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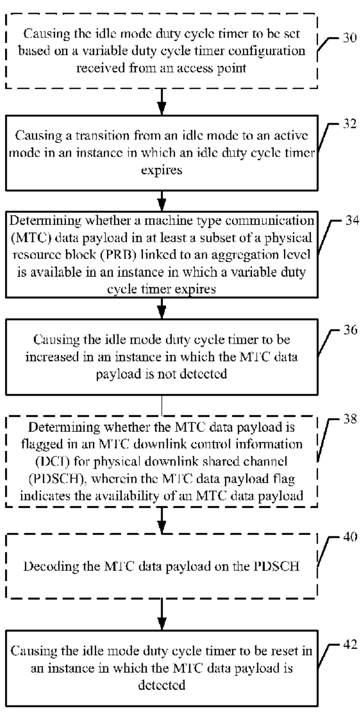

FIG. 3

(57) **Abstract**: A method, apparatus and computer program product are provided for providing an idle duty cycle for intermittent and low-data payload transmissions. In this regard, a method is provided that includes causing a transition from an idle mode to an active mode in an instance in which an idle duty cycle timer expires. The method of this embodiment may also include determining whether a MTC data payload in a physical resource block (PRB) linked to an aggregation level is available in an instance in which a variable duty cycle timer expires. The method of this embodiment may also include causing the idle mode duty cycle timer to be increased in an instance in which the MTC data payload is not detected. The method of this embodiment may also include causing the idle mode duty cycle timer to be reset in an instance in which the MTC data payload is detected.

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METHOD AND APPARATUS FOR COMMUNICATIONS DEVICE DUTY CYCLES

TECHNOLOGICAL FIELD

[0001] Embodiments of the present invention relate generally to communications technology and, more particularly, to duty cycles and signaling for machine type communications (MTC).

BACKGROUND

[0002] Many MTC devices are targeting low-end (low cost, low data rate) applications that can be handled adequately by Global System for Mobile Communications (GSM) and/or General packet radio service (GPRS). Based on to the low cost of these devices and the coverage of GSM/GPRS, there is very little motivation for an MTC device supplier to use modules supporting the long term evolution (LTE) radio interface.

[0003] Reducing the bandwidth that an MTC communications device is required to support (i.e. to support a bandwidth below the deployed system bandwidth) could be considered as a way to reduce component cost. However, legacy physical channels Physical Control Format Indicator Channel (PCFICH) / Physical HARQ Indicator Channel (PHICH) / Physical Downlink Control Channel (PDCCH) are distributed across the entire bandwidth and active communications devices (e.g. not in Discontinuous Reception (DRX) sleep mode) expect these channels to be transmitted on continuously, thus requiring each of the physical channels to be monitored. Low-data rate MTC devices may only need intermittent data transmissions a few times a day, possibly less often, and hence monitoring the legacy physical channels PCFICH/PHICH/PDCCH may drain the battery of MTC devices.

BRIEF SUMMARY

[0004] In one embodiment, a method is provided that comprises causing a transition from an idle mode to an active mode in an instance in which an idle duty cycle timer expires. The method of this embodiment may also include determining whether a MTC data payload in a physical resource block (PRB) linked to an aggregation level is available in an instance in which a variable duty cycle timer expires. The method of this embodiment may also include causing the idle mode duty cycle timer to be increased in an instance in which the MTC data payload is not detected. The method of this embodiment may also include causing the idle mode duty cycle timer to be reset in an instance in which the MTC data payload is detected. Advantageously, the apparatus, method and computer program product as described herein may enable efficient and robust MTC signaling for a communications device that may request intermittent and/or low-data payload transmissions. For example, the apparatus described herein may include a simplified radio frequency design. Further, efficient signaling may result in a longer battery life, the use of a smaller battery, and/or the use of an alternate power source.

[0005] In another embodiment, an apparatus is provided that includes at least one processor and at least one memory including computer program code with the at least one memory and the computer program code being configured, with the at least one processor, to cause the apparatus to at least cause a transition from an idle mode to an active mode in an instance in which an idle duty cycle timer expires. The at least one memory and computer program code may also be configured to, with the at least one processor, cause the apparatus to determine whether a MTC data payload in a PRB linked to an aggregation level is available in an instance in which a variable duty cycle timer expires. The at least one memory and computer program code may also be configured to, with the at least one processor, cause the apparatus to cause the idle mode duty cycle timer to be increased in an instance in which the MTC data payload is not detected. The at least one memory and computer program code may also be configured to, with the at least one processor, cause the apparatus to cause the idle mode duty cycle timer to be reset in an instance in which the MTC data payload is detected.

[0006] In the further embodiment, a computer program product may be provided that includes at least one non-transitory computer-readable storage medium having computer-readable program instructions stored therein with the computer-readable program instructions including program instructions configured to cause a transition from an idle mode to an active mode in an instance in which an idle duty cycle timer expires. The computer-readable program instructions may also include program instructions configured to determine whether a MTC data payload in a PRB linked to an aggregation level is available in an instance in which a variable duty cycle timer expires. The computer-readable program instructions may also include program instructions configured to cause the idle mode duty cycle timer to be increased in an instance in which the MTC data payload is not detected. The computer-readable program instructions may also include program instructions configured to cause the idle mode duty cycle timer to be reset in an instance in which the MTC data payload is detected.

[0007] In yet another embodiment, an apparatus is provided that includes means for causing a transition from an idle mode to an active mode in an instance in which an idle duty cycle timer expires. The apparatus of this embodiment may also include means for determining whether a MTC data payload in a PRB linked to an aggregation level is available in an instance in which a variable duty cycle timer expires. The apparatus of this embodiment may also include means for causing the idle mode duty cycle timer to be increased in an instance in which the MTC data payload is not detected. The apparatus of this embodiment may also include means for causing the idle mode duty cycle timer to be reset in an instance in which the MTC data payload is detected.

[0008] In one embodiment, a method is provided that comprises determining, for at least one communications device, a variable duty cycle timer configuration for space time domain multiplexing (SDMA). The method of this embodiment may also include causing the SDMA duty cycle to be transmitted to the at least one communications device. In some example embodiments the variable duty cycle timer configuration is configured to cause an idle mode duty cycle timer to be set on the at least one communications device. The method of this embodiment may also include determining whether a MTC data payload in a physical resource block (PRB) linked to an aggregation level is available for the at least one communications device. The method of this embodiment may also include causing a MTC payload repetition to be flagged in a MTC downlink control information (DCI) for a physical downlink shared channel (PDSCH). In some example embodiments the MTC payload repetition flag indicates the availability of an MTC data payload to the at least one communications device and the MTC payload repetition flag is configured to be checked at least when the idle mode duty cycle timer expires.

[0009] In another embodiment, an apparatus is provided that includes at least one processor and at least one memory including computer program code with the at least one memory and the computer program code being configured, with the at least one processor, to cause the apparatus to at least determine, for at least one communications device, a variable duty cycle timer configuration for SDMA. The at least one memory and computer program code may also be configured to, with the at least one processor, cause the apparatus to cause the SDMA duty cycle to be transmitted to the at least one communications device. In some example embodiments the variable duty cycle timer configuration is configured to cause an idle mode duty cycle timer to be set on the at least one communications device. The at least one memory and computer program code may also be configured to, with the at least one processor, cause the apparatus to determine whether a MTC data payload in a PRB linked to an aggregation level is available for the at least one communications device. The at least one memory and computer program code may also be configured to, with the at least one processor, cause the apparatus to cause a MTC payload repetition to be flagged in an MTC DCI for a PDSCH. In some example embodiments the MTC payload repetition flag indicates the availability of an MTC data payload to the at least one communications device and the MTC payload repetition flag is configured to be checked at least when the idle mode duty cycle timer expires.

[0010] In the further embodiment, a computer program product may be provided that includes at least one non-transitory computer-readable storage medium having computer-readable program instructions stored therein with the computer-readable program instructions including program instructions configured to determine, for at least one communications device, a variable duty cycle timer configuration for SDMA. The computer-readable program instructions may also include program instructions configured to cause the SDMA duty cycle to be transmitted to the at least one communications device. In some example embodiments the variable duty cycle timer configuration is configured to cause an idle mode duty cycle timer to be set on the at least one communications device. The computer-readable program instructions may also include program instructions configured to determine whether a MTC data payload in a PRB linked to an aggregation level is available for the at least one communications device. The computer-readable program instructions may also include program instructions configured to cause a MTC payload repetition to be flagged in an MTC DCI for a PDSCH. In some example embodiments the MTC payload repetition flag indicates the availability of an MTC data payload to the at least one communications device and the MTC payload repetition flag is configured to be checked at least when the idle mode duty cycle timer expires.

[0011] In yet another embodiment, an apparatus is provided that includes means for determining, for at least one communications device, a variable duty cycle timer configuration for SDMA. The apparatus of this embodiment may also include means for causing the SDMA duty cycle to be transmitted to the at least one communications device. In some example embodiments the variable duty cycle timer configuration is configured to cause an idle mode duty cycle timer to be set on the at least one communications device. The apparatus of this embodiment may also include means for determining whether a MTC data payload in a PRB linked to an aggregation level is available for the at least one communications device. The apparatus of this embodiment may also include means for causing a MTC payload repetition to be flagged in an MTC DCI for a PDSCH. In some example embodiments the MTC payload repetition flag indicates the availability of an MTC data payload to the at least one communications device and the MTC payload repetition flag is configured to be checked at least when the idle mode duty cycle timer expires.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] Having thus described the example embodiments of the invention in general terms, reference will now be made to the accompanying drawings, which are not necessarily drawn to scale, and wherein:

[0013] Figure 1 is a schematic representation of a system having a mobile terminal that may utilize an idle mode duty cycle and that may benefit from an embodiment of the present invention;

[0014] Figure 2 is a block diagram of an apparatus that may be embodied by a mobile terminal in accordance with some example embodiments of the present invention;

[0015] Figure 3 is a flow chart illustrating operations performed by an example mobile terminal in accordance with some example embodiments of the present invention;

[0016] Figure 4 is a flow chart illustrating operations performed by an example access point in accordance with some example embodiments of the present invention;

[0017] Figure 5 illustrates SMDA based Evolved Physical Downlink Control Channel (ePDCCH) multiplexing in accordance with some example embodiments of the present invention; and

[0018] Figure 6 illustrates Control Channel Element (CCE) aggregation of ePDCCH and PDSCH repetition in accordance with some example embodiments of the present invention.

DETAILED DESCRIPTION

[0019] The present invention now will be described more fully hereinafter with reference to the accompanying drawings, in which some, but not all embodiments of the inventions are shown. Indeed, these inventions may be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will satisfy applicable legal requirements. Like numbers refer to like elements throughout.

[0020] As used in this application, the term 'circuitry' refers to all of the following: (a)hardware-only circuit implementations (such as implementations in only analog and/or digital circuitry) and (b) to combinations of circuits and software (and/or firmware), such as (as applicable): (i) to a combination of processor(s) or (ii) to portions of processor(s)/software (including digital signal processor(s)), software, and memory(ies) that work together to cause an apparatus, such as a mobile phone or server, to perform various functions) and (c) to circuits, such as a microprocessor(s) or a portion of a microprocessor(s), that require software or firmware for operation, even if the software or firmware is not physically present.

[0021] This definition of "circuitry" applies to all uses of this term in this application, including in any claims. As a further example, as used in this application, the term "circuitry" would also cover an implementation of merely a processor (or multiple processors) or portion of a processor and its (or their) accompanying software and/or firmware. The term "circuitry" would also cover, for example and if applicable to the particular claim element, a baseband integrated circuit or application specific integrated circuit for a mobile phone or a similar integrated circuit in server, a cellular network device, or other network device.

[0022] Although the method, apparatus and computer program product as described herein may be implemented in a variety of different systems, one example of such a system is shown in Figure 1, which includes a first communication device (*e.g.*, communications device 10) that is capable of communication via an access point 12, such as a base station, a macro cell, a Node B, an evolved Node B (eNB), a coordination unit, a macro base station or other access point, with a network 14 (*e.g.*, a core network). While the network may be configured in accordance with LTE or LTE-Advanced (LTE-A), other networks may support the method, apparatus and computer program product of embodiments of the present invention including those configured in accordance with wideband code division multiple access (W-CDMA), CDMA2000, global system for mobile communications (GSM), general packet radio service (GPRS) and/or the like.

[0023] The network 14 may include a collection of various different nodes, devices or functions that may be in communication with each other via corresponding wired and/or wireless interfaces. For example, the network may include one or more cells, including access point 12 and which may serve a respective coverage area. The access point 12 could be, for example, part of one or more cellular or mobile networks or public land mobile networks (PLMNs). In turn, other devices such as processing devices (*e.g.*, personal computers, server computers or the like) may be coupled to the communications device 10 and/or other communication devices via the network.

[0024] A communication device, such as the communications device 10 (also known as user equipment (UE)), may be in communication with other communication devices or other devices via the access point 12 and, in turn, the network 14. In some cases, the communication device may include an antenna for transmitting signals to and for receiving signals from an access point.

[0025] In some example embodiments, the communications device 10 may be a mobile communication device such as, for example, a mobile telephone, portable digital assistant (PDA), pager, laptop computer, or any of numerous other hand held or portable communication devices, computation devices, content generation devices, content consumption devices, or combinations thereof. However, as is described herein, the communications device 10 may also take the form a communications enabled appliance, such as a thermostat configured to connect with an access point 12. Other such devices that are configured to connect to the network include, but are not limited to a refrigerator, a security system, a home lighting system, and/or the like. As such, the communications device 10 may include one or more processors that may define processing circuitry and a processing system, either alone or in combination with one or more memories. The processing circuitry may utilize instructions stored in the memory to cause the communications device 10 to operate in a particular way or execute specific functionality when the instructions are executed by the one or more processors. The communications device 10 may also include communication circuitry and corresponding hardware/software to enable communication with other devices and/or the network 14.

[0026] In one embodiment, for example, the communications device 10 and/or the access point 12 may be embodied as or otherwise include an apparatus 20 as generically represented by the block diagram of Figure 2. While the apparatus 20 may be employed, for example, by a communications device 10 or an access point 12, it should be noted that the components, devices or elements described below may not be mandatory and thus some may be omitted in certain embodiments. Additionally, some embodiments may include further or different components, devices or elements beyond those shown and described herein.

[0027] As shown in Figure 2, the apparatus 20 may include or otherwise be in communication with processing circuitry 22 that is configurable to perform actions in accordance with example embodiments described herein. The processing circuitry may be configured to perform data processing, application execution and/or other processing and management services according to an example embodiment of the present invention. In some embodiments, the apparatus or the processing circuitry may be embodied as a chip or chip set. In other words, the apparatus or the processing circuitry may comprise one or more physical packages (*e.g.*, chips) including materials, components and/or wires on a structural assembly (*e.g.*, a baseboard). The structural assembly may provide physical strength, conservation of size, and/or limitation of electrical interaction for component circuitry included thereon. The apparatus or the processing circuitry may therefore, in some cases, be configured to implement an embodiment of the present invention on a single chip or as a single "system on a chip." As such, in some cases, a chip or chipset may constitute means for performing one or more operations for providing the functionalities described herein.

[0028] In an example embodiment, the processing circuitry 22 may include a processor 24 and memory 26 that may be in communication with or otherwise control a communication interface 26 and, in some cases, a user interface 29. As such, the processing circuitry may be embodied as a circuit chip (*e.g.*, an integrated circuit chip) configured (*e.g.*, with hardware, software or a combination of hardware and software) to perform operations described herein. However, in some embodiments taken in the context of the communications device 10, the processing circuitry may be embodied as a portion of a mobile computing device or other mobile terminal.

[0029] The user interface 29 (if implemented) may be in communication with the processing circuitry 22 to receive an indication of a user input at the user interface and/or to provide an audible, visual, mechanical or other output to the user. As such, the user interface may include, for example, a keyboard, a mouse, a joystick, a display, a touch screen, a microphone, a speaker, and/or other input/output mechanisms. The apparatus 20 need not always include a user interface. For example, in instances in which the apparatus is embodied as an access point 12, the apparatus may not include a user interface. As such, the user interface is shown in dashed lines in Figure 2.

[0030] The communication interface 26 may include one or more interface mechanisms for enabling communication with other devices and/or networks. In some cases, the communication interface may be any means such as a device or circuitry embodied in either hardware, or a combination of hardware and software that is configured to receive and/or transmit data from/to a network 14 and/or any other device or module in communication with the processing circuitry 22, such as between the communications device 10 and the access point 12. In this regard, the communication interface may include, for example, an antenna (or multiple antennas) and supporting hardware and/or software for enabling communications with a wireless communication network and/or a communication modem or other hardware/software for supporting communication via cable, digital subscriber line (DSL), universal serial bus (USB), Ethernet or other methods.

[0031] In an example embodiment, the memory 26 may include one or more non-transitory memory devices such as, for example, volatile and/or non-volatile memory that may be either fixed or removable. The memory may be configured to store information, data, applications, instructions or the like for enabling the apparatus 20 to carry out various functions in accordance with example embodiments of the present invention. For example, the memory could be configured to buffer input data for processing by the processor 24. Additionally or alternatively, the memory could be configured to store instructions for execution by the processor. As yet another alternative, the memory may include one of a plurality of databases that may store a variety of files, contents or data sets. Among the contents of the memory, applications may be stored for execution by the processor in order to carry out the functionality associated with each respective application. In some cases, the memory may be in communication with the processor via a bus for passing information among components of the apparatus.

[0032] The processor 24 may be embodied in a number of different ways. For example, the processor may be embodied as various processing means such as one or more of a microprocessor or other processing element, a coprocessor, a controller or various other computing or processing devices including integrated circuits such as, for example, an ASIC (application specific integrated circuit), an FPGA (field programmable gate array), or the like. In an example embodiment, the processor may be configured to execute instructions stored in the memory 26 or otherwise accessible to the processor. As such, whether configured by hardware or by a combination of hardware and software, the processor may represent an entity (*e.g.*, physically embodied in circuitry – in the form of processing circuitry 22) capable of performing operations according to embodiments of the present invention while configured accordingly. Thus, for example, when the processor is embodied as an ASIC, FPGA or the like, the processor may be specifically configured hardware for conducting the operations described herein. Alternatively, as another example, when the processor is embodied as an executor of software instructions, the instructions may specifically configure the processor to perform the operations described herein.

[0033] In some example embodiments one or more communications devices 10 may be configured to connect to an access point 12. However these communications devices 10 may only require intermittent and/or low payload data transmissions. For example, a communications device 10 may only check for new data periodically. In such cases, the communications device 10 remain in an idle state to enable efficient transmission and to minimize drain on a battery. An idle mode duty cycle may then be used to cause the communications device 10 to activate at the expiration of the idle mode duty cycle duration. While an idle mode is described herein, the communications device 10 may be caused to activate in other situations, for example user interaction, power cycling and or the like.

[0034] To implement an idle mode duty cycle, in one example embodiment, the network 14, such as via Evolved Universal Terrestrial Radio Access Network (E-UTRAN) may configure multiple communications devices 10 on the same physical resources in an SDMA mode via multi-user multiple-input and multiple-output (MU-MIMO) transmission mode. MU MIMO for SDMA of MTC transmissions may, for example, improve MTC efficiency without necessarily increasing MTC complexity. For example, a communications device 10 may only decode, such as by the processing circuitry 22, the processor 24 or the like, SDMA transmissions based on its configured communications device specific Reference Signal, such as a DM RS parameter (e.g. rank 1 transmission). An access point, such as access point 12, where may be configured to schedule multiple communications devices 10 via SDMA (e.g. MU-MIMO) on the same Physical Resource Blocks (PRB).

[0035] In some example embodiments, a variable duty cycle (e.g. an SDMA duty cycle) may be configured by the access point 12, such as by the processing circuitry 22, the processor 24 or the like, and may be transmitted to a communications device via dedicated signaling, such as via the communications interface 26. The SDMA duty cycle may be configured to enable an idle mode duration (e.g. an idle mode duty cycle) during which the communications device 10 is not configured to, and indeed to save battery resources does not, monitor the enhanced PDCCH for MTC communications in the configured SDMA resources.

[0036] In some example embodiments, the primary synchronization channel and/or the secondary synchronization channel, the master information block (MIB) in mid-6 PRBs in system bandwidth may also be monitored initially by a communications device 10 during an initial attachment, such as by the processing circuitry 22, the processor 24, the communications interface 26 or the like. Cell system info acquisition may then be performed on the new SIB based on System Information Radio Network Temporary Identifier (SI-RNTI) of PDCCH cyclic redundancy check (CRC) scrambling to indicate cell specific MTC parameters.

[0037] The communications device 10, in some example embodiments may be configured receive, such as via the communications interface 26 or the like, a variable duty cycle configuration from the access point 12. The variable duty cycle may cause the communications device 10 to be configured for idle periods (e.g. idle mode duty cycle) during which it will not cause, such as by the processing circuitry 22, the processor 24 or the like, the PDCCH to be monitored on the configured SDMA resources (i.e. PRB subsets, DM RS parameters). The variable duty cycle configuration may be received via dedicated signaling for a machine-specific duty cycle or via a MTC system information block (SIB) for cell-specific duty cycles on the SDMA configured resources for a larger set of the communications devices 10.

[0038] In some example embodiments, MTC typically consists of small traffic payloads, intermittent transmissions and/or event driven transmissions, thus the variable duty cycles and the idle mode duty cycle timer may be of a duration varying exponentially. An idle mode duty cycle timer may be set to a 2 duty cycle (DC) for the first idle period, and at the expiration of the timer value, the communications device 10, such as by using the processing circuitry 22, the processor 24, the communications interface 26 or the like, may determine whether a dedicated signaling from an access point 12 indicates a new idle duty cycle duration of 2^{K*DC} if there is no data for the communications device 10 or from the communications device 10. In some embodiments, the communications device 10 may increment the K value. The value K may be varied linearly each time an idle period finishes (i.e. 1, 2, 3, 4, etc.), in steps (2, 4, 6, 8, etc.), exponentially or any other way from a minimum K value up to a maximum K value. The maximum K value may be determined by the communications device 10, the access point 12, and/or it may be a predetermined value. Alternatively or additionally, in certain example embodiments, the communications device 10 may be caused to wake up during an idle period before the idle period duty cycle timer expires and may initiate a scheduling request to cause time critical MTC data to be transmitted.

[0039] In some example embodiments, a small data payload may be transmitted by the access point 12, such as by the processing circuitry 22, the processor 24, the communications interface 26 or the like, over a PRB subset linked to an aggregation level. The data payload may be configured to fit in a single PRB, or a subset of PRBs in an instance in which a Control Channel Element (CCE) aggregation is used with the Downlink Control Information (DCI) format in ePDCCH mapped around the DM RS in OFDM Symbols (OS) #4-7 in a 1st slot and a CCE aggregation across PRBs.

[0040] As illustrated in Figure 5, the legacy PDCCH may be mapped to the first 1-3 OS in the 1st slot. The PDSCH is mapped to the OS may not be used by the legacy PDCCH and the ePDCCH in the 1st slot and 2nd slot of the PRB. In an instance in which the communications device 10 is operating at low SINR conditions, PDSCH repetition may optionally be caused, , such as by the processing circuitry 22, the processor 24, the communications interface 26 or the like, across the PRBs.

[0041] The legacy PDCCH may be transmitted, such as by the access point 12 via the communications interface 26 or the like in the first OFDM symbols. The communications device 10 may detect, such as by using the processing circuitry 22, the processor 24, the communications interface 26 or the like, the Downlink Control Information (DCI) format 1A/1B by monitoring the common search space. The DCI is then configured to allow for an initial MTC configuration for communications device-specific RRC parameters via dedicated RRC signaling (e.g. communications device specific SDMA sub-band and DM RS parameters such as DM RS port index) and via an SIB message for communications device-common MTC parameters (e.g. SDMA sub band configurations supported in the cell, carrier configurations, MTC bandwidth, etc.). In some example embodiments, the communications device 10 may receive, such as by the communications interface 26, small data payloads and may support only one receive antenna, which are may result in a rank-1 transmission (e.g. 1 DM RS port).

[0042] For example, in MIMO, as configured for LTE release 10, 24-resource elements (RE) patterns for communications device-specific DM RS to support rank 1-8 are specified. For example, Rank 1-4 on DM RS port 7-10 is supported. Rank 1-4 uses occ=2 {1,1; +1, -1) mapped to a block of 2 REs on DM RS ports 7&8 to code division multiplexing (CDM) layers 1&2 and mapped to a block of 2 REs on DM RS ports 9&10 to CDM layers 3&4; then may be repeated 6 times in PRB over 24 REs total. Rank 1-8 on DM RS port 7, 8, 9, 10 may also be supported. Rank 1-8uses occ=4 {+1,+1,+1,+1; +1, -1, +1, -1; -1, +1, -1, +1; +1, -1, -1, +1) mapped to a block of 4 REs on DM RS ports 7&8 to CDM layers 1-4 and mapped to a block of 4 REs on DM RS ports 9&10 to CDM layers 5-8; then repeated 3 times in PRB over 24 REs total.

[0043] In some example embodiments, SDMA-based MTC transmissions for 4 machines may be supported for ePDCCH and PDSCH by configuring occ=2 on DM RS ports #7-#10 assuming rank 1-4 supported via higher layer as illustrated in Figure 5; or up to 8 machines by configuring occ=4 on DM RS ports #7-#10 assuming rank 1-8 supported. In Figure 5, aggregation level 1 is shown and the legacy PDCCH is mapped to OS#0-2. The PDSCH is mapped to OS#3 in 1st slot and OS#7-#13 in 2nd slot.

[0044] In some example embodiments, the channel estimator may also use all the DM RS within a subframe – i.e. in OS #5, #6 in 1st slot and OS #12, #13 in 2nd slot. For example, to generate channel estimates for all the OS within the subframe, an intra-subframe a Time-Domain (TD) interpolator can typically be used by the channel estimator. For example, better accuracy of intra-subframe TD interpolation for channel estimates corresponding to OS #4 and OS#6 since DM RS in central position in OS #5, #6 may be possible for channel estimates for OS further away from DM RS OS. The more accurate channel estimates in these OS positions may enable an improved ePDCCH detection performance

[0045] In some example embodiments, localized ePDCCH for inter-cell coordination may be used, for example there may not be sub-block interleaving over system bandwidth (BW) used before mapping of ePDCCH to a resource element group (REG). In some example embodiments, PDSCH repetition, as illustrated in Figure 6, may be accomplished, for example, across the 2nd slot of PRBs used for the data payload transmission to improve detection on PDSCH (in case aggregation level L=2/4/8 is used, then repetition of data payload over 2nd slot of 2/4/8 PRBs give 3/6/9 dB gain). In the instance in which at least one OFDM Symbols is not used in the first slot by either the legacy PDCCH or ePDCCH for MTC, the OFDM Symbols may be used for PDSCH transmission as well the OFDM Symbols in the 2nd slot.

[0046] In some example embodiments, to allow efficient reference signaling for MTC transmissions antenna ports #7-10 may be configured on the SDMA resources as indicated via the higher layer. For example, cell specific reference signals on antenna ports #0-#3 may not be supported in these resources. Since PDSCH is implicitly assumed to be transmitted in OS that is not used by the legacy PDCCH or the ePDCCH in the PRB, in an instance in which communications device 10 detects, such as by the processing circuitry 22, the processor 24 or the like, DCI format in a 1st slot in the PRB subset linked to the aggregation level in use, then an implicit downlink (DL) grant may be determined. The DCI format may include a MTC payload repetition flag to indicate whether the data payload is repeated in the 2nd slot in the PRB subset used for the aggregated CCEs.

[0047] In some example embodiments, a design for the DCI format may be based on DCI format 1A, but may also omit one or more fields. For example, the table below shows one example of the compact DCI format, where N/A indicates that the field is present for DCI format 1A but not for the compact DCI format, N1 = ceil[log2(Nrb*(Nrb+1)/2)]+1, where Nrb represents the number of PRBs in the entire bandwidth.

[0048] Assuming a bandwidth of 10Mhz for DCI format 1A and assuming the Modulation and Coding Schemes (MCS) indication bits for MTC is N2 = 3 (which means eight MCS levels are supported by the MTC user), the DCI size for Format 1A and the compact DCI are 30 bits and 11 bits, respectively without any padding bits. An example of Compact DCI Format for SDMA-based MTC transmissions includes, but is not limited to:

Fields in DCI format 1A in LTE Rel-	Fields in the Compact DCI format

10	
Carrier indicator, 3 bits	N/A
Flag for format0/format1A differentiation, 1 bit	Flag for format0/format1A differentiation, 1 bit
Resource allocation filed, N1 bits	N/A
Modulation and coding scheme, 5 bit	Modulation and coding scheme, N2 bit
Hybrid automatic repeat request (HARQ) process, 3 bits for FDD	HARQ process, 3 bits for FDD
New data indicator, 1 bit	New data indicator, 1 bit
Redundancy version, 2 bits	Redundancy version, 2 bits
Transmit power control (TPC) command for Physical Uplink Control Channel (PUCCH), 2 bits	TPC command for PUCCH, 2 bits
Sounding Reference Signal (SRS) request – 0 or 1 bit	SRS request – 0 or 1 bit
Padding bits if any	Padding bits if any

[0049] A channel state information (CSI) report may be generated, such as by the communications device 10 via the processing circuitry 22, the processor 24 or the like, during the on-duration of the idle mode duty cycles for MTC transmissions for communications device-specific PRB sets used for the SDMA of MTC transmissions. In an instance in which a CSI is reported by a communications device 10, such as via the communications interface 26, the access point 12 may schedule other communications device-specific PRB sets used for the SDMA of MTC transmissions.

[0050] In some example embodiments, two slots of a PUCCH channel may be distributed in the frequency. In some example embodiments, PUCCH may be used for CSI reporting of SDMA PRB subsets. For example, PUCCH format 3 resource allocation is designed such that it can address the whole bandwidth (11 bits in Radio Resource Control (RRC) to locate on PUCCH channel). Then for some PRB subsets, the access point 12 may assign, such as by the processing circuitry 22, the processor 24 or the like, the PUCCH channel in the band center, which means the frequency distance between the RBs in the two slots is small (e.g. similar to PUCCH format 1a/1b when the offset defined for format 2 is very large). The PUCCH format 3 allocation may be made transparent to a communications device 10 using PUCCH format 1a or 1b. The limitation is the number of center PUCCH channels' may, in some embodiments, be limited to 5 communications devices per PRB.

[0051] Alternatively or additionally, the SDMA PRB subset may be caused to report the CSI via higher-layer configured PUSCH resources in corresponding uplink (UL) SDMA PRB subset. For example, using the higher layer has more flexibility for the communications device 10 as it may use UL resources anywhere within the UL system bandwidth. Based on the reported SDMA PRB subset Channel Quality Indicator (CQI), the access point 12 may be configured to (a) schedule MTC traffic via implicit DL grant and UL grant via ePDCCH on the configured SDMA PRB subsets, and (b) change the SDMA duty cycle via dedicated signaling. Advantageously, for example, high level signaling may allow for MTC resource allocation optimization based on channel conditions of a given narrow band communications device; and/or b) may allow for optimization of MTC resource allocation for some or all the communications devices in case interference becomes a bottleneck if many SDMA PRB subsets in the cell.

[0052] Figures 3 and 4 illustrate example operations performed by a method, apparatus and computer program product, such as apparatus 20 of Figure 2 in accordance with one embodiment of the present invention are illustrated. It will be understood that each block of the flowcharts, and combinations of blocks in the flowcharts, may be implemented by various means, such as hardware, firmware, processor, circuitry and/or other device associated with execution of software including one or more computer program instructions. For example, one or more of the procedures described above may be embodied by computer program instructions. In this regard, the computer program instructions which embody the procedures described above may be stored by a memory device 28 of an apparatus employing an embodiment of the present invention and executed by a processor 24 in the apparatus. As will be appreciated, any such computer program instructions may be loaded onto a computer or other programmable apparatus (*e.g.*, hardware) to produce a machine, such that the resulting computer or other programmable apparatus provides for implementation of the functions specified in the flowcharts' block(s). These computer program instructions may also be stored in a non-transitory computer-readable storage memory that may direct a computer or other programmable apparatus to function in a particular manner, such that the instructions stored in the computer-readable storage memory produce an article of manufacture, the execution of which implements the function specified in the flowcharts' block(s). The computer program instructions may also be loaded onto a computer or other programmable apparatus to cause a series of operations to be performed on the computer or other programmable apparatus to produce a computer-implemented process such that the instructions which execute on the computer or other programmable apparatus provide operations for implementing the functions specified in the flowcharts' block(s). As such, the operations of Figures 3 and 4, when executed, convert a computer or processing circuitry into a particular machine configured to perform an example embodiment of the present invention. Accordingly, the operations of Figures 3 and 4 define an algorithm for configuring a computer or processing circuitry 22, *e.g.*, processor, to perform an example embodiment. In some cases, a general purpose computer may be provided with an instance of the processor which performs the algorithm of Figures 3 and 4 to transform the general purpose computer into a particular machine configured to perform an example embodiment.

[0053] Accordingly, blocks of the flowcharts support combinations of means for performing the specified functions and combinations of operations for performing the specified functions. It will also be understood that one or more blocks of the flowchart, and combinations of blocks in the flowcharts, can be implemented by special purpose hardware-based computer systems which perform the specified functions, or combinations of special purpose hardware and computer instructions.

[0054] In some embodiments, certain ones of the operations above may be modified or further amplified as described below. Moreover, in some embodiments additional optional operations may also be included (some examples of which are shown in dashed lines in Figure 3). It should be appreciated that each of the modifications, optional additions or amplifications below may be included with the operations above either alone or in combination with any others among the features described herein.

[0055] Figure 3 is a flow chart illustrating a mobile terminal idle mode duty cycle performed in accordance with some example embodiments of the present invention. In some example embodiments, the apparatus 20 embodied, for example, by a communications device 10, may include means, such as the processing circuitry 22, the processor 24 or the like, for detecting an MTC data payload at the expiration of an idle mode duty cycle. In an instance in which a MTC data payload is not detected, the idle mode duty cycle's duration may be increased.

[0056] As shown in operation 30, the apparatus 20 embodied, for example, by a communications device 10, may include means, such as the processing circuitry 22, the processor 24, the communications interface 26 or the like, for causing the idle mode duty cycle timer to be set based on a variable duty cycle timer configuration received from an access point. In some example embodiments, the variable duty cycle timer configuration is configured for SDMA resources. In some example embodiments, the variable duty cycle timer is configured based on an exponential function. In further example embodiments, the variable duty cycle timer configuration may be received via at least one of a dedicated signaling for a machine-specific duty cycle or a SIB for a cell-specific duty cycle.

[0057] As shown in operation 32, the apparatus 20 embodied, for example, by a communications device 10, may include means, such as the processing circuitry 22, the processor 24 or the like, for causing a transition from an idle mode to an active mode in an instance in which an idle duty cycle timer expires. As shown in operation 34 the apparatus 20 embodied, for example, by a communications device 10, may include means, such as the processing circuitry 22, the processor 24, the communications interface 26 or the like, for determining whether a MTC data payload in a PRB linked to an aggregation level is available in an instance in which a variable duty cycle timer expires. As shown in operation 36, the apparatus 20 embodied, for example, by a communications device 10, may include means, such as the processing circuitry 22, the processor 24 or the like, for causing the idle mode duty cycle timer to be increased in an instance in which the MTC data payload is not detected.

[0058] As shown in operation 38, the apparatus 20 embodied, for example, by a communications device 10, may include means, such as the processing circuitry 22, the processor 24, the communications interface 26 or the like, for determining whether the MTC payload repetition is flagged in an MTC DCI for PDSCH, wherein the MTC payload repetition flag indicates the availability of an MTC data payload. As shown in operation 40, the apparatus 20 embodied, for example, by a communications device 10, may include means, such as the processing circuitry 22, the processor 24 or the like, for decoding the MTC data payload on the PDSCH. As shown in operation 42, the apparatus 20 embodied, for example, by a communications device 10, may include means, such as the processing circuitry 22, the processor 24 or the like, for causing the idle mode duty cycle timer to be reset in an instance in which the MTC data payload is detected.

[0059] As shown in operation 50 of Figure 4, the apparatus 20 embodied, for example, by an access point 12, may include means, such as the processing circuitry 22, the processor 24 or the like, for Determining, for at least one communications device, a variable duty cycle timer configuration for SDMA. In some example embodiments, the variable duty cycle timer is configured based on an exponential function. In further example embodiments, the variable duty cycle timer configuration may be received via at least one of a dedicated signaling for a machine-specific duty cycle or a SIB for a cell-specific duty cycle.

[0060] As shown in operation 52, the apparatus 20 embodied, for example, by an access point 12, may include means, such as the processing circuitry 22, the processor 24, the communications interface 26 or the like, for Causing the SDMA duty cycle to be transmitted to the at least one communications device, wherein the variable duty cycle timer configuration is configured to cause an idle mode duty cycle timer to be set on the at least one communications device.

[0061] As shown in operation 54, the apparatus 20 embodied, for example, by an access point 12, may include means, such as the processing circuitry 22, the processor 24 or the like, for Determining whether a MTC data payload in a PRB linked to an aggregation level is available for the at least one communications device. As shown in operation 56, the apparatus 20 embodied, for example, by an access point 12, may include means, such as the processing circuitry 22, the processor 24, the communications interface 26 or the like, for Causing a MTC payload repetition to be flagged in an MTC DCI for a PDSCH. In some example embodiments, the MTC payload repetition flag indicates the availability of an MTC data payload to the at least one communications device and the MTC payload repetition flag is configured to be checked at least when the idle mode duty cycle timer expires.

[0062] Many modifications and other embodiments of the inventions set forth herein will come to mind to one skilled in the art to which these inventions pertain having the benefit of the teachings presented in the foregoing descriptions and the associated drawings. Therefore, it is to be understood that the inventions are not to be limited to the specific embodiments disclosed and that modifications and other embodiments are intended to be included within the scope of the appended claims. Moreover, although the foregoing descriptions and the associated drawings describe example embodiments in the context of certain example combinations of elements and/or functions, it should be appreciated that different combinations of elements and/or functions may be provided by alternative embodiments without departing from the scope of the appended claims. In this regard, for example, different combinations of elements and/or functions than those explicitly described above are also contemplated as may be set forth in some of the appended claims. Although specific terms are employed herein, they are used in a generic and descriptive sense only and not for purposes of limitation.

WHAT IS CLAIMED IS:

1. A method comprising:

causing a transition from an idle mode to an active mode in an instance in which an idle duty cycle timer expires;

determining whether a machine type communication (MTC) data payload in at least a subset of a physical resource block (PRB) is available in an instance in which a variable duty cycle timer expires;

causing an idle mode duty cycle timer to be increased in an instance in which a MTC data payload is not detected; and

causing the idle mode duty cycle timer to be reset in an instance in which the MTC data payload is detected.

2. A method according to Claim 1, further comprising:

determining whether the MTC data payload is flagged in an MTC downlink control information (DCI) for physical downlink shared channel (PDSCH), wherein a MTC data payload flag indicates that a MTC data payload is available.

3. A method according to any one of Claims 1 to 2, further comprising:

decoding the MTC data payload on a physical downlink shared channel (PDSCH).

4. A method according to any one of Claims 1 to 3, further comprising:

causing the idle mode duty cycle timer to be set based on a variable duty cycle timer configuration received from an access point, wherein the variable duty cycle timer configuration is configured for space time domain multiplexing (SDMA) resources.

5. A method according to Claim 4, wherein the idle mode duty cycle timer is configured based on an exponential function.

6. A method according to Claim 4, wherein the variable duty cycle timer configuration is received via a dedicated signaling for a machine-specific duty cycle.

7. A method according to Claim 4, wherein the variable duty cycle timer configuration is received via a system information block (SIB) for a cell-specific duty cycle.

8. A method according to any one of Claims 1 to 7, wherein the idle mode duty cycle timer is configured to be increased exponentially until it reaches a predetermined maximum value.

9. A method according to any one of Claims 1 to 8, wherein the at least the subset of a PRB is linked to an aggregation level.

10. An apparatus comprising:

at least one processor; and

at least one memory including computer program code, the at least one memory and the computer program code configured to, with the at least one processor, cause the apparatus to at least:

cause a transition from an idle mode in an instance in which an idle duty cycle timer expires;

determine whether a machine type communication (MTC) data payload in at least a subset of a physical resource block (PRB) is available in an instance in which a variable duty cycle timer expires;

cause an idle mode duty cycle timer to be increased in an instance in which a MTC data payload is not detected; and

cause the idle mode duty cycle timer to be reset in an instance in which the MTC data payload is detected.

11. An apparatus according to Claim 10, wherein the at least one memory including the computer program code is further configured to, with the at least one processor, cause the apparatus to:

determine whether the MTC data payload is flagged in an MTC downlink control information (DCI) for physical downlink shared channel (PDSCH), wherein a MTC data payload flag indicates that a MTC data payload is available.

12. An apparatus according to any one of Claims 10 to 11, wherein the at least one memory including the computer program code is further configured to, with the at least one processor, cause the apparatus to:

decode the MTC data payload on a physical downlink shared channel (PDSCH).

13. An apparatus according to any one of Claims 10 to 12 wherein the at least one memory including the computer program code is further configured to, with the at least one processor, cause the apparatus to:

cause the idle mode duty cycle timer to be set based on a variable duty cycle timer configuration received from an access point, wherein the variable duty cycle timer configuration is configured for space time domain multiplexing (SDMA) resources.

14. An apparatus according to Claim 13, wherein the idle mode duty cycle timer is configured based on an exponential function.

15. An apparatus according to Claim 13, wherein the variable duty cycle timer configuration is received via at least one of a dedicated signaling for a machine-specific duty cycle or a system information block (SIB) for a cell-specific duty cycle.

16. An apparatus according to any one of Claims 10 to 15, wherein the idle mode duty cycle timer is configured to be increased exponentially to a predetermined maximum value.

17. An apparatus according to any one of Claims 10 to 16, wherein the at least the subset of a PRB is linked to an aggregation level.

18. A computer program product comprising:

at least one computer readable non-transitory memory medium having program code stored thereon, the program code which when executed by an apparatus cause the apparatus at least to:

cause a transition from an idle mode in an instance in which an idle duty cycle timer expires;

determine whether a machine type communication (MTC) data payload in at least a subset of a physical resource block (PRB) is available in an instance in which a variable duty cycle timer expires;

cause an idle mode duty cycle timer to be increased in an instance in which a MTC data payload is not detected; and

cause the idle mode duty cycle timer to be reset in an instance in which the MTC data payload is detected.

19. A computer program product according to Claim 18, further comprising program code instructions configured to:

determine whether the MTC data payload is flagged in an MTC downlink control information (DCI) for physical downlink shared channel (PDSCH), wherein a MTC data payload flag indicates that a MTC data payload is available.

20. A computer program product according to any one of Claims 18 to 19, further comprising program code instructions configured to:

decode the MTC data payload on a physical downlink shared channel (PDSCH).

21. A computer program product according to any one of Claims 18 to 20, further comprising program code instructions configured to:

cause the idle mode duty cycle timer to be set based on a variable duty cycle timer configuration received from an access point, wherein the variable duty cycle timer configuration is configured for space time domain multiplexing (SDMA) resources.

22. A computer program product according to Claim 21, wherein the idle mode duty cycle timer is configured based on an exponential function.

23. A computer program product according to Claim 21, wherein the variable duty cycle timer configuration is received via at least one of a dedicated signaling for a machine-specific duty cycle or a system information block (SIB) for a cell-specific duty cycle.

24. A computer program product according to any one of Claims 18 to 23, wherein the idle mode duty cycle timer is configured to be increased exponentially to a predetermined maximum value.

25. A computer program product according to any one of Claims 18 to 24, wherein the at least the subset of a PRB is linked to an aggregation level.

26. An apparatus comprising:

means for causing a transition from an idle mode to an active mode in an instance in which an idle duty cycle timer expires;

means for determining whether a machine type communication (MTC) data payload in at least a subset of a physical resource block (PRB) is available in an instance in which a variable duty cycle timer expires;

means for causing an idle mode duty cycle timer to be increased in an instance in which a MTC data payload is not detected; and

means for causing the idle mode duty cycle timer to be reset in an instance in which the MTC data payload is detected.

27. An apparatus according to Claim 26, further comprising:

means for determining whether the MTC data payload is flagged in an MTC downlink control information (DCI) for physical downlink shared channel (PDSCH), wherein a MTC data payload flag indicates that a MTC data payload is available.

28. An apparatus according to any one of Claims 26 to 27, further comprising:

means for decoding the MTC data payload on a physical downlink shared channel (PDSCH).

29. An apparatus according to any one of Claims 26 to 28, further comprising:

means for causing the idle mode duty cycle timer to be set based on a variable duty cycle timer configuration received from an access point, wherein the variable duty cycle timer configuration is configured for space time domain multiplexing (SDMA) resources.

30. An apparatus according to Claim 29, wherein the idle mode duty cycle timer is configured based on an exponential function.

31. An apparatus according to Claim 29, wherein the variable duty cycle timer configuration is received via a dedicated signaling for a machine-specific duty cycle.

32. An apparatus according to Claim 29, wherein the variable duty cycle timer configuration is received via a system information block (SIB) for a cell-specific duty cycle.

33. An apparatus according to any one of Claims 26 to 32, wherein the idle mode duty cycle timer is configured to be increased exponentially until it reaches a predetermined maximum value.

34. An apparatus according to any one of Claims 26 to 34, wherein the at least the subset of a PRB is linked to an aggregation level.

35. A method comprising:

determining, for at least one communications device, a variable duty cycle timer configuration for space time domain multiplexing (SDMA);

causing the variable duty cycle timer configuration to be transmitted to the at least one communications device, wherein the variable duty cycle timer configuration is configured to cause an idle mode duty cycle timer to be set on the at least one communications device;

determining whether a machine type communication (MTC) data payload in at least a subset of a physical resource block (PRB) is available for the at least one communications device; and

causing a MTC payload repetition to be flagged in an MTC downlink control information (DCI) for a physical downlink shared channel (PDSCH), wherein the MTC payload repetition flag indicates that a MTC data payload is available to the at least one communications device and the MTC payload repetition flag is configured to be checked at least in an instance in which the idle mode duty cycle timer expires.

36. A method according to Claim 35, wherein the idle mode duty cycle timer is configured based on an exponential function.

37. A method according to any one of Claims 35 to 36, wherein the variable duty cycle timer configuration is transmitted via a dedicated signaling for a machine-specific duty cycle.

38. A method according to any one of Claims 35 to 37, wherein the variable duty cycle timer configuration is transmitted via a system information block (SIB) for a cell-specific duty cycle.

39. A method according to any one of Claims 35 to 38, wherein the idle mode duty cycle timer is configured to be increased exponentially to a predetermined maximum value.

40. A method according to any one of Claims 35 to 39, wherein the at least the subset of a PRB is linked to an aggregation level.

41. An apparatus comprising:

at least one processor; and

at least one memory including computer program code, the at least one memory and the computer program code configured to, with the at least one processor, cause the apparatus to at least:

determine, for at least one communications device, a variable duty cycle timer configuration for space time domain multiplexing (SDMA);

cause the variable duty cycle timer configuration to be transmitted to the at least one communications device, wherein the variable duty cycle timer configuration is configured to cause an idle mode duty cycle timer to be set on the at least one communications device;

determine whether a machine type communication (MTC) data payload in at least a subset of a physical resource block (PRB) is available for the at least one communications device; and

cause a MTC payload repetition to be flagged in an MTC downlink control information (DCI) for a physical downlink shared channel (PDSCH), wherein the MTC payload repetition flag indicates that a MTC data payload is available to the at least one communications device and the MTC payload repetition flag is configured to be checked at least in an instance in which the idle mode duty cycle timer expires.

42. An apparatus according to Claim 41, wherein the idle mode duty cycle timer is configured based on an exponential function.

43. An apparatus according to any one of Claims 41 to 42, wherein the variable duty cycle timer configuration is transmitted via a dedicated signaling for a machine-specific duty cycle.

44. An apparatus according to any one of Claims 41 to 43, wherein the variable duty cycle timer configuration is transmitted via a system information block (SIB) for a cell-specific duty cycle.

45. An apparatus according to any one of Claims 41 to 44, wherein the idle mode duty cycle timer is configured to be increased exponentially to a predetermined maximum value.

46. An apparatus according to any one of Claims 41 to 45, wherein the at least the subset of a PRB is linked to an aggregation level.

47. A computer program product comprising:

at least one computer readable non-transitory memory medium having program code stored thereon, the program code which when executed by an apparatus cause the apparatus at least to:

determine, for at least one communications device, a variable duty cycle timer configuration for space time domain multiplexing (SDMA);

cause the variable duty cycle timer configuration to be transmitted to the at least one communications device, wherein the variable duty cycle timer configuration is configured to cause an idle mode duty cycle timer to be set on the at least one communications device;

determine whether a machine type communication (MTC) data payload in at least a subset of a physical resource block (PRB) is available for the at least one communications device; and

cause a MTC payload repetition to be flagged in an MTC downlink control information (DCI) for a physical downlink shared channel (PDSCH), wherein the MTC payload repetition flag indicates that a MTC data payload is available to the at least one communications device and the MTC payload repetition flag is configured to be checked at least in an instance in which the idle mode duty cycle timer expires.

48. A computer program product according to Claim 47, wherein the idle mode duty cycle timer is configured based on an exponential function.

49. A computer program product according to any one of Claims 47 to 48, wherein the variable duty cycle timer configuration is transmitted via a dedicated signaling for a machine-specific duty cycle.

50. A computer program product according to any one of Claims 47 to 49, wherein the variable duty cycle timer configuration is transmitted via a system information block (SIB) for a cell-specific duty cycle.

51. A computer program product according to any one of Claims 47 to 50, wherein the idle mode duty cycle timer is configured to be increased exponentially to a predetermined maximum value.

52. A computer program product according to any one of Claims 47 to 51, wherein the at least the subset of a PRB is linked to an aggregation level.

53. An apparatus comprising:

means for determining, for at least one communications device, a variable duty cycle timer configuration for space time domain multiplexing (SDMA);

means for causing the variable duty cycle timer configuration to be transmitted to the at least one communications device, wherein the variable duty cycle timer configuration is configured to cause an idle mode duty cycle timer to be set on the at least one communications device;

means for determining whether a machine type communication (MTC) data payload in at least a subset of a physical resource block (PRB) is available for the at least one communications device; and means for causing a MTC payload repetition to be flagged in an MTC downlink control information (DCI) for a physical downlink shared channel (PDSCH), wherein the MTC payload repetition flag indicates that a MTC data payload is available to the at least one communications device and the MTC payload repetition flag is configured to be checked at least in an instance in which the idle mode duty cycle timer expires.

54. An apparatus according to Claim 53, wherein the idle mode duty cycle timer is configured based on an exponential function.

55. An apparatus according to any one of Claims 53 to 54, wherein the variable duty cycle timer configuration is transmitted via a dedicated signaling for a machine-specific duty cycle.

56. An apparatus according to any one of Claims 53 to 55, wherein the variable duty cycle timer configuration is transmitted via a system information block (SIB) for a cell-specific duty cycle.

57. An apparatus according to any one of Claims 53 to 56, wherein the idle mode duty cycle timer is configured to be increased exponentially to a predetermined maximum value.

58. An apparatus according to any one of Claims 53 to 57, wherein the at least the subset of a PRB is linked to an aggregation level.

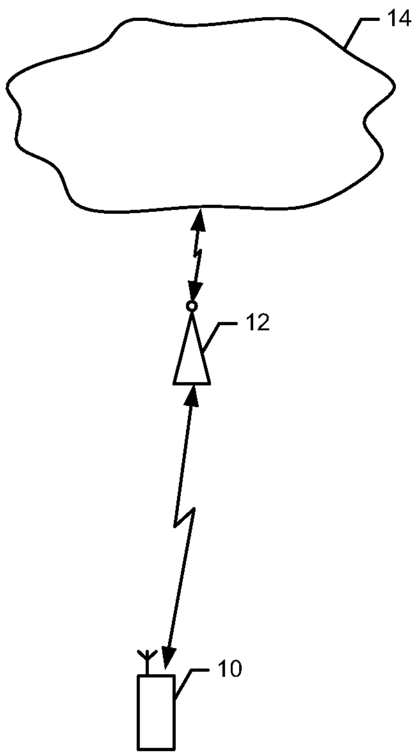

FIG. 1

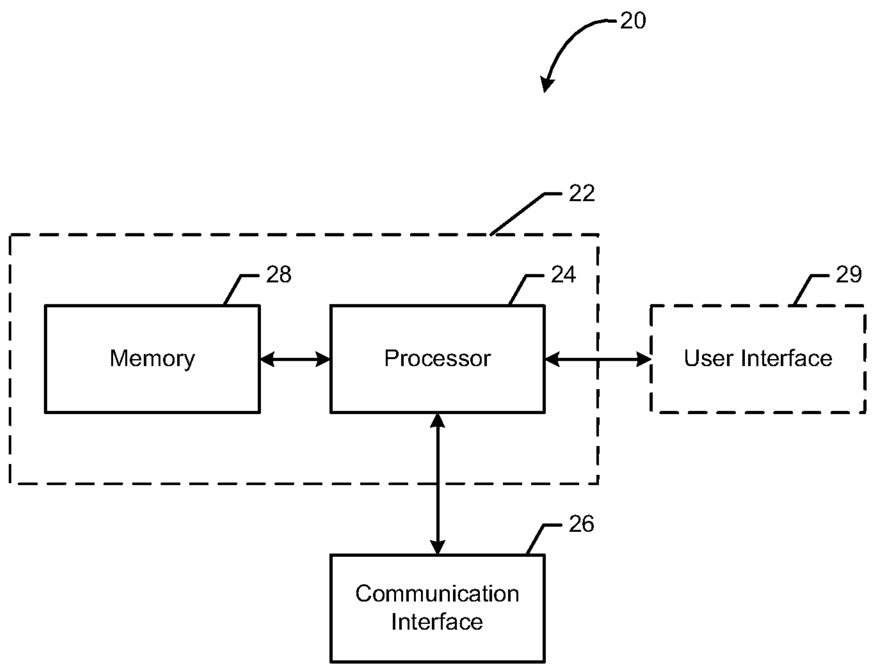
20
22
28
24
29
Memory
Processor
User Interface
26
Communication
Interface

FIG. 2

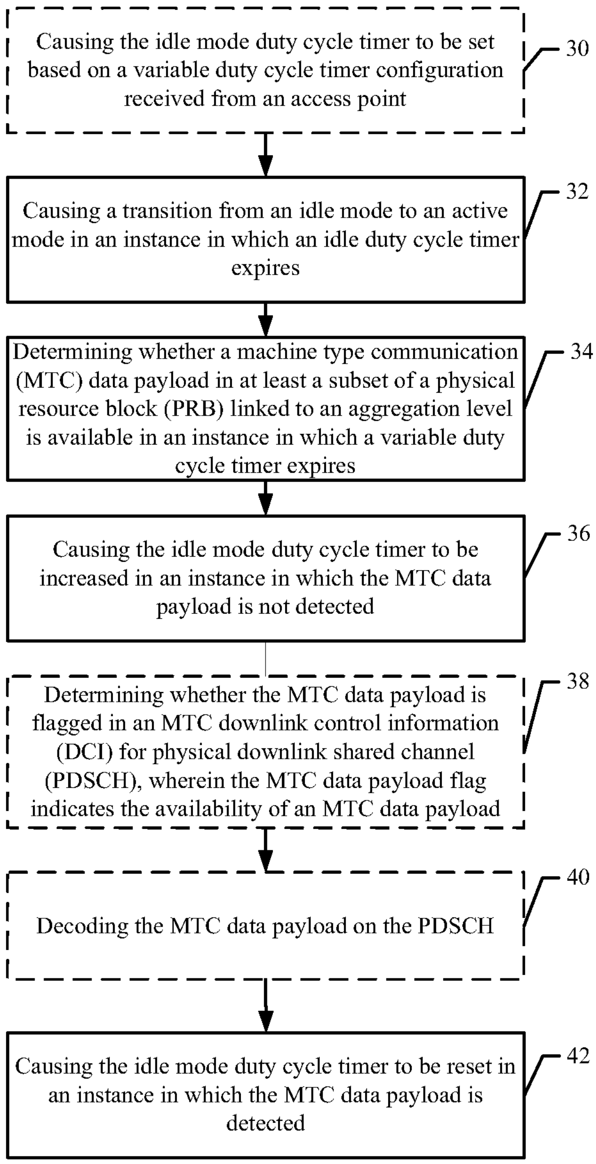
Causing the idle mode duty cycle timer to be set based on a variable duty cycle timer configuration received from an access point
30
Causing a transition from an idle mode to an active mode in an instance in which an idle duty cycle timer expires
32
Determining whether a machine type communication (MTC) data payload in at least a subset of a physical resource block (PRB) linked to an aggregation level is available in an instance in which a variable duty cycle timer expires
34
Causing the idle mode duty cycle timer to be increased in an instance in which the MTC data payload is not detected
36
Determining whether the MTC data payload is flagged in an MTC downlink control information (DCI) for physical downlink shared channel (PDSCH), wherein the MTC data payload flag indicates the availability of an MTC data payload
38
Decoding the MTC data payload on the PDSCH
40
Causing the idle mode duty cycle timer to be reset in an instance in which the MTC data payload is detected
42

FIG. 3

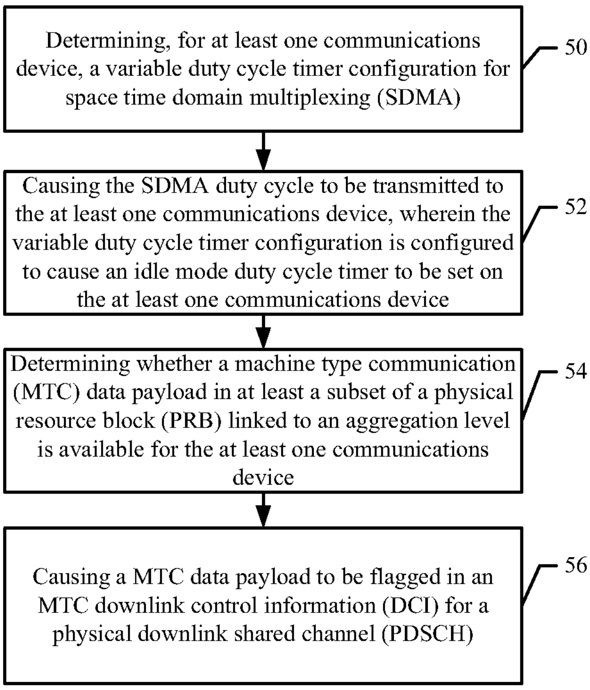
Determining, for at least one communications device, a variable duty cycle timer configuration for space time domain multiplexing (SDMA)
50
Causing the SDMA duty cycle to be transmitted to the at least one communications device, wherein the variable duty cycle timer configuration is configured to cause an idle mode duty cycle timer to be set on the at least one communications device
52
Determining whether a machine type communication (MTC) data payload in at least a subset of a physical resource block (PRB) linked to an aggregation level is available for the at least one communications device
54
Causing a MTC data payload to be flagged in an MTC downlink control information (DCI) for a physical downlink shared channel (PDSCH)
56

FIG. 4

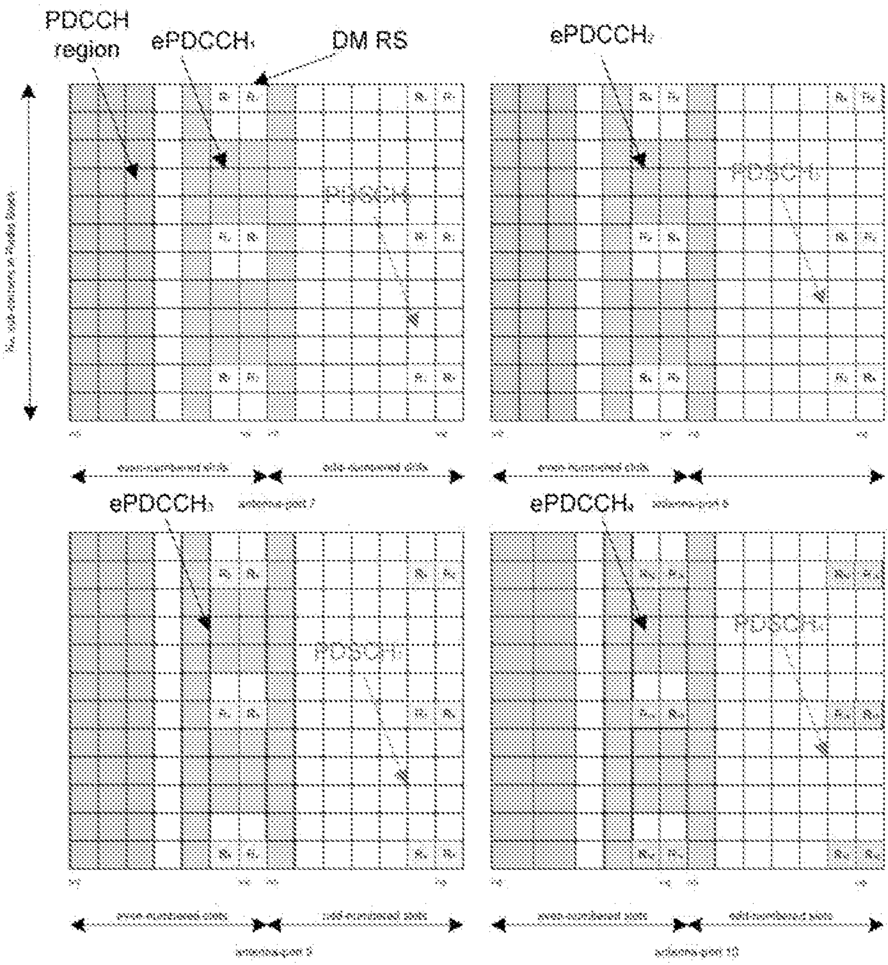

FIG. 5

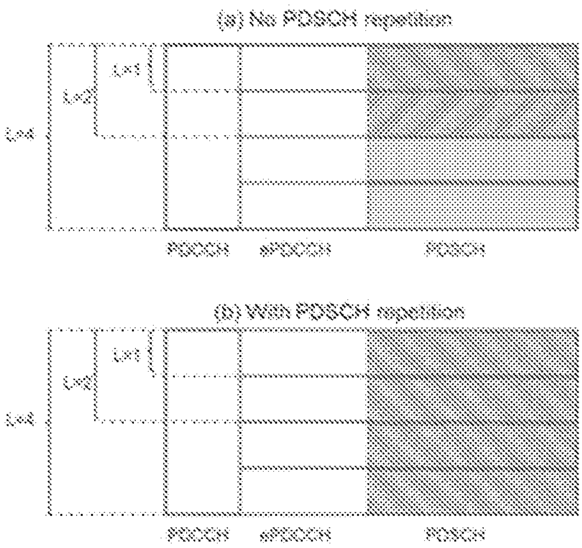
(a) No PDSCH repetition
L=1
L=2
L=4
PDCCH
ePDCCH
PDSCH
(b) With PDSCH repetition
L=1
L=2
L=4
PDCCH
ePDCCH
PDSCH

FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2012/070706

A. CLASSIFICATION OF SUBJECT MATTER

H04W 88/02 (2009.01) i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: H04W,H04B,H04Q

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

CNABS;CNTXT;CNKI;VEN: idle, sleep, doze, standby, power save, mode, active, awake, duty cycle timer, DCT, timer?, machine type communication, MTC, payload?, physical resource block, PRB, space time domain multiplexing, SDMA

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CN101610597A (ZTE CORP.) 23 Dec. 2009(23.12.2009) the whole document	1-58
A	CN101087172A (SONY CORP.) 12 Dec. 2007(12.12.2007) the whole document	1-58
A	CN1714586A (NTT DOCOMO INC.) 28 Dec. 2005(28.12.2005) the whole document	1-58
A	CN101803446A (PANASONIC CORP.) 11 Aug. 2010(11.08.2010) the whole document	1-58

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

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim (S) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&"document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
06 Oct. 2012(06.10.2012)	**18 Oct. 2012 (18.10.2012)**

Name and mailing address of the ISA/CN
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100088
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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2012/070706

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
CN101610597A	23.12.2009	CN101610597B	09.05.2012
CN101087172A	12.12.2007	EP1865664A2	12.12.2007
		JP2007329696A	20.12.2007
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CN101803446A	11.08.2010	WO2010007739A1	21.01.2010
		US2010232415A1	16.09.2010
		EP2302976A1	30.03.2011
		JP2010520752T2	05.01.2012