[0001] # IMPLICIT DRX CYCLE LENGTH ADJUSTMENT CONTROL IN LTE_ACTIVE MODE

[0002] ## FIELD OF DISCLOSURE

[0003] The present invention is in the field of wireless communications.

[0004] ## BACKGROUND

[0005] A goal of the Third Generation Partnership Project (3GPP) Long Term Evolution (LTE) program is to develop new technology, new architecture and new methods for settings and configurations in wireless communication systems in order to improve spectral efficiency, reduce latency and better utilize the radio resource to bring faster user experiences and richer applications and services to users with lower costs.

[0006] In a typical LTE network, a wireless transmit/receive unit (WTRU) may operate in a number of modes. While in LTE_ACTIVE mode, the WTRU may operate in a discontinuous reception (DRX) mode. DRX mode allows the WTRU to operate in a low power, or sleep mode, for a preset time, and then switch to a full power, or awake, mode for another preset time in order to reduce battery consumption. The DRX cycle lengths are generally configured by the enhanced universal terrestrial radio access network (E-UTRAN) so that an enhanced Node B (eNB) and the WTRU are synchronized on a consistent sleep and wake-up cycle.

[0007] Live traffic situations and WTRU mobility may require frequent adjustment of the DRX cycle length in order to balance system performance, WTRU performance and WTRU power savings. However, relying only on WTRU/E-UTRAN signaling to make the fine DRX cycle adjustment may incur a heavy system and WTRU signaling load.

[0008] Implicit rules for DRX cycle length adjustment may be used for smooth LTE_ACTIVE DRX operations to reduce battery power consumption while not effecting system or WTRU performance issues. Implicit rules may

assist the implicit DRX cycle length transitions between the WTRU and the E-UTRAN without using excessive explicit signaling.

[0009] SUMMARY

[0010] A method and apparatus are disclosed for controlling discontinuous reception in a WTRU. The method may include defining a plurality of DRX levels, wherein each DRX level includes a respective DRX cycle length, and transitioning between DRX levels based on a set of criteria. Transitioning may be triggered by implicit rules. Triggering may be invoked by a measurement event, a timer, a counter or a downlink command, for example. The transitions between DRX states may occur without explicit signaling.

[0011] BRIEF DESCRIPTION OF THE DRAWINGS

[0012] A more detailed understanding may be had from the following description, given by way of example and to be understood in conjunction with the accompanying drawings wherein:

[0013] Figure 1 shows a wireless communications system in accordance with one embodiment;

[0014] Figure 2 is a functional block diagram of a WTRU and an e Node B (eNB) in accordance with one embodiment; and

[0015] Figure 3 is a state diagram of implicit DRX transition in accordance with one embodiment;

[0016] Figure 4 is a signal flow diagram for implicit DRX transition in accordance with one embodiment;

[0017] Figure 5 is a flow diagram for a method of implicit DRX signaling in accordance with one embodiment;

[0018] Figure 6 is a flow diagram for a method of implicit DRX signaling in accordance with another embodiment;

[0019] Figure 7 is a flow diagram for a method of implicit DRX signaling in accordance with an alternative embodiment; and

[0020] Figure 8 is a flow diagram for a method of implicit DRX signaling in accordance with another alternative embodiment.

[0021] DETAILED DESCRIPTION

[0022] When referred to hereafter, the terminology "wireless transmit/receive unit (WTRU)" includes but is not limited to a user equipment (UE), a mobile station, a fixed or mobile subscriber unit, a pager, a cellular telephone, a personal digital assistant (PDA), a computer, or any other type of user device capable of operating in a wireless environment. When referred to hereafter, the terminology "base station" includes but is not limited to a Node-B, a site controller, an access point (AP), or any other type of interfacing device capable of operating in a wireless environment.

[0023] Figure 1 shows a wireless communication system 100 in accordance with one embodiment. The system 100 includes a plurality of WTRUs 110 and an eNB 120. As shown in Figure 1, the WTRUs 110 are in communication with the eNB 120. Although three WTRUs 110 and one eNB 120 are shown in Figure 1, it should be noted that any combination of wireless and wired devices may be included in the wireless communication system 100. The eNB 120 and the WTRUs 110 may communicate while in DRX mode and may have coordinated DRX cycles.

[0024] Figure 2 is a functional block diagram 200 of a WTRU 110 and the eNB 120 of the wireless communication system 100 of Figure 1. As shown in Figure 1, the WTRU 110 is in communication with the eNB 120. Both WTRU 110 and eNB 120 may operate in DRX mode.

[0025] In addition to the components that may be found in a typical WTRU, the WTRU 110 includes a processor 215, a receiver 216, a transmitter 217, and an antenna 218. The processor 215 may be configured to adjust DRX cycle length as necessary. The receiver 216 and the transmitter 217 are in communication with the processor 215. The antenna 218 is in communication with both the receiver 216 and the transmitter 217 to facilitate the transmission and reception of wireless data.

[0026] In addition to the components that may be found in a typical eNB 120, the eNB 120 includes a processor 225, a receiver 226, a transmitter 227, and an antenna 228. The processor 225 is configured to communicate with the receiver 226 and transmitter 227 to adjust DRX cycles as necessary. The receiver 226 and the transmitter 227 are in communication with the processor 225. The antenna 228 is in communication with both the receiver 226 and the transmitter 227 to facilitate the transmission and reception of wireless data.

[0027] In order to improve battery life, but not limit the eNB 120 and WTRU 110 performance, transitions between DRX cycle length states may be defined implicitly, rather than explicitly. The implicit rules may be implemented at the radio resource control (RRC) and the medium access control (MAC) levels while the WTRU 110 is in a LTE_ACTIVE DRX state.

[0028] Approximately half of WTRU 110 to eNB 120 interaction involves WTRU 110 requests and reports and eNB 120 responses while the WTRU 110 is in LTE_ACTIVE DRX mode. When the WTRU 110 measures a particular scenario, measurement events may be reported to the eNB 120, and the eNB 120 may respond to the situation by commanding the WTRU 110 to start a new service, mobility activity, and the like. If the downlink command transmission or reception is limited by a relatively long DRX cycle length, WTRU 110 and eNB 120 system performance during LTE_ACTIVE DRX mode may suffer. However, certain measurement events may make good candidates for the anticipated network downlink commands.

[0029] Figure 3 shows an implicit DRX transition state machine 300 in accordance with one embodiment. The state machine 300, as well as associated transition mechanisms and parameter values, may be configured by the eNB (120 of Figure 1). The state machine 300 may have a life span, also configured by the eNB 120. Each state may be applied at the WTRU (110 of Figure 1) and at the eNB 120, so that operation is consistent and synchronized. At each defined and configured DRX state, a different DRX cycle length is associated with both the WTRU 110 and the eNB 120 operations.

[0030] The DRX cycle length transition rules may be based on WTRU 110 and eNB 120 experiences. Given a certain elapsed time, or a given set of measurement values, the WTRU 110 and the eNB 120 may learn and predict traffic patterns. These learned and predicted traffic patterns may be superimposed on a general model for a state machine, resulting in the DRX state machine 300 for a WTRU 110/eNB 120 system that permits implicit transition operation and consistent DRX actions for both the WTRU 110 and the eNB 120. The eNB 120 can prescribe DRX states for service and mobility conditions with the potential for continuous improvement and learned traffic patterns upon every invocation.

[0031] Figure 3 shows 3 defined DRX levels, 302, 304, 306 and an undefined DRX level 308. In DRX level 3 306, the WTRU 110 is operating in a normal DRX cycle. The actual length of the normal state may be defined by the eNB 120. DRX level 2 304 is a shorter cycle length than DRX level 3 306, and is associated with more frequent activity than normal. The eNB 120 may also define the cycle length for DRX level 2 304, and may also set a "resume" period. A resume period is a length of time in which there are no new transmissions and after which the WTRU 110 may return to DRX level 3 306 operation, unless the WTRU 110 is commanded to do otherwise.

[0032] DRX level 1 302 has the shortest DRX cycle length, and may be used by a WTRU 110 or eNB 120 to handle predicted immediate downlink commands and when uplink traffic patterns are recognized by the WTRU 110 and the eNB 120 as requiring immediate downlink action, such as during a handover event, for example.

[0033] A DRX level n 308 may be configured with longer DRX cycles than that for the DRX Level 3 306. The eNB 120 can redefine the DRX cycle lengths for each state at the end of the DRX configuration life span but may observe a DRX cycle length rule that lower level DRX states have shorter DRX lengths.

[0034] For a WTRU 110 at DRX level 3 306, a timer or counter trigger may be defined to trigger a transition to DRX Level 2 304 if the eNB 120 determines that the WTRU 110 should periodically transition to a “busy” cycle to check

downlink data. This may be considered a trigger based on a measurement event. Another trigger based on a measurement event can also be defined to transition a WTRU 110 from DRX level-3 306 to DRX Level 1 when a traffic volume event on a certain radio bearer accumulating a larger amount of uplink data than a threshold is reported and an anticipated Radio Bearer (RB) Reconfiguration command is imminent.

[0035] If the WTRU 110 in DRX Level 1 302 state receives a RB Reconfiguration command, the current DRX Level 1 state is over. If the WTRU 110 at DRX Level 1 state 302 does not receive the anticipated command for the defined "resume period", it can go back to its original DRX state and resume the power saving DRX cycle. Regular timers and counters may be used during a DRX mode to trigger the implicit DRX cycle length transition. The choice between the timers and counters and the values of the timers or counters may be based on learned traffic patterns and models with respect to the mobility and/or service state of the WTRU 110 at a particular time while the WTRU 110 is in LTE_ACTIVE DRX mode. The timer or counter triggers may be used as transition triggers to bring up the DRX cycle length as well as to bring down the DRX cycle length as the DRX state changes.

[0036] The eNB 120 may configures DRX parameters based on a network traffic monitoring operation and analysis. Several methods exist to select the parameter values, such as by including a default system value set that is defined for implicit DRX transition operation. Optionally, the parameters may be published in system information broadcasts, or they can be determined by the eNB 120 from time to time and loaded to a particular WTRU 110 via higher layer signaling before an intended DRX mode period.

[0037] Transitions between different states may be signaled in an information element. An example of a skeleton for signaling an implicit DRX cycle transition if shown in Table 1. As shown in Table 1, the Implicit DRX Transition List is mandatory and is limited to a value indicating a maximum number of DRX states.

[0038] The DRX cycle length IE is mandatory, and is an integer. The trigger mechanisms are optional, and may be a trigger to move up a DRX state level, or move down a DRX state level. The Implicit DRX Transition configured life Span IE is mandatory, and sets the resume period for non-normal states. The Initial DRX state is optional, and may set the DRX state of the WTRU 110 at start-up.

[0039] To aid with easier DRX cycle length transition and maintain DRX cycle length synchronization between the WTRU 110 and the eNB 120, the DRX cycle length definition may be given as a function of the shortest DRX base number (L). Then various DRX length values may be:

[0040] $DRX\text{-}cycle\text{-}len = L \times 2^n$, Equation(1)

where n = 0, 1, 2... such that the resulting DRX-cycle-len does not exceed a maximum DRX cycle length. The shortest DRX cycle length possible occurs when n=0, and is a fraction of a longer DRX cycle length.

[0041] The use of DRX cycle lengths that are multiples of each other reduces the probability that DRX periods may be mismatched and provides an efficient mechanism to resynchronize DRX periods between the WTRU 110 and eNB 120. When DRX periods are defined as multiples of each other, and when DRX periods become mismatched between the WTRU 110 and the eNB 120, each entity can determine the period of the other by increasing or decreasing the cycle length to determine the period being used by the other entity, and resynchronizing the entities accordingly.

[0042] Typically, a WTRU 110 in DRX Level 1 302 may count n times before it transits back to the original DRX state. The default may be given as: n = (Level-k DRX Cycle Length or original DRX cycle length) / Level-1 DRX Cycle Length; where Level-k cycle length is the length of the DRX cycle before the WTRU 110 enters DRX Level 1 302. Alternatively, the network may configure n for the "resume method".

Information Element/Group name	Need	Multi	Type and reference	Semantics description
Implicit DRX Transition List	MP	maxDR Xstates		

Information Element/Group name	Need	Multi	Type and reference	Semantics description
		(TBD)		
>DRX Cycle Length	MP		Integer (TBD)	
>Trigger-UP-1	OP		Trigger Mechanism A.B.C.D	To next upper level DRX State
>Trigger-UP-2	OP		Trigger Mechanism A.B.C.D	Used by Level-1 for resume
>Trigger-Down-1	OP		Trigger Mechanism A.B.C.D	To next lower level DRX state
>Trigger-Down-2	OP		Trigger Mechanism A.B.C.D	To Level-1 trigger
Implicit DRX Transition configured life span	MP		TBD	Time in seconds
Initial DRX state	OP		TBD	

[0043] TABLE 1

[0044] Transitions from state to state may be initiated by a trigger. Table 2 shows an example of transition trigger IEs. Each of the IEs is mandatory, except for the resume period. The Transition Trigger is mandatory and is specified by the network if specified as shown in Table 1. The CHOICE mechanism allows the network to configure the WTRU 110 for implicit DRX operational triggers. The trigger Timer value may be in units of absolute time, LTE frames or transmission time intervals (TTIs) and is used to monitor or regulate ON and OFF periods for network signaling channel activities or data channel activities for the WTRU 110. The Counter values may be an integer value used to check the occurrences of certain trigger events. The measurement event may enumerate the event that causes the trigger. The resume period may be a time period given in seconds, DRX cycles, or some other value, that denotes the total time a WTRU 110 may remain in an elevated state without receiving a command to move back to normal state.

Information Element/Group name	Need	Multi	Type and reference	Semantics description
Transition Trigger	MP			
CHOICE mechanism	MP			
>Timer				
>> Timer Value	MP		Integer TBD	
>Counter				
>> Counts	MP		Integer TBD	
> Measurement Event				
>> measurement Event-Id	MP		Enumerated (TBD)	
>resume period	CV-Trigger -UP-2		TBD	Could be default in Level-1 State. Default is to stay n Level-1 cycles so the total length is equivalent to its original DRX state DRX length

[0045] TABLE 2

[0046] Figure 4 is a signal flow diagram for implicit DRX transition 400 in accordance with one embodiment. A WTRU 402 may receive an RRC message or an IE 406 from the E-UTRAN 404 that triggers the WTRU 402 to enter DRX mode. The WTRU 402 may enter DRX mode 408 at a default level which may be a normal cycle length DRX level 3 (306 of Figure 3). Both the WTRU 402 and the E-UTRAN 404 enter DRX mode (408, 410 respectively). The WTRU 402 may receive another RRC message or IE 412 that triggers the WTRU 402 to enter a faster DRX cycle mode (DRX level 1 302 of Figure 3). The WTRU 402 and the E-UTRAN 404 enter the DRX level 1 (414, 416 respectively). A WTRU timer 418, synchronized with an E-UTRAN timer (not shown), expires. As the timers are synchronized, no notice of timer expiration is required. The expiration of the timer 418 triggers the WTRU 402 and the E-UTRAN 404 to return to normal DRX level. The WTRU 402 returns 422 to DRX level-3 306 at the same time that the E-UTRAN 404 returns 424 to DRX level-3 306.

[0047] Figure 5 is a flow diagram of a method of implicit signaling 500 in accordance with one embodiment. At step 502 the WTRU is in normal operating

mode, or Level-3. At step 504, the WTRU checks to see if a timer has timed-out, or a trigger has been received that would force the WTRU to move to another DRX state. If no, at step 506, the WTRU remains in normal state. If the WTRU detects a time out signal or a trigger at step 504, at step 508, the WTRU determines if it should move to DRX Level 1 or DRX level 2. If the WTRU determines that the trigger is a level-2 trigger, at step 510 the WTRU moves to DRX Level 2. At step 512, the WTRU determines that the resume period has ended, and returns to DRX level-3. If, however, the WTRU, at step 508, determines that it received a level 1 trigger, at step 514, the WTRU goes into a DRX level 1. At step, 516, the WTRU determines if it has received a Radio Bearer Reconfiguration message. If not, the WTRU, at step 518, waits for the resume period to end and returns to normal operation at step 522. If, however, at step 518, the WTRU receives a radio bearer reconfigure message, at step 520, the WTRU returns to normal DRX cycle operation.

[0048] Figure 6 is a flow diagram of an implicit DRX method 600 in accordance with another embodiment. At step 602, the WTRU is in normal or DRX Level-3 mode. At step 604, the WTRU conducts a traffic volume measurement. At step 606, the WTRU compares the traffic volume measurement with a threshold. It if the volume is below the threshold, at step 608, the WTRU takes no action and remains in DRX Level-3 mode. However, if, at step 606, the WTRU determines that the traffic is above a threshold, at step 610, the WTRU changes mode to a shorter DRX cycle. Based on the traffic, the new DRX mode may be DRX level-2 or DRX level-1. At step 612, the WTRU determines if a command or message has been received. If yes, at step 614, the WTRU returns to Level-3 mode. If not, the WTRU, at step 616 the WTRU waits the resume period before returning to level-3 mode at step 618. Optionally, the E-UTRAN may determine the traffic volume measurement reporting threshold level for DRX state transition triggering. Once the defined traffic volume measurement event occurs, the DRX state transition is triggered.

[0049] While in LTE_ACTIVE DRX mode, a WTRU may perform traffic volume measurements for uplink traffic. The E-UTRAN may configure the

WTRU to report the events on threshold crossing. Based on learned traffic patterns, the E-UTRAN determines that there is a large volume change, which may means that an RB addition, an RB reconfiguration or an RB release command is imminent. Therefore, the traffic volume event reports may be used as implicit DRX transition triggers. For example, a large volume change may be used to trigger the WTRU into the shortest DRX cycle (DRX level 1, 302 of Figure 3, for example) in order to receive the network command. The network, when receiving the predetermined measurement event, may determine the WTRU's DRX state via implicit DRX transition rules and either sends the anticipated command to the WTRU or wait for the WTRU to return to its previous DRX state with the specified "resume period".

[0050] By way of another example, the WTRU, while in LTE_ACTIVE mode, may use configured handover measurements. Certain measurement event reports may indicate that a handover (HO) command is imminent for intra-frequency, inter-frequency or an inter-radio access technology (RAT) handover. Depending on handover measurement events, certain other measurement events may act as triggers for DRX transition control. Figure 7 is a flow diagram of a method of implicit DRX signaling 700 in accordance with an alternative embodiment. At step 702, the WTRU is in normal DRX level 3 state. At step 704, the WTRU determines that a serving cell measurement is below a threshold. The WTRU may then determine that an intra-frequency measurement is high 706, meaning that an intra-frequency neighbor is measuring as the best cell. Alternatively, the WTRU may determine that an inter-frequency band measures to be the best 708. As another alternative, the WTRU may determine that a non-LTE system measures the best 710.

[0051] At step 712, the WTRU, due to the measurements, may anticipate a handover command. At step 714, the WTRU reports the measurement event. This may invoke, at step 716, an implicit DRX transition trigger that causes the WTRU to go to a Level-1 DRX state in order to receive the possible handover command from the network. At step 718, the WTRU receives the handover command. At step 720, the WTRU transitions back to its original DRX state.

[0052] Figure 8 is a flow diagram of a method of implicit DRX cycle signaling 800 in accordance with yet another embodiment. At step 802, the WTRU is level-1 mode. At step 804, the WTRU begins to monitor a Level 1/Level 2 control channel to intercept anticipated downlink commands. At step 806, the WTRU determines if an anticipated network command is received. If received, at step 808, the WTRU will follow the command to end the DRX mode or will receive instruction on the next DRX activity with the command. If the command is not received, at step 810, the WTRU transitions back to its original DRX state before entering the Level-1 state.

[0053] EMBODIMENTS

1. A method for controlling discontinuous reception (DRX) in a wireless transmit/receive unit (WTRU), the method comprising defining a plurality of DRX levels, wherein each DRX level includes a respective DRX cycle length.

2. The method as in embodiment 1 further comprising transitioning between DRX levels based on a set of criteria.

3. The method as in embodiment 2 wherein the set of criteria is predefined.

4. The method as in embodiment 2 wherein the set of criteria is based on events detected by the WTRU.

5. The method as in embodiment 2 wherein the set of criteria is based on explicit signals received by the WTRU.

6. The method as in embodiment 2 or 3 wherein the set of criteria is defined dynamically.

7. The method as in any one of embodiments 2-6 wherein transitioning between the plurality of DRX levels is based upon learned traffic patterns.

8. The method as in any one of embodiments 2-6 wherein transitioning between the plurality of DRX levels is based upon measured events.

9. The method as in any one of embodiments 1-8 further comprising defining three DRX levels.

10. The method as in any one of embodiments 1-9 further comprising defining two DRX levels.

11. The method as in any one of embodiments 1-10 wherein each respective DRX cycle length is a function of a shortest DRX cycle length.

12. The method as in embodiment 11 wherein each respective DRX cycle length is below a maximum DRX cycle length.

13. The method as in any one of embodiments 1-12 wherein each respective cycle length is a multiple of a base cycle length.

14. The method as in any one of embodiments 1-13 further comprising the WTRU synchronizing DRX cycle length with an e Node B (eNB).

15. The method as in embodiment 14 further comprising the WTRU increasing the DRX cycle length upon loss of synchronization.

16. The method as in embodiment 15 further comprising the WTRU increasing the DRX cycle length until the WTRU is synchronized with the eNB.

17. The method as in embodiment 14 further comprising the WTRU decreasing the DRX cycle length upon loss of synchronization.

18. The method as in embodiment 17 further comprising the WTRU decreasing the DRX cycle length until the WTU is synchronized with the eNB.

19. The method as in any one of embodiments 1-18 further comprising defining a DRX life span; and redefining the DRX cycle lengths of the plurality of DRX levels once per DRX life span.

20. The method as in any one of embodiments 2-19 further comprising periodically changing the DRX level of a WTRU to a DRX level having a shorter DRX cycle length.

21. The method as in any one of embodiments 2-20 further comprising changing DRX levels based on a trigger.

22. The method as in embodiment 21 wherein the trigger is the expiry of a timer.

23. The method as in embodiment 22 further comprising resetting the timer upon transmission activity.

24. The method as in embodiment 21 wherein the trigger is a traffic event.

25. The method as in embodiment 24 wherein the traffic event is a transmission.

26. The method as in embodiment 21 wherein the trigger is a radio bearer reconfiguration request.

27. The method as in any one of embodiments 2-20 further comprising changing DRX levels periodically based on learned traffic patterns.

28. The method as in any one of embodiments 1-27 further comprising measuring traffic volume at a WTRU; and adjusting the DRX cycle length of the plurality of DRX levels based on the measured traffic volume.

29. The method as embodiment 28 further comprising shortening the DRX cycle length when traffic volume is above a predetermined threshold; and lengthening the DRX cycle length when traffic volume is below a predetermined threshold.

30. The method as in embodiment 27 further comprising adding a radio bearer when the measured traffic volume exceeds a predetermined threshold.

31. The method as in any one of embodiments 1-30 further comprising setting a resume period timer upon adjusting a DRX cycle length; and returning the DRX cycle length to an original value upon expiration of the resume period timer.

32. The method as in any one of embodiments 1-21 further comprising changing the DRX level of a WTRU based on handover measurements.

33. The method as in embodiment 32 further comprising changing the DRX level of a WTRU when a serving cell measurement is below a predetermined threshold.

34. The method as in embodiment 33 further comprising changing the DRX level of a WTRU when an intra-frequency neighbor cell measurement is above a threshold.

35. The method as in embodiment 34 further comprising changing the DRX level of a WTRU when an inter-frequency neighbor cell measurement is above a threshold.

36. The method as in embodiment 34 further comprising changing the DRX level of a WTRU when an inter-radio access technology (RAT) neighbor measurement is above a threshold.

37. The method as in any one of embodiments 1-36 further comprising receiving downlink commands at the WTRU; and changing the DRX level based on the type of downlink command.

38. A wireless transmit receive unit (WTRU) comprising a processor, the processor configured to define a plurality of DRX levels, wherein each DRX level includes a respective DRX cycle length.

39. The WTRU as in embodiment 38 wherein the processor is further configured to transition the WTRU between DRX levels based on a set of criteria.

40. The WTRU as in embodiment 38 or 39 wherein the processor is further configured to periodically change the DRX level of the WTRU to a shorter DRX cycle length.

41. The WTRU as in any one of embodiments 38-40 wherein the processor is further configured to transition the WTRU between DRX levels based on a trigger.

42. The WTRU as in embodiment 41 wherein the trigger comprises a measurement event.

43. The WTRU as in embodiment 41 wherein the trigger comprises a timer.

44. The WTRU as in embodiment 41 wherein the trigger comprises a counter.

45. The WTRU as in embodiment 41 wherein the trigger comprises a downlink command.

[0054] Although the features and elements are described in the embodiments in particular combinations, each feature or element can be used alone without the other features and elements or in various combinations with or

without other features and elements. The methods or flow charts provided may be implemented in a computer program, software, or firmware tangibly embodied in a computer-readable storage medium for execution by a general purpose computer or a processor. Examples of computer-readable storage mediums include a read only memory (ROM), a random access memory (RAM), a register, cache memory, semiconductor memory devices, magnetic media such as internal hard disks and removable disks, magneto-optical media, and optical media such as CD-ROM disks, and digital versatile disks (DVDs).

[0055] Suitable processors include, by way of example, a general purpose processor, a special purpose processor, a conventional processor, a digital signal processor (DSP), a plurality of microprocessors, one or more microprocessors in association with a DSP core, a controller, a microcontroller, Application Specific Integrated Circuits (ASICs), Field Programmable Gate Arrays (FPGAs) circuits, any other type of integrated circuit (IC), and/or a state machine.

[0056] A processor in association with software may be used to implement a radio frequency transceiver for use in a wireless transmit receive unit (WTRU), user equipment (UE), terminal, base station, radio network controller (RNC), or any host computer. The WTRU may be used in conjunction with modules, implemented in hardware and/or software, such as a camera, a video camera module, a videophone, a speakerphone, a vibration device, a speaker, a microphone, a television transceiver, a hands free headset, a keyboard, a Bluetooth® module, a frequency modulated (FM) radio unit, a liquid crystal display (LCD) display unit, an organic light-emitting diode (OLED) display unit, a digital music player, a media player, a video game player module, an Internet browser, and/or any wireless local area network (WLAN) module.

* * *

CLAIMS

What is claimed is:

1. A method for controlling discontinuous reception (DRX) in a wireless transmit/receive unit (WTRU), the method comprising:

defining a plurality of DRX levels, wherein each DRX level includes a respective DRX cycle length; and

transitioning between DRX levels based on a set of criteria.

2. The method as in claim 1 wherein the set of criteria is predefined.

3. The method as in claim 1 wherein the set of criteria is based on events detected by the WTRU.

4. The method as in claim 1 wherein the set of criteria is based on explicit signals received by the WTRU.

5. The method as in claim 1 wherein the set of criteria is defined dynamically.

6. The method as in claim 1 wherein transitioning between the plurality of DRX levels is based upon learned traffic patterns.

7. The method of claim as in claim 1 wherein transitioning between the plurality of DRX levels is based upon measured events.

8. The method as in claim 1 further comprising defining three DRX levels.

9. The method as in claim 1 further comprising defining two DRX levels.

10. The method as in claim 1 wherein each respective DRX cycle length is a function of a shortest DRX cycle length.

11. The method as in claim 10 wherein each respective DRX cycle length is below a maximum DRX cycle length.

12. The method as in claim 1 wherein each respective cycle length is a multiple of a base cycle length

13. The method as in claim 1 further comprising the WTRU synchronizing DRX cycle length with an E Node B (eNB).

14. The method as in claim 13 further comprising the WTRU increasing the DRX cycle length upon loss of synchronization.

15. The method as in claim 14 further comprising the WTRU increasing the DRX cycle length until the WTRU is synchronized with the eNB.

16. The method as in claim 13 further comprising the WTRU decreasing the DRX cycle length upon loss of synchronization.

17. The method as in claim 16 further comprising the WTRU decreasing the DRX cycle length until the WTRU is synchronized with the eNB.

18. The method as in claim 1 further comprising:

defining a DRX life span; and

redefining the DRX cycle lengths of the plurality of DRX levels once per DRX life span.

19. The method as in claim 1 further comprising:

periodically changing the DRX level of a WTRU to a DRX level having a shorter DRX cycle length.

20. The method as in claim 1 further comprising changing DRX levels based on a trigger.

21. The method as in claim 11 wherein the trigger is the expiry of a timer.

22. The method as in claim 21 further comprising resetting the timer upon transmission activity.

23. The method as in claim 20 wherein the trigger is a traffic event.

24. The method as in claim 23 wherein the traffic event is a transmission.

25. The method as in claim 20 wherein the trigger is a radio bearer reconfiguration request.

26. The method as in claim 19 further comprising changing DRX levels periodically based on learned traffic patterns.

27. The method as in claim 1 further comprising:

measuring traffic volume at a WTRU;

adjusting the DRX cycle length of the plurality of DRX levels based on the measured traffic volume.

28. The method as in claim 27 further comprising:

shortening the DRX cycle length when traffic volume is above a predetermined threshold; and

lengthening the DRX cycle length when traffic volume is below a predetermined threshold.

29. The method as in claim 26 further comprising:

adding a radio bearer when the measured traffic volume exceeds a predetermined threshold.

30. The method as in claim 1 further comprising:

setting a resume period timer upon adjusting a DRX cycle length; and

returning the DRX cycle length to an original value upon expiration of the resume period timer.

31. The method as in claim 1 further comprising changing the DRX level of a WTRU based on handover measurements.

32. The method as in claim 31 further comprising changing the DRX level of a WTRU when a serving cell measurement is below a predetermined threshold.

33. The method as in claim 32 further comprising changing the DRX level of a WTRU when an intra-frequency neighbor cell measurement is above a threshold.

34. The method as in claim 32 further comprising changing the DRX level of a WTRU when an inter-frequency neighbor cell measurement is above a threshold.

35. The method as in claim 32 further comprising changing the DRX level of a WTRU when an inter-radio access technology (RAT) neighbor measurement is above a threshold.

36. The method as in claim 1 further comprising:

receiving downlink commands at the WTRU; and

changing the DRX level based on the type of downlink command.

37. A wireless transmit receive unit (WTRU) comprising a processor, the processor configured to:

define a plurality of DRX levels, wherein each DRX level includes a respective DRX cycle length; and

transition the WTRU between DRX levels based on a set of criteria.

38. The WTRU as in claim 37 wherein the processor is further configured to periodically change the DRX level of the WTRU to a shorter DRX cycle length.

39. The WTRU as in claim 37 wherein the processor is further configured to transition the WTRU between DRX levels based on a trigger.

40. The WTRU as in claim 39 wherein the trigger comprises a measurement event.

41. The WTRU as in claim 39 wherein the trigger comprises a timer.

42. The WTRU as in claim 39 wherein the trigger comprises a counter.

43. The WTRU as in claim 39 wherein the trigger comprises a downlink command.