SYSTEMS AND METHODS FOR OPERATING IN A LOW-POWER STATE

TECHNICAL FIELD

[0001] The disclosure relates generally to wireless communications, including but not limited to systems and methods for operating in a low-power state.

BACKGROUND

[0002] The standardization organization Third Generation Partnership Project (3GPP) is currently in the process of specifying a new Radio Interface called 5G New Radio (5G NR) as well as a Next Generation Packet Core Network (NG-CN or NGC). The 5G NR will have three main components: a 5G Access Network (5G-AN), a 5G Core Network (5GC), and a User Equipment (UE). In order to facilitate the enablement of different data services and requirements, the elements of the 5GC, also called Network Functions, have been simplified with some of them being software based, and some being hardware based, so that they could be adapted according to need.

SUMMARY

[0003] The example examples disclosed herein are directed to solving the issues relating to one or more of the problems presented in the prior art, as well as providing additional features that will become readily apparent by reference to the following detailed description when taken in conjunction with the accompany drawings. In accordance with various examples, example systems, methods, devices and computer program products are disclosed herein. It is understood, however, that these examples are presented by way of example and are not limiting, and it will be apparent to those of ordinary skill in the art who read the present disclosure that various modifications to the disclosed examples can be made while remaining within the scope of this disclosure.

[0004] At least one example is directed to a system, method, apparatus, or a computer-readable medium. A wireless communication device may enter a first low-power operating state to monitor for a defined signal. The wireless communication device may monitor for the defined signal, while in the first low-power operating state.

[0005] In some examples, monitoring for the defined signal may comprise monitoring for the defined signal continuously or intermittently over a length of time. In certain examples, the defined signal can include a wake-up signal (WUS) or a signal for triggering state transition. In some examples, the wireless communication device can monitor for the defined signal, while the wireless communication device is in the first low-power operating state or in a second low-power operating state. In certain examples, the second low-power operating state may comprise: a radio resource control (RRC) idle state, a RRC inactive state, a RRC connected state, or a state that incorporates at least one period of being in the first low-power state. In some examples, entering the first low-power operating state may comprise transitioning between a low-power off state and the first low-power operating state, according to a defined configuration, or a configuration from a wireless communication node. The transitioning can be according to at least one of: a defined duty cycle between the low-power off state and the first low-power state, a transition between the low-power off state and the first low-power state after a defined time period or according to a defined periodicity, a transition between the low-power off state and the first low-power state according to a defined length of time period when no signal is detected, a transition between the low-power off state and the first low-power state according to a defined number of detections in which no signal is detected, a transition between the low-power off state and the first low-power state if energy detected from the defined signal meets a condition with respect to a pre-defined or configured first threshold, or a transition between the low-power off state and the first low-power state if an amount of change in energy detected from the defined signal meets a condition with respect to a pre-defined or configured second threshold.

[0006] The wireless communication device may transition between a first state and a second state, according to at least one of: an event, an indication in the defined signal, another defined signal, a specific type of defined signal, a defined length of time period when no signal is detected, a defined number of detections in which no signal is detected, energy detected from the defined signal, an amount of change in energy detected from the defined signal, energy detected from the defined signal exceeds a pre-defined or configured first threshold, a result of comparing an amount of change in the energy detected from the defined signal with a pre-defined or configured second threshold, channel quality measured after a condition between energy detected from the defined signal and the pre-defined or configured first threshold is fulfilled, channel

quality measured after a condition between an amount of change in energy detected from the defined signal and the pre-defined or configured second threshold is fulfilled, channel quality measured after a condition between energy detected from the defined signal and the pre-defined or configured first threshold is fulfilled, meets another condition with respect to a pre-defined or configured third threshold, or change of channel quality measured after a condition between an amount of change in energy detected from the defined signal and the pre-defined or configured second threshold is fulfilled, meets another condition with respect to a pre-defined or configured fourth threshold. In certain examples, the first state and the second state each may comprise: the first low-power operating state, a low-power off state, a combination state that incorporates at least one period of being in the first low-power state, or a legacy state comprising a radio resource control (RRC) idle state, a RRC inactive state, or a RRC connected state.

[0007] In certain examples, the wireless communication device may transition from the first low-power operating state to the legacy state, in response to receiving the defined signal that includes an indication that a network may have a message for the wireless communication device, or that the network may intend to wake up the wireless communication device. In some examples, the wireless communication device may transition from the first low-power operating state to the low-power off state, if the defined signal is not detected after a first defined duration. In certain examples, the wireless communication device may transition from the low-power off state to the first low-power operating state, after a second defined duration. In some examples, the wireless communication device may transition from the first low-power operating state to the legacy state, if: the defined signal, or the defined signal that includes an indication that a network may have a message for the wireless communication device, is not detected after a first defined duration, or the wireless communication device detects a cell change. In certain examples, the wireless communication device may transition from the first low-power operating state to the second state, in response to the defined signal indicating to transition specifically to the second state.

[0008] In some examples, the wireless communication device may send a message to a wireless communication node to stop transmission of defined signals, prior to transitioning to a low-power off state. In certain examples, the wireless communication device may transition from the first low-power operating state to the low-power off state, after sending the message. In

some examples, the defined signal can be specifically configured for the wireless communication device or for a device group that includes the wireless communication device. In certain examples, the defined signal may be scheduled on at least one resource specifically configured for the wireless communication device, or for the device group. In some examples, the wireless communication device may detect at least one defined signal each corresponding to a respective cell and indicative of at least one of: an existence of the respective cell or a channel quality of the respective cell. In some examples, the wireless communication device may detect at least one defined signal each corresponding to a respective cell. The wireless communication device may perform clock synchronization using the at least one defined signal. In some examples, the defined signal may include an indication to activate or deactivate the monitoring of subsequent defined signals. In certain examples, the defined signal may include an indication to indicate arrival of a paging message to one or more devices that moved from another cell to the respective cell.

[0009] In certain examples, the wireless communication device may determine whether the wireless communication device is within a signal coverage region for receiving the defined signal. In some examples, the wireless communication device may enter or maintain the first low-power operating state in response to being within the signal coverage region. In some examples, the wireless communication device may send at least one of: a request for extending time domain resources for the defined signal or increasing a transmission energy for the defined signal, an indication of a time duration for the wireless communication device to transition from the first low-power operation state or a state incorporating the first low-power operation state, to a radio resource control (RRC) idle state or a RRC inactive state, or a capability of the wireless communication device to support the defined signal. In certain examples, the wireless communication device may receive at least one of: a configuration for the defined signal, an indication for triggering a transition between states, or an indication for indicating to the wireless communication device to enter the first low-power operating state.

[0010] In some examples, the configuration or the indication is received via at least one of: a dedicated signaling, a broadcast signaling, a user plane packet, or a downlink signaling during at least one of: radio resource control (RRC) establishment procedure, RRC resume procedure, RRC reconfiguration procedure, RRC reestablishment procedure, RRC release

procedure, early data transmission procedure, or small data transmission procedure. In certain examples, the configuration includes at least one of: at least one manner for transitioning between states, a manner for monitoring the defined signal, a criteria for determining a signal coverage region or range for the defined signal, a criteria or threshold for determining infeasibility of performing monitoring for the defined signal, or for triggering a transition to a radio resource control (RRC) idle state or a RRC inactive state, a design or format of the defined signal, or a design or format for at least one defined signal each corresponding to a respective cell. In some examples, the wireless communication device may determine whether the configuration is for a cell in which the wireless communication device currently resides. In certain examples, the wireless communication device may use the configuration if the configuration is for the cell in which the wireless communication device currently resides. The wireless communication device may terminate the monitoring of the defined signal if the configuration is not for the cell in which the wireless communication device currently resides. The wireless communication device may monitor the defined signal if the configuration is for the cell in which the wireless communication device currently resides.

[0011] At least one example is directed to a system, method, apparatus, or a computer-readable medium (e.g., a non-transitory computer readable medium). A wireless communication node (e.g., a ground terminal, a base station, a gNB, an eNB, or a serving node) may detect no signal or indication from a wireless communication device, or no signal or indication from any wireless communication device. The wireless communication node may indicate a status of the wireless communication device to a core network. The wireless communication node may send paging in a fallback mode to the wireless communication device. The fallback mode may comprise sending the paging in a defined way, sending the paging using defined resources, sending the paging based on a configuration or indication from the core network, or sending the paging in all cells in a registration area of the wireless communication device.

[0012] At least one example is directed to a system, method, apparatus, or a computer-readable medium (e.g., a non-transitory computer readable medium). A wireless communication node may provide a configuration for transmitting a defined signal or an indication. The wireless communication node may transmit the defined signal.

[0012a] In one aspect, the present disclosure refers to a method comprising, entering, by a wireless communication device, a first low-power operating state to monitor for a defined signal, and monitoring, by the wireless communication device, for the defined signal, while in the first low-power operating state.

[**0012b]** In another aspect, the present disclosure refers to a wireless communication device, comprising, at least one processor configured to, enter a first low-power operating state to monitor for a defined signal, and monitor for the defined signal, while in the first low-power operating state.

[0013] In certain examples, the configuration can include at least one of: at least one manner for transitioning between states, a manner for monitoring the defined signal, a criteria for determining a signal coverage region or range for the defined signal, a criteria or threshold for determining infeasibility of performing monitoring for the defined signal, or for triggering a transition to a radio resource control (RRC) idle state or a RRC inactive state, a design or format of the defined signal, or a design or format for at least one defined signal each corresponding to a respective cell. In some examples, the indication can include at least one of: an indication for triggering a transition between states in a wireless communication device, or an indication for indicating to the wireless communication device to enter a first low-power operating state.

[0014] The systems and methods discussed herein can include novel approach for defining and/or configuring a novel low-power operating state and/or sub-states, such as LP-WUS_IDLE, LP-WUS_INACTIVE, LP-WUS-ON and/or LP-WUS-OFF. The novel approach may describe one or more transition operations between the novel low-power operating states and/or other operating states (e.g., legacy states). The systems and methods described herein can include novel approach for configuring and/or determining a novel defined signal for a wireless communication device (e.g., UE) and/or for a device group (e.g., UE group-specific defined signal). The defined signal (e.g., LP-WUS signal) can be used for detecting cells and/or determining a channel quality of the cells. In certain examples, the defined signal can be a cell-specific defined signal. Furthermore, the systems and methods described herein can include a configuration for the defined signal, and/or a request for the defined signal. In certain examples, the systems and methods can include criteria for determining whether a wireless communication device is located within an area/range of the defined signal.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] Various example embodiments of the present solution are described in detail below with reference to the following figures or drawings. The drawings are provided for purposes of illustration only and merely depict example embodiments of the present solution to facilitate the reader's understanding of the present solution. Therefore, the drawings should not be considered limiting of the breadth, scope, or applicability of the present solution. It should be noted that for clarity and ease of illustration, these drawings are not necessarily drawn to scale.

CLAIMS

1. A method comprising:

entering, by a wireless communication device, a first low-power operating state to monitor for a defined signal; and

monitoring, by the wireless communication device, for the defined signal, while in the first low-power operating state.

2. The method of claim 1,

wherein monitoring for the defined signal comprises monitoring for the defined signal continuously or intermittently over a length of time,

wherein the defined signal includes a wake-up signal (WUS) or a signal for triggering state transition.

3. The method of claim 1, comprising:

monitoring, by the wireless communication device, for the defined signal, while the wireless communication device is in the first low-power operating state or in a second low-power operating state,

wherein the second low-power operating state comprises: a radio resource control (RRC) idle state, a RRC inactive state, a RRC connected state, or a state that incorporates at least one period of being in the first low-power state.

4. The method of claim 1, wherein entering the first low-power operating state comprises:

transitioning between a low-power off state and the first low-power operating state, according to a defined configuration, or a configuration from a wireless communication node,

wherein the transitioning is according to at least one of:

a defined duty cycle between the low-power off state and the first low-power state,

a transition between the low-power off state and the first low-power state after a defined time period or according to a defined periodicity,

a transition between the low-power off state and the first low-power state according to a defined length of time period when no signal is detected,

a transition between the low-power off state and the first low-power state according to a defined number of detections in which no signal is detected,

a transition between the low-power off state and the first low-power state if energy detected from the defined signal meets a condition with respect to a pre-defined or configured first threshold, or

a transition between the low-power off state and the first low-power state if an amount of change in energy detected from the defined signal meets a condition with respect to a pre-defined or configured second threshold.

5. The method of claim 1, comprising:

transitioning, by the wireless communication device, between a first state and a second state, according to at least one of:

an event,

an indication in the defined signal,

another defined signal,

a specific type of defined signal,

a defined length of time period when no signal is detected,

a defined number of detections in which no signal is detected,

energy detected from the defined signal, an amount of change in energy detected from the defined signal,

energy detected from the defined signal exceeds a pre-defined or configured first threshold,

a result of comparing an amount of change in the energy detected from the defined signal with a pre-defined or configured second threshold,

channel quality measured after a condition between energy detected from the defined signal and the pre-defined or configured first threshold is fulfilled,

channel quality measured after a condition between an amount of change in energy detected from the defined signal and the pre-defined or configured second threshold is fulfilled,

channel quality measured after a condition between energy detected from the defined signal and the pre-defined or configured first threshold is fulfilled, meets another condition with respect to a pre-defined or configured third threshold, or

change of channel quality measured after a condition between an amount of change in energy detected from the defined signal and the pre-defined or configured second threshold is fulfilled, meets another condition with respect to a pre-defined or configured fourth threshold,

wherein the first state and the second state each comprises:

the first low-power operating state,

a low-power off state,

a combination state that incorporates at least one period of being in the first low-power state, or

a legacy state comprising a radio resource control (RRC) idle state, a RRC inactive state, or a RRC connected state.

6. The method of claim 5, comprising:

transitioning, by the wireless communication device, from the first low-power operating state to the legacy state, in response to receiving the defined signal that includes an indication that a network may have a message for the wireless communication device, or that the network may intend to wake up the wireless communication device.

7. The method of claim 5, comprising:

transitioning, by the wireless communication device, from the first low-power operating state to the low-power off state, if the defined signal is not detected after a first defined duration;

transitioning, by the wireless communication device, from the low-power off state to the first low-power operating state, after a second defined duration.

8. The method of claim 5, comprising:

transitioning, by the wireless communication device, from the first low-power operating state to the legacy state, if:

the defined signal, or the defined signal that includes an indication that a network may have a message for the wireless communication device, is not detected after a first defined duration, or

the wireless communication device detects a cell change.

9. The method of claim 5, comprising:

transitioning, by the wireless communication device, from the first low-power operating state to the second state, in response to the defined signal indicating to transition specifically to the second state.

10. The method of claim 1, comprising:

sending, by the wireless communication device, a message to a wireless communication node to stop transmission of defined signals, prior to transitioning to a low-power off state; and

transitioning, by the wireless communication device, from the first low-power operating state to the low-power off state, after sending the message.

11. The method of claim 1, wherein the defined signal is:

specifically configured for the wireless communication device or for a device group that includes the wireless communication device; or

scheduled on at least one resource specifically configured for the wireless communication device, or for the device group.

12. The method of claim 1, comprising:

detecting, by the wireless communication device, at least one defined signal each corresponding to a respective cell and indicative of at least one of: an existence of the respective cell or a channel quality of the respective cell.

13. The method of claim 1, comprising:

detecting, by the wireless communication device, at least one defined signal each corresponding to a respective cell; and

performing, by the wireless communication device, clock synchronization using the at least one defined signal.

14. The method of claim 12, wherein the defined signal includes an indication to:

activate or deactivate the monitoring of subsequent defined signals; or

indicate arrival of a paging message to one or more devices that moved from another cell

to the respective cell.

15. The method of claim 1, comprising:

determining, by the wireless communication device, whether the wireless communication device is within a signal coverage region for receiving the defined signal; and

entering or maintaining, by the wireless communication device, the first low-power operating state in response to being within the signal coverage region.

16. The method of claim 1, comprising:

sending, by the wireless communication device, at least one of:

a request for extending time domain resources for the defined signal or increasing a transmission energy for the defined signal,

an indication of a time duration for the wireless communication device to transition from the first low-power operation state or a state incorporating the first low-power operation state, to a radio resource control (RRC) idle state or a RRC inactive state, or

a capability of the wireless communication device to support the defined signal.

17. The method of claim 1, comprising:

receiving, by the wireless communication device, at least one of:

a configuration for the defined signal,

an indication for triggering a transition between states, or

an indication for indicating to the wireless communication device to enter the first low-power operating state.

18. The method of claim 1, wherein the configuration or the indication is received via at least one of:

a dedicated signaling,

a broadcast signaling, or

a user plane packet, or

a downlink signaling during at least one of: radio resource control (RRC) establishment procedure, RRC resume procedure, RRC reconfiguration procedure, RRC reestablishment

procedure, RRC release procedure, early data transmission procedure, or small data transmission procedure.

19. The method of claim 17, wherein the configuration includes at least one of:

at least one manner for transitioning between states;

a manner for monitoring the defined signal;

a criteria for determining a signal coverage region or range for the defined signal;

a criteria or threshold for determining infeasibility of performing monitoring for the defined signal, or for triggering a transition to a radio resource control (RRC) idle state or a RRC inactive state;

a design or format of the defined signal; or

a design or format for at least one defined signal each corresponding to a respective cell.

20. A wireless communication device, comprising:

at least one processor configured to:

enter a first low-power operating state to monitor for a defined signal; and

monitor for the defined signal, while in the first low-power operating state.