **130** measurements.

[0033] The channel evaluation unit **124** can be configured to determine whether the channel activity level **130A** (or the channel activity level moving average **134A**) satisfies a threshold activity level **136**. For example, the channel evaluation unit **124** can determine whether the channel activity level **130A** (or the channel activity level moving average **134A**) is above the threshold activity level **136**. The threshold activity level **136** can correspond to a programmable level that is indicative of noise on a channel. As a non-limiting example, and as further described with respect to FIG. 3, the threshold activity level **136** can be equal to -40 decibels (dB). The channel evaluation unit **124** can determine whether there is sustained noise over -40 dB on the channel **106A** by comparing the channel activity level moving average **134A** to the threshold activity level **136**. The channel evaluation unit **124** can determine whether there is current noise over -40 dB on the channel **106A** by comparing the latest channel activity level **130A** measurement to the threshold activity level **136**. It should be understood that -40 dB is merely used for illustrative purposes and should not be construed as limiting. In other implementations, the threshold activity level **136** can have a different value.

[0034] The channel selector **126** can be configured to switch the hub station **102** to a different channel **106B**, **106C** to communicate with the low-energy devices **104**, at least in part, in response to determining that the channel activity level **130A** (or the channel activity level moving average **134A**) satisfies the threshold activity level **136**. As used herein, “switching” to a particular channel corresponds to tuning the transceiver **114** to a frequency associated with the particular channel to enable the transceiver **114** to send and receive data using the particular channel. According to one implementation, if the channel evaluation unit **124** determines that the channel activity level **130A** (or the channel activity level moving average **134A**) associated with the channel **106A** satisfies the threshold activity level **136** and the channel activity level **130B** (or the channel activity level moving average **134B**) associated with the channel **106B** fails to satisfy the threshold activity level **136**, the hub station **102** can switch to the channel **106B** to communicate with the low-energy devices **104**.

[0035] According to another implementation, if the channel evaluation unit **124** determines that the channel activity level **130A** (or the channel activity level moving average **134A**) associated with the channel **106A** satisfies the threshold activity level **136** and the channel activity level **130B** (or the channel activity level moving average **134B**) associated with the channel **106B** is less than the channel activity level **130A** (or the channel activity level moving average **134A**), the hub station **102** can switch to the channel **106B** to communicate with the low-energy devices **104**. In this implementation, channel selector **126** can select the channel **106B** with less noise (e.g., less jamming activity), even if the channel **106B** with less noise has a channel activity level **130B** above the threshold activity level **136**.

[0036] Although the above examples describe switching from the channel **106A** to the channel

106B, it should be understood that the techniques described herein are not limited to switching between the channels **106A**, **106B**. In other implementations, the hub station **102** can switch from the channel **106A** to the channel **106C** if the channel activity level **130C** (or the channel activity moving average **134B**) associated with the channel **106C** is below the threshold activity level **136** or below the channel activity level **130A** associated with the channel **106A**. In some scenarios, the hub station **102** can switch from the channel **106A** to whichever channel **106B**, **106C** has a lower channel activity level **130** (or channel activity level moving average **134**). For example, if the channel evaluation unit **124** determines that the channel activity level **130B** associated with the channel **106B** is less than the channel activity level **130C** associated with the channel **106C**, the hub station **102** can switch to the channel **106C** in response to determining that the channel activity level **130A** (or the channel activity level moving average **134A**) satisfies the threshold activity level **136**. However, if the channel evaluation unit **124** determines that the channel activity level **130C** associated with the channel **106C** is less than the channel activity level **130B** associated with the channel **106B**, the hub station **102** can switch to the channel **106B**.

[0037] For ease of explanation, unless otherwise noted, the following description is based on the assumption that the hub station **102** switched from the primary channel **106A** to the channel **106B**. In response to switching to the channel **106B**, the hub station **102** bypasses sending a notification to the low-energy devices **104** that the hub station **102** switched to the channel **106B**. Thus, when the hub station **102** switches to the channel **106B**, the low-energy devices **104** continue to use the channel **106A** in an attempt to communicate with the hub station **102**. As described below, the low-energy devices **104** are notified of the hub station's **102** switch from the primary channel **106A** to the channel **106B** by receiving an acknowledgment message **170** on the channel **106B** in response to sending a message to the hub station **102** on the channel **106B**. The acknowledgment message **170** can be generated by the message generator **128**.

[0038] The low-energy devices **104** can correspond to any device that can enter into a low-energy mode. A non-limiting example of a low-energy device **104** is a motion sensor. When no motion is detected, the low-energy device **104** can operate in the low-energy mode. However, upon motion detection, the low-energy device **104** can transition from the low-energy mode into a normal operating mode.

[0039] The low-energy device **104A** includes a sensor unit **150A**, a processor **152A**, and a transceiver **154A**. According to one implementation, the sensor unit **150A** can correspond to a motion detection module that is operable to detect motion. For example, the sensor unit **150B** can include a camera and an image processor that are usable to detect motion in a field of view of the camera. In response to detecting motion, the processor **152A** can transition into a normal operating mode and a message generator **160A** within the processor **152A** can generate a message **164A** indicating that motion has been detected. The transceiver **154A** can be configured to send the message **164A** to the hub station **102** using one of the channels **106**. Thus, the low-energy device **104A** can remain in an idle state (e.g., the low-energy mode) absent detection of a wake-up event (e.g., motion detection), and the message **164A** can be sent to the hub station **102** in response to the wake-up event.

[0040] It should be understood that motion detection is merely an example of a wake-up event that triggers transmission of a message **164A** to the hub station **102**. In other implementations, the low-energy device **104A** can send a message **164A** to the hub station **102** in response to other wake-up events. As a non-limiting example, the low-energy device **104A** can correspond to an entry sensor and the wake-up event can correspond to detection of someone entering a premises (e.g., a home premises). As another non-limiting example, the low-energy device **104A** can correspond to a keypad and the wake-up event can correspond to compression of a key.

[0041] As described above, the hub station **102** switched from the primary channel **106A** to the channel **106B** without notifying the low-energy device **104A**. Thus, the transceiver **154A** of the low-energy device **104A** remains tuned to the primary channel **106A** and sends the message **164A**

to the hub station **102** using the primary channel **106A**. Because the hub station **102** has switched to the channel **106B**, the hub station **102** will not receive the message **164A** sent from the low-energy device **104A** using the primary channel **106A**, and thus, will not send the acknowledgement message **170** to the low-energy device **104A**. As a result, the low-energy device's **104A** attempt to send the message **164A** to the hub station **102** on the primary channel **106A** is unsuccessful. An unsuccessful attempt to send the message **164A** to the hub station **102** on the primary channel **106A** occurs when the low-energy device **104A** fails to receive the acknowledgement message **170** from the hub station **102** on the primary channel **106A**.

[0042] In some scenarios, the low-energy device **104A** can switch from the primary channel **106A** to another channel **106B**, **106C** after one unsuccessful attempt to send the message **164A** to the hub station **102** on the primary channel **106A**. In other scenarios, the low-energy device **104A** can switch from the primary channel **106A** to another channel **106B**, **106C** after two or more unsuccessful attempts to send the message **164A** to the hub station **102** on the primary channel **106A**.

[0043] The low-energy device **104A** can select another channel **106B**, **106C** on which to send the message **164A** to the hub station **102** after the unsuccessful attempt(s) to send the message **164A** on the primary channel **106A**. In some scenarios, the low-energy device **104A** can select the other channel **106B**, **106C** at random. In other scenarios, the low-energy device **104A** can select the channel **106B**, **106C** that is closer (in frequency) to the primary channel **106A**. In other scenarios, the low-energy device **104A** can select the channel **106B**, **106C** according to a hierarchy. For example, if the channel **106B** is more compatible with communications between the low-energy device **104A** and the hub station **102** than the channel **106C**, the low-energy device **104A** can select the channel **106B** after the unsuccessful attempt(s) to send the message **164A** on the primary channel **106A**. For ease of illustration, let's assume that the low-energy device **104A** selected the channel **106B** (e.g., the channel on which the hub station **102** switched).

[0044] After switching to the channel **106B**, the low-energy device **104A** can send the message **164A** to the hub station **102** using the channel **106B**. Because the hub station **102** switched to the channel **102B**, the hub station **102** can receive the message **164A** from the low-energy device **104A** on the channel **106B**. In response to receiving the message **164A** from the low-energy device **104A** on the channel **106B**, the hub station **102** can be configured to notify the low-energy device **104A** that the hub station **102** switched to the channel **106B** by sending the acknowledgment message **170** to the low-energy device **104A** on the channel **106B**. Once the low-energy device **104** receives the acknowledgment message **170** on the channel **106B**, the attempt to send the message **164A** to the hub station **102** is determined to be successful at the low-energy device **104A**. As a result, the low-energy device **104A** will send messages to the hub station **102** on the channel **106B** going forward (e.g., until the low-energy device **104A** experiences one or more unsuccessful attempts to send a message to the hub station **102** on the channel **106B**).

[0045] The low-energy device **104B** includes a sensor unit **150B**, a processor **152B**, and a transceiver **154B**. The low-energy device **104B** can operate in a substantially similar manner as the low-energy device **104A**. For example, the sensor unit **150B** can detect motion, and, in response to detecting the motion, the processor **152B** can transition into a normal operating mode. A message generator **160B** within the processor **152B** can generate a message **164B** indicating that motion has been detected. The transceiver **154B** can be configured to send the message **164** to the hub station **102** using one of the channels **106**. In a similar manner as described above, if the low-energy device **104B** fails to receive the acknowledgment message **170**, the low-energy device **104B** can switch channels and resend the message **164B** on the different channel and wait to receive the acknowledgment message **170**. Once the low-energy device **104B** sends the message **164B** on a particular channel and receives the acknowledgment message **170** on the same channel, the low-energy device **104B** can remain on the channel to communicate with the hub station **102**.

[0046] As described above, in some scenarios, the channel **106A** can correspond to a primary

channel that has a higher compatibility rating, associated with communications between the hub station **102** and the low-energy devices **104**, than the other channels **106B**, **106C**. As a result, in some implementations, the hub station **102** may attempt to switch back to the primary channel **106A** after switching to the channel **106B**. For example, the channel activity monitor **120** can monitor the channel activity level **130A** associated with the primary channel **106A** after switching to the channel **106B**. In response to determining that the channel activity level **130A** fails to satisfy (e.g., is lower than) the threshold activity level **136**, the channel selector **126** can switch back to the primary channel **106A** to communicate with the low-energy devices **104**. Alternatively, in response to determining that the channel activity level **130A** is lower than the channel activity level **130B** associated with the channel **106B**, the channel selector **126** can switch back to the primary channel **106A** to communicate with the low-energy devices **104**.

[0047] The techniques described with respect to FIG. **1** provides the hub station **102** with the agility to quickly switch channels **106** without notifying the low-energy devices **104** of the switch. For example, the hub station **102** can monitor (e.g., listen on) the channels **106** to select a channel **106** that does not have consistent radio energy (e.g., jamming). After selecting the channel **106**, instead of directly notifying the low-energy devices **104**, the low-energy devices **104** will find the channel **106** (e.g., the frequency) to which the hub station **102** moved by sending messages to the hub station **102** on different channels and awaiting an acknowledgment message. Thus, if the hub station **102** frequently switches between multiple channels **106**, battery power can be conserved at the low-energy devices **104** because the hub station **102** bypasses sending channel switching notifications to the low-energy devices **104**, which would cause the low-energy devices to “wake-up”. As a result, the low-energy devices **104** can remain in a low-energy mode until detecting a wake-up event.

III. Example Computing System

[0048] FIG. **2** is a simplified block diagram of an example computing system **200**. The computing system **200** can be configured to perform and/or can perform various operations, such as the operations described in this disclosure. The computing system **200** can include various components, such as a processor **202**, a data storage unit **204**, a communication interface **206**, and/or a user interface **208**.

[0049] The processor **202** can be or include a general-purpose processor (e.g., a microprocessor) and/or a special-purpose processor (e.g., a digital signal processor). The processor **202** can execute program instructions included in the data storage unit **204** as described below.

[0050] The data storage unit **204** can be or include one or more volatile, non-volatile, removable, and/or non-removable storage components, such as magnetic, optical, and/or flash storage, and/or can be integrated in whole or in part with the processor **202**. Further, the data storage unit **204** can be or include a non-transitory computer-readable storage medium, having stored thereon program instructions (e.g., compiled or non-compiled program logic and/or machine code) that, upon execution by the processor **202**, cause the computing system **200** and/or another computing system to perform one or more operations, such as the operations described in this disclosure. These program instructions can define, and/or be part of, a discrete software application.

[0051] In some instances, the computing system **200** can execute program instructions in response to receiving an input, such as an input received via the communication interface **206** and/or the user interface **208**. The data storage unit **204** can also store other data, such as any of the data described in this disclosure.

[0052] The communication interface **206** can allow the computing system **200** to connect with and/or communicate with another entity according to one or more protocols. Therefore, the computing system **200** can transmit data to, and/or receive data from, one or more other entities according to one or more protocols. In one example, the communication interface **206** can be or include a wired interface, such as an Ethernet interface or a High-Definition Multimedia Interface (HDMI). In another example, the communication interface **206** can be or include a wireless

interface, such as a cellular or WI-FI interface.

[0053] The user interface **208** can allow for interaction between the computing system **200** and a user of the computing system **200**. As such, the user interface **208** can be or include an input component such as a keyboard, a mouse, a remote controller, a microphone, and/or a touch-sensitive panel. The user interface **208** can also be or include an output component such as a display screen (which, for example, can be combined with a touch-sensitive panel) and/or a sound speaker.

[0054] The computing system **200** can also include one or more connection mechanisms that connect various components within the computing system **200**. For example, the computing system **200** can include the connection mechanisms represented by lines that connect components of the computing system **200**, as shown in FIG. 2.

[0055] The computing system **200** can include one or more of the above-described components and can be configured or arranged in various ways. For example, the computing system **200** can be configured as a server and/or a client (or perhaps a cluster of servers and/or a cluster of clients) operating in one or more server-client type arrangements, such as a partially or fully cloud-based arrangement, for instance.

[0056] The hub station **102** can take the form of a computing system, such as the computing system **200**. In some cases, some or all of these entities can take the form of a more specific type of computing system.

IV. Example Energy Transmission Energy Levels

[0057] FIG. 3 depicts diagrams of radio transmission energy levels on different

[0058] channels. For example, in FIG. 3, the radio transmission energy levels **132** for each channel **106** are illustrated.

[0059] For each channel **106**, the radio transmission levels **132** span between -80 dB and 0 dB. It should be understood that this range of radio transmission levels **132** is for illustrative purposes and should not be construed as limiting. In other implementations, the range for the radio transmission levels **132** can span lower than -80 dB, higher than 0 dB, or both. Additionally, in FIG. 3, the threshold activity level **136** is -40 dB. It should be understood that the threshold activity level **136** is for illustrative purposes and should not be construed as limiting. In other implementations, the threshold activity level **136** can be lower than -40 dB or higher than -40 dB. In some implementations, the threshold activity level **136** is programmable.

[0060] In other implementations, the threshold activity level **136** can be based on historical radio transmission levels **132**. For example, historically, if radio transmission levels **132** on the channels **106** are consistently above -40 dB, the threshold activity level **136** can be raised to reduce the amount of times channel switching is initiated. However, historically, if radio transmission levels **132** on the channels **106** are consistently below -40 dB, the threshold activity level **136** can be lowered to increase the amount of times channel switching is initiated and ensure that the hub station **102** selects the channel **106** with the least amount of jamming activity.

[0061] Referring to the channel **106A** in FIG. 3, the radio transmission energy **132A** can be monitored and measured (e.g., recorded) at six different clock cycles. For example, the radio transmission energy **132A** for the channel **106A** is approximately -20 dB at clock cycle (t-5), the radio transmission energy **132A** for the channel **106A** is approximately -45 dB at clock cycle (t-4), the radio transmission energy **132A** for the channel **106A** is approximately -20 dB at clock cycle (t-3), the radio transmission energy **132A** for the channel **106A** is approximately -55 dB at clock cycle (t-2), the radio transmission energy **132A** for the channel **106A** is approximately -60 dB at clock cycle (t-1), and the radio transmission energy **132A** for the channel **106A** is approximately -60 dB at clock cycle (t). At clock cycle (t-1), the moving average of the radio transmission energy **132A** for the last five clock cycles satisfies (e.g., is greater than) -40 dB. For example, the channel activity level moving average **134A** is greater than the threshold activity level **136**. As a result, the channel switching operation described with respect to FIG. 1 is initiated.

[0062] Referring to the channel **106B** in FIG. 3, the radio transmission energy **132A** can be monitored and measured (e.g., recorded) at six different clock cycles. For example, the radio transmission energy **132B** for the channel **106B** is approximately **-60** dB at each clock cycle (t-5, t-4, t-3, t-2, t-1, and 5). Thus, at clock cycle (t-1), the moving average of the radio transmission energy **132B** for the last five clock cycles satisfies (e.g., is less than) **-40** dB. For example, the channel activity level moving average **134B** is less than the threshold activity level **136**. As a result, the channel **106B** is a viable channel for the hub station **102** to select.

[0063] Referring to the channel **106C** in FIG. 3, the radio transmission energy **132C** can be monitored and measured (e.g., recorded) at six different clock cycles. For example, the radio transmission energy **132C** for the channel **106C** is approximately **-60** dB at clock cycle (t-5), the radio transmission energy **132C** for the channel **106C** is approximately **-50** dB at clock cycle (t-4), the radio transmission energy **132C** for the channel **106C** is approximately **-10** dB at clock cycle (t-3), the radio transmission energy **132C** for the channel **106C** is approximately **-50** dB at clock cycle (t-2), the radio transmission energy **132C** for the channel **106C** is approximately **-60** dB at clock cycle (t-1), and the radio transmission energy **132C** for the channel **106C** is approximately **-60** dB at clock cycle (t). Thus, at clock cycle (t-1), the moving average of the radio transmission energy **132C** for the last five clock cycles satisfies (e.g., is less than) **-40** dB. For example, the channel activity level moving average **134C** is less than the threshold activity level **136**. As a result, the channel **106C** is a viable channel for the hub station **102** to select.

[0064] In one implementation, because both channels **106B**, **106C** are viable channels, the hub station **102** can select the channel with the lowest channel activity level moving average **134** (e.g., the channel **106B**). In another implementation, because channels **106B**, **106C** are viable channels, the hub station **102** can select the channel that is most compatible with communications between the hub station **102** and the low-energy devices **104**.

[0065] Additionally, referring to the channel **106A** in FIG. 3, a return to primary channel threshold activity level **336** is depicted. For example, in FIG. 3, the threshold activity level **336** is **-50** dB. It should be understood that the return to primary channel threshold activity level **336** is for illustrative purposes and should not be construed as limiting. In other implementations, the return to primary channel threshold activity level **336** can be different (e.g., lower or higher). After the hub station **102** switches to one of the other channels **106B**, **106C** in response to the radio transmission energy **132A** for the channel **106A** (or the channel activity level moving average **134A**) raising above the threshold activity level **136**, the hub station **102** can switch back to the channel **106A** in response to the radio transmission energy **132A** for the channel **106A** (or the channel activity level moving average **134A**) falling below the return to primary channel threshold activity level **336**. Using the return to primary channel threshold activity level **336** to trigger the hub station **102** switching back to the channel **106A** prevents frequent channel switching when the radio transmission energy **132A** for the channel **106A** (or the channel activity level moving average **134A**) is near the threshold activity level **136**.

V. Example Methods

[0066] FIG. 4 is a flow chart illustrating an example method **400**. The method **400** can be carried out by a communication system, such as the communication system **100**, or by a hub station, such as the hub station **102**.

[0067] The method **400** includes monitoring, by a hub station, a first channel activity level associated with a first channel of a plurality of channels within a particular frequency range, at block **402**. The hub station communicates with a low-energy device using the first channel. For example, referring to FIG. 1, the hub station **102** can monitor the channel activity level **130A** associated with the channel **106A** of the plurality of channels **106A**, **106B**, **106C** within a particular frequency range. The hub station **102** communicates with the low-energy device **104A** using the channel **106A**.

[0068] The method **400** also includes determining, by the hub station, that the first channel activity

level satisfies a threshold activity level, at block **404**. For example, referring to FIG. **1**, the hub station **102** determines that the channel activity level **130A** satisfies (e.g., is greater than) the threshold activity level **136**.

[0069] The method **400** also includes switching, by the hub station, to a second channel of the plurality of channels to communicate with the low-energy device, at least in part, in response to determining that the first channel activity level satisfies the threshold activity level, at block **406**. For example, referring to FIG. **1**, the hub station **102** switches to the second channel **106B** of the plurality of channels **106A**, **106B**, **106C** to communicate with the low-energy device **104A**, at least in part, in response to determining that the channel activity level **130A** satisfies (e.g., is greater than) the threshold activity level **136**.

[0070] The method **400** also includes notifying the low-energy device that the hub station switched to the second channel by sending an acknowledgement message to the low-energy device on the second channel in response to receiving a message from the low-energy device on the second channel, at block **408**. The message is sent to the hub station on the second channel after at least one unsuccessful attempt to send the message to the hub station on the first channel. For example, referring to FIG. **1**, the hub station **102** notifies the low-energy device **104A** that the hub station **102** switched to the channel **106B** by sending the acknowledgement message **170** to the low-energy device **104A** on the channel **106B** in response to receiving the message **164A** from the low-energy device **104A** on the channel **106B**. The message **164A** is sent to the hub station **102** (from the low-energy device **104A**) on the channel **106B** after at least one unsuccessful attempt to send the message **164A** to the hub station **102** on the channel **106A**.

[0071] According to one implementation, the method **400** includes monitoring, by the hub station, a second channel activity level associated with the second channel. For example, referring to FIG. **1**, the hub station **102** can monitor the channel activity level **130B** associated with the channel **106B**. The method **400** can also include determining, by the hub station, that the second channel activity level fails to satisfy the threshold activity level. For example, referring to FIG. **1**, the hub station **102** can determine that the channel activity level **130B** fails to satisfy (e.g., is less than or equal to) the threshold activity level. In this implementation, the hub station switches to the second channel in response to determining that the second channel activity level fails to satisfy the threshold activity level.

[0072] According to one implementation, the method **400** includes monitoring, by the hub station, a second channel activity level associated with the second channel. For example, referring to FIG. **1**, the hub station **102** can monitor the channel activity level **130B** associated with the channel **106B**. The method **400** can also include determining, by the hub station, that the second channel activity level is lower than the first channel activity level. For example, referring to FIG. **1**, the hub station **102** can determine that the channel activity level **130B** is lower than the channel activity level **130A**. In this implementation, the hub station switches to the second channel in response to determining that the second channel activity level is lower than the first channel activity level.

[0073] According to one implementation of the method **400**, the first channel activity level corresponds to a level of radio transmission energy on the first channel. According to one implementation of the method **400**, the first channel activity level corresponds to a moving average of channel activity levels on the first channel. The moving average of channel activity levels can be based on channel activity level measurements on the first channel for five consecutive clock cycles.

[0074] According to one implementation of the method **400**, the low-energy device remains in an idle state absent detection of a wake-up event. The message can be sent to the hub station, from the low-energy device, in response to the wake-up event. According to one implementation of the method **400**, the low-energy device corresponds to a motion sensor. According to other implementations of the method **400**, the low-energy device corresponds to a keypad or an entry sensor.

[0075] According to one implementation of the method **400**, an unsuccessful attempt to send the

message to the hub station on the first channel occurs when the low-energy device fails to receive the acknowledgment message from the hub station on the first channel. According to one implementation of the method **400**, the message is sent to the hub station on the second channel after two unsuccessful attempts, by the low-energy device, to send the message to the hub station on the first channel. For example, the hub station may monitor radio transmission energy levels on the different channels during a brief monitoring period. During the monitoring period, the low-energy device may wake up and attempt to send a message to the hub station on the first channel (e.g., a primary channel). Because the hub station is monitoring radio transmission energy levels on different channels, the attempt may be unsuccessful. As a result of the unsuccessful attempt, the hub station may lose the message transmitted by the low-energy device. The low-energy device can retransmit the message after an acknowledgement period. After the monitoring period, the hub station can return to normal operation on the first channel, receive the retransmitted message from the low-energy device, and send an acknowledgement to the low-energy device. Thus, to ensure that message is not lost, the acknowledgment period is greater than the monitoring period.

[0076] According to one implementation of the method **400**, the hub station bypasses, in response to switching to the second channel, sending a notification to the low-energy device that the hub station switched to the second channel. According to one implementation of the method **400**, the low-energy device sends messages to the hub station on the second channel after receiving the acknowledgment message.

[0077] According to one implementation, the method **400** includes monitoring, by the hub station, the first channel activity level after switching to the second channel. For example, referring to FIG. **1**, the hub station **102** can monitor the channel activity level **130A** after switching to the channel **106B**. The method **400** can also include switching back to the first channel to communicate with the low-energy device in response to determining that the first channel activity level is lower than a second channel activity level associated with the second channel. For example, referring to FIG. **1**, the hub station **102** can switch back to the channel **106A** to communicate with the low-energy device **104A** in response to determining that the channel activity level **130A** is lower than the channel activity level **130B** associated with the channel **106B**.

[0078] According to one implementation, the method **400** includes monitoring, by the hub station, the first channel activity level after switching to the second channel. For example, referring to FIG. **1**, the hub station **102** can monitor the channel activity level **130A** after switching to the channel **106B**. The method **400** can also include switching back to the first channel to communicate with the low-energy device in response to determining that the first channel activity level fails to satisfy the threshold activity level. For example, referring to FIG. **1**, the hub station **102** can switch back to the channel **106A** to communicate with the low-energy device **104A** in response to determining that the channel activity level **130A** fails to satisfy (e.g., is less than or equal to) the threshold activity level **136**. In this implementation, the first channel is a primary channel that has a higher compatibility rating, associated with communications between the hub station and the low-energy device, than the second channel.

[0079] According to one implementation of the method **400**, the plurality of channels includes the first channel, the second channel, and at least one other channel. The hub station is configurable to communicate with the low-energy device using any channel in the plurality of channels. According to one implementation, when the hub station monitors the first channel activity level, channel activity levels associated with other channels of the plurality of channels are unmonitored by the hub station. According to one implementation of the method **400**, the particular frequency range correspond to a frequency range under one gigahertz (GHz). According to one implementation of the method **400**, the threshold activity level is programmable.

[0080] The method **400** of FIG. **4** provides the hub station **102** with the agility to quickly switch channels **106** without notifying the low-energy devices **104** of the switch. For example, the hub station **102** can monitor (e.g., listen on) the channels **106** to select a channel **106** that does not have

consistent radio energy (e.g., jamming). After selecting the channel **106**, instead of directly notifying the low-energy devices **104**, the low-energy devices **104** will find the channel **106** (e.g., the frequency) to which the hub station **102** moved by sending messages to the hub station **102** on different channels and awaiting an acknowledgment message. Thus, if the hub station **102** frequently switches between multiple channels **106**, battery power can be conserved at the low-energy devices **104** because the hub station **102** bypasses sending channel switching notifications to the low-energy devices **104**, which would cause the low-energy devices to “wake-up”. As a result, the low-energy devices **104** can remain in a low-energy mode until detecting a wake-up event.

[0081] Additional methods **500**, **600** are disclosed with respect to FIGS. **5** and **6**. According to the method **500** of FIG. **5**, the hub station **102** listen for messages on the primary channel **106A** if radio transmission energy **132A** on the primary channel **106A** is less than a threshold level. Thus, according to the method **500** of FIG. **5**, if the radio transmission energy **132A** on the primary channel is below a threshold level, the hub station **102** listens for messages on the primary channel **106A** regardless of whether the radio transmission energy **132B** on the secondary channel **106B** is less than the radio transmission energy **132A** on the primary channel **106A**. It may be beneficial to switch to the primary channel **106A** because the primary channel **106A** may have a higher compatibility rating, associated with communications between the hub station **102** and the low-energy devices **104**, than the secondary channel **106B**.

[0082] However, according to the method **600** of FIG. **6**, the hub station **102** listens for messages on whichever channel **106** has the lowest radio transmission energy **132**. Thus, according to the method **600** of FIG. **6**, one channel **106A** may not present improved compatibility than the other channel **106B**. As a result, it may be beneficial to switch to whichever channel **106** has the lowest radio transmission energy **132**.

[0083] FIG. **5** is a flow chart illustrating another example method **500**. The method **500** can be carried out by a communication system, such as the communication system **100**, or by a hub station, such as the hub station **102**.

[0084] According to the method **500**, at block **502**, a hub station monitors a radio transmission energy level on a primary channel. For example, referring to FIG. **1**, the hub station **102** monitors the radio transmission energy **132A** on the channel **106A**.

[0085] At decision block **504**, the hub station determines if the radio transmission energy level on the primary channel greater than a threshold. For example, referring to FIG. **1**, the hub station **102** determines whether the radio transmission energy **132A** on the channel **106A** is greater than the threshold activity level **136**.

[0086] If the radio transmission energy level on the primary channel is not greater than the threshold, at decision block **504**, the method **500** moves to block **506**. At block **506**, the hub station listens for messages on the primary channel. For example, referring to FIG. **1**, the hub station **102** listens for messages **164** from the low-energy devices **104** on the channel **106A**.

[0087] At decision block **508**, the hub station determines whether a message from a low-energy device been received on the primary channel. For example, referring to FIG. **1**, hub station **102** determines whether a message **164** has been received from one of the low-energy devices **104** on the channel **106A**.

[0088] If a message from the low-energy device has not been received on the primary channel, at decision block **508**, the method **500** moves back to block **502**. However, if a message from the low-energy device has been received on the primary channel, at decision block **508**, the method **500** moves to block **510**. At block **510**, the hub station sends an acknowledgment message to the low-energy device on the primary channel. For example, referring to FIG. **1**, if the message **164A** from the low-energy device **104A** has been received by the hub station **102** on the channel **106A**, the hub station **102** sends the acknowledgment message **170** to the low-energy device **104A** on the channel **106A**. After sending the acknowledgment message, at block **510**, the method **500** moves back to

block **502**.

[0089] If the radio transmission energy level on the primary channel is greater than the threshold, at decision block **504**, the method **500** moves to block **512**. At block **512**, the hub station switches to a secondary channel having a lower radio transmission energy level than the threshold. For example, referring to FIG. **1**, the hub station **102** switches to the channel **106B** (assuming that the radio transmission energy **132B** on the channel **106B** is lower than the threshold activity level **136**).

[0090] At block **514**, the hub station listens for messages on the secondary channel. For example, referring to FIG. **1**, the hub station **102** listens for messages **164** from the low-energy devices **104** on the channel **106B**.

[0091] At decision block **516**, the hub station determines whether a message from a low-energy device been received on the secondary channel. For example, referring to FIG. **1**, the hub station **102** determines whether a message **164** has been received from one of the low-energy devices **104** on the channel **106B**.

[0092] If a message from the low-energy device has not been received on the secondary channel, at decision block **516**, the method **500** moves to block **518**. At block **518**, the hub station remains on the secondary channel and periodically monitors the radio transmission energy level on the primary channel. For example, referring to FIG. **1**, the hub station **102** remains on the channel **106B** and periodically monitors the radio transmission energy **132A** on the channel **106A**.

[0093] However, if a message from the low-energy device has been received on the secondary channel, at decision block **516**, the method **500** moves to block **520**. At block **520**, the hub station sends an acknowledgment message to the low-energy device on the secondary channel. For example, referring to FIG. **1**, if the message **164A** from the low-energy device **104A** has been received by the hub station **102** on the channel **106B**, the hub station **102** sends the acknowledgment message **170** to the low-energy device **104A** on the channel **106B**. After sending the acknowledgment message, at block **520**, the method **500** moves to block **518**.

[0094] At decision block **522**, the hub station determines if the radio transmission energy level on the primary channel greater than a threshold. For example, referring to FIG. **1**, the hub station **102** determines whether the radio transmission energy **132A** on the channel **106A** is greater than the threshold activity level **136**.

[0095] If the radio transmission energy level on the primary channel is not greater than the threshold, at decision block **522**, the method **500** moves to block **524**. At block **524**, the hub station switches to the primary channel. For example, referring to FIG. **1**, the hub station **102** switches back to the channel **106A**. After the hub station switches back to the primary channel, at block **524**, the method **500** moves back to block **506**. If the radio transmission energy level on the primary channel is greater than the threshold, at decision block **522**, the method **500** moves to block **514**.

[0096] The method **500** of FIG. **5** provides the hub station **102** with the agility to quickly switch from a primary channel **106A** to a secondary channel **106B** based on whether the primary channel **106A** has consistent radio energy (e.g., jamming). Thus, according to the method **500** of FIG. **5**, hub station **102** reverts back to the primary channel **106A** if the radio energy on the primary channel **106A** is less than a threshold, regardless of whether the secondary channel **106B** has less radio energy than the primary channel **106A**. It may be beneficial to switch (e.g., revert back) to the primary channel **106A** because the primary channel **106A** may have a higher compatibility rating, associated with communications between the hub station **102** and the low-energy devices **104**, than the secondary channel **106B**.

[0097] FIG. **6** is a flow chart illustrating another example method **600**. The method **600** can be carried out by a communication system, such as the communication system **100**, or by a hub station, such as the hub station **102**.

[0098] According to the method **600**, at block **602**, a hub station monitors a first radio transmission energy level on a first channel and a second radio transmission energy level on a second channel. For example, referring to FIG. **1**, the hub station **102** monitors the radio transmission energy **132A**

on the channel **106A** and the radio transmission energy level **132B** on the channel **106B**.

[0099] At decision block **604**, the hub station determines if the second radio transmission energy level is less than the first radio transmission energy level. For example, referring to FIG. **1**, the hub station **102** determines whether the radio transmission energy **132B** is less than the radio transmission energy **132A**.

[0100] If the second radio transmission energy level on the second channel is not less than the first radio transmission energy level on the first channel, at decision block **604**, the method **600** moves to block **606**. At block **606**, the hub station listens for messages on the first channel. For example, referring to FIG. **1**, the hub station **102** listens for messages **164** from the low-energy devices **104** on the channel **106A**.

[0101] At decision block **608**, the hub station determines whether a message from a low-energy device been received on the first channel. For example, referring to FIG. **1**, hub station **102** determines whether a message **164** has been received from one of the low-energy devices **104** on the channel **106A**.

[0102] If a message from the low-energy device has not been received on the first channel, at decision block **608**, the method **600** moves back to block **602**. However, if a message from the low-energy device has been received on the first channel, at decision block **608**, the method **600** moves to block **610**. At block **610**, the hub station sends an acknowledgment message to the low-energy device on the first channel. For example, referring to FIG. **1**, if the message **164A** from the low-energy device **104A** has been received by the hub station **102** on the channel **106A**, the hub station **102** sends the acknowledgment message **170** to the low-energy device **104A** on the channel **106A**. After sending the acknowledgment message, at block **610**, the method **600** moves back to block **602**.

[0103] If the second radio transmission energy level on the second channel is less than the first radio transmission energy level on the first channel, at decision block **604**, the method **600** moves to block **612**. At block **612**, the hub station switches to a second channel. For example, referring to FIG. **1**, the hub station **102** switches to the channel **106B**.

[0104] At block **614**, the hub station listens for messages on the second channel. For example, referring to FIG. **1**, the hub station **102** listens for messages **164** from the low-energy devices **104** on the channel **106B**.

[0105] At decision block **616**, the hub station determines whether a message from a low-energy device been received on the second channel. For example, referring to FIG. **1**, the hub station **102** determines whether a message **164** has been received from one of the low-energy devices **104** on the channel **106B**.

[0106] If a message from the low-energy device has not been received on the second channel, at decision block **616**, the method **600** moves to block **618**. At block **618**, the hub station remains on the second channel and periodically monitors the first and second radio transmission energy levels. For example, referring to FIG. **1**, the hub station **102** remains on the channel **106B** and periodically monitors the radio transmission energy **132A** on the channel **106A** and the radio transmission energy **132B** on the channel **106B**.

[0107] However, if a message from the low-energy device has been received on the second channel, at decision block **616**, the method **600** moves to block **620**. At block **620**, the hub station sends an acknowledgment message to the low-energy device on the second channel. For example, referring to FIG. **1**, if the message **164A** from the low-energy device **104A** has been received by the hub station **102** on the channel **106B**, the hub station **102** sends the acknowledgment message **170** to the low-energy device **104A** on the channel **106B**. After sending the acknowledgment message, at block **620**, the method **600** moves to block **618**.

[0108] At decision block **622**, the hub station determines if the second radio transmission energy level is less than the first radio transmission energy level. For example, referring to FIG. **1**, the hub station **102** determines whether the radio transmission energy **132B** is less than the radio

transmission energy **132A**.

[0109] If the second radio transmission energy level on the second channel is not less than the first radio transmission energy level, at decision block **622**, the method **600** moves to block **624**. At block **624**, the hub station switches to the first channel. For example, referring to FIG. **1**, the hub station **102** switches back to the channel **106A**. After the hub station switches back to the first channel, at block **624**, the method **600** moves back to block **606**. If the second radio transmission energy level is less than the first radio transmission energy level, at decision block **622**, the method **600** moves to block **614**.

[0110] The method **600** of FIG. **6** provides the hub station **102** with the agility to quickly switch from a first channel **106A** to a second channel **106B** based on whether the first channel **106A** has consistent radio energy (e.g., jamming). According to the method **600** of FIG. **6**, the hub station **102** listens for messages on whichever channel **106** has the lowest radio transmission energy **132** because one channel **106A** may not present improved compatibility than the other channel **106B**. As a result, it may be beneficial to switch to whichever channel **106** has the lowest radio transmission energy **132**.

[0111] FIG. **7** is a flow chart illustrating another example method **700**. The method **700** can be carried out by a communication system, such as the communication system **100**, or by a low-energy device, such as the low-energy device **104A** or the low-energy device **104B**.

[0112] According to the method **700**, at block **702**, a low-energy device transmits a message to a hub station using a current channel. For example, referring to FIG. **1**, the low-energy device **104A** transmits the message **164A** to the hub station **102** using the channel **106A**.

[0113] At block **704**, the low-energy device waits for an acknowledgment message from the hub station. For example, referring to FIG. **1**, the low-energy device **104A** waits for the acknowledgment message **170** from the hub station **102** in response to sending the message **164A**.

[0114] At decision block **706**, the low-energy device determines whether the acknowledgment message was receiving during an acknowledgment period. For example, referring to FIG. **1**, the low-energy device **104A** determines whether the acknowledgment message **170** was received from the hub station **102** during a time period (e.g., an acknowledgment period) after transmitting the message **164A**. If the acknowledgment message was received during the acknowledgment period, at decision block **706**, the method **700** continues to block **708**. At block **708**, the low-energy device stays on the current channel and enters into a low-power mode. However, if the acknowledgement message was not received during the acknowledgment period, at block **710**, the method **700** continues to block **710**.

[0115] At block **710**, the low-energy device transmits a message to a hub station using a current channel. For example, referring to FIG. **1**, the low-energy device **104A** retransmits the message **164A** to the hub station **102** using the channel **106A**.

[0116] At block **712**, the low-energy device waits for an acknowledgment message

[0117] for the retransmitted message from the hub station. For example, referring to FIG. **1**, the low-energy device **104A** waits for the acknowledgment message **170** from the hub station **102** in response to sending the message **164A**.

[0118] At decision block **714**, the low-energy device determines whether the acknowledgment message for the retransmitted message was receiving during an acknowledgment period. For example, referring to FIG. **1**, the low-energy device **104A** determines whether the acknowledgment message **170** was received from the hub station **102** during a time period (e.g., an acknowledgment period) after retransmitting the message **164A**. If the acknowledgment message was received during the acknowledgment period, at decision block **714**, the method **700** continues to block **708**. However, if the acknowledgement message was not received during the acknowledgment period, at block **714**, the method **700** continues to block **716**.

[0119] At block **716**, the low-energy device switches to a different channel and different channel becomes the new “current channel”. For example, referring to FIG. **1**, the low-energy device **104A**

switches to the channel **106B** and the channel **106B** becomes the new current channel (e.g., the channel that the low-energy device **104A** uses to communicate with the hub station **102**). After switching, at block **716**, the method **700** returns to block **702** and the low-energy device transmits the message to the hub station using the new current channel.

VI. Example Variations

[0120] Although some of the acts and/or functions described in this disclosure have been described as being performed by a particular entity, the acts and/or functions can be performed by any entity, such as those entities described in this disclosure. Further, although the acts and/or functions have been recited in a particular order, the acts and/or functions need not be performed in the order recited. However, in some instances, it can be desired to perform the acts and/or functions in the order recited. Further, each of the acts and/or functions can be performed responsive to one or more of the other acts and/or functions. Also, not all of the acts and/or functions need to be performed to achieve one or more of the benefits provided by this disclosure, and therefore not all of the acts and/or functions are required.

[0121] Although certain variations have been discussed in connection with one or more examples of this disclosure, these variations can also be applied to all of the other examples of this disclosure as well.

[0122] Although select examples of this disclosure have been described, alterations and permutations of these examples will be apparent to those of ordinary skill in the art. Other changes, substitutions, and/or alterations are also possible without departing from the invention in its broader aspects as set forth in the following claims.

Claims

1. A method comprising: switching, by a hub station, from a first channel to a second channel; and notifying the device that the hub station switched to the second channel by sending an acknowledgement message to the device on the second channel in response to receiving a message from the device on the second channel, wherein the message is sent to the hub station on the second channel after at least one unsuccessful attempt to send the message to the hub station on the first channel.
2. The method of claim 1, wherein the hub station switches from the first channel to the second channel in response to a determination that first channel activity level associated with the first channel satisfies a threshold activity level.
3. The method of claim 1, wherein switching from the first channel to the second channel is based at least on a second channel activity level associated with the second channel.
4. The method of claim 3, wherein the hub station switches from the first channel to the second channel in response to a determination that the second channel activity level fails to satisfy a threshold activity level.
5. The method of claim 1, wherein first channel activity level associated with the first channel corresponds to a level of radio transmission energy on the first channel.
6. The method of claim 1, wherein first channel activity level associated with the first channel corresponds to a moving average of channel activity levels on the first channel.
7. The method of claim 6, wherein the moving average of channel activity levels is based on channel activity level measurements on the first channel for five consecutive clock cycles.
8. The method of claim 1, wherein the device corresponds to a motion sensor.
9. The method of claim 1, wherein an unsuccessful attempt to send the message to the hub station on the first channel occurs when the device fails to receive the acknowledgment message from the hub station on the first channel.
10. The method of claim 1, wherein the message is sent to the hub station on the second channel after two unsuccessful attempts, by the device, to send the message to the hub station on the first

channel.

11. The method of claim 1, wherein the hub station bypasses, in response to switching to the second channel, sending a notification to the device that the hub station switched to the second channel.

12. The method of claim 1, wherein the device sends messages to the hub station on the second channel after receiving the acknowledgment message.

13. The method of claim 1, further comprising switching back to the first channel to communicate with the device in response to determining that first channel activity level associated with the first channel fails to satisfy a threshold activity level, wherein the first channel is a primary channel that has a higher compatibility rating, associated with communications between the hub station and the device, than the second channel.

14. A hub station comprising: a memory; and a processor coupled to the memory, the processor configured to: switch from a first channel to a second channel; and notify the device that the hub station switched to the second channel by sending an acknowledgement message to the device on the second channel in response to receiving a message from the device on the second channel, wherein the message is sent to the hub station on the second channel after at least one unsuccessful attempt to send the message to the hub station on the first channel.

15. The hub station of claim 14, wherein the hub station switches from the first channel to the second channel in response to a determination that first channel activity level associated with the first channel satisfies a threshold activity level.

16. The hub station of claim 14, wherein switching from the first channel to the second channel is based at least on a second channel activity level associated with the second channel.

17. The hub station of claim 16, wherein the hub station switches from the first channel to the second channel in response to a determination that the second channel activity level fails to satisfy a threshold activity level.

18. The hub station of claim 14, wherein first channel activity level associated with the first channel corresponds to a level of radio transmission energy on the first channel.

19. A non-transitory computer-readable medium comprising instructions that, when executed by a processor within a hub station, causes the processor to perform operations comprising: switching from a first channel to a second channel; and notifying the device that the hub station switched to the second channel by sending an acknowledgement message to the device on the second channel in response to receiving a message from the device on the second channel, wherein the message is sent to the hub station on the second channel after at least one unsuccessful attempt to send the message to the hub station on the first channel.

20. The non-transitory computer-readable medium of claim 19, wherein the operations further comprise switching back to the first channel to communicate with the device in response to determining that first channel activity level associated with the first channel fails to satisfy a threshold activity level, wherein the first channel is a primary channel that has a higher compatibility rating, associated with communications between the hub station and the device, second channel.
