

Draft new Recommendation ITU-T Y.3141 (ex.Y.IMT2020-REEM)

Energy efficiency management of virtual resources in IMT-2020 networks and beyond

Summary

This Recommendation specifies AI-assisted energy efficiency management of virtual resources in IMT-2020 networks and beyond. This recommendation covers the following aspects:

- Functional requirements of energy efficiency management of virtual resources in IMT-2020 networks and beyond;
- Architectural model of energy efficiency management of virtual resources in IMT-2020 networks and beyond;
- Reference points of energy efficiency management of virtual resources in IMT-2020 networks and beyond;
- Procedures of energy efficiency management of virtual resources in IMT-2020 networks and beyond.

Keywords

Energy efficiency, AI-assisted, virtual resources

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1 Scope

This Recommendation specifies AI-assisted energy efficiency management of virtual resources in IMT-2020 networks and beyond. This recommendation includes:

- Functional requirements of energy efficiency management of virtual resources in IMT-2020 networks and beyond;
- Architectural model of energy efficiency management of virtual resources in IMT-2020 networks and beyond;
- Reference points of energy efficiency management of virtual resources in IMT-2020 networks and beyond;
- Procedures of energy efficiency management of virtual resources in IMT-2020 networks and beyond.

2 References

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 Y.3011] Recommendation ITU-T Y.3011 (2012), *Framework of network virtualization for future networks*
- [ITU-T Y.3100] Recommendation ITU-T Y.3100 (2017), *Terms and definitions for IMT-2020 network*
- [ITU-T Y.3111] Recommendation ITU-T Y.3111 (2017), *IMT-2020 network management and orchestration framework*
- [ITU-T Y.3150] Recommendation ITU-T Y.3150 (2020), *High-level technical characteristics of network softwarization for IMT-2020*
- [ITU-T Y.3156] Recommendation ITU-T Y.3156 (2020), *Framework of network slicing with AI-assisted analysis in IMT-2020 networks*
- [ITU-T Y.3179] Recommendation ITU-T Y.3179 (2021), *Architectural framework for machine learning model serving in future networks including IMT-2020*
- [ITU-T Y.3321] Recommendation ITU-T Y.3321 (2015), *Requirements and capability framework for NICE implementation making use of software-defined networking technologies*
- [ETSI ES 203 228] Environmental Engineering (EE); *Assessment of mobile network energy efficiency*

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 virtual resource [ITU-T Y.3011]: An abstraction of physical or logical resource, which may have different characteristics from the physical or logical resource and whose capability may be not bound to the capability of the physical or logical resource.

3.1.2 network function [ITU-T Y.3100]: In the context of IMT-2020, a processing function in a network.

NOTE 1 – Network functions include but are not limited to network node functionalities, e.g., session management, mobility management and transport functions, whose functional behaviour and interfaces are defined.

NOTE 2 – Network functions can be implemented on a dedicated hardware or as virtualized software functions.

NOTE 3 – Network functions are not regarded as resources, but rather any network functions can be instantiated using the resources.

3.1.3 virtualized network function [ITU-T Y.3321]: A network function whose functional software is decoupled from hardware, and runs on virtual machine(s).

3.2 Terms defined in this Recommendation

None.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

DV	Data Volumes
EC	Energy Consumption
EEM	Energy Efficiency Management
EEO	Energy Efficiency Orchestrator
NF	Network Function
RAN	Radio Access Network
REEM	Energy Efficiency Management of Resources
RP	Reference Point
VNF	Virtualized Network Function

5 Conventions

In this Recommendation:

The keywords "is required to" indicate a requirement which must be strictly followed and from which no deviation is permitted, if conformance to this Recommendation is to be claimed.

The keywords "is recommended" indicate a requirement which is recommended but which is not absolutely required. Thus, this requirement need not be present to claim conformance.

6 Overview

Virtualization technology builds infrastructure into a resource pool, including the three underlying resources of network, computing and storage, forming the integration of these resources. With the deployment and application of IMT-2020 networks, the continuous increase of new services has brought the complexity of resource management and control, how to flexibly schedule, integrate and release resources to improve the energy efficiency is a challenge. The introduction of AI technology will help to enable intelligent network management and improve energy efficiency of IMT-2020 network.

With the growth of IMT-2020 networks, it is expected that by 2025, radio access network energy consumption (EC) will account for 50.6% of the total network EC, data centers will account for 23.3%, and edge, core networks and service core will account for 13.3%, others will account for 12.8% [b-Lorincz]. AI-assisted energy saving methods for radio access network (RAN) equipment has been introduced in [b-ITU-T L.1390] and [b-ITU-T M.3381]. Besides energy efficiency of RAN, AI-assisted energy efficiency management of virtual resources will also play an important role to reduce energy consumption of IMT-2020 networks.

AI-assisted energy efficiency management needs to monitor and collect data related to energy usage of virtual resources, detect resource utilization patterns with AI algorithms, make intelligent energy-saving decision taking workload characteristics and energy usage into consideration, dynamically adjust the allocation and status of virtual resources, and optimize the energy efficient policies based on the evaluation of energy-saving effect, and the changes of workload demands and environmental conditions.

7 Functional requirements of energy efficiency management of virtual resources in IMT-2020 networks and beyond

7.1 Requirements for energy efficiency related data management

This clause describes high-level requirements of energy efficiency related data management to enable energy efficiency management of virtual resources in IMT-2020 networks and beyond.

[REQ-DM-001] Energy efficiency management of resources (REEM) is required to support the management of multiple data sets. The data sets are required to include network data (traffic data, resource configuration data, etc.) and EC data (current, voltage, power, etc.).

[REQ-DM-002] REEM is recommended to support the collection and storage of different types of data by various collection frequencies.

[REQ-DM-003] REEM is required to support the real-time backup of key EC data, and the keyword query of specified query conditions.

[REQ-DM-004] REEM is required to support cleaning, auditing and validation of data collected from different data sources.

[REQ-DM-005] REEM is required to label data based on data labeling rules.

[REQ-DM-006] REEM is recommended to provide visualization of EC information, temperature information and energy saving statistics.

7.2 Requirements for energy efficiency related model management

This clause describes high-level requirements of energy efficiency related model management of virtual resources in IMT-2020 networks and beyond.

[REQ-MM-001] REEM is required to support the energy efficiency related model selection, model training, and model interference [ITU-T Y.3179].

[REQ-MM-002] REEM is required to support the iteration of the model based on network performance and energy consumption.

[REQ-MM-003] REEM is recommended to support building an energy management model library, the historical models stored inside can be selected for reusing in the same and similar energy management scenarios.

[REQ-MM-004] REEM is recommended to encapsulate the inference model as an API service or image file for invocation.

[REQ-MM-005] REEM is recommended to support version management and maintenance of AI models.

7.3 Requirements for network status awareness and prediction for energy-saving

This clause describes high-level requirements of status awareness to enable energy efficiency management of virtual resources in IMT-2020 networks and beyond.

[REQ-NSAP-1] REEM is required to continuously monitor network operation status (latency, jitter, bandwidth, resource usage, etc.) and aware the requirements for triggering energy-saving.

[REQ-NSAP-2] REEM is required to intelligently predict network traffic, service load and dynamically adjust energy-saving policies.

7.4 Requirements for energy efficiency related policy management

This clause describes high-level requirements of policy management to enable energy efficiency management of virtual resources in IMT-2020 networks and beyond.

[REQ-PM-001] REEM is required to support effective energy-saving policies on adjustment, evaluation, iteration and execution..

[REQ-PM-002] REEM is required to support the manual adjustment based on the policy generated by Energy Efficiency Orchestrator (EEO).

[REQ-PM-003] REEM is required to support the energy-saving effect evaluation before and after the execution of energy-saving policies.

[REQ-PM-004] REEM is recommended to support building an energy-saving policy library to record the policies generated in all cases, and support adding, deleting, modifying and checking the energy-saving policies in the policy library.

[REQ-PM-005] REEM is recommended to support labeling the policies that have no energy-saving effects or may cause anomalies.

7.5 Requirements for energy-saving abnormal situation management

This clause describes high-level requirements of energy-saving abnormal situation management in IMT-2020 networks and beyond.

[REQ-ASM-1] REEM is required to support real-time abnormality detection and pre-warning, update the energy-saving policy or recover the original policy (namely without using energy-saving policy) if the abnormal results are caused by the implementation of energy-saving policies.

[REQ-ASM-2] The abnormal situation management is required to adjust resource configuration of VNF to ensure the network performance and user experience if network congestion and other faults occur after the execution of the energy-saving policies.

[REQ-ASM-3] REEM is required to support the statistics and analysis of alarms caused by energy-saving policies.

[REQ-ASM-004] REEM is recommended to support building an alarm processing policy library to handle the energy-saving abnormal situation in a timely and efficient manner.

7.6 Requirements for security management

This clause describes high-level requirements of security management to enable energy efficiency management of virtual resources IMT-2020 networks and beyond.

[REQ-SM-1] REEM is required to provide security protection and privacy preservation for data sets, model training, model aggregation and ML services.

[REQ-SM-2] REEM is required to support the authorization and authentication of consumers to invoke the energy-saving services.

8 Architectural model of energy efficiency management of virtual resources in IMT-2020 networks and beyond

8.1 Architectural model and energy efficiency management service

The architecture model of energy efficiency management is depicted in Figure 8-1. It consists of four layers which includes resource layer, data service layer, energy efficiency management layer and energy efficiency management consumer layer.

The resource layer consists of SDN infrastructure, NFV infrastructure, cloud infrastructure and physical infrastructure [ITU-T Y.3150].

Data service layer collects network data and EC data from the resource layer.

Energy efficiency management layer is performed by Energy Efficiency Orchestrator, and can act as data service consumer and energy efficiency management provider. It consumes energy efficiency related data provided by data service layer, and provides energy efficiency management services to the consumer layer.

Energy efficiency management consumer invokes energy efficiency management services such as data analysis, energy efficiency models, energy-saving policies, and energy efficiency evaluation services. It is responsible for the energy-saving policies execution to reduce the EC of the resource within its management domain.

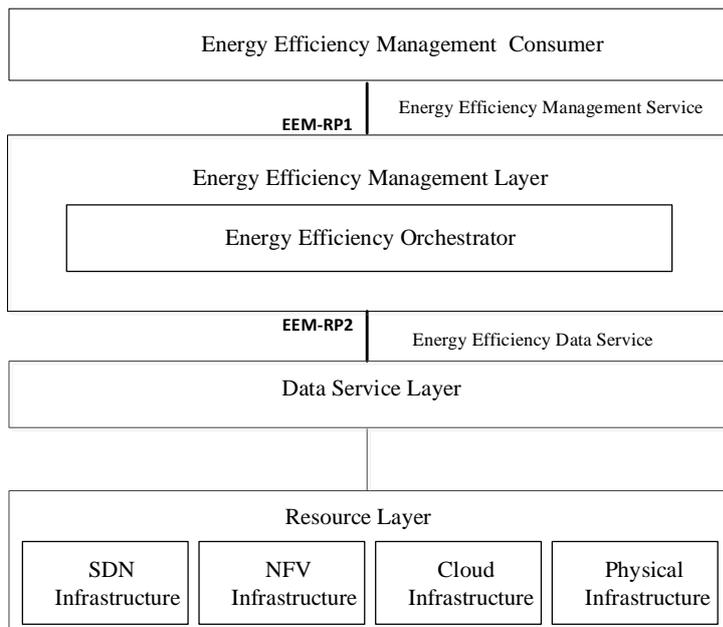


Figure 8-1- Architectural model of energy efficiency management of virtual resources in IMT-2020 networks and beyond

Energy efficiency management layer communicates with energy efficiency management consumer via reference point EEM-RP1, and it exchanges information with data service layer via reference point EEM-RP2. These two reference points are defined in detail in clause 9.

8.2 Detailed functional components of Energy Efficiency Orchestrator

The energy efficiency management services are provided by Energy Efficiency Orchestrator in the energy efficiency management layer, and the figure 8-2 shows the functional components of Energy Efficiency Orchestrator.

Energy Efficiency Orchestrator consists of five functions: data management, AI modelling and model management, energy efficiency policy management, energy efficiency evaluation and abnormal situation management for energy efficiency management.

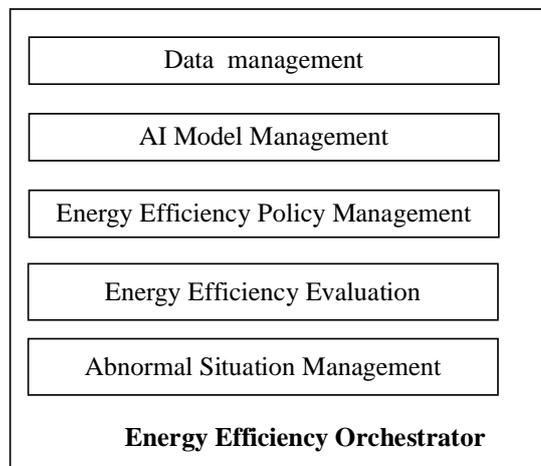


Figure 8-2- Functional components of Energy Efficiency Orchestrator

8.2.1 Data management

Data management function support the collection, storage and processing of multiple data sets.

1) Data collection of energy consuming objects

Energy consuming objects include virtual machines, server nodes which run a set of virtual machines, resource clusters located in a set of racks or a data center, and etc. The data needs to be collected of these energy consuming objects is shown in table 1.

Table 1 Data collection of energy consuming objects

Data type	Information element
Configuration data of virtual machines	The configuration data of virtual machines can be resource ID, resource IP, service type, host resource ID to which it belongs, CPU core number, memory size, the number and size of network ports, disk capacity, active service port traffic , collection time, and etc.
Operation data of virtual machines	The operation data of virtual machines can be resource ID, maximum CPU usage, minimum CPU usage, average CPU usage, maximum memory usage, minimum memory usage, average memory usage, maximum network traffic, minimum network traffic, average network traffic, maximum disk IO, minimum disk IO, average disk IO, maximum hard disk usage, minimum hard disk usage, average hard disk usage, collection time, and etc.

Configuration data of server nodes	The configuration data of server nodes can be resource ID, host type, host role, resource name, resource IP, service type, CPU model, CPU cores, memory size, disk capacity, rated power, active service port traffic, collection time, and etc.
Operation data of server nodes	The operation data of server nodes can be resource ID, maximum CPU usage, minimum CPU usage, average CPU usage, maximum memory usage, minimum memory usage, average memory usage, maximum network traffic, minimum network traffic, average network traffic, maximum disk IO, minimum disk IO, average disk IO, maximum hard disk usage, minimum hard disk usage, average hard disk usage, collection time, and etc.
Configuration data of resource clusters	The configuration data of resource clusters can be cluster ID, data center ID, cluster activation time, number of hosts, cluster type, collection time, and etc.
Configuration data of services	The configuration data of services can be service ID, data center ID, service activation date, number of hosts, service description, collection time, and etc.
EC related data	CPU load, CPU temperature, fan speed, active power of electricity
NOTE: The collection frequency of configuration data is recommended to be collected by day, The collection frequency of operation data is recommended to be collected by hour or minute.	

2) Data management and maintenance

Data management function provides the capabilities of data query, update and deletion.

Data management function provides data quality management such as cleaning, auditing and validation of data collected from different data sources, evaluates the current data quality based on some key data dimensions and provides analysis for data quality improvement.

NOTE: Data quality refers to the accuracy of data format, ranges, values, and collection frequency, and etc.

Data management function provides visualization of EC information, energy reduction information, machine temperature trend information.

8.2.2 AI model management

AI model management function provides energy-saving model training, retraining and interference, also provides models version management and energy management model library maintenance.

1) Energy-saving model training and retraining

AI model management function can train different energy-saving models for energy consuming objects based on the collected data, such as energy-saving model for virtual machines which will be introduced in clause 10.1 and energy-saving model for server nodes which will be introduced in clause 10.2.

Energy-saving models will be retraining if data quality is improved and model accuracy needs to be improved.

2) Energy management model library

AI model management function provides evaluation (such as application and accuracy) of each model in the model library, and the newly trained models including online training models and offline training models are recommended to be updated in model library once the models test validation is successful.

8.2.3 Energy efficiency policy management

Energy efficiency policy management function provides policy generation, execution and manual adjustment.

1) Energy efficiency policy generation

The energy efficiency policy generation can be triggered through timed tasks, condition threshold or forced triggering.

Timed tasks triggering: By configuring timed tasks, energy-saving policies are generated based on task execution frequency.

Condition threshold triggering: By configuring condition threshold, energy-saving policies are generated if some energy-saving indicators (such as CPU usage, memory usage, disk usage) are reached condition threshold.

Forced triggering: It is triggered by personnel through interface operations.

2) Energy efficiency policy confirmation

When some energy-saving policies involve important services, the policies need to be manually verified before execution. The personnel can review policies, revise energy-saving policies or exclude adjustments to the energy consuming objects if the services performed on these energy consuming objects cannot be affected by energy consumption.

General energy-saving policies can be configured automatically.

3) Energy efficiency policy switch

Energy efficiency policy management function provides a switch between using energy-saving policy and non energy-saving policy.

8.2.4 Energy efficiency evaluation function

The energy efficiency evaluation function provides energy-saving metrics measurement and visualization, such as daily average energy saving, cumulative energy saving, annualized energy saving, average energy saving rate, energy efficiency and etc.

1) Energy-saving value measurement

Energy-saving value measurement indicates the calculation of daily average energy saving, cumulative energy saving and annualized energy saving. The daily average energy saving can be measured by calculating the difference between EC before and after the execution of energy-saving policies and energy-saving duration in similar service condition. The cumulative energy saving and annualized energy saving can be measured based on daily average energy saving and total energy saving time duration.

2) Energy-saving rate measurement

Energy-saving rate measurement is energy-saving value divided by the energy consumption in non energy-saving state.

3) Energy efficiency measurement

Energy efficiency of IMT-2020 networks relies on the following principles:

It is based on the two high-level EE KPIs defined in [ETSI ES 203 228]:

$$- EE_{MN,DV} = \frac{DV_{MN}}{EC_{MN}}$$

$EE_{MN,DV}$ requires the collection of both Data Volumes (DV) and EC of IMT-2020 Network Functions (NF), measurement method for VNFs are not in the scope of this Recommendation.

8.2.5 Abnormal situation management function

Abnormal situation management function provides real-time abnormality detection, pre-warning and abnormal recovery.

1) Abnormal situation automatically handling

If the alarms are detected by the implementation of energy-saving policy, then the abnormal situation management function will automatically switch to the original policy in non energy-saving state.

2) Alarm policy library

Abnormal situation management function builds an alarm policy library to provide solutions to handle the energy-saving abnormal situations.

9 Reference points of energy efficiency management of virtual resources in IMT-2020 networks and beyond

In the architectural model of energy efficiency management of virtual resources in IMT-2020 networks and beyond, the two reference points EEM-RP1 and EEM-RP2 are specified in clause 8. These two reference points need to support the capabilities for exchanging information and accomplishing the energy management.

9.1 Requirements for EEM-RP1

[REQ-EEM-RP1-001]: Energy Efficiency Orchestrator is required to provide energy efficiency management services to the consumer via reference point EEM-RP1.

[REQ-EEM-RP1-002]: Energy Efficiency Orchestrator is recommended to provide energy efficiency data analysis, energy efficiency models, energy-saving policies, and energy efficiency evaluation services to the consumer via reference point EEM-RP1.

[REQ-EEM-RP1-003]: Energy Efficiency Orchestrator is recommended to provide comprehensive energy efficiency analysis services of different domains (e.g. core network, transport network, cloud, etc.) to the consumer via reference point EEM-RP1.

[REQ-EEM-RP1-004]: It is recommended that the consumer subscribes/requests energy efficiency management policies such as scaling down and end up a VNF instance, from Energy Efficiency Orchestrator via reference point EEM-RP1.

9.2 Requirements for EEM-RP2

[REQ-EEM-RP2-001]: Energy Efficiency Orchestrator is required to collect data from data service layer via reference point EEM-RP2.

[REQ-EEM-RP2-002]: It is recommended that data service layer provides data from different domains (e.g. core network, transport network, cloud, etc.) to Energy Efficiency Orchestrator via reference point EEM-RP2.

[REQ-EEM-RP2-003]: Energy Efficiency Orchestrator is recommended to subscribe and query service information (e.g. service type, resource usage, etc) via reference point EEM-RP2.

[REQ-EEM-RP2-004]: Energy Efficiency Orchestrator is recommended to subscribe and query configuration and usage information of cloud resources (e.g. virtual machine, bare metal server, cloud storage, etc) via reference point EEM-RP2.

[REQ-EEM-RP2-005]: Energy Efficiency Orchestrator is recommended to subscribe and query network status and performance data of transport devices (e.g. virtual switches, routers) via reference point EEM-RP2.

[REQ-EEM-RP2-006]: Energy Efficiency Orchestrator is recommended to subscribe and query configuration and performance data of VNF instances of core network via reference point EEM-RP2.

10 Procedures of energy efficiency management of virtual resources in IMT-2020 networks and beyond

10.1 Procedure of capacity management for virtual machine

The figure 10-1 illustrates the procedure of capacity management for virtual machine, which avoids the waste of virtual machine resources in idle state.

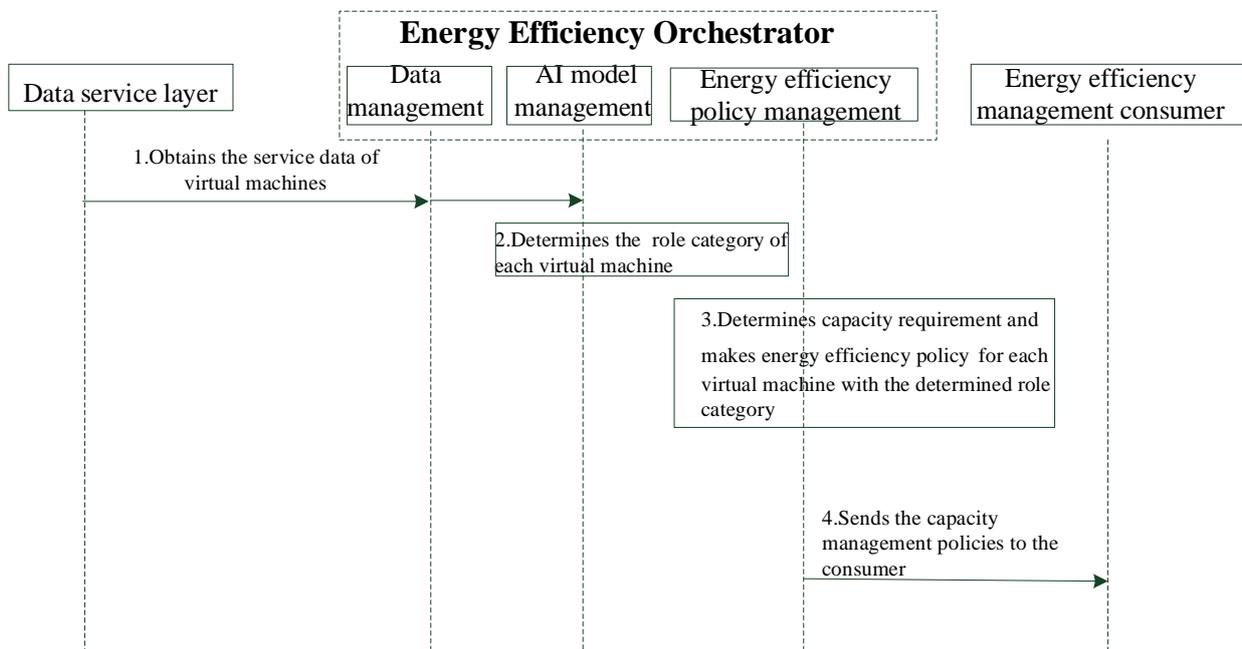


Figure 10-1 Procedure of capacity management for virtual machine

1. Energy Efficiency Orchestrator obtains the service data of each virtual machine in the cloud server from the data service layer, and the service data refers to configuration parameter information required for service execution.

2. The AI model management of Energy Efficiency Orchestrator uses the service data to train AI clustering models, and it determines the role category of each virtual machine according to the service data.

NOTE 1: Role categories indicate the service categories that the virtual machines execute, such as traffic service, disk service, memory service, CPU service, and etc.

NOTE 2: The input of clustering models is service data of virtual machines and the output of clustering models for virtual machines includes multiple clustering sets. For each cluster, the virtual machine in the cluster can be divided into at least two sub sets (such as a task subset and a non task subset) based on whether the virtual machine executes the service of the cluster set, and then role category of the virtual machine is determined based on sub sets it belongs.

3. The energy efficiency policy management of Energy Efficiency Orchestrator analyzes and determines the capacity requirements of each virtual machine according to the role categories, and

makes energy efficiency policies (e.g reducing CPU cores or memory size) of capacity management for each virtual machine with the determined role category.

NOTE 3:The priority list is pre-configured to avoid capacity scaling down for some virtual machines. If the role category of a virtual machine belongs to the priority list, then the virtual machine’s capacity resource can be adjusted but except scaling down. If the virtual machine does not belong to the priority list, its capacity resource can be scaled down.

4. Energy Efficiency Orchestrator sends the energy efficiency policies of capacity management for virtual machines to the consumer who subscribes/requests the services of energy efficiency analysis (e.g. cloud resource management system).

10.2 Procedure of on/off control for server nodes

The figure 10-2 illustrates the procedure of on/off control for server nodes in idle state.

NOTE: The server nodes represent the infrastructure that carry some of the IMT-2020 NFs, IMT-2020 network controllers, IMT-2020 management systems, IMT-2020 services, and etc.

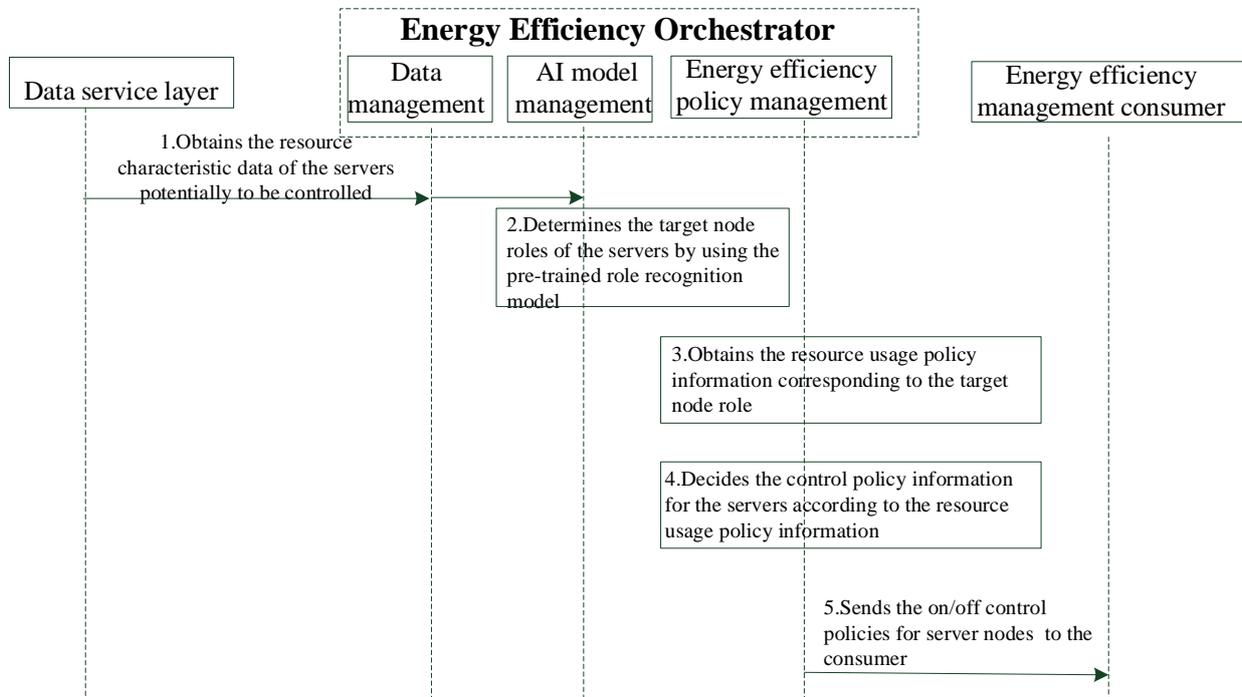


Figure 10-2 Procedure of on/off control for server nodes

1. Energy Efficiency Orchestrator obtains the resource characteristic data (e.g maximum/minimum/average CPU usage, maximum/minimum/average memory usage, maximum/minimum/average network traffic, etc) of the servers potentially to be controlled from the data service layer.

2. The AI model management of Energy Efficiency Orchestrator uses the pre-trained role recognition model to process the characteristic data in order to determine the target node roles of the servers to be controlled,

NOTE 1: Role recognition model is pre-trained using the characteristic data in the collection period and the node role label which can be an identifier of a node role (e.g. standby node identifier, data node identifier, and etc).

3. The energy efficiency policy management of Energy Efficiency Orchestrator obtains the resource usage policy information corresponding to the target node role based on node information database. The resource usage policy information indicates the resource usage threshold when server nodes have on/off behavior.

NOTE 2: Node information database is built by the node role label and resource state information (e.g. CPU and memory resource usage) and configuration information of servers in the sampling period.

4. The energy efficiency policy management of Energy Efficiency Orchestrator decides the control policy information (e.g. switch control on to off) for the servers potentially to be controlled, according to the resource usage policy information corresponding to the target node role and the current resource state information.

NOTE 3: If the target node role belongs to a preset role (e.g. necessary task role) in the target cluster, control policy information of the server will be determined as keeping running state.

5. Energy Efficiency Orchestrator sends the energy efficiency policies of on/off control for server nodes to the consumer (e.g. bare metal servers management system).

10.3 Procedure of virtual machine migration based on load balancing

The figure 10-3 illustrates the procedure of virtual machine migration based on load balancing, which ensures the dynamic load balance in the cluster, and improves the overall utilization rate.

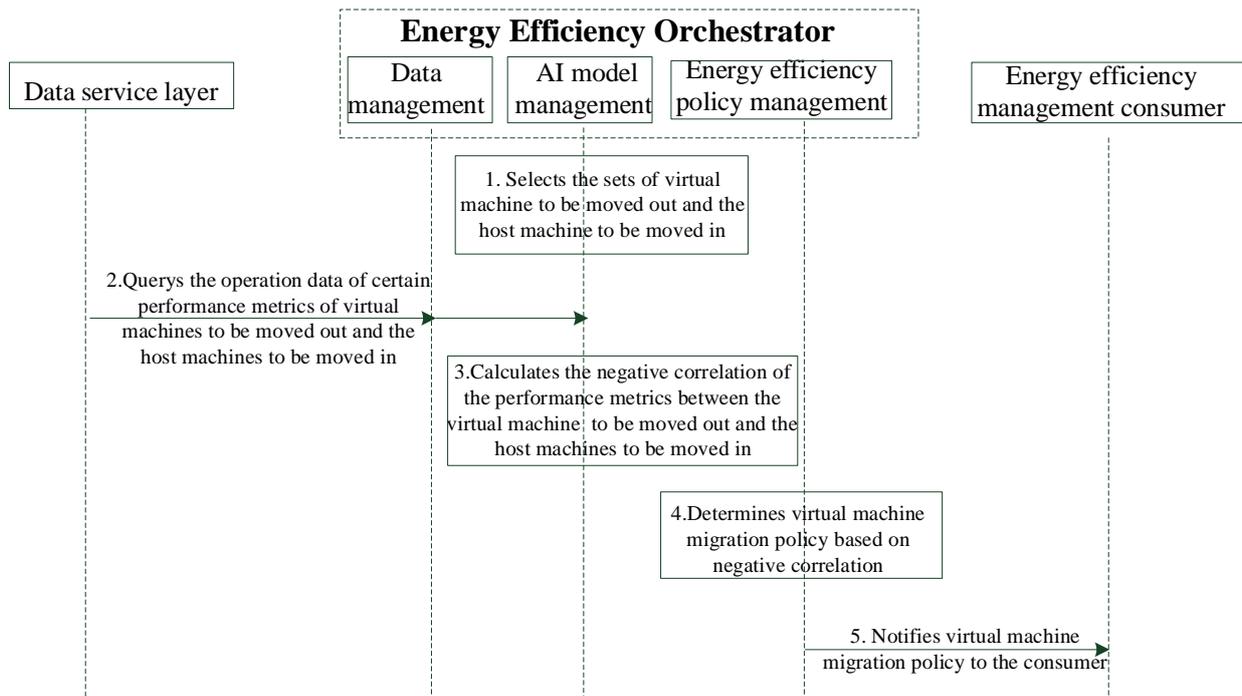


Figure 10-3 Procedure of virtual machine migration based on load balancing

1. Energy Efficiency Orchestrator selects the sets of virtual machines to be moved out and the host machines to be moved in from the host cluster. Energy Efficiency Orchestrator calculates the number of hosts to be moved out based on the configuration of host and virtual machine resource, and EEO selects the hosts according to the disequilibrium of CPU and memory resource usage of the host and resource requirement priority information, thus all the virtual machines on these selected hosts needs to be moved out. The set of the host machine to be moved in is selected to meet the resource configuration requirement of the virtual machine mentioned above.

NOTE 1: Step1 is triggered by EEO itself based on pre-configured polices for load balancing.

2. Energy Efficiency Orchestrator queries the operation data of certain performance metrics (e.g. CPU and memory usage ratio) during collection periods of virtual machines to be moved out and the host machines to be moved in from the data service layer.

3. Energy Efficiency Orchestrator calculates the negative correlation between the virtual machine to be moved out and the host machines to be moved in according to the respective operation data of the performance metrics, and negative correlation calculation could focus on one main performance metric if this type of resource of virtual machine is scarce.

NOTE 2: Energy Efficiency Orchestrator builds respective time series based on the respective operation data of the virtual machine to be moved out and the host machines to be moved in, and then calculates the negative correlation.

NOTE 3: The length and interval of the time series can be changed based on the actual situation, the length of the time series can be weeks, months, days, intervals of the time series can be 1, 5, 15 minutes, etc

4. Energy Efficiency Orchestrator determines virtual machine migration policies, includes selecting the virtual machine which has the highest priority from the set of virtual machines to be moved out and then migrating it into the potential host machine which can meet the resource requirement and has the highest negative correlation.

5. Energy Efficiency Orchestrator notifies the consumer who subscribes the load balancing analysis and energy-saving management service.

10.4 Procedure of energy efficiency management for VNF instances

The figure 10-4 illustrates the procedure of energy efficiency management for VNF instances if they meet the energy-saving requirements, the energy management will be triggered to release the resources in idle state and low usage state.

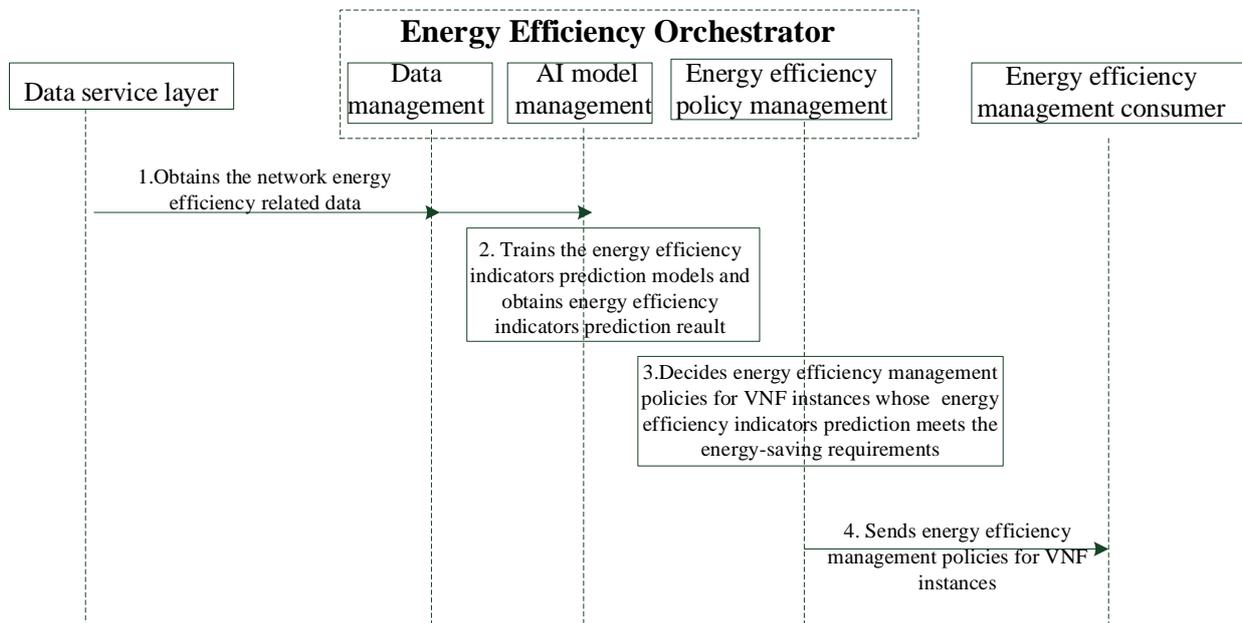


Figure 10-4 Procedure of energy efficiency management for VNF instances

1. Energy Efficiency Orchestrator obtains the network energy efficiency related data, which includes dynamic operation data(e.g. energy cost, VNF instance throughput, VNF instance resource usage data,etc) and static data(e.g. configuration information) from the data service layer.

2.The AI model management of Energy Efficiency Orchestrator trains the energy efficiency indicators prediction models (e.g. neural network models) and obtains energy efficiency indicators prediction result.

3.The energy efficiency policy management of energy efficiency orchestrator decides energy efficiency management policies for VNF instances, by deactivating or terminating the VNF instances whose energy efficiency indicators prediction reach the energy-saving threshold.

4. Energy Efficiency Orchestrator sends energy efficiency management policies for VNF instances to the consumer (e.g MANO system).

11 Security consideration

This Recommendation specifies AI-assisted energy efficiency management of virtual resources in IMT-2020 networks and beyond. It is assumed that security considerations in general are based on the security of IMT-2020 network management and orchestration [ITU-T Y.3111] and IMT-2020 network slicing with AI-assisted analysis [ITU-T Y.3156]. Specifically, the major security requirements for energy efficiency management of virtual resources in IMT-2020 networks and beyond are listed in the following:

[REQ-SM-1] REEM is required to provide security protection and privacy preservation for data sets, model training, model aggregation and ML services.

[REQ-SM-2] REEM is required to support the authorization and authentication of consumers to invoke the energy-saving services.

Bibliography

- [b-ITU-T L.1390] Recommendation ITU-T L.1390(2022), *Energy saving technologies and best practices for 5G radio access network (RAN) equipment*.
- [b-ITU-T M.3381] Recommendation ITU-T M.3381 (2022), *Requirements for energy saving management of 5G radio access network (RAN) systems with artificial intelligence (AI)*.
- [b-Lorincz] Lorincz J , Capone A , Wu J (2019), *Greener, Energy-Efficient and Sustainable Networks: State-Of-The-Art and New Trends[J]*, Sensors, 19(22):4864-.<https://doi.org/10.3390/s19224864>
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