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(54) Title: METHOD AND DEVICE FOR CONNECTION-LESS ADVERTISING IN BLUETOOTH LOW ENERGY

(57) Abstract: The present disclosure relates to methods and arrangements for short-range wireless device communication and in particular to methods and arrangements for improving performance of data transfer operations realized by wireless devices using connection-less advertising. A method is disclosed, for enabling unsolicited data reception in a device capable of operating in accordance with Bluetooth Low Energy, BLE, wherein the device is logically separated into a controller configured to implement at least a physical layer functionality and a link layer functionality for the device and a host configured to control and configure operation of the controller. The method comprises to initiate (S42) a primary channel indicator timer and perform a scanning operation (S43) for advertising message indicator on one or more predetermined primary BLE advertising channel(s). Operation of the primary channel indicator timer is controlled based on detection of an advertising message indicator. The controller sends an Advertising Indication report to the host in response to detecting the advertising message indicator and the timer control operation comprises to discontinue (S44) the scanning operation in response to a time-out of the primary channel indicator timer or to activate (S46) secondary BLE advertising channel reception when the primary channel indicator timer is interrupted in response to detecting (S45) an advertising message indicator.

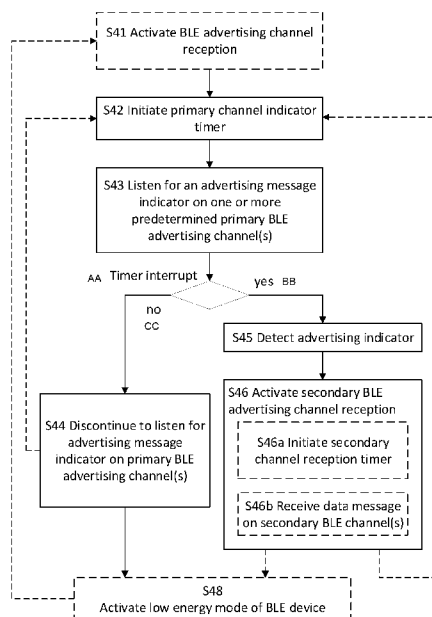


Fig. 4a



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Method and device for connection-less advertising in Bluetooth Low Energy

TECHNICAL FIELD

The present disclosure relates to methods and arrangements for short-range wireless device communication and in particular to methods and arrangements for improving performance of data transfer operations realized by wireless devices using connection-less advertising.

BACKGROUND

Emerging radio access technologies, e.g., for Internet of Things, IoT, are being developed to address the ever emerging market needs and use cases. Such emerging radio technologies include short-range radio technologies, such as RFID, WirelessHart, Zigbee, and Bluetooth Low Energy (BLE); technologies developed for use in short-range wireless personal area networks, WPANs. BLE is a low-power radio technology that utilizes the unlicensed 2.4 GHz band for communication.

Such short-range personal area networks are aimed at novel applications involving devices with low power consumption in, e.g., healthcare, fitness, security, and home automation industries. Low power wireless communication is a key feature for IoT, where communication will be required from devices powered by small batteries expected to have a long life-time. In many instances, the short-range WPAN will be used to connect groups of small devices to the Internet over an external network such as a cellular network or a Wi-Fi network.

A BLE device is logically, and sometimes physically, separated into a controller part and a host part. The controller is typically a hardware module (chip) and implements the physical layer and the link layer functionalities. The host part is typically implemented in software and may be part of the operating system of a device. For example, in a smartphone the BLE controller is (part of) a chip, which may also support Bluetooth classic and WiFi. The BLE host is implemented in the operating system, e.g., the iOS or the Android. Communication between the host and the controller happens through the Host Controller Interface (HCI), which is a standard interface defined by the Bluetooth specification. The host may control and configure the operation of the controller via so called HCI commands. Messages and state updates are received via so called HCI events.

BLE devices may be interconnected in a network, e.g., a tree network, a star network or a multi-hop mesh network configuration; data may be transferred with or without provisioned connections using a so called advertising procedure.

5 Advertising in BLE happens over the advertising channels. In advertising mode, devices may broadcast data that can be received by other devices located in the radio range of the broadcasting device. In present standards, there are 40 channels defined in BLE. Three of them are reserved for broadcast / advertising purpose, which are named advertising channels. The rest of the channels are called data channels. Typically, each broadcasted message is repeated
10 over all three advertising channels.

In BLE specification v4.0, v4.1, and v4.2, advertising uses the three advertising channels only. The advertising Protocol Data Unit (PDU) can contain at maximum 37 B; out of which 6 B is used for the advertising address and up to 31 B can be used for advertising data. Parts of the advertising data is reserved for transmitting information such as the advertising data type (AD-
15 type).

A device that would like to receive broadcasted messages scans the three advertising channels one by one. Once the broadcasting device transmits on the channel on which some other device is scanning, the data can be received by the scanning device. Broadcasting over the advertising channels is often referred to as connection-less data transfer. Such connection-less data
20 transfer is unreliable, in the sense that there is no (link layer) acknowledgement from the receiver to the transmitter that indicates whether the data was delivered successfully or not.

The new Bluetooth 5 specification contains a feature referred to as extended advertising (or advertising extensions). With extended advertising, the payload carried by an advertising PDU is increased to 255 B. However, extended advertising also changes the basic mechanism for
25 performing advertising. Instead of transmitting all the advertising data directly on the advertising channels, with extended advertising the packet transmitted on the advertising channels essentially contains only a pointer to one of the data channels, in which the actual payload is transferred. Hence, a broadcasting device will transmit a short packet on each of the advertising channels pointing to a data channel in which the data is transmitted. The time from

the pointer on the primary advertising channels and the transmission of the extended advertising in the secondary advertising channel is configurable by the controller, but can be up to around 2.5 s.

While using extended advertising, a scanning device continues scanning on one of the advertising channels. Once the scanner detects an advertisement, it can read the pointer and from there it knows where and when (AUX Offset) to find the content of the advertising message. The scanning device may then tune the receiver to that channel to receive the payload. In addition to the pointer information, the packet transmitted over the advertising channels may also contain the address of the advertising device. In the context of extended advertising, the advertising channels over which the short pointer is transmitted is referred to as the primary advertising channels, and the data channels over which the payload is transmitted, is referred to as the secondary advertising channels. An example of scanning behavior using extended advertising is disclosed in FIGURE 1.

The host of a scanning device receives a report (LE Extended Advertising Report) at the reception of the extended advertising message in the secondary advertising channel. Consequently, if the host expects a message to be received using extended advertising at a given time, it needs to wait until the report is received, or a timeout elapses. The timeout interval needs to account for the maximum delay introduced by the controller to transmit the message over extended advertising. This time can be up to 2.5 seconds, during which, the host does not know the status of the reception.

Another drawback in the present procedure for extended advertising is related to the sleeping schedule of battery-powered devices. This is particularly relevant for the definition of profiles that make explicit use of extended advertising mode for acknowledged message transactions.

The IP Link specification currently developed within the Bluetooth Internet Working Group is an example of such a profile. If the controller receives the advertising indication, the controller knows in which channel and at which time the auxiliary message is expected. In this case, the controller can tune the receiver to stop scanning and resume scanning in the secondary channel when the expected message comes. This operation can be done transparently to the host. However, if the advertising indication is lost due to e.g., collision or bad channel conditions, the scanning devices need to continuously scan a channel until the timeout is expired. Only after

the timeout, the host is informed and can stop scanning for the expected message. This will drain the battery of low power devices quickly.

SUMMARY

An object of the present disclosure is to provide methods which seek to mitigate, alleviate, or eliminate one or more of the above-identified deficiencies in the art and to improve performance of data transfer operations realized by wireless devices using connection-less advertising.

According to a first aspect, this object is obtained by a method, for enabling unsolicited data reception in a device capable of operating in accordance with Bluetooth Low Energy, BLE, wherein the device is logically separated into a controller configured to implement at least a physical layer functionality and a link layer functionality for the device and a host configured to control and configure operation of the controller. The method comprises to initiate a primary channel indicator timer and perform a scanning operation for advertising message indicator on one or more predetermined primary BLE advertising channel(s). Operation of the primary channel indicator timer is controlled based on detection of an advertising message indicator. The controller sends an Advertising Indication report to the host in response to detecting the advertising message indicator and the timer control operation comprises to discontinue the scanning operation in response to a time-out of the primary channel indicator timer or to activate secondary BLE advertising channel reception when the primary channel indicator timer is interrupted in response to detecting an advertising message indicator.

According to some embodiments of the disclosure, the primary channel indicator timer is typically implemented in the host, and the primary channel indicator timer is interrupted in response to receiving the Advertising Indication report in the host. The controller typically implements the scanning operation.

Consequently, the time when actively listening for the primary BLE advertising channel may be significantly reduced causing corresponding reductions in energy consumption. This is particularly beneficial in battery-powered devices. Some embodiments of the present disclosure provide for reduction of unnecessary scanning time if the extended advertising indication is lost, i.e., not received in the scanning device. Low power operation of device that is capable of operating in accordance with Bluetooth Low Energy, BLE is enabled.

According to some embodiments of the disclosure, performing a scanning operation for advertising message indicator is performed by the controller and comprises to listen for a pointer message, ADV_EXT_IND, on any of the predetermined primary BLE advertising channel(s) and to generate the Advertising Indication report when receiving the pointer message ADV_EXT_IND. The controller sends the Advertising Indication report to the host.

According to some embodiments of the disclosure, the primary channel indicator timer is initiated at a time when the BLE device expects to detect the advertising message indicator.

According to some embodiments of the disclosure, the time when the BLE device expects to detect the advertising indicator is one or more of: a time of an expected acknowledgement from an advertising BLE device, a time agreed with an advertising BLE device, and a periodically recurring time.

According to some embodiments of the disclosure, the timer-value of the primary channel indicator timer is selected from a range of 5-100 ms, 5-50ms, or 5-25ms.

According to some embodiments of the disclosure, the timer-value of the primary channel indicator timer is selected to 20ms.

According to some embodiments of the disclosure activating the secondary BLE advertising channel reception comprises to enable data reception on one or more secondary BLE advertising channels.

According to some embodiments of the disclosure activating the secondary BLE advertising channel reception comprises to initiate a secondary channel reception timer with an auxiliary time period retrieved from the pointer message, ADV_EXT_IND and to enable data reception on the one or more secondary BLE advertising channels during the auxiliary time period. An advertising report is sent to the host to confirm correct reception when receiving a correct Protocol Data Unit, PDU, at the controller during the auxiliary time period.

According to some embodiments, the received data is comprised in the advertising report.

According to some embodiments of the disclosure a transmission offset value, AUX Offset, is retrieved from the pointer message, ADV_EXT_IND and the BLE device is deactivated during a

time period determined by the AUX Offset when the AUX Offset is greater than a predetermined threshold value.

According to some embodiments of the disclosure BLE advertising channel reception is activated in the BLE device according to a predetermined sleeping schedule of the BLE device.

- 5 According to some embodiments of the disclosure a low energy mode of the BLE device is activated in response to one or more of: time-out of the primary channel indicator timer, time-out of the secondary channel reception timer, and a completion of the data transfer procedure.

10 According to some embodiments of the disclosure, the method is iterated in response to time-out of the primary channel indicator timer or time-out of the secondary channel reception timer.

Embodiments of the present disclosure reduces energy consumption of battery-powered devices, by avoiding unnecessary scanning time if an extended advertising indication is lost. It also allows device to go to low power mode while waiting for an incoming auxiliary message on
15 the secondary BLE advertising channel.

Embodiments of the present disclosure allows for a significant reduction of scanning time for lost indications, i.e., up to a factor of 125, compared to the baseline mechanism. When used in the context of, e.g., acknowledgements for Bluetooth IP Link messages, the proposed feature can further be used to speed up retransmissions of lost messages; enhancing the effective data
20 transfer speed , lowering the round-trip time and reducing power consumption for nodes of the Bluetooth IP Link.

According to a second aspect, the object of the present disclosure is obtained by a computer readable storage medium having stored thereon a computer program. When executed in a device capable of operating in accordance with Bluetooth Low Energy, BLE, the computer
25 program code causes the device to execute the above disclosed method for enabling unsolicited data reception.

According to a third aspect, the object of the present disclosure is obtained by Bluetooth Low Energy, BLE, device configured for enabling unsolicited data reception, the BLE device comprising radio circuitry and processing circuitry, wherein the processing circuitry is logically

separated into a controller configured to implement at least a physical layer functionality and a link layer functionality for the device and a host configured to control and configure operation of the controller. The processing circuitry is configured to initiate a primary channel indicator timer, perform a scanning operation for advertising message indicator on one or more
5 predetermined primary BLE advertising channel(s), and control timer operation of the primary channel indicator timer based on detection of an advertising message indicator, causing the controller to send an Advertising Indication report to the host in response to detecting the advertising message indicator. The timer control operation further comprises to discontinue the scanning operation in response to a time-out of the primary channel indicator timer or to
10 activate secondary BLE advertising channel reception when the primary channel indicator timer is interrupted in response to detecting an advertising message indicator.

According to some embodiments of the disclosure, the processing circuitry is further configured to cause the controller to listen for a pointer message, ADV_EXT_IND, on any of the predetermined primary BLE advertising channel(s), to generate the Advertising Indication report when
15 receiving the pointer message ADV_EXT_IND; and to send the Advertising Indication report to the host.

The Bluetooth Low Energy, BLE, device and the computer program provide corresponding advantages as those described above in relation to the method for enabling unsolicited data reception.

20 BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing will be apparent from the following more particular description of the example embodiments, as illustrated in the accompanying drawings in which like reference characters refer to the same parts throughout the different views. The drawings are not necessarily to scale, emphasis instead being placed upon illustrating the example embodiments.

25 Figure 1 is a signaling diagram disclosing prior art signaling between an advertising device and a scanning device;

Figure 2 discloses an exemplary communication environment comprising BLE devices;

Figure 3

a. discloses signaling between an advertising device and a scanning device for a case
30 when the advertising indication is lost;

- b. discloses signaling between an advertising device and a scanning device for a case when the advertising is successful;

Figure 4

- a. is a flowchart illustrating example method steps performed in a BLE device;
- 5 b. is a flowchart illustrating a host perspective for the example method steps of Figure 4a;
- c. is a flowchart illustrating a controller perspective for the example method steps of Figure 4a;

Figure 5

- 10 a. illustrates an example node configuration for a BLE device;
- b. illustrates an example node configuration for a BLE device.

DETAILED DESCRIPTION

Aspects of the present disclosure will be described more fully hereinafter with reference to the
15 accompanying drawings. The methods and arrangements disclosed herein can, however, be realized in many different forms and should not be construed as being limited to the aspects set forth herein. Like numbers in the drawings refer to like elements throughout.

The terminology used herein is for the purpose of describing particular aspects of the disclosure only, and is not intended to limit the invention. As used herein, the singular forms "a", "an" and
20 "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise.

Turning back to prior art advertising and connection-less data transfer, advertising in BLE happens over the advertising channels. In advertising mode, devices may broadcast data that can be received by other devices located in the radio range of the broadcasting device. There
25 are 40 channels defined in BLE. Three of them are reserved for broadcast / advertising purpose, which are named advertising channels. The rest of the channels are called data channels. Typically, each broadcasted message is repeated over all three advertising channels. A device that would like to receive broadcasted messages scan the three advertising channels one by one. Once the broadcasting device transmits on the channel on which some other device is
30 scanning, the data can be received by the scanning device. Broadcasting over the advertising channels is often referred to as connection-less data transfer. Such connection-less data

transfer is unreliable, in the sense that there is no (link layer) acknowledgement from the receiver to the transmitter that indicates whether the data was delivered successfully or not.

In BLE specification v4.0, v4.1, and v4.2, advertising uses the three advertising channels only. The advertising Protocol Data Unit (PDU) can contain at maximum 37 B; out of which 6 B is used for the advertising address and up to 31 B can be used for advertising data. Parts of the advertising data are reserved for transmitting information such as the advertising data type (AD-type).

The new Bluetooth 5 specification contains a feature referred to as extended advertising (or advertising extensions). With extended advertising, the payload carried by an advertising PDU is increased to 255 B. However, extended advertising also changes the basic mechanism for performing advertising. Instead of transmitting all the advertising data directly on the advertising channels, with extended advertising the packet transmitted on the advertising channels essentially contains only a pointer to one of the data channels, in which the actual payload is transferred. Hence, a broadcasting device will transmit a short packet on each of the advertising channels pointing to a data channel in which the data is transmitted. The time from the pointer on the primary advertising channels and the transmission of the extended advertising in the secondary advertising channel is configurable by the controller, but can be up to around 2.5 s.

Using extended advertising, a scanning device scans on one of the advertising channels. Once the scanner detects an advertisement, it can read the pointer and from there it knows where and when (AUX Offset) to find the content of the advertising message. The scanning device may then tune the receiver to that channel to receive the payload. In addition to the pointer information, the packet transmitted over the advertising channels may also contain the address of the advertising device. In the context of extended advertising, the advertising channels over which the short pointer is transmitted is referred to as the primary advertising channels, and the data channels over which the payload is transmitted, is referred to as the secondary advertising channels.

Figure 1 discloses an example of scanning behavior using extended advertising and interaction between host and controller in a signaling diagram format. The host prepares the controller for a scanning operation by transmitting relevant parameters in a message "LE Set Extended Scan

Parameters". The Controller A responds with 'Command Complete'. The host then enables the scanning operation in the controller by transmitting a message 'LE Set Extended Scan Enable (ON)' to the controller. A 'Command Complete' response is received from the controller informing the host that the controller will now listen for an advertising indicator message on one at least one primary channel. The signaling diagram discloses an advertising procedure where a Device B sends an advert "ADV_EXT_IND" that is to be perceived by a Device A. The controller of Device A, LL A, listens for "ADV_EXT_IND" on a primary channel. The host of Device A only receives a report from the controller at the reception of the extended advertising in the secondary advertising channel. In the scenario of Figure 1, the controller A is unable to receive the "ADV_EXT_IND" message; consequently, no information is provided to the host in this regard and the controller remains in an active scanning mode for the indicated Time-out duration of 2.5s. At Time-out, the host sends a message 'LE Set Extended Scan Enable (OFF)' to disable the controller; thereby preserving power in the device.

Figure 2 discloses an exemplary communication environment comprising devices employing Bluetooth radio technologies. The following disclosure will be directed to the use of Bluetooth Low Energy, BLE. The disclosure of Figure 2 represents a simplified scenario, but it will be appreciated that the discussion based on this simplified scenario is equally applicable to networks comprising many more device nodes. As disclosed in Figure 2 a plurality of BLE devices may be provisioned in connected network structures and/or exist as connection-less devices capable of data transfer according to an advertising mode used in BLE. In Figure 2, connection-less BLE devices are represented as scanning devices 50a or advertising devices 50b, but may of course alternate between being a scanning device and an advertising device.

A BLE device 50 is logically, and sometimes physically, separated into a controller part and a host part. The controller is typically a hardware module (chip) and implements the physical layer and the link layer functionalities. The host part is typically implemented in software and may be part of the operating system of a device. For example, in a smartphone the BLE controller is (part of) a chip, which may also support Bluetooth classic and WiFi. The BLE host is implemented in the operating system, e.g., the iOS or the Android. Communication between the host and the controller happens through the Host Controller Interface (HCI), which is a standard interface defined by the Bluetooth specification. The host may control and configure the operation of the

controller via so called HCI commands. Messages and state updates are received via so called HCI events.

Figures 3a and b, disclose signaling between an advertising device and a scanning device for a case when the advertising indication is lost and for the case when advertising is successful. The solution proposed here introduces an LE Advertising Indication Report message from the controller to the host. The controller sends the report when receiving a pointer (ADV_EXT_IND) on the primary advertising channels. The report contains relevant information to determine whether an expected message by the host has been scheduled for transmission at the secondary advertising channel.

The invention makes use of the received reports by letting the host set the scanning timeout for expected messages to a time that is equal to the maximum time between the first and the last extended advertising indication (i.e., 20 milliseconds) and configure the controller to stop scanning if no valid LE Advertising Indication Report is received within the timeout.

The invention proposes additional implementation of the host and controller parts of the BLE device. In addition, the device implements handlers for an additional event, denoted here as LE Advertising Indication Report, which is sent from the controller to the host upon reception of a valid ADV_EXT_IND PDU for the device and it includes at least the value of the AuxPtr field, necessary to calculate the time at which the auxiliary advertisement is sent.

In the example presented here, the host of a first device (implementing the invention) is expecting a packet transmitted from the host of a second device. The first device knows, with reasonable approximation, the time at which the second device will start to transmit, because the first device is expecting an acknowledgement from the second device or, more generally, the time has been previously agreed between the two devices. It is assumed that the expected message fits a single AUX_ADV_IND PDU. In addition, the first device runs on battery, and would like to reduce the scanning time as much as possible.

Turning to Figure 3a an example of active scanning behavior using extended advertising and interaction between host and controller is disclosed in a signaling diagram format. The host prepares the controller for a scanning operation by transmitting relevant parameters in a message "LE Set Extended Scan Parameters". The Controller A responds with 'Command

Complete'. The host then enables the scanning operation in the controller by transmitting a message 'LE Set Extended Scan Enable (ON) to the controller. A 'Command Complete' response is received from the controller informing the host that the controller will now listen for an advertising indicator message on at least one primary channel. The signaling diagram discloses
5 an advertising procedure where a Device B sends an advert "ADV_EXT_IND" that is to be perceived by a Device A. Figure 3a discloses the scenario where the PDU ADV_EXT_IND is lost.

When the scanning process is initiated, a timer in Device A, e.g., a primary channel indicator timer, is set to a timer-value of 20 ms. When the host does not receive an LE Advertising Indication report within the time-out period determined by the timer-value, the host will
10 determine that the pointer packet has been lost on the primary advertising channel with the consequence that further data transfer on the secondary advertising channel will not be possible. At that point, the host may disable the scanning operation in the controller until a new primary channel transmission opportunity is expected; thereby saving energy in the BLE device.

Turning to Figure 3b an example of scanning behavior using extended advertising and
15 interaction between host and controller is disclosed in a signaling diagram format. The signaling diagram discloses the same advertising procedure as disclosed in Figure 3a, where a Device B sends an advert "ADV_EXT_IND" for reception by a Device A. However, Figure 3b discloses the scenario where the PDU ADV_EXT_IND is received in the controller. Following reception of ADV_EXT_IND, the controller sends an LE Advertising Indication report to the host and activates
20 secondary BLE advertising channel reception. The primary advertising channel timer is interrupted when receiving the report and the host will allow continued reception of data, i.e., the PDU AUX_EXT_IND. In addition to disclosing the power saving aspects from using the Advertising Indication report, Figure 3b also discloses the possibility to set an auxiliary time-out, AUX Time-out during which the controller can optionally turn the radio off and sleep for that
25 duration, before scanning the indicated secondary channel.

Figure 4a is a flowchart illustrating example method steps performed in a BLE device or any other wireless device capable of operating in accordance with Bluetooth Low Energy, BLE. The device is logically separated into a controller configured to implement at least a physical layer functionality and a link layer functionality for the device and a host configured to control and
30 configure operation of the controller. The controller is typically a hardware module (chip) and

implements the physical layer and the link layer functionalities. The second part, i.e., the host, is typically implemented in software and may be part of the operating system of a device. Communication between the host and the controller may be performed through a Host Controller Interface (HCI), which is a standard interface defined by the Bluetooth specification.

5 The host may control and configure the operation of the controller via so called HCI commands. Messages and state updates are received via so called HCI events.

In a general sense, the present disclosure relates to enabling unsolicited data reception in the device, e.g., in a sensor device, an M2M device or other type of Internet of Things, IoT, device that may be mobile, stationary or semi-stationary. BLE supports an advertising method using
10 advertising channels for ad hoc data transfer or other data transfer without establishing a dedicated connection, i.e., connection-less data transfer to a receiving device that may or may not have prior knowledge of the data transfer, and where the data transfer procedure is uncorrelated to a transfer request from the receiving device.

The below presented disclosure will be describing method steps performed in the device to
15 which the data transfer is to occur. Such a device will in the following be denominated as a scanning device. The device from which the data transfer occurs will be denominated as advertising device. However, it will be understood by the skilled person that a device of the present disclosure is capable of being a scanning device in some instants, an advertising device in other instants, and is also capable of overlapping performance of the scanning and advertising
20 functions. Furthermore, the device may have established connections to other devices in a provisioned network in combination with the herein disclosed connection-less data transfer.

An optional embodiment of the present disclosure comprises activating S41 BLE advertising channel reception in the device according to a predetermined sleeping schedule of the BLE device. In an example, the host of a scanning device has prior knowledge that a packet is to
25 be transferred at a certain time, i.e., is expecting a packet to be transmitted from the host of an advertising device. The scanning device knows, with reasonable approximation, the time at which the advertising device will start to transmit, because the scanning device is expecting an acknowledgement from the second device in response to previous data transfer from the scanning device or, more generally, the time has been previously agreed between the two
30 devices.

Consequently, the host of the scanning device may activate BLE advertising channel reception in the device, i.e., enable the scanning mode of the controller, at the time of the expected the transmission.

In its most generic form the method disclosed herein comprises initiating S42 a primary channel indicator timer, performing a scanning operation S43 for advertising message indicator on one or more predetermined primary BLE advertising channel(s), and controlling timer operation of the primary channel indicator timer based on detection of an advertising message indicator. According to aspects of the disclosure, the timer initialization and the timer operation is performed in the host. As part of timer operation control, the controller sends an Advertising Indication report to the host in response to detecting the advertising message indicator. The timer operation control comprises to discontinue S44 the scanning operation in response to a time-out of the primary channel indicator timer or to activate S46 secondary BLE advertising channel reception when the primary channel indicator timer is interrupted in response to detecting S45 an advertising message indicator. According to some embodiments of the disclosure, the primary channel indicator timer is typically implemented in the host, and the primary channel indicator timer is interrupted in response to receiving the Advertising Indication report in the host. The controller typically implements the scanning operation.

In a preferred embodiment, the primary channel indicator timer is initiated at a time when the scanning device expects to detect the advertising message indicator. As mentioned above, the scanning device may know, with reasonable approximation, the time at which the advertising device will start to transmit, the host of the scanning device may use this knowledge to initiate the primary channel indicator. According to an embodiment, the primary channel indicator timer is initiated at a time when the BLE device expects to detect the advertising message indicator, e.g., one or more of: a time of an expected acknowledgement from an advertising BLE device, a time agreed with an advertising BLE device, and a periodically recurring time. The primary channel indicator timer may also be initiated at the same time as activating the controller for reception, with an offset or predetermined delay related to the time of activating the controller, or at an absolute time independent of when the procedure for activating the controller was performed. In a current preferred embodiment a timer-value for the timer is selected to 20 ms, corresponding to the maximum allowed delay for the controller of an advertising device to transmit a triplet of PDUs, i.e., the ADV_EXT_IND as indicated in

Figures 1, 3a and 3b, according to the standard specifications. However, the present disclosure is not limited to this timer-value selected based on a current standard setting, but allows for timer-values within any range that is significantly shorter than the maximum delay for the actual data transfer, i.e., the delay introduced by the controller to transmit the message using the disclosed BLE technology, also known as extended advertising. This delay may be up to 2.5 seconds, during which, the host does not know the status of the transmission. With the above delay in mind, a timer-value of the primary channel indicator timer may be selected from a range of 5-100 ms, 5-50ms, or 5-25ms.

The device, is configured to perform a scanning operation S43 for advertising message indicator on one or more predetermined primary BLE advertising channel(s), e.g., by listening for a pointer message, ADV_EXT_IND, on any of the predetermined primary BLE advertising channel(s) and generating and sending the Advertising Indication report when receiving the pointer message ADV_EXT_IND, as previously discussed with reference to Figure 3b.

According to an embodiment, activating S46 of the secondary BLE advertising channel reception comprises enabling S46b data reception on one or more secondary BLE advertising channels, e.g., by initiating S46a a secondary channel reception timer with an auxiliary time period retrieved from the pointer message, ADV_EXT_IND and enabling S46b data reception on the one or more secondary BLE advertising channels during the auxiliary time period. Thus, if a valid Advertising Indication report is received, then secondary channel reception timer is set to an AUX timeout. In an optional embodiment the primary channel reception timer and the secondary channel reception timer are the same, implying that the timer is first set to a time-value determining an indication time-out, and following successful receipt of the Advertising Indication report in the host, is updated to the AUX timeout. The AUX timeout includes the time for auxiliary advertisement reception, as derived from the AuxPtr field reported. If the AUX time is larger than a threshold, the host can optionally enable low power operations for the controller during the time, as will be discussed further below with reference to Figure 4b. When the controller receives a correct Protocol Data Unit, PDU, during the auxiliary time period, an advertising report is sent S47 to the host to confirm correct reception. According to aspects of the disclosure, advertising data sent from the controller to the host may be comprised in the advertising report. According to an embodiment, the advertising message indicator, e.g., the pointer message pointer message, ADV_EXT_IND, may also comprise a

transmission offset value, AUX Offset. If the duration of the AUX Offset is larger than a threshold (e.g., greater than the time it takes to switch to a different channel), radio reception may optionally be turned off deactivating the BLE device, or at least the controller, during a time period determined by the AUX Offset, before scanning the indicated secondary channel.

5 Thus, If the AUX time is larger than a threshold, the host can optionally enable low power operations for the controller during the time. According to another aspect of the disclosure, the controller autonomously enters a low power state, transparent for the host.

According to an embodiment, the above disclose method is iterated and re-iterated for as long as scanning of the primary channel is enabled in the device. Accordingly, in response to time-
10 out of the primary channel indicator timer, the controller may repeat the above discussed scanning procedure, e.g., at the time when an advertisement is expected on the primary BLE advertising and following initiation of the primary channel indicator timer. The method may also be iterated following time-out of the secondary channel reception timer or in following successful reception of the data transfer according to the above disclosed advertising
15 procedure. Optionally, the a low energy mode may be activated S48 for the device in response to one or more of: time-out of the primary channel indicator timer, time-out of the secondary channel reception timer, and a completion of the data transfer procedure.

Thus, in summary, the present disclosure proposes a new procedure for enabling unsolicited data reception in a device capable of operating in accordance with Bluetooth Low Energy, BLE
20 using a new report from a BLE controller to a BLE host, indicated as an "LE Advertising Indication Report" in Figure 3b. This report is sent from the controller to the host at the reception of a pointer (ADV_EXT_IND) over the primary advertising channels. The host can utilize the knowledge that such a report is transmitted by the controller when the indication is received to speed up retransmissions of lost messages; enhancing the effective data transfer speed,
25 lowering the round-trip time and reducing power consumption. For example, when expecting a message from a peer device but no LE Advertising Indication Report is received within an agreed (short) time, the host can, without waiting for the actual message on the secondary channel, conclude that no message from the peer can be expected and act accordingly. If the expected message from the peer is an acknowledgement on a previously transmitted message, the host
30 may, e.g., determine to retransmit the message.

An LE Advertising Indication Report message is proposed. The message is to be sent from the controller to the host when receiving a pointer (ADV_EXT_IND) on the primary advertising channels. The report contains relevant information to determine whether an expected message by the host has been scheduled for transmission at the secondary advertising channel. The introduction of these report messages are used to let the host set the scanning timeout for expected messages to a time that is equal to the maximum time between the first and the last extended advertising indication (i.e., 20 milliseconds) and configure the controller to stop scanning if no valid LE Advertising Indication report is received within the timeout.

A device using the above disclosed method reduces energy consumption of battery-powered devices, by avoiding unnecessary scanning time if the extended advertising indication is lost: The method also allows the device to go to low power mode while waiting for the incoming auxiliary message. The proposed method allows for a reduction of scanning time for lost indications of a factor 100-150, as compared to prior art methods. When used in the context of, e.g., acknowledgements for Bluetooth IP Link messages, the proposed feature can further be used to speed up retransmissions of lost messages, which enhances the effective data transfer speed and lowers the round-trip time of the Bluetooth IP Link.

Turning to Figure 4b, a host perspective is provided for the example method steps previously discussed for Figure 4a. The host of the first device enables the scanning mode of the controller at the time the transmission from the second device is expected to commence, and sets an Indication timeout to, e.g., 20 milliseconds. 20 milliseconds is the maximum delay that the controller of the second device can take to transmit a triplet of ADV_EXT_IND PDUs according to the standard specifications. Alternatively, if the exact delay is known at the first device, the Indication timeout is set accordingly. If no valid Advertising Indication report, also denominated as LE Advertising Indication report, is received before the Indication timeout, the ADV_EXT_IND is assumed to be lost and scanning mode is disabled to save energy and the host can also already at this time take other appropriate action, e.g., if the expected message is an acknowledgement of a previously transmitted message the retransmission of this message can now be initiated. If a valid LE Advertising Indication report is received, then the timeout is updated to the AUX timeout, which includes the time for auxiliary advertisement reception, as derived from the AuxPtr field reported. If the AUX time is larger than a threshold, the host can optionally enable low power operations for the controller during the time.

Turning to Figure 4c, a controller perspective is provided for the example method steps previously discussed for Figure 4a. The controller of the first device start scanning the primary advertising channels when configured by the host. As soon as a valid ADV_EXT_IND for the device is received, the controller sends a LE Advertising Indication report to the host. If the duration of the AUX Offset is larger than a threshold (e.g., greater than the time it takes to switch to a different channel), the controller can optionally turn the radio off and sleep for that duration, before scanning the indicated secondary channel. If the correct AUX_ADV_IND PDU is received within the AUX timeout, a standard LE Extended Advertising report is sent to the host to confirm the correct reception. As mentioned above, the payload may also be included in the advertising report. The controller goes back to scan the primary channel until the scanning procedure is disabled by the host.

Figure 5a discloses an example Bluetooth Low Energy, BLE, device 50 comprising radio circuitry 51 and processing circuitry 52; the processing circuitry being logically separated into a controller 52a configured to implement at least a physical layer functionality and a link layer functionality for the device and a host 52b configured to control and configure operation of the controller. According to aspects of the disclosure, the controller may comprise the radio circuitry and associated processing circuitry for implementing the physical layer functionality as well as the link layer functionality.

According to aspects of the disclosure, the controller 52a is typically a hardware module (chip) and implements the physical layer and the link layer functionalities and the host 52b is typically implemented in software and may be part of the operating system of the processing circuitry. For example, in a smartphone the BLE controller is (part of) a chip, which may also support Bluetooth classic and WiFi. The BLE host is implemented in the operating system, e.g., the iOS or the Android. Communication between the host and the controller happens through the Host Controller Interface (HCI), which is a standard interface defined by the Bluetooth specification. The host may control and configure the operation of the controller via so called HCI commands. Messages and state updates are received via so called HCI events.

The processing circuitry 52 is configured to initiate a primary channel indicator timer and perform a scanning operation for advertising message indicator on one or more predetermined primary BLE advertising channel(s). The processing circuitry is further

configured to control timer operation of the primary channel indicator timer based on detection of an advertising message indicator, causing the controller 52a to send an Advertising Indication report to the host 52b in response to detecting the advertising message indicator, and discontinuing the scanning operation in response to a time-out of the primary channel indicator timer or activating secondary BLE advertising channel reception when the primary channel indicator timer is interrupted in response to detecting an advertising message indicator.

According to aspects of the disclosure, the processing circuitry comprises a processor and a memory. The processor may be any suitable type of computation unit or circuit, e.g. a microprocessor, digital signal processor, DSP, field programmable gate array, FPGA, or application specific integrated circuit, ASIC or any other form of circuitry. It should be appreciated that the processing circuitry need not be provided as a single unit but may be provided as any number of units or circuitry.

The memory may be configured to store information received about the wireless device ranking order and/or the scheduling order. The memory may further be configured to store received or transmitted data and/or executable program instructions. The memory may be any suitable type of computer readable memory and may be of volatile and/or non-volatile type. According to an aspect of the disclosure, the processing circuitry comprises a processor and a memory. The processor may be any suitable type of computation unit or circuit, e.g. a microprocessor, digital signal processor, DSP, field programmable gate array, FPGA, or application specific integrated circuit, ASIC or any other form of circuitry. It should be appreciated that the processing circuitry need not be provided as a single unit but may be provided as any number of units or circuitry.

In an optional embodiment of the present disclosure, processing circuitry is further configured to cause the controller 52a to listen for a pointer message, ADV_EXT_IND, on any of the predetermined primary BLE advertising channel(s); generate the Advertising Indication report when receiving the pointer message ADV_EXT_IND; and send the Advertising Indication report to the host 52b.

Figure 5b discloses an example Bluetooth Low Energy, BLE, device 50 which may incorporate some of the example embodiments discussed above. The BLE device is logically separated into

a controller configured to implement at least a physical layer functionality and a link layer functionality for the device and a host configured to control and configure operation of the controller. The BLE device is configured to enable unsolicited data reception. The BLE device 50 comprises an timer setting module 521 configured for initiating a primary channel indicator timer; a scan performing module 522 configured for performing a scanning operation for advertising message indicator on one or more predetermined primary BLE advertising channel(s); and a timer operation control module 523 configured for controlling timer operation of the primary channel indicator timer based on detection of an advertising message indicator, causing the controller to send an Advertising Indication report to the host 10 in response to detecting the advertising message indicator and wherein the timer operation controlling comprises discontinuing the scanning operation in response to a time-out of the primary channel indicator timer; or activating secondary BLE advertising channel reception when the primary channel indicator timer is interrupted in response to detecting an advertising message indicator.

15 It should be understood that entities in the drawings, e.g., blocks of the block diagrams, and also combinations of entities in the drawings, can be implemented by computer program instructions, which instructions can be stored in a computer-readable memory, and also loaded onto a computer or other programmable data processing apparatus. Such computer program instructions can be provided to a processor of a general purpose computer, a special purpose 20 computer and/or other programmable data processing apparatus to produce a machine, such that the instructions, which execute via the processor of the computer and/or other programmable data processing apparatus, create means for implementing the functions/acts specified in the block diagrams and/or flowchart block or blocks.

In some implementations and according to some aspects of the disclosure, functions disclosed 25 as performed in a certain order in a block of the block diagram can occur out of the order.

In the drawings and specification, there have been disclosed exemplary aspects of the disclosure. However, many variations and modifications can be made to these aspects without substantially departing from the principles of the present disclosure. Thus, the disclosure should be regarded as illustrative rather than restrictive, and not as being limited to the

particular aspects discussed above. Accordingly, although specific terms are employed, they are used in a generic and descriptive sense only and not for purposes of limitation.

It should be noted that although terminology from Bluetooth Low Energy has been used and additional implementation of the host and controller of a Bluetooth 5.0 device is discussed, other short range wireless technologies using similar advertising procedure for connection-less data transfer, may also benefit from the example embodiments disclosed herein.

The description of the example embodiments provided herein have been presented for purposes of illustration. The description is not intended to be exhaustive or to limit example embodiments to the precise form disclosed, and modifications and variations are possible in light of the above teachings or may be acquired from practice of various alternatives to the provided embodiments. The examples discussed herein were chosen and described in order to explain the principles and the nature of various example embodiments and its practical application to enable one skilled in the art to utilize the example embodiments in various manners and with various modifications as are suited to the particular use contemplated. The features of the embodiments described herein may be combined in all possible combinations of source nodes, target nodes, corresponding methods, and computer program products. It should be appreciated that the example embodiments presented herein may be practiced in combination with each other.

CLAIMS

1. A method for enabling unsolicited data reception in a device capable of operating in accordance with Bluetooth Low Energy, BLE, wherein the device is logically separated into a controller configured to implement at least a physical layer functionality and a link layer
5 functionality for the device and a host configured to control and configure operation of the controller, the method comprising:
 - initiating (S42) a primary channel indicator timer;
 - performing a scanning operation (S43) for advertising message indicator on one or more predetermined primary BLE advertising channel(s);
 - 10 – controlling timer operation of the primary channel indicator timer based on detection of an advertising message indicator, wherein the controller sends an Advertising Indication report to the host in response to detecting the advertising message indicator and wherein the timer operation controlling comprises:
 - discontinuing (S44) the scanning operation in response to a time-out of the
15 primary channel indicator timer; or
 - activating (S46) secondary BLE advertising channel reception when the primary channel indicator timer is interrupted in response to detecting (S45) an advertising message indicator.
- 20 2. The method of claim 1, wherein the primary channel indicator timer is implemented in the host, and the primary channel indicator timer is interrupted in response to receiving the Advertising Indication report in the host.
3. The method of claim 1 or 2, wherein performing a scanning operation for advertising
25 message indicator is performed by the controller and comprises:
 - listening for a pointer message, ADV_EXT_IND, on any of the predetermined primary BLE advertising channel(s);
 - generating the Advertising Indication report when receiving the pointer message ADV_EXT_IND; and
 - 30 - sending the Advertising Indication report to the host.

4. The method of any of claims 1 to 3, wherein the primary channel indicator timer is initiated at a time when the BLE device expects to detect the advertising message indicator.
5. The method of claim 4, wherein the time when the BLE device expects to detect the advertising indicator is one or more of: a time of an expected acknowledgement from an advertising BLE device, a time agreed with an advertising BLE device, and a periodically recurring time.
6. The method of any of claims 1-5, wherein a timer-value of the primary channel indicator timer is selected from a range of 5-100 ms, 5-50ms, or 5-25ms.
7. The method of any of claims 1-6, wherein the timer-value of the primary channel indicator timer is selected to 20ms.
8. The method of any of the preceding claims, wherein activating (S46) of the secondary BLE advertising channel reception comprises
 - enabling (S46b) data reception on one or more secondary BLE advertising channels.
9. The method of claim 8, wherein activating (S46) the secondary BLE advertising channel reception further comprises:
 - initiating (S46a) a secondary channel reception timer with an auxiliary time period retrieved from the pointer message, ADV_EXT_IND;
 - enabling (S46b) data reception on the one or more secondary BLE advertising channels during the auxiliary time period; and
 - sending (S47) an advertising report to the host to confirm correct reception when receiving a correct Protocol Data Unit, PDU, at the controller during the auxiliary time period.
10. The method of claim 9, further comprising retrieving a transmission offset value, AUX Offset, from the pointer message, ADV_EXT_IND and deactivating the BLE device during a

time period determined by the AUX Offset when the AUX Offset is greater than a predetermined threshold value.

11. The method of any of the preceding claims, further comprising:

- 5 – activating (S41) BLE advertising channel reception in the BLE device according to a predetermined sleeping schedule of the BLE device.

12. The method of any of the preceding claims, further comprising the step of

- 10 – activating (S48) a low energy mode of the BLE device in response to one or more of: time-out of the primary channel indicator timer, time-out of the secondary channel reception timer, and a completion of the data transfer procedure.

13. The method of an of claims 1 to 10, further comprising the step of iterating the method in response to time-out of the primary channel indicator timer or time-out of the secondary channel reception timer.

15

14. A computer readable storage medium, having stored thereon a computer program which, when executed in a in a device capable of operating in accordance with Bluetooth Low Energy, BLE, causes the device to execute the methods according to any of claims 1-12.

20

15. A Bluetooth Low Energy, BLE, device (50) configured for enabling unsolicited data reception, the BLE device comprising radio circuitry (51) and processing circuitry (52), wherein the processing circuitry is logically separated into a controller (52a) configured to implement at least a physical layer functionality and a link layer functionality for the device and a host (52b) configured to control and configure operation of the controller (52a) and wherein the processing circuitry (52) is configured to:

25

- initiate a primary channel indicator timer;
- perform a scanning operation for advertising message indicator on one or more predetermined primary BLE advertising channel(s); and

- control timer operation of the primary channel indicator timer based on detection of an advertising message indicator, causing the controller to send an Advertising Indication report to the host in response to detecting the advertising message indicator and wherein the timer operation control comprises:

- 5 ○ discontinuing the scanning operation in response to a time-out of the primary channel indicator timer; or
- activating secondary BLE advertising channel reception when the primary channel indicator timer is interrupted in response to detecting an advertising message indicator.

10

16. The BLE device of claim 15 wherein the processing circuitry is further configured to cause the controller to

- listen for a pointer message, ADV_EXT_IND, on any of the predetermined primary BLE advertising channel(s);
- 15 – generate the Advertising Indication report when receiving the pointer message ADV_EXT_IND; and
- send the Advertising Indication report to the host.

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50a BLE device: scanning

50b BLE device: advertising

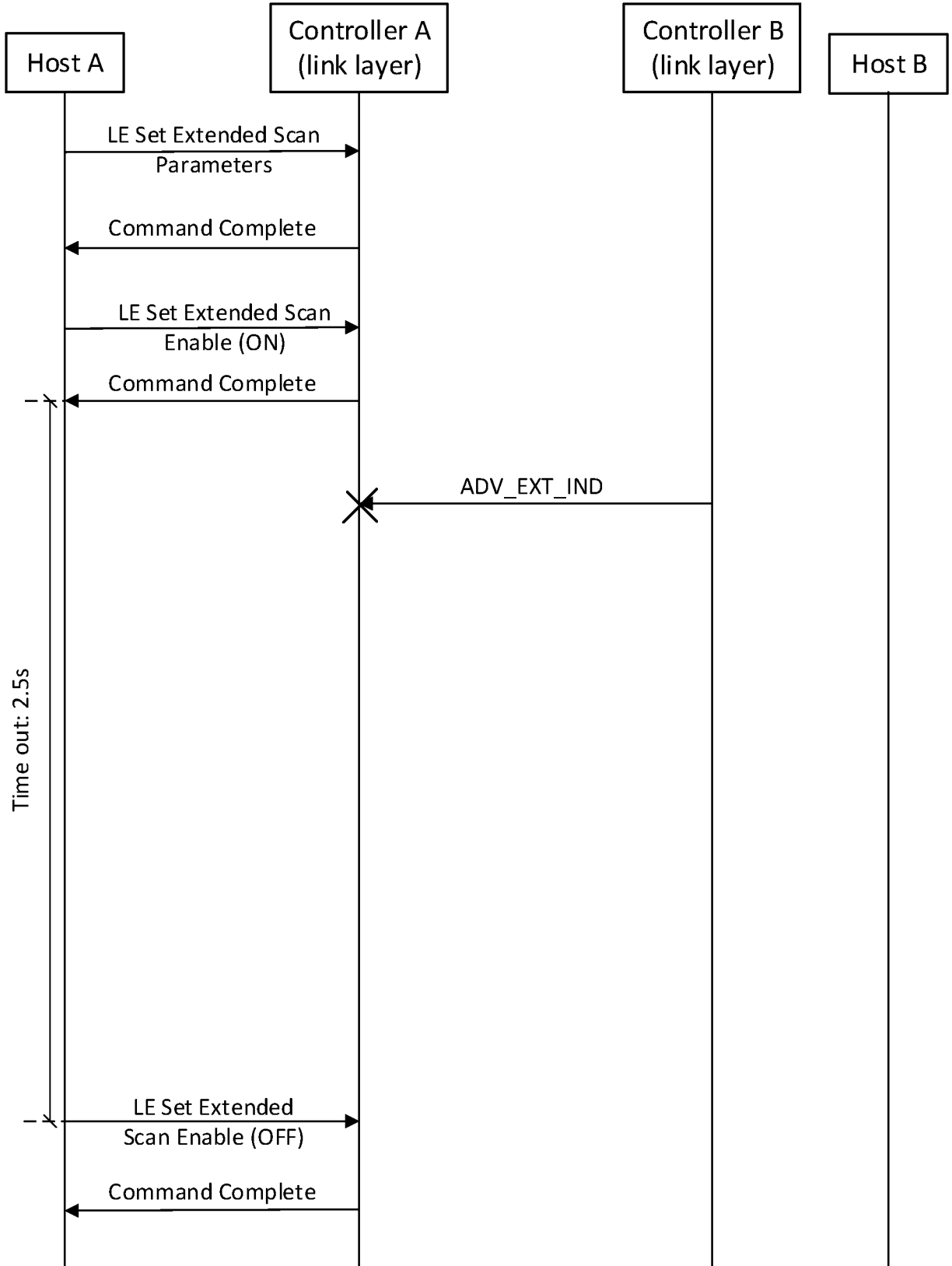


Fig. 1 (Prior Art)

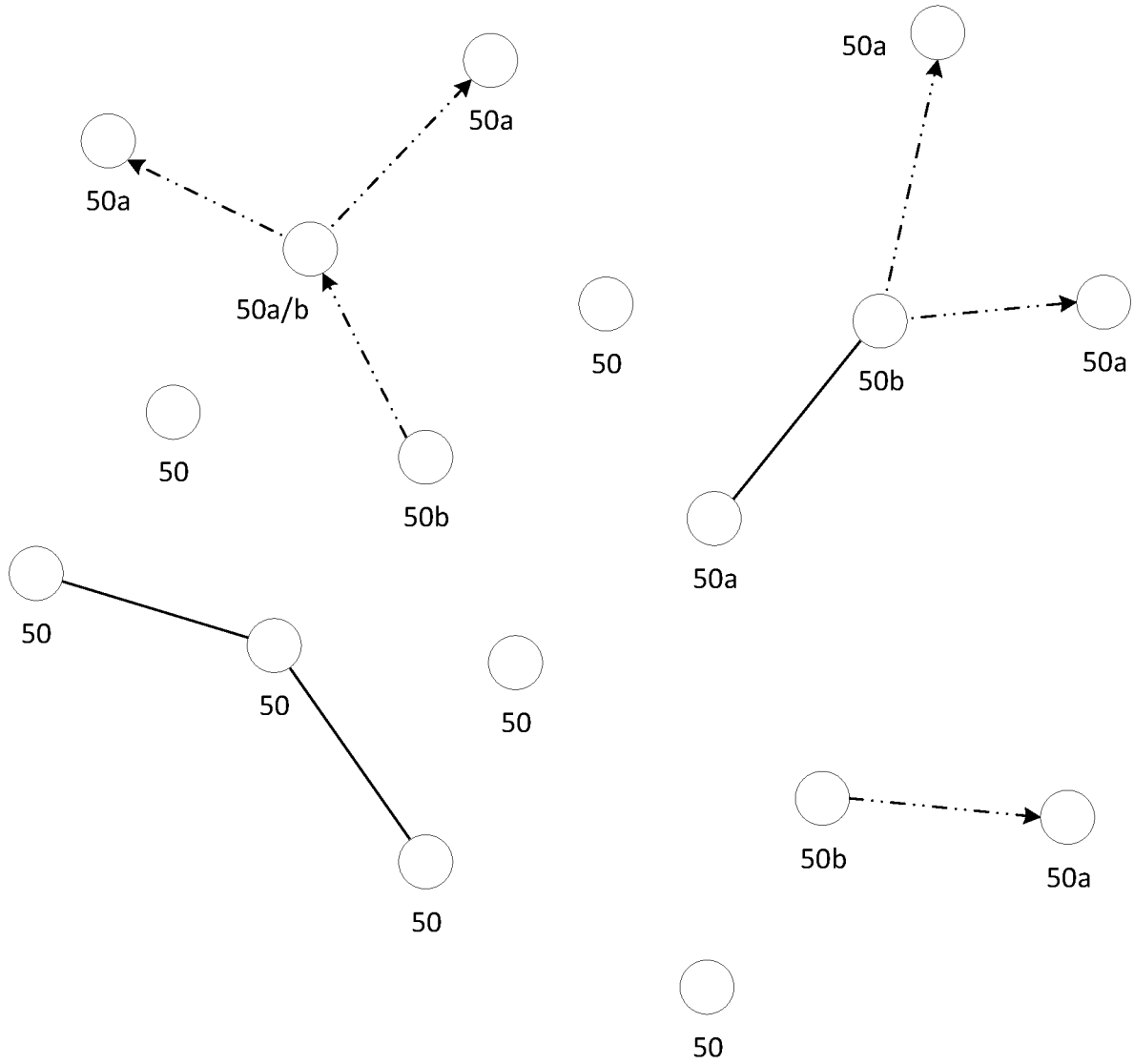


Fig. 2

50a BLE device: scanning

50b BLE device: advertising

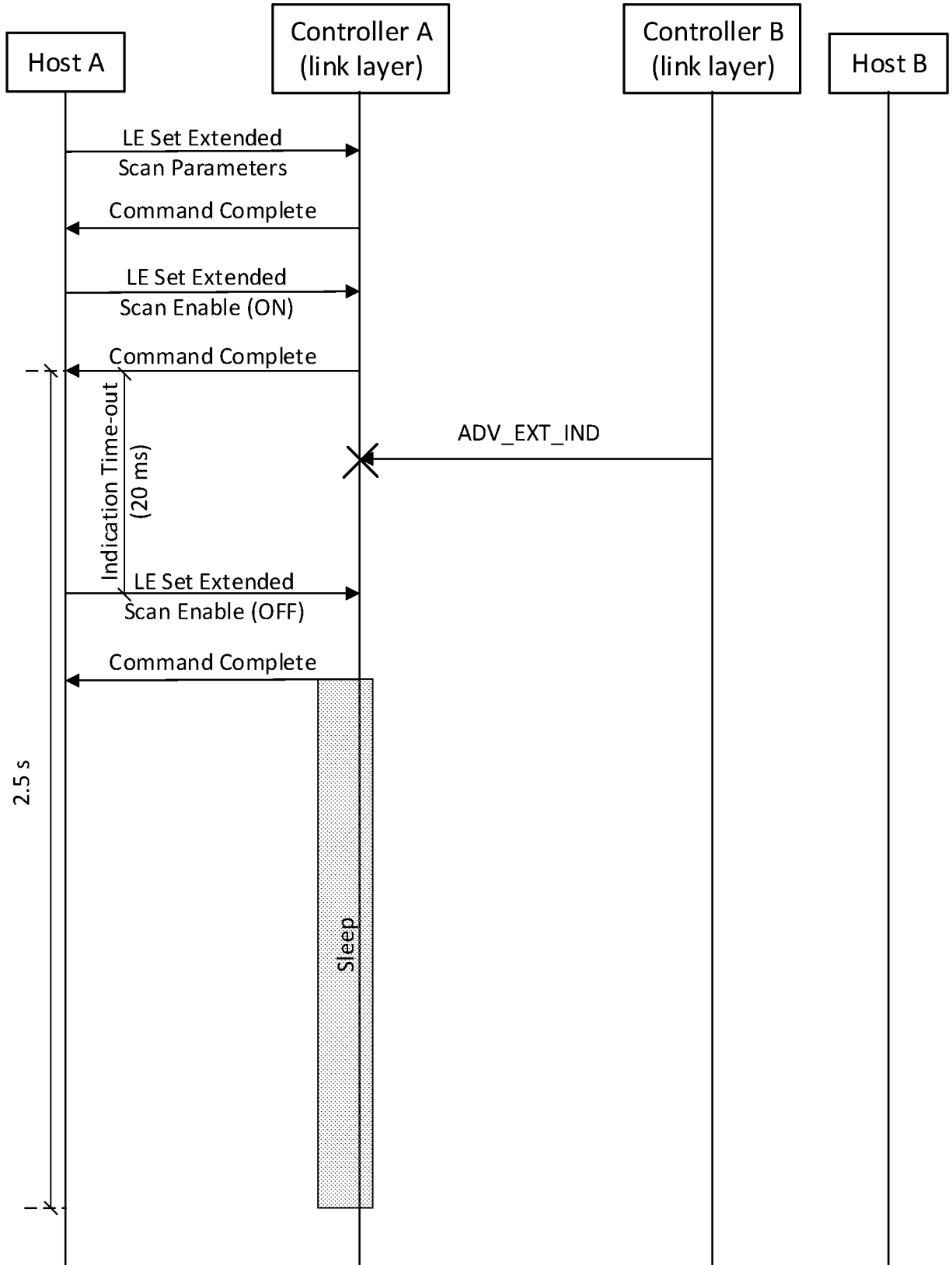


Fig. 3a (Case of loss)

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50a BLE device: scanning

50b BLE device: advertising

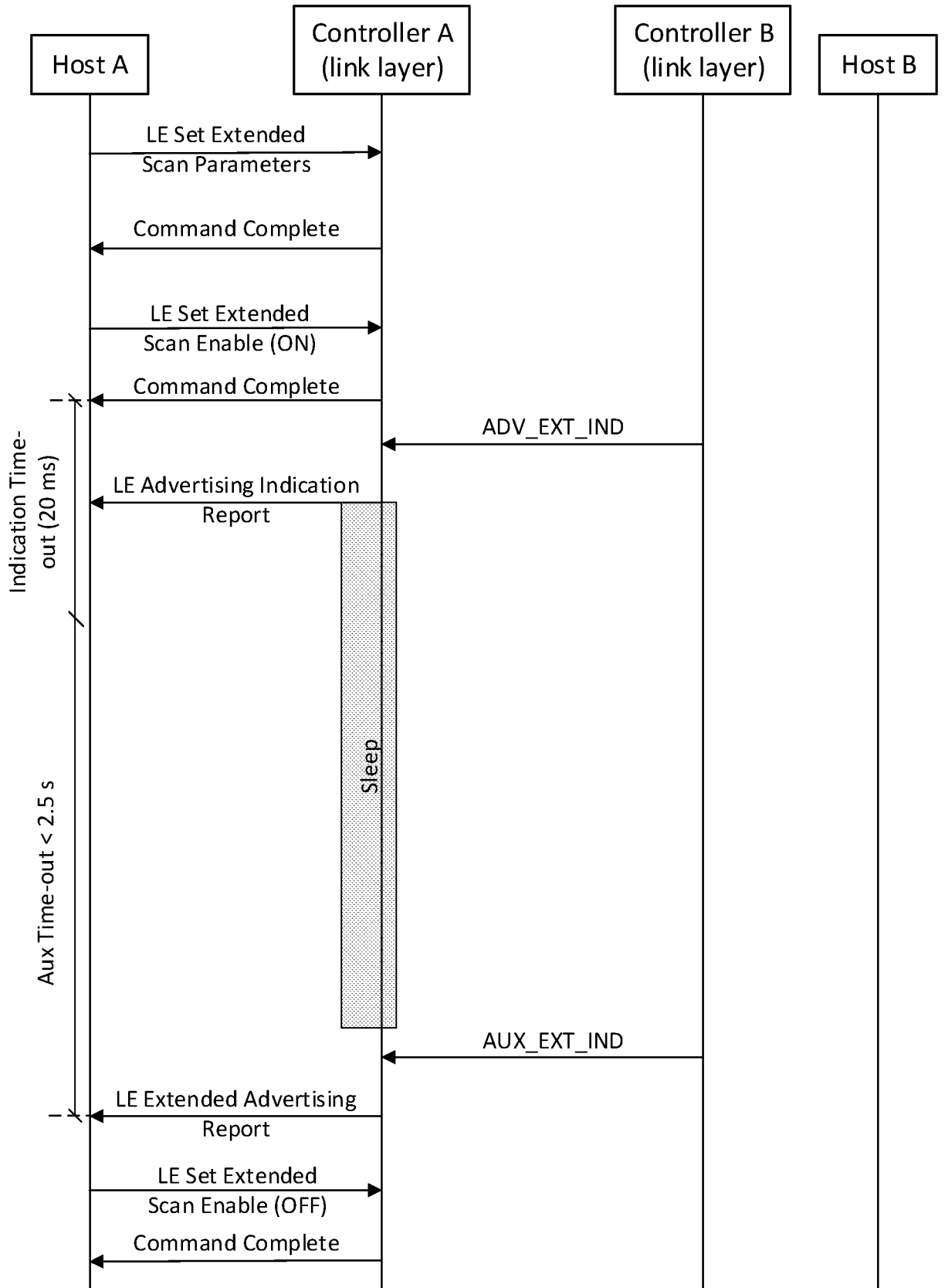


Fig. 3b (Case of success)

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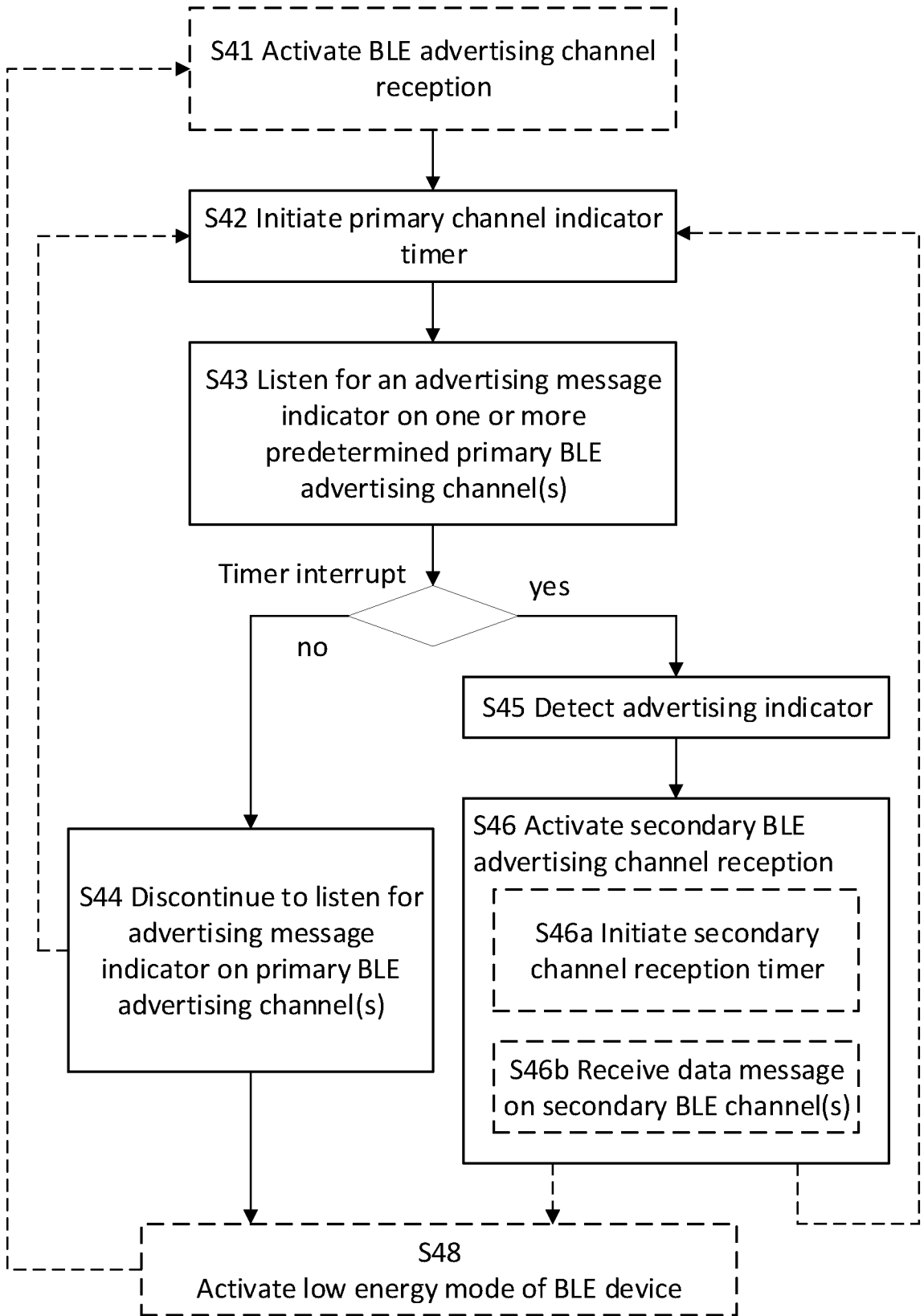


Fig. 4a

50 BLE Device/Host

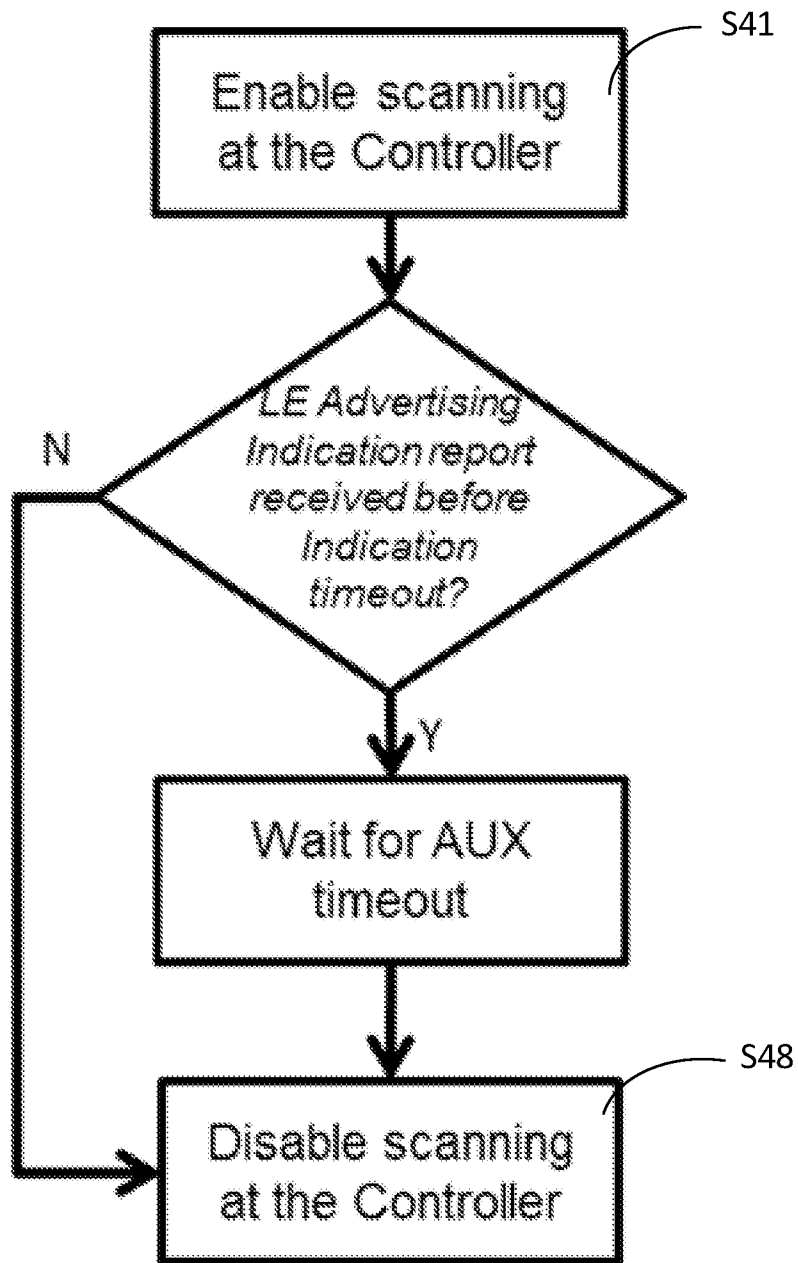


Fig. 4b

50 BLE Device/Controller

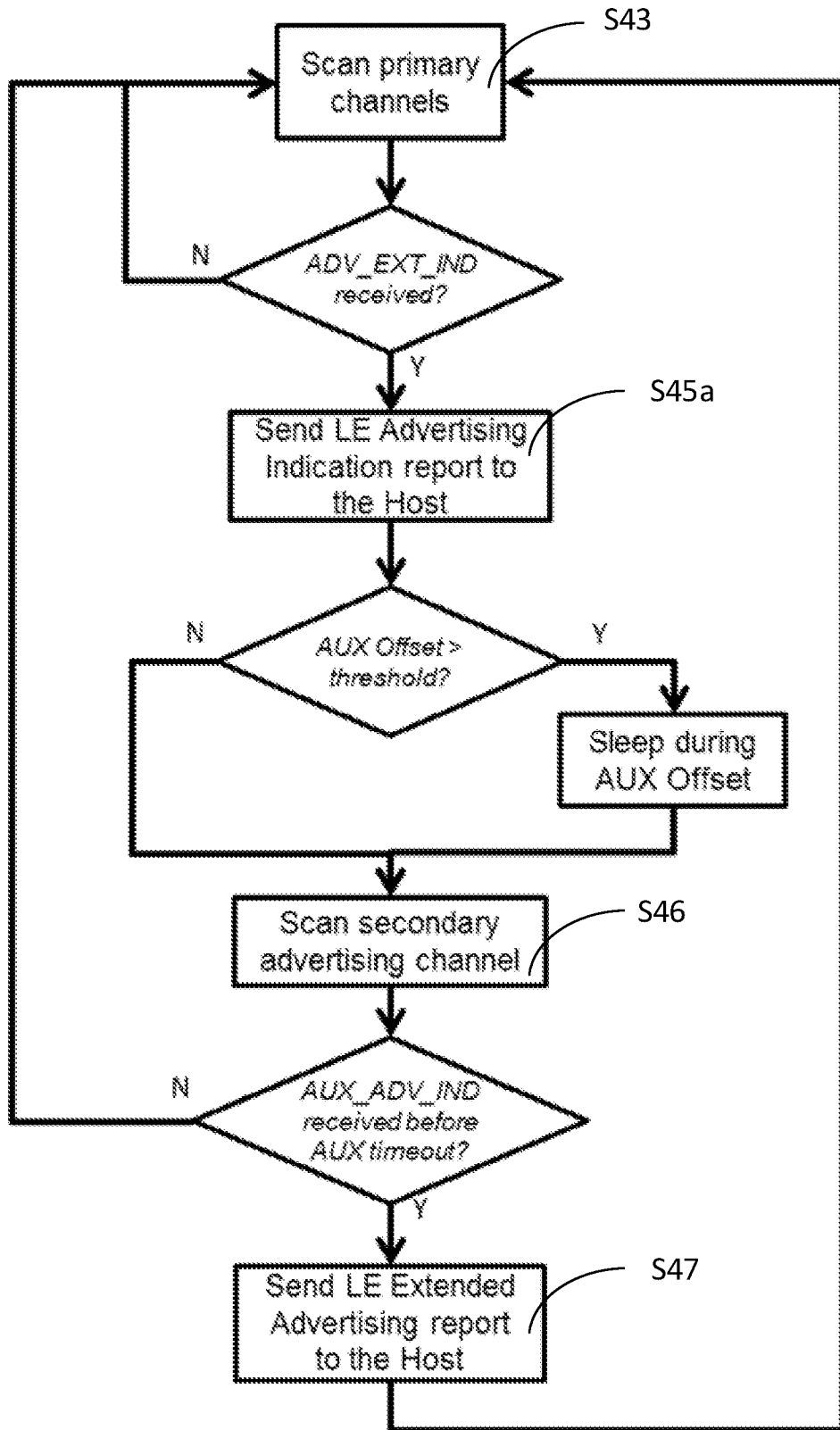


Fig. 4c

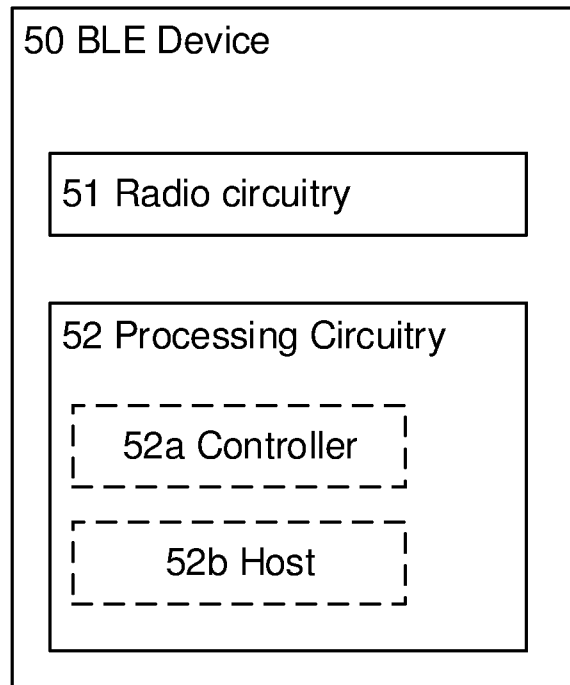


Fig. 5a

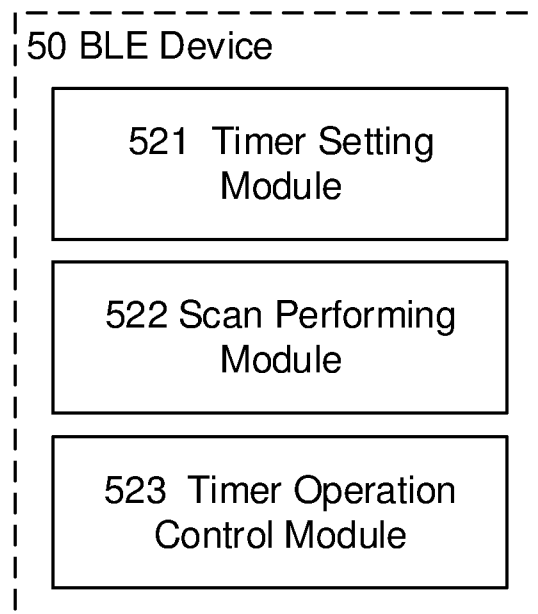


Fig. 5b

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2018/050607

A. CLASSIFICATION OF SUBJECT MATTER		
IPC: see extra sheet		
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)		
IPC: H04W		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
SE, DK, FI, NO classes as above		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)		
EPO-Internal, PAJ, WPI data, COMPENDEX, INSPEC		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	"Core System Package [Low Energy Controller volume]", Specification of the Bluetooth System, Specification Volume 6, Covered Core Package Version: 5.0, Publication date: Dec 06 2016, retrieved from: https://inst.eecs.berkeley.edu/~ee290c/sp18/note/BLE_Vol6.p df ; abstract; Chapters 3 and 4.	1-16
Y	WO 2014080252 A1 (NOKIA CORP), 30 May 2014 (2014-05- 30); abstract; pages 16-17	1-16
<input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C. <input checked="" type="checkbox"/> See patent family annex.		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 26-10-2018		Date of mailing of the international search report 26-10-2018
Name and mailing address of the ISA/SE Patent- och registreringsverket Box 5055 S-102 42 STOCKHOLM Facsimile No. + 46 8 666 02 86		Authorized officer Ralf Boström Telephone No. + 46 8 782 28 00

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2018/050607

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	"A novel architecture for IoT and smart Community", Proceedings of the International Conference on IoT in Social, Mobile, Analytics and Cloud (I-SMAC 2017), 2017-02-10.; abstract; Chapter III --	1-16
A	'Bluetooth Low Energy Mesh Networks: A Survey', by Seyed Mahdi Darroudi, et al, 22 June 2017; abstract; Section 2.4 -- -----	1-16

Continuation of: second sheet

International Patent Classification (IPC)

H04W 4/23 (2018.01)

H04W 8/00 (2009.01)

H04W 4/70 (2018.01)

H04W 4/80 (2018.01)

H04W 84/18 (2009.01)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/SE2018/050607

WO 2014080252 A1 30/05/2014 NONE
