features, functions, and/or benefits of some of the embodiments disclosed herein. Applications 720 are run in virtualization environment 700 which provides hardware 730 comprising processing circuitry 760 and memory 790. Memory 790 contains instructions 795 executable by processing circuitry 760 whereby application 720 is operative to provide one or more of the features, benefits, and/or functions disclosed herein.

Virtualization environment 700, comprises general-purpose or special-purpose network hardware devices 730 comprising a set of one or more processors or processing circuitry 760, which may be commercial off-the-shelf (COTS) processors, dedicated Application Specific Integrated Circuits (ASICs), or any other type of processing circuitry including digital or analog hardware components or special purpose processors. Each hardware device may comprise memory 790-1 which may be non-persistent memory for temporarily storing instructions 795 or software executed by processing circuitry 760. Each hardware device may comprise one or more network interface controllers (NICs) 770, also known as network interface cards, which include physical network interface 780. Each hardware device may also include non-transitory, persistent, machine-readable storage media 790-2 having stored therein software 795 and/or instructions executable by processing circuitry 760. Software 795 may include any type of software including software for instantiating one or more virtualization layers 750 (also referred to as hypervisors), software to execute virtual machines 740 as well as software allowing it to execute functions, features and/or benefits described in relation with some embodiments described herein.

Virtual machines 740, comprise virtual processing, virtual memory, virtual networking or interface and virtual storage, and may be run by a corresponding virtualization layer 750 or hypervisor. Different embodiments of the instance of virtual appliance 720 may be implemented on one or more of virtual machines 740, and the implementations may be made in different ways.

During operation, processing circuitry 760 executes software 795 to instantiate the hypervisor or virtualization layer 750, which may sometimes be referred to as a virtual machine monitor (VMM). Virtualization layer 750 may present a virtual operating platform that appears like networking hardware to virtual machine 740.

As shown in FIGURE 10, hardware 730 may be a standalone network node with generic or specific components. Hardware 730 may comprise antenna 7225 and may implement some functions via virtualization. Alternatively, hardware 730 may be part of a larger cluster of hardware (e.g. such as in a data center or customer premise equipment (CPE)) where many hardware nodes work together and are managed via management and orchestration (MANO) 7100, which, among others, oversees lifecycle management of applications 720.

Virtualization of the hardware is in some contexts referred to as network function virtualization (NFV). NFV may be used to consolidate many network equipment types onto industry standard high-volume server hardware, physical switches, and physical storage, which can be located in data centers, and customer premise equipment.

In the context of NFV, virtual machine 740 may be a software implementation of a physical machine that runs programs as if they were executing on a physical, non-virtualized machine. Each of virtual machines 740, and that part of hardware 730 that executes that virtual machine, be it hardware dedicated to that virtual machine and/or hardware shared by that virtual machine with others of the virtual machines 740, forms a separate virtual network elements (VNE).

Still in the context of NFV, Virtual Network Function (VNF) is responsible for handling specific network functions that run in one or more virtual machines 740 on top of hardware networking infrastructure 730 and corresponds to application 720 in FIGURE 10.

In some embodiments, one or more radio units 7200 that each include one or more transmitters 7220 and one or more receivers 7210 may be coupled to one or more antennas 7225. Radio units 7200 may communicate directly with hardware nodes 730 via one or more appropriate network interfaces and may be used in combination with the virtual components to provide a virtual node with radio capabilities, such as a radio access node or a base station.

In some embodiments, some signalling can be affected with the use of control system 7230 which may alternatively be used for communication between the hardware nodes 730 and radio units 7200.

FIGURE 11 illustrates a telecommunication network connected via an intermediate network to a host computer, in accordance with some embodiments. With reference to FIGURE 11, in accordance with an embodiment, a communication system includes telecommunication network 810, such as a 3GPP-type cellular network, which comprises access network 811, such as a radio access network, and core network 814. Access network 811 comprises a plurality of base stations 812a, 812b, 812c, such as NBs, eNBs, gNBs or other types of wireless access points, each defining a corresponding coverage area 813a, 813b, 813c. Each base station 812a, 812b, 812c is connectable to core network 814 over a wired or wireless connection 815. A first UE 891 located in coverage area 813c is configured to wirelessly connect to, or be paged by, the corresponding base station 812c. A second UE 892 in coverage area 813a is wirelessly connectable to the corresponding base station 812a. While a plurality of UEs 891, 892 are illustrated in this example, the disclosed embodiments are equally applicable to a situation where a sole UE is in the coverage area or where a sole UE is connecting to the corresponding base station 812.

Telecommunication network 810 is itself connected to host computer 830, which may be embodied in the hardware and/or software of a standalone server, a cloud-implemented server, a distributed server or as processing resources in a server farm. Host computer 830 may be under the ownership or control of a service provider, or may be operated by the service provider or on behalf of the service provider. Connections 821 and 822 between telecommunication network 810 and host computer 830 may extend directly from core network 814 to host computer 830 or may go via an optional intermediate network 820. Intermediate network 820 may be one of, or a combination of more than one of, a public, private or hosted network; intermediate network 820, if any, may be a backbone network or the Internet; in particular, intermediate network 820 may comprise two or more sub-networks (not shown).

The communication system of FIGURE 11 as a whole enables connectivity between the connected UEs 891, 892 and host computer 830. The connectivity may be described as an over-the-top (OTT) connection 850. Host computer 830 and the connected UEs 891, 892 are configured to communicate data and/or signaling via OTT connection 850, using access network 811, core network 814, any intermediate network 820 and possible further infrastructure (not shown) as intermediaries. OTT

connection 850 may be transparent in the sense that the participating communication devices through which OTT connection 850 passes are unaware of routing of uplink and downlink communications. For example, base station 812 may not or need not be informed about the past routing of an incoming downlink communication with data originating from host computer 830 to be forwarded (e.g., handed over) to a connected UE 891. Similarly, base station 812 need not be aware of the future routing of an outgoing uplink communication originating from the UE 891 towards the host computer 830.

FIGURE 12 illustrates a host computer communicating via a base station with a user equipment over a partially wireless connection, in accordance with some embodiments. Example implementations, in accordance with an embodiment, of the UE, base station and host computer discussed in the preceding paragraphs are described with reference to FIGURE 12.

In communication system 900, host computer 910 comprises hardware 915 including communication interface 916 configured to set up and maintain a wired or wireless connection with an interface of a different communication device of communication system 900. Host computer 910 further comprises processing circuitry 918, which may have storage and/or processing capabilities. In particular, processing circuitry 918 may comprise one or more programmable processors, application-specific integrated circuits, field programmable gate arrays or combinations of these (not shown) adapted to execute instructions. Host computer 910 further comprises software 911, which is stored in or accessible by host computer 910 and executable by processing circuitry 918. Software 911 includes host application 912. Host application 912 may be operable to provide a service to a remote user, such as UE 930 connecting via OTT connection 950 terminating at UE 930 and host computer 910. In providing the service to the remote user, host application 912 may provide user data which is transmitted using OTT connection 950.

Communication system 900 further includes base station 920 provided in a telecommunication system and comprising hardware 925 enabling it to communicate with host computer 910 and with UE 930. Hardware 925 may include communication interface 926 for setting up and maintaining a wired or wireless connection with an interface of a different communication device of communication system 900, as well

as radio interface 927 for setting up and maintaining at least wireless connection 970 with UE 930 located in a coverage area (not shown in FIGURE 12) served by base station 920. Communication interface 926 may be configured to facilitate connection 960 to host computer 910. Connection 960 may be direct or it may pass through a core network (not shown in FIGURE 12) of the telecommunication system and/or through one or more intermediate networks outside the telecommunication system. In the embodiment shown, hardware 925 of base station 920 further includes processing circuitry 928, which may comprise one or more programmable processors, application-specific integrated circuits, field programmable gate arrays or combinations of these (not shown) adapted to execute instructions. Base station 920 further has software 921 stored internally or accessible via an external connection.

Communication system 900 further includes UE 930 already referred to. Its hardware 935 may include radio interface 937 configured to set up and maintain wireless connection 970 with a base station serving a coverage area in which UE 930 is currently located. Hardware 935 of UE 930 further includes processing circuitry 938, which may comprise one or more programmable processors, application-specific integrated circuits, field programmable gate arrays or combinations of these (not shown) adapted to execute instructions. UE 930 further comprises software 931, which is stored in or accessible by UE 930 and executable by processing circuitry 938. Software 931 includes client application 932. Client application 932 may be operable to provide a service to a human or non-human user via UE 930, with the support of host computer 910. In host computer 910, an executing host application 912 may communicate with the executing client application 932 via OTT connection 950 terminating at UE 930 and host computer 910. In providing the service to the user, client application 932 may receive request data from host application 912 and provide user data in response to the request data. OTT connection 950 may transfer both the request data and the user data. Client application 932 may interact with the user to generate the user data that it provides.

It is noted that host computer 910, base station 920 and UE 930 illustrated in FIGURE 12 may be similar or identical to host computer 830, one of base stations 812a, 812b, 812c and one of UEs 891, 892 of FIGURE 11, respectively. This is to say,

the inner workings of these entities may be as shown in FIGURE 12 and independently, the surrounding network topology may be that of FIGURE 11.

In FIGURE 12, OTT connection 950 has been drawn abstractly to illustrate the communication between host computer 910 and UE 930 via base station 920, without explicit reference to any intermediary devices and the precise routing of messages via these devices. Network infrastructure may determine the routing, which it may be configured to hide from UE 930 or from the service provider operating host computer 910, or both. While OTT connection 950 is active, the network infrastructure may further take decisions by which it dynamically changes the routing (e.g., on the basis of load balancing consideration or reconfiguration of the network).

Wireless connection 970 between UE 930 and base station 920 is in accordance with the teachings of the embodiments described throughout this disclosure. One or more of the various embodiments improve the performance of OTT services provided to UE 930 using OTT connection 950, in which wireless connection 970 forms the last segment. More precisely, the teachings of these embodiments may improve the latency and power consumption and thereby provide benefits such as reduced user waiting time, better responsiveness, and extended battery lifetime.

A measurement procedure may be provided for the purpose of monitoring data rate, latency and other factors on which the one or more embodiments improve. There may further be an optional network functionality for reconfiguring OTT connection 950 between host computer 910 and UE 930, in response to variations in the measurement results. The measurement procedure and/or the network functionality for reconfiguring OTT connection 950 may be implemented in software 911 and hardware 915 of host computer 910 or in software 931 and hardware 935 of UE 930, or both. In embodiments, sensors (not shown) may be deployed in or in association with communication devices through which OTT connection 950 passes; the sensors may participate in the measurement procedure by supplying values of the monitored quantities exemplified above, or supplying values of other physical quantities from which software 911, 931 may compute or estimate the monitored quantities. The reconfiguring of OTT connection 950 may include message format, retransmission settings, preferred routing etc.; the reconfiguring need not affect base station 920, and it may be unknown or imperceptible to base station 920. Such procedures and

functionalities may be known and practiced in the art. In certain embodiments, measurements may involve proprietary UE signaling facilitating host computer 910's measurements of throughput, propagation times, latency and the like. The measurements may be implemented in that software 911 and 931 causes messages to be transmitted, in particular empty or 'dummy' messages, using OTT connection 950 while it monitors propagation times, errors etc.

FIGURE 13 is a flowchart illustrating a method implemented in a communication system, in accordance with one embodiment. The communication system includes a host computer, a base station and a UE which may be those described with reference to FIGURES 11 and 12. For simplicity of the present disclosure, only drawing references to FIGURE 13 will be included in this section. In step 1010, the host computer provides user data. In substep 1011 (which may be optional) of step 1010, the host computer provides the user data by executing a host application. In step 1020, the host computer initiates a transmission carrying the user data to the UE. In step 1030 (which may be optional), the base station transmits to the UE the user data which was carried in the transmission that the host computer initiated, in accordance with the teachings of the embodiments described throughout this disclosure. In step 1040 (which may also be optional), the UE executes a client application associated with the host application executed by the host computer.

FIGURE 14 is a flowchart illustrating a method implemented in a communication system, in accordance with one embodiment. The communication system includes a host computer, a base station and a UE which may be those described with reference to FIGURES 11 and 12. For simplicity of the present disclosure, only drawing references to FIGURE 14 will be included in this section. In step 1110 of the method, the host computer provides user data. In an optional substep (not shown) the host computer provides the user data by executing a host application. In step 1120, the host computer initiates a transmission carrying the user data to the UE. The transmission may pass via the base station, in accordance with the teachings of the embodiments described throughout this disclosure. In step 1130 (which may be optional), the UE receives the user data carried in the transmission.

FIGURE 15 is a flowchart illustrating a method implemented in a communication system, in accordance with one embodiment. The communication

system includes a host computer, a base station and a UE which may be those described with reference to FIGURES 11 and 12. For simplicity of the present disclosure, only drawing references to FIGURE 15 will be included in this section. In step 1210 (which may be optional), the UE receives input data provided by the host computer. Additionally or alternatively, in step 1220, the UE provides user data. In substep 1221 (which may be optional) of step 1220, the UE provides the user data by executing a client application. In substep 1211 (which may be optional) of step 1210, the UE executes a client application which provides the user data in reaction to the received input data provided by the host computer. In providing the user data, the executed client application may further consider user input received from the user. Regardless of the specific manner in which the user data was provided, the UE initiates, in substep 1230 (which may be optional), transmission of the user data to the host computer. In step 1240 of the method, the host computer receives the user data transmitted from the UE, in accordance with the teachings of the embodiments described throughout this disclosure.

FIGURE 16 is a flowchart illustrating a method implemented in a communication system, in accordance with one embodiment. The communication system includes a host computer, a base station and a UE which may be those described with reference to FIGURES 11 and 12. For simplicity of the present disclosure, only drawing references to FIGURE 16 will be included in this section. In step 1310 (which may be optional), in accordance with the teachings of the embodiments described throughout this disclosure, the base station receives user data from the UE. In step 1320 (which may be optional), the base station initiates transmission of the received user data to the host computer. In step 1330 (which may be optional), the host computer receives the user data carried in the transmission initiated by the base station.

Any appropriate steps, methods, features, functions, or benefits disclosed herein may be performed through one or more functional units or modules of one or more virtual apparatuses. Each virtual apparatus may comprise a number of these functional units. These functional units may be implemented via processing circuitry, which may include one or more microprocessor or microcontrollers, as well as other digital hardware, which may include digital signal processors (DSPs), special-purpose digital logic, and the like. The processing circuitry may be configured to execute

program code stored in memory, which may include one or several types of memory such as read-only memory (ROM), random-access memory (RAM), cache memory, flash memory devices, optical storage devices, etc. Program code stored in memory includes program instructions for executing one or more telecommunications and/or data communications protocols as well as instructions for carrying out one or more of the techniques described herein. In some implementations, the processing circuitry may be used to cause the respective functional unit to perform corresponding functions according one or more embodiments of the present disclosure.

FIGURE 17 depicts a method 1400 in accordance with particular embodiments, the method begins at step 1402 with monitoring for a wakeup signal during a wakeup signal monitoring occasion. If the wireless device detects a wakeup signal during the wakeup signal monitoring occasion, the wireless device may monitor a downlink channel during a downlink channel monitoring occasion associated with a monitoring occasion of the detected wakeup signal. The wireless device may resume monitoring for other wakeup signals at a later time, e.g., after re-entering a sleep or DRX mode.

If, however, the wireless device does not detect a wakeup signal during the wakeup signal monitoring occasion, at step 1404, the wireless device may determine whether a condition is met. The wireless device may fail to detect a wakeup signal if no wakeup signal was sent by the network node or if the wireless device missed a wakeup signal (e.g., the network node sent a wake up signal, but the wireless device failed to receive the wakeup signal at all, or the wireless device received the wake up signal but was unable to successfully decode it). In certain embodiments, determining whether the condition is met may be based on whether conditions exist that increase the likelihood that the wireless device missed a wakeup signal that was sent by the network node. For example, a determination may be made if the wireless device is in a deep fade or other challenging RF environment. In particular, in certain embodiments, the condition may be whether a measured value, e.g., a quality metric or a decoder metric, at the wireless device is below a predetermined threshold value. In this example, the wireless device may determine the condition is met if the signal quality is below the threshold, implying that even if a wakeup signal was transmitted, the wireless device would not have been able to detect it.

At step 1406, if the condition was met, the wireless device monitors the downlink channel during a downlink channel monitoring occasion associated with a monitoring occasion of the detected wakeup signal. For example, even if the wakeup signal was not detected, the wireless device may still monitor the PDCCH as if it did. This may increase the robustness of the wireless device's wakeup signal operation to ensure it receives downlink information from the network node with less missed transmissions. Alternatively, if the condition is not met (e.g., if the wireless device is in a good RF environment), failure to detect the wakeup signal may indicate that the network node did not send any wakeup signal to the wireless device such that, in certain embodiments, the wireless device need not wakeup and monitor the PDCCH. This may conserve battery power of the wireless device under conditions where the wireless is unlikely to have missed a wakeup signal. Accordingly, a conditional wakeup signal operation may be implemented via the method shown in FIGURE 17.

FIGURE 18 illustrates a schematic block diagram of an apparatus 1500 in a wireless network (for example, the wireless network shown in FIGURE 6). The apparatus may be implemented in a wireless device or network node (e.g., wireless device 510 or network node 560 shown in FIGURE 6). Apparatus 1500 is operable to carry out the example method described with reference to FIGURE 17 and possibly any other processes or methods disclosed herein. It is also to be understood that the method of FIGURE 17 is not necessarily carried out solely by apparatus 1500. At least some operations of the method can be performed by one or more other entities.

Virtual Apparatus 1500 may comprise processing circuitry, which may include one or more microprocessor or microcontrollers, as well as other digital hardware, which may include digital signal processors (DSPs), special-purpose digital logic, and the like. The processing circuitry may be configured to execute program code stored in memory, which may include one or several types of memory such as read-only memory (ROM), random-access memory, cache memory, flash memory devices, optical storage devices, etc. Program code stored in memory includes program instructions for executing one or more telecommunications and/or data communications protocols as well as instructions for carrying out one or more of the techniques described herein, in several embodiments. In some implementations, the processing circuitry may be used to cause monitoring unit 1502, the condition unit

1504, and any other suitable units of apparatus 1500 to perform corresponding functions according one or more embodiments of the present disclosure.

As illustrated in FIGURE 18, apparatus 1500 includes monitoring unit 1502 and condition unit 1504. Monitoring unit 1502 is configured monitor for a wakeup signal during a wakeup signal monitoring occasion. If a wakeup signal is detected during the wakeup signal monitoring occasion, the downlink channel may be monitored during a downlink channel monitoring occasion associated with a monitoring occasion of the detected wakeup signal. Further monitoring for other wakeup signals may be continued at a later time, e.g., after re-entering a sleep or DRX mode. If, however, a wakeup signal is not detected during the wakeup signal monitoring occasion, condition unit 1504 may determine whether a condition is met. For example, condition unit 1504 may determine whether conditions exist that increase the likelihood that the wakeup signal was missed (e.g., the wireless device was unable to detect or decode a wakeup signal sent by the network node). In particular, in certain embodiments, the condition may be whether a measured value, e.g., a quality metric or a decoder metric, at the wireless device is below a predetermined threshold value. In this example, condition unit 1504 may determine the condition is met if the signal quality is below the threshold, implying that even if a wakeup signal was transmitted, monitoring unit 1502 would not have been able to detect it.

Additionally, monitoring unit 1502 may also monitor the downlink channel during a downlink channel monitoring occasion associated with a monitoring occasion of the detected wakeup signal. For example, even if the wakeup signal was not detected, PDCCH may be monitored as if the wakeup signal was detected. This may increase the robustness of the wakeup signal operation to ensure that downlink information is received with less missed transmissions. Accordingly, a conditional wakeup signal operation may be implemented using virtual apparatus 1500.

The term unit may have conventional meaning in the field of electronics, electrical devices and/or electronic devices and may include, for example, electrical and/or electronic circuitry, devices, modules, processors, memories, logic solid state and/or discrete devices, computer programs or instructions for carrying out respective tasks, procedures, computations, outputs, and/or displaying functions, and so on, as such as those that are described herein.

In some embodiments a computer program, computer program product or computer readable storage medium comprises instructions which when executed on a computer perform any of the embodiments disclosed herein. In further examples the instructions are carried on a signal or carrier, and the instructions are executable on a computer wherein when executed perform any of the embodiments disclosed herein.

FIGURE 19 illustrates another example method 1600 by a wireless device 510 according to certain embodiments. The method begins at step 1602 when the wireless device 510 monitors for a first WUS during a first WUS monitoring occasion. In step 1604, in response to the wireless device 510 detecting the first WUS during the first WUS monitoring occasion, wireless device 510 monitors a downlink control channel during a downlink control channel monitoring occasion associated with the detected first WUS and abstains from monitoring for a second WUS in a second WUS monitoring occasion based on a condition.

In a particular embodiment, the condition includes the second WUS monitoring occasion overlapping an active time. In a further particular embodiment, the active time comprises a time slot during which the wireless device is monitoring the downlink control channel.

In a particular embodiment, the abstaining from monitoring the second WUS based on the condition is in response to receiving an indication from a network node 560 to not monitor for wakeup signals (WUSs) during a predetermined period of time.

In a particular embodiment, in response to detecting the first WUS, wireless device 510 detects a downlink signal while monitoring the downlink control channel, after detecting the downlink signal sets an inactivity timer associated with the predetermined period of time, abstains from monitoring for the second WUS while the inactivity timer is running during the predetermined period of time, and resets the inactivity timer in response to detecting a subsequent downlink signal in the downlink control channel before the inactivity timer expires.

In a particular embodiment, in response to the wireless device 510 detecting the first WUS during the first WUS monitoring occasion, wireless device 510 transmits, to a network node 560, an acknowledgement signal associated with the detected first WUS.

In a particular embodiment, wireless device 510 determines, based on the detected first WUS, to send the acknowledgement signal to the network node 560.

In a particular embodiment, monitoring the downlink control channel during the downlink control channel monitoring occasion associated with the detected first WUS comprises monitoring the downlink control channel during an ON duration associated with the first WUS monitoring occasion.

In a particular embodiment, while abstaining from monitoring for the second WUS in the second WUS monitoring occasion, wireless device 510 monitors the downlink control channel during at least one additional downlink control channel monitoring occasion associated with the second WUS monitoring occasion.

FIGURE 20 illustrates another apparatus 1700 in a wireless network (for example, the wireless network shown in FIGURE 6). The apparatus may be implemented in a wireless device or network node (e.g., wireless device 510 or network node 560 shown in FIGURE 6). Apparatus 1700 is operable to carry out the example method described with reference to FIGURE 19 and possibly any other processes or methods disclosed herein. It is also to be understood that the method of FIGURE 19 is not necessarily carried out solely by apparatus 1700. At least some operations of the method can be performed by one or more other entities.

Virtual Apparatus 1700 may comprise processing circuitry, which may include one or more microprocessor or microcontrollers, as well as other digital hardware, which may include digital signal processors (DSPs), special-purpose digital logic, and the like. The processing circuitry may be configured to execute program code stored in memory, which may include one or several types of memory such as read-only memory (ROM), random-access memory, cache memory, flash memory devices, optical storage devices, etc. Program code stored in memory includes program instructions for executing one or more telecommunications and/or data communications protocols as well as instructions for carrying out one or more of the techniques described herein, in several embodiments. In some implementations, the processing circuitry may be used to cause first monitoring unit 1702, second monitoring unit 1704, abstaining unit 1706, and any other suitable units of apparatus 1700 to perform corresponding functions according one or more embodiments of the present disclosure.

As illustrated in FIGURE 20, apparatus 1700 includes first monitoring unit 1702, second monitoring unit 1704, abstaining unit 1706. First monitoring unit 1702 is configured to monitor for a first WUS during a first WUS monitoring occasion. In response to the wireless device 510 detecting the first WUS during the first WUS monitoring occasion, second monitoring unit 1704 monitors a downlink control channel during a downlink control channel monitoring occasion associated with the detected first WUS. Abstaining unit 1706 abstains from monitoring for a second WUS in a second WUS monitoring occasion based on a condition.

The term unit may have conventional meaning in the field of electronics, electrical devices and/or electronic devices and may include, for example, electrical and/or electronic circuitry, devices, modules, processors, memories, logic solid state and/or discrete devices, computer programs or instructions for carrying out respective tasks, procedures, computations, outputs, and/or displaying functions, and so on, as such as those that are described herein.

In some embodiments a computer program, computer program product or computer readable storage medium comprises instructions which when executed on a computer perform any of the embodiments disclosed herein. In further examples the instructions are carried on a signal or carrier, and the instructions are executable on a computer wherein when executed perform any of the embodiments disclosed herein.

FIGURE 21 illustrates still another example method 1800 by a wireless device configured for DRX, according to certain embodiments. The method begins at step 1802 when wireless device 510 monitors for a first WUS during a first WUS monitoring occasion. Then at step 1804, in response to not detecting the first WUS during the first WUS monitoring occasion, wireless device 510 determines whether a condition is met and, based on determining that the condition was met, monitors the downlink control channel during a downlink control channel monitoring occasion associated with the first WUS monitoring occasion.

In a particular embodiment, the at least one condition is met when a metric is above a threshold value. In a further particular embodiment, the metric comprises a quality metric and the condition is met when the quality metric is above a predetermined threshold. The quality metric is based on one or more of a RSRP, a RSRQ, a CSI condition, and a synchronization condition.

In a particular embodiment, wireless device 510 receives, from the network node 560, information from which the wireless device obtains the condition that the wireless device is to use in determining whether the condition is met.

FIGURE 22 illustrates still another apparatus 1900 in a wireless network (for example, the wireless network shown in FIGURE 6). The apparatus may be implemented in a wireless device or network node (e.g., wireless device 510 or network node 560 shown in FIGURE 6). Apparatus 1900 is operable to carry out the example method described with reference to FIGURE 21 and possibly any other processes or methods disclosed herein. It is also to be understood that the method of FIGURE 21 is not necessarily carried out solely by apparatus 1900. At least some operations of the method can be performed by one or more other entities.

Virtual Apparatus 1900 may comprise processing circuitry, which may include one or more microprocessor or microcontrollers, as well as other digital hardware, which may include digital signal processors (DSPs), special-purpose digital logic, and the like. The processing circuitry may be configured to execute program code stored in memory, which may include one or several types of memory such as read-only memory (ROM), random-access memory, cache memory, flash memory devices, optical storage devices, etc. Program code stored in memory includes program instructions for executing one or more telecommunications and/or data communications protocols as well as instructions for carrying out one or more of the techniques described herein, in several embodiments. In some implementations, the processing circuitry may be used to cause first monitoring unit 1902, determining unit 1904, second monitoring unit 1906, and any other suitable units of apparatus 1900 to perform corresponding functions according one or more embodiments of the present disclosure.

As illustrated in FIGURE 22, apparatus 1900 includes first monitoring unit 1902, determining unit 1904, second monitoring unit 1906. First monitoring unit 1902 is configured to monitor for a first WUS during a first WUS monitoring occasion. In response to not detecting the first WUS during the first WUS monitoring occasion, determining unit 1904 determines whether a condition is met. Based on the condition being met, second monitoring unit 1906 monitors the downlink control channel during

a downlink control channel monitoring occasion associated with the first WUS monitoring occasion.

The term unit may have conventional meaning in the field of electronics, electrical devices and/or electronic devices and may include, for example, electrical and/or electronic circuitry, devices, modules, processors, memories, logic solid state and/or discrete devices, computer programs or instructions for carrying out respective tasks, procedures, computations, outputs, and/or displaying functions, and so on, as such as those that are described herein.

In some embodiments a computer program, computer program product or computer readable storage medium comprises instructions which when executed on a computer perform any of the embodiments disclosed herein. In further examples the instructions are carried on a signal or carrier, and the instructions are executable on a computer wherein when executed perform any of the embodiments disclosed herein.

FIGURE 23 illustrates yet another example method 2000 by a wireless device 510, according to certain embodiments. The method begins at step 2002 when wireless device 510 receives an indication from a network node 560 to monitor for a WUS in a N number of WUS monitoring occasions. After the Nth WUS monitoring occasion, wireless device 510 monitors a downlink control channel during one or more downlink control channel monitoring occasions without waiting for a WUS to prompt the monitoring of the downlink control channel.

In a particular embodiment, wireless device 510 detects a WUS in one of the N WUS monitoring occasions and, in response to the detection, monitors the downlink control channel during one or more downlink control channel monitoring occasions associated with the WUS monitoring occasion.

In a particular embodiment, the indication from the network node 560 further indicates to the wireless device 510 to monitor M number of the N number of WUS monitoring occasions, wherein M<N.

FIGURE 24 illustrates still another apparatus 2100 in a wireless network (for example, the wireless network shown in FIGURE 6). The apparatus may be implemented in a wireless device or network node (e.g., wireless device 510 or network node 560 shown in FIGURE 6). Apparatus 2100 is operable to carry out the example method described with reference to FIGURE 23 and possibly any other

processes or methods disclosed herein. It is also to be understood that the method of FIGURE 23 is not necessarily carried out solely by apparatus 2100. At least some operations of the method can be performed by one or more other entities.

Virtual Apparatus 2100 may comprise processing circuitry, which may include one or more microprocessor or microcontrollers, as well as other digital hardware, which may include digital signal processors (DSPs), special-purpose digital logic, and the like. The processing circuitry may be configured to execute program code stored in memory, which may include one or several types of memory such as read-only memory (ROM), random-access memory, cache memory, flash memory devices, optical storage devices, etc. Program code stored in memory includes program instructions for executing one or more telecommunications and/or data communications protocols as well as instructions for carrying out one or more of the techniques described herein, in several embodiments. In some implementations, the processing circuitry may be used to cause receiving unit 2102, monitoring unit 2104, and any other suitable units of apparatus 2100 to perform corresponding functions according one or more embodiments of the present disclosure.

As illustrated in FIGURE 24, apparatus 2100 includes receiving unit 2102 and monitoring unit 2104. Receiving unit 2102 is configured to receive an indication from a network node 560 to monitor for a WUS in a N number of WUS monitoring occasions. After the Nth WUS monitoring occasion, monitoring unit 2104 monitors a downlink control channel during one or more downlink control channel monitoring occasions without waiting for a WUS to prompt the monitoring of the downlink control channel.

The term unit may have conventional meaning in the field of electronics, electrical devices and/or electronic devices and may include, for example, electrical and/or electronic circuitry, devices, modules, processors, memories, logic solid state and/or discrete devices, computer programs or instructions for carrying out respective tasks, procedures, computations, outputs, and/or displaying functions, and so on, as such as those that are described herein.

In some embodiments a computer program, computer program product or computer readable storage medium comprises instructions which when executed on a computer perform any of the embodiments disclosed herein. In further examples the

instructions are carried on a signal or carrier, and the instructions are executable on a computer wherein when executed perform any of the embodiments disclosed herein.

FIGURE 25 illustrates an example method 2200 by a network node 560, according to certain embodiments. The method begins at step 2202, when network node 560 transmits a first WUS to a wireless device configured with DRX, during a first WUS monitoring occasion. At step 2204, network node 560 transmits a downlink signal on a downlink control channel during a downlink control channel monitoring occasion associated with the first WUS. At step 2206, network node 560 abstains from transmitting a second WUS to the wireless device until after a predetermined period of time.

In a particular embodiment, the predetermined period of time is based on a preconfigured time period during which the wireless device abstains from monitoring for the second WUS.

In a particular embodiment, the network node 560 sends a configuration to the wireless device 510. The configuration comprises instructions for the wireless device, instructing the wireless device to, in response to detecting a downlink signal while monitoring the downlink control channel, set an inactivity timer after detecting the downlink signal and abstain from monitoring for other WUS while the inactivity timer is running and reset the inactivity timer in response to detecting a subsequent downlink signal in the downlink control channel before the inactivity timer expires.

FIGURE 26 illustrates still another apparatus 2300 in a wireless network (for example, the wireless network shown in FIGURE 6). The apparatus may be implemented in a wireless device or network node (e.g., wireless device 510 or network node 560 shown in FIGURE 6). Apparatus 2300 is operable to carry out the example method described with reference to FIGURE 25 and possibly any other processes or methods disclosed herein. It is also to be understood that the method of FIGURE 25 is not necessarily carried out solely by apparatus 2300. At least some operations of the method can be performed by one or more other entities.

Virtual Apparatus 2300 may comprise processing circuitry, which may include one or more microprocessor or microcontrollers, as well as other digital hardware, which may include digital signal processors (DSPs), special-purpose digital logic, and the like. The processing circuitry may be configured to execute program code stored

in memory, which may include one or several types of memory such as read-only memory (ROM), random-access memory, cache memory, flash memory devices, optical storage devices, etc. Program code stored in memory includes program instructions for executing one or more telecommunications and/or data communications protocols as well as instructions for carrying out one or more of the techniques described herein, in several embodiments. In some implementations, the processing circuitry may be used to cause first transmitting unit 2302, second transmitting unit 2304, abstaining unit 2306, and any other suitable units of apparatus 2300 to perform corresponding functions according one or more embodiments of the present disclosure.

As illustrated in FIGURE 26, apparatus 2300 includes first transmitting unit 2302, second transmitting unit 2304, abstaining unit 2306. First transmitting unit 2302 is configured to transmit a first WUS to a wireless device configured with DRX, during a first WUS monitoring occasion. Second transmitting unit 2304 is configured to transmit a downlink signal on a downlink control channel during a downlink control channel monitoring occasion associated with the first WUS. Abstaining unit 2306 is configured to abstain from transmitting a second WUS to the wireless device until after a predetermined period of time.

The term unit may have conventional meaning in the field of electronics, electrical devices and/or electronic devices and may include, for example, electrical and/or electronic circuitry, devices, modules, processors, memories, logic solid state and/or discrete devices, computer programs or instructions for carrying out respective tasks, procedures, computations, outputs, and/or displaying functions, and so on, as such as those that are described herein.

In some embodiments a computer program, computer program product or computer readable storage medium comprises instructions which when executed on a computer perform any of the embodiments disclosed herein. In further examples the instructions are carried on a signal or carrier, and the instructions are executable on a computer wherein when executed perform any of the embodiments disclosed herein.

FIGURE 27 illustrates another example method 2400 by a network node 560, according to certain embodiments. The method begins at step 2402 when the network node 560 transmits, to a wireless device 510 configured for DRX, information

indicating that, in response to the wireless device failing to detect a first WUS during a first WUS monitoring occasion and at least one condition being met, the wireless device 510 is to monitor a downlink control channel during a downlink control channel monitoring occasion associated with the first WUS monitoring occasion.

In a particular embodiment, the at least one condition is met when a metric is above a threshold value. In a further particular embodiment, the metric comprises a quality metric and the condition is met when the quality metric is above a predetermined threshold, wherein the quality metric is based on one or more of a RSRP, a RSRQ, a CSI condition, and a synchronization condition.

In a particular embodiment, network node 560 transmits information comprising or indicating the condition to the wireless device.

FIGURE 28 illustrates still another apparatus 2500 in a wireless network (for example, the wireless network shown in FIGURE 6). The apparatus may be implemented in a wireless device or network node (e.g., wireless device 510 or network node 560 shown in FIGURE 6). Apparatus 2500 is operable to carry out the example method described with reference to FIGURE 27 and possibly any other processes or methods disclosed herein. It is also to be understood that the method of FIGURE 27 is not necessarily carried out solely by apparatus 2500. At least some operations of the method can be performed by one or more other entities.

Virtual Apparatus 2500 may comprise processing circuitry, which may include one or more microprocessor or microcontrollers, as well as other digital hardware, which may include digital signal processors (DSPs), special-purpose digital logic, and the like. The processing circuitry may be configured to execute program code stored in memory, which may include one or several types of memory such as read-only memory (ROM), random-access memory, cache memory, flash memory devices, optical storage devices, etc. Program code stored in memory includes program instructions for executing one or more telecommunications and/or data communications protocols as well as instructions for carrying out one or more of the techniques described herein, in several embodiments. In some implementations, the processing circuitry may be used to cause transmitting unit 2502 and any other suitable units of apparatus 2500 to perform corresponding functions according one or more embodiments of the present disclosure.

As illustrated in FIGURE 28, apparatus 2500 includes transmitting unit 2502, which is configured to transmit, to a wireless device 510 configured for DRX, information indicating that, in response to the wireless device failing to detect a first WUS during a first WUS monitoring occasion and at least one condition being met, the wireless device 510 is to monitor a downlink control channel during a downlink control channel monitoring occasion associated with the first WUS monitoring occasion.

The term unit may have conventional meaning in the field of electronics, electrical devices and/or electronic devices and may include, for example, electrical and/or electronic circuitry, devices, modules, processors, memories, logic solid state and/or discrete devices, computer programs or instructions for carrying out respective tasks, procedures, computations, outputs, and/or displaying functions, and so on, as such as those that are described herein.

In some embodiments a computer program, computer program product or computer readable storage medium comprises instructions which when executed on a computer perform any of the embodiments disclosed herein. In further examples the instructions are carried on a signal or carrier, and the instructions are executable on a computer wherein when executed perform any of the embodiments disclosed herein.

FIGURE 29 illustrates yet another example method 2600 by a network node 560, according to certain embodiments. The method begins at step 2602 when network node 560 transmits an indication to a wireless device 510 to monitor for a WUS in a N number of WUS monitoring occasions. The indication implicitly or explicitly indicates that after the Nth WUS monitoring occasion, the wireless device 510 is to monitor a downlink control channel during one or more downlink control channel monitoring occasions without waiting for a WUS to prompt the monitoring of the downlink control channel.

In a particular embodiment, network node 560 transmits the WUS in one of the N WUS monitoring occasions and transmits the downlink signal during a downlink control channel monitoring occasion associated with the WUS monitoring occasion.

In a particular embodiment, the indication further indicates to the wireless device 510 to monitor M number of the N number of WUS monitoring occasions, wherein M<N.

FIGURE 30 illustrates still another apparatus 2700 in a wireless network (for example, the wireless network shown in FIGURE 6). The apparatus may be implemented in a wireless device or network node (e.g., wireless device 510 or network node 560 shown in FIGURE 6). Apparatus 2700 is operable to carry out the example method described with reference to FIGURE 29 and possibly any other processes or methods disclosed herein. It is also to be understood that the method of FIGURE 29 is not necessarily carried out solely by apparatus 2700. At least some operations of the method can be performed by one or more other entities.

Virtual Apparatus 2700 may comprise processing circuitry, which may include one or more microprocessor or microcontrollers, as well as other digital hardware, which may include digital signal processors (DSPs), special-purpose digital logic, and the like. The processing circuitry may be configured to execute program code stored in memory, which may include one or several types of memory such as read-only memory (ROM), random-access memory, cache memory, flash memory devices, optical storage devices, etc. Program code stored in memory includes program instructions for executing one or more telecommunications and/or data communications protocols as well as instructions for carrying out one or more of the techniques described herein, in several embodiments. In some implementations, the processing circuitry may be used to cause transmitting unit 2702 and any other suitable units of apparatus 2700 to perform corresponding functions according one or more embodiments of the present disclosure.

As illustrated in FIGURE 30, apparatus 2700 includes transmitting unit 2702, which is configured to transmit an indication to a wireless device 510 to monitor for a WUS in a N number of WUS monitoring occasions. The indication implicitly or explicitly indicates that after the Nth WUS monitoring occasion, the wireless device 510 is to monitor a downlink control channel during one or more downlink control channel monitoring occasions without waiting for a WUS to prompt the monitoring of the downlink control channel.

The term unit may have conventional meaning in the field of electronics, electrical devices and/or electronic devices and may include, for example, electrical and/or electronic circuitry, devices, modules, processors, memories, logic solid state and/or discrete devices, computer programs or instructions for carrying out respective

tasks, procedures, computations, outputs, and/or displaying functions, and so on, as such as those that are described herein.

In some embodiments a computer program, computer program product or computer readable storage medium comprises instructions which when executed on a computer perform any of the embodiments disclosed herein. In further examples the instructions are carried on a signal or carrier, and the instructions are executable on a computer wherein when executed perform any of the embodiments disclosed herein.

FIGURE 31 illustrates an example method 2800 by a network node 560, according to certain embodiments. The method begins at step 2802, when network node 560 transmits a first WUS to a wireless device 510 configured with DRX during a first WUS monitoring occasion. At step 2804, the network node 560 transmits a downlink signal on a downlink control channel during a downlink control channel monitoring occasion associated with the first WUS monitoring occasion. At step 2806, the network node abstains from transmitting a second WUS to the wireless device until after a predetermined period of time.

In a particular embodiment, abstaining from transmitting the second WUS to the wireless device until after the predetermined period of time comprises abstaining from transmitting the second WUS in a second WUS monitoring occasion based on a condition.

In a particular embodiment, the condition comprises the second WUS monitoring occasion overlapping an active time.

In a particular embodiment, the active time comprises a time slot during which the wireless device is monitoring the downlink control channel.

In a particular embodiment, the predetermined period of time is based on a preconfigured time period during which the wireless device abstains from monitoring for the second WUS.

In a particular embodiment, the network node 560 transmits, to the wireless device 510, an indication to not monitor for the second WUS.

In a particular embodiment, the network node 560 sends a configuration to the wireless device. The configuration comprises instructions for the wireless device, instructing the wireless device to, in response to detecting the downlink signal while monitoring the downlink control channel, set an inactivity timer after detecting the

downlink signal, abstain from monitoring for the second WUS while the inactivity timer is running, reset the inactivity timer in response to detecting a subsequent downlink signal in the downlink control channel before the inactivity timer expires.

In a particular embodiment, in response to the wireless device detecting the first WUS during the first WUS monitoring occasion, the network node receives an acknowledgement signal associated with the detected first WUS from the wireless device.

In a particular embodiment, the network node configures the wireless device to monitor the downlink control channel during an ON duration associated with the first WUS monitoring occasion.

FIGURE 32 illustrates still another apparatus 2900 in a wireless network (for example, the wireless network shown in FIGURE 6). The apparatus may be implemented in a wireless device or network node (e.g., wireless device 510 or network node 560 shown in FIGURE 6). Apparatus 2900 is operable to carry out the example method described with reference to FIGURE 31 and possibly any other processes or methods disclosed herein. It is also to be understood that the method of FIGURE 32 is not necessarily carried out solely by apparatus 2900. At least some operations of the method can be performed by one or more other entities.

Virtual Apparatus 2900 may comprise processing circuitry, which may include one or more microprocessor or microcontrollers, as well as other digital hardware, which may include digital signal processors (DSPs), special-purpose digital logic, and the like. The processing circuitry may be configured to execute program code stored in memory, which may include one or several types of memory such as read-only memory (ROM), random-access memory, cache memory, flash memory devices, optical storage devices, etc. Program code stored in memory includes program instructions for executing one or more telecommunications and/or data communications protocols as well as instructions for carrying out one or more of the techniques described herein, in several embodiments. In some implementations, the processing circuitry may be used to cause first transmitting unit 2902, second transmitting unit 2904, abstaining unit 2906, and any other suitable units of apparatus 2900 to perform corresponding functions according one or more embodiments of the present disclosure.

As illustrated in FIGURE 32, apparatus 2900 includes first transmitting unit 2902, second transmitting unit 2904, abstaining unit 2906. First transmitting unit 2902 is configured to transmit a first WUS to a wireless device 510 configured with DRX during a first WUS monitoring occasion. Second transmitting unit 2904 is configured to transmit a downlink signal on a downlink control channel during a downlink control channel monitoring occasion associated with the first WUS monitoring occasion. Abstaining unit 2306 is configured to abstain from transmitting a second WUS to the wireless device until after a predetermined period of time.

The term unit may have conventional meaning in the field of electronics, electrical devices and/or electronic devices and may include, for example, electrical and/or electronic circuitry, devices, modules, processors, memories, logic solid state and/or discrete devices, computer programs or instructions for carrying out respective tasks, procedures, computations, outputs, and/or displaying functions, and so on, as such as those that are described herein.

In some embodiments a computer program, computer program product or computer readable storage medium comprises instructions which when executed on a computer perform any of the embodiments disclosed herein. In further examples the instructions are carried on a signal or carrier, and the instructions are executable on a computer wherein when executed perform any of the embodiments disclosed herein.

EXAMPLE EMBODIMENTS

Embodiment 1. A method performed by a wireless device, the method comprising: monitoring for a WUS during a WUS monitoring occasion; if the wireless device detects a WUS during the WUS monitoring occasion: monitoring a downlink channel during a downlink channel monitoring occasion associated with the detected WUS; abstaining from monitoring for other WUSs while monitoring the downlink channel; and resuming monitoring for other WUSs at subsequent WUS monitoring occasions;

if the wireless device does not detect a WUS during the WUS monitoring occasion, continuing to monitor for other WUSs at subsequent WUS monitoring occasions.

Embodiment 2. The method of embodiment 1, further comprising abstaining from

monitoring for other WUSs based on an indication from a network node to not monitor for WUSs during specified times.

Embodiment 3. The method of any of the previous embodiments, wherein if the wireless device detects a WUS, the method further comprises: detecting a downlink signal while monitoring the downlink channel; setting an inactivity timer after detecting the downlink signal; abstaining from monitoring for other WUS while the inactivity timer is running.

Embodiment 4. The method of any of the previous embodiments, further comprising: resetting the inactivity timer in response to detecting a subsequent downlink signal in the downlink channel before the inactivity timer expired.

Embodiment 5. A method performed by a wireless device, the method comprising:

monitoring for a WUS during a WUS monitoring occasion;

if the wireless device does not detect a WUS during the WUS monitoring occasion: determining whether a condition is met; based on determining that the condition was met, monitoring the downlink channel during a downlink channel monitoring occasion associated with a monitoring occasion of the detected WUS.

Embodiment 6. The method of embodiment 5, wherein the condition is whether a quality metric is below a predetermined threshold, wherein the quality metric is based on one or more of a RSRP, a RSRQ, a CSI condition, a synchronization condition, etc.

Embodiment 7. The method of embodiment 5, wherein the condition is whether a decoding metric is below a predetermined threshold, wherein the decoding metric is one of a S-metric, a mean extrinsic information magnitude, a soft value quality metric, a message reliability, a path metric, etc.

Embodiment 8. The method of any of embodiments 5-7, further comprising: receiving information from the network node from which the wireless device obtains the condition (e.g., quality metric or decoding metric) that the wireless device is to use in determining whether the condition is met.

Embodiment 9. The method of embodiment 5, further comprising, in response to detecting a WUS during the WUS monitoring occasion, monitoring a downlink channel during a downlink channel monitoring occasion associated with the detected WUS.

Embodiment 10. The method of embodiment 9, further comprising resuming

monitoring for other WUSs at subsequent WUS monitoring occasions.

Embodiment 11. The method of any of embodiments 9-10, further comprising: detecting a downlink signal on the downlink channel during the downlink channel monitoring occasion; setting an inactivity timer after detecting the downlink signal; abstaining from monitoring for other WUS while the inactivity timer is running.

Embodiment 12. A method performed by a wireless device, the method comprising:

monitoring for a WUS during a WUS monitoring occasion;

if the wireless device detects a WUS during the WUS monitoring occasion: transmitting an acknowledgement signal to a network node associated with the detected WUS; and monitoring a downlink channel during a downlink channel monitoring occasion associated with the detected WUS;

if the wireless device does not detect a WUS during the WUS monitoring occasion, continuing to monitor for other WUSs at subsequent WUS monitoring occasions.

Embodiment 13. The method of embodiment 9, further comprising: determining, based on the detected WUS, to send the acknowledgement signal to the network node.

Embodiment 14. The method of embodiment 9, further comprising: receiving a configuration from a network, wherein the configuration specifies the wireless device to send an acknowledgement signal in response to detecting the WUS after a predetermined period of time or number of slots/subslots after detection.

Embodiment 15. A method performed by a wireless device, the method comprising:

receiving an indication from a network node to monitor for a WUS in the next N number of WUS monitoring occasions;

after the Nth WUS monitoring occasion, monitoring a downlink channel during one or more downlink channel monitoring occasions (e.g., without waiting for a WUS to prompt the monitoring of the downlink channel).

Embodiment 16. The method of embodiment 15, further comprising: detecting a WUS in one of the N WUS monitoring occasions; in response to the detection, monitoring the downlink channel one or more downlink channel monitoring occasions associated with the detected WUS.

Embodiment 17. The method of any of embodiments 15-16, wherein the indication from the network node further indicates to monitor M number of the next N number

of WUS monitoring occasions, wherein M<N.

Embodiment 18. The method of any of the previous embodiments, further comprising: providing user data; and forwarding the user data to a host computer via the transmission to the base station.

Embodiment 19. A method performed by a network node, the method comprising:

transmitting for a WUS to a wireless device during a WUS monitoring occasion;

transmitting a downlink signal on a downlink channel during a downlink channel monitoring occasion associated with the WUS; and

abstaining from transmitting another WUS to the wireless device until after a predetermined period of time.

Embodiment 20. The method of embodiment 19, wherein the predetermined period of time is based on a preconfigured time period during which the wireless device abstains from monitoring for other WUSs.

Embodiment 21. The method of any of the previous embodiments, sending a configuration to the wireless device, wherein the configuration comprises instructions for the wireless device, in response to detecting a downlink signal while monitoring the downlink channel, to: set an inactivity timer after detecting the downlink signal; and abstain from monitoring for other WUS while the inactivity timer is running.

Embodiment 22. A method performed by a network node, the method comprising:

transmitting, to a wireless device, information indicating one or more conditions during which, in the event that the wireless device fails to detect a WUS during a WUS monitoring occasion, the wireless device is to monitor a downlink channel (e.g., without waiting to receive the WUS).

Embodiment 23. The method of embodiment 22, wherein the one or more conditions comprise a threshold value.

Embodiment 24. The method of any of embodiments 22-23, wherein the one or more conditions comprise a quality metric, wherein the quality metric is based on one or more of a RSRP, a RSRQ, a CSI condition, a synchronization condition, etc.

Embodiment 25. The method of any of embodiments 22-24, wherein the one or more conditions comprise a decoding metric, wherein the decoding metric is one of a S-metric, a mean extrinsic information magnitude, a soft value quality metric, a message

reliability, a path metric, etc.

Embodiment 26. The method of any of embodiments 22-25, further comprising: determining the information indicating the one or more conditions.

Embodiment 27. The method of embodiment 26, wherein the information indicating the one or more conditions is determined based on a likelihood that the wireless device will fail to detect the WUS when the one or more conditions are met.

Embodiment 28. The method of any of embodiments 22-27, further comprising: transmitting a WUS to a wireless device during a WUS monitoring occasion; and transmitting a downlink signal on a downlink channel during a downlink channel monitoring occasion associated with the WUS.

Embodiment 29. A method performed by a network node, the method comprising:

transmitting for a WUS to a wireless device during a WUS monitoring occasion; and

receiving an acknowledgement signal to a network node associated with the detected WUS; and

in response to the acknowledgment signal, transmitting a downlink signal on a downlink channel during a downlink channel monitoring occasion associated with the WUS.

Embodiment 30. The method of embodiment 29, further comprising: transmitting a message instructing the wireless device to send acknowledgement signals in response to detecting WUSs.

Embodiment 31. The method of embodiment 30, further comprising: determining whether to transmit the message instructing the wireless device to send the acknowledgement signals based on a range of the cell served by the network node or a quality metric value measured at the wireless device.

Embodiment 32. The method of any of embodiments 29-31, further comprising: reconfiguring WUS resources for the wireless device in response to receiving an acknowledgement signal from the wireless device.

Embodiment 33. The method of any of embodiments 29-32, further comprising: abstaining from sending a downlink signal during a downlink channel monitoring occasion if no acknowledgement signal is sent that corresponds to the downlink channel monitoring occasion.

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Embodiment 34. A method performed by a network node, the method comprising:

transmitting an indication to a wireless device to monitor for a WUS in the next N number of WUS monitoring occasions;

wherein the indication implicitly or explicitly indicates that after the Nth WUS monitoring occasion, the wireless device is to monitor a downlink channel during one or more downlink channel monitoring occasions (e.g., without waiting for a WUS to prompt the monitoring of the downlink channel).

Embodiment 35. The method of embodiment 34, further comprising: transmitting a WUS in one of the N WUS monitoring occasions; and transmitting a downlink channel on a downlink channel monitoring occasion associated with the WUS.

Embodiment 36. The method of any of embodiments 34-35, wherein the indication further indicates to the wireless device to monitor M number of the next N number of WUS monitoring occasions, wherein M<N.

Embodiment 37. The method of any of the previous embodiments, further comprising: obtaining user data; and forwarding the user data to a host computer or a wireless device.

Embodiment 38. A wireless device, the wireless device comprising:

processing circuitry configured to perform any of the steps of any of Embodiments 1 to 18; and

power supply circuitry configured to supply power to the wireless device.

Embodiment 39. A base station, the base station comprising:

processing circuitry configured to perform any of the steps of any of Embodiments 19 to 37;

power supply circuitry configured to supply power to the base station.

Embodiment 40. A user equipment (UE), the UE comprising:

an antenna configured to send and receive wireless signals;

radio front-end circuitry connected to the antenna and to processing circuitry, and configured to condition signals communicated between the antenna and the processing circuitry;

the processing circuitry being configured to perform any of the steps of any of Embodiments 1 to 18;

an input interface connected to the processing circuitry and configured to allow

input of information into the UE to be processed by the processing circuitry;

an output interface connected to the processing circuitry and configured to output information from the UE that has been processed by the processing circuitry; and

a battery connected to the processing circuitry and configured to supply power to the UE.

Embodiment 41. A computer program, the computer program comprising instructions which when executed on a computer perform any of the steps of any of Embodiments 1 to 18.

Embodiment 42. A computer program product comprising a computer program, the computer program comprising instructions which when executed on a computer perform any of the steps of any of Embodiments 1 to 18.

Embodiment 43. A non-transitory computer-readable storage medium or carrier comprising a computer program, the computer program comprising instructions which when executed on a computer perform any of the steps of any of Embodiments 1 to 18.

Embodiment 44. A computer program, the computer program comprising instructions which when executed on a computer perform any of the steps of any of Embodiments 19 to 37.

Embodiment 45. A computer program product comprising a computer program, the computer program comprising instructions which when executed on a computer perform any of the steps of any of Embodiments 19 to 37.

Embodiment 46. A non-transitory computer-readable storage medium or carrier comprising a computer program, the computer program comprising instructions which when executed on a computer perform any of the steps of any of Embodiments 19 to 37.

Embodiment 47. A communication system including a host computer comprising:

processing circuitry configured to provide user data; and

a communication interface configured to forward the user data to a cellular network for transmission to a user equipment (UE),

wherein the cellular network comprises a base station having a radio interface and processing circuitry, the base station's processing circuitry configured to perform

any of the steps of any of Embodiments 19 to 37.

Embodiment 48. The communication system of the pervious embodiment further including the base station.

Embodiment 49. The communication system of the previous 2 embodiments, further including the UE, wherein the UE is configured to communicate with the base station.

Embodiment 50. The communication system of the previous 3 embodiments, wherein: the processing circuitry of the host computer is configured to execute a host application, thereby providing the user data; and the UE comprises processing circuitry configured to execute a client application associated with the host application.

Embodiment 51. A method implemented in a communication system including a host computer, a base station and a user equipment (UE), the method comprising:

at the host computer, providing user data; and

at the host computer, initiating a transmission carrying the user data to the UE via a cellular network comprising the base station, wherein the base station performs any of the steps of any of Embodiments 19 to 37.

Embodiment 52. The method of the previous embodiment, further comprising, at the base station, transmitting the user data.

Embodiment 53. The method of the previous 2 embodiments, wherein the user data is provided at the host computer by executing a host application, the method further comprising, at the UE, executing a client application associated with the host application.

Embodiment 54. A user equipment (UE) configured to communicate with a base station, the UE comprising a radio interface and processing circuitry configured to performs the of the previous 3 embodiments.

Embodiment 55. A communication system including a host computer comprising:

processing circuitry configured to provide user data; and

a communication interface configured to forward user data to a cellular network for transmission to a user equipment (UE),

wherein the UE comprises a radio interface and processing circuitry, the UE's components configured to perform any of the steps of any of Embodiments 1 to 18.

Embodiment 56. The communication system of the previous embodiment, wherein the cellular network further includes a base station configured to communicate with

the UE.

Embodiment 57. The communication system of the previous 2 embodiments, wherein:

the processing circuitry of the host computer is configured to execute a host application, thereby providing the user data; and

the UE's processing circuitry is configured to execute a client application associated with the host application.

Embodiment 58. A method implemented in a communication system including a host computer, a base station and a user equipment (UE), the method comprising:

at the host computer, providing user data; and

at the host computer, initiating a transmission carrying the user data to the UE via a cellular network comprising the base station, wherein the UE performs any of the steps of any of Embodiments 1 to 18.

Embodiment 59. The method of the previous embodiment, further comprising at the UE, receiving the user data from the base station.

Embodiment 60. A communication system including a host computer comprising:

communication interface configured to receive user data originating from a transmission from a user equipment (UE) to a base station,

wherein the UE comprises a radio interface and processing circuitry, the UE's processing circuitry configured to perform any of the steps of any of Embodiments 1 to 18.

Embodiment 61. The communication system of the previous embodiment, further including the UE.

Embodiment 62. The communication system of the previous 2 embodiments, further including the base station, wherein the base station comprises a radio interface configured to communicate with the UE and a communication interface configured to forward to the host computer the user data carried by a transmission from the UE to the base station.

Embodiment 63. The communication system of the previous 3 embodiments, wherein:

the processing circuitry of the host computer is configured to execute a host application; and

the UE's processing circuitry is configured to execute a client application associated with the host application, thereby providing the user data.

Embodiment 64. The communication system of the previous 4 embodiments, wherein:

the processing circuitry of the host computer is configured to execute a host application, thereby providing request data; and

the UE's processing circuitry is configured to execute a client application associated with the host application, thereby providing the user data in response to the request data.

Embodiment 65. A method implemented in a communication system including a host computer, a base station and a user equipment (UE), the method comprising:

at the host computer, receiving user data transmitted to the base station from the UE, wherein the UE performs any of the steps of any of Embodiments 1 to 18.

Embodiment 66. The method of the previous embodiment, further comprising, at the UE, providing the user data to the base station.

Embodiment 67. The method of the previous 2 embodiments, further comprising:

at the UE, executing a client application, thereby providing the user data to be transmitted; and

at the host computer, executing a host application associated with the client application.

Embodiment 68. The method of the previous 3 embodiments, further comprising:

at the UE, executing a client application; and

at the UE, receiving input data to the client application, the input data being provided at the host computer by executing a host application associated with the client application,

wherein the user data to be transmitted is provided by the client application in response to the input data.

Embodiment 69. A communication system including a host computer comprising a communication interface configured to receive user data originating from a transmission from a user equipment (UE) to a base station, wherein the base station comprises a radio interface and processing circuitry, the base station's processing circuitry configured to perform any of the steps of any of Embodiments 19 to 37.

Embodiment 70. The communication system of the previous embodiment further including the base station.

Embodiment 71. The communication system of the previous 2 embodiments, further including the UE, wherein the UE is configured to communicate with the base station.

Embodiment 72. The communication system of the previous 3 embodiments, wherein:

the processing circuitry of the host computer is configured to execute a host application;

the UE is configured to execute a client application associated with the host application, thereby providing the user data to be received by the host computer.

Embodiment 73. A method implemented in a communication system including a host computer, a base station and a user equipment (UE), the method comprising:

at the host computer, receiving, from the base station, user data originating from a transmission which the base station has received from the UE, wherein the UE performs any of the steps of any of Embodiments 1 to 18.

Embodiment 74. The method of the previous embodiment, further comprising at the base station, receiving the user data from the UE.

Embodiment 75. The method of the previous 2 embodiments, further comprising at the base station, initiating a transmission of the received user data to the host computer.

ABREVIATIONS

At least some of the following abbreviations may be used in this disclosure. If there is an inconsistency between abbreviations, preference should be given to how it is used above. If listed multiple times below, the first listing should be preferred over any subsequent listing(s).

RSRP	Reference Signal Received Power
CSI-RSRP	CSI Reference Signal Received Power
CSI-RSRQ	CSI Reference Signal Received Quality
SS-RSRP	Synchronization Signal Reference Signal Received Power
SS-RSRQ	Synchronization Signal Reference Signal Received Quality
TBS	Transport block size
SCS	Subcarrier spacing

eMBB	enhanced Mobile BroadBand
LTE	Long Term Evolution
NR	Next Radio
PDCCH	Physical Downlink Control Channel
UE	User Equipment
1x RTT	CDMA2000 1x Radio Transmission Technology
3GPP	3rd Generation Partnership Project
5G	5th Generation
ABS	Almost Blank Subframe
ARQ	Automatic Repeat Request
AWGN	Additive White Gaussian Noise
BCCH	Broadcast Control Channel
BCH	Broadcast Channel
CA	Carrier Aggregation
CC	Carrier Component
CCCH SDU	Common Control Channel SDU
CDMA	Code Division Multiplexing Access
CGI	Cell Global Identifier
CIR	Channel Impulse Response
CP	Cyclic Prefix
CPICH	Common Pilot Channel
CPICH Ec/No	CPICH Received energy per chip divided by the power density in the band
CQI	Channel Quality information
C-RNTI	Cell RNTI
CSI	Channel State Information
DCCH	Dedicated Control Channel
DL	Downlink
DM	Demodulation
DMRS	Demodulation Reference Signal
DRX	Discontinuous Reception
DTX	Discontinuous Transmission

DTCH	Dedicated Traffic Channel
DUT	Device Under Test
E-CID	Enhanced Cell-ID (positioning method)
E-SMLC	Evolved-Serving Mobile Location Centre
ECGI	Evolved CGI
eNB	E-UTRAN NodeB
ePDCCH	enhanced Physical Downlink Control Channel
E-SMLC	evolved Serving Mobile Location Center
E-UTRA	Evolved UTRA
E-UTRAN	Evolved UTRAN
FDD	Frequency Division Duplex
FFS	For Further Study
GERAN	GSM EDGE Radio Access Network
gNB	Base station in NR
GNSS	Global Navigation Satellite System
GSM	Global System for Mobile communication
HARQ	Hybrid Automatic Repeat Request
HO	Handover
HSPA	High Speed Packet Access
HRPD	High Rate Packet Data
LOS	Line of Sight
LPP	LTE Positioning Protocol
LTE	Long-Term Evolution
MAC	Medium Access Control
MBMS	Multimedia Broadcast Multicast Services
MBSFN	Multimedia Broadcast multicast service Single Frequency Network
MBSFN ABS	MBSFN Almost Blank Subframe
MDT	Minimization of Drive Tests
MIB	Master Information Block
MME	Mobility Management Entity
MSC	Mobile Switching Center

NPDCCH	Narrowband Physical Downlink Control Channel
NR	New Radio
OCNG	OFDMA Channel Noise Generator
OFDM	Orthogonal Frequency Division Multiplexing
OFDMA	Orthogonal Frequency Division Multiple Access
OSS	Operations Support System
OTDOA	Observed Time Difference of Arrival
O&M	Operation and Maintenance
PBCH	Physical Broadcast Channel
P-CCPCH	Primary Common Control Physical Channel
PCell	Primary Cell
PCFICH	Physical Control Format Indicator Channel
PDCCH	Physical Downlink Control Channel
PDP	Profile Delay Profile
PDSCH	Physical Downlink Shared Channel
PGW	Packet Gateway
PHICH	Physical Hybrid-ARQ Indicator Channel
PLMN	Public Land Mobile Network
PMI	Precoder Matrix Indicator
PRACH	Physical Random Access Channel
PRS	Positioning Reference Signal
PSS	Primary Synchronization Signal
PUCCH	Physical Uplink Control Channel
PUSCH	Physical Uplink Shared Channel
RACH	Random Access Channel
QAM	Quadrature Amplitude Modulation
RAN	Radio Access Network
RAT	Radio Access Technology
RLM	Radio Link Management
RNC	Radio Network Controller
RNTI	Radio Network Temporary Identifier
RRC	Radio Resource Control

RRM	Radio Resource Management
RS	Reference Signal
RSCP	Received Signal Code Power
RSRP	Reference Symbol Received Power OR Reference Signal Received Power
RSRQ	Reference Signal Received Quality OR Reference Symbol Received Quality
RSSI	Received Signal Strength Indicator
RSTD	Reference Signal Time Difference
SCH	Synchronization Channel
SCell	Secondary Cell
SDU	Service Data Unit
SFN	System Frame Number
SGW	Serving Gateway
SI	System Information
SIB	System Information Block
SNR	Signal to Noise Ratio
SON	Self Optimized Network
SS	Synchronization Signal
SSS	Secondary Synchronization Signal
TDD	Time Division Duplex
TDOA	Time Difference of Arrival
TOA	Time of Arrival
TSS	Tertiary Synchronization Signal
TTI	Transmission Time Interval
UE	User Equipment
UL	Uplink
UMTS	Universal Mobile Telecommunication System
USIM	Universal Subscriber Identity Module
UTDOA	Uplink Time Difference of Arrival
UTRA	Universal Terrestrial Radio Access
UTRAN	Universal Terrestrial Radio Access Network

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WCDMA	Wide CDMA
WLAN	Wide Local Area Network

CLAIMS

1. A method performed by a wireless device (510) configured with Discontinuous Reception, DRX, the method comprising:

monitoring (1602) for a first wakeup signal, WUS, during a first WUS monitoring occasion;

in response to the wireless device detecting the first WUS during the first WUS monitoring occasion:

monitoring (1604) a downlink control channel during a downlink control channel monitoring occasion associated with the detected first WUS; and

abstaining (1604) from monitoring for a second WUS in a second WUS monitoring occasion based on a condition.

2. The method of Claim 1, wherein the condition comprises the second WUS monitoring occasion overlapping an active time.

3. The method of Claim 2, wherein the active time comprises a time slot during which the wireless device is monitoring the downlink control channel.

4. The method of any one of Claims 1 to 3, wherein the abstaining from monitoring the second WUS based on the condition is in response to receiving an indication from a network node (560) to not monitor for wakeup signal, WUS, during a predetermined period of time.

5. The method of any one of Claims 1 to 4, wherein in response to detecting the first WUS, the method further comprises:

detecting a downlink signal while monitoring the downlink control channel;

after detecting the downlink signal, setting an inactivity timer associated with a predetermined period of time;

abstaining from monitoring for the second WUS while the inactivity timer is running during the predetermined period of time; and

resetting the inactivity timer in response to detecting a subsequent downlink signal in the downlink control channel before the inactivity timer expires.

6. The method of any one of Claims 1 to 5, further comprising:

in response to the wireless device detecting the first WUS during the first WUS monitoring occasion, transmitting, to a network node, an acknowledgement signal