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SERIES M: TELECOMMUNICATION MANAGEMENT, INCLUDING TMN AND NETWORK MAINTENANCE

Telecommunications management network

Requirements for energy saving management of 5G radio access network (RAN) systems with artificial intelligence (AI)

Recommendation ITU-T M.3381

ITU-T

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Recommendation ITU-T M.3381

Requirements for energy saving management of 5G radio access network (RAN) systems with artificial intelligence (AI)

Summary

Recommendation ITU-T M.3381 provides requirements for energy saving management of a 5G radio access network (RAN) system with artificial intelligence (AI). Recommendation ITU-T M.3381 explains the requirements of using AI technology to achieve energy saving management for communication units and virtualized hardware resources of a 5G RAN system, via an element management system (EMS) and open interfaces provided by vendors, from the operation support system (OSS) level. In addition, this Recommendation includes process recommendations for sending intelligent energy saving strategies from OSS to EMS and then to wireless equipment.

This Recommendation describes functional requirements for energy saving management of 5G RAN system with AI, and use cases of energy saving management of 5G RAN system with AI.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T M.3381	2022-01-13	2	11.1002/1000/14834

Keywords

5G, AI, energy saving, telecom operation management.

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Requirements for energy saving management of 5G radio access network (RAN) systems with artificial intelligence (AI)

1 Scope

This Recommendation provides requirements for energy saving management of a fifth generation (5G) radio access network (RAN) system with artificial intelligence (AI). This Recommendation explains the requirements of the use of AI technology to achieve energy saving management for communication units and virtualized hardware resources of a 5G RAN system, via an element management system (EMS) and open interfaces provided by vendors, from the operation support system (OSS) level. In addition, this Recommendation includes process recommendations for sending intelligent energy saving strategies from OSS to EMS and then to wireless equipment. This Recommendation covers the following aspects of energy saving management of a 5G RAN system with AI:

1) functional requirements;
2) use cases.

Requirements for energy saving control directly at the equipment level, requirements for generating energy saving strategies directly at the radio base station, energy saving requirements for non-communication units such as air conditioning refrigeration and hardware material design lie outside the scope of this Recommendation.

2 Reference

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T L.1303] Recommendation ITU-T L.1303 (2018), *Functional requirements and framework of green data centre energy-saving management system.*

[ITU-T M.3041] Recommendation ITU-T M.3041 (2020), *Framework of smart operation, management and maintenance.*

[ITU-T M.3080] Recommendation ITU-T M.3080 (2021), *Framework of artificial intelligence enhanced telecom operation and management (AITOM)*.

[ITU-T Y.3172] Recommendation ITU-T Y.3172 (2019), *Architectural framework for machine learning in future networks including IMT-2020.*

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 functional block (in SDL) [b-ITU-T Q.9]: A functional block is an object of manageable size and relevant internal relationship, containing one or more processes.

3.1.2 management [b-ITU-T Y.3100]: In the context of IMT-2020, the processes aiming at fulfilment, assurance, and billing of services, network functions, and resources in both physical and virtual infrastructure including compute, storage, and network resources.

3.1.3 service [b-ITU-T M.3050.1]: Services are developed by a service provider for sale within products. The same service may be included in multiple products, packaged differently, with different pricing, etc.

3.1.4 user [b-ITU-T M.3010]: A person or process applying management services for the purpose of fulfilling management operations.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 energy saving strategy: A plan of action intended to accomplish an energy saving goal.

4 Abbreviations and acronyms

5G	Fifth Generation
AAU	Active Antenna Unit
AI	Artificial Intelligence
AITOM	Artificial Intelligence enhanced Telecom Operation and Management
BBU	Base Band Unite
BSS	Business Support System
CPU	Central Processing Unit
CQI	Channel Quality Indication
CU	Centralized Unit
DU	Distribution Unit
E-OSF	Element management layer – Operations Systems Function
E-RAB	Evolved Radio Access Bearer
EMS	Element Management System
FDD	Frequency Division Dual
GPS	Global Positioning System
IMT-2020	International Mobile Telecommunication-2020
KPI	Key Performance Indicator
MR	Measurement Report
NMS	Network Management System
OAM	Operation Administration and Maintenance
OPEX	Operational Expense
OSS	Operation Support System
PRB	Physical Resource Block
RAN	Radio Access Network
RF	Radio Frequency

RRC	Radio Resource Control
RRU	Remote Radio Unit
RSRP	Reference Signal Received Power
RSRQ	Reference Signal Receiving Quality
SDL	Specification and Description Language
SDO	Standards Development Organization
SINR	Signal-to-Interference and Noise Ratio
SS	Synchronization Signal
TCP	Transmission Control Protocol
TCXO	Temperature Compensated Crystal Oscillator
TDD	Test-Driven Development

5 Conventions

None.

6 Overview of energy saving management of 5G RAN system with AI

This Recommendation provides requirements for energy saving management of a 5G RAN system with AI. First, the most urgent problem to be solved by operators in 5G commercial applications, namely that of energy saving in cost management, is studied, including use cases. In this way, at the OSS level, through the open interface provided by EMS and suppliers, the virtualized hardware resources of communication units and base stations are managed for energy saving to reduce operational expense (OPEX). This Recommendation mainly contains the functional requirements and use cases of energy saving management of a 5G RAN system with AI. This Recommendation explains the requirements of using AI technology to achieve energy saving management for communication units and virtualized hardware resources of a base station, via open interfaces provided by EMS and vendors, from the OSS level. In addition, this Recommendation includes process suggestions for sending intelligent energy saving strategies from OSS to EMS and then to wireless equipment.

7 Framework for energy saving management of 5G RAN system with AI

7.1 Functional block diagram for energy saving management of 5G RAN system with AI

Figure 7-1 is a functional block diagram of energy saving management of a 5G RAN system with AI, including:

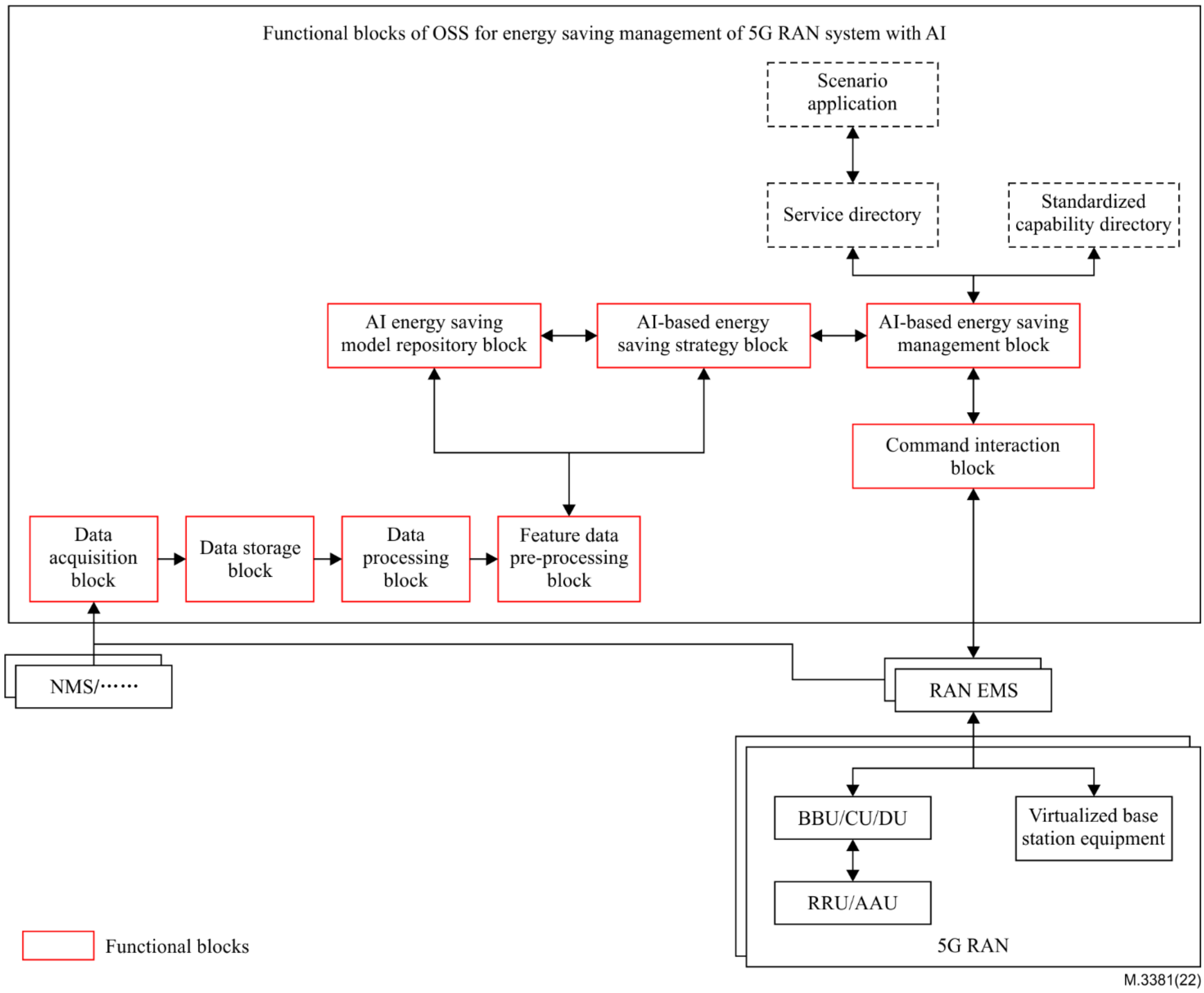


Figure 7-1 – Functional block diagram for energy saving management of 5G RAN system with AI

1) Data acquisition block: The data basis of AI model training. Before energy saving, a large amount of data from a RAN EMS, network management system (NMS) or other management system, should be collected in this block. For functions of this block, see clause 8.3.3.2 of [ITU-T M.3041].

NOTE 1 – In Figure 7-1, the main functional blocks for energy saving management of a 5G RAN system with AI have red borders.

NOTE 2 – A RAN EMS, NMS or other management system can come from multiple manufacturers.

NOTE 3 – The ellipsis represents other management systems, i.e., those other than NMS, RAN EMS and OSS. Such systems can also provide energy-saving related data for the OSS.

NOTE 4 – For the relationship of EMS, NMS and OSS, see Annex A of [ITU-T M.3041].

2) Data storage block: The data from the data acquisition block should be stored, managed and updated in this block, which provides data for the data processing block. For other functions of this block, see clause 8.3.3.2 of [ITU-T M.3041].

3) Data processing block: For the main functions of this block, see clause 8.3.3.2 of [ITU-T M.3041], including data cleaning and tagging.

4) Feature data pre-processing block: This block is an important requirement for AI model training, which needs to prepare pre-processed offline feature data to train AI model and online feature data to generate an AI-based energy saving strategy. For other functions in this block, see clause 8.2.4 of [ITU-T M.3080].

5) AI energy saving model repository block: This block mainly trains, stores and manages different AI energy saving models. Offline training data are used to train multiple single AI models, while the offline test data are used to adjust parameters of multiple single AI models.

NOTE 5 – The multiple single AI models in the AI energy saving model repository block may include the energy saving scenario recognition model based on the extreme gradient boosting (XGBoost) algorithm and the base station traffic prediction model based on the light gradient boosting machine (LightGBM) algorithm. For the process of energy saving model training, see clause A.3.1.1.

6) AI-based energy saving strategy block: Based on the trained multiple single AI models and online data, this block fuses multiple AI models, generates AI-based energy saving strategies and maintains AI-based energy saving strategies.

7) AI-based energy saving capability management block: This block provides AI-based energy saving capability parsing, distribution, registration, cancellation and activation. This block distributes an AI-based energy saving strategy to a service directory that realizes scenario application and standardized capability to be used by external customers of telecommunication operators. For other functions of this block, see clause 8.2.2 of [ITU-T M.3080].

NOTE 6 – For the functions of the service directory, scenario application and standardized capability, see [ITU-T M.3080]. They are not specified in this Recommendation.

NOTE 7 – The AI-based energy saving capability management block can parse energy saving requirements from the scenario application and standardized capability directory, and send them to an AI-based energy saving strategy block, AI energy saving model repository block and feature data pre-processing block to realize model training, energy saving strategy generation and feature data selection, respectively.

8) Command interaction block: After generating the AI-based energy saving strategy, the system needs to send commands through the command interaction block to control the base station equipment and execute the energy saving strategy. The AI-based energy saving strategy needs to be delivered to a base band unite/centralized unit/distribution unit (BBU/CU/DU) through the interactive interface provided by an RAN EMS, and then delivered to a remote radio unit/active antenna unit (RRU/AAU). At the same time, the AI-based energy saving strategy is delivered to the virtualized base station equipment through the interactive interface provided by the RAN EMS. In addition, feedback is required of the status of the energy saving strategy reception between an AI-based energy saving strategy block, command interaction block and base station equipment.

NOTE 8 – The RAN EMS and 5G RAN may come from multiple manufacturers.

NOTE 9 – 5G RAN includes the real base station equipment, like BBU/CU/DU, RRU/AAU, and the virtualized base station equipment, like virtual RAN functions and virtualized resources from a cloud platform.

NOTE 10 – The command signals sent by command interaction block include "ON", "Standby", "Sleep" and "OFF" as described in clause A.2.1.5.

The functional requirements of each functional block for energy saving management of 5G RAN system with AI are introduced in clause 8.

7.2 Relationship between framework for energy saving management of 5G RAN system with AI and AITOM framework

The energy-saving management of a 5G RAN system with AI is a use case for the artificial intelligence enhanced telecom operation and management (AITOM) framework, but this Recommendation focuses on the functional requirements of energy saving management of 5G RAN system with AI, as well as the functional block diagram for energy saving management of a 5G RAN system with AI that references a functional framework of AITOM. The relationship between them is shown in Figure 7-2.

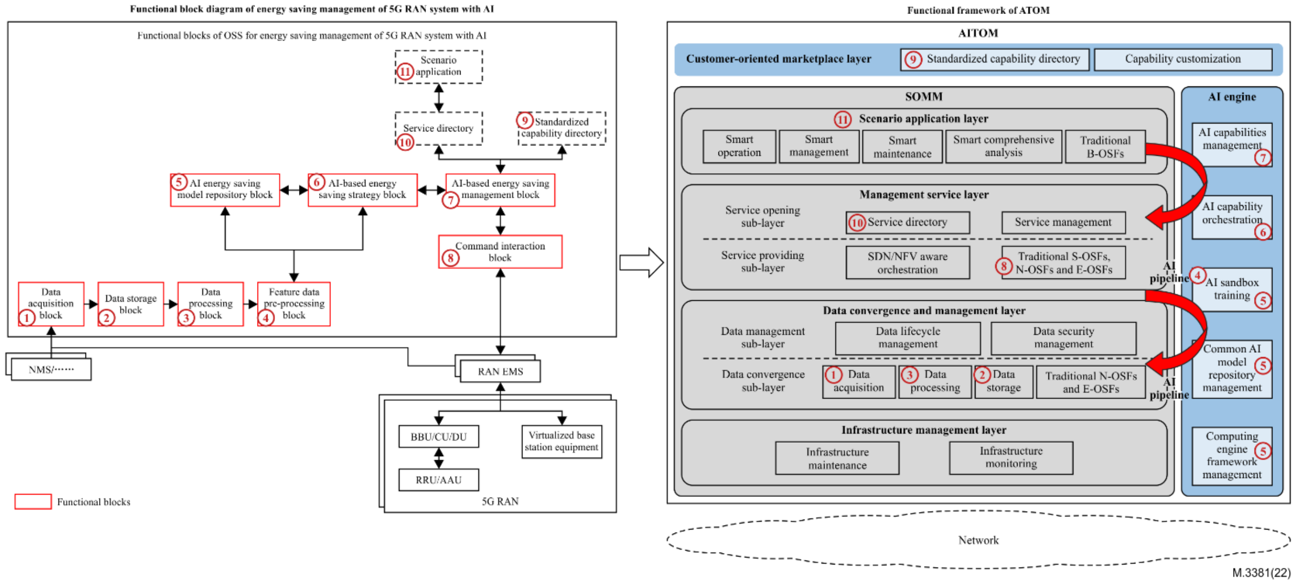


Figure 7-2 – Mapping the relationship between functional block diagram for energy saving management of 5G RAN system with AI and AITOM framework

NOTE 1 – Numbers circled in red in Figure 7-2 represent the mapping relationship between the functional block diagram for energy saving management of the 5G RAN system with AI and the AITOM framework.

NOTE 2 – The functional block diagram for energy saving management of an 5G RAN system with AI is at the OSS level, which can provide energy saving data and capability for the management service layer and customer-oriented marketplace layer of the AITOM framework.

The relationship between the functional block diagram for energy saving management of a 5G RAN system with AI and the AITOM framework in Figure 7-2 can be described as follows.

– The block name and functions of the data acquisition block, data storage block and data processing block correspond to data acquisition, data storage and data processing, respectively, of the AITOM framework. However, the data acquisition in this block is based on the energy saving scenario.

  NOTE 3 – These three blocks correspond to the red circles numbered 1, 2 and 3, respectively, in Figure 7-2.

– The block name and functions of the feature data pre-processing block correspond to the feature data pre-processing in AI sandbox training of the AITOM framework. However, the functions of this block are enhanced in this Recommendation.

  NOTE 4 – This block corresponds to the red circle numbered 4 in Figure 7-2.

– The functions of the AI energy saving model repository block correspond to computing engine framework management, common AI model repository management and AI sandbox training in the AI engine of the AITOM framework.

  NOTE 5 – This block corresponds to the red circle numbered 5 in Figure 7-2.

– The functions of the AI-based energy saving strategy block correspond to AI capability orchestration of the AITOM framework. However, for the generation of energy saving, strategies should be based on in this Recommendation.

  NOTE 6 – This block corresponds to the red circle numbered 6 in Figure 7-2.

– The functions of the AI-based energy saving capability management block correspond to AI capabilities management of the AITOM framework. However, the specific scenario of management object is energy saving.

  NOTE 7 – This block corresponds to the red circle numbered 7 in Figure 7-2.

– The function of the command interaction block corresponds to traditional element management layer-operations systems functions (E-OSFs) in the management service layer of the AITOM framework. In this Recommendation, the command interaction block not only provides command interaction for traditional, but also virtualized devices.

  NOTE 8 – This block corresponds to the red circle numbered 8 in Figure 7-2.

– The block name and functions of the standardized capability directory, service directory and scenario application correspond to the standardized capability directory, service directory and scenario application, respectively, of the AITOM framework.

  NOTE 9 – These three blocks correspond to the red circles numbered 9, 10 and 11, respectively, in Figure 7-2.

8 Functional requirements of energy saving management of 5G RAN system with AI

8.1 Functional requirements of the data acquisition block

Data sources for the 5G RAN system include NMS, RAN EMS and other management systems. The following requirements should be followed in the data acquisition block.

– Openness of the interface: The interfaces of management systems should be ensured to be open so that data can be collected at any time to avoid problems during the process.

– Appropriate collection period: The periodicity of data collection should be determined according to different business requirements. For example, when predicting dynamic shutdown based on a physical resource block (PRB) and radio resource control (RRC), the RRC of the cell in real time needs periodically to be queried. Minutes or hours or other suitable periods can be chosen based on business requirements. For this requirement, see the requirements for collecting and storing data given in [ITU-T L.1303].

– Accuracy and completeness of data collection: During collection of data from interfaces and their storage in the data acquisition block, errors in or losses of data are not allowable. Corrupted data should be re-collected or handled simply.

  NOTE 1 – The following data need to be collected (non-exhaustive list).

– Performance data: Including network key performance indicator (KPI) index and flow data in EMS, such as PRB utilization rate, RRC connection number, load flow rate, central processing unit (CPU) utilization, RRC success rate, evolved radio access bearer (E-RAB) success rate, channel quality indication (CQI), delay, transmission control protocol (TCP) delay and video traffic.

– Customer data: Including customer order data in the business support system (BSS).

– Measurement report (MR) data: Including MR latitude and longitude, direction angle, synchronization signal-reference signal received power (SS-RSRP), SS-reference signal receiving quality (SS-RSRQ) and SS-signal-to-interference and noise ratio (SS-SINR).

– Parameter data: Including base station information data and location data in the NMS, such as latitude and longitude, direction angle, transmit power, beam parameters (e.g., the inclination angle, the number of antennas and beam width), RSRP, RSRQ) and frequency.

– Configuration data: Including high available components configuration data, such as each kind of component number in cluster, the components indicates switch, router etc.

  NOTE 2 – The data will be used to train the AI model to realize energy saving, such as in the use case in clause A.2.1.1, where latitude, longitude and load flow rate of base station may be used to identify different deployment scenarios, and different energy strategies can be made based on different deployment scenarios.

The data in other management systems are optional, but in the EMS and NMS they are mandatory and need to be chosen based on specific service scenarios and requirements.

8.2 Functional requirements of data storage block

After collection, the data need to be stored in the storage block. There are many tools for storing data, such as Hadoop, Hive and structured query language (SQL), but the following requirements should be followed for each tool to storage data.

– Consistent data format: Data with the same characteristics, even though they are from different interfaces, shall be stored with consistent format to efficiently control the energy management 5G RAN energy saving system. For this requirement of data storage, see the requirements for collecting and storing data given in [ITU-T L.1303].

– Classified storage for different data: There are multiple data types for energy saving, as described in clause 8.1, such as performance data and parameter data. Different data need to be stored categorically to be better analysed.

– Reasonable storage period: To prevent storage space overflow, a reasonable data storage period needs to be formulated based on the data collection period and data storage space.

8.3 Functional requirements of data processing block

It is necessary for data to be processed in a processing block, mainly to clean them.

The following requirements should be followed in this block.

– Missing value handling: Missing values may affect the results of the analysis. Missing values can be interpolated by some AI algorithms. If interpolation is not necessary, drop missing values.

– Unit consistency: The same indicator from different systems or from the same system needs to be unit consistent.

– Outlier handling: Outlier handling may affect the results of the analysis, which can be supplied by some AI algorithms.

– Data transformation: data duplicates are removed (except for some special cases, e.g., padding data); some unnecessary variables, such as Boolean values, are dropped and replaced according to predefined criteria.

NOTE – AI algorithms used in this block can be provided by the AI Engine of the AITOM framework specified in [ITU-T M.3080].

8.4 Functional requirements of feature data pre-processing block

Feature data pre-processing is an important step to prepare the feature data for AI model training and AI-based energy saving strategy. The following requirements should be followed in this block.

– Feature data selection: For the functional requirements of feature data selection, see clause 8.2.4 in [ITU-T M.3080].

– Feature data normalization or standardization: Normalization is to convert the characteristic value of the sample to the same dimension, such as mapping the data to the interval [0,1] or [−1,1]. Standardization is to process data according to the columns of the characteristic matrix, which is converted into a standard normal distribution by the *z*-score method. The similarity between them is that they can cancel the errors caused by different dimensions. Feature data normalization or standardization needs to be chosen based on the scenario.

– Feature extraction: Including feature construction and feature dimensionality reduction. Feature construction needs to be considered if the features of data are insufficient for analysis. However, if there is a strong correlation between features, the dimensionality of feature needs to be reduced.

NOTE – AI technology can be applied to realize feature extraction, which is provided by the AI engine of the AITOM framework specified in [ITU-T M.3080].

8.5 Functional requirements of the AI energy saving model repository block

Business logic needs to be combined in the AI energy saving model repository to deploy AI models for the AI-based energy saving strategy block. In the process of model training, the parameters of a single AI model in this block can be modified in real time based on test data.

For other functional requirements, see clause 8.2.4 of [ITU-T M.3080], including common AI model selection, offline training and model decision.

8.6 Functional requirements of the AI-based energy saving strategy block

In the whole energy saving process, energy saving strategy generation, energy saving effects evaluation and energy saving capability maintenance should be considered.

– Energy saving strategy generation: The energy saving strategy can be generated according to the AI energy saving model described in clause 7.1. For example, the automatic recognition of typical scenes can be realized through the energy saving scene recognition model, which can improve the accuracy of time series prediction. Then the results of automatic scene recognition and the base station traffic prediction model are combined to predict the load time series of base stations with different granularity.
– Energy saving effects evaluation: The energy saving effect evaluation block needs to evaluate the energy saving effect through the energy saving effect evaluation index, and feeds the result back to the energy saving strategy generation module to realize closed-loop feedback of the energy saving system and automatic adjustment of the energy saving strategy.
– Energy saving capability maintenance: For the functions for energy saving capability maintenance, see list entry 3) of clause 8.2.3 of [ITU-T M.3080].

8.6.1 Energy saving strategy generation

Energy saving strategy generation is a key requirement step for modelling of AI. It is necessary to combine the business scenarios to generate the optimal energy saving strategy based on the trained AI model trained in the AI energy saving model repository block.

Base station load traffic forecasting is a key demand step in the generation of energy saving strategies. It is necessary to predict the base station load traffic based on the AI model trained in the AI energy saving model repository. The integrity and consistency of data and characteristics, the consistency between models and the accuracy of model prediction should be attended to when forecasting base station load traffic.

8.6.2 Energy saving effect evaluation

Energy saving effect evaluation is an important step for AI test optimization. Through the evaluation based on the prediction results, the advantages and disadvantages of energy saving strategies and potential problems shall be evaluated, which can provide real-time feedback to the energy saving strategy module.

The evaluation of energy saving effects should have the following requirements.

– The evaluation of energy saving effects should be based on the evaluation index system of scenarios and business needs, including base station performance index data that comes from the EMS, and user perception data that comes from the BSS.
– There should be a feedback mechanism between the energy saving strategy selection model and the energy saving effect evaluation to realize iterative optimization.

8.6.3 Energy saving capability maintenance

– For the functional requirements for energy saving capability maintenance, see list entry 3) of clause 8.2.3 of [ITU-T M.3080].

8.7 Functional requirements of AI-based energy saving capability management block

For the functional requirements of an AI-based energy saving capability management block, see list entries 1) to 5) of clause 8.2.2 of [ITU-T M.3080], namely: AI-based energy saving capability requirement parsing; AI-based energy saving capability distribution; AI-based energy saving capability registration; AI-based energy saving capability cancellation; and AI-based energy saving capability activation.

– For AI-based energy saving capability delivery, four energy saving methods can be considered, including: carrier frequency shutdown; channel shutdown; symbol shutdown; and deep sleep.

8.8 Functional requirements of the command interaction block

The command interaction block mainly realizes the sending of commands for AI-based energy saving strategy to base station equipment, and feedback status of command reception from base station equipment to the AI-based energy saving capability management block. Interactive interfaces can be compatible with EMSs from multiple manufacturers.

The following requirements should be followed in this block.

– Unified command format: The unified command format from the AI-based energy saving capability management block to the RAN EMS needs to be unified when the command interaction block sends AI-based energy saving strategies.
– Real-time status feedback: The receiving status of the AI-based energy saving strategy is fed back in real time from the RAN EMS and to the AI-based energy saving capability management block through the command interaction block.

9 Security consideration

For the security considerations in this Recommendation, see [ITU-T M.3080].

Annex A

Use cases for energy saving management of a 5G RAN system with AI

(This annex forms an integral part of this Recommendation.)

A.1 Use case template

The use cases should adopt the following unified format for consistent readability and convenient material organization.

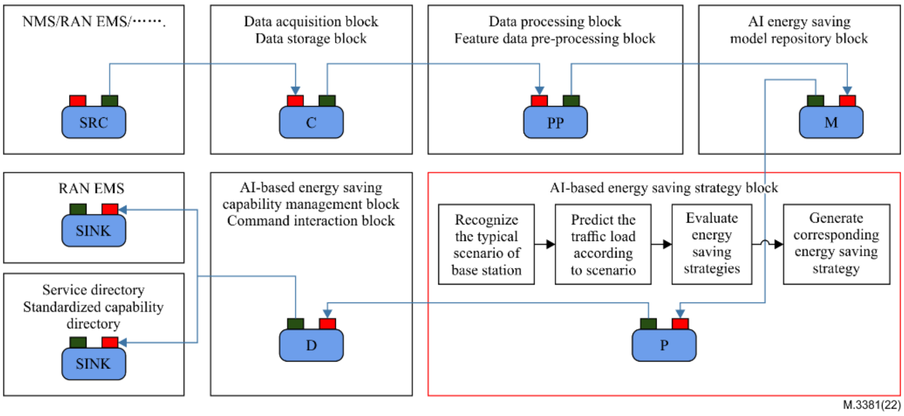
Title	Title of the use case
Description	Scenario description of the use case, including the purpose and related process to achieve it
Roles	Roles involved in the use case, including any primary roles/persons that is directly responsible for this use case and any secondary roles/persons that are related to this use case (such as customer care manager or network operations centre manager)
Graphic (optional)	Graphic to explain the use case, but this is not mandatory
Pre-conditions (optional)	The necessary pre-conditions that should be achieved before starting the use case
Post-conditions (optional)	The post-conditions that are carried out after the termination of current use case
Derived requirements	Requirements derived from the use cases, whose detailed descriptions are presented in the relevant clauses.

A.2 Typical use cases of energy saving management of a 5G RAN system with AI

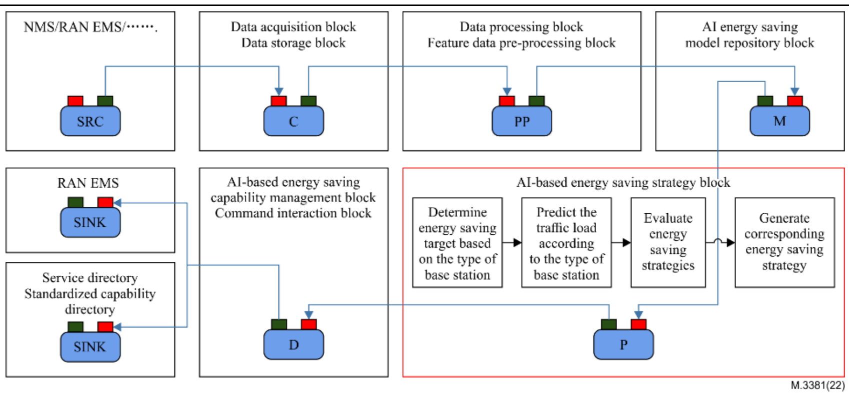
A.2.1 Energy saving for base station equipment

A.2.1.1 Energy saving for different deployment scenario

Title	Energy saving for different deployment scenario
Description	Different deployment scenarios (e.g., shopping mall, school or office building) have different traffic characteristics. Based on these characteristics, a specific energy saving strategy should be adopted to reduce OPEX. When 5G energy saving is performed, the energy saving strategy generated should be service logic combined with different deployment scenarios in the AI-based energy saving strategy block. The process to realize 5G energy saving is as follows. 1) Obtain base station historical data from the NMS, RAN EMS or other management system. NOTE 1 – The base station historical data can be parameter data, MR data (e.g., latitude, longitude and direction angle) and performance data (e.g., PRB utilization rate, RRC connection number and load flow rate). 2) Collect historical data in the data acquisition block or data storage block, and clean the data. 3) Process data in the data processing block, and pre-process feature data in the feature data pre-processing block. NOTE 2 – For this use case, the feature data pre-processing of latitude, longitude, direction angle, see clause A.3.2. NOTE 3 – Global positioning system (GPS) data may be used to obtain accurate base station location data in the feature data pre-processing block in some cases.

Title	Energy saving for different deployment scenario
	4) Train multiple single AI models (e.g., the energy saving scenario recognition model and base station traffic prediction model) based on pre-processed base station historical data and adjust the parameters of the AI model based on tools or methods in the AI energy saving model repository block. 5) Recognize the typical scenario of the base station and generate the optimal energy saving strategy. The main flow includes: • recognize the typical scenario of the base station through the energy saving scene recognition model; • combine the deployment scenario and base station traffic prediction technology to predict the load time series of base stations; • evaluate the advantages and disadvantages of energy saving strategies and potential problems based on the prediction results – the energy saving effect evaluation can provide real-time feedback to the energy saving strategy selection mechanism; • finally, generate the corresponding energy saving strategy after several iterative optimizations. 6) Distribute the energy saving strategy through the AI-based energy saving capability management block and command interaction block. 7) Finally, the energy saving strategy is sent to the EMS, service directory and standardized capability directory (target of energy saving strategy output).
Roles	Communication service provider, infrastructure vendor, customer, operation administration and maintenance (OAM) engineer
Graphic (optional)	 For details of the symbols in the graphic, see [ITU-T Y.3172] and [ITU-T M.3080].
Pre-conditions (optional)	Traffic characteristics need to be determined.
Post-conditions (optional)	Optimal performance of energy saving is achieved based on a specific strategy.
Derived requirements	All requirements are based on clause 8.

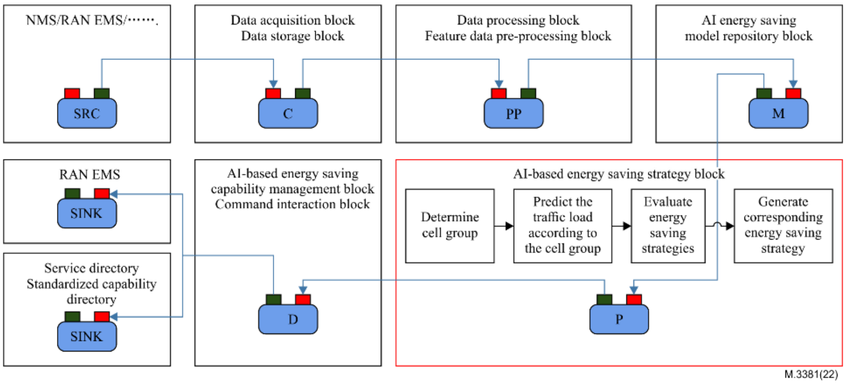
A.2.1.2 Energy saving for different type of base station

Title	Energy saving for different type of base station
Description	A macro base station is used for a larger cell and a micro base station is used for an indoor scenario or smaller cell. For a macro base station, the target is to save energy of the radio frequency (RF) while for micro base station, both the energy of the RF and BBU need to be saved. When 5G energy saving is performed, the energy saving strategy generated should be service logic combined with different types of base station in the AI-based energy saving strategy block. The process to realize 5G energy saving is as follows. 1) Obtain base station historical data from the NMS, RAN EMS or other management system. NOTE – The base station historical data can be parameter data (e.g., the type of base station) and performance data (e.g., PRB utilization rate, RRC connection number and load flow rate). 2) Collect historical data in the data acquisition block or data storage block, and clean the data. 3) Process data in the data processing block, and pre-process feature data in the feature data pre-processing block. 4) Train multiple single AI models (e.g., base station traffic prediction model) based on pre-processed base station historical data and adjust the parameters of the AI model based on tools or methods in the AI energy saving model repository block. 5) Determine the energy saving target based on type of base station and generate the corresponding optimal energy saving strategy. The main flow includes the following. • Determine the energy saving target based on the type of base station obtained in the feature data pre-processing block. • Predict the base station load traffic based on base station traffic prediction model. • Evaluate the advantages and disadvantages of energy saving strategies and potential problems based on the prediction results and energy saving target. The energy saving effect evaluation can provide real-time feedback to the energy saving strategy selection mechanism. • Finally, generate the corresponding energy saving strategy after several iterative optimizations. 6) Distribute the energy saving strategy through AI-based energy saving capability management block and command interaction block. 7) Finally, the energy saving strategy is sent to EMS, service directory and standardized capability directory (target of energy saving strategy output).
Roles	Communication service provider, infrastructure vendor, customer, OAM engineer.
Graphic (optional)	 For details of the symbols in the graphic, see [ITU-T Y.3172] and [ITU-T M.3080].
Pre-conditions (optional)	Type of base station needs to be determined.

Title	Energy saving for different type of base station
Post-conditions (optional)	Optimal performance of energy saving is achieved based on a specific strategy.
Derived requirements	All requirements are based on clause 8.

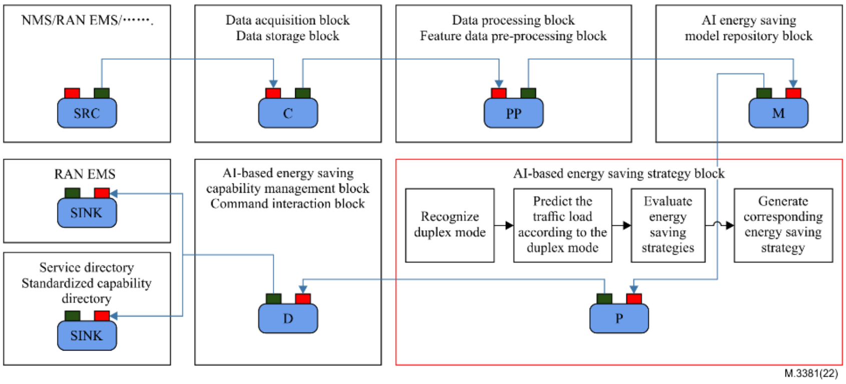
A.2.1.3 Energy saving for cooperation among multiple cells

Title	Energy saving for cooperation between multiple cells
Description	Each cell may have an independent AI strategy for energy saving, but that will cause collision and impact the performance. For the whole network, cooperation of multiple cells from the energy saving strategy point of view is needed. When 5G energy saving is performed, the energy saving strategy generated should be service logic based on cooperation between multiple cells in the AI-based energy saving strategy block. The process to realize 5G energy saving is as follows. 1) Obtain base station historical data from the NMS, RAN EMS or other management system. NOTE 1 – The base station historical data can be parameter data, MR data (e.g., latitude, longitude, direction angle, SS-RSRP, SS-RSRQ and SS-SINR) and performance data (e.g., PRB utilization rate, RRC connection number and load flow rate). 2) Collect historical data in the data acquisition block or data storage block, and clean the data. 3) Process data in the data processing block, and pre-process feature data in the feature data pre-processing block. NOTE 2 – In this use case, for the feature data pre-processing of latitude, longitude, direction angle, see clause A.3.2. NOTE 3 – GPS data may be used to obtain accurate base station location data in the feature data pre-processing block in some cases. 4) Train multiple single AI models (e.g., the base station traffic prediction model) based on pre-processed base station historical data and adjust the parameters of the AI model based on tools or methods in the AI energy saving model repository block. 5) Considering the cooperation of multiple cells for the whole network, generate corresponding optimal energy saving strategy. The main flow includes the following. • Determine a cell group based on associated cells and coverage. • Predict the base station load traffic based on the base station traffic prediction model among the cooperation of multiple cells. • Evaluate the advantages and disadvantages of energy saving strategies and potential problems based on the prediction results and the cooperation of multiple cells. The energy saving effect evaluation can provide real-time feedback to the energy saving strategy selection mechanism. • Finally, generate the corresponding energy saving strategy after several iterative optimizations. 6) Distribute the energy saving strategy through the AI-based energy saving capability management block and command interaction block. 7) Finally, the energy saving strategy is sent to the EMS, service directory and standardized capability directory (target of energy saving strategy output).
Roles	Communication service provider, infrastructure vendor, customer, OAM engineer.

Title	Energy saving for cooperation between multiple cells
Graphic (optional)	 For details of the symbols in the graphic, see [ITU-T Y.3172] and [ITU-T M.3080].
Pre-conditions (optional)	Cooperation of multiple cells is feasible
Post-conditions (optional)	Optimal performance of energy saving of the network is achieved based on a specific strategy.
Derived requirements	All requirements are based on clause 8.

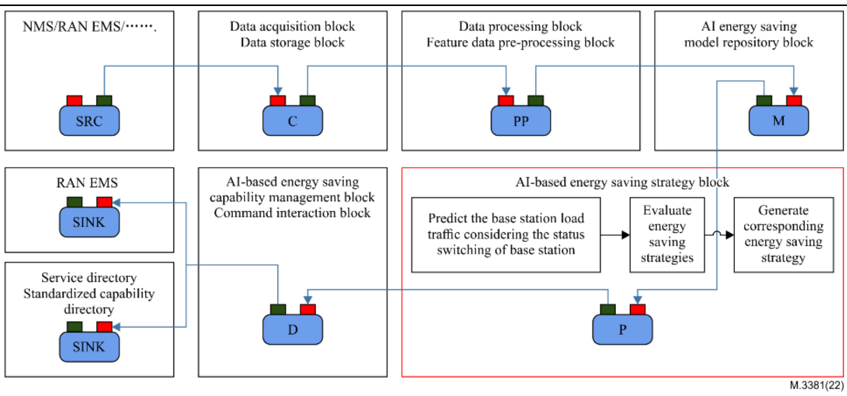
A.2.1.4 Energy saving for different duplex mode

Title	Energy saving for different duplex mode
Description	For test-driven development (TDD), the energy saving strategy adopted for downlink needs to take uplink traffic into account. For frequency division dual (FDD), the energy saving strategy needs to be considered for downlink and uplink, respectively. When 5G energy saving is performed, the energy saving strategy generated should be service logic combined with different duplex modes in the AI-based energy saving strategy block. The process to realize 5G energy saving is as follows. 1) Obtain base station historical data from the NMS, RAN EMS or other management system. NOTE – The base station historical data can be parameter data (e.g., the duplex mode of base station) and performance data (e.g., PRB utilization rate, RRC connection number and load flow rate). 2) Collect historical data in the data acquisition block or data storage block, and clean the data. 3) Process data in the data processing block, and pre-process feature data in the feature data pre-processing block. 4) Train multiple single AI models (e.g., the energy saving scenario recognition model and base station traffic prediction model) based on pre-processed base station historical data and adjust the parameters of the AI model based on tools or methods in the AI energy saving model repository block. 5) Generate the optimal energy saving strategy considering the duplex mode. The main flow includes: • recognize duplex mode (TDD or FDD) and determine which transmission direction (uplink or downlink) should be taken into account for generation of energy saving strategy; • predict the base station load traffic based on the base station traffic prediction model;

Title	Energy saving for different duplex mode
	• evaluate the advantages and disadvantages of energy saving strategies and potential problems based on the prediction results. The energy saving effect evaluation can provide real-time feedback to the energy saving strategy selection mechanism; • finally, generate the corresponding energy saving strategy after several iterative optimizations. 6) Distribute the energy saving strategy through the AI-based energy saving capability management block and command interaction block. 7) Finally, the energy saving strategy is sent to the EMS, service directory and standardized capability directory (target of energy saving strategy output).
Roles	Communication service provider, infrastructure vendor, customer, OAM engineer.
Graphic (optional)	 For details of the symbols in the graphic, see [ITU-T Y.3172] and [ITU-T M.3080].
Pre-conditions (optional)	Duplex mode needs to determined.
Post-conditions (optional)	Optimal performance of energy saving is achieved based on a specific strategy.
Derived requirements	All requirements are based on clause 8.

A.2.1.5 Energy saving for status switching of base station

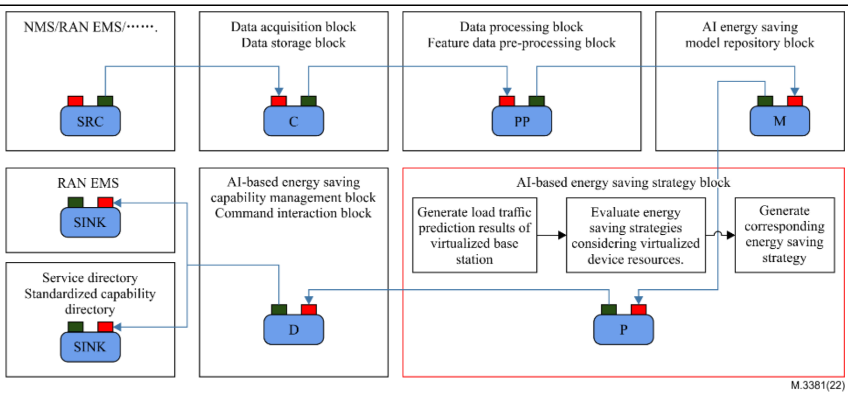
Title	Energy saving for status switching of base station
Description	Using AI to realize optimal status switching of a base station among "ON", "Standby", "Sleep" and "OFF". ON: both BBU and RRU are activated. Standby: only RRU and the temperature compensated crystal oscillator (TCXO) heater are inactive. Other components like BBU are active. Sleep: only power supply, backend connection and CPU are active. OFF: all components are inactive. When 5G energy saving is performed, the energy saving strategy generated should be based on status switching of the base station in the AI-based energy saving strategy block. The process to realize 5G energy saving is as follows. 1) Obtain base station historical data from the NMS, RAN EMS or other management systems. NOTE – The base station historical data can be performance data (e.g., PRB utilization rate, RRC connection number and load flow rate). 2) Collect historical data in the data acquisition block or data storage block, and clean the data.

<table>
<tr><th>Title</th><th>Energy saving for status switching of base station</th></tr>
<tr><td></td><td>3) Process data in the data processing block, and pre-process feature data in the feature data pre-processing block.
4) Train multiple single AI models (e.g., the energy saving scenario recognition model and base station traffic prediction model) based on pre-processed base station historical data and adjust the parameters of the AI model based on tools or methods in the AI energy saving model repository block.
5) Generate the optimal energy saving strategy based on the trained AI energy saving model to realize optimal status switching of the base station. The main flow includes the following.
• Considering the status switching of the base station, generate prediction results based on base station traffic prediction model.
• Evaluate the advantages and disadvantages of energy saving strategies and potential problems based on the prediction results and status switching of base station. The energy saving effect evaluation can provide real-time feedback to the energy saving strategy selection mechanism.
• Finally, generate the corresponding energy saving strategy after several iterative optimizations.
6) Distribute the energy saving strategy through the AI-based energy saving capability management block and command interaction block.
7) Finally, the energy saving strategy is sent to the EMS, service directory and standardized capability directory (target of energy saving strategy output).</td></tr>
<tr><td>Roles</td><td>Communication service provider, infrastructure vendor, customer, OAM engineer.</td></tr>
<tr><td>Graphic (optional)</td><td>

For details of the symbols in the graphic, see [ITU-T Y.3172] and [ITU-T M.3080].</td></tr>
<tr><td>Pre-conditions (optional)</td><td>Four statuses of energy saving are supported.</td></tr>
<tr><td>Post-conditions (optional)</td><td>Optimal performance of energy saving is achieved based on a specific strategy.</td></tr>
<tr><td>Derived requirements</td><td>All requirements are based on clause 8.</td></tr>
</table>

A.2.2 Energy saving for virtualized base station equipment

A.2.2.1 Energy saving for virtualized hardware resources

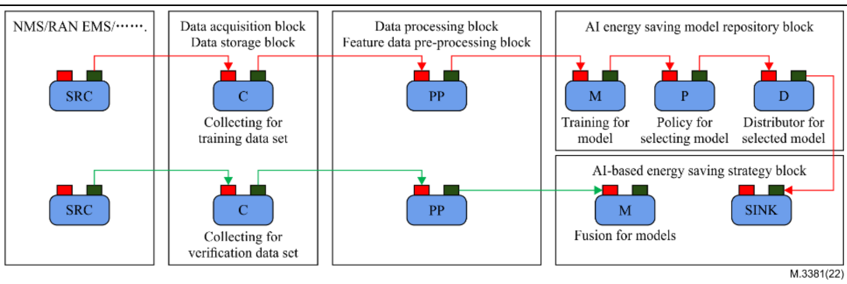
Title	Energy saving for virtualized hardware resources
Description	BBU/(CU,DU) (alternatively RRU/AAU) are virtualized on top of the cloud platform, which consumes energy. An AI-based strategy is used to realize optimal utilization of cloud resources so that energy is saved. When formulating energy saving strategies, the energy consumption of virtualized device resources of the part SINK should be considered. The process to realize 5G energy saving is as follows. 1) Obtain virtualized device resource historical data from the NMS, RAN EMS or other management system. NOTE – The virtualized device resource historical data can be performance data (e.g., PRB utilization rate, RRC connection number and load flow rate) or configuration data (e.g., high available components configuration, including each kind of component number in cluster, the components indicates switch or router). 2) Collect historical data in the data acquisition block or data storage block, and clean the data. 3) Process data in the data processing block, and pre-process feature data in the feature data pre-processing block. 4) Train multiple single AI models (e.g., the base station traffic prediction model) based on pre-processed virtualized device resource historical data and adjust the parameters of the AI model based on tools or methods in the AI energy saving model repository block. 5) Generate the energy saving strategy considering the energy consumption of virtualized device resources. The main flow includes the following. • Generate load traffic prediction results based on the traffic prediction model considering the energy consumption of virtualized device resources. • Evaluate the advantages and disadvantages of energy saving strategies and potential problems based on the prediction results. The energy saving effect evaluation can provide real-time feedback to the energy saving strategy selection mechanism. • Finally, generate the corresponding energy saving strategy after several iterative optimizations. 6) Distribute the energy saving strategy through the AI-based energy saving capability management block and command interaction block of virtualized devices. 7) Finally, the energy saving strategy is sent to the EMS, service directory and standardized capability directory (target of energy saving strategy output).
Roles	Communication service provider, infrastructure vendor, customer, OAM engineer.
Graphic (optional)	 For details of the symbols in the graphic, see [ITU-T Y.3172] and [ITU-T M.3080].

Title	Energy saving for virtualized hardware resources
Pre-conditions (optional)	A virtualized cloud platform is implemented for wireless communication units like BBU/(CU,DU) or RRU/AAU.
Post-conditions (optional)	Optimal performance of energy saving is achieved based on a specific strategy.
Derived requirements	All requirements are based on clause 8.

A.3 Typical technical use cases of energy saving management of 5G RAN system with AI

A.3.1 Energy saving strategy generation for base station equipment

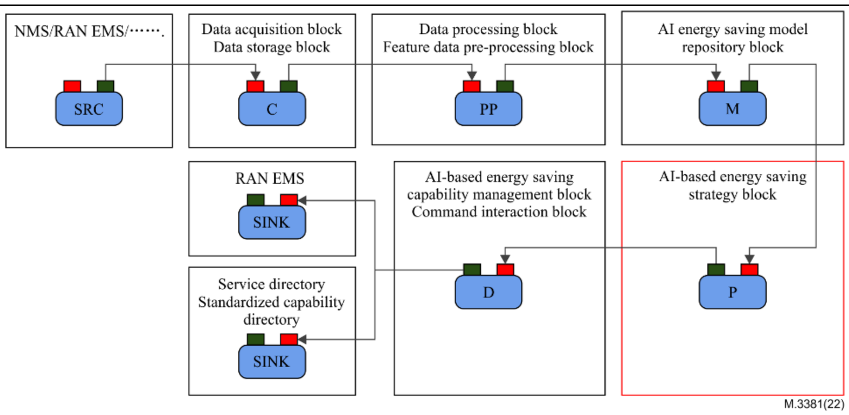
A.3.1.1 Energy saving model training and fusion for base station equipment

Title	Energy saving model training and fusion for base station equipment
Description	Before the energy saving strategy is generated, AI-based energy saving models need to be trained and fused, including the following steps. 1) Obtain base station historical data from the NMS, RAN EMS or other management system. 2) Collect the training data set and verification data set in the data acquisition block or data storage block based on the historical data, and clean the data. 3) Process data in the data processing block, and pre-process feature data in the feature data pre-processing block, including pre-processing for the training data set and verification data set. 4) The main flow needs to be performed in the AI energy saving model repository block, including the following. • Train multiple single AI models based on common AI models (such as the XGBoost model and LightGBM model) and computing the engine framework (such as TensorFlow) with the training data set. During single model training, model parameters are adjusted based on tools or methods, such as Hyperopt (a library of hyperparameter optimization). • Make the policy based on the application scenario for selecting which model should be used. • Distribute selected models to the AI-based energy saving strategy block (target module). • Multiple AI models need to be fused and the verification data set needs to be used to update model parameters and improve model quality. Finally, AI-based energy saving models are fused.
Roles	OAM engineer.
Graphic (optional)	 For details of the symbols in the graphic, see [ITU-T Y.3172] and [ITU-T M.3080]. NOTE – The two flows are the development state of AI-based energy saving.

Title	Energy saving model training and fusion for base station equipment
Pre-conditions (optional)	Select the corresponding training data set and verification data set for model training based on specific application scenarios.
Post-conditions (optional)	Based on the verification data set, automatic adjustment of model parameters during training is allowed.
Derived requirements	Requirements are based on clause 8.3.

A.3.1.2 Energy saving strategy recommendation for base station equipment

<table>
<tr><th>Title</th><th>Energy saving strategy recommendation for base station equipment</th></tr>
<tr><td>Description</td><td>
It is necessary to use trained models to make energy saving strategies, and determine the recommendation information of each strategy for the target base station, including the following steps.

1) Obtain online data from the NMS, RAN EMS or other management system corresponding to the target base station.
2) Collect online data in the data acquisition block or data storage block to generate the prediction data set.
3) Process data in the data processing block, and pre-process feature data in the feature data pre-processing block for the online data set.
4) Use fused AI models in the AI-based energy saving strategy block to perform prediction for the online data set, and generate new prediction samples based on the prediction results.
5) The main flow is determining the recommendation information of each AI model based on the trained energy saving strategy recommendation model and new prediction samples in the AI-based energy saving strategy block, including:
   - calculate the energy saving strategy recommendation degree;
   - make policy for energy saving model recommendation;
   - generate an energy saving strategy.
6) Distribute the recommended energy saving strategy that has the highest recommendation through the AI-based energy saving capability management block and command interaction block.
7) Finally, the recommended energy saving strategy is sent to the EMS, service directory and standardized capability directory (target of energy saving strategy output).
</td></tr>
<tr><td>Roles</td><td>OAM engineer.</td></tr>
<tr><td>Graphic (optional)</td><td>


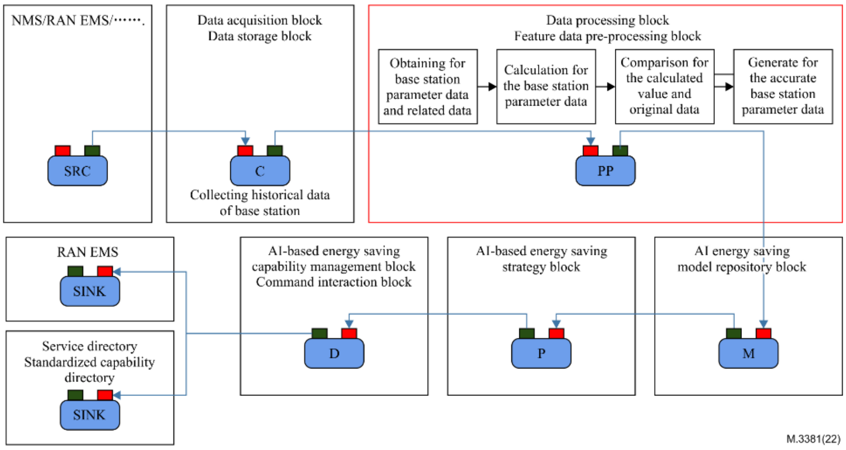
For details of the symbols in the graphic, see [ITU-T Y.3172] and [ITU-T M.3080].

NOTE – This flow is the operation state of AI-based energy saving.
</td></tr>
</table>

Title	Energy saving strategy recommendation for base station equipment
Pre-conditions (optional)	Prediction data set and trained AI models are available.
Post-conditions (optional)	Selection rules for the recommendation degree of energy saving strategy are formulated.
Derived requirements	Requirements are based on clause 8.4.

A.3.2 Feature data pre-processing for base station parameter data

Title	Feature data pre-processing for base station parameter data
Description	Base station parameter data is used for training energy saving model. However, base station parameter data in the EMS system may be inaccurate when erroneously entered manually or the update of base parameter data may be not timely, which could affect the accuracy of the energy saving model and the AI energy saving model strategy. In order to ensure the correctness of the feature data and improve the accuracy of the energy saving model, it is therefore necessary to audit the parameter data based on AI technology, including the following steps. 1) Obtain base station historical data from the NMS, RAN EMS or other management system. 2) Collect historical data in the data acquisition block or data storage block, and clean the data. 3) Process data in the data processing block, and pre-process feature data in the feature data pre-processing block. The main flow of feature data pre-processing includes: • obtain base station parameter data and related data (e.g., MR data and GPS data, which can include the latitude, longitude, direction angle); • calculate base station parameter data based on related data. NOTE 1 – For example, obtain the calculated base station latitude and longitude based on the MR latitude and longitude, and obtain the calculated base station direction angle based on the MR direction angle. Specifically, the calculation of base station latitude and longitude includes the following steps: – first, select the MR data corresponding to the target base station; – then divide the MR data into cells for each base station, filter abnormal MR data using AI technology (e.g., using the local outlier factor for detection), calculate the average of the MR latitude and the average of MR longitude as latitude and longitude of each cell. – Finally calculate the average of the latitude and longitude of cells as base station latitude and longitude. • Compare the obtained value of base station parameter data (e.g., latitude and longitude, direction angle) with the original base station parameter data (e.g., latitude and longitude, direction angle). NOTE 2 – For example, set a threshold A, then calculate the absolute value of difference between obtained value and the original data, if the absolute value is less than A, select the original data, if the difference is more than A, update the original data based on the obtained value. • Generate the accurate base station parameter data. 4) Select accurate base station parameter data as the input for the construction of an AI energy saving model in the AI energy saving model repository block. 5) Generate the energy saving strategy in the AI-based energy saving strategy block. 6) Distribute the energy saving strategy through the AI-based energy saving capability management block and command interaction block. 7) Finally, the energy saving strategy is sent to the RAN EMS, service directory and standardized capability directory (target of energy saving strategy output).
Roles	Communication service provider, Infrastructure vendor, customer, OAM engineer.

Title	Feature data pre-processing for base station parameter data
Graphic (optional)	 Details of the symbols in the graphic, see [ITU-T Y.3172] and [ITU-T M.3080].
Pre-conditions (optional)	MR data, base station parameter data and general AI technology could be obtained.
Post-conditions (optional)	Select accurate base station parameter data as the input for the construction of the AI energy saving model and the generation of an AI-based energy saving strategy.
Derived requirements	All requirements are based on clauses 8.3 and 8.4.

Appendix I

The background of Requirements for energy saving management of 5G RAN system with AI

(This appendix does not form an integral part of this Recommendation.)

A 5G network has a higher frequency band and weaker coverage than one of 4G, so the number of base stations needed has increased greatly, and the energy consumption has also increased sharply. The power consumption of a 5G single station is about 2.5 to 3.5 times one of 4G, of which the power consumption of wireless communication unit is more than 50% of that of base station. At the same time, the complexity of network and the difficulty of operation and management make OPEX increase rapidly.

The energy saving technology of the traditional general model cannot meet the requirement of 5G large-scale deployment and high-efficiency energy saving, so it is necessary to introduce AI technology to realize intelligent monitoring and optimization of equipment and network. How to use AI to save energy in wireless communication unit has therefore become a key issue to be considered in telecommunication operation and management. In addition, as discussed in O-RAN [b-O-RAN-WG6.CAD-V01.00.00], for wireless communication units like BBU and RRU, they may be implemented over a cloud platform as a virtualized network function. For these cloud platforms (e.g., memory and computer resource), there would be some energy consumption as well. Using AI to realize optimal cloud resource utilization is therefore also beneficial for energy saving. At the same time, the application of telecommunication operation management needs to be driven and realized by designing a new architecture (see [ITU-T M.3080]) that integrates AI capabilities, which will drive relevant technology to bring major changes to the model, causing service processes to be re-specified and designed.

Although research on energy saving of 5G RAN has been carried out in some standards development organizations (SDOs), current researches have not solved the problem of how AI is applied to energy saving management of a 5G RAN system. For example, the research of the TM Forum focuses on the AI maturity assessment model, AI service management architecture and user case collection. The research conducted at ITU-T is mainly focused on IMT-2020, most of which are still in the discussion stage. ITU-R WP 5D does not have any work at this time related to energy savings management and AI. ETSI is more focused on network-level AI applications, and so far, only a few use cases have been proposed. 3GPP has no relevant standard output for operation management in AI. Although standardization research on AI has been carried out in several major international SDOs, it has not systematically explained how AI is used in telecommunication operation and management in the published results, as a general technical means.

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