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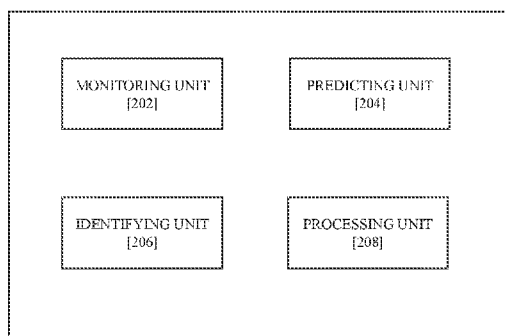
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[200]

FIG. 2



(57) Abstract: The present disclosure relates to a method and a system for proactive energy optimization in a cellular network. The present disclosure encompasses monitoring, by a monitoring unit [202], a network traffic load associated with a plurality of cells of the cellular network. After monitoring the disclosure encompasses predicting, by a predicting unit [204] using a trained model, a traffic pattern for at least one cell of the plurality of cells based on the monitored network traffic load. Further, the disclosure encompasses: identifying, by an identifying unit [206], one or more radio units (RUs) for transitioning into one or more sleep modes based on the predicted traffic pattern; and initiating, by a processing unit [208], at least one of the one or more sleep modes for each of the identified one or more RUs to optimize power consumption.

METHOD AND SYSTEM FOR PROACTIVE ENERGY OPTIMIZATION IN A CELLULAR NETWORK

FIELD OF INVENTION

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[0001] Embodiments of the present disclosure generally relate to network performance management systems. More particularly, embodiments of the present disclosure relate to methods and systems for proactive energy optimization in a cellular network.

10 BACKGROUND

[0002] The following description of the related art is intended to provide background information pertaining to the field of the disclosure. This section may include certain aspects of the art that may be related to various features of the present disclosure. However, it should be appreciated that
15 this section is used only to enhance the understanding of the reader with respect to the present disclosure, and not as admissions of the prior art.

[0003] Wireless communication technology has rapidly evolved over the past few decades, with each generation bringing significant improvements and advancements. The first generation of
20 wireless communication technology was based on analog technology and offered only voice services. However, with the advent of the second-generation (2G) technology, digital communication and data services became possible, and text messaging was introduced. The third generation (3G) technology marked the introduction of high-speed internet access, mobile video calling, and location-based services. The fourth generation (4G) technology revolutionized
25 wireless communication with faster data speeds, better network coverage, and improved security. Currently, the fifth generation (5G) technology is being deployed, promising even faster data speeds, low latency, and the ability to connect multiple devices simultaneously. With each generation, wireless communication technology has become more advanced, sophisticated, and capable of delivering more services to its users.

30 [0004] In wireless communication technologies, it is important to optimize the energy of cells and therefore several solutions have been developed for energy optimization. Existing solutions often rely on reactive mechanisms and include triggering sleep modes based on observed low traffic conditions, wherein in a sleep mode one or more functionalities of a cell or a radio unit of a cellular
35 network are turned off or disabled for a specific time period. These reactive approaches of the

existing solutions can lead to inefficiencies and latency in network performance, as they must wait for low usage periods to trigger energy-saving modes (i.e., sleep modes).

[0005] Conventional energy-saving techniques frequently use fixed thresholds or timers to transition between active and sleep states. In the active state (or active mode) the one or more functionalities of a cell or a radio unit of a cellular network is turned on or enabled. This fixed thresholds or timers-based transition between active and sleep states can lead to sub-optimal energy savings, as these thresholds / timers may not adapt to dynamic network conditions and traffic patterns. Further, the energy-saving modes in existing arts typically lack granularity. They often offer a binary choice between a fully active state and a sleep state, without considering intermediate stages that could offer more balanced energy savings and performance. Currently known techniques fail to efficiently and effectively identify the most appropriate times to activate or deactivate sleep modes, potentially leading to inefficient use of resources. Moreover, the prior solutions may not be adequately adaptable to changes in network conditions, such as fluctuations in network load, varying Quality of Service (QoS) requirements, or changing user behaviour patterns. This lack of adaptability could lead to energy wastage and reduced network performance.

[0006] Thus, there exists an imperative need in the art for a technical solution that aims to address at least the above-mentioned technical issues by managing an energy consumption in cellular networks in an efficient and effective manner.

SUMMARY

[0007] This section is provided to introduce certain aspects of the present disclosure in a simplified form that are further described below in the detailed description. This summary is not intended to identify the key features or the scope of the claimed subject matter.

[0008] An aspect of the present disclosure may relate to a method for proactive energy optimization in a cellular network. The method comprising monitoring, by a monitoring unit, a network traffic load associated with a plurality of cells of the cellular network. Further, the method encompassing predicting, by a predicting unit using a trained model, a traffic pattern for at least one cell of the plurality of cells based on the monitored network traffic load. Further, the method encompassing identifying, by an identifying unit, one or more radio units (RUs) for transitioning into one or more sleep modes based on the predicted traffic pattern. Furthermore, the method

comprises initiating, by a processing unit, at least one of the one or more sleep modes for each of the identified one or more RUs to optimize power consumption.

[0009] In an exemplary aspect of the present disclosure, the method further comprises quantifying, by the processing unit, an energy saving achieved by the at least one of the one or more sleep modes by mapping a power utilization to a physical resource block (PRB) usage.

[0010] In an exemplary aspect of the present disclosure, the method further comprises reactivating, by the processing unit, the one or more RUs from the one or more sleep modes based at least on one of a traffic load breaching a predefined traffic threshold, and a set of predefined triggers.

[0011] In an exemplary aspect of the present disclosure, the method further comprises predicting, by the predicting unit, one or more coverage holes within the cellular network based on the one or more RUs being in the at least one of the one or more sleep modes.

[0012] In an exemplary aspect of the present disclosure, the method further comprises utilizing, by the processing unit, one or more neighbour cells for balancing the network traffic load and maintaining coverage during the one or more sleep modes.

[0013] In an exemplary aspect of the present disclosure, the method further comprises providing, by the processing unit, a neighbour management profile based on at least one of a geographical location and a handover (HO) count for each of the one or more sleep modes for each of the one or more RUs, to facilitate in managing neighbour relationship and provide a list of targeted neighbours for coverage hole analysis and a load balancing.

[0014] In an exemplary aspect of the present disclosure, the trained model is one of a Support Vector Machine (SVM), and a neural network.

[0015] In an exemplary aspect of the present disclosure, the model is trained based on a dataset comprising a historical network performance data and a corresponding traffic load pattern observed within the cellular network.

[0016] In an exemplary aspect of the present disclosure, the one or more sleep modes are selected from a group comprising of a radio unit (RU) Hibernation mode, a Deep Sleep mode, a Light Sleep mode, an Uplink (UL) Transmission Only mode, and a Downlink (DL) Transmission Only mode.

[0017] In an exemplary aspect of the present disclosure, the one or more sleep modes pertain to one or more levels of one or more energy-saving techniques without causing one or more service interruptions in the at least one cell.

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[0018] In an exemplary aspect of the present disclosure, the method further comprises creating, by the processing unit, at least one profile for each of the one or more sleep modes for one or more cells, where each of the at least one profile comprises a profile mode for an advanced tilt optimization, a power optimization, and a scheduling methodology to meet a desired quality of service (QoS), and wherein each of the one or cells comprises at least a set of RUs of the one or more RUs.

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[0019] In an exemplary aspect of the present disclosure, the method further comprises receiving, by the processing unit, an input from a power management system at a base station to activate the one or more sleep modes, wherein the input comprises at least one of a battery output and an alternating current (AC).

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[0020] In an exemplary aspect of the present disclosure, the method further comprises identifying, by the identifying unit, a power emergency with the one or more cells, the power emergency comprises at least one of low battery and operating on diesel generator.

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[0021] In an exemplary aspect of the present disclosure, the method further comprises activating, by the processing, the one or more sleep modes based on the identified power emergency.

[0022] In an exemplary aspect of the present disclosure, the method further comprises using self-optimizing network performance, a load balancing, and coverage hole prediction to meet one or more QoS requirements.

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[0023] In an exemplary aspect of the present disclosure, the network traffic load comprises at least one of a data transmission volume, a user activity, and one or more resource utilization metrics within the cellular network.

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[0024] In an exemplary aspect of the present disclosure, the traffic pattern corresponds to a forecast period of low activity and a potential for an energy saving.

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[0025] Another aspect of the present disclosure may relate to a system for proactive energy optimization in a cellular network. The system comprises a monitoring unit that is configured to monitor a network traffic load associated with a plurality of cells of the cellular network. Further, the system comprises a predicting unit that is configured to predict, using a trained model, a traffic pattern for at least one cell of the plurality of cells based on the monitored network traffic load. Further, the system comprises an identifying unit configured to identify one or more radio units (RUs) for transitioning into one or more sleep modes based on the predicted traffic pattern. Furthermore, the system comprises a processing unit that is configured to initiate at least one of the one or more sleep modes for the identified one or more RUs to optimize power consumption.

[0026] Yet another aspect of the present disclosure may relate to a non-transitory computer readable storage medium storing instructions for proactive energy optimization in a cellular network, the instructions include executable code which, when executed by one or more units of a system, causes: a monitoring unit of the system to monitor a network traffic load associated with a plurality of cells of the cellular network; a predicting unit of the system to predict, using a trained model, a traffic pattern for at least one cell of the plurality of cells based on the monitored network traffic load; an identifying unit of the system to identify one or more radio units (RUs) for transitioning into one or more sleep modes based on the predicted traffic pattern; and a processing unit of the system to initiate at least one of the one or more sleep modes for the identified one or more RUs to optimize power consumption.

OBJECTS OF THE DISCLOSURE

[0027] Some of the objects of the present disclosure, which at least one embodiment disclosed herein satisfies are listed herein below.

[0028] It is an object of the present disclosure to provide a system and a method for proactive energy optimization in a cellular network.

[0029] It is another object of the present disclosure to provide a system and method for proactive energy optimization in cellular networks that improve energy efficiency in 5G networks, particularly during periods of low or no data transmission.

[0030] It is another object of the present disclosure to achieve improved energy efficiency in cellular networks through a proactive identification and management of multi-level advanced sleep modes.

5 [0031] It is another object of the present disclosure to provide a system and method for proactive energy optimization in cellular networks that reduce the operational costs associated with energy usage in 5G networks by optimizing power consumption.

10 [0032] It is another object of the present disclosure to provide a system and method for proactive energy optimization in cellular networks that by taking into account load conditions and Quality of Service (QoS) requirements, seeks to ensure that network performance remains optimal even while energy consumption is reduced.

15 [0033] It is another object of the present disclosure to provide a system and method for proactive energy optimization in cellular networks that provide a precise quantification of power saving, and mapping of power utilization to physical resource block (PRB) usage.

20 [0034] It is another object of the present disclosure to provide a system and method for proactive energy optimization in cellular networks that aims to employ a proactive approach in identifying cells for action, relying on machine learning techniques for traffic prediction.

[0035] It is another object of the present disclosure to provide a solution that takes into account variations in traffic patterns over time, day of the week, and seasonal changes etc., to provide a more efficient and responsive cellular network.

25 [0036] It is another object of the present disclosure to provide a system and method for proactive energy optimization in cellular networks that seeks to implement a range of advanced sleep modes, such as radio unit (RU) Hibernation, Deep Sleep, Light Sleep, and Uplink (UL) Transmission Only etc., providing a granular approach to energy savings and ensuring an efficient response to diverse
30 network conditions.

[0037] It is yet another object of the present disclosure to provide a system and method for proactive energy optimization in cellular networks that aims to be easily adoptable into standard technology, offering improvements in energy efficiency and network performance without
35 necessitating significant infrastructural changes.

DESCRIPTION OF THE DRAWINGS

[0038] The accompanying drawings, which are incorporated herein, and constitute a part of this disclosure, illustrate exemplary embodiments of the disclosed methods and systems in which like reference numerals refer to the same parts throughout the different drawings. Components in the drawings are not necessarily to scale, emphasis instead being placed upon clearly illustrating the principles of the present disclosure. Also, the embodiments shown in the figures are not to be construed as limiting the disclosure, but the possible variants of the method and system according to the disclosure are illustrated herein to highlight the advantages of the disclosure. It will be appreciated by those skilled in the art that disclosure of such drawings includes disclosure of electrical components or circuitry commonly used to implement such components.

[0039] Figure 1 illustrates a multi-vendor self-organizing network (SON) for proactive energy optimization in a cellular network, in accordance with exemplary implementations of the present disclosure.

[0040] Figure 1A illustrates an exemplary block diagram of a radio access network (RAN) management layer and the RAN layer, in accordance with exemplary implementations of the present disclosure.

[0041] Figure 1B illustrates another exemplary block diagram of a radio access network (RAN) management layer and the RAN layer, in accordance with exemplary implementations of the present disclosure.

[0042] Figure 2 illustrates an exemplary block diagram of a system for proactive energy optimization in a cellular network in accordance with exemplary implementations of the present disclosure.

[0043] Figure 3 illustrates a method flow diagram for proactive energy optimization in cellular networks in accordance with exemplary implementations of the present disclosure.

[0044] Figure 4 illustrates a timeline for implementing the method as per the present disclosure in accordance with exemplary implementations of the present disclosure.

[0045] Figure 5 illustrates an exemplary block diagram of a computing device upon which the features of the present disclosure may be implemented in accordance with exemplary implementation of the present disclosure.

- 5 [0046] The foregoing shall be more apparent from the following more detailed description of the disclosure.

DETAILED DESCRIPTION

- 10 [0047] In the following description, for the purposes of explanation, various specific details are set forth in order to provide a thorough understanding of embodiments of the present disclosure. It will be apparent, however, that embodiments of the present disclosure may be practiced without these specific details. Several features described hereafter may each be used independently of one another or with any combination of other features. An individual feature may not address any of
15 the problems discussed above or might address only some of the problems discussed above.

- [0048] The ensuing description provides exemplary embodiments only, and is not intended to limit the scope, applicability, or configuration of the disclosure. Rather, the ensuing description of the exemplary embodiments will provide those skilled in the art with an enabling description for
20 implementing an exemplary embodiment. It should be understood that various changes may be made in the function and arrangement of elements without departing from the spirit and scope of the disclosure as set forth.

- [0049] Specific details are given in the following description to provide a thorough understanding
25 of the embodiments. However, it will be understood by one of ordinary skill in the art that the embodiments may be practiced without these specific details. For example, circuits, systems, processes, and other components may be shown as components in block diagram form in order not to obscure the embodiments in unnecessary detail.

- 30 [0050] Also, it is noted that individual embodiments may be described as a process which is depicted as a flowchart, a flow diagram, a data flow diagram, a structure diagram, or a block diagram. Although a flowchart may describe the operations as a sequential process, many of the operations may be performed in parallel or concurrently. In addition, the order of the operations may be re-arranged. A process is terminated when its operations are completed but could have
35 additional steps not included in a figure.

[0051] The word “exemplary” and/or “demonstrative” is used herein to mean serving as an example, instance, or illustration. For the avoidance of doubt, the subject matter disclosed herein is not limited by such examples. In addition, any aspect or design described herein as “exemplary” and/or “demonstrative” is not necessarily to be construed as preferred or advantageous over other aspects or designs, nor is it meant to preclude equivalent exemplary structures and techniques known to those of ordinary skill in the art. Furthermore, to the extent that the terms “includes,” “has,” “contains,” and other similar words are used in either the detailed description or the claims, such terms are intended to be inclusive—in a manner similar to the term “comprising” as an open transition word—without precluding any additional or other elements.

[0052] As used herein, a “processing unit” or “processor” or “operating processor” includes one or more processors, wherein processor refers to any logic circuitry for processing instructions. A processor may be a general-purpose processor, a special purpose processor, a conventional processor, a digital signal processor, a plurality of microprocessors, one or more microprocessors in association with a Digital Signal Processing (DSP) core, a controller, a microcontroller, Application Specific Integrated Circuits, Field Programmable Gate Array circuits, any other type of integrated circuits, etc. The processor may perform signal coding data processing, input/output processing, and/or any other functionality that enables the working of the system according to the present disclosure. More specifically, the processor or processing unit is a hardware processor.

[0053] As used herein, “a user equipment”, “a user device”, “a smart-user-device”, “a smart-device”, “an electronic device”, “a mobile device”, “a handheld device”, “a wireless communication device”, “a mobile communication device”, “a communication device” may be any electrical, electronic and/or computing device or equipment, capable of implementing the features of the present disclosure. The user equipment/device may include, but is not limited to, a mobile phone, smart phone, laptop, a general-purpose computer, desktop, personal digital assistant, tablet computer, wearable device or any other computing device which is capable of implementing the features of the present disclosure. Also, the user device may contain at least one input means configured to receive an input from unit(s) which are required to implement the features of the present disclosure.

[0054] As used herein, “storage unit” or “memory unit” refers to a machine or computer-readable medium including any mechanism for storing information in a form readable by a computer or similar machine. For example, a computer-readable medium includes read-only memory

(“ROM”), random access memory (“RAM”), magnetic disk storage media, optical storage media, flash memory devices or other types of machine-accessible storage media. The storage unit stores at least the data that may be required by one or more units of the system to perform their respective functions.

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[0055] As used herein “interface” or “user interface” refers to a shared boundary across which two or more separate components of a system exchange information or data. The interface may also be referred to a set of rules or protocols that define communication or interaction of one or more modules or one or more units with each other, which also includes the methods, functions, or procedures that may be called.

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[0056] All modules, units, components used herein, unless explicitly excluded herein, may be software modules or hardware processors, the processors being 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 (ASIC), Field Programmable Gate Array circuits (FPGA), any other type of integrated circuits, etc.

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[0057] As used herein the transceiver unit include at least one receiver and at least one transmitter configured respectively for receiving and transmitting data, signals, information, or a combination thereof between units/components within the system and/or connected with the system.

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[0058] Further, in accordance with the present disclosure, it is to be acknowledged that the functionality described for the various the components/units can be implemented interchangeably.

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While specific embodiments may disclose a particular functionality of these units for clarity, it is recognized that various configurations and combinations thereof are within the scope of the disclosure. The functionality of specific units as disclosed in the disclosure should not be construed as limiting the scope of the present disclosure. Consequently, alternative arrangements and substitutions of units, provided they achieve the intended functionality described herein, are considered to be encompassed within the scope of the present disclosure.

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[0059] As discussed in the background section, the current known solutions have several shortcomings. The present disclosure aims to overcome the above-mentioned and other existing problems in this field of technology by providing method and system for proactive energy optimization in a cellular network.

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[0060] The present disclosure relates to a method and a system for proactive energy optimization in a cellular network. The present disclosure provides a system and method for proactive energy optimization in cellular networks that aims to be easily adoptable into standard technology, offering improvements in energy efficiency and network performance without necessitating significant infrastructural changes. Further the present disclosure provides precise quantification of power saving, mapping power utilization to physical resource block (PRB) usage. This enables an accurate assessment of the energy-saving impacts. Further the present disclosure provides implementation of a range of advanced sleep modes, such as radio unit (RU) Hibernation, Deep Sleep, Light Sleep, and Uplink (UL) Transmission Only, providing a granular approach to energy savings and ensuring an efficient response to diverse network conditions. Furthermore, the present disclosure provides proactive energy optimization in cellular networks by taking into account load conditions and Quality of Service (QoS) requirements, seeks to ensure that network performance remains optimal even while energy consumption is reduced, and reduces the operational costs associated with energy usage in cellular networks such as 5G networks by optimizing power consumption.

[0061] More specifically, the present disclosure provide a solution that at least encompasses: 1) monitoring a network traffic load associated with a plurality of cells of the cellular network, 2) predicting, using a trained model, a traffic pattern for at least one cell of the plurality of cells based on the monitored network traffic load, 3) identifying, one or more radio units (RUs) for transitioning into one or more sleep modes based on the predicted traffic pattern, and 4) initiating, at least one of the one or more sleep modes for each of the identified one or more RUs to optimize power consumption.

[0062] Hereinafter, exemplary embodiments of the present disclosure will be described with reference to the accompanying drawings.

[0063] Referring to Figure 1, that illustrates a multi-vendor self-organizing network (SON) for proactive energy optimization in a cellular network, in accordance with exemplary implementations of the present disclosure. Particularly, the multi-vendor SON provides proactive energy optimization in the cellular network with the help of the system [200] as depicted in Figure 2.

[0064] As indicated in the Figure 1, the multi-vendor SON architecture for proactive energy optimization in the cellular network comprises at least one Intelligent Platform/Non-Real Time Radio Intelligent Controller (NRT-RIC) layer [102], at least one service management and orchestration (SMO) layer/ a self-organizing network (SON) layer [104], at least one network management layer [106], and at least one Radio Access Network (RAN) Layer [114]. Further, the RAN layer [114] is connected to the SMO layer/ SON layer [104] by a Centralized SON (CSON) interface [156]. Also, in Figure 1 only a few units are shown, however, the multi-vendor SON architecture may comprise multiple such units or the multi-vendor SON architecture may comprise any such numbers of said units, as required to implement the features of the present disclosure.

[0065] Further, the RAN layer [114] comprises a combined centralized and distributed unit (CCDU) [116] and an open radio access network radio unit (O-RU) [136]. The CCDU [116] is a unit which performs the operation for both a centralized unit and a decentralized unit and handles both the higher layers and the lower layers of a protocol stack, which includes the higher/upper physical layer [128], a media access control (MAC) layer [126], and a radio link control (RLC) layer [124] and also a service data adaptation protocol (SDAP) layer, a packet data convergence protocol (PDCP) layer, and a radio resource control (RRC) layer. The O-RU [136] is a component of open radio access network (O-RAN) that perform the function of radio access nodes and connects the user equipment with the wireless communication network. The OFH (ORAN Front Haul)/ M-Plane [134] as depicted in the Figure 1 is an interface which is responsible for managing the O-RU.

[0066] The CCDU [116] comprises of a Radio Resource Control (RRC) Packet Data Convergence Protocol - Control (PDCP-C) [118] (referred herein as RRC PDCP-C [118]), a Service Data Adaptation Protocol - User (SDAP PDCP-U) [120] (referred herein as SDAP PDCP-U [120]), a distributed self-organizing network (DSON) [122], the Radio Link Control (RLC) layer [124], the Medium Access Control (MAC layer) [126], the higher physical layer [128], an Open Radio Access Network - Centralized Unit - User-Plane (ORAN-C-U-S Plane) [130], and an Open Radio Access Network Management Plane (O-RAN M-Plane) [132]. The Distributed Self-Organizing Network (DSON) [122] allows the network to automatically optimize itself without manual intervention. Further the RRC PDCP-C [118] comprises of the Radio Resource Control protocol (RRC) and the Packet Data Convergence Protocol - Control (PDCP-C). The RRC manages radio resources like assigning channels and power. Further, the Packet Data Convergence Protocol - Control (PDCP-C) prepares data for transmission (PDCP-C for control data, PDCP-U for user

data). The PDCP-C is located in the air interface on the top of the RLC layer [124]. The Radio Link Control (RLC) layer [124] ensures reliable data delivery over the radio link.

[0067] Further, the Medium Access Control (MAC) layer [126], manages how different devices share the radio channel. Further, the higher physical layer [128], transmits and receives raw radio signals. Furthermore, the ORAN-C-U-S Plane (Centralized Unit - User-Plane) [130], splits the processing between a central unit and distributed units for user data handling. Moreover, the O-RAN M-Plane (Management Plane) [132] manages the overall network configuration.

[0068] The O-RU [136] comprises at least one of the ORAN-C-U-S Plane [130], the O-RAN M-Plane [132], an Inverse Fast Fourier Transform / Preamble Format (PRACH) (IFFT/PRACH) Precoding [138], a Channel Frequency Response (CFR) [146], a Cyclic Prefix (CP) Addition [140], a digital Beamforming (digital BF) [142], a digital pre-distortion (DPD) [144], a digital up converter (DUC)/ a digital down converter (DDC) [148], a Power Amplifier (PA)/ a low-noise amplifier (LNA) [150], an analog-digital converter (ADC)/ a digital-analog converter (DAC) [152], a duplexer/ a circulator [154]. Furthermore, the IFFT/PRACH Precoding [138] comprises of the Inverse Fast Fourier Transform (IFFT) and the Preamble Format (PRACH) Precoding. The Inverse Fast Fourier Transform (IFFT) converts frequency-domain data into time-domain signals, essential for OFDM (Orthogonal Frequency Division Multiplexing) transmission. Further, the Preamble Format (PRACH) Precoding, prepares the random-access preamble for transmission, enabling initial access and synchronization between the UE and the network. Further, the Channel Frequency Response (CFR) [146] measures and characterizes how the transmitted signal is altered by the propagation channel. This information is used to compensate for channel impairments and to improve signal quality. The Cyclic Prefix (CP) Addition [140], adds a cyclic prefix to each OFDM symbol to mitigate inter-symbol interference (ISI) caused by multipath propagation. This enhances the robustness of the transmitted signal. Moreover, the digital BF (Beamforming) [142] utilizes digital signal processing to direct the transmission and reception of signals in specific directions, improving signal strength and reducing interference. This enhances overall network performance and coverage.

[0069] The DPD [144] is a baseband signal processing technique that corrects the impairments in RF power amplifiers (PAs). The digital up converter (DUC) [148] is a device which translates a signal from baseband to intermediate frequency (IF) band, and the digital down converter (DDC) [148] is a device which converts a signal from intermediate frequency band to baseband. The PA [150] is a type of electronic amplifier that converts a low-power radio-frequency (RF) signal into

a higher-power signal. The LNA [150] is a component at the front-end of a radio receiver circuit which reduces the unwanted noises in the radio signal. The ADC [152] is a device that converts an analogue signal into a limited number of digital output codes and the DAC [152] is a device that converts a limited number of digital output codes into an analogue signal. The duplexer [154] is an electronic device that allows bi-directional (duplex) communication over a single path and isolates the receiver from the transmitter while permitting them to share a common antenna. The circulator [154] is a passive, non-reciprocal three-port or four-port device that only allows a microwave or radio-frequency (RF) signal to exit through the port directly after the one it entered.

[0070] Moreover, for proactive energy optimization in a cellular network the system [200] works in conjunction with at least one of the Intelligent Platform/NRT-RIC layer [102], the service management and orchestration (SMO) layer/ the self-organizing network (SON) layer [104], and the network management layer [106].

[0071] Particularly, the Intelligent Platform/NRT-RIC layer [102] provides efficient control and optimization / regulation of network functions and services in real-time or near-real-time through fine-grained data collection and actions. The intelligent platform layer/ the NRT-RIC layer [102] performs tasks such as including but not limited to scenario identification, predictive analysis of one or more traffic levels, parameter optimization for example, regulating energy consumption by optimizing power usage of the one or more cell sites, training of an artificial intelligence / machine learning (AI/ML) model based on AI/ML techniques and data aggregations. The intelligent platform layer/ the NRT-RIC layer [102] collects data from a site data base, configuration parameters from a configuration management (CM) module [112], performance counters from a performance management (PM) module [110] and alarms from the fault management (FM) and alarm handling module [108] for all elements from the RAN layer via the network management layer [106].

[0072] The service management and orchestration (SMO) layer/ self-organizing network (SON) layer [104] manages the components and network functions of an open RAN. The self-organizing network (SON) layer [104] comprises an automation technology designed to make the planning, configuration, management, optimization and healing of mobile radio access networks in a simpler and faster way. The SMO layer/SON layer is responsible for making/implementing policies, modelling and slicing the network, and also performing the functions for user session management, medium access/radio management, device downlink/uplink management, and data acquisition. The SON layer [104] acts as a central intelligence controller, communicating with the network

management layer [106], CCDU [116], and O-RU [136] through standardized interfaces and incorporates above mentioned AI/ML policies to make intelligent decisions for optimizing network performance, resource allocation, and energy efficiency. The macro gNodeBs /outdoor small cell (ODSC)/indoor small cell (IDSC) integrate with the SON/SMO layer [104] directly. The SON layer [104] houses SON techniques for network optimization, acting as the brain. It leverages a network operator platform for other vendor gNodeBs and interfaces directly with such gNodeBs from other vendors network operator through its network management layer [106] for its nodes.

[0073] The present disclosure provides a solution that is implemented in the intelligent platform layer/ the NRT-RIC layer [102]. It communicates with the network management layer [106] to gather details such as network information, performance metrics, and configuration data. It exchanges control signals and receives instructions from the network management layer [106] to orchestrate and optimize the RAN operations.

[0074] Referring to Figure 1A and Figure 1B that illustrates an exemplary block diagram of a RAN management layer [158] and the RAN layer [114], the RAN management layer [158] (i.e., Intelligent Platform/NRT-RIC Layer [102] and the Network Management Layer [106]) collects data for monitoring the performance of the one or more cell sites and implement one or more sleep modes. The performance monitoring includes monitoring at least the one or more current or past traffic levels, and the predicted one or more traffic levels, a coverage map, etc. For model training, the RAN management layer [158] utilizes the AI/ML techniques for effective and efficient functioning of the RAN management layer [158]. For predictive analysis, the RAN management layer [158] utilizes the historic data associated with one or more traffic levels at the one or more cell sites in the past. The RAN management layer [158] is responsible for triggering the one or more sleep modes, if the predefined thresholds for the one or more traffic levels is satisfied by the selected cell site. For instance, Figure 1A depicts that if for a monitoring period a Threshold $T1 > LTS$ threshold (long-term statistical threshold,), then the RAN management layer [158] will trigger the RU Hibernation mode and Figure 1B depicts that if for a monitoring period say M1 the $T1 < LTS$ as, then the RAN management layer [158] will trigger advanced sleep mode.

[0075] Further it is also depicted in the Figure 1A that once the RU Hibernation mode is triggered then after waiting for a reactivation timer (RTh), a reactivation process starts (by notifying a central controller), activating the RU's radio resources, and enabling the transmit/receive functions. The configuration and state of the reactivated RU are then restored.

[0076] Also, it is depicted in the Figure 1B that once the advanced sleep mode is triggered then in case of any configuration update, new user identification, and/or incoming signal detection, a reactivation procedure is activated, and normal operations are resumed after reactivation from the advanced sleep mode.

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[0077] Also, the RAN management layer [158] is responsible for performing the functions, as illustrated in the Figure 1A and Figure 1B, such as data collection, performance monitoring (predicted traffic level, actual traffic level and coverage map), predictive analysis, parameter optimization, scenario identification, managing AI/ML techniques, model training, data aggregation, and configuration management, etc.

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[0078] Further referring to Figure 2, an exemplary block diagram of a system [200] for proactive energy optimization in a cellular network, is shown, in accordance with the exemplary implementations of the present disclosure. The system [200] comprises at least one monitoring unit [202], at least one predicting unit [204], at least one identifying unit [206] and at least one processing unit [208]. Also, all of the components/ units of the system [200] are assumed to be connected to each other unless otherwise indicated below. Also, in Figure 2 only a few units are shown, however, the system [200] may comprise multiple such units or the system [200] may comprise any such numbers of said units, as required to implement the features of the present disclosure. The system [200] may reside in a server or a network entity.

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[0079] The system [200] is configured for proactive energy optimization in the cellular network, with the help of the interconnection between the components/units of the system [200].

[0080] Particularly, for proactive energy optimization in the cellular network initially the monitoring unit [202] is configured to monitor a network traffic load associated with a plurality of cells of the cellular network. The cellular network is a radio network that is distributed over land areas called cells. Further, in the cellular network each cell uses a different set frequency from its neighbouring cell to avoid interference and provide guaranteed bandwidth within each cell. Further, the network traffic load comprises but not limited to at least one of a data transmission volume, a user activity, and one or more resource utilization metrics within the cellular network. In an implementation the monitoring unit [202] works in conjunction with the Non-Real Time Radio Intelligent Controller (NRT-RIC) layer [102]. The NRT-RIC layer [102] is a part of a network architecture that collects and processes data about network traffic and performance. The monitoring unit [202] collects data concerning various aspects of a network traffic and a

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performance, such as the number of active users, a data throughput, a signal strength, and one or more quality of service. Once the data is collected, the data is then processed to provide a comprehensive view of the network's current state and performance. The processed data includes information like the areas of high traffic density, periods of peak usage, and points of congestion or weak signal strength.

[0081] Once the monitoring unit [202] monitors the network traffic load, the predicting unit [204] is configured to predict, using a trained model, a traffic pattern for at least one cell of the plurality of cells based on the monitored network traffic load. Further, the traffic pattern corresponds to a forecast period of a low activity and a potential for an energy saving. The forecast period of low activity includes the time period during which the traffic on the one or more cells is low or there is almost no activity on the one or more cells. Further, the low activity on the one or more cells provides that there is potential or possibility of saving energy on the one or more cells. The trained model is one of a Support Vector Machine (SVM), and a neural network. Further, the model is trained based on a dataset comprising a historical network performance data and a corresponding traffic load pattern observed within the cellular network. Furthermore, the SVM is a model based on the machine learning that uses supervised learning algorithm to solve complex classification and regression problems. Further, the neural network is a machine learning program that mimics the human brain i.e., it makes decision in a manner similar to the human brain. Further, the prediction unit [204] considers the historical data and current trends to forecast the likely demand on the network resources.

[0082] Further, the identifying unit [206] is configured to identify one or more radio units (RUs) for transitioning into one or more sleep modes based on the predicted traffic pattern. The one or more sleep modes are selected from a group comprising of a remote unit (RU) Hibernation mode, a Deep Sleep mode, a Light Sleep mode, an Uplink (UL) Transmission Only mode, and a Downlink (DL) Transmission Only mode. Further, the one or more sleep modes pertain to one or more levels of one or more energy-saving techniques without causing one or more service interruptions in the at least one cell. Also, the RU Hibernation is energy-saving feature in cellular networks such as 5G that allows Radio Units (RUs) to enter a hibernation mode during extended periods of no traffic for longer period of time. By completely shutting down the RU and conserving power, RU Hibernation significantly reduces energy consumption and contributes to overall energy savings in the network. Further, the Deep Sleep refers to a power-saving mode where the radio unit is temporarily deactivated or put into a low-power state when there is no traffic or minimal traffic. By entering deep sleep, the RU significantly reduces its power consumption,

resulting in energy savings without impacting network performance. Further, the Light Sleep is a power-saving mode where the radio unit operates in a low-power state while remaining active to quickly respond to incoming traffic. This mode allows the RU to conserve energy while maintaining the ability to quickly resume normal operations when needed. Further, the UL (Uplink) Only Transmission is an energy-saving feature that enables the radio unit to transmit data only in the uplink direction, while suspending or reducing downlink transmissions. This mode is beneficial when the network experiences asymmetric traffic, allowing efficient resource utilization and power optimization. The Downlink (DL) Transmission Only mode is an energy-saving feature that enables the radio unit to transmit data only in the downlink direction, while suspending or reducing uplink transmissions.

[0083] Once the identifying unit [206] identifies one or more radio units for transitioning, the processing unit [208] is configured to initiate at least one of the one or more sleep modes for the identified one or more RUs to optimize power consumption. The processing unit [208] is further configured to quantify an energy saving achieved by the at least one of the one or more sleep modes by mapping a power utilization to a physical resource block (PRB) usage. PRBs are units of resources in the cellular networks such as a 5G network, and this mapping allows the system [200] to directly tie energy savings to network performance. The PRBs are fundamental components of the cellular networks that represent a chunk of frequency and time used for data transmission. By correlating power utilization to PRB usage, the system [200] can estimate the amount of power saved during the sleep period. The energy savings measurement provides a concrete metric that can be used to evaluate the efficiency of the sleep mode implementation. This energy saving metric reflects the trade-off between network performance and energy consumption. It can also guide future decisions regarding the power management of the network, as it offers insights into the impact of different energy-saving strategies. This way, the system not only optimizes power usage but also provides a quantitative measure to evaluate the effectiveness of energy-saving interventions in the network.

[0084] Also, processing unit [208] is configured to reactivate the one or more RUs from the one or more sleep modes based at least on one of a traffic load breaching a predefined traffic threshold, and a set of predefined triggers. Predefined triggers may include a time schedule, a specific network events, or a threshold level of network demand. This functionality ensures that the system [200] can swiftly respond to any upsurge in network demand. As a result, it strikes a balance between energy optimization and maintaining a high quality of service. Therefore, the reactivation of the one or more RUs from the one or more sleep modes is particularly important during peak

usage times or when a significant load is expected on the network, such as during a major event or during certain times of the day.

[0085] The predicting unit [204] is further configured to predict one or more coverage holes within the cellular network based on the one or more RUs being in the at least one of the one or more sleep modes. Coverage holes are areas where client devices cannot receive a signal from the wireless network. Coverage holes are caused due to physical obstructions such as walls, buildings, etc. Further, the processing unit [208] is configured to utilize one or more neighbour cells for balancing the network traffic load and maintaining coverage during the one or more sleep modes. Once the predicting unit [204] predicts the coverage holes, the processing unit [208] utilizes the neighbouring cells and transfers the load from the one or more cells to the other cells in the cellular network for balancing the load and to provide proper network connectivity to the users. The processing unit [208] further provides a neighbour management profile based on at least one of a geographical location and a handover (HO) count for each of the one or more sleep modes for each of the one or more RUs, to facilitate in managing neighbour relationship and provide a list of targeted neighbours for a coverage hole analysis and a load balancing.

[0086] The processing unit [208] is further configured to create at least one profile for each of the one or more sleep modes for one or more cells, where each of the at least one profile comprises a profile mode for an advanced tilt optimization, a power optimization, and a scheduling methodology to meet a desired quality of service (QoS), and wherein each of the one or cells comprises at least a set of RUs of the one or more RUs. In an implementation the advanced tilt optimization is associated with a configuration required for efficiently and effectively tilting one or more radio units, the power optimization is associated with a configuration required for efficiently and effectively regulating power of the one or more radio units, and the scheduling methodology is associated with a configuration required for efficiently and effectively scheduling the one or more radio units.

[0087] Further, the processing unit [208] is configured to receive an input from a power management system at a base station to activate the one or more sleep modes, wherein the input comprises at least one of a battery output and an alternating current (AC). The identifying unit [206] is further configured to identify a power emergency with the one or more cells, the power emergency comprises at least one of a low battery and an operating on diesel generator. Further, the processing unit [208] is configured to activate the one or more sleep modes based on the identified power emergency.

[0088] Moreover, the system [200] in an implementation is also configured to use a self-optimizing network performance, a load balancing, and a coverage hole prediction to meet one or more QoS requirement.

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[0089] Further referring to Figure 3, a method flow diagram of an exemplary method [300] for proactive energy optimization in a cellular network, in accordance with exemplary implementations of the present disclosure is shown. In an implementation the method [300] is performed by the system [200]. Further, in an implementation, the system [200] may be present in a server device to implement the features of the present disclosure. Also, as shown in Figure 3, the method [300] starts at step [302].

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[0090] At step [304], the method [300] comprises monitoring, by a monitoring unit [202], a network traffic load associated with a plurality of cells of the cellular network. The cellular network is a radio network that is distributed over land areas called cells. Further, in the cellular network each cell uses a different set frequency from its neighbouring cell to avoid interference and provide guaranteed bandwidth within each cell. Further, the network traffic load comprises but not limited to at least one of a data transmission volume, a user activity, and one or more resource utilization metrics within the cellular network. The monitoring of a network traffic load step may be performed by a Non-Real Time Radio Intelligent Controller (NRT-RIC) layer [102] in conjunction with the monitoring unit [202]. The NRT-RIC layer [102] is a part of the 5G network architecture that collects and processes data about network traffic and performance. The monitoring unit [202] to monitor the network traffic load collects data concerning various aspects of network traffic and performance, such as the number of active users, a data throughput, a signal strength, and one or more quality of service. The monitoring unit [202] further processes that data to provide a comprehensive view of the network's current state and performance. The processed data includes information like the areas of high traffic density, a period of peak usage, and a point of congestion or weak signal strength.

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[0091] Once the monitoring of the network traffic load is performed by the monitoring unit [202] the method [300], at step [306], comprises predicting, by a predicting unit [204] using a trained model, a traffic pattern for at least one cell of the plurality of cells based on the monitored network traffic load. The traffic pattern corresponds to forecast period of a low activity and potential for an energy saving. The forecast period of low activity includes the time period during which the traffic on the one or more cells is low or there is almost no activity on the one or more cells. Further, the

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low activity on the one or more cells provides that there is potential or possibility of saving energy on the one or more cells. Further, the trained model used to predict the traffic pattern is one of a Support Vector Machine (SVM), and a neural network. The SVM is the machine learning that uses supervised learning model to solve complex classification and regression problems. Further the neural network is a machine learning program that mimics the human brain i.e., it makes decision in a manner similar to the human brain. Further, the prediction unit [204] considers the historical data and current trends to forecast the likely demand on the network resources. Furthermore, the model is trained based on a dataset comprising a historical network performance data and corresponding traffic load pattern observed within the cellular network.

[0092] Further, at step [308] the method [300] comprises identifying, by an identifying unit [206], one or more radio units (RUs) for transitioning into one or more sleep modes based on the predicted traffic pattern. The one or more sleep modes are selected from a group comprising of a radio unit (RU) Hibernation mode, a Deep Sleep mode, a Light Sleep mode, an Uplink (UL) Transmission Only mode, and a Downlink (DL) Transmission Only mode. Further, the one or more sleep modes pertain to various levels of one or more energy-saving techniques without causing service interruptions in the at least one cell.

[0093] Also, RU Hibernation is energy-saving feature in cellular networks such as 5G that allows Radio Units (RUs) to enter a hibernation mode during extended periods of no traffic for longer period of time. By completely shutting down the RU and conserving power, RU Hibernation significantly reduces energy consumption and contributes to overall energy savings in the network. Further, RU Deep Sleep refers to a power-saving mode where the radio unit is temporarily deactivated or put into a low-power state when there is no traffic or minimal traffic. By entering deep sleep, the RU significantly reduces its power consumption, resulting in energy savings without impacting network performance. Further, the Light Sleep is a power-saving mode where the radio unit operates in a low-power state while remaining active to quickly respond to incoming traffic. This mode allows the RU to conserve energy while maintaining the ability to quickly resume normal operations when needed. Further, UL (Uplink) Only Transmission is an energy-saving feature that enables the radio unit to transmit data only in the uplink direction, while suspending or reducing downlink transmissions. This mode is beneficial when the network experiences asymmetric traffic, allowing efficient resource utilization and power optimization. The Downlink (DL) Transmission Only mode is an energy-saving feature that enables the radio unit to transmit data only in the downlink direction, while suspending or reducing uplink transmissions.

[0094] Thereafter, at step [310] the method comprises initiating, by a processing unit [208], at least one of the one or more sleep modes for each of the identified one or more RUs to optimize power consumption. Additionally, the processing unit [208] measure the effectiveness of the process, further the processing unit [208] quantifies energy savings achieved by at least one of the one or more sleep modes by mapping a power utilization to a physical resource block (PRB) usage. The PRBs are units of resources in the cellular networks such as a 5G network, and this mapping allows the system [200] to directly tie energy savings to network performance. The PRBs are fundamental components of the cellular networks that represent a chunk of frequency and time used for data transmission. By correlating power utilization to PRB usage, the system [200] can estimate the amount of power saved during the sleep period. The energy savings measurement provides a concrete metric that can be used to evaluate the efficiency of the sleep mode implementation. This energy saving metric reflects the trade-off between network performance and energy consumption. It can also guide future decisions regarding the power management of the network, as it offers insights into the impact of different energy-saving strategies. This way, the system not only optimizes power usage but also provides a quantitative measure to evaluate the effectiveness of energy-saving interventions in the network.

[0095] Further, the processing unit [208] reactivates the one or more RUs from the one or more sleep modes based at least on one of a traffic load breaching a predefined traffic threshold, and a set of predefined triggers. Predefined triggers may include a time schedule, a specific network events, or a threshold level of network demand. Reactivation of the one or more cells in the cellular network ensures that the system [200] can swiftly respond to any upsurge in network demand. Further, the reactivation strikes a balance between energy optimization and maintaining a high quality of service. Additionally, the reactivation ensures that the system [200] can swiftly respond to any upsurge in network demand, resulting in striking a balance between energy optimization and maintaining a high quality of service. The reactivation is particularly important during peak usage times or when a significant load is expected on the network, such as during a major event or during certain times of the day.

[0096] The prediction unit [204] further predicts one or more coverage holes within the cellular network based on the one or more RUs being in the at least one of the one or more sleep modes. Coverage holes are areas where client devices cannot receive a signal from the wireless network. Coverage holes are caused due to physical obstructions such as walls, buildings, etc. Thereafter,

the processing unit [208] utilizes one or more neighbour cells for balancing the network traffic load and maintaining coverage during the one or more sleep modes. Once the predicting unit [204] predicts the coverage holes the processing unit [208] utilizes the neighbouring cells and transfers the load from the one or more cells to the other cells in the cellular network for balancing the load and to provide proper network connectivity to the users. Further the processing unit [208] provides a neighbour management profile based on at least one of geographical location and handover (HO) count for each of the one or more sleep modes for each of the one or more RUs, to facilitate in managing neighbour relationships and provide a list of targeted neighbours for coverage hole analysis and load balancing. Additionally, the processing unit [208] creates at least one profile for each of the one or more sleep modes for one or more cells, where each of the at least one profile comprises profile mode for an advanced tilt optimization, a power optimization, and a scheduling methodology to meet a desired quality of service (QoS), and wherein each of the one or cells comprises at least a set of RUs of the one or more RUs. In an implementation the advanced tilt optimization is associated with a configuration required for efficiently and effectively tilting one or more radio units, the power optimization is associated with a configuration required for efficiently and effectively regulating power of the one or more radio units, and the scheduling methodology is associated with a configuration required for efficiently and effectively scheduling the one or more radio units.

[0097] Further, the processing unit [208] receives input from a power management system at a base station to activate the one or more sleep modes, wherein the input comprises at least one of battery output and alternating current (AC). Thereafter the identifying unit [206] identifies power emergency with the one or more cells, the power emergency comprises at least one of low battery and operating on diesel generator. Additionally, the method [300] comprises using self-optimizing network performance, load balancing, and coverage hole prediction to meet QoS requirements.

[0098] Thereafter, the method terminates at step [312].

[0099] Further, referring to Figure 4 that illustrates a timeline for implementing the method as per the present disclosure in accordance exemplary implementations of the present disclosure. In the implementation for proactive energy optimization in a cellular network, as per the timeline shown in figure 4, the method [300] begins at time T1, where the system [200] starts monitoring the sleep conditions for triggering one or more advanced sleep modes in the one or more Remote Units (RUs). Once the sleep conditions are met at time T2 the system [200] starts timer to trigger the one or more sleep mode. Further, at time T3 after the timer stops, the system [200] triggers the

start of the one or more advanced sleep modes in the one or more RUs. Also, at T3 the system [200] starts monitoring the conditions for reactivation of the one or more RUs. At T4 when the conditions for reactivation, that are for instance at least one of a traffic load breaching a predefined traffic threshold, and a set of predefined triggers etc, are met then the system [200] starts the timer for reactivation of the one or more RUs that are in the one or more advanced sleep modes. Finally, at T5 the timer stops, and the one or more RUs reactivate from one or more advanced sleep modes.

[0100] Figure 5 illustrates an exemplary block diagram of a computing device [500] (or as used herein as computer system [500]) upon which the features of the present disclosure may be implemented in accordance with exemplary implementation of the present disclosure. In an implementation, the computing device [500] may be in communication with a cellular network to perform the technical features as disclosed in the present disclosure. Also, in an implementation the computing device [500] implements a method for proactive energy optimization in the cellular network utilising the system [200]. In another implementation, the computing device [500] itself implements the method for proactive energy optimization in the cellular network using one or more units configured within the computing device [500], wherein a person skilled in the art would appreciate that said one or more units are capable of implementing the features as disclosed in the present disclosure.

[0101] The computing device [500] may include a bus [502] or other communication mechanism for communicating information, and a hardware processor [504] coupled with bus [502] for processing information. The hardware processor [504] may be, for example, a general-purpose microprocessor. The computing device [500] may also include a main memory [506], such as a random-access memory (RAM), or other dynamic storage device, coupled to the bus [502] for storing information and instructions to be executed by the processor [504]. The main memory [506] also may be used for storing temporary variables or other intermediate information during execution of the instructions to be executed by the processor [504]. Such instructions, when stored in non-transitory storage media accessible to the processor [504], render the computing device [500] into a special-purpose machine that is customized to perform the operations specified in the instructions. The computing device [500] further includes a read only memory (ROM) [508] or other static storage device coupled to the bus [502] for storing static information and instructions for the processor [504].

[0102] A storage device [510], such as a magnetic disk, optical disk, or solid-state drive is provided and coupled to the bus [502] for storing information and instructions. The computing

device [500] may be coupled via the bus [502] to a display [512], such as a cathode ray tube (CRT), Liquid crystal Display (LCD), Light Emitting Diode (LED) display, Organic LED (OLED) display, etc. for displaying information to a computer user. An input device [514], including alphanumeric and other keys, touch screen input means, etc. may be coupled to the bus [502] for communicating information and command selections to the processor [504]. Another type of user input device may be a cursor controller [516], such as a mouse, a trackball, or cursor direction keys, for communicating direction information and command selections to the processor [504], and for controlling cursor movement on the display [512]. The input device typically has two degrees of freedom in two axes, a first axis (e.g., x) and a second axis (e.g., y), that allow the device to specify positions in a plane.

[0103] The computing device [500] may implement the techniques described herein using customized hard-wired logic, one or more ASICs or FPGAs, firmware and/or program logic which in combination with the computing device [500] causes or programs the computing device [500] to be a special-purpose machine. According to one implementation, the techniques herein are performed by the computing device [500] in response to the processor [504] executing one or more sequences of one or more instructions contained in the main memory [506]. Such instructions may be read into the main memory [506] from another storage medium, such as the storage device [510]. Execution of the sequences of instructions contained in the main memory [506] causes the processor [504] to perform the process steps described herein. In alternative implementations of the present disclosure, hard-wired circuitry may be used in place of or in combination with software instructions.

[0104] The computing device [500] also may include a communication interface [518] coupled to the bus [502]. The communication interface [518] provides a two-way data communication coupling to a network link [520] that is connected to a local network [522]. For example, the communication interface [518] may be an integrated services digital network (ISDN) card, cable modem, satellite modem, or a modem to provide a data communication connection to a corresponding type of telephone line. As another example, the communication interface [518] may be a local area network (LAN) card to provide a data communication connection to a compatible LAN. Wireless links may also be implemented. In any such implementation, the communication interface [518] sends and receives electrical, electromagnetic, or optical signals that carry digital data streams representing various types of information.

[0105] The computing device [500] can send messages and receive data, including program code, through the network(s), the network link [520] and the communication interface [518]. In the Internet example, a server [530] might transmit a requested code for an application program through the Internet [528], the ISP [526], the local network [522], the host [524] and the communication interface [518]. The received code may be executed by the processor [504] as it is received, and/or stored in the storage device [510], or other non-volatile storage for later execution.

[0106] Moreover, one of the aspect of the present disclosure relates to a non-transitory computer readable storage medium storing instructions for proactive energy optimization in a cellular network, the instructions include executable code which, when executed by one or more units of a system, causes: a monitoring unit [202] of the system [200] to monitor a network traffic load associated with a plurality of cells of the cellular network; a predicting unit [204] of the system [200] to predict, using a trained model, a traffic pattern for at least one cell of the plurality of cells based on the monitored network traffic load; an identifying unit [206] of the system [200] to identify one or more radio units (RUs) for transitioning into one or more sleep modes based on the predicted traffic pattern; and a processing unit [208] of the system [200] to initiate at least one of the one or more sleep modes for the identified one or more RUs to optimize power consumption.

[0107] As is evident from the above, the present disclosure provides a technically advanced solution for proactive energy optimization in a cellular network. The present disclosure provides a system and method for proactive energy optimization that improve energy efficiency in cellular networks such as in 5G networks, particularly during periods of low or no data transmission. This is achieved through a proactive identification and management of multi-level advanced sleep modes.

[0108] The present disclosure provides a system and method for proactive energy optimization in cellular networks that reduce the operational costs associated with energy usage in cellular networks such as in 5G networks by optimizing power consumption.

[0109] The present disclosure provides a system and method for proactive energy optimization in cellular networks that by taking into account load conditions and Quality of Service (QoS) requirements, seeks to ensure that network performance remains optimal even while energy consumption is reduced.

[0110] The present disclosure provides a system and method for proactive energy optimization in cellular networks that provide a precise quantification of power saving, mapping power utilization to physical resource block (PRB) usage. This enables an accurate assessment of the energy-saving impacts.

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[0111] The present disclosure provides a system and method for proactive energy optimization in cellular networks that aims to employ a proactive approach in identifying cells for action, relying on machine learning techniques for traffic prediction. This takes into account variations in traffic patterns over time, day of the week, and seasonal changes, leading to a more efficient and responsive network.

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[0112] The present disclosure provides a system and method for proactive energy optimization in cellular networks that seeks to implement a range of advanced sleep modes, such as RU Hibernation, Deep Sleep, Light Sleep, and UL Transmission Only, providing a granular approach to energy savings and ensuring an efficient response to diverse network conditions.

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[0113] The present disclosure provides a system and method for proactive energy optimization in cellular networks that aims to be easily adoptable into standard technology, offering improvements in energy efficiency and network performance without necessitating significant infrastructural changes.

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[0114] While considerable emphasis has been placed herein on the disclosed embodiments, it will be appreciated that many embodiments can be made and that many changes can be made to the embodiments without departing from the principles of the present disclosure. These and other changes in the embodiments of the present disclosure will be apparent to those skilled in the art, whereby it is to be understood that the foregoing descriptive matter to be implemented is illustrative and non-limiting.

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I/We Claim:

1. A method [300] for proactive energy optimization in a cellular network, said method [300] comprising:
 - monitoring, by a monitoring unit [202], a network traffic load associated with a plurality of cells of the cellular network;
 - predicting, by a predicting unit [204] using a trained model, a traffic pattern for at least one cell of the plurality of cells based on the monitored network traffic load;
 - identifying, by an identifying unit [206], one or more radio units (RUs) for transitioning into one or more sleep modes based on the predicted traffic pattern; and
 - initiating, by a processing unit [208], at least one of the one or more sleep modes for each of the identified one or more RUs to optimize power consumption.
2. The method [300] as claimed in claim 1, the method [300] comprises quantifying, by the processing unit [208], an energy saving achieved by at least one of the one or more sleep modes by mapping a power utilization to a physical resource block (PRB) usage.
3. The method [300] as claimed in claim 1, the method [300] comprises reactivating, by the processing unit [208], the one or more RUs from the one or more sleep modes based at least on one of a traffic load breaching a predefined traffic threshold, and a set of predefined triggers.
4. The method [300] as claimed in claim 1, the method [300] comprises predicting, by the predicting unit [204], one or more coverage holes within the cellular network based on the one or more RUs being in at least one of the one or more sleep modes.
5. The method [300] as claimed in claim 4, the method [300] comprises utilizing, by the processing unit [208], one or more neighbour cells for balancing the network traffic load and maintaining coverage during the one or more sleep modes.
6. The method [300] as claimed in claim 5, the method [300] comprises providing, by the processing unit [208], a neighbour management profile based on at least one of a geographical location and a handover (HO) count for each of the one or more sleep modes for each of the one or more RUs, to facilitate in managing neighbour relationship and provide a list of targeted neighbours for a coverage hole analysis and a load balancing.
7. The method [300] as claimed in claim 1, wherein the trained model is one of a Support Vector Machine (SVM), and a neural network.
8. The method [300] as claimed in claim 1, wherein the model is trained based on a dataset comprising a historical network performance data and a corresponding traffic load pattern observed within the cellular network.

9. The method [300] as claimed in claim 1, wherein the one or more sleep modes are selected from a group comprising of a radio unit (RU) Hibernation mode, a Deep Sleep mode, a Light Sleep mode, an Uplink (UL) Transmission Only mode, and a Downlink (DL) Transmission Only mode.
- 5 10. The method [300] as claimed in claim 1, wherein the one or more sleep modes pertain to one or more levels of one or more energy-saving techniques without causing one or more service interruptions in the at least one cell.
11. The method [300] as claimed in claim 1, the method [300] comprises creating, by the processing unit [208], at least one profile for each of the one or more sleep modes for one or
10 more cells, where each of the at least one profile comprises a profile mode for an advanced tilt optimization, a power optimization, and a scheduling methodology to meet a desired quality of service (QoS), and wherein each of the one or cells comprises at least a set of RUs of the one or more RUs.
12. The method [300] as claimed in claim 1, the method [300] comprises receiving, by the
15 processing unit [208], an input from a power management system at a base station to activate the one or more sleep modes, wherein the input comprises at least one of a battery output and an alternating current (AC).
13. The method [300] as claimed in claim 11, the method [300] comprises identifying, by the identifying unit [206], a power emergency with the one or more cells, the power emergency
20 comprises at least one of a low battery and an operating on diesel generator.
14. The method [300] as claimed in claim 13, the method [300] comprises activating, by the processing unit [208], the one or more sleep modes based on the identified power emergency.
15. The method [300] as claimed in claim 1, the method [300] comprises using a self-optimizing network performance, a load balancing, and a coverage hole prediction to meet one or more
25 QoS requirements.
16. The method [300] as claimed in claim 1, wherein the network traffic load comprises at least one of a data transmission volume, a user activity, and one or more resource utilization metrics within the cellular network.
17. The method [300] as claimed in claim 1, wherein the traffic pattern corresponds to a forecast
30 period of low activity and a potential for an energy saving.
18. A system [200] for proactive energy optimization in a cellular network, the system [200] comprises:
a monitoring unit [202] configured to monitor a network traffic load associated with a plurality of cells of the cellular network;

a predicting unit [204] configured to predict, using a trained model, a traffic pattern for at least one cell of the plurality of cells based on the monitored network traffic load;

an identifying unit [206] configured to identify one or more radio units (RUs) for transitioning into one or more sleep modes based on the predicted traffic pattern; and

5 a processing unit [208] configured to initiate at least one of the one or more sleep modes for the identified one or more RUs to optimize power consumption.

19. The system [200] as claimed in claim 18, wherein the processing unit [208] is configured to quantify an energy saving achieved by at least one of the one or more sleep modes by mapping a power utilization to a physical resource block (PRB) usage.

10 20. The system [200] as claimed in claim 18, wherein the processing unit [208] is configured to reactivate the one or more RUs from the one or more sleep modes based at least on one of a traffic load breaching a predefined traffic threshold, and a set of predefined triggers.

21. The system [200] as claimed in claim 18, wherein the predicting unit [204] is configured to predict one or more coverage holes within the cellular network based on the one or more
15 RUs being in at least one of the one or more sleep modes.

22. The system [200] as claimed in claim 21, wherein the processing unit [208] is configured to utilize one or more neighbour cells for balancing the network traffic load and maintaining coverage during the one or more sleep modes.

23. The system [200] as claimed in claim 22, wherein the processing unit [208] is configured to provide a neighbour management profile based on at least one of a geographical location and a handover (HO) count for each of the one or more sleep modes for each of the one or
20 more RUs, to facilitate in managing neighbour relationship and provide a list of targeted neighbours for a coverage hole analysis and a load balancing.

24. The system [200] as claimed in claim 18, wherein the trained model is one of a Support
25 Vector Machine (SVM), and a neural network.

25. The system [200] as claimed in claim 18, wherein the model is trained based on a dataset comprising a historical network performance data and a corresponding traffic load pattern observed within the cellular network.

26. The system [200] as claimed in claim 18, wherein the one or more sleep modes are selected
30 from a group comprising of a radio unit (RU) Hibernation mode, a Deep Sleep mode, a Light Sleep mode, an Uplink (UL) Transmission Only mode, and a Downlink (DL) Transmission Only mode.

27. The system [200] as claimed in claim 18, wherein the one or more sleep modes pertain to one or more levels of one or more energy-saving techniques without causing one or more
35 service interruptions in the at least one cell.

28. The system [200] as claimed in claim 18, wherein the processing unit [208] is further configured to create at least one profile for each of the one or more sleep modes for one or more cells, where each of the at least one profile comprises a profile mode for an advanced tilt optimization, a power optimization, and a scheduling methodology to meet a desired quality of service (QoS), and wherein each of the one or cells comprises at least a set of RUs of the one or more RUs.
29. The system [200] as claimed in claim 18, wherein the processing unit [208] is configured to receive an input from a power management system at a base station to activate the one or more sleep modes, wherein the input comprises at least one of a battery output and an alternating current (AC).
30. The system [200] as claimed in claim 28, wherein the identifying unit [206] is configured to identify a power emergency with the one or more cells, the power emergency comprises at least one of a low battery and an operating on diesel generator.
31. The system [200] as claimed in claim 30, wherein the processing unit [208] is configured to activate the one or more sleep modes based on the identified power emergency.
32. The system [200] as claimed in claim 18, the system utilises a self-optimizing network performance, a load balancing, and a coverage hole prediction to meet one or more QoS requirements.
33. The system [200] as claimed in claim 18, wherein the network traffic load comprises at least one of a data transmission volume, a user activity, and one or more resource utilization metrics within the cellular network.
34. The system [200] as claimed in claim 18, wherein the traffic pattern corresponds to a forecast period of low activity and a potential for an energy saving.
35. A non-transitory computer-readable storage medium storing instructions for proactive energy optimization in a cellular network, the storage medium comprising executable code which, when executed by one or more units of a system [200], causes:
- a monitoring unit [202] of the system [200] to monitor a network traffic load associated with a plurality of cells of the cellular network;
 - a predicting unit [204] of the system [200] to predict, using a trained model, a traffic pattern for at least one cell of the plurality of cells based on the monitored network traffic load;
 - an identifying unit [206] of the system [200] to identify one or more radio units (RUs) for transitioning into one or more sleep modes based on the predicted traffic pattern; and

a processing unit [208] of the system [200] to initiate at least one of the one or more sleep modes for the identified one or more RUs to optimize power consumption.

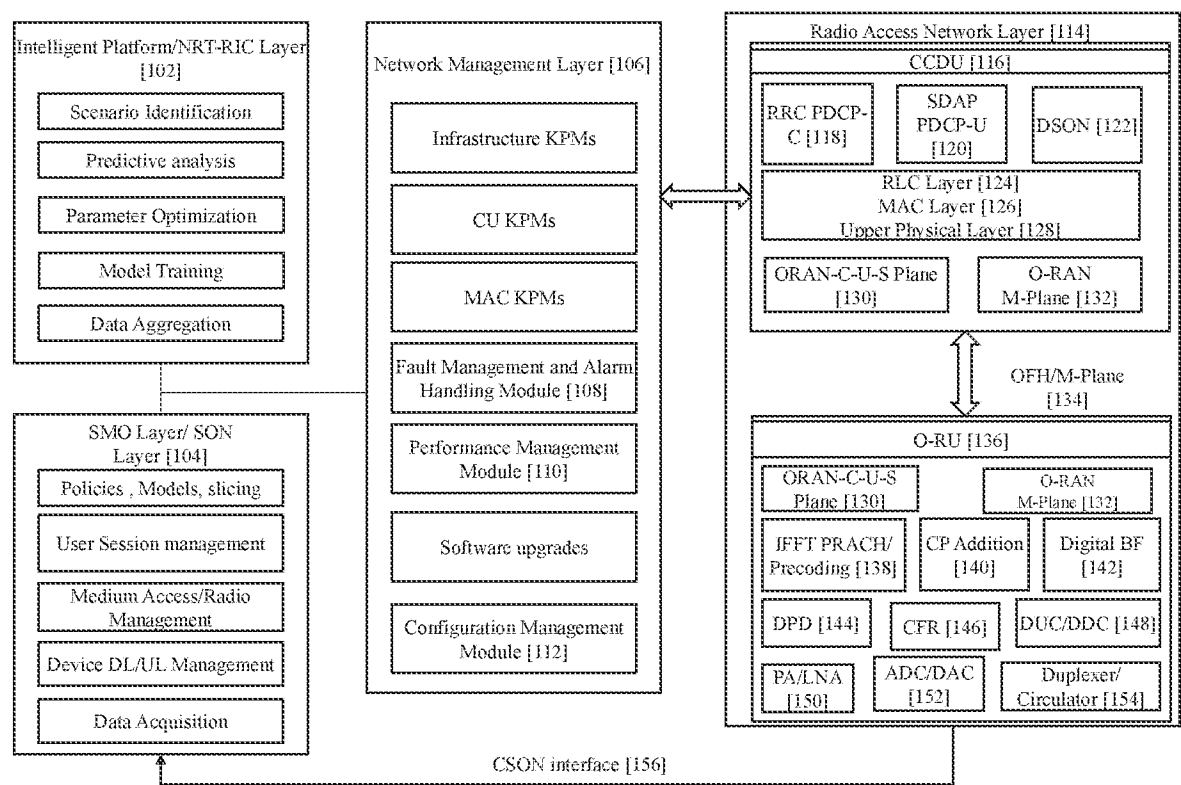


FIG. 1

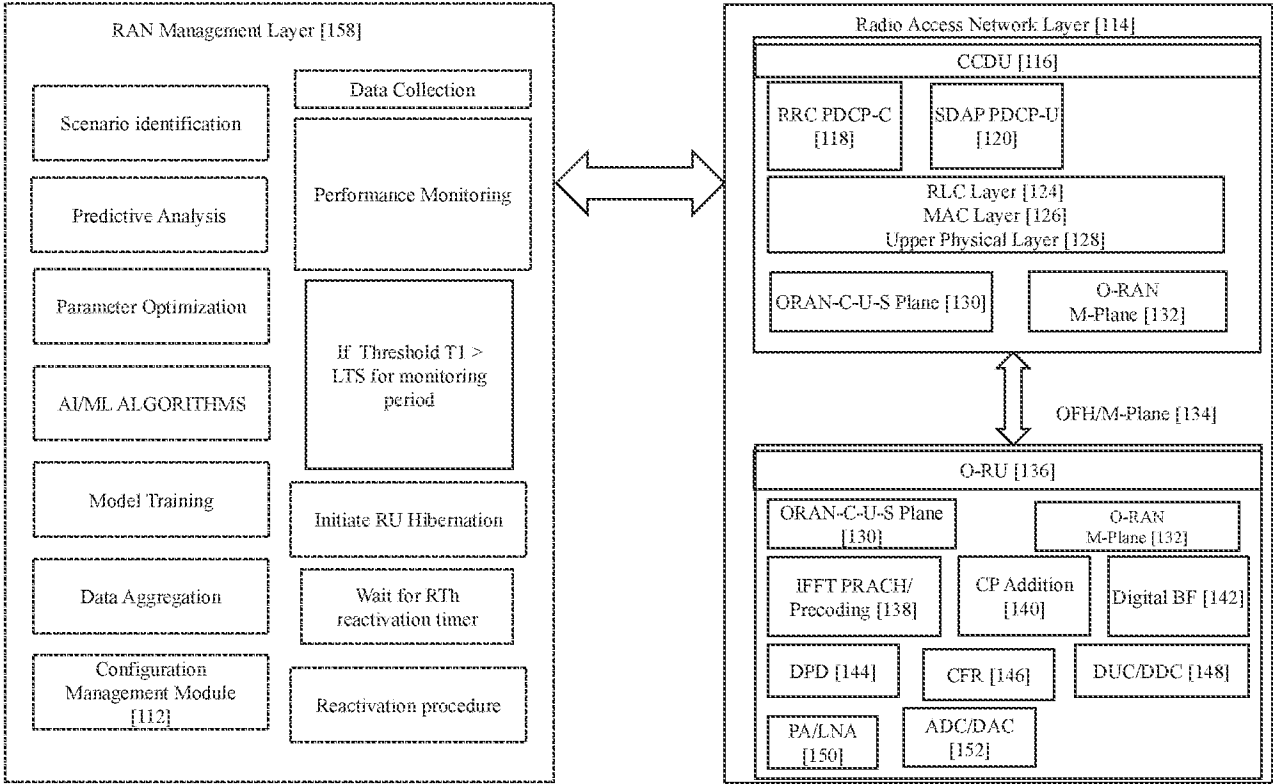


FIG. 1A

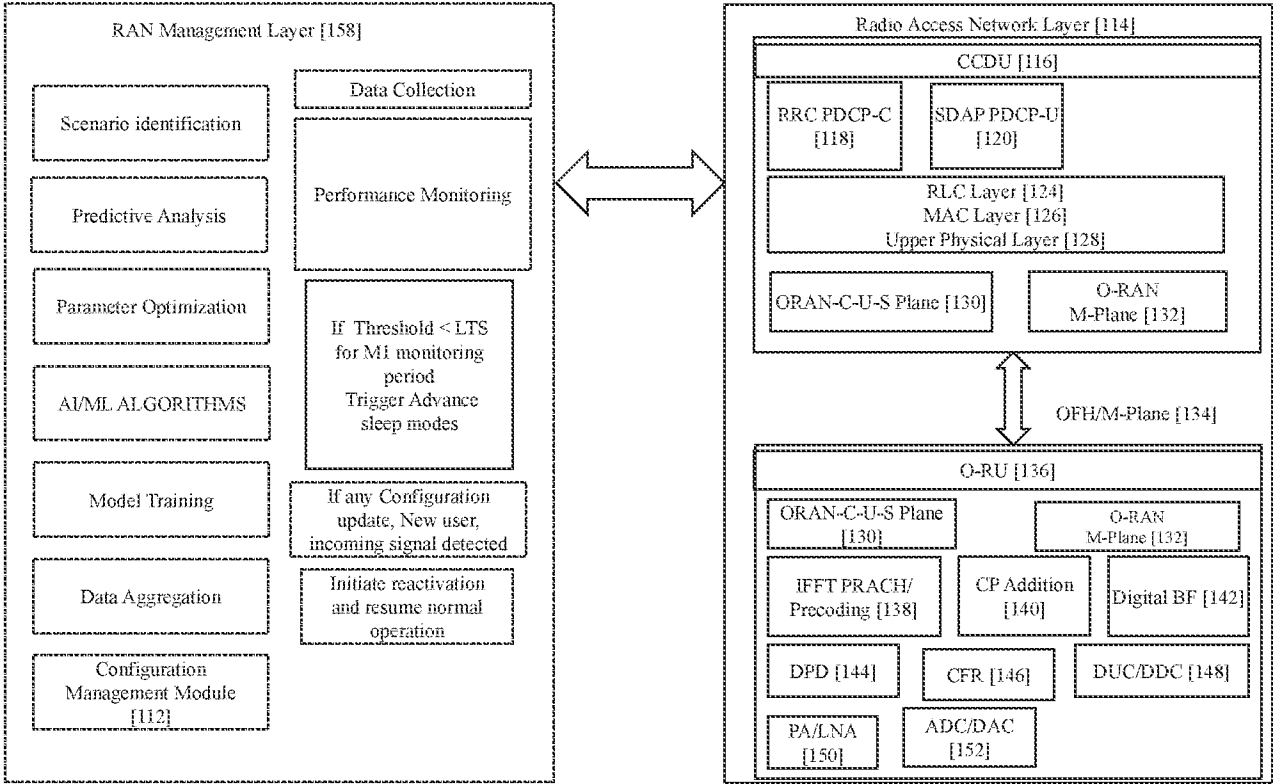


FIG. 1B

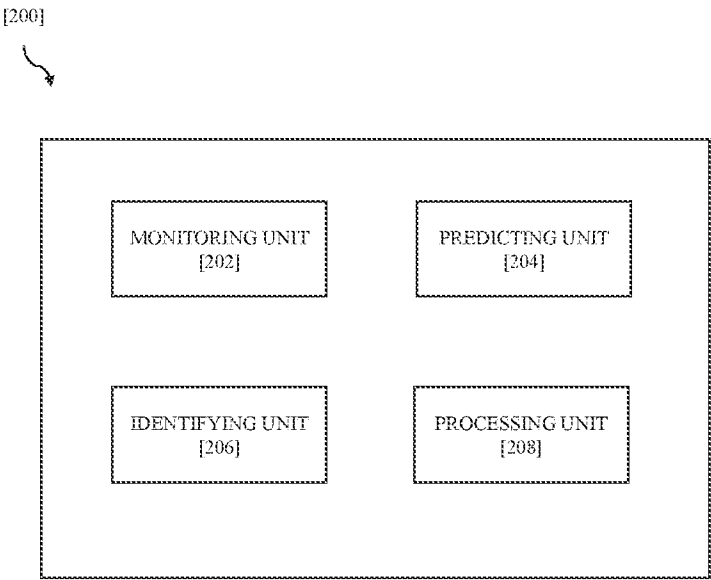


FIG. 2

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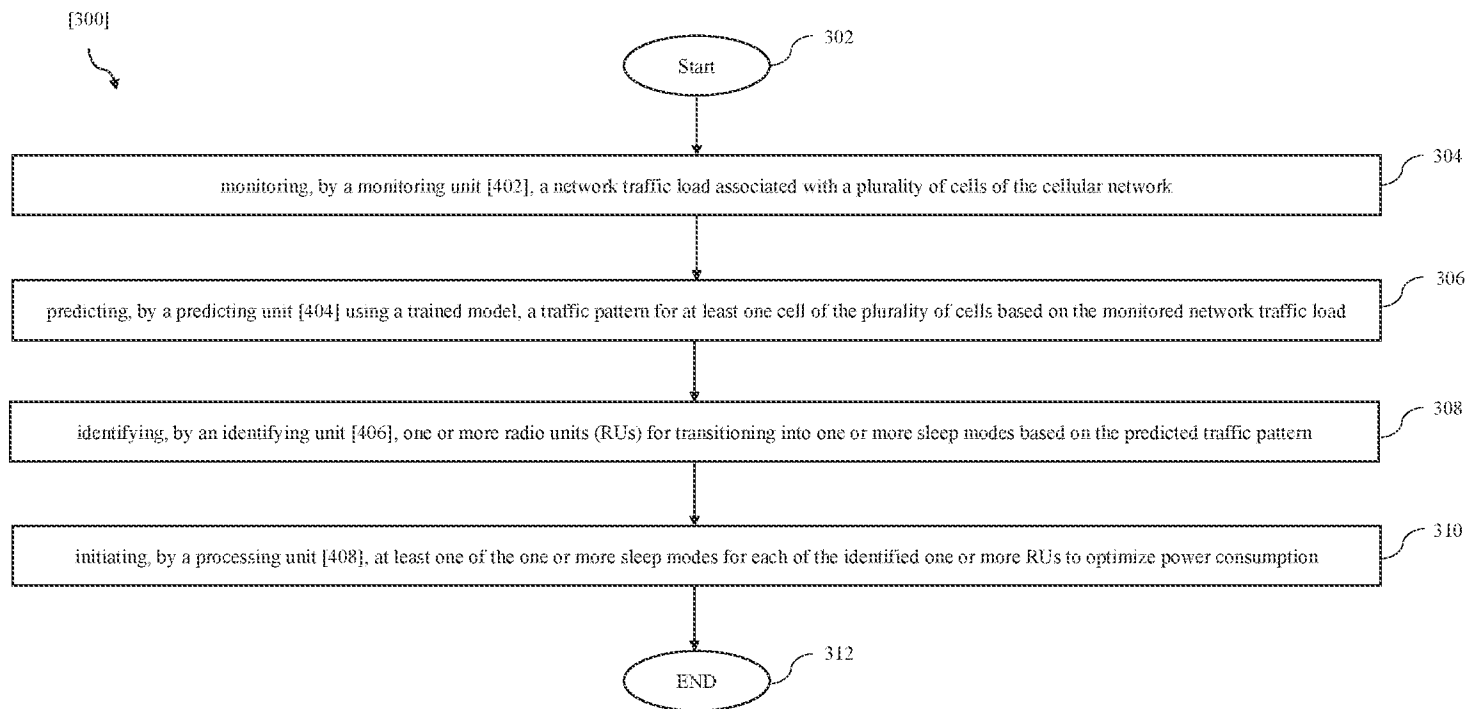


FIG. 3

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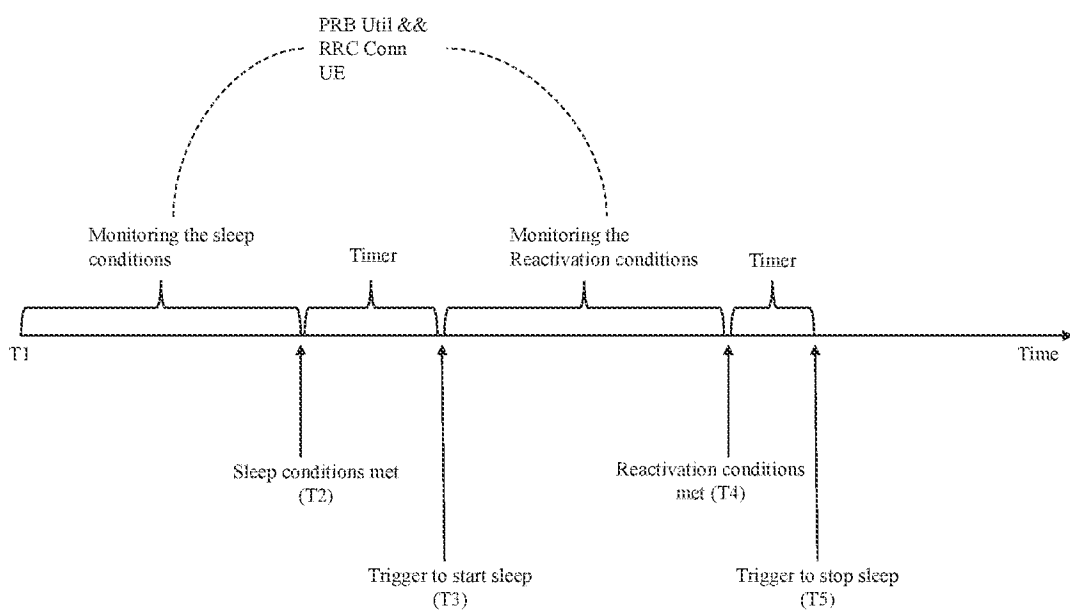


FIG. 4

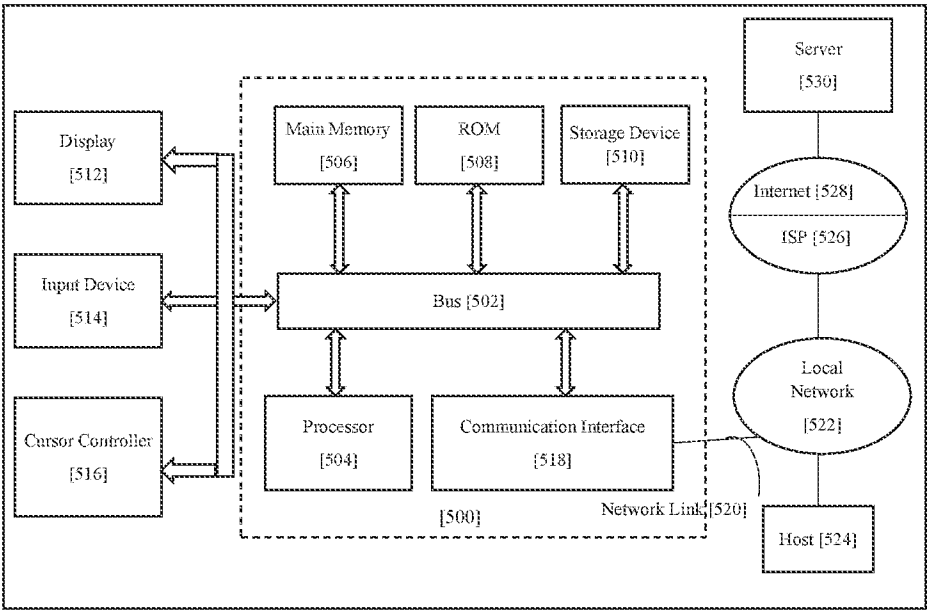


FIG. 5