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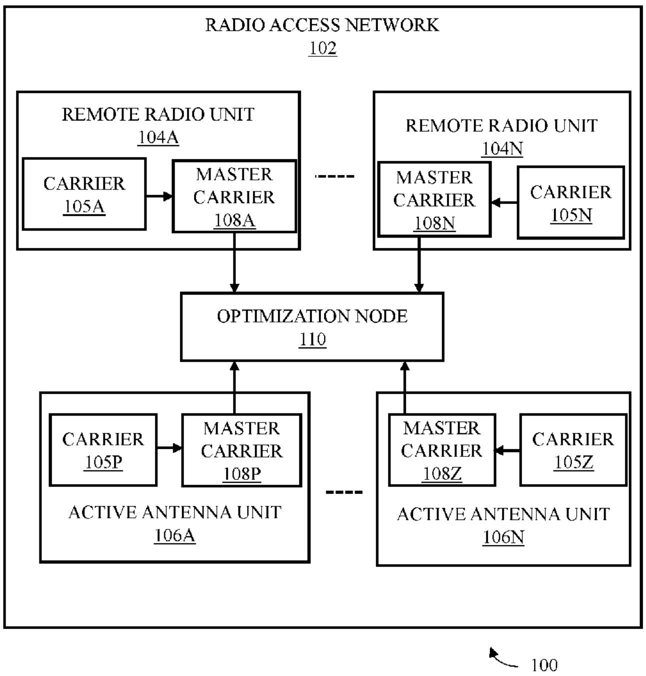

FIG. 1

(57) Abstract: For estimating an energy consumption in a radio access network, RAN, each carrier in each of Remote Radio Units, RRUs, and/or Active Antenna Units, AAUs, in the RAN reports energy consumption related parameters of the carrier to a master carrier of the RRUs or AAUs. Each master carrier creates a local mapping between the energy consumption related parameters and an energy consumption of the RRU or AAU using a local Artificial Intelligence, AI, or Machine Learning, ML, based energy consumption estimator with the reported energy consumption related parameters of the carriers. Each master carrier then reports local mapping to an optimization node that creates a general mapping between the energy consumption related parameters and the energy consumption of all the RRUs and/or AAUs in the RAN using a general AI and/or ML-based energy consumption estimator.

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METHOD AND SYSTEM FOR ESTIMATING ENERGY CONSUMPTION IN RADIO ACCESS NETWORK

TECHNICAL FIELD

The disclosure relates generally to a radio access network, and more particularly, the disclosure relates to a method and system for estimating energy consumption in the radio access network.

BACKGROUND

The 3rd Generation Partnership Project, 3GPP, New Radio, NR, Release 16 defines an energy consumption model for 5G User Equipment, UE,. 3GPP NR Release 18 further attempts to develop a set of flexible and dynamic network energy saving solutions. Network energy saving solutions should take into account the influence of key 5G Base Station, BS, energy consumption factors, such as power amplifier, PA, number of TxRU, and static circuit parts, while also considering 5G BS sleep modes and their associated transition times, among others. There is no accurate 5G BS energy consumption estimation framework known to be able to accommodate the requirements of the 3GPP. Due to this reason, the 3GPP has set the construction of such a BS energy consumption estimation framework as the first important objective to construct and evaluate network energy saving solutions.

In an existing solution, a model is provided that explicitly shows a linear relationship between the network power consumption and transmitted power. The model may additionally support massive multiple-input multiple-outputs,mMIMOs, and energy saving capabilities, considering different sleep depths and transition times between different energy states. However, this solution does not consider multi-carrier and/or carrier aggregation,CA, capabilities, and mMIMOs power consumption estimates seem to be inaccurate, with an optimistic 40.5 W per BS.

Another existing solution includes mMIMO and multi-carrier capabilities features, i.e., intra-band contiguous, intra-band non-contiguous, and inter-band. However, none of these works consider all the requirements of the 3GPP. Importantly, these estimation frameworks are mostly theoretical, and not accurate enough to capture the energy consumption of real 5G radio units, and in turn, networks.

It should be noted that the radio units are the main energy consumers of the overall network. According to GSMA, 73% of the energy is consumed in a radio access network,RAN, and the radio units consume from 66% up to 82% of the energy consumed in the BS. In practice, a radio unit, which is in charge of performing TX/RX signal processing, may take the form of: 1. a Remote Radio Unit,RRU, which exchanges (a) digital signals with the baseband unit,BBU, through a fiber optic cable, and (b) analog signals with passive antenna elements through a coaxial cable, or 2. an Active Antenna Unit,AAU,, which roughly speaking, integrates the RRU functionality and the passive antenna elements into one unit, and provides hardware and logic to (i) control the precoding coefficients of each passive antenna element, and (ii) combine/divide the digital signals from/to each passive antenna element.

In 3GPP terminology, the radio unit is also referred to as “a Transmission Reception Point,TRP, which is an antenna array with one or more antenna elements available to the network located at a specific geographical location for a specific area”. Traditionally, RRUs, AAUs, or TRPs are multi-carrier, and use a wideband PA to operate such multiple carriers.

It follows from the above discussion that the energy consumption of a carrier or a cell cannot be determined independently from actions of other carriers or cells that are co-located in the same RRU/AUU, as they share circuitry. As a result, creating an energy consumption estimation framework per carrier or cell would result in an inaccurate BS/network energy consumption estimation, as the mentioned multi-carrier characteristics of the RRU or AAU would not be considered.

Another major problem is that using only local cell data does not allow to create a generalised energy consumption estimation framework for each RRU or AAU, as the data used to realise the estimation would be limited to the configuration and scenarios observed locally by such RRU or AAU. For example, in a given area, due to high load, not all energy saving modes may be activated in a given RRU or AAU. The target instead is to predict the RRU or AAU energy consumption for any operating point/ configuration of this RRU or AAU, even if it has not been observed locally.

Therefore, there arises a need to address the aforementioned technical problem/ drawbacks in estimating energy consumption in the RANs.

SUMMARY

It is an object of the disclosure to provide a method of estimating an energy consumption in a radio access network, RAN, and a system for estimating an energy consumption in the RAN, while avoiding one or more disadvantages of prior art approaches.

This object is achieved by the features of the independent claims. Further, implementation forms are apparent from the dependent claims, the description, and the figures.

The disclosure provides a method of estimating an energy consumption in a RAN.

According to a first aspect, there is provided a method of estimating an energy consumption in a RAN. The method includes reporting, by each carrier in each of one or more Remote Radio Units, RRUs, and/or one or more Active Antenna Units, AAUs, in the RAN, energy consumption related parameters of the carrier to a master carrier of the RRU or AAU. The method includes creating, by the master carrier in each of the one or more RRUs and/or AAUs, a local mapping between the energy consumption related parameters and an energy consumption of the RRU or AAU using a local Artificial Intelligence, AI, or Machine Learning, ML, -based energy consumption estimator with the reported energy consumption related parameters of the carriers in the RRU or AAU. The method includes reporting, by the master carrier in each of the one or more RRUs and/or AAUs, the local mapping to an optimization node of the RAN. The method includes creating, by the optimization node, a general mapping between the energy consumption related parameters and the energy consumption of all the RRUs and/or AAUs in the RAN using a general AI and/or ML-based energy consumption estimator with all the reported local mappings. The method includes refining, by the optimization node, the local mapping between the energy consumption related parameters and the energy consumption for each of the RRUs and/or AAUs using the local AI and/or ML-based energy consumption estimator of the RRU or AAU with all the reported local mappings.

This method enables improved network energy saving optimization because of increased accuracy of network energy consumption estimation. This method uses network and energy-related information gathered at each of the RRU or AAU, which allows to locally capture (i) specific networking conditions, e.g. traffic, massive MIMO at, and (ii) particularities, e.g. manufacturing variances and temperature effects at each of the RRU or AAU.

This method provides more accurate network energy consumption estimations for a heterogeneous multi-vendor network comprising different radio units including RRUs and AAUs from any vendor, and any possible network configurations.

This method enables obtaining generalisation properties that are key for the network energy efficiency optimization. This method generalises over multiple products and parameter configurations, and thus, for example, can generate accurate energy consumption estimations for a first RRU or AAU in scenarios where configuration of the first RRU or AAU has not been measured and is not available in the data that is used to construct the estimator, but the configuration is available for another RRUs or AAUs, for example, a second RRU or AAU or a third RRU or AAU.

Optionally, the method includes reporting, by the optimization node, the refined local mapping to the master carrier in each of the one or more RRUs and/or AAUs in the RAN.

Optionally, the method includes updating, by the master carrier in each of the one or more RRUs or AAUs, the local AI or ML-based energy consumption estimator with the refined local mapping and repeating the method using the updated local AI or ML-based energy consumption estimator.

Optionally, the method includes applying, by the optimization node, pre-defined network energy efficiency optimization policies to the RRUs or AAUs in the RAN using current state of the general AI and/or ML-based energy consumption estimator.

Optionally, the optimization node comprises a controller of the RAN or a master carrier of a master RRU or AAU in the RAN.

Optionally, the master RRU or AAU in the RAN is pre-selected among all the RRUs and/or AAUs in the RAN by the controller of the RAN.

Optionally, the master carrier in each of the one or more RRUs and/or AAUs is pre-selected by a controller of the RAN among all carriers in each of the one or more RRUs and/or AAUs.

Optionally, the method includes defining, by a controller of the RAN, an architecture of the local AI or ML-based energy consumption estimator in each master carrier in each of the one or more RRUs and/or AAUs, the architecture including inputs and outputs of the local AI or ML-based energy consumption estimator, and time periods for reporting the energy consumption related parameters by the other carriers in each of the one or more RRUs and/or AAUs, and defining, by the controller of the RAN, an architecture of the general AI or ML-based energy consumption estimator for the optimization node, the architecture including inputs and outputs of the general AI or ML-based energy consumption estimator.

Optionally, the method includes defining, by the master carrier in each of the one or more RRUs and/or AAUs, the energy consumption related parameters to be reported by the other carriers of the RRU or AAU based on the defined inputs of the local AI or ML-based energy consumption estimator.

Optionally, the energy consumption related parameters reported by the carriers in each of the one or more RRUs and/or AAUs include configuration parameters of the RRU or AAU and carrier-level key performance indicators, KPIs, related to the energy consumption of the RRU or AAU.

According to a second aspect, there is provided a system for estimating an energy consumption in a RAN including one or more Remote Radio Units, RRUs, and/or one or more Active Antenna Units, AAUs. The system includes carriers in each of the one or more RRUs and/or AAUs configured for reporting energy consumption related parameters of each carrier to a master carrier of the RRU or AAU. The master carrier in each of the one or more RRUs and/or AAUs is configured for creating a local mapping between the reported energy consumption related parameters and an energy consumption of the RRU or AAU using a local Artificial Intelligence, AI, or Machine Learning, ML, -based energy consumption estimator with the reported energy consumption related parameters of the carriers in the RRU or AAU, and reporting the local mapping to an optimization node of the RAN. The optimization node is configured for creating a general mapping between the energy consumption related parameters and the energy consumption of all the RRUs and/or AAUs in the RAN using a general AI and/or ML-based energy consumption estimator with all the reported local mappings. The optimization node is configured for refining the local mapping between the energy consumption related parameters and the energy consumption for each of the RRUs and/or AAUs using the local AI and/or ML-based energy consumption estimator of the RRU or AAU with all the reported local mappings.

The system enables improved network energy saving optimization because of increased accuracy of network energy consumption estimation. The system uses network and energy-related information gathered at each RRU or AAU, which allows to locally capture at each RRU or AAU (i) specific networking conditions, e.g. traffic, massive MIMO, and (ii) particularities, e.g. manufacturing variances and temperature effects.

The system provides more accurate network energy consumption estimations in heterogeneous multi-vendor networks comprising different radio units including RRUs and or AAUs from any vendor, and any possible network configurations.

The system enables obtaining generalisation properties that are key for network energy efficiency optimization. The system generalises over multiple products and parameter configurations, and thus, for example, can generate accurate energy consumption estimations for a first RRU or AAU in scenarios where the configuration of the first RRU or AAU has not been measured and is not available in the data that is used to construct the estimator, but the configuration is available for another RRUs or AAUs, for example, a second RRU or AAU or a third RRU or AAU.

Optionally, the optimization node is further configured for reporting the refined local mapping to the master carrier in each of the one or more RRUs and/or AAUs in the RAN.

Optionally, the master carrier in each of the one or more RRUs or AAUs is further configured for updating the local AI or ML-based energy consumption estimator with the refined local mapping.

Optionally, the optimization node is further configured for applying pre-defined network energy efficiency optimization policies to the RRUs or AAUs in the RAN using current state of the general AI and/or ML-based energy consumption estimator.

Optionally, the optimization node comprises a controller of the RAN or a master carrier of a master RRU or AAU in the RAN.

Optionally, the master RRU or AAU in the RAN is pre-selected among all the RRUs and/or AAUs in the RAN by the controller of the RAN.

Optionally, the master carrier in each of the one or more RRUs and/or AAUs is pre-selected by a controller of the RAN among all carriers in each of the one or more RRUs and/or AAUs.

Optionally, a controller of the RAN is configured for defining an architecture of the local AI or ML-based energy consumption estimator in each master carrier in each of the one or more RRUs and/or AAUs, the architecture including inputs and outputs of the local AI or ML-based energy consumption estimator, and time periods for reporting the energy consumption related parameters by the other carriers in each of the one or more RRUs and/or AAUs, and defining an architecture of the general AI or ML-based energy consumption estimator for the optimization node, the architecture including inputs and outputs the general AI or ML-based energy consumption estimator.

Optionally, the master carrier in each of the one or more RRUs and/or AAUs is configured for defining the energy consumption related parameters to be reported by the other carriers of the RRU or AAU based on the defined inputs of the local AI or ML-based energy consumption estimator.

Optionally, the energy consumption related parameters reported by the carriers in each of the one or more RRUs and/or AAUs comprise configuration parameters of the RRU or AAU and carrier-level key performance indicators, KPIs, related to the energy consumption of the RRU or AAU.

These and other aspects of the disclosure will be apparent from and the implementation(s) described below.

BRIEF DESCRIPTION OF DRAWINGS

Implementations of the disclosure will now be described, by way of example only, with reference to the accompanying drawings, in which:

FIG. 1 is a block diagram of a system for estimating an energy consumption in a radio access network, RAN in accordance with an implementation of the disclosure;

FIG. 2 is a flow chart of a method of estimating energy consumption based on artificial intelligence/machine learning in accordance with an implementation of the disclosure;

FIGS. 3A-3C are exemplary illustrations of an Active Antenna Unit, AAU used for estimating energy consumption in accordance with an implementation of the disclosure;

FIG. 4 is an interaction diagram that illustrates information exchange between a central controller, a master AAU, and one or more slave AAUs in accordance with an implementation of the disclosure;

FIGS. 5A-5B are exemplary illustrations of a master carrier within an Active Antenna Unit, AAU used for estimating energy consumption in intra-AAU operations in accordance with an implementation of the disclosure;

FIG. 5C is an exemplary illustration of a model trained by the master carrier of FIG. 1

with the information of operations within the Active Antenna Unit, AAU in accordance with an implementation of the disclosure;

FIGS. 6A-6B are exemplary illustrations of one or more slave AAUs with a master AAU and a central controller in an inter-AAU model exchange in accordance with an implementation of the disclosure;

FIG. 7 is an exemplary illustration of a federated learning approach to build and improve a local and a general AI/ML based network energy consumption estimators in accordance with an implementation of the disclosure;

FIG. 8 is an exemplary illustration of a federated learning approach to build and improve a local and a general AI/ML based network plus user equipment, UE energy consumption estimators in accordance with an implementation of the disclosure;

FIG. 9 is an interaction diagram that illustrates information exchange between a central controller, a master AAU, and one or more slave AAUs and UEs in accordance with an implementation of the disclosure;

FIGS. 10A and 10B are flow diagrams that illustrate a method of estimating an energy consumption in a RAN in accordance with an implementation of the disclosure; and

FIG. 11 is an illustration of a computer system (e.g. an optimization node) in which the various architectures and functionalities of the various previous implementations may be implemented.

DETAILED DESCRIPTION OF THE DRAWINGS

Implementations of the disclosure provide a method and system for estimating an energy consumption in a radio access network, RAN.

To make solutions of the disclosure more comprehensible for a person skilled in the art, the following implementations of the disclosure are described with reference to the accompanying drawings.

Terms such as "a first", "a second", "a third", and "a fourth" (if any) in the summary, claims, and foregoing accompanying drawings of the disclosure are used to distinguish between similar objects and are not necessarily used to describe a specific sequence or order. It should be understood that the terms so used are interchangeable under appropriate circumstances, so that the implementations of the disclosure described herein are, for example, capable of being implemented in sequences other than the sequences illustrated or described herein. Furthermore, the terms "include" and "have" and any variations thereof, are intended to cover a non-exclusive inclusion. For example, a process, a method, a system, a product, or a device that includes a series of steps or units, is not necessarily limited to expressly listed steps or units but may include other steps or units that are not expressly listed or that are inherent to such process, method, product, or device.

FIG. 1 is a block diagram of a system **100** for estimating an energy consumption in a RAN **102** in accordance with an implementation of the disclosure. The system **100** includes carriers **105A-Z** in each of the one or more remote radio units, RRUs **104A-N**, and/or active antenna units, AAUs **106A-N**. The carriers **105A-Z** are configured for reporting energy consumption related parameters of each carrier **105A-Z** to a master carrier **108A-Z** of the RRU **104A** or AAU **106A**. The master carrier **108A-Z** in each of the one or more RRUs **104A-N** and/or AAUs **106A-N** is configured for creating a local mapping between the reported energy consumption related parameters and an energy consumption of the RRU **104A** or AAU **106A** using a local Artificial Intelligence, AI, or Machine Learning, ML, based energy consumption estimator with the reported energy consumption related parameters of the carriers **105A-Z** in the RRU **104A** or AAU **106A**. The master carrier **108A-Z** in each of the one or more RRUs **104A-N** and/or AAUs **106A-N** is configured for reporting the local mapping to an optimization node **110** of the RAN **102**. The optimization node **110** is configured for creating a general mapping between the energy consumption related parameters and the energy consumption of all the RRUs **104A-N** and/or AAUs **106A-N** in the RAN **102** using a general AI and/or ML-based energy consumption estimator with all the reported local mappings. The optimization node **110** is configured for refining the local mapping between the energy consumption related parameters and the energy consumption for each of the RRUs **104A-N** and/or AAUs **106A-N** using the local AI and/or ML-based energy consumption estimator of the RRU **104A** or AAU **106A** with all the reported local mappings.

The system **100** enables improved network energy saving optimization because of increased accuracy of network energy consumption estimation. The system **100** uses network and energy-related information gathered at each of the one or more RRUs **104A-N** or the one or more AAUs **106A-N**, which allows to locally capture at each RRU or AAU (i) specific networking conditions, e.g. traffic, massive MIMO, and (ii) particularities, e.g. manufacturing variances and temperature effects.

The system **100** provides more accurate network energy consumption estimations for a method for a better network energy saving optimization of heterogeneous multi-vendor networks comprising different radio units including RRUs and or AAUs from any vendor, and any possible network configurations.

The system **100** enables obtaining generalisation properties that are key for network energy efficiency optimization. The system **100** generalises over multiple products and parameter configurations, and thus, for example, can generate accurate energy consumption estimations for the RRU **104A** or the AAU **106A** in scenarios where configuration of the RRU **104A** or the AAU **106A** has not been measured and is not available in the data that is used to construct the estimator, but the configuration is available for another RRUs or AAUs, for example, an RRU **104B/** AAU **106B** or an RRU **104N** or an AAU **106N**.

Optionally, the optimization node **110** is further configured for reporting the refined local mapping to the master carrier **108A-Z** in each of the one or more RRUs **104A-N** and/or AAUs **106A-N** in the RAN **102**.

Optionally, the master carrier **108A-Z** in each of the one or more RRUs **104A-N** or AAUs **106A-N**, is further configured for updating the local AI or ML-based energy consumption estimator with the refined local mapping.

Optionally, the optimization node **110** is further configured for applying pre-defined network energy efficiency optimization policies to the RRUs **104A-N** or AAUs **106A-N** in the RAN **102** using current state of the general AI and/or ML-based energy consumption estimator.

Optionally, the optimization node **110** includes a controller of the RAN **102** or a master carrier **108A** of a master RRU or AAU in the RAN **102**.

Optionally, the master RRU or AAU in the RAN **102** is pre-selected among all the RRUs **104A-N** and/or AAUs **106A-N** in the RAN **102** by the controller of the RAN **102**.

Optionally, the master carrier **108A-Z** in each of the one or more RRUs **104A-N** and/or AAUs **106A-N** is pre-selected by a controller of the RAN **102** among all carriers **105A-Z** in each of the one or more RRUs **104A-N** and/or AAUs **106A-N**.

Optionally, the controller of the RAN **102** is configured for: defining an architecture of the local AI or ML-based energy consumption estimator in each master carrier **108A-Z** in each of the one or more RRUs **104A-N** and/or AAUs **106A-N**, the architecture including inputs and outputs of the local AI or ML-based energy consumption estimator, and time periods for reporting the energy consumption related parameters by the other carriers in each of the one or more RRUs **104A-N** and/or AAUs **106A-N** table is split into shards consisting of rows based on date values comprised in a data field in each row, and, defining an architecture of the general AI or ML-based energy consumption estimator for the optimization node **110**, the architecture including inputs and outputs of the general AI or ML-based energy consumption estimator.

Optionally, the master carrier **108A-Z** in each of the one or more RRUs **104A-N** and/or AAUs **106A-N** defining the energy consumption related parameters to be reported by the other carriers of the RRU **104A** or AAU **106A** based on the defined inputs of the local AI or ML-based energy consumption estimator.

Optionally, the energy consumption related parameters reported by the carriers **105A-Z** in each of the one or more RRUs **104A-N** and/or AAUs **106A-N** comprise configuration parameters of the RRU **104A** or AAU **106A** and carrier-level key performance indicators, KPIs, related to the energy consumption of the RRU **104A** or AAU **106A**.

The optimization node **110** may be a central controller (deployed, e.g. at operations, administration, and maintenance network management functions), or an apriori selected master carrier of an apriori selected master RRU or AAU of a group of RRUs or AAUs. The optimization node **110** enables optimization of network energy efficiency of the RAN **102**.

FIG. 2 is a flow chart of a method of estimating energy consumption based on an artificial intelligence/machine learning in accordance with an implementation of the disclosure. At a step **202**, the method starts. A controller of the RAN identifies the master carrier of each of the one or more RRUs and/or AAUs and defines the AI/ML-based energy consumption estimator architecture or a mapping architecture, including inputs and outputs as well as measurement and reporting periods. At a step **204**, mapping setup is performed. The controller of the RAN indicates to the master carrier each of the one or more RRUs and/or AAUs such decisions, and the master carrier of each of the one or more RRUs and/or AAUs indicates to its slave carriers, i.e. the other carriers deployed in the same RRU or AAU, the cell-level key performance indicators,KPIs, to be reported together with a measurement and reporting timing. The RAN controller may directly configure the slave carriers.

At a step **206**, if there is a measurement and reporting timing, the slave carriers assess and exchange the relevant cell-level KPIs according to the configuration in the second step with their master carrier, else the step **204** is repeated. At a step **208**, the master carrier of each RRU or AAU updates, using AI/ML methods, the local AI/ML-based energy consumption mapping, i.e., the AI/ML-based energy consumption estimator of its RRU or AAU.

At a step **210**, after the local AI/ML-based energy consumption estimator has been updated, an inter-AAU communication phase occurs, where the master carrier of each RRU or AAU reports updated local AI/ML-based energy consumption mapping to an optimization node. The optimization node enables optimizing the network energy efficiency through a Xn interface. At a step **212**, the optimization node updates, using AI/ML techniques, general AI/ML-based energy consumption mapping. At a step **214**, the optimization node updates, using AI/ML techniques, each one of the local AI/ML-based energy consumption mappings.

At a step **216**, the optimization node may use this mapping to run pre-defined network energy efficiency optimization policies. The general AI/ML-based energy consumption mapping may be provided as an input to a larger and existing network energy efficiency optimization method. At a step **218**, an inter-AAU communication phase occurs, where the optimization node reports the updated local AI/ML-based energy consumption mappings to the master carriers of each RRU or AAU. Upon subsequent measurements and reporting timings, the method is repeated from the step **206** onwards.

FIGS. 3A-3C are exemplary illustrations of an Active Antenna Unit, AAU used for estimating energy consumption in accordance with an implementation of the disclosure. As an example, a RAN that includes X sites, where each site has Y AAUs, and where each AAU supports Z carriers. In this example, the Z carriers powered by the same AAU reuse the same transceiver, comprising M transceiver ports. FIG. 3A illustrates an AAU **302** that supports Z carriers. It is assumed that, in line with reality, energy consumption can only be measured at the AAU level. The Z carriers mounted on an RRU or AAU **302** are not aware of the energy consumption of its RRU or AAU **302**, and thus, the energy consumption cannot be measured per carrier or cell. Optionally, a network comprised of AAUs is selected. Optionally, network energy consumption estimation is also performed for a network comprised of RRUs or a combination of AAUs and RRUs.

FIG. 3B illustrates local AI/ML energy consumption mapping per AAU. A local AI/ML-based energy consumption estimator/mapping is created per AAU based on local observations of the carriers of such AAU. In the example, Y local estimators are created.

FIG. 3C illustrates local AI/ML energy consumption mapping exchange from a plurality of local AAUs to the optimization node. The master carrier of each of the plurality of local AAUs **304A-N** shares the local AI/ML-based energy consumption estimator/mapping with an optimization node **306** in charge of optimizing network energy efficiency. As an example, Y local estimators are exchanged.

Local AI/ML power consumption mapping is exchanged between the plurality of local

AAUs **304A-N** and the optimization node **306**, that creates a general AI/ML-based energy consumption mapping for the network at a coordination node, and a general estimator. The optimization node **306** (a) refines the local AI/ML-based energy consumption mapping using overall view, (b) use the network AI/ML energy consumption mapping for network energy efficiency optimization, and (c) shares the updated local AI/ML-based energy consumption mappings with the master carrier of each of the plurality of local AAUs **304A-N**. In this example, Y updated local estimators are exchanged. Updated local AI/ML energy consumption mapping is also exchanged from the optimization node **306** to each of the plurality of local AAUs **304A-N**.

FIG. 4 is an interaction diagram that illustrates information exchange between a central controller **402**, a master AAU **404**, and one or more slave AAUs **406** in accordance with an implementation of the disclosure. At a step **408**, a mapping update is requested by the central controller **402**. At a step **410**, a mapping input is requested from the master AAU **404** to the one or more slave AAUs **406**. At a step **412**, the mapping input is transferred from the one or more slave AAUs **406** to the master AAU **404**. At a step **414**, a local mapping input is measured in the master AAU **404**. At a step **416**, the local mapping input is updated. At a step **418**, a model is shared with the central controller **402**. At a step **420**, a network mapping is updated in the master AAU **404**. At a step **422**, network optimization is performed based on the network mapping. At a step **424**, the local mapping is updated. At a step **426**, the central controller **402** shares mapping to the one or more slave AAUs **406**.

FIGS. 5A-5B are exemplary illustrations of a master carrier within an Active Antenna Unit, AAU used for estimating energy consumption in intra-AAU operations in accordance with an implementation of the disclosure. Each AAU includes a master carrier **502** and a plurality of slave carriers **504A-N.** Optionally, a reporting timing relationship is determined for each of a plurality of slave carriers **504A-N**. The master carrier **502** may be the one with a lowest frequency, i.e. the one with a largest coverage. Each measurement at the plurality of slave carriers **504A-N** is immediately followed by reporting of the measurement to the master carrier **502**. Optionally, the reporting may be performed sometime after the measurement. The reporting timing may be periodic, e.g. 1 minute or may be aperiodic.

The master carrier **502** of the AAU may have access to the power consumption of such AAU. Then, in each reporting period, the master carrier **502** within each AAU collects (i) necessary input data to construct a local AI/ML energy consumption mapping for the AAU, (ii) necessary output data to construct the local AI/ML energy consumption mapping for the AAU, and (iii) necessary input information data to construct a local AI/ML energy consumption mapping for the AAU. Similarly, at each reporting period, each of the plurality of slave carriers **504A-N** in the AAU collects and sends to the master carrier **502** within the AAU.

Each of the plurality of slave carriers **504A-N** in the AAU sends data to the master carrier **502** within the AAU. Necessary input information per carrier to create the AI/ML energy consumption estimator/mapping for the AAU includes Number of TRX available, Carrier transmission mode, i.e. TDD/FDD, SUL usage, Carrier frequency, Carrier bandwidth, Carrier maximum transmit power during the reporting period, Carrier DL and UL PRB load during the reporting period, Duration of symbol shutdown during the reporting period, Duration of channel shutdown during the reporting period, Duration of carrier shutdown during the reporting period, Duration of deep dormancy during the reporting period.

FIG. 5C is an exemplary illustration of a model **506** trained by a master carrier of FIG. 1 with information of operations within an Active Antenna Unit, AAU in accordance with an implementation of the disclosure. The energy consumption related parameters required to create the AI/ML power consumption estimator/mapping for the AAU includes AAU power consumption during the reporting period. After acquiring all the above information, the master carrier **502** in the AAU trains the AI/ML power consumption estimator/mapping of this AAU. Optionally, the goal of the training is to penalize both prediction error and uncertainty. Optionally, the AI/ML power consumption mapping/estimator is an artificial neural network,ANN.

FIGS. 6A-6B are exemplary illustrations of one or more slave AAUs **604A-N** with a master AAU **602** and a central controller **606** in an inter-AAU model exchange in accordance with an implementation of the disclosure. The optimization node is a master AAU **602** having a master carrier responsible for optimizing network energy efficiency. A master AAU selection process may be needed for inter-AAU model exchange. Optionally, the optimization node is the central controller **606** responsible for optimizing network energy efficiency. The central controller **606** may be in a control layer or a core (i.e. a management and orchestration entity). Optionally, the central controller **606** is an ORAN controller (e.g., Near-RT RIC or Non-RT-RIC).

In the inter-AAU model exchange, a reporting periodicity may be selected. The reporting periodicity may be set to 1 minute. Optionally, the master carrier of each of the one or more slave AAUs **604A-N** sends trained local AI/ML-based energy consumption estimator/mapping to the master carrier of the master AAU **602** or to the central controller **606** at each reporting period.

In case of the intra-AAU model exchange, the exchange is realized through the master carriers of the slave AAUs and the master carrier of the master AAU through the Xn interface. In case of intra-AAU model exchange, the exchange is realized through the proper interface depending on a location of the central controller **606**.

FIG. 7 is an exemplary illustration of a federated learning approach to build and improve a local and a general AI/ML based network energy consumption estimator in accordance with an implementation of the disclosure. The exemplary illustration includes a plurality of networks **702A-N** that include a plurality of master carriers **704A-N**, and a central controller **706.** Using each of the AI/ML estimators/mappings received and AI/ML techniques, a master carrier of the master AAU of the plurality of networks **702A-N** or the central controller **706** of the plurality of networks **702A-N** trains and continuously improves the general AI/ML-based energy consumption estimator/mapping for the plurality of networks **702A-N**, and each of the local AI/ML-based energy consumption estimators/mappings using the overall ‘view’, the other local mappings. Optionally, federated learning methods are used to build and improve the local and general AI/ML-based energy consumption estimators/mappings.

Optionally, the general AI/ML-based energy consumption estimator/mapping may be used for network energy efficiency optimization. The master carrier of the master

AAU of the plurality of networks **702A-N** or the central controller **706** runs its network energy efficiency optimization logic using as input the general AI/ML-based energy consumption estimator/mapping. The general AI/ML-based energy consumption estimator/mapping may be built with local information of each AAU of the plurality of networks **702A-N** that allows an optimization node to predict the energy consumption of any energy saving policy configuration tested in an optimization process and identifies better network energy saving configurations for the plurality of networks **702A-N**.

FIG. 8 is an exemplary illustration of a federated learning approach to build and improve a local and a general AI/ML based network plus user equipment, UE energy consumption estimators in accordance with an implementation of the disclosure. The exemplary illustrations include a plurality of networks plus UE arrangements **802A-N** that include a plurality of master carriers **804A-N** and a plurality of UEs **806A-N**, and a central controller **808**. For a holistic network energy consumption optimization, consumption of the plurality of networks plus UE arrangements **802A-N** may be modelled. Each UE in the plurality of networks plus UE arrangements **802A-N** creates its own AI/ML UE energy consumption estimator/mapping, using the same AI/ML framework used by the master carrier of an RRU or AAU to create its estimator/mapping. At each reporting period, each AI/ML UE energy consumption estimator/mapping of the plurality of networks plus UE arrangements **802A-N** is reported to a serving cell via an air interface, and then each serving carrier combines the AI/ML UE energy consumption estimator/mapping together with its own local AI/ML AAU energy consumption estimator/mapping using the central controller **808**.

FIG. 9 is an interaction diagram that illustrates information exchange between a central controller **902**, a master Active Antenna Unit, AAU, **904** and a slave Active Antenna Unit, AAU, **906** and a user equipment, UE, **908** in accordance with an implementation of the disclosure. At a step **910**, the slave AAU **906** requests input for cell key performance indicators, KPIs from the UE **908**. At a step **912**, cell level KPIs are updated by the slave AAU **906**. At a step **914**, the central controller **902** requests a model update from the central controller **902**. At a step **916**, the master AAU **904** request mapping input from the slave AAU **906**. At a step **918**, the slave AAU **906** transfers the mapping input to the master AAU **904**. At a step **920**, local mapping input is measured by the master AAU **904**. At a step **922**, the local mapping input is updated by the master AAU **904**. At a step **924**, the master AAU **904** shares the mapping to the central controller **902**. At a step **926**, network mapping is updated by the central controller **902**. At a step **928**, network optimization is performed by the central controller **902**. At a step **930**, local mapping updates are applied by the central controller **902**. At a step **932**, the mapping is shared by the central controller **902** to the master AAU **904**, the slave AAU **906**, and the UE **908**.

FIGS. 10A and 10B are flow diagrams that illustrate a method of estimating an energy consumption in a RAN in accordance with an implementation of the disclosure. At a step **1002**, energy consumption related parameters of the carrier are reported to a master carrier of the RRU or AAU by each carrier in each of one or more Remote Radio Units, RRUs, and/or one or more Active Antenna Units, AAUs, in the RAN. At a step **1004**, the master carrier in each of the one or more RRUs and/or AAUs, a local mapping between the energy consumption related parameters and an energy consumption of the RRU or AAU is created by the master carrier in each of the one or more RRUs AND/OR AAUs using a local Artificial Intelligence, AI, or Machine Learning, ML, based energy consumption estimator with the reported energy consumption related parameters of the carriers in the RRU or AAU. At a step **1006**, the local mapping is reported to an optimization node of the RAN by the master carrier in each of the one or more RRUs and/or AAUs. At a step **1008**, a general mapping between the energy consumption related parameters and the energy consumption of all the RRUs and/or AAUs in the RAN is created by the optimization node using a general AI and/or ML-based energy consumption estimator with all the reported local mappings. At a step **1010**, the local mapping between the energy consumption related parameters and the energy consumption is refined by the optimization node for each of the RRUs and/or AAUs using the local AI and/or ML-based energy consumption estimator of the RRU or AAU with all the reported local mappings.

This method enables improved network energy saving optimization because of increased accuracy of network energy consumption estimation. This method uses network and energy-related information gathered at each of the RRU or AAU, which allows to locally capture (i) specific networking conditions, e.g. traffic, massive MIMO at, and (ii) particularities, e.g. manufacturing variances and temperature effects at each of the RRU or AAU.

This method enables obtaining generalization properties that are key for network energy efficiency optimization. This method generalizes over multiple products and parameter configurations, and thus, for example, can generate accurate energy consumption estimations for a first RRU or AAU in scenarios where configuration of the first RRU or AAU has not been measured and is not available in the data that is used to construct the estimator, but the configuration is available for another RRUs or AAUs, for example a second RRU or AAU or a third RRU or AAU.

Optionally, the method includes reporting, by the optimization node, the refined local mapping to the master carrier in each of the one or more RRUs and/or AAUs in the RAN.

Optionally, the method includes updating, by the master carrier in each of the one or more RRUs or AAUs, the local AI or ML-based energy consumption estimator with the refined local mapping and repeating the steps of claim 1 using the updated local AI or ML-based energy consumption estimator.

Optionally, the method includes applying, by the optimization node, pre-defined network energy efficiency optimization policies to the RRUs or AAUs in the RAN using current state of the general AI and/or ML-based energy consumption estimator.

Optionally, the optimization node includes a controller of the RAN or a master carrier of a master RRU or AAU in the RAN.

Optionally, the master RRU or AAU in the RAN is pre-selected among all the RRUs and/or AAUs in the RAN by the controller of the RAN.

Optionally, the master carrier in each of the one or more RRUs and/or AAUs is pre-selected by a controller of the RAN among all carriers in each of the one or more RRUs and/or AAUs.

Optionally, the method includes defining, by a controller of the RAN, an architecture of the local AI or ML-based energy consumption estimator in each master carrier in each of the one or more RRUs and/or AAUs, the architecture including inputs and outputs of the local AI or ML-based energy consumption estimator, and time periods for reporting the energy consumption related parameters by the other carriers in each of the one or more RRUs and/or AAUs table is split into shards consisting of rows based on date values comprised in a data field in each row, and, defining, by the controller of the RAN, an architecture of the general AI or ML-based energy consumption estimator for the optimization node, the architecture including inputs and outputs of the general AI or ML-based energy consumption estimator.

Optionally, the method includes defining, by the master carrier in each of the one or more RRUs and/or AAUs, the energy consumption related parameters to be reported by the other carriers of the RRU or AAU based on the defined inputs of the local AI or ML-based energy consumption estimator.

Optionally, the energy consumption related parameters reported by the carriers in each of the one or more RRUs and/or AAUs comprise configuration parameters of the RRU or AAU and carrier-level key performance indicators, KPIs, related to the energy consumption of the RRU or AAU.

Optionally, two cells exchange information or AI/ML-based mapping related to its RRU or AAU energy consumption over the air or Xn interface. Exchange of information can be checked by monitoring such interface using test equipment. A test cell may be deployed in a test RRU or AAU, next to another cell of an already deployed RRU or AAU, and test cell may send data about information or AI/ML-based mappings related to its RRU or AAU energy consumption over the air or Xn interface.

Optionally, the method does not require standardization and can be implemented building on top of an existing network energy efficiency platform. Optionally, standardization for inter-BS information exchange is required to enhance performance and allow inter-operability.

FIG. 11 is an illustration of a computer system (e.g. a database management system) in which the various architectures and functionalities of the various previous implementations may be implemented. As shown, the computer system **1100** includes at least one processor **1104** that is connected to a bus **1102**, wherein the computer system **1100** may be implemented using any suitable protocol, such as PCI (Peripheral Component Interconnect), PCI-Express, AGP (Accelerated Graphics Port), Hyper Transport, or any other bus or point-to-point communication protocol (s). The computer system **1100** also includes a memory **1106**.

Control logic (software) and data are stored in the memory **1106** which may take a form of random-access memory (RAM). In the disclosure, a single semiconductor platform may refer to a sole unitary semiconductor-based integrated circuit or chip. It should be noted that the term single semiconductor platform may also refer to multi-chip modules with increased connectivity which simulate on-chip modules with increased connectivity which simulate on-chip operation, and make substantial improvements over utilizing a conventional central processing unit (CPU) and bus implementation. Of course, the various modules may also be situated separately or in various combinations of semiconductor platforms per the desires of the user.

The computer system **1100** may also include a secondary storage **1110**. The secondary storage **1110** includes, for example, a hard disk drive and a removable storage drive, representing a floppy disk drive, a magnetic tape drive, a compact disk drive, digital versatile disk (DVD) drive, recording device, universal serial bus (USB) flash memory. The removable storage drive at least one of reads from and writes to a removable storage unit in a well-known manner.

Computer programs, or computer control logic algorithms, may be stored in at least one of the memory **1106** and the secondary storage **1110**. Such computer programs, when executed, enable the computer system **1100** to perform various functions as described in the foregoing. The memory **1106**, the secondary storage **1110**, and any other storage are possible examples of computer-readable media.

In an implementation, the architectures and functionalities depicted in the various previous figures may be implemented in the context of the processor **1104**, a graphics processor coupled to a communication interface **1112**, an integrated circuit (not shown) that is capable of at least a portion of the capabilities of both the processor **1104** and a graphics processor, a chipset (namely, a group of integrated circuits designed to work and sold as a unit for performing related functions, and so forth).

Furthermore, the architectures and functionalities depicted in the various previous-described figures may be implemented in a context of a general computer system, a circuit board system, a game console system dedicated for entertainment purposes, an application-specific system. For example, the computer system **1100** may take the form of a desktop computer, a laptop computer, a server, a workstation, a game console, an embedded system.

Furthermore, the computer system **1100** may take the form of various other devices including, but not limited to a personal digital assistant (PDA) device, a mobile phone device, a smart phone, a television, and so forth. Additionally, although not shown, the computer system **1100** may be coupled to a network (for example, a telecommunications network, a local area network (LAN), a wireless network, a wide area network (WAN) such as the Internet, a peer-to-peer network, a cable network, or the like) for communication purposes through an I/O interface **1108**.

It should be understood that the arrangement of components illustrated in the figures described are exemplary and that other arrangement may be possible. It should also be understood that the various system components (and means) defined by the claims, described below, and illustrated in the various block diagrams represent components in some systems configured according to the subject matter disclosed herein. For example, one or more of these system components (and means) may be realized, in whole or in part, by at least some of the components illustrated in the arrangements illustrated in the described figures.

In addition, while at least one of these components are implemented at least partially as an electronic hardware component, and therefore constitutes a machine, the other components may be implemented in software that when included in an execution environment constitutes a machine, hardware, or a combination of software and hardware.

Although the disclosure and its advantages have been described in detail, it should be understood that various changes, substitutions, and alterations can be made herein without departing from the spirit and scope of the disclosure as defined by the appended claims.

CLAIMS

1. A method of estimating an energy consumption in a radio access network, RAN (102), comprising:

reporting, by each carrier (105A-Z) in each of one or more Remote Radio Units, RRUs (104A-N), and/or one or more Active Antenna Units, AAUs (106A-N), in the RAN (102), energy consumption related parameters of the carrier (105A-Z) to a master carrier (108A-Z) of the RRU (104A) or AAU (106A),

creating, by the master carrier (108A-Z) in each of the one or more RRUs (104A-N) and/or AAUs (106A-N), a local mapping between the energy consumption related parameters and an energy consumption of the RRU (104A) or AAU (106A) using a local Artificial Intelligence, AI, or Machine Learning, ML, -based energy consumption estimator with the reported energy consumption related parameters of the carriers (105A-Z) in the RRU (104A) or AAU (106A),

reporting, by the master carrier (108A-Z) in each of the one or more RRUs (104A-N) and/or AAUs (106A-N), the local mapping to an optimization node (110, 306) of the RAN (102),

creating, by the optimization node (110, 306), a general mapping between the energy consumption related parameters and the energy consumption of all the RRUs (104A-N) and/or AAUs (106A-N) in the RAN (102) using a general AI and/or ML-based energy consumption estimator with all the reported local mappings, and

refining, by the optimization node (110, 306), the local mapping between the energy consumption related parameters and the energy consumption for each of the RRUs (104A-N) and/or AAUs (106A-N) using the local AI and/or ML-based energy consumption estimator of the RRU (104A) or AAU (106A) with all the reported local mappings.

2. The method of claim 1, further comprising:

reporting, by the optimization node (110, 306), the refined local mapping to the master carrier (108A-Z) in each of the one or more RRUs (104A-N) and/or AAUs (106A-N) in the RAN (102).

3. The method of claim 1 or 2, further comprising:

updating, by the master carrier (108A-Z) in each of the one or more RRUs (104A-N) or AAUs (106A-N), the local AI or ML-based energy consumption estimator with the refined local mapping, and

repeating the steps of claim 1 using the updated local AI or ML-based energy consumption estimators.

4. The method of any of claims 1 to 3, further comprising:

applying, by the optimization node (110, 306), pre-defined network energy efficiency optimization policies to the RRUs (104A-N) or AAUs (106A-N) in the RAN (102) using current state of the general AI and/or ML-based energy consumption estimator.

5. The method of any of claims 1 to 4, wherein the optimization node (110, 306) comprises a controller of the RAN (102) or a master carrier (108A-Z) of a master RRU or AAU in the RAN (102).

6. The method of claim 5, wherein the master RRU or AAU in the RAN (102) is pre-selected among all the RRUs (104A-N) and/or AAUs (106A-N) in the RAN (102) by the controller of the RAN (102).

7. The method of any of claims 1 to 6, wherein the master carrier (108A-Z) in each of the one or more RRUs (104A-N) and/or AAUs (106A-N) is pre-selected by a controller of the RAN (102) among all carriers (105A-Z) in each of the one or more RRUs (104A-N) and/or AAUs (106A-N).

8. The method of any of claims 1 to 7, further comprising:

defining, by a controller of the RAN (102), an architecture of the local AI or ML-based energy consumption estimator in each master carrier (108A-Z) in each of the one or more RRUs (104A-N) and/or AAUs (106A-N), the architecture including inputs and outputs of the local AI or ML-based energy consumption estimator, and time periods for reporting the energy consumption related parameters by the other carriers in each of the one or more RRUs (104A-N) and/or AAUs (106A-N), and

defining, by the controller of the RAN (102), an architecture of the general AI or ML-based energy consumption estimator for the optimization node (110, 306), the architecture including inputs and outputs of the general AI or ML-based energy consumption estimator.

9. The method of claims 8, further comprising:

defining, by the master carrier (108A-Z) in each of the one or more RRUs (104A-N) and/or AAUs (106A-N), the energy consumption related parameters to be reported by the other carriers of the RRU (104A) or AAU (106A) based on the defined inputs of the local AI or ML-based energy consumption estimator.

10. The method of any of claims 1 to 9, wherein the energy consumption related parameters reported by the carriers (105A-Z) in each of the one or more RRUs (104A-N) and/or AAUs (106A-N) comprise configuration parameters of the RRU (104A) or

AAU (106A) and carrier-level key performance indicators, KPIs, related to the energy consumption of the RRU (104A) or AAU (106A).

11. A system (100) for estimating an energy consumption in a radio access network, RAN (102), comprising one or more Remote Radio Units, RRUs (104A-N), and/or one or more Active Antenna Units, AAUs (106A-N), the system (100) comprising:

carriers (105A-Z) in each of the one or more RRUs (104A-N) and/or AAUs (106A-N) configured for reporting energy consumption related parameters of each carrier to a master carrier (108A-Z) of the RRU (104A) or AAU (106A),

wherein the master carrier (108A-Z) in each of the one or more RRUs (104A-N) and/or AAUs (106A-N) is configured for

creating a local mapping between the reported energy consumption related parameters and an energy consumption of the RRU (104A) or AAU (106A) using a local Artificial Intelligence, AI, or Machine Learning, ML, based energy consumption estimator with the reported energy consumption related parameters of the carriers (105A-Z) in the RRU (104A) or AAU (106A), and

reporting the local mapping to an optimization node (110, 306) of the RAN (102), and

wherein the optimization node (110, 306) is configured for

creating a general mapping between the energy consumption related parameters and the energy consumption of all the RRUs (104A-N) and/or AAUs (106A-N) in the RAN (102) using a general AI and/or ML-based energy consumption estimator with all the reported local mappings, and

refining the local mapping between the energy consumption related parameters and the energy consumption for each of the RRUs (104A-N) and/or

AAUs (106A-N) using the local AI and/or ML-based energy consumption estimator of the RRU (104A) or AAU (106A) with all the reported local mappings.

12. The system (100) of claim 11, wherein the optimization node (110, 306) is further configured for reporting the refined local mapping to the master carrier (108A-Z) in each of the one or more RRUs (104A-N) and/or AAUs (106A-N) in the RAN (102).

13. The system (100) of claim 12, wherein the master carrier (108A-Z) in each of the one or more RRUs (104A-N) or AAUs (106A-N) is further configured for updating the local AI or ML-based energy consumption estimator with the refined local mapping.

14. The system (100) of any of claims 11 to 13, wherein the optimization node (110, 306) is further configured for

applying pre-defined network energy efficiency optimization policies to the RRUs (104A-N) or AAUs (106A-N) in the RAN (102) using current state of the general AI and/or ML-based energy consumption estimator.

15. The system (100) of any of claims 11 to 14, wherein the optimization node (110, 306) comprises a controller of the RAN (102) or a master carrier (108) of a master RRU or AAU in the RAN (102).

16. The system (100) of claim 15, wherein the master RRU or AAU in the RAN (102) is pre-selected among all the RRUs (104A-N) and/or AAUs (106A-N) in the RAN (102) by the controller of the RAN (102).

17. The system (100) of any of claims 11 to 16, wherein the master carrier (108A-Z) in each of the one or more RRUs (104A-N) and/or AAUs (106A-N) is pre-selected by a controller of the RAN (102) among all carriers (105A-Z) in each of the one or more RRUs (104A-N) and/or AAUs (106A-N).

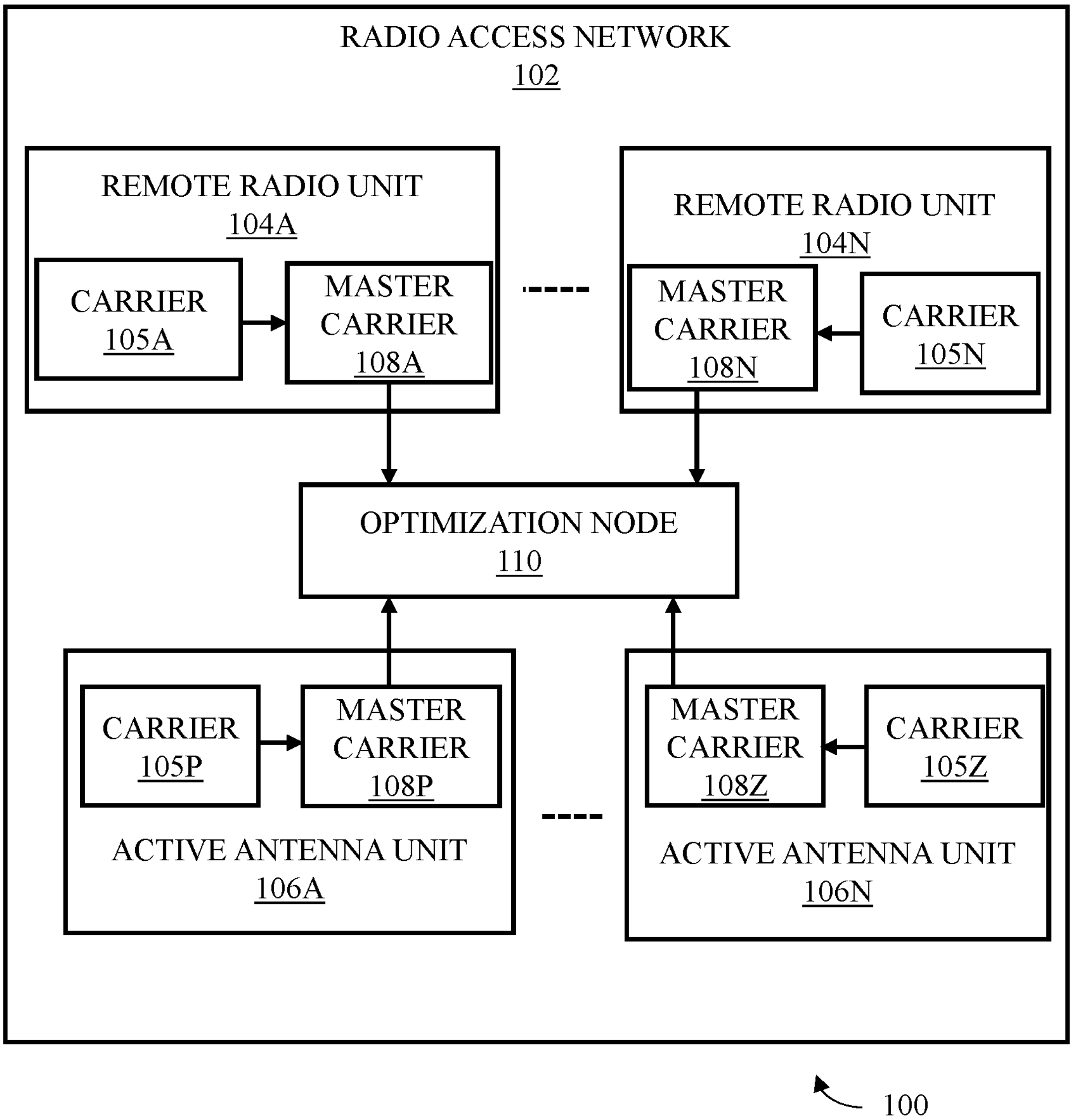
18. The system (100) of any of claims 11 to 17, wherein a controller of the RAN (102) is configured for:

defining an architecture of the local AI or ML-based energy consumption estimator in each master carrier (108A-Z) in each of the one or more RRUs (104A-N) and/or AAUs (106A-N), the architecture including inputs and outputs of the local AI or ML-based energy consumption estimator, and time periods for reporting the energy consumption related parameters by the other carriers in each of the one or more RRUs (104A-N) and/or AAUs (106A-N), and

defining an architecture of the general AI or ML-based energy consumption estimator for the optimization node (110, 306), the architecture including inputs and outputs the general AI or ML-based energy consumption estimator.

19. The system (100) of claims 18, wherein the master carrier (108A-Z) in each of the one or more RRUs (104A-N) and/or AAUs (106A-N) is configured for defining the energy consumption related parameters to be reported by the other carriers of the RRU (104A) or AAU (106A) based on the defined inputs of the local AI or ML-based energy consumption estimator.

20. The system (100) of any of claims 11 to 19, wherein the energy consumption related parameters reported by the carriers (105A-Z) in each of the one or more RRUs (104A-N) and/or AAUs (106A-N) comprise configuration parameters of the RRU (104A) or AAU (106A) and carrier-level key performance indicators, KPIs, related to the energy consumption of the RRU (104A) or AAU (106A).


RADIO ACCESS NETWORK
102
REMOTE RADIO UNIT
104A
CARRIER
105A
MASTER
CARRIER
108A
REMOTE RADIO UNIT
104N
MASTER
CARRIER
108N
CARRIER
105N
OPTIMIZATION NODE
110
CARRIER
105P
MASTER
CARRIER
108P
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106A
MASTER
CARRIER
108Z
CARRIER
105Z
ACTIVE ANTENNA UNIT
106N
100

FIG. 1

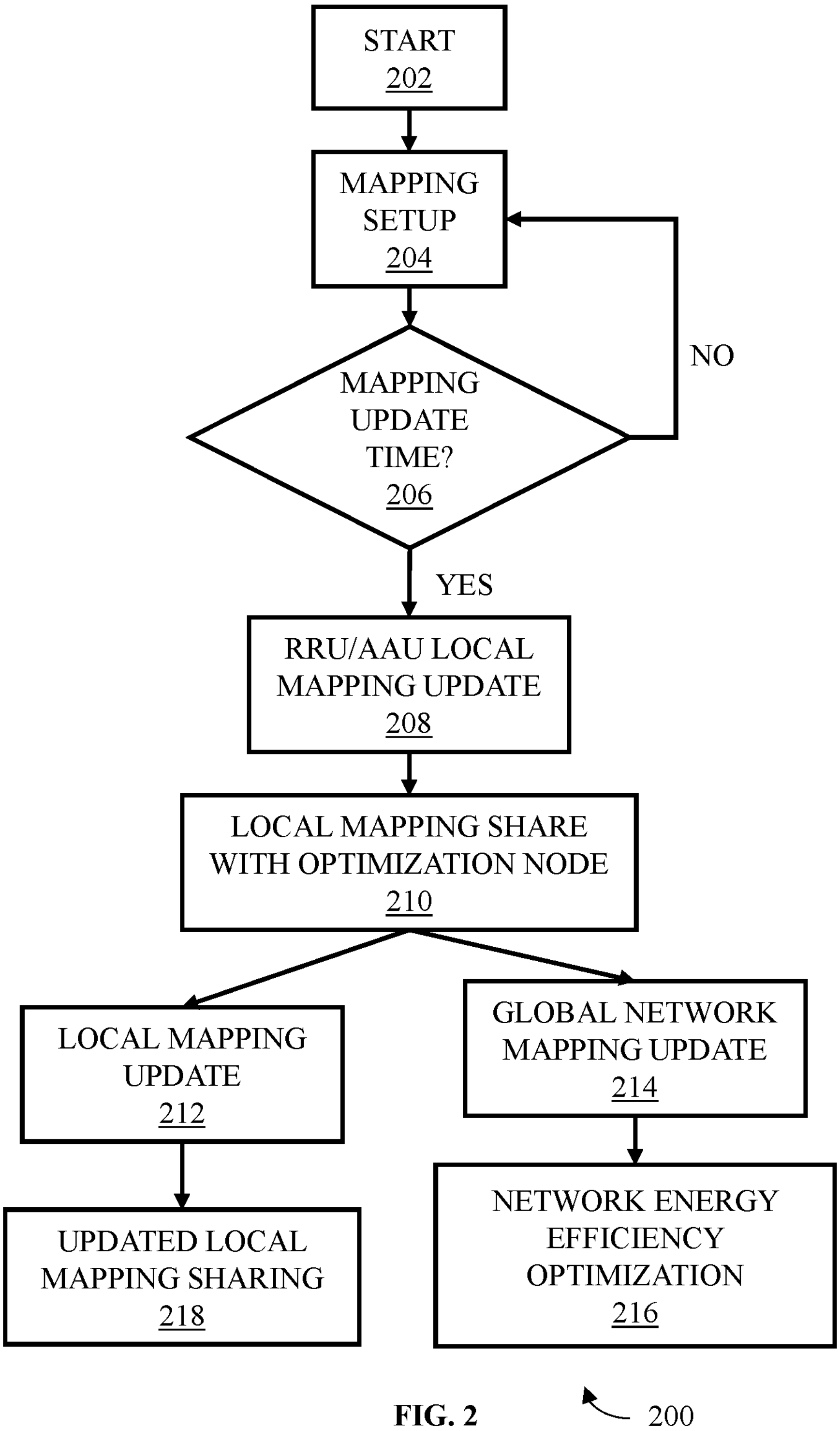

START
202
MAPPING
SETUP
204
MAPPING
UPDATE
TIME?
206
NO
YES
RRU/AAU LOCAL
MAPPING UPDATE
208
LOCAL MAPPING SHARE
WITH OPTIMIZATION NODE
210
LOCAL MAPPING
UPDATE
212
GLOBAL NETWORK
MAPPING UPDATE
214
UPDATED LOCAL
MAPPING SHARING
218
NETWORK ENERGY
EFFICIENCY
OPTIMIZATION
216
200

FIG. 2

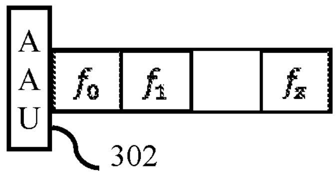


FIG. 3A

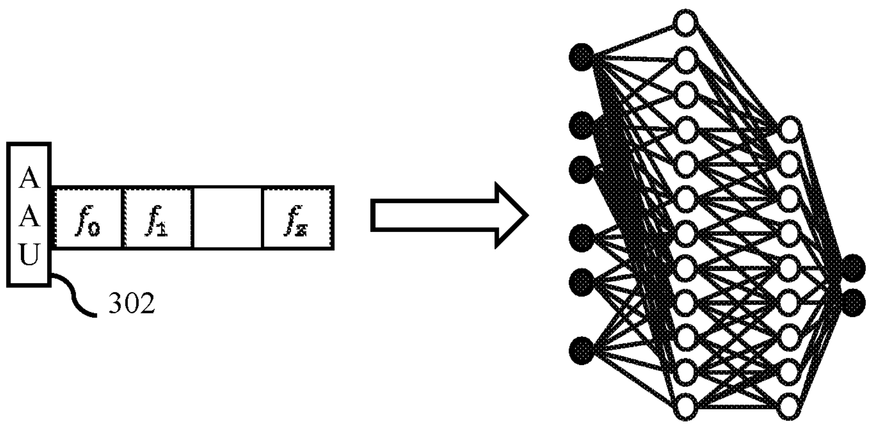


FIG. 3B

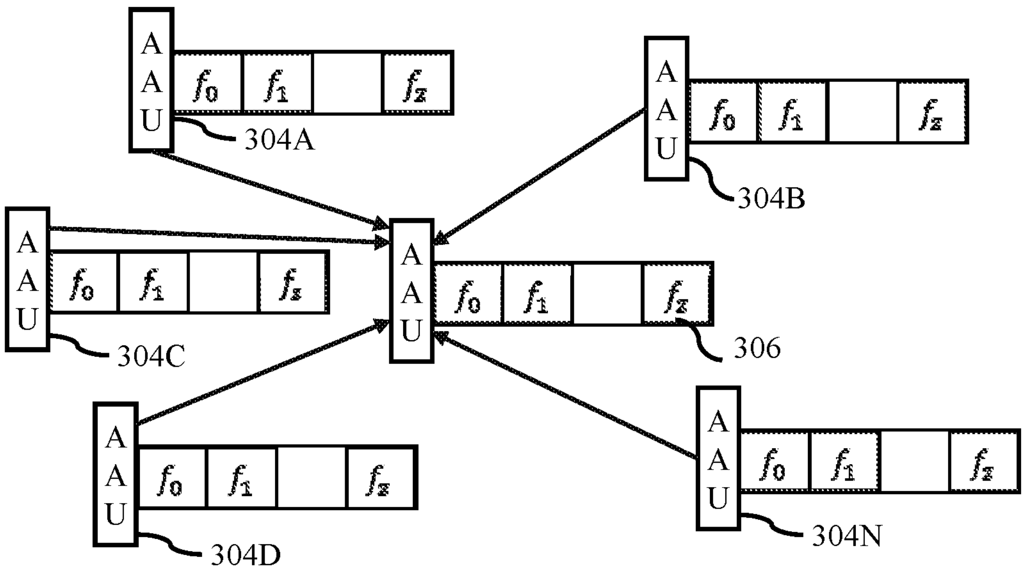
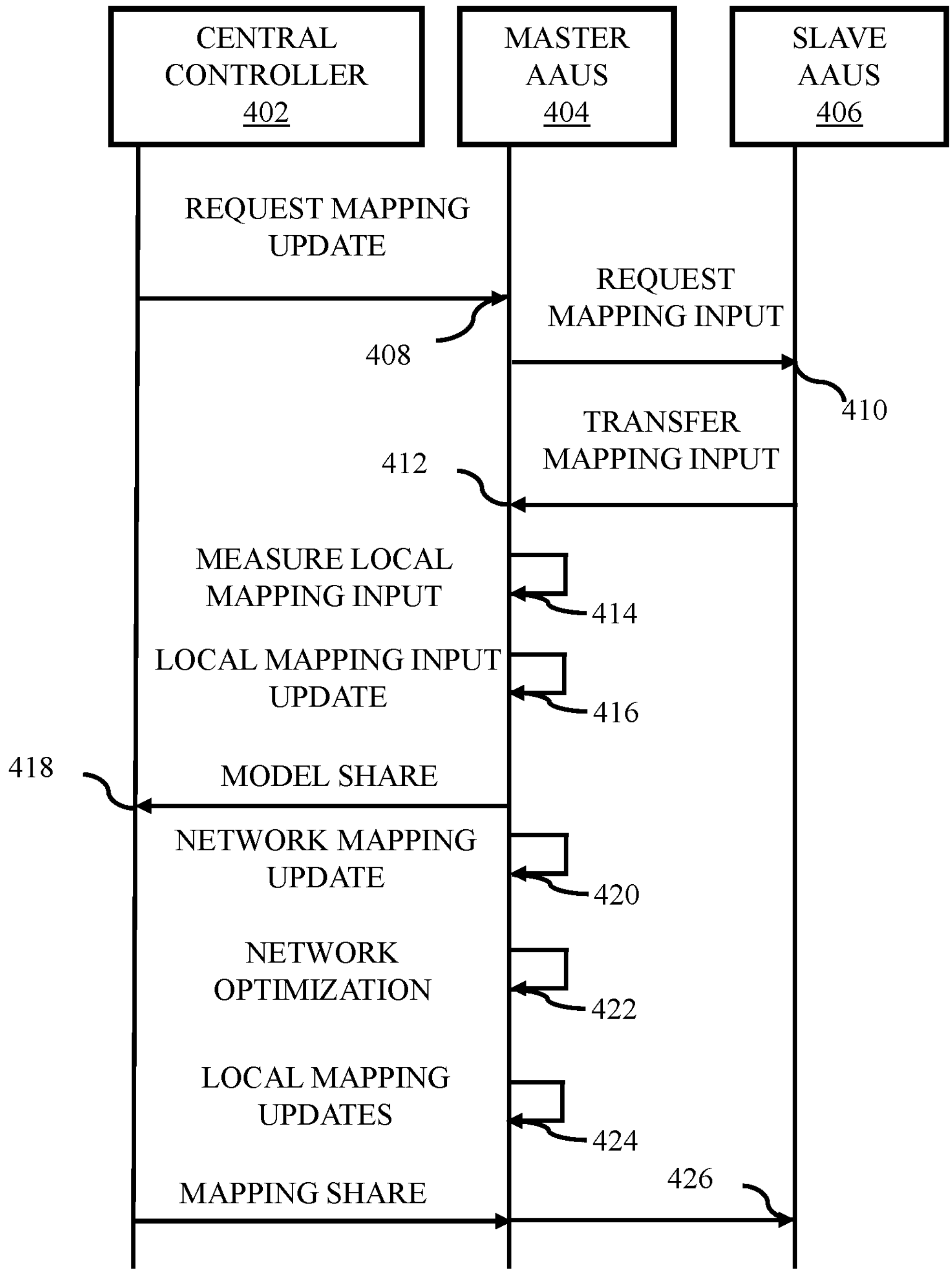


FIG. 3C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CONTROLLER
402
MASTER
AAUS
404
SLAVE
AAUS
406
REQUEST MAPPING
UPDATE
408
REQUEST
MAPPING INPUT
410
TRANSFER
MAPPING INPUT
412
MEASURE LOCAL
MAPPING INPUT
414
LOCAL MAPPING INPUT
UPDATE
416
418
MODEL SHARE
NETWORK MAPPING
UPDATE
420
NETWORK
OPTIMIZATION
422
LOCAL MAPPING
UPDATES
424
MAPPING SHARE
426

FIG. 4

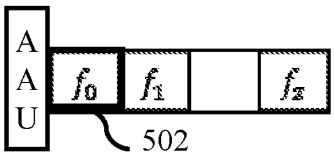


FIG. 5A

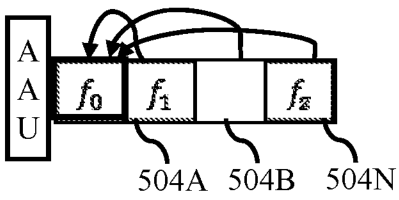


FIG. 5B

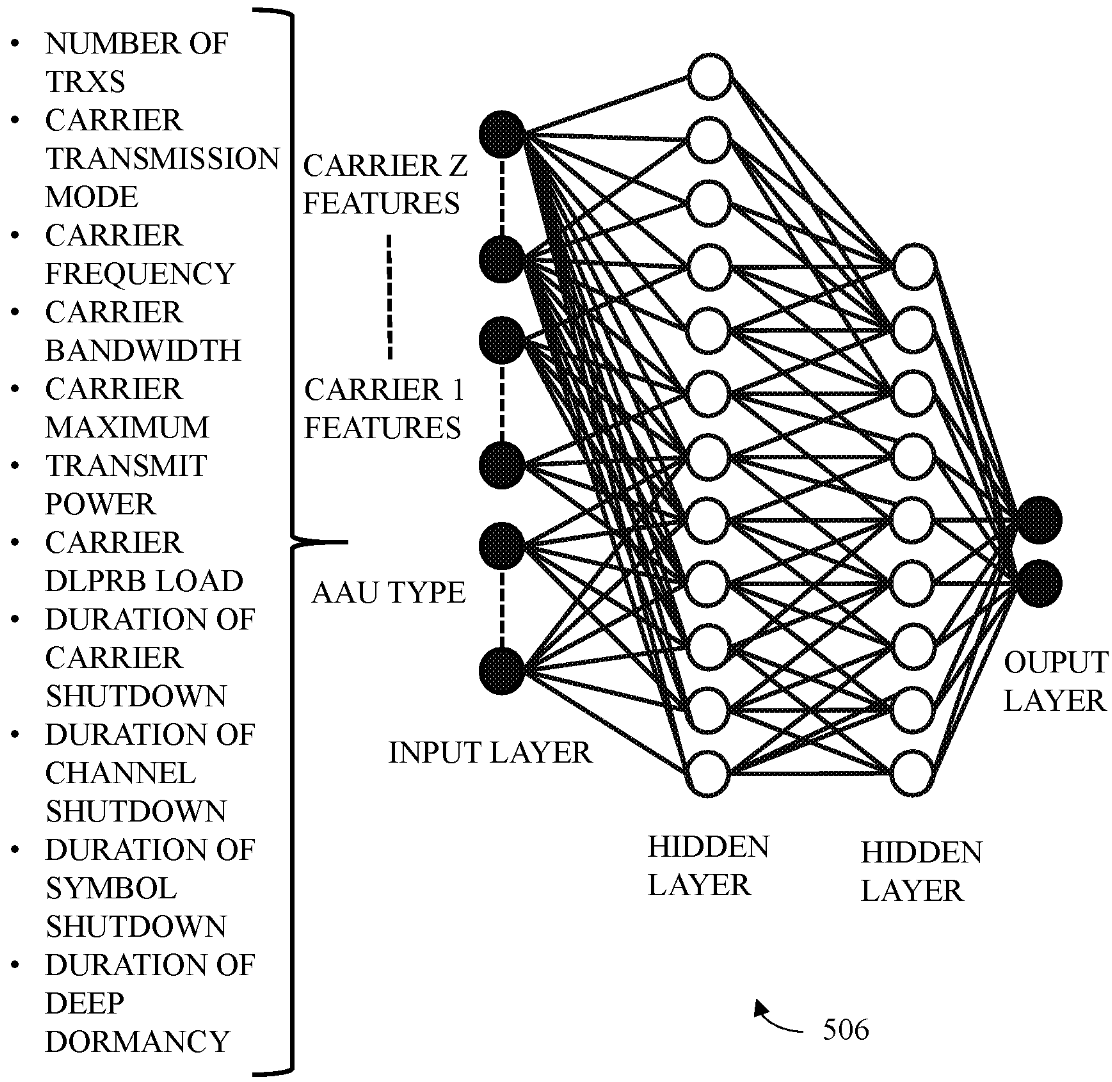
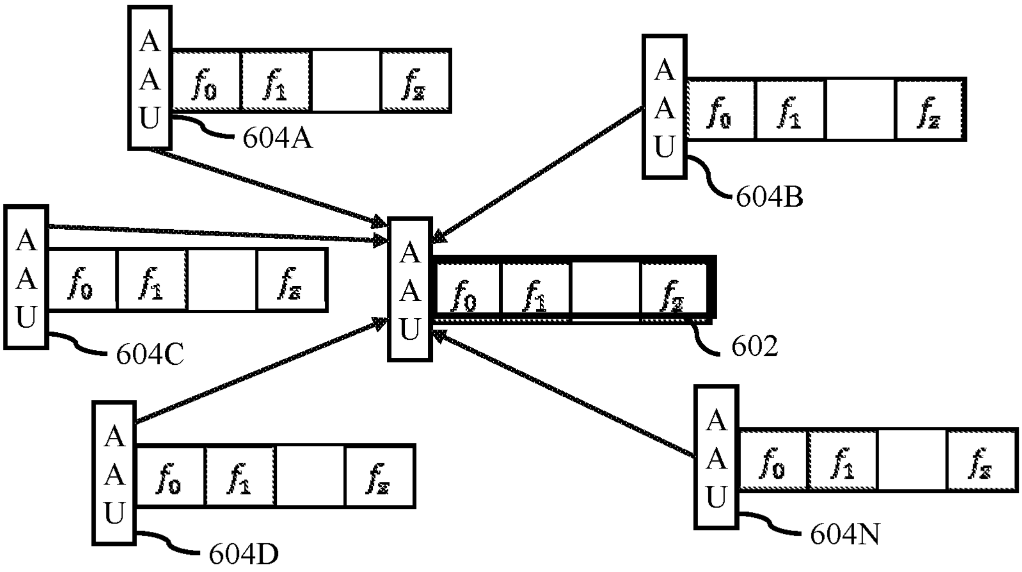


FIG. 5C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604A
604B
604C
604D
604N
602

FIG. 6A

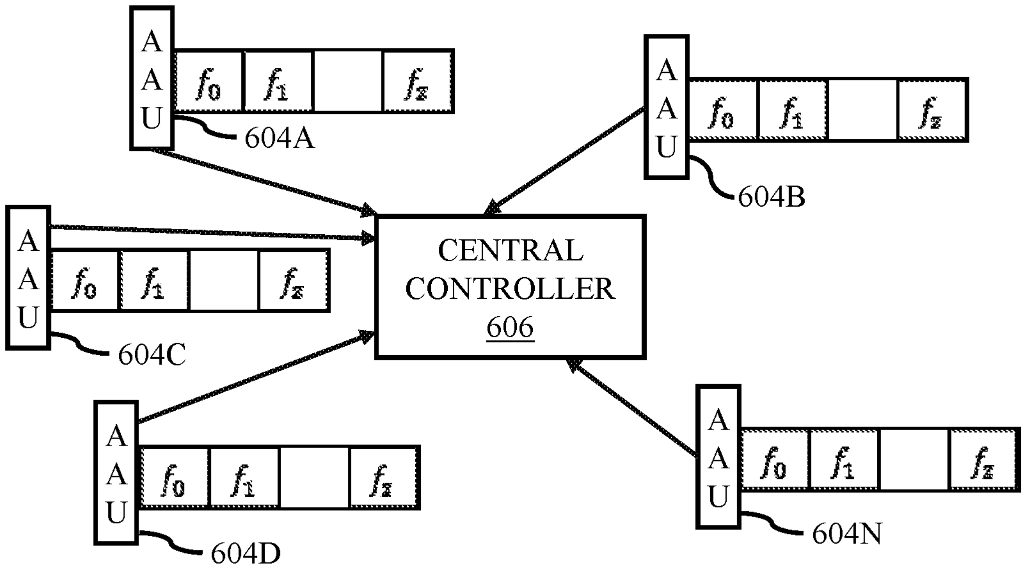
AAU
f_0 f_1 f_z
CENTRAL CONTROLLER 606
604A
604B
604C
604D
604N

FIG. 6B

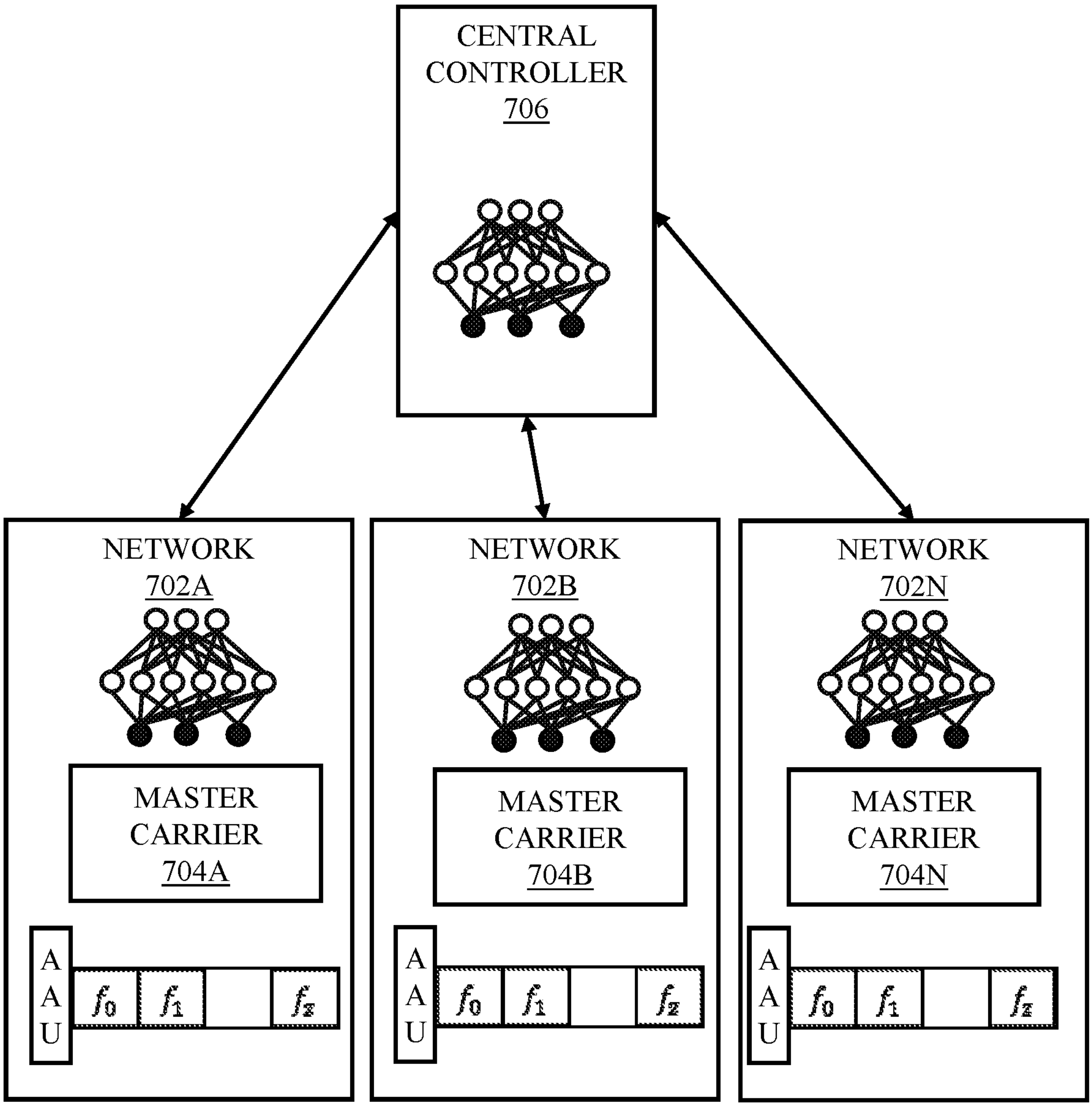
CENTRAL
CONTROLLER
706
NETWORK
702A
MASTER
CARRIER
704A
AAU
f_0
f_1
f_2
NETWORK
702B
MASTER
CARRIER
704B
AAU
f_0
f_1
f_2
NETWORK
702N
MASTER
CARRIER
704N
AAU
f_0
f_1
f_2

FIG. 7

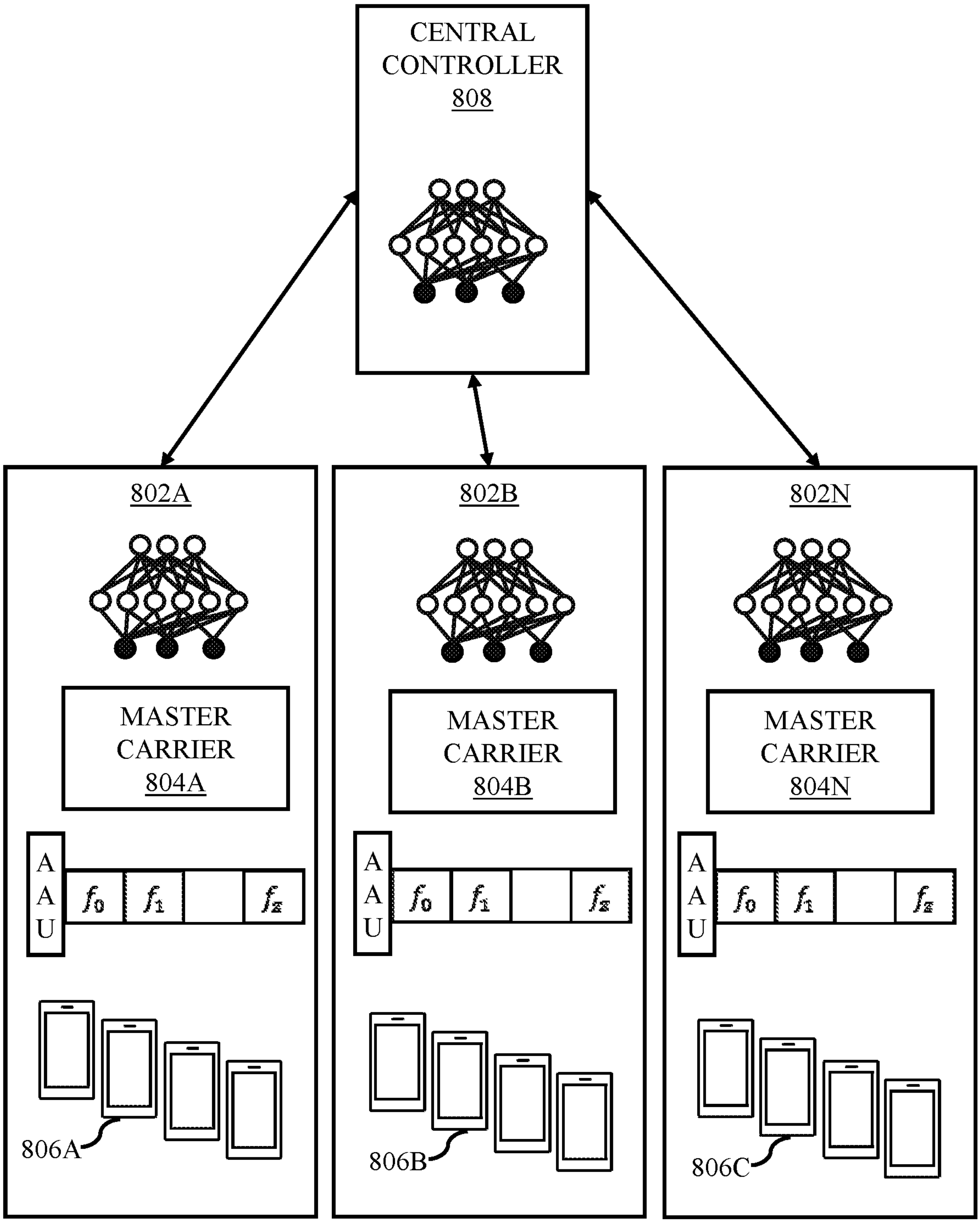
CENTRAL
CONTROLLER
808
802A
802B
802N
MASTER
CARRIER
804A
MASTER
CARRIER
804B
MASTER
CARRIER
804N
AAU
f_0
f_1
f_z
806A
806B
806C

FIG. 8

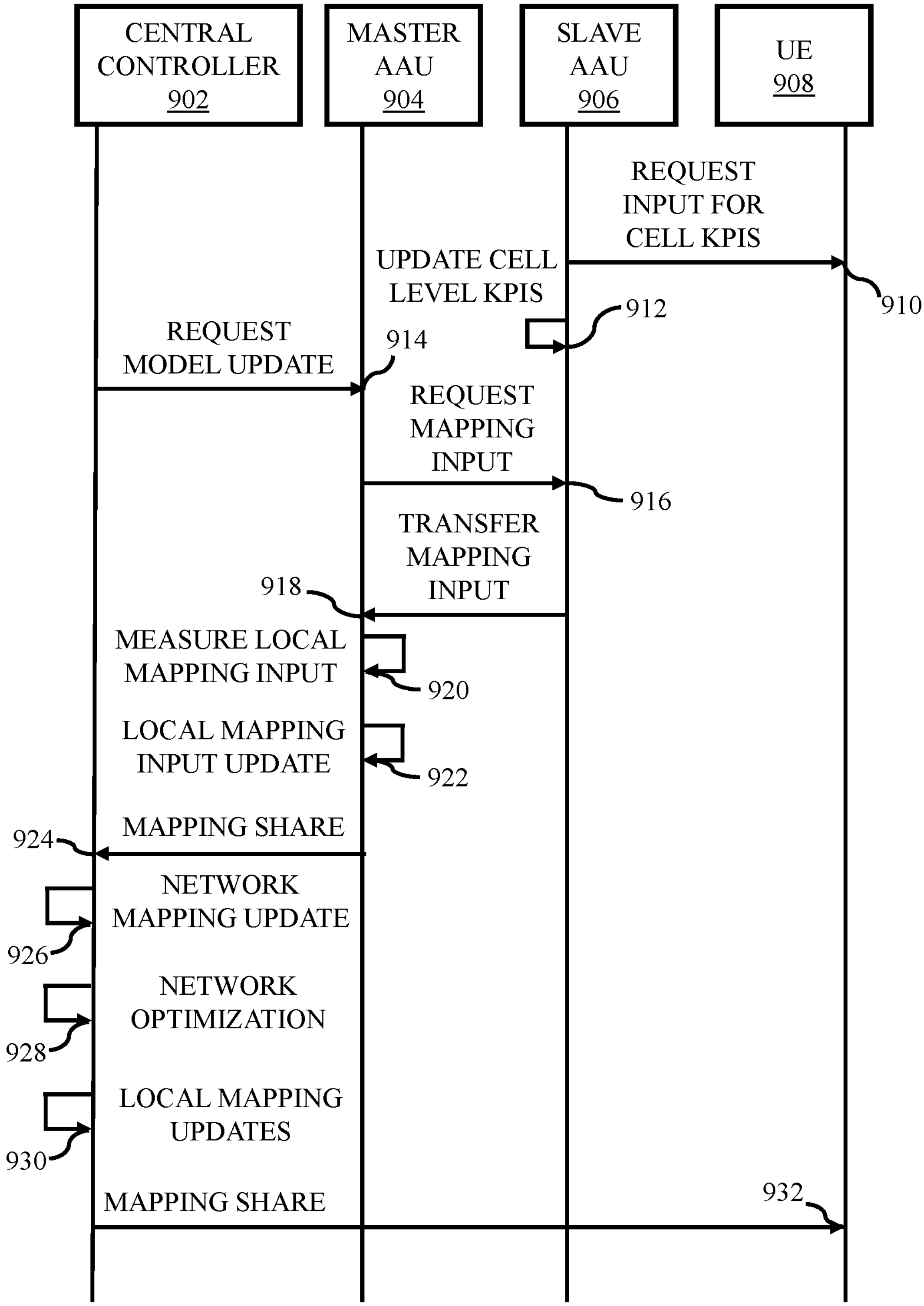
CENTRAL CONTROLLER 902
MASTER AAU 904
SLAVE AAU 906
UE 908
REQUEST INPUT FOR CELL KPIS
910
UPDATE CELL LEVEL KPIS
912
REQUEST MODEL UPDATE
914
REQUEST MAPPING INPUT
916
TRANSFER MAPPING INPUT
918
MEASURE LOCAL MAPPING INPUT
920
LOCAL MAPPING INPUT UPDATE
922
MAPPING SHARE
924
NETWORK MAPPING UPDATE
926
NETWORK OPTIMIZATION
928
LOCAL MAPPING UPDATES
930
MAPPING SHARE
932

FIG. 9

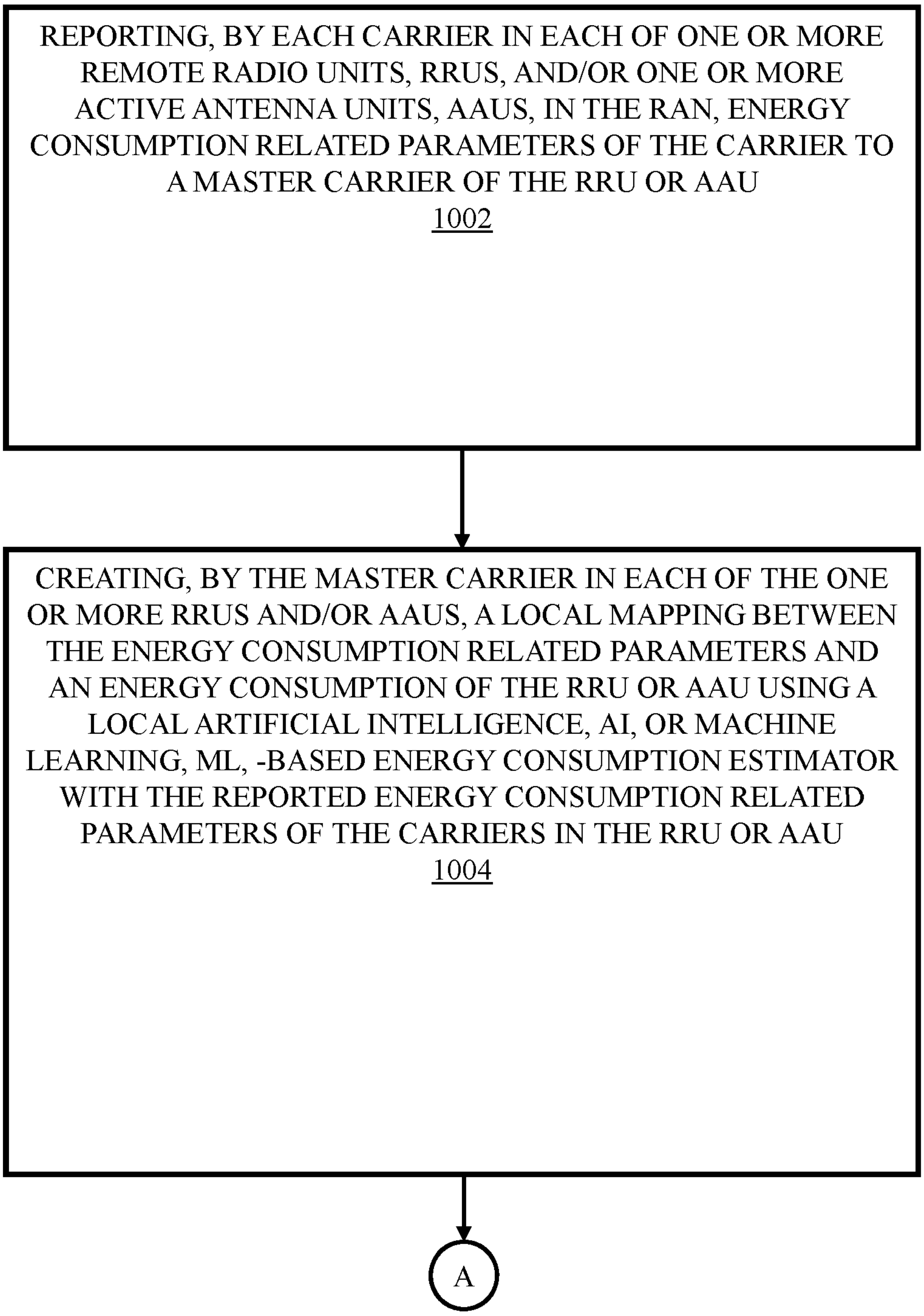
REPORTING, BY EACH CARRIER IN EACH OF ONE OR MORE REMOTE RADIO UNITS, RRUS, AND/OR ONE OR MORE ACTIVE ANTENNA UNITS, AAUS, IN THE RAN, ENERGY CONSUMPTION RELATED PARAMETERS OF THE CARRIER TO A MASTER CARRIER OF THE RRU OR AAU
1002
CREATING, BY THE MASTER CARRIER IN EACH OF THE ONE OR MORE RRUS AND/OR AAUS, A LOCAL MAPPING BETWEEN THE ENERGY CONSUMPTION RELATED PARAMETERS AND AN ENERGY CONSUMPTION OF THE RRU OR AAU USING A LOCAL ARTIFICIAL INTELLIGENCE, AI, OR MACHINE LEARNING, ML, -BASED ENERGY CONSUMPTION ESTIMATOR WITH THE REPORTED ENERGY CONSUMPTION RELATED PARAMETERS OF THE CARRIERS IN THE RRU OR AAU
1004
A

FIG. 10A

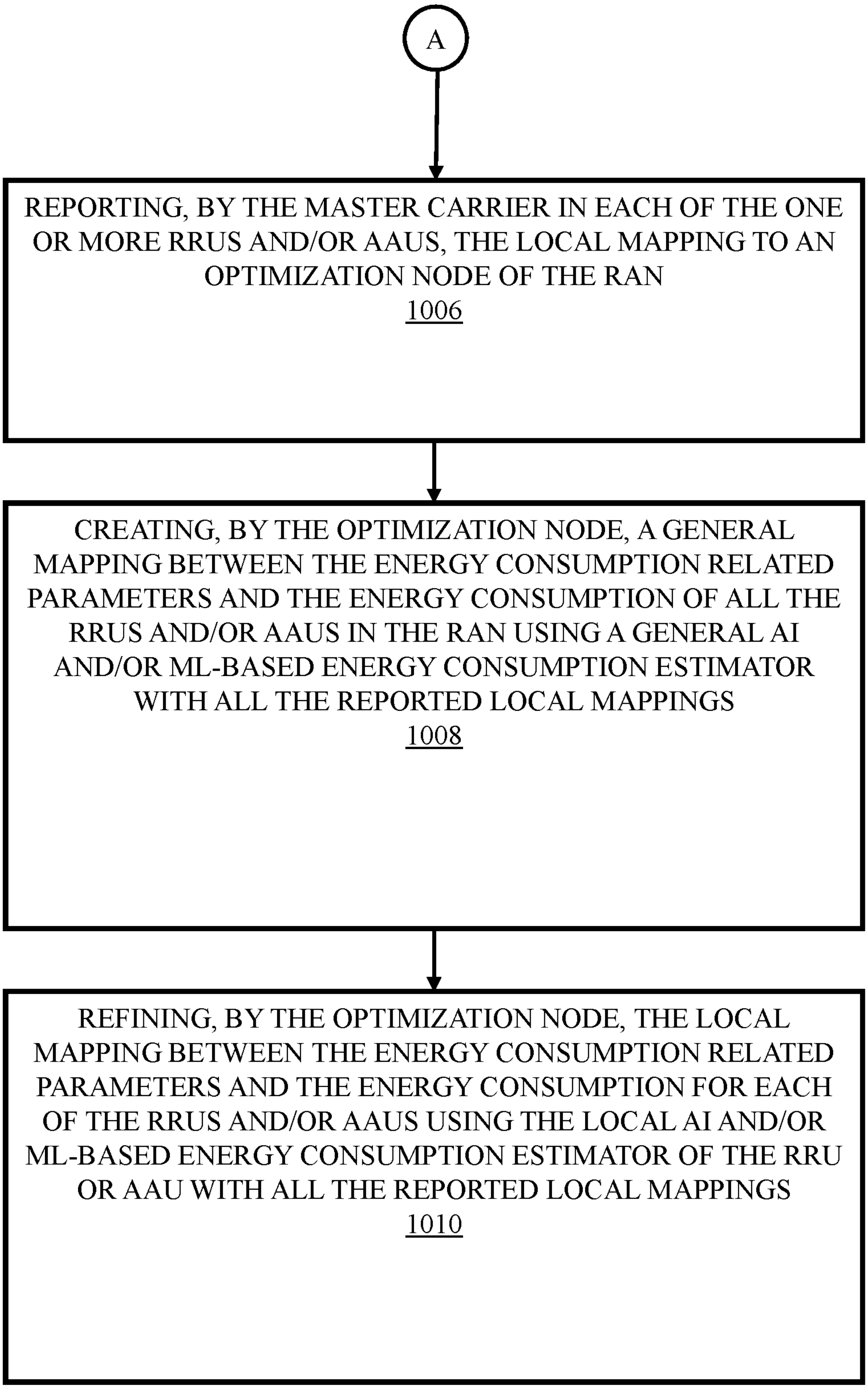
A
REPORTING, BY THE MASTER CARRIER IN EACH OF THE ONE OR MORE RRUS AND/OR AAUS, THE LOCAL MAPPING TO AN OPTIMIZATION NODE OF THE RAN
1006
CREATING, BY THE OPTIMIZATION NODE, A GENERAL MAPPING BETWEEN THE ENERGY CONSUMPTION RELATED PARAMETERS AND THE ENERGY CONSUMPTION OF ALL THE RRUS AND/OR AAUS IN THE RAN USING A GENERAL AI AND/OR ML-BASED ENERGY CONSUMPTION ESTIMATOR WITH ALL THE REPORTED LOCAL MAPPINGS
1008
REFINING, BY THE OPTIMIZATION NODE, THE LOCAL MAPPING BETWEEN THE ENERGY CONSUMPTION RELATED PARAMETERS AND THE ENERGY CONSUMPTION FOR EACH OF THE RRUS AND/OR AAUS USING THE LOCAL AI AND/OR ML-BASED ENERGY CONSUMPTION ESTIMATOR OF THE RRU OR AAU WITH ALL THE REPORTED LOCAL MAPPINGS
1010

FIG. 10B

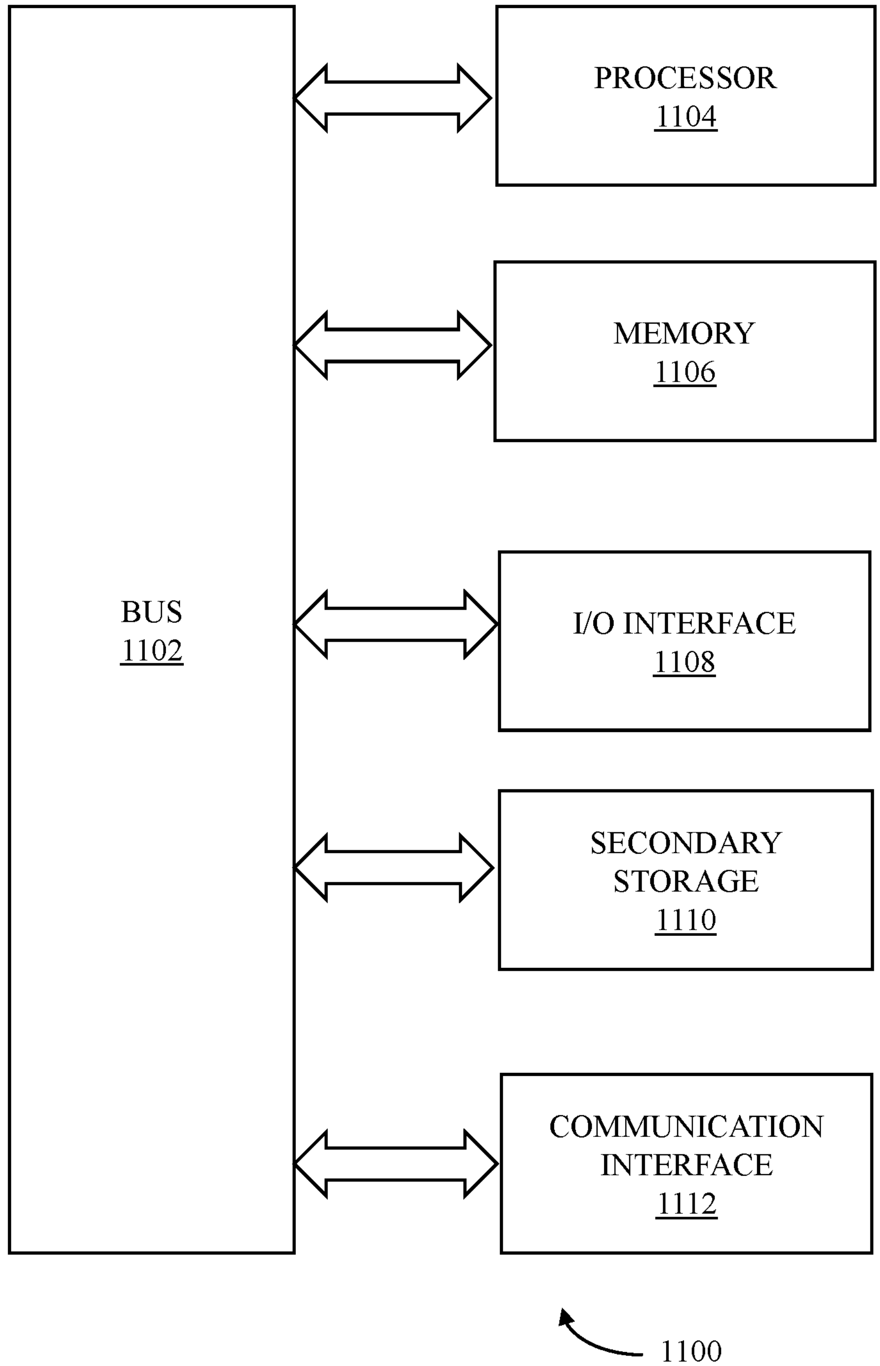
PROCESSOR
1104
MEMORY
1106
BUS
1102
I/O INTERFACE
1108
SECONDARY
STORAGE
1110
COMMUNICATION
INTERFACE
1112
1100

FIG. 11

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2023/071462

A. CLASSIFICATION OF SUBJECT MATTER

H04W24/10(2009.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: H04W, H04L

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

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

CNTXT; CNKI; ENTXTC; DWPI; 3GPP: carrier, remote radio unit, RRU, active antenna unit, AAU, energy, power, saving, consumption, parameter, master, local, mapping, artificial intelligence, AI, machine learning, ML

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	ZTE et al. "Solution to AI based Energy Saving" *3GPP TSG-RAN WG3 #113-e R3-213757,* 26 August 2021 (2021-08-26), section 5	1-20
A	CMCC. "Open Issues on AI/ML for NG-RAN Energy Saving" *3GPP TSG-RAN WG3 Meeting #117-bis R3-225813,* 18 October 2022 (2022-10-18), the whole document	1-20
A	CN 104969607 A (HUAWEI TECHNOLOGIES CO., LTD.) 07 October 2015 (2015-10-07) the whole document	1-20
A	US 2013064131 A1 (PANTECH CO., LTD.) 14 March 2013 (2013-03-14) the whole document	1-20

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

* Special categories of cited documents:
- "A" document defining the general state of the art which is not considered to be of particular relevance
- "D" document cited by the applicant in the international application
- "E" earlier application or patent but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed
- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
- "&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
11 August 2023	**21 August 2023**

Name and mailing address of the ISA/CN	Authorized officer
CHINA NATIONAL INTELLECTUAL PROPERTY ADMINISTRATION 6, Xitucheng Rd., Jimen Bridge, Haidian District, Beijing 100088, China	**WAN,ShaSha** Telephone No. **(+86) 010-53961576**

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2023/071462

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
CN 104969607 A	07 October 2015	WO 2015103772 A1	16 July 2015
US 2013064131 A1	14 March 2013	WO 2011159123 A2	22 December 2011
		KR 20110137446 A	23 December 2011
		KR 20110139978 A	30 December 2011