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(71) Applicant: TELEFONAKTIEBOLAGET LM ERICSSON (PUBL) [SE/SE]; SE-164 83 Stockholm (SE).

(72) Inventors: MAX, Sebastian; Jesuitengasse 87a, 50737 Cologne (DE). PETTERSSON, Charlie; Näckrosvägen 7, SE-169 37 Solna (SE). WILHELMSSON, Leif; Karl XII Gatan 9, SE-222 20 Lund (SE). DI TARANTO, Rocco; Arkivgatan 7F, SE-223 59 Lund (SE).

(74) Agent: ERICSSON; Torshamnsgatan 21-23, 164 80 STOCKHOLM (SE).

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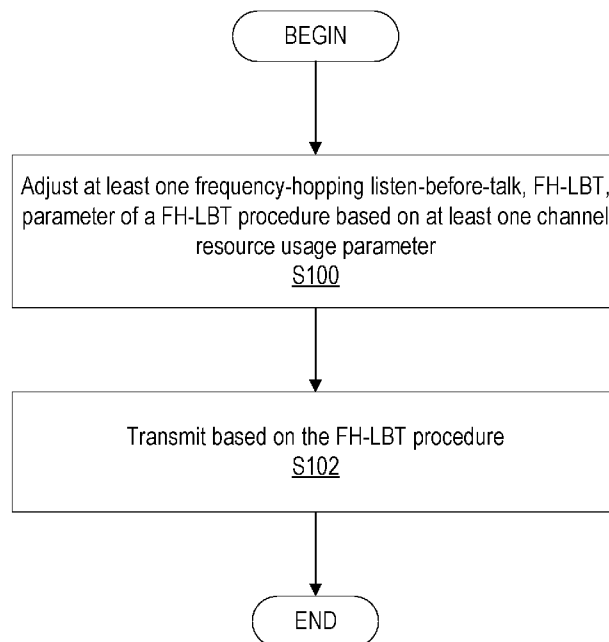


FIG. 3

(57) Abstract: A method, system and apparatus are disclosed. In an example embodiment, A network node configured to communicate with a wireless device is provided. The network node is configured to adjust at least one frequency-hopping listen-before-talk, FH-LBT, parameter of a FH-LBT procedure based on at least one channel resource usage parameter. The network node is configured to transmit based on the FH-LBT procedure.



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## ADAPTIVE LISTEN-BEFORE-TALK FOR NARROW BAND FREQUENCY HOPPING

### FIELD

The present disclosure relates to wireless communications, and in particular, to a  
5 dynamic Listen-before Talk (LBT) operation for narrow-band frequency hopping systems.

### INTRODUCTION

When operating in unlicensed bands, e.g., the 2.4 GHz industrial, scientific, and  
medical (ISM), the 5 GHz band, or the 6 GHz band, some method of spectrum sharing  
10 mechanism may be required unless the transmissions are limited to use a very low power.  
The two most commonly used spectrum sharing mechanisms are listen before talk (LBT)  
(also referred to as carrier sense multiple access with collision avoidance (CSMA/CA))  
and frequency hopping (FH).

With CSMA/CA-based LBT, before a transmission can be initiated, the transmitter  
15 listens on the channel to determine whether the channel is idle or if there is already  
another transmission ongoing (also referred to as “Carrier Sense”). If the channel is found  
to be idle, the transmission can be initiated. If the channel is found to be busy, the  
transmitter must defer from transmitting. To reduce the probability that two or more  
devices transmit at the same time, the channel sensing duration may be randomized, and  
20 the range of the duration is adapted based on recent transmission success rates (also  
referred to as “Collision Avoidance”). CSMA/CA-based LBT is used by different variants  
of the Institute of Electrical Engineers (IEEE) 802.11 standard, commonly referred to as  
Wi-Fi. It is also employed by standards developed by the Third Generation Partnership  
Project (3GPP) operating in the 5 GHz band, e.g., New Radio Unlicensed (NR-U).

25 If FH is used, the spectrum sharing is based on only using a relatively small part of  
the band for a relatively small fraction of the total time, leaving room for other  
transmissions. FH is the approach used by, for example, Bluetooth.

Whether to employ CSMA/CA-based LBT or FH is not obvious, but typically LBT  
is the preferred approach if the channel bandwidth to be used is relatively large, e.g., 20  
30 MHz or more, and the required usage of the channel is very dynamic with a lot of  
variance. FH, on the other hand, is well suited for narrowband systems where the occupied  
bandwidth is much less (e.g., on the order of 1 or 2 MHz) and a predictable, deterministic  
channel usage is required.

Although both CSMA/CA-based LBT and FH can be viewed as effective spectrum sharing mechanisms, each typically only works well if all devices are using the same spectrum sharing mechanism, i.e., if all devices either apply LBT or use FH. However, if some devices use LBT and others use FH, problems may arise. For example, a wideband system using LBT may detect a narrowband transmission and defer from transmitting, even though such a transmission may have been successful without causing any noticeable harm to the narrowband system. Conversely, the wideband system may not detect a narrowband system, since the average sensed power within the wideband channel is relatively low, and then initiate a transmission that potentially can result in harmful interference to the narrowband system.

The above situation may be present in the 2.4 GHz ISM band, where Wi-Fi uses CSMA/CA-based LBT, whereas Bluetooth uses FH. To allow for better coexistence between the two standards, Bluetooth has developed support for adaptive FH (AFH), whereby Bluetooth devices identify channels with high interference and then adapt the hopping pattern used for FH such that these channels are no longer used. Furthermore, as the assumption is that the interference originates from Wi-Fi, all frequencies coinciding with the overlapping 20 MHz Wi-Fi channel are also removed from the hopping pattern. As a result, eventually Bluetooth devices vacate the spectrum used by Wi-Fi. In Bluetooth Low Energy (BLE), additional specific measures are taken to limit the interference to Wi-Fi by only using three channels for the initial link establishment, and these three channels are selected such that they will not overlap with the three most commonly used Wi-Fi channels (Wi-Fi Channels 1, 6 and 11).

AFH may be an effective coexistence mechanism in some cases, but it is limited by being relatively slow to adapt. For example, it takes time to determine whether a frequency channel should be considered as occupied by another system and therefore should not be used, and also to determine when it is no longer occupied so that it may be used again. How long this takes may also depend on how much the channel is used, and it can be expected that if a channel is only used, e.g., 10% of the time, many FH transmissions may be needed in order to determine that in fact the channel is occupied. During this time, the impact on the wideband system may be non-negligible.

Another approach for enhancing the coexistence between a FH system and a wideband system using CSMA/CA-based LBT is to let the FH system use a simplified form of LBT, referred to as frequency-hopping LBT (FH-LBT). Specifically, for the FH system, before transmitting a narrow band signal on a new frequency, whether the

narrowband channel is idle or busy is checked first. If the channel is idle, the transmission is started. However, if the channel is found to be busy, the transmission on the channel is skipped, and the transmitter waits for the next attempt on the next channel according to its frequency hopping pattern. In comparison to the CSMA/CA-based LBT, the FH-LBT does not randomize or adapt the sensing duration, as the “Collision Avoidance” part is already addressed by the random selection of the narrow band channel.

FH-LBT can be combined with AFH, i.e., the system remembers that channels have been sensed as occupied regularly, and then removes them completely from the hopping pattern. Adding FH-LBT to AFH may speed up the convergence of AFH to unoccupied spectrum, as not only reception errors trigger a removal of a channel from the hopping pattern. Furthermore, even before convergence, the FH system is more careful not to interfere with the wideband system as it backs off its transmission if it detects the channel as occupied. Of course, the time it takes until the FH-LBT converges introduces additional delay to the narrowband system because it will skip transmission opportunities every time the FH-LBT detects a channel that is still in the hopping pattern as busy.

Generally, FH-LBT and AFH may only be effective when it is possible to converge to some channels that are free from interference. However, if the wideband system is using 100% of the available spectrum, the FH-LBT will eventually classify all narrowband channels as unusable such that the FH system may be unable to operate.

The wideband system using the entire spectrum is a problem if Bluetooth is used in the 6 GHz band. In the 6 GHz band, Wi-Fi may use 80 MHz, 160 MHz, 320 MHz, or even larger channel sizes in the future. Furthermore, neighboring Wi-Fi Access Points (APs) may strive to use non-overlapping channels for their operation to reduce the inter-cell interference. Hence, the presence of three APs, each using 160 MHz, will occupy the lower 480 MHz of the 6 GHz band, which is the only available part according to some regulations, such as those propagated in the European Union. This means that AFH may fail to identify available channels due to Wi-Fi's occupancy, and Bluetooth has to fall back to using a minimum number of remaining, interfered channels, limiting its performance. Furthermore, the performance of the Wi-Fi networks may also be impacted, as a device/system may detect the Bluetooth transmissions and defer from transmitting due to its LBT procedure or else may be interfered by the Bluetooth transmissions.

## SUMMARY

Aspects are provided by the appended independent claims, and embodiments thereof are provided by the appended dependent claims.

5 Some embodiments advantageously provide methods, systems, and apparatuses for a dynamic Listen-before Talk (LBT) operation for narrow-band frequency hopping systems.

Embodiments described herein relate to adapting the LBT parameters depending on the current channel hop configuration. If the set of channels is large or covers a large total bandwidth, the LBT may be adapted to be more careful, e.g., by adjusting the  
10 threshold for energy detection or the duration for channel sensing. If the set of channels is small or covers a small total bandwidth, the LBT may be adapted to be less sensitive by, e.g., adjusting the same thresholds. Consequently, the aggressiveness of the channel access may depend on the overall resource consumption and may result in an efficient weighting of channel usage and traffic requirements.

15 Some embodiments may allow for a simple yet efficient way for a narrow-band frequency hopping system to share the available license-exempt spectrum with a wideband system, without the risk of being too aggressive or too mild and thus not sharing the resources in a fair manner. In addition, the some embodiments might not require any changes to the wideband system, providing a feasible approach to operate with legacy  
20 wideband systems.

## BRIEF DESCRIPTION OF THE DRAWINGS

A more complete understanding of the present embodiments, and the attendant advantages and features thereof, will be more readily understood by reference to the  
25 following detailed description when considered in conjunction with the accompanying drawings wherein:

FIG. 1 is a schematic diagram of an example network architecture illustrating a communication system according to principles disclosed herein;

30 FIG. 2 is a block diagram of a network node in communication with a wireless device over a wireless connection according to some embodiments of the present disclosure;

FIG. 3 is a flowchart of an example process in a network node according to some embodiments of the present disclosure;

FIG. 4 is a flowchart of an example process in a wireless device according to some embodiments of the present disclosure;

FIG. 5 is a diagram of an example deployment scenario;

FIG. 6 is an example diagram of Bluetooth packet delay performance;

5 FIG. 7 is another example diagram of Bluetooth packet delay performance;

FIG. 8 is a diagram of an example power density spectrum measured by a Bluetooth link; and

10 FIG. 9 is an diagram of an example of a FH-LBT Energy Detect Threshold (EDT) based on the channel hopping size according to some embodiments of the present disclosure.

## DETAILED DESCRIPTION

Before describing in detail example embodiments, it is noted that the embodiments reside primarily in combinations of apparatus components and processing steps related to a dynamic LBT operation for narrow-band frequency hopping systems. Accordingly, components have been represented where appropriate by conventional symbols in the drawings, showing only those specific details that are pertinent to understanding the embodiments so as not to obscure the disclosure with details that will be readily apparent to those of ordinary skill in the art having the benefit of the description herein.

20 As used herein, relational terms, such as “first” and “second,” “top” and “bottom,” and the like, may be used solely to distinguish one entity or element from another entity or element without necessarily requiring or implying any physical or logical relationship or order between such entities or elements. The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the concepts described herein. As used herein, the singular forms “a”, “an” and “the” are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms “comprises,” “comprising,” “includes” and/or “including” when used herein, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof.

30 In embodiments described herein, the joining term, “in communication with” and the like, may be used to indicate electrical or data communication, which may be accomplished by physical contact, induction, electromagnetic radiation, radio signaling,

infrared signaling or optical signaling, for example. One having ordinary skill in the art will appreciate that multiple components may interoperate and modifications and variations are possible of achieving the electrical and data communication.

5 In some embodiments described herein, the term “coupled,” “connected,” and the like, may be used herein to indicate a connection, although not necessarily directly, and may include wired and/or wireless connections.

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

15 The term “network node” used herein can be any kind of network node comprised in a radio network which may further comprise any of base station (BS), radio base station, base transceiver station (BTS), base station controller (BSC), radio network controller (RNC), g Node B (gNB), evolved Node B (eNB or eNodeB), Node B, multi-standard radio (MSR) radio node such as MSR BS, multi-cell/multicast coordination entity (MCE), relay node, donor node controlling relay, radio access point (AP), transmission points, transmission nodes, Remote Radio Unit (RRU) Remote Radio Head (RRH), a core network node (e.g., mobile management entity (MME), self-organizing network (SON) node, a coordinating node, positioning node, MDT node, etc.), an external node (e.g., 3rd party node, a node external to the current network), nodes in distributed antenna system (DAS), a spectrum access system (SAS) node, an element management system (EMS), etc. The network node may also comprise test equipment. The term “radio node” used herein may be used to also denote a wireless device (WD) such as a wireless device (WD) or a radio network node. The network node may also comprise test equipment. In some embodiments, the network node may comprise a radio router, a radio transceiver, WiFi access point, wireless local area network (WLAN) access point, a network controller, a Bluetooth transceiver, etc.

In some embodiments, the non-limiting terms wireless device (WD) or a user equipment (UE) are used interchangeably. In some embodiments, the device may be and/or comprise an access point (AP) station (STA). In some embodiments, the device

may be and/or comprise a non-access point station (non-AP STA) The WD herein can be any type of wireless device capable of communicating with a network node or another WD over radio signals, such as wireless device (WD). The WD may also be a radio communication device, target device, device to device (D2D) WD, machine type WD or  
5 WD capable of machine to machine communication (M2M), low-cost and/or low-complexity WD, a sensor equipped with WD, Tablet, mobile terminals, smart phone, laptop embedded equipped (LEE), laptop mounted equipment (LME), USB dongles, Customer Premises Equipment (CPE), an Internet of Things (IoT) device, or a Narrowband IoT (NB-IOT) device etc.

10 Note also that some embodiments of the present disclosure may be supported by an Institute of Electrical Engineers (IEEE) 802.11 standard. IEEE 802.11 denotes a set of Wireless Local Area Network (WLAN) air interface standards developed by the IEEE 802.11 committee for short-range communications (e.g., tens of meters to a few hundred meters). Some embodiments may also be supported by standard documents disclosed in  
15 Third Generation Partnership Project (3GPP) technical specifications. That is, some embodiments of the description can be supported by the above documents. In addition, all the terms disclosed in the present document may be described by the above standard documents.

Note that although terminology from one particular wireless system, such as, for  
20 example, Bluetooth, IEEE 802.11, 3GPP, Long Term Evolution (LTE), 5th Generation (5G) and/or New Radio (NR) may be used in this disclosure, this should not be seen as limiting the scope of the disclosure to only the aforementioned system. Other wireless systems, including without limitation Wide Band Code Division Multiple Access (WCDMA), Worldwide Interoperability for Microwave Access (WiMax), Ultra Mobile  
25 Broadband (UMB) and Global System for Mobile Communications (GSM), may also benefit from exploiting the ideas covered within this disclosure.

In some embodiments, the general description elements in the form of “one of A and B” corresponds to A or B. In some embodiments, at least one of A and B corresponds to A, B or AB, or to one or more of A and B, or one or both of A and B. In some  
30 embodiments, at least one of A, B and C corresponds to one or more of A, B and C, and/or A, B, C or a combination thereof.

Note further, that functions described herein as being performed by a wireless device or a network node may be distributed over a plurality of wireless devices and/or network nodes. In other words, it is contemplated that the functions of the network node

and wireless device described herein are not limited to performance by a single physical device and, in fact, can be distributed among several physical devices.

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

Some embodiments are directed to a dynamic LBT operation for narrow-band frequency hopping systems.

Referring to the drawing figures, in which like elements are referred to by like reference numerals, there is shown in FIG. 1 a schematic diagram of a communication system 10, according to an embodiment, such as a wireless local area network (WLAN) that may support standards such as, for example, IEEE 802.11 and/or Bluetooth and/or other non-cellular standards/specifications, which comprises an access network 12, such as a radio access network. The access network 12 comprises a plurality of network nodes 16a, 16b, 16c (referred to collectively as network nodes 16), or other types of wireless access points, each defining a corresponding coverage area 18a, 18b, 18c (referred to collectively as coverage areas 18). A first wireless device (WD) 22a located in coverage area 18a is configured to wirelessly connect to, or be paged by, the corresponding network node 16a. A second WD 22b in coverage area 18b is wirelessly connectable to the corresponding network node 16b. While a plurality of WDs 22a, 22b (collectively referred to as wireless devices 22) are illustrated in this example, the disclosed embodiments are equally applicable to a situation where a sole WD is in the coverage area or where a sole WD is connecting to the corresponding network node 16. Note that although only two WDs 22 and three network nodes 16 are shown for convenience, the communication system may include many more WDs 22 and network nodes 16.

Also note that although network nodes 16 are illustrated as some kind of base stations and the wireless devices are illustrated as some kind of phone, the invention and its principle are by no means limited to such apparatuses and structures. The network nodes 16 can be any kind of apparatuses including radio interface etc. as for example demonstrated with reference to Fig. 2 and may operate under suitable communication standard. For example, for the Bluetooth context, the network node 16 will be a Central Device (previously known as Master Device) and the wireless device 22 will be a

Peripheral Device (previously known as Slave Device). Thus, the belonging to either NN 16 or WD 22 can depend on a role that the respective apparatus takes rather than a specific structure of the device. However, the NN 16 and the WD 22 may inherently have different structures for other contexts such as for traditional cellular systems as specified e.g., under the 3GPP, or other contexts where devices are dedicated to a certain hierarchical level (nodeB, base station, access point, etc. vs. UE, terminal, (non-AP) station, etc.) of a communication system.

Also, it is contemplated that a WD 22 can be in simultaneous communication and/or configured to separately communicate with more than one network node 16 and more than one type of network node 16.

A network node 16 is configured to include a network node (NN) coexistence unit 24 which is configured to perform one or more network node 16 functions described herein, including functions related to a dynamic LBT operation for narrow-band frequency hopping systems. A wireless device 22 is configured to include a wireless device (WD) coexistence unit 26 which is configured to perform one or more wireless device 22 functions described herein, including functions related to a dynamic LBT operation for narrow-band frequency hopping systems.

A first system may comprise one or more network nodes 16 communicating with one or more wireless devices 22 using a first standard, e.g., Wi-Fi. A second system may comprise one or more network nodes 16 communicating with one or more wireless devices 22 using a second standard different from the first standard, e.g., Bluetooth.

Example implementations, in accordance with an embodiment, of the WD 22 and network node 16 discussed in the preceding paragraphs will now be described with reference to FIG. 2.

The communication system 10 includes a network node 16a provided in a communication system 10 and including hardware 28 enabling it to communicate with the WD 22. The hardware 28 may include a radio interface 30 for setting up and maintaining at least a wireless connection 32 with a WD 22 located in a coverage area 18 served by the network node 16. The radio interface 30 may be formed as or may include, for example, one or more RF transmitters, one or more RF receivers, and/or one or more RF transceivers. The radio interface 30 includes an array of antennas 34 to radiate and receive signal(s) carrying electromagnetic waves.

In the embodiment shown, the hardware 28 of the network node 16 further includes processing circuitry 36. The processing circuitry 36 may include a processor 38

and a memory 40. In particular, in addition to or instead of a processor, such as a central processing unit, and memory, the processing circuitry 36 may comprise integrated circuitry for processing and/or control, e.g., one or more processors and/or processor cores and/or FPGAs (Field Programmable Gate Array) and/or ASICs (Application Specific Integrated Circuitry) adapted to execute instructions. The processor 38 may be configured to access (e.g., write to and/or read from) the memory 40, which may comprise any kind of volatile and/or nonvolatile memory, e.g., cache and/or buffer memory and/or RAM (Random Access Memory) and/or ROM (Read-Only Memory) and/or optical memory and/or EPROM (Erasable Programmable Read-Only Memory).

Thus, the network node 16 further has software 42 stored internally in, for example, memory 40, or stored in external memory (e.g., database, storage array, network storage device, etc.) accessible by the network node 16 via an external connection. The software 42 may be executable by the processing circuitry 36. The processing circuitry 36 may be configured to control any of the methods and/or processes described herein and/or to cause such methods, and/or processes to be performed, e.g., by network node 16. Processor 38 corresponds to one or more processors 38 for performing network node 16 functions described herein. The memory 40 is configured to store data, programmatic software code and/or other information described herein. In some embodiments, the software 42 may include instructions that, when executed by the processor 38 and/or processing circuitry 36, causes the processor 38 and/or processing circuitry 36 to perform the processes described herein with respect to network node 16. For example, processing circuitry 36 of the network node 16 may include a NN coexistence unit 24, which is configured to perform one or more network node 16 functions described herein, including functions related to a dynamic LBT operation for narrow-band frequency hopping systems.

The communication system 10 further includes the WD 22 already referred to. The WD 22 may have hardware 44 that may include a radio interface 46 configured to set up and maintain a wireless connection 32 with one or more network nodes 16a, 16b serving a coverage area 18 in which the WD 22 is currently located. The radio interface 46 may be formed as or may include, for example, one or more RF transmitters, one or more RF receivers, and/or one or more RF transceivers. The radio interface 46 includes an array of antennas 48 to radiate and receive signal(s) carrying electromagnetic waves.

The hardware 44 of the WD 22 further includes processing circuitry 50. The processing circuitry 50 may include a processor 52 and memory 54. In particular, in

addition to or instead of a processor, such as a central processing unit, and memory, the processing circuitry 50 may comprise integrated circuitry for processing and/or control, e.g., one or more processors and/or processor cores and/or FPGAs (Field Programmable Gate Array) and/or ASICs (Application Specific Integrated Circuitry) adapted to execute  
5 instructions. The processor 52 may be configured to access (e.g., write to and/or read from) memory 54, which may comprise any kind of volatile and/or nonvolatile memory, e.g., cache and/or buffer memory and/or RAM (Random Access Memory) and/or ROM (Read-Only Memory) and/or optical memory and/or EPROM (Erasable Programmable Read-Only Memory).

10 Thus, the WD 22 may further comprise software 56, which is stored in, for example, memory 54 at the WD 22, or stored in external memory (e.g., database, storage array, network storage device, etc.) accessible by the WD 22. The software 56 may be executable by the processing circuitry 50. The software 56 may include a client application 58. The client application 58 may be operable to provide a service to a human  
15 or non-human user via the WD 22.

The processing circuitry 50 may be configured to control any of the methods and/or processes described herein and/or to cause such methods, and/or processes to be performed, e.g., by WD 22. The processor 52 corresponds to one or more processors 52 for performing WD 22 functions described herein. The WD 22 includes memory 54 that is  
20 configured to store data, programmatic software code and/or other information described herein. In some embodiments, the software 56 and/or the client application 58 may include instructions that, when executed by the processor 52 and/or processing circuitry 50, causes the processor 52 and/or processing circuitry 50 to perform the processes described herein with respect to WD 22. For example, the processing circuitry 50 of the wireless device 22  
25 may include a WD coexistence unit 26 which is configured to perform one or more wireless device 22 functions described herein, including functions related to a dynamic LBT operation for narrow-band frequency hopping systems.

In some embodiments, the inner workings of the network node 16 and WD 22 may be as shown in FIG. 2 and independently, the surrounding network topology may be that  
30 of FIG. 1.

The wireless connection 32 between the WD 22 and the network nodes 16a, 16b is in accordance with the teachings of the embodiments described throughout this disclosure. More precisely, the teachings of some of these embodiments may improve the data rate, latency, and/or power consumption and thereby provide benefits such as reduced user

waiting time, relaxed restriction on file size, better responsiveness, extended battery lifetime, etc. In some embodiments, a measurement procedure may be provided for the purpose of monitoring data rate, latency and other factors on which the one or more embodiments improve.

5           Although FIGS. 1 and 2 show various “units,” such as NN coexistence unit 24, WD coexistence unit 26, as being within a respective processor, it is contemplated that these units may be implemented such that a portion of the unit is stored in a corresponding memory within the processing circuitry. In other words, the units may be implemented in hardware or in a combination of hardware and software within the processing circuitry.

10           FIG. 3 is a flowchart of an example process in a network node 16 according to some embodiments of the present disclosure. One or more blocks described herein may be performed by one or more elements of network node 16 such as by one or more of processing circuitry 36 (including the NN coexistence unit 24), processor 38, and/or radio interface 30. Network node 16 is configured to adjust at least one frequency-hopping  
15 listen-before-talk, FH-LBT, parameter of a FH-LBT procedure based on at least one channel resource usage parameter (Block S100). Network node 16 is configured to transmit based on the FH-LBT procedure (Block S102).

          In at least one embodiment, the at least one FH-LBT parameter includes at least one of: an energy detection threshold; a duration for sensing the channel bandwidth  
20 conditions; and a transmission duration for transmitting after sensing that a channel is idle.

          In at least one embodiment, the at least one channel resource usage parameter includes at least one of: a count of a plurality of channels of a frequency hopping configuration; a frequency delta between a highest channel of the plurality of channels and a lowest channel of the plurality of channels; and a transmission priority value.

25           In at least one embodiment, the at least one FH-LBT parameter is adjusted based on which wideband channels are covered by a plurality of channels in a channel hopping set.

          In at least one embodiment, the FH-LBT procedure corresponds to a plurality of channels, and the at least one FH-LBT parameter is adjusted for a subset of the plurality of  
30 channels.

          FIG. 4 is a flowchart of an example process in a wireless device 22 according to some embodiments of the present disclosure. One or more blocks described herein may be performed by one or more elements of wireless device 22 such as by one or more of processing circuitry 50 (including the WD coexistence unit 26), processor 52, and/or radio

interface 46. Wireless device 22 is configured to adjust at least one frequency-hopping listen-before-talk, FH-LBT, parameter of a FH-LBT procedure based on at least one channel resource usage parameter (Block S104). Wireless device 22 is configured to transmit based on the FH-LBT procedure (Block S106).

5 In at least one embodiment, the at least one FH-LBT parameter includes at least one of: an energy detection threshold; a duration for sensing the channel bandwidth conditions; and a transmission duration for transmitting after sensing that a channel is idle.

In at least one embodiment, the at least one channel resource usage parameter includes at least one of: a count of a plurality of channels of a frequency hopping  
10 configuration; a frequency delta between a highest channel of the plurality of channels and a lowest channel of the plurality of channels; and a transmission priority value.

In at least one embodiment, the at least one FH-LBT parameter is adjusted based on which wideband channels are covered by a plurality of channels in a channel hopping set.

15 In at least one embodiment, the FH-LBT procedure corresponds to a plurality of channels, and the at least one FH-LBT parameter is adjusted for a subset of the plurality of channels.

Having described the general process flow of arrangements of the disclosure and having provided examples of hardware and software arrangements for implementing the  
20 processes and functions of the disclosure, the sections below provide details and examples of arrangements for a dynamic LBT operation for narrow-band frequency hopping systems. One or more network node 16 functions described below may be performed by one or more of processing circuitry 36, processor 38, NN coexistence unit 24, WD coexistence unit 26, etc.

25 Various embodiments are described herein in the context of a narrow-band frequency-hopping radio system positioned in the same area as one, two or three wideband radio systems. FIG. 5 shows an example of such a scenario, where the narrow-band frequency-hopping is represented by a Bluetooth link, and the wideband radio systems are represented by Wi-Fi links.

30 In this example scenario, the available license-exempt spectrum is, in total, 480 MHz (corresponding to the lower 6 GHz band, 5945 MHz to 6425 MHz), and each Wi-Fi link uses one of the available, non-overlapping 160 MHz channels defined by, e.g., the IEEE 802.11 standard. Under these conditions, if only one of the three Wi-Fi links is constantly active, it will occupy 1/3 of the spectrum. If the Bluetooth link uses FH-LBT to

detect the channel condition before every transmission, 1/3 of the time it has to defer from the channel access and delay its transmission to the next channel access opportunity, and in 2/3 of the time it will find the channel as idle and start the transmission. Hence, overall, the Bluetooth transmissions will observe a delay of roughly zero in 2/3 of the time, and a much larger delay in 1/3 of the time, in addition to the time required for the transmission itself. FIG. 6 shows the corresponding Cumulative Distribution Functions (CDFs) of the packet delay, assuming a channel switch time of 10 ms and a packet size of 320 B. When only a single Wi-Fi link is in operation (line denoted by “1” in FIG. 6), with a probability of 2/3, the packet is transmitted immediately, resulting in a delay of roughly 3 ms; with a probability of 1/3 the delay is larger than 10 ms – with a small probability, it is even larger than 20 ms, indicating that two consecutive FH-LBTs have detected the channel as busy.

If instead of a single Wi-Fi link, two Wi-Fi links are active (line denoted by “2” in FIG. 6), then the probability of finding the channel to be idle drops to 1/3, and the probability for multiple, consecutive FH-LBT with a busy channel is further increased. Nevertheless, the Bluetooth link may eventually hop to a channel, according to its hopping pattern, that is detected as idle by the FH-LBT, and then transmits successfully. As shown in FIG. 6, in some cases this can take up to four attempts (i.e., 40 ms delay), and in some cases it is possible that it requires four or more attempts.

The results where three Wi-Fi links are active are demonstrated by the line denoted by “3” in FIG. 6. Here, the Bluetooth link may rarely be able to detect the channel as idle (only with a small probability if the FH-LBT is in coincidence with a frame gap of the Wi-Fi link); hence, the Bluetooth link is over saturated by the load of the application (320 B every 20 ms), and it cannot meet the required throughput anymore.

As shown in FIG. 7, the performance of the Bluetooth link might improve if FH-LBT is combined with AFH. In the case of one or two active wideband Wi-Fi links, the packet delay is equal to the case where no interference at all is present: the packet delay consists only of the ~3 ms required for the data transmission itself, there is no delay due to skipping a busy channel. However, also visible from FIG. 7 (referring to the line denoted by “3”), this strategy fails if the wideband systems use all available spectrum, and the Bluetooth link's AFH reduces its channel hopping set to a minimum.

In these example scenarios, not all channels can be considered equally "busy" from the viewpoint of the Bluetooth link. If the center or right-hand Wi-Fi link transmits, then the received power at the Bluetooth link is, due to the small distance, much larger than if the left-hand Wi-Fi link transmits (which is at a larger distance). An example power

density spectrum might look like as depicted in FIG. 8: In the first third, the measured power is -58dBm/MHz, -71dBm/MHz in the middle third, and -55dBm/MHz in the last third. A constant energy detection threshold (EDT) of -75dBm/MHz (following, e.g., European Telecommunications Standards Institute (ETSI) Harmonized European Standard (EN) 303 687 v1.1.1, for a device with a maximum transmit power of 10dBm) results in a busy channel detected over the complete spectrum.

Embodiments described herein may address this issue whereby the narrow-band frequency hopping system (e.g., via a network node 16 and/or wireless device 22) adapts its FH-LBT parameters depending on the used channel bandwidth. An example is illustrated by FIG. 9, which depicts FH-LBT Energy Detect Threshold (EDT) based on the channel hopping size. If the total bandwidth that is used for the channel hopping (i.e., the channel hopping size) corresponds to the complete spectrum (480 MHz), then the EDT that determines if a channel is observed as idle or busy is -80 dBm/MHz. However, if the channel hopping set is limited to, let's say, 160 MHz, then the EDT may be increased to -60 dBm/MHz, resulting in a more aggressive usage of the channel. Hence, the Bluetooth link is allowed to operate in the middle 160 MHz of the spectrum, without being blocked by the third Wi-Fi link.

In some embodiments, this is not only beneficial for the Bluetooth link, which is able to transmit without delay, but also advantageous for the Wi-Fi systems. As Bluetooth restricts its hopping pattern to a part of the complete spectrum (e.g., via a network node 16 and/or wireless device 22), Wi-Fi can predict its interference more reliably and then avoid using this part of the spectrum, for example by changing the used channel or by employing puncturing.

It should be appreciated that the specific relation between channel hopping size and the EDT shown in FIG. 9 is just one example. The depicted shape of the curve (here: linear with 0 MHz / -50dBm, 480 MHz / -80dBm) is intended as a visualization of the principle, and the shape may vary between other embodiments while still achieving the benefits described herein. Other shapes (for example, step-wise) and other values might be selected to promote a fair sharing of the license-exempt spectrum between the different systems.

Furthermore, some embodiments may, in addition to or instead of the relationship between channel hopping size and EDT as described above, use other options to tune the aggressiveness of the FH-LBT (e.g., via a network node 16 and/or wireless device 22).

Some embodiments may use a dynamic adaptation of other FH-LBT's parameters is also conceivable, for example, which may:

• Adapt the maximum transmission duration after observing the channel as idle. For example, it might be required to transmit at most for 1 ms, or to check for an idle channel again after 1 ms of transmission. The FH-LBT becomes less aggressive if the maximum transmission duration is shortened and more checks of the channel have to be done.

• Adapt the listening duration of the FH-LBT, ranging from only a few  $\mu\text{s}$  to several tens of  $\mu\text{s}$ . The FH-LBT becomes less aggressive if a longer duration of channel listening duration has to be performed, since during the whole time the received power may be required to be below the EDT.

In some embodiments, the adaptation of the FH-LBT's parameters may be based on the resource usage of the narrow-band frequency hopping link. The resource usage can be measured, for example, by the following parameters of the channel hopping configuration:

• by the sum bandwidth covered by the frequency hopping, i.e., the number of channels in the channel hopping set multiplied with the narrow-band channel bandwidth. The adaptation may be such that the less the sum bandwidth is, the more aggressive the FH-LBT parameters can be used.

• by the total bandwidth covered by the frequency hopping, i.e., the difference between the maximum channel frequency and the minimum channel frequency. This motivates the AFH to prune the channel hopping set such that few "holes" occur. The adaptation may be such that the less the total bandwidth covered by the frequency hopping, the more aggressive the FH-LBT parameters can be used.

• by the priority category of the traffic to be delivered, giving higher priority traffic more aggressive FH-LBT parameters.

• by taking into account the specific wideband channels that are covered by the channel hopping set. Some parts of the spectrum may be commonly used by Wi-Fi to transmit critical network management information like beacons or association requests/responses. Under the assumption that these parts are known to the frequency hopping devices, the FH-LBT may be forced to used less aggressive parameters if these parts are included in the hopping set. This motivates the AFH to prune the channel hopping set such that few of the parts critical for wideband operation are covered. The knowledge of these parts might be achieved by prior agreements (for example, every nth

20 MHz channel), or by direct communication of a narrow-band device with a wideband device (for example in the case that the two devices are contained in the same user end-device, as may be the case for Wi-Fi and Bluetooth).

In some embodiments, the parameters of the FH-LBT are adapted (e.g., via a network node 16 and/or wireless device 22) only in some parts of the used frequency spectrum. For example, instead of completely removing from the hopping list those channels that are used more intensively by Wi-Fi, a Bluetooth device might be permitted to use these channels with a very sensitive energy detection threshold and long listening duration. Other channels that are used less often by Wi-Fi are used with the default, or even more aggressive, FH-LBT parameters.

Thus, more sensitive LBT implies that the requirements for declaring the channel to be available for transmission is higher, e.g. the used energy detection threshold is lower than for a more aggressive LBT, and, correspondingly, where less sensitive LBT (more aggressive LBT) implies that the requirements for declaring the channel to be available for transmission is lower, e.g. the used energy detection threshold is higher than for the less aggressive LBT (more sensitive LBT).

To promote correct operation in scenarios where many devices of different vendors are active, the specific settings of the FH-LBT's parameters and their dependence to the current resource usage may preferably be standardized, similar to how the parameters for the Wi-Fi wideband LBT are standardized by, e.g., the IEEE 802.11 standard.

Example embodiments include:

Example 1. A spectrum sharing mechanism for a narrow-band frequency hopping system employing listen-before talk, where at least one of the parameters of the listen-before-talk determining the aggressiveness of the channel access is adjusted depending on at least one parameters of the current channel hopping configuration.

Example 2. As in Example 1, where the parameter of the listen-before-talk to be adjusted is one of, or a combination of:

- a. the energy detection threshold;
- b. the duration of channel sensing; and
- c. the duration of the transmission after sensing the channel as idle.

Example 3. As in Example 1, where the parameters of the channel hopping configuration is one of, or a combination of:

- a. the count of the channels in the hopping configuration;
- b. the frequency delta between the highest channel and the lowest channel;

- c. the urgency of the data that is to be delivered; and
- d. the specific wideband channels covered by the hopping configuration.

Example 4. As in any one of Examples 1-3, where the parameters of the listen-before-talk are adjusted only in a part of the available spectrum.

5 As will be appreciated by one of skill in the art, the concepts described herein may be embodied as a method, data processing system, computer program product and/or computer storage media storing an executable computer program. Accordingly, the concepts described herein may take the form of an entirely hardware embodiment, an entirely software embodiment or an embodiment combining software and hardware  
10 aspects all generally referred to herein as a “circuit” or “module.” Any process, step, action and/or functionality described herein may be performed by, and/or associated to, a corresponding module, which may be implemented in software and/or firmware and/or hardware. Furthermore, the disclosure may take the form of a computer program product on a tangible computer usable storage medium having computer program code embodied  
15 in the medium that can be executed by a computer. Any suitable tangible computer readable medium may be utilized including hard disks, CD-ROMs, electronic storage devices, optical storage devices, or magnetic storage devices.

Some embodiments are described herein with reference to flowchart illustrations and/or block diagrams of methods, systems and computer program products. It will be  
20 understood that each block of the flowchart illustrations and/or block diagrams, and combinations of blocks in the flowchart illustrations and/or block diagrams, can be implemented by computer program instructions. These computer program instructions may be provided to a processor of a general purpose computer (to thereby create a special purpose computer), special purpose computer, or other programmable data processing  
25 apparatus to produce a machine, such that the instructions, which execute via the processor of the computer or other programmable data processing apparatus, create means for implementing the functions/acts specified in the flowchart and/or block diagram block or blocks.

These computer program instructions may also be stored in a computer readable  
30 memory or storage medium that can direct a computer or other programmable data processing apparatus to function in a particular manner, such that the instructions stored in the computer readable memory produce an article of manufacture including instruction means which implement the function/act specified in the flowchart and/or block diagram block or blocks.

The computer program instructions may also be loaded onto a computer or other programmable data processing apparatus to cause a series of operational steps to be performed on the computer or other programmable apparatus to produce a computer implemented process such that the instructions which execute on the computer or other programmable apparatus provide steps for implementing the functions/acts specified in the flowchart and/or block diagram block or blocks.

It is to be understood that the functions/acts noted in the blocks may occur out of the order noted in the operational illustrations. 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. Although some of the diagrams include arrows on communication paths to show a primary direction of communication, it is to be understood that communication may occur in the opposite direction to the depicted arrows.

Computer program code for carrying out operations of the concepts described herein may be written in an object oriented programming language such as Python, Java® or C++. However, the computer program code for carrying out operations of the disclosure may also be written in conventional procedural programming languages, such as the "C" programming language. The program code may execute entirely on the user's computer, partly on the user's computer, as a stand-alone software package, partly on the user's computer and partly on a remote computer or entirely on the remote computer. In the latter scenario, the remote computer may be connected to the user's computer through a local area network (LAN) or a wide area network (WAN), or the connection may be made to an external computer (for example, through the Internet using an Internet Service Provider).

Many different embodiments have been disclosed herein, in connection with the above description and the drawings. It will be understood that it would be unduly repetitious and obfuscating to literally describe and illustrate every combination and subcombination of these embodiments. Accordingly, all embodiments can be combined in any way and/or combination, and the present specification, including the drawings, shall be construed to constitute a complete written description of all combinations and subcombinations of the embodiments described herein, and of the manner and process of making and using them, and shall support claims to any such combination or subcombination.

Abbreviations that may be used in the preceding description include:

	<u>Abbreviation</u>	<u>Explanation</u>
	AFH	Adaptive Frequency Hopping
	AP	Access Point
	BLE	Bluetooth Low Energy
5	CDF	Cumulative Distribution Function
	CSMA/CA	Carrier Sense Multiple Access with Collision Avoidance
	EDT	Energy Detection Threshold
	FH	Frequency Hopping
	LBT	Listen Before Talk
10	NR-U	New Radio Unlicensed

It will be appreciated by persons skilled in the art that the embodiments described herein are not limited to what has been particularly shown and described herein above. In addition, unless mention was made above to the contrary, it should be noted that all of the accompanying drawings are not to scale. A variety of modifications and variations are possible in light of the above teachings.

Example embodiments:

Embodiment A1. A network node configured to communicate with a wireless device, the network node being configured to, and/or comprising a radio interface and/or comprising processing circuitry configured to:

adjust at least one frequency-hopping listen-before-talk, FH-LBT, parameter of a FH-LBT procedure based on at least one channel resource usage parameter; and transmit based on the FH-LBT procedure.

Embodiment A2. The network node of Embodiment A1, wherein the at least one FH-LBT parameter includes at least one of:

an energy detection threshold;  
a duration for sensing the channel bandwidth conditions; and  
a transmission duration for transmitting after sensing that a channel is idle.

Embodiment A3. The network node of Embodiment A1, wherein the at least one channel resource usage parameter includes at least one of:

a count of a plurality of channels of a frequency hopping configuration;  
a frequency delta between a highest channel of the plurality of channels and a lowest channel of the plurality of channels; and  
a transmission priority value.

Embodiment A4. The network node of Embodiment A1, wherein the at least one FH-LBT parameter is adjusted based on which wideband channels are covered by a plurality of channels in a channel hopping set.

Embodiment A5. The network node of Embodiment A1, wherein the FH-LBT procedure corresponds to a plurality of channels, and the at least one FH-LBT parameter is adjusted for a subset of the plurality of channels.

Embodiment B1. A method implemented in a network node that is configured to communicate with a wireless device, the method comprising:

adjusting at least one frequency-hopping listen-before-talk, FH-LBT, parameter of a FH-LBT procedure based on at least one channel resource usage parameter; and transmitting based on the FH-LBT procedure.

Embodiment B2. The method of Embodiment B1, wherein the at least one FH-LBT parameter includes at least one of:

an energy detection threshold;  
a duration for sensing the channel bandwidth conditions; and  
a transmission duration for transmitting after sensing that a channel is idle.

Embodiment B3. The method of Embodiment B1, wherein the at least one channel resource usage parameter includes at least one of:

a count of a plurality of channels of a frequency hopping configuration;  
a frequency delta between a highest channel of the plurality of channels and a lowest channel of the plurality of channels; and  
a transmission priority value.

Embodiment B4. The method of Embodiment B1, wherein the at least one parameter is adjusted based on which wideband channels are covered by a plurality of channels in a channel hopping set.

Embodiment B5. The method of Embodiment B1, wherein the FH-LBT procedure corresponds to a plurality of channels, and the at least one FH-LBT parameter is adjusted for a subset of the plurality of channels.

Embodiment C1. A wireless device configured to communicate with a network node, the wireless device being configured to, and/or comprising a radio interface and/or comprising processing circuitry configured to:

adjust at least one frequency-hopping listen-before-talk, FH-LBT, parameter of a FH-LBT procedure based on at least one channel resource usage parameter; and transmit based on the FH-LBT procedure.

Embodiment C2. The wireless device of Embodiment C1, wherein the at least one FH-LBT parameter includes at least one of:

an energy detection threshold;

a duration for sensing the channel bandwidth conditions; and  
a transmission duration for transmitting after sensing that a channel is idle.

Embodiment C3. The wireless device of Embodiment C1, wherein the at least one channel resource usage parameter includes at least one of:

- 5 a count of a plurality of channels of a frequency hopping configuration;  
a frequency delta between a highest channel of the plurality of channels and a lowest channel of the plurality of channels; and  
a transmission priority value.

Embodiment C4. The wireless device of Embodiment C1, wherein the at least one parameter is adjusted based on which wideband channels are covered by the a plurality of channels in a channel hopping set.

Embodiment C5. The wireless device of Embodiment C1, wherein the FH-LBT procedure corresponds to a plurality of channels, and the at least one FH-LBT parameter is adjusted for a subset of the plurality of channels.

15 Embodiment D1. A method implemented in a wireless device that is configured to communicate with a network node, the method comprising:  
adjusting at least one frequency-hopping listen-before-talk, FH-LBT, parameter of a FH-LBT procedure based on at least one channel resource usage parameter; and  
transmitting based on the FH-LBT procedure.

20 Embodiment D2. The method of Embodiment D1, wherein the at least one FH-LBT parameter includes at least one of:  
an energy detection threshold;  
a duration for sensing the channel bandwidth conditions; and  
a transmission duration for transmitting after sensing that a channel is idle.

25 Embodiment D3. The method of Embodiment D1, wherein the at least one channel resource usage parameter includes at least one of:  
a count of a plurality of channels of a frequency hopping configuration;  
a frequency delta between a highest channel of the plurality of channels and a lowest channel of the plurality of channels; and  
30 a transmission priority value.

Embodiment D4. The method of Embodiment D1, wherein the at least one parameter is adjusted based on which wideband channels are covered by a plurality of channels in a channel hopping set.

Embodiment D5. The method of Embodiment D1, wherein the FH-LBT procedure corresponds to a plurality of channels, and the at least one FH-LBT parameter is adjusted for a subset of the plurality of channels.

## CLAIMS

1. A network node (16) configured to communicate with a wireless device (22), the network node (16) being configured to, and/or comprising a radio interface (30) and/or comprising processing circuitry (36) configured to:
- 5 adjust at least one frequency-hopping listen-before-talk, FH-LBT, parameter of a FH-LBT procedure based on at least one channel resource usage parameter such that the FH-LBT parameter causes a more sensitive LBT for a channel resource usage parameter covering more frequency resources while the FH-LBT parameter causes a less sensitive
- 10 LBT for a channel resource usage parameter covering fewer frequency resources; and transmit based on the FH-LBT procedure.
2. The network node (16) of claim 1, wherein the at least one FH-LBT parameter includes at least one of:
- 15 an energy detection threshold;
- a duration for sensing the channel bandwidth conditions; and
- a transmission duration for transmitting after sensing that a channel is idle.
3. The network node (16) of claim 1, wherein the at least one channel
- 20 resource usage parameter includes at least one of:
- a count of a plurality of channels of a frequency hopping configuration;
- a frequency delta between a highest channel of the plurality of channels and a lowest channel of the plurality of channels; and
- a transmission priority value.
- 25
4. The network node (16) of claim 1, wherein the at least one FH-LBT parameter is adjusted based on which wideband channels are covered by a plurality of channels in a channel hopping set.
- 30
5. The network node (16) of claim 1, wherein the FH-LBT procedure corresponds to a plurality of channels, and the at least one FH-LBT parameter is adjusted for a subset of the plurality of channels.
6. A method implemented in a network node (16) that is configured to
- 35 communicate with a wireless device (22), the method comprising:

adjusting (S100) at least one frequency-hopping listen-before-talk, FH-LBT, parameter of a FH-LBT procedure based on at least one channel resource usage parameter; and

transmitting (S102) based on the FH-LBT procedure.

5

7. The method of claim 6, wherein the at least one FH-LBT parameter includes at least one of:

an energy detection threshold;

a duration for sensing the channel bandwidth conditions; and

10

a transmission duration for transmitting after sensing that a channel is idle.

8. The method of 6, wherein the at least one channel resource usage parameter includes at least one of:

a count of a plurality of channels of a frequency hopping configuration;

15

a frequency delta between a highest channel of the plurality of channels and a lowest channel of the plurality of channels; and

a transmission priority value.

9. The method of claim 6, wherein the at least one parameter is adjusted based on which wideband channels are covered by a plurality of channels in a channel hopping set.

20

10. The method of claim 6, wherein the FH-LBT procedure corresponds to a plurality of channels, and the at least one FH-LBT parameter is adjusted for a subset of the plurality of channels.

25

11. A wireless device (22) configured to communicate with a network node (16), the wireless device (22) being configured to, and/or comprising a radio interface (46) and/or comprising processing circuitry (50) configured to:

30

adjust at least one frequency-hopping listen-before-talk, FH-LBT, parameter of a FH-LBT procedure based on at least one channel resource usage parameter such that the FH-LBT parameter causes a more sensitive LBT for a channel resource usage parameter covering more frequency resources while the FH-LBT parameter causes a less sensitive LBT for a channel resource usage parameter covering fewer frequency resources; and

transmit based on the FH-LBT procedure.

12. The wireless device (22) of claim 11, wherein the at least one FH-LBT parameter includes at least one of:

- 5 an energy detection threshold;  
a duration for sensing the channel bandwidth conditions; and  
a transmission duration for transmitting after sensing that a channel is idle.

13. The wireless device (22) of claim 11, wherein the at least one channel  
10 resource usage parameter includes at least one of:

- a count of a plurality of channels of a frequency hopping configuration;  
a frequency delta between a highest channel of the plurality of channels and a  
lowest channel of the plurality of channels; and  
a transmission priority value.

15

14. The wireless device (22) of claim 11, wherein the at least one parameter is adjusted based on which wideband channels are covered by the a plurality of channels in a channel hopping set.

20 15. The wireless device (22) of claim 11, wherein the FH-LBT procedure corresponds to a plurality of channels, and the at least one FH-LBT parameter is adjusted for a subset of the plurality of channels.

25 16. A method implemented in a wireless device (22) that is configured to communicate with a network node (16), the method comprising:

adjusting (S104) at least one frequency-hopping listen-before-talk, FH-LBT, parameter of a FH-LBT procedure based on at least one channel resource usage parameter; and

transmitting (S106) based on the FH-LBT procedure.

30

17. The method of claim 16, wherein the at least one FH-LBT parameter includes at least one of:

- an energy detection threshold;  
a duration for sensing the channel bandwidth conditions; and

a transmission duration for transmitting after sensing that a channel is idle.

18. The method of claim 16, wherein the at least one channel resource usage parameter includes at least one of:

- 5 a count of a plurality of channels of a frequency hopping configuration;  
a frequency delta between a highest channel of the plurality of channels and a  
lowest channel of the plurality of channels; and  
a transmission priority value.

10 19. The method of claim 16, wherein the at least one parameter is adjusted based on which wideband channels are covered by a plurality of channels in a channel hopping set.

15 20. The method of claim 16, wherein the FH-LBT procedure corresponds to a plurality of channels, and the at least one FH-LBT parameter is adjusted for a subset of the plurality of channels.

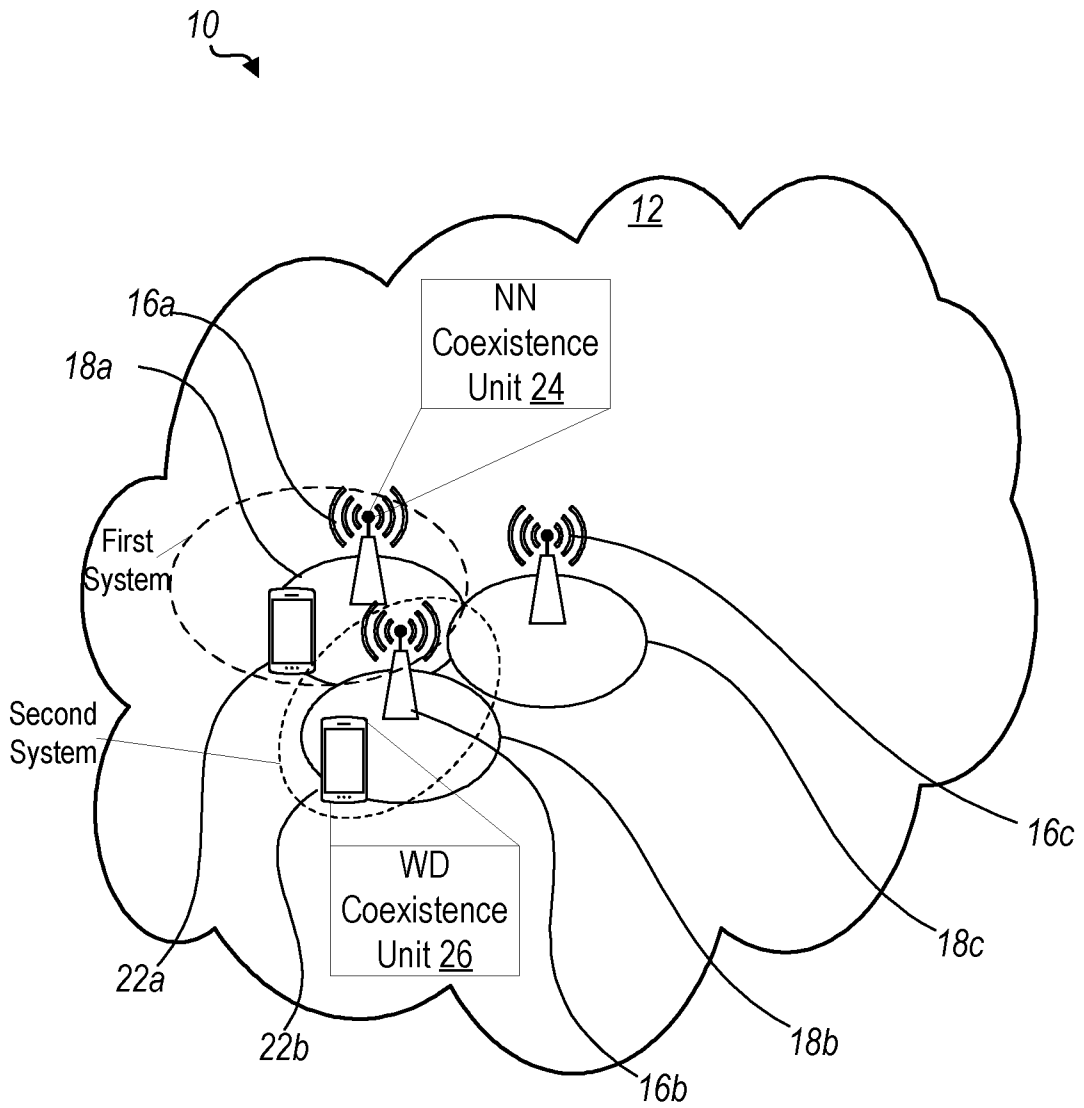


FIG. 1

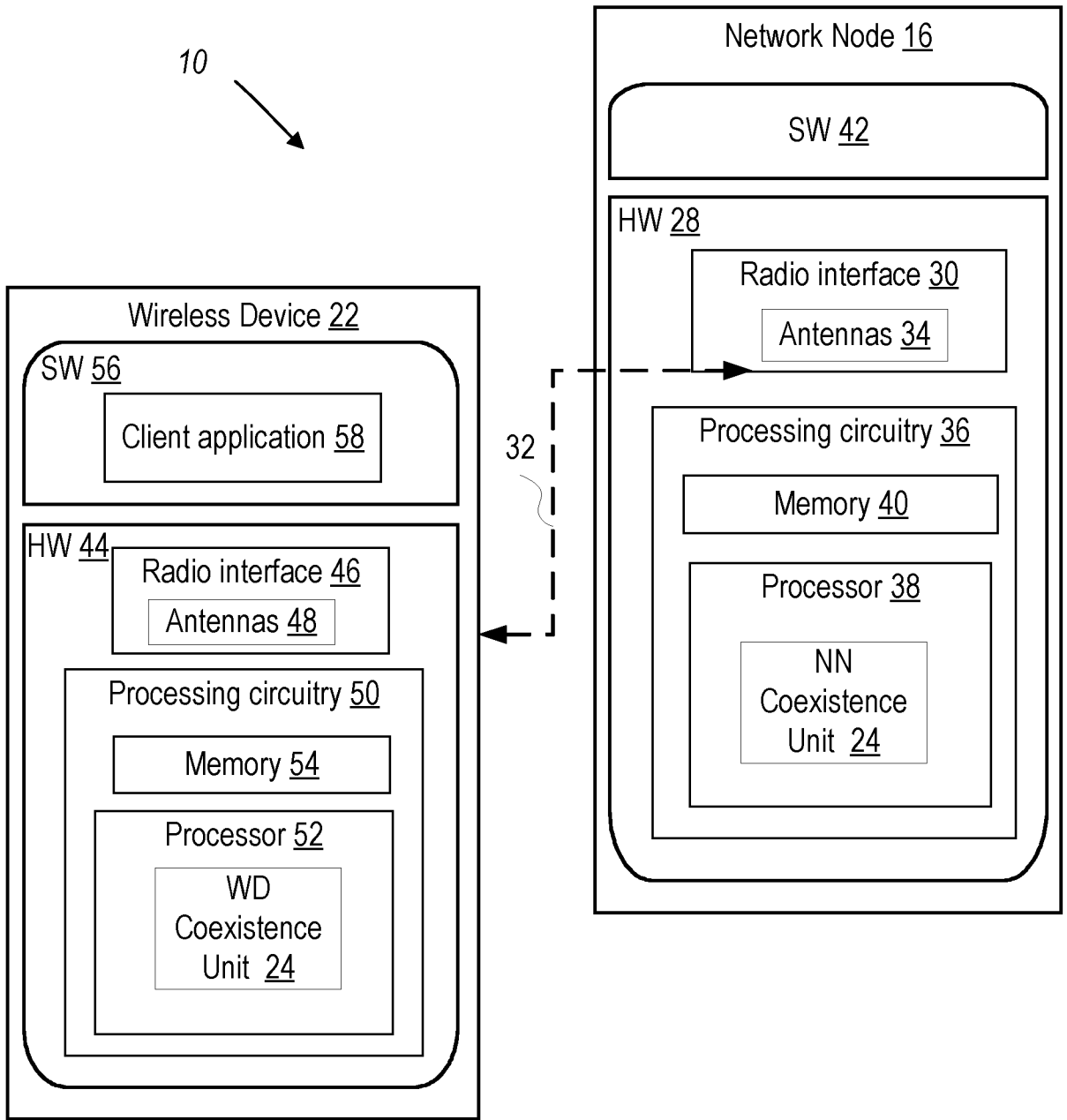


FIG. 2

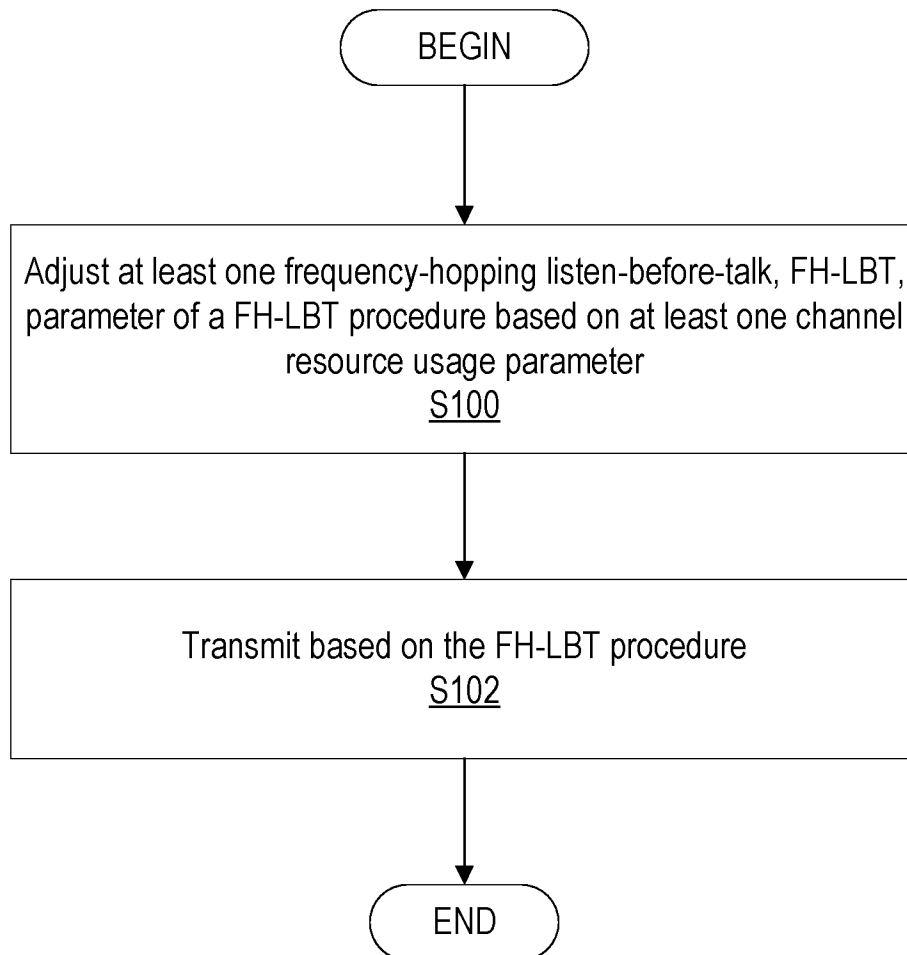


FIG. 3

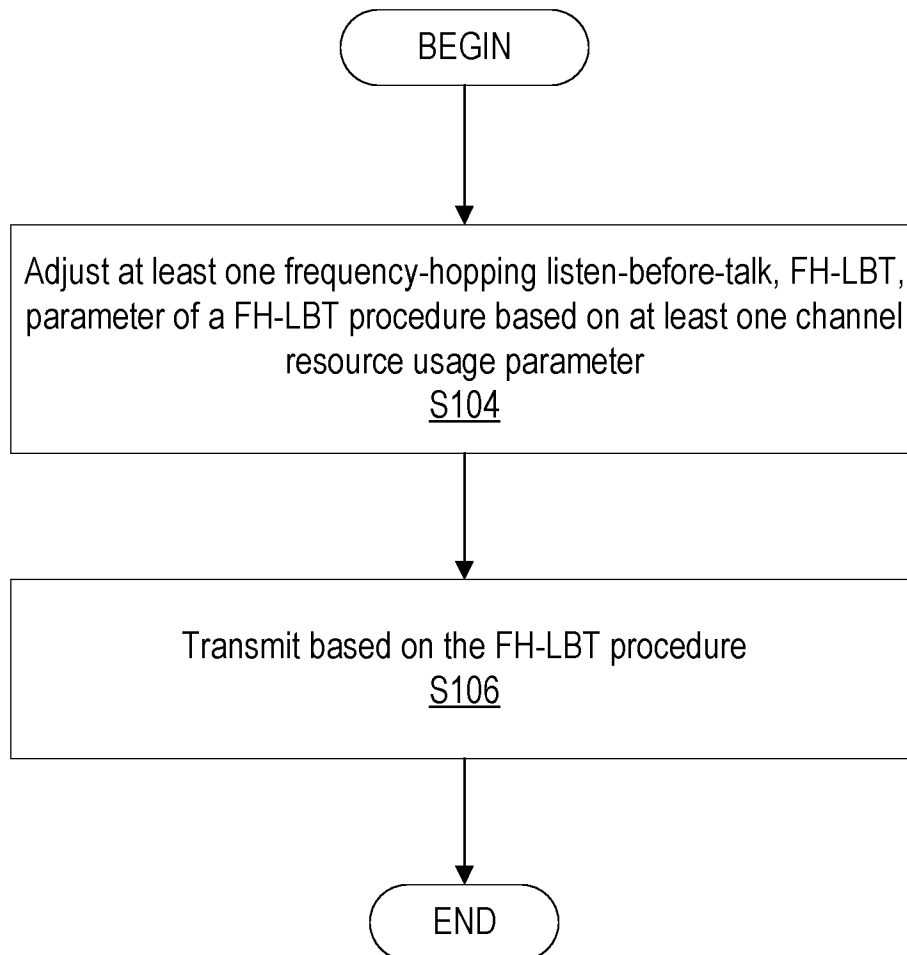


FIG. 4

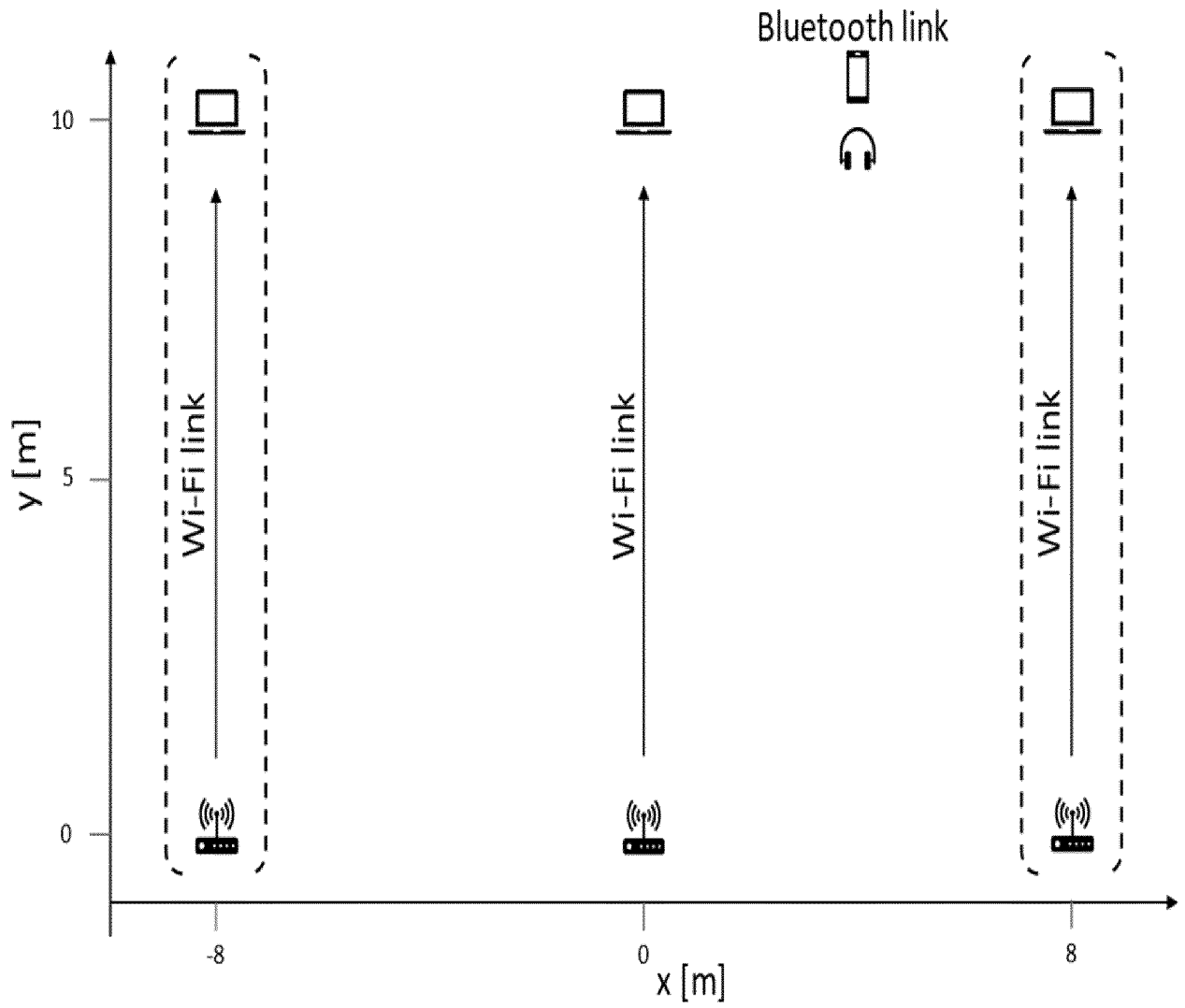


FIG. 5

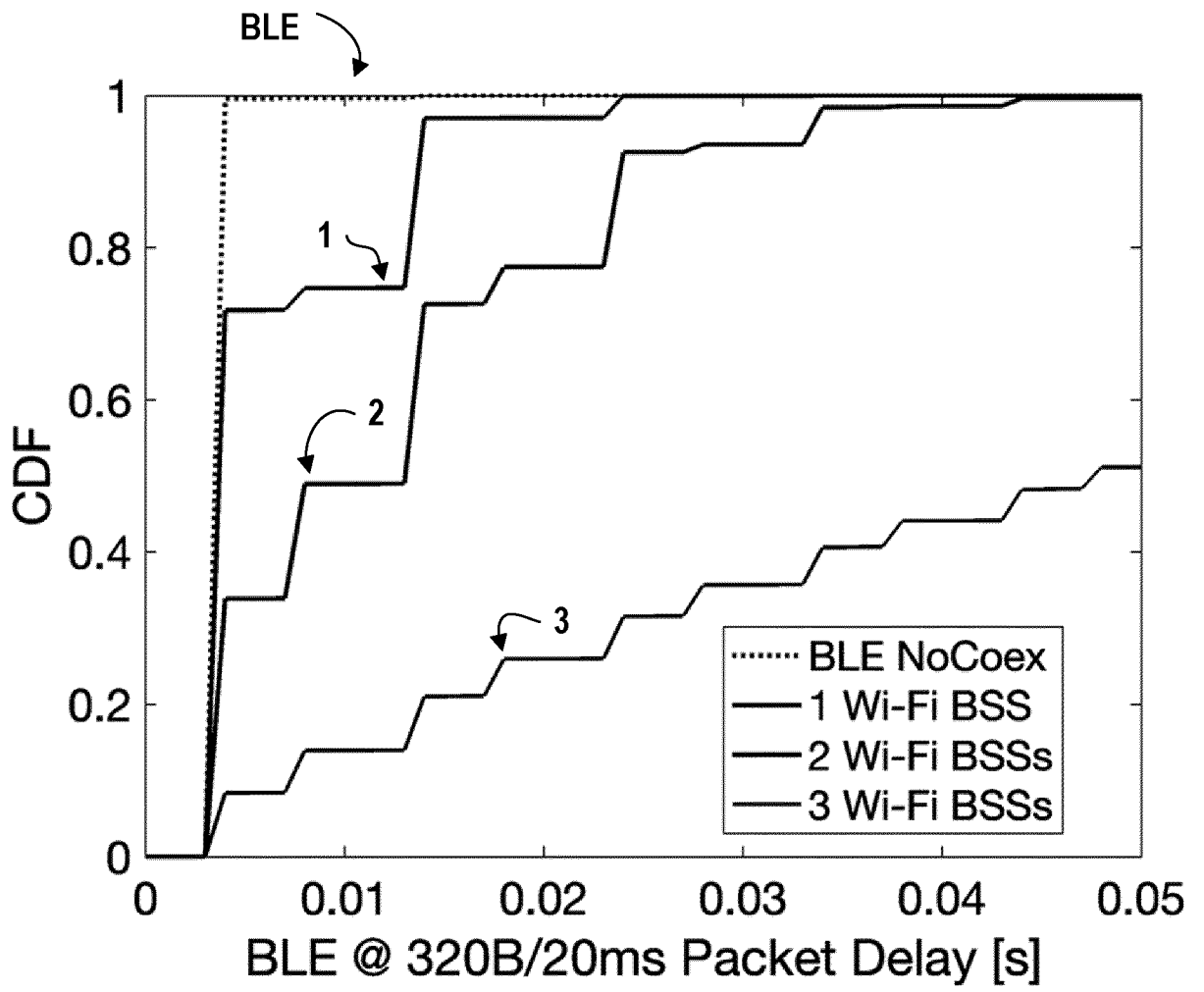


FIG. 6

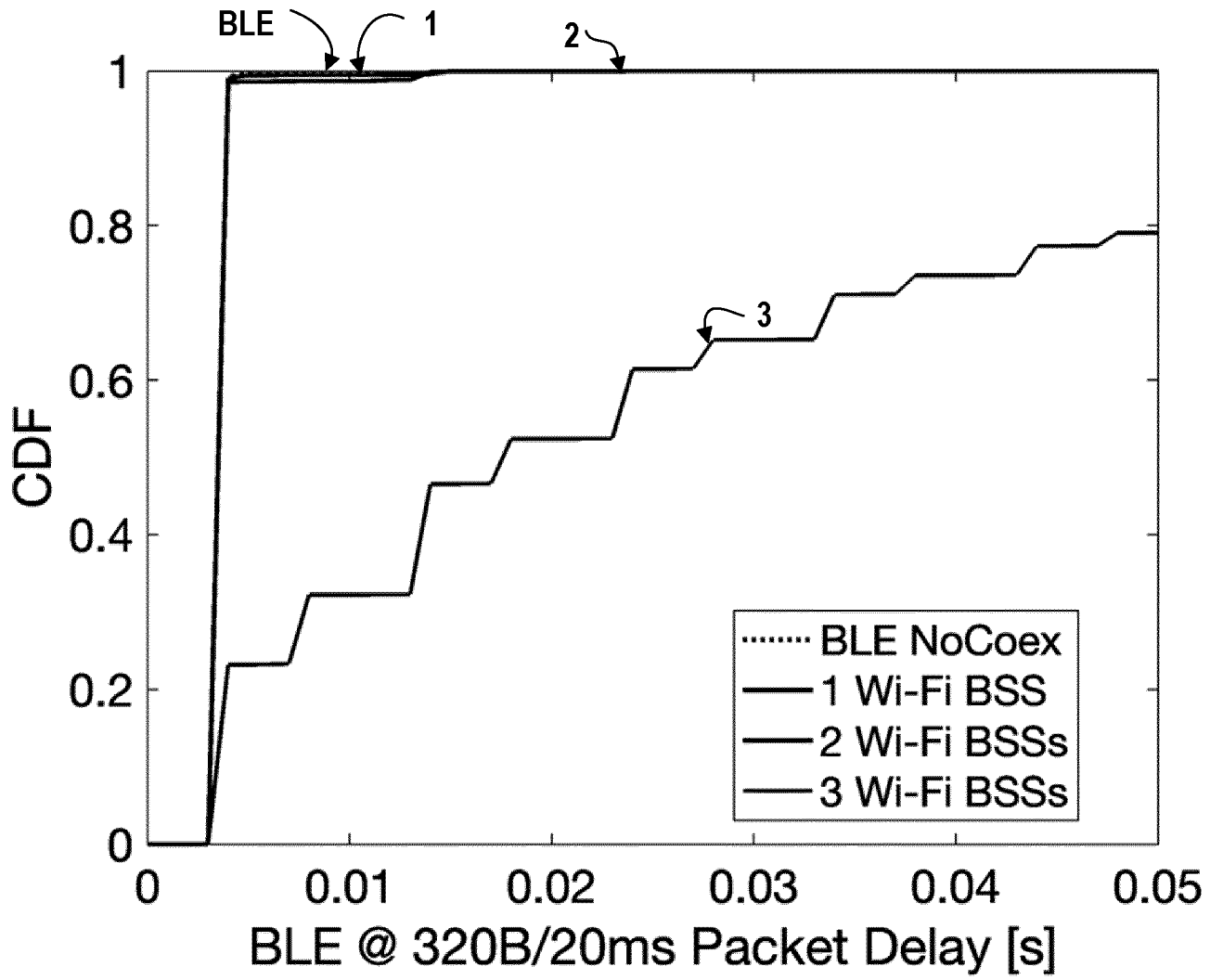


FIG. 7

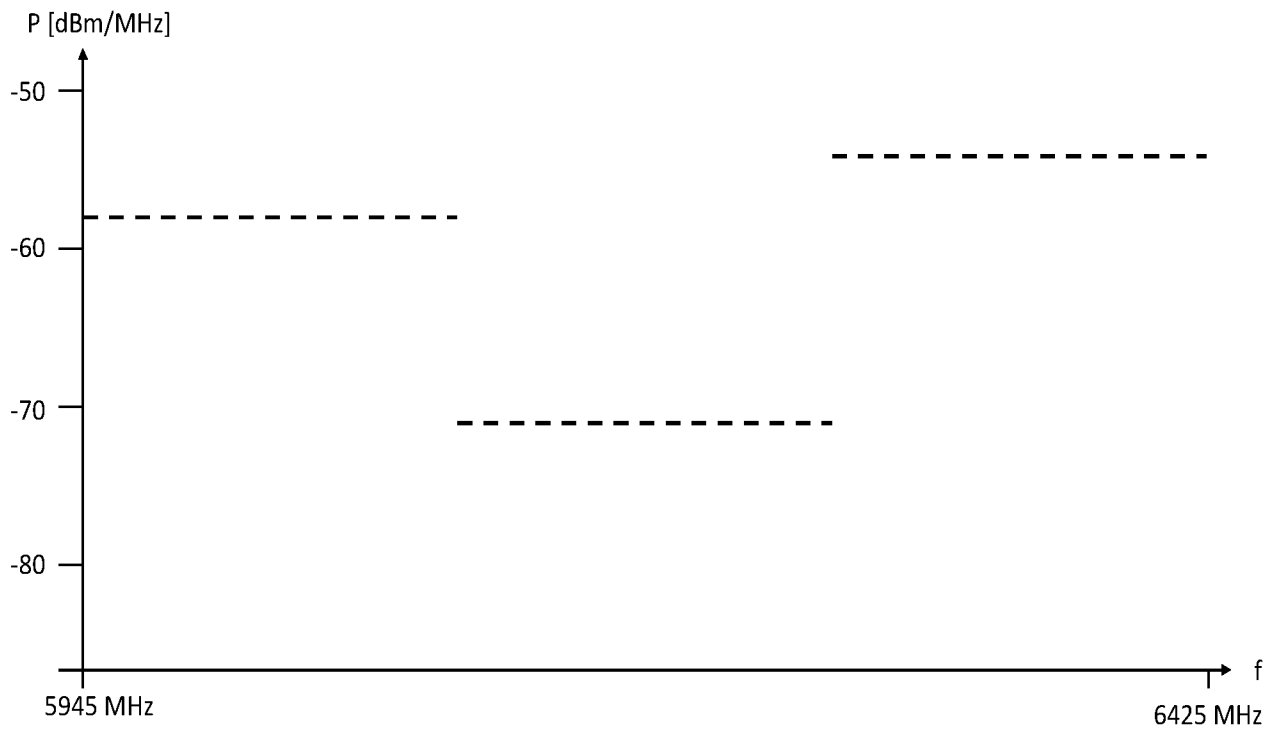


FIG. 8

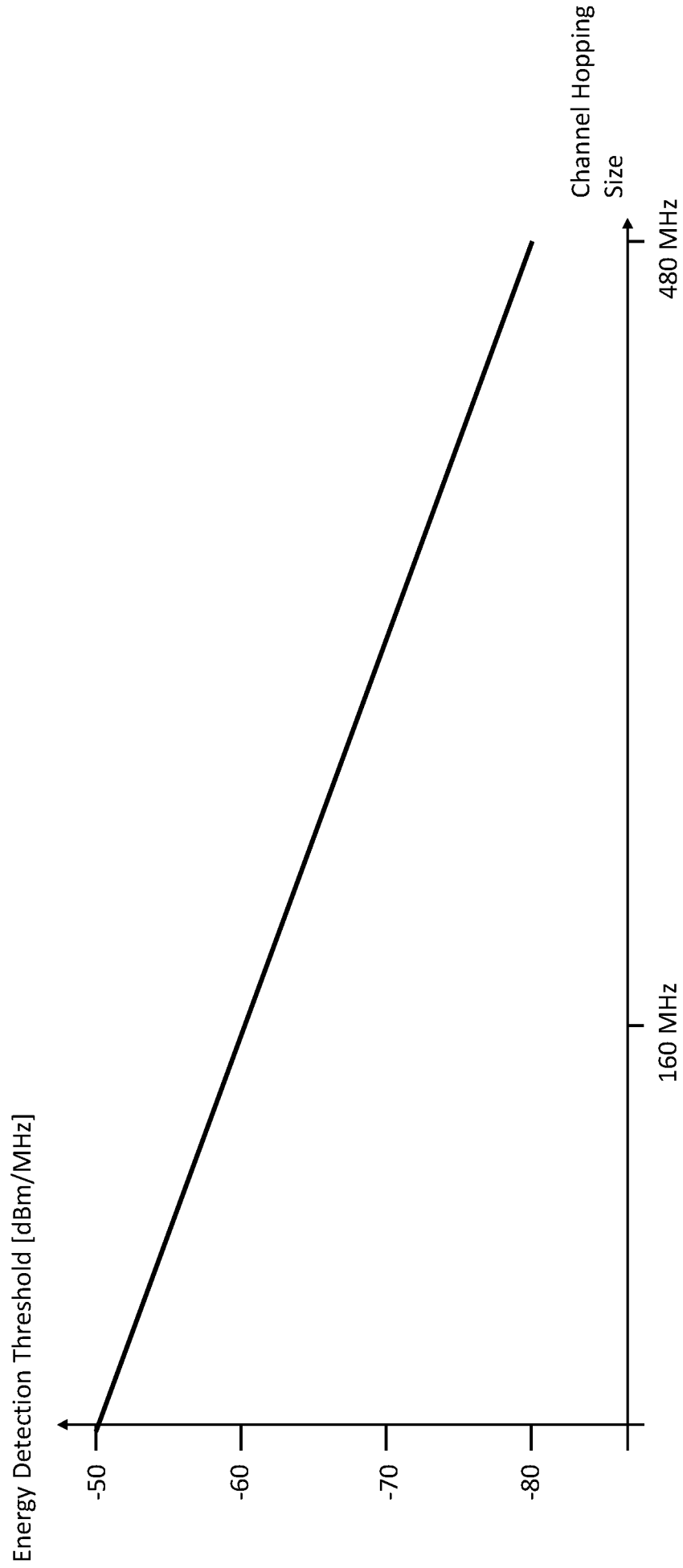


FIG. 9

# INTERNATIONAL SEARCH REPORT

International application No PCT/EP2024/059723
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**A. CLASSIFICATION OF SUBJECT MATTER**  
 INV. H04W74/0808 H04W16/14 H04B1/59 H04L5/00  
 ADD. H04W72/02

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**  
 Minimum documentation searched (classification system followed by classification symbols)  
**H04W H04L H04B**

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)  
**EPO-Internal, WPI Data**

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
<b>X</b>	US 2020/275484 A1 (XU KAI [US] ET AL) 27 August 2020 (2020-08-27) paragraph [0314] - paragraph [0315] paragraph [0344] - paragraph [0352] paragraph [0400] - paragraph [0406] paragraph [0450] - paragraph [0452] paragraph [0456] - paragraph [0461] paragraph [0467] - paragraph [0469] paragraph [0474] - paragraph [0477] paragraph [0483] - paragraph [0485] paragraph [0499] - paragraph [0505] ----- - / - -	1 - 20

Further documents are listed in the continuation of Box C.       See patent family annex.

\* Special categories of cited documents :

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Date of the actual completion of the international search  <b>30 June 2024</b>	Date of mailing of the international search report  <b>10/07/2024</b>
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Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer  <b>Puiulet, Alexandru</b>
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## INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2024/059723

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2023/072395 A1 (ERICSSON TELEFON AB L M [SE]) 4 May 2023 (2023-05-04) page 2, line 12 - page 3, line 4 page 6, line 4 - page 7, line 14 page 8, lines 4-31 page 9, line 10 - page 11, line 11 page 12, line 6 - page 13, line 11 page 15, line 6 - page 17, line 20 -----	1-20

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2024/059723

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2020275484 A1	27-08-2020	CA 3102267 A1	13-02-2020
		CN 112567872 A	26-03-2021
		CN 117156596 A	01-12-2023
		EP 3673707 A1	01-07-2020
		JP 7273855 B2	15-05-2023
		JP 2021525977 A	27-09-2021
		KR 20210042353 A	19-04-2021
		US 2020275484 A1	27-08-2020
		US 2021235495 A1	29-07-2021
		WO 2020033363 A1	13-02-2020
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WO 2023072395 A1	04-05-2023	NONE	
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