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SERIES L: ENVIRONMENT AND ICTS, CLIMATE CHANGE, E-WASTE, ENERGY EFFICIENCY; CONSTRUCTION, INSTALLATION AND PROTECTION OF CABLES AND OTHER ELEMENTS OF OUTSIDE PLANT

Functional requirements and framework of green data centre energy-saving management system

Recommendation ITU-T L.1303

International Telecommunication Union

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ENVIRONMENT AND ICTS, CLIMATE CHANGE, E-WASTE, ENERGY EFFICIENCY; CONSTRUCTION, INSTALLATION AND PROTECTION OF CABLES AND OTHER ELEMENTS OF OUTSIDE PLANT

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Recommendation ITU-T L.1303

Functional requirements and framework of green data centre energy-saving management system

Summary

Recommendation ITU-T L.1303 describes the functional requirements and framework of an energy-saving management system for green data centres. Functional requirements of energy-saving management include requirements for measuring energy consumption and environmental conditions data, collecting and storing data, reporting data and conducting energy-saving. The energy-saving management system consists of the following functional blocks: data collecting block; data storing block; data process and analysis block; external system interfacing block; user interface block; control block. The operational flow of the energy-saving management system is also included.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T L.1303	2018-11-13	5	11.1002/1000/13722

Keywords

Energy efficiency, energy-saving management system, green data centre.

* To access the Recommendation, type the URL http://handle.itu.int/ in the address field of your web browser, followed by the Recommendation's unique ID. For example, http://handle.itu.int/11.1002/1000/11830-en.

FOREWORD

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Functional requirements and framework of green data centre energy-saving management system

1 Scope

This Recommendation describes the functional requirements and framework of a green data centres energy-saving management system. The energy-saving will be achieved by increasing the energy efficiency of data centres.

The scope of this Recommendation includes:

– Characteristics and operation flow of a green data centre energy-saving management system

– Functionality requirements of a green data centre energy-saving management system (e.g., energy consumption data acquisition; energy consumption data analysis and chart show; energy consumption data query; energy consumption monitoring and early warning.)

– Framework of a green data centre energy-saving management system including functional blocks such as data collecting, data storing, data process and analysis, external system interface, user interface and control block.

Sensor definition, interface and protocol are not included in the scope of this Recommendation.

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 L.1300] Recommendation ITU-T L.1300 (2014), *Best practices for green data centres.*

[ITU-T L.1301] Recommendation ITU-T L.1301 (2015), *Minimum data set and communication interface requirements for data centre energy management.*

[ITU-T L.1302] Recommendation ITU-T L.1302 (2015), *Assessment of energy efficiency on infrastructure in data centres and telecom centres.*

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following term defined elsewhere:

3.1.1 energy efficiency (EE): [b-ITU-T L.1330] The relation between the useful output and energy/power consumption.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 collecting gateway: A system, which periodically collects the measured data from the measurement devices and relays them to the energy-saving management system (ESMS). The

collecting gateway could be a standalone system or an internal function block (data collecting block) in the ESMS.

3.2.2 energy-saving management system (ESMS): A system for monitoring and managing energy consumption and environmental condition data in green data centres for energy saving purposes.

3.2.3 measurement devices: Devices to measure energy consumption or environmental conditions data, which can be sensors, meters and appropriate software programs.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

BMS Building Management System

CMS Cable Management System

CPU Central Processing Unit

CRAC Computer Room Air Conditioner

DCIE Data Centre Infrastructure Efficiency

ESMS Energy-Saving Management System

FMS Facility Management System

ICT Information and Communications Technology

ICTMS ICT Management System

ID Identifier

IPC Inter-Process Communication

ITEE IT Equipment Efficiency

KPI Key Performance Indicator

MIS Management Information System

NMS Network Management System

PDU Power Distribution Unit

PUE Power Usage Effectiveness

UPS Uninterruptible Power Supply

WUE Water Usage Effectiveness

5 Conventions

None.

6 Functional requirements for energy-saving management systems in data centres

6.1 Requirements for measuring energy consumption and environmental condition

Energy-saving management systems (ESMS) should measure energy consumption in facilities, and environmental conditions data (e.g., ambient temperature and humidity). The measured data can be utilized to produce energy efficiency indicators and increase the energy efficiency in data centres. A representative key performance indicator, power usage effectiveness (PUE), needs periodically measured power consumption of facility equipment and ICT equipment. Ambient temperature and

humidity in each zone in a data centre should be measured to save energy consumption and to control the data centre environment. Measurement devices are necessary to measure power consumption, temperature, humidity, etc. The requirements for measuring energy consumption and environmental conditions data are defined in Table 1. Each item is categorized as mandatory or optional according to its importance.

Table 1 – Requirements for measuring energy consumption and environmental conditions data

Items	Description	Note
Measuring energy consumption in data centre	It is necessary to measure energy consumption in data centres. Energy is lost in power systems and distribution and consumed by cooling systems, lighting systems and ICT equipment. If the data centre shares the space with offices that are not related, it needs to measure energy consumption of offices which shall be discriminated from the whole data centre energy consumption. The data can be used to calculate performance indicators such as PUE. Measurement devices shall be installed at the measuring points defined in [ITU-T L.1302].	Mandatory
Measuring energy consumption of facility equipment	It is necessary to measure energy consumption of facility equipment such as UPS, PDU, cooling systems, computer room air conditioner (CRAC) and so on. Measurement devices shall be installed at the measuring points.	Mandatory
Measuring energy consumption of ICT equipment	It is necessary to measure energy consumption of ICT equipment. Measurement devices shall be installed at the measuring points.	Mandatory
Measuring environmental condition in each zone	It is necessary to measure environmental conditions data such as ambient temperature and humidity in each zone in the data centre. A measuring zone can be a room, a hot or cold containment aisle, a row of racks, or a server rack. Measurement devices such as temperature sensors, humidity sensors and smoke detection sensors shall be installed in measuring zones.	Mandatory
Measuring temperature and humidity at CRAC	It is necessary to measure temperature and humidity of supplying and returning fluid at the CRAC inlet and outlet. Measurement devices shall be installed at the measuring points.	Mandatory
Measuring energy consumption at the input of PDU	Measurement of energy consumption of ICT equipment shall be done at least at the input of PDU. Measurement devices shall be installed at the measuring points. NOTE – ICT equipment energy consumption also can be measured at rack level or equipment level.	Mandatory
Measuring operating information on ICT equipment	Operating information of ICT equipment such as CPU utilization, memory utilization, storage utilization, or network utilization needs to be measured. Software programs should be installed in the considered equipment.	Optional
Accuracy in measured data	Measured data accuracy shall be kept within a predetermined range defined in clause 7.1 of [ITU-T L.1302] as class I or in [b-ETSI ES 202 336-12] as class II.	Mandatory

6.2 Requirements for collecting and storing data

Measured data for energy consumption and environmental conditions should be collected and stored into the ESMS. A measurement period and collection period may or may not be equal. Depending

on the application of the measured data and the design of databases, the way of storing data will be decided. Requirements for collecting and storing measured data are presented in Table 2.

Table 2 – Requirements for collecting and storing data

Requirements	Description	Note
Establishing a collection network	Data network shall be established to reliably collect data from measurement devices.	Mandatory
Consistent data format	Measured data shall be collected and stored in a consistent format to efficiently control the energy management system. All collected data shall be in an identical format even though they are measured using different measurement devices.	Mandatory
A proper collection period	Proper measurement collection period shall be defined to improve data centres energy efficiency. For example, changes in ambient temperature and humidity can affect the operation of cooling systems and change data centre efficiency, therefore, a measurement collection period of them should be short, less than 15min.	Mandatory
No errors or loss during data collection	During collecting data from measurement devices and storing them into the ESMS errors in data or data losses are not allowable. Corrupted data should be re-collected or replaced by an average value of the previous and the next data.	Mandatory

6.3 Requirements for reporting data

Stored data in the ESMS should be reported in a specific format. If the data includes abnormal conditions in data centres, it should be reported to managers as an event or an alarm through various methods. A manager who receives events or alarms should conduct proper processes to operate the data centre to return a normal condition. Table 3 presents requirements for reporting data to managers.

Table 3 – Requirements for reporting data

Requirements	Description	Note
Providing operating information on facility equipment	Operating information on facility equipment shall be provided via user interfaces defined in clause 7.	Mandatory
Providing operating information on computing room or building	Operating information on computer room or building shall be provided via user interfaces defined in clause 7.	Mandatory
Providing operating information on ICT equipment	Operating information on ICT equipment should be provided via user interfaces defined in clause 7.	Optional
Providing KPIs	ESMS should produce key performance indicators (KPIs) based on the collected data and provide them via user interfaces defined in clause 7.	Optional
Alarm	In case of exceeding the predetermined limits for measured data, the ESMS shall notify managers via one of the user interfaces defined in clause 7.	Mandatory
Printing a report	Collected data is possible to print as a formal report.	Optional

6.4 Requirements for conducting energy-saving

A data centre manager may establish energy-saving policy based on the energy-related data provided from the ESMS in order to save energy. The ESMS is recommended to provide the function to conduct the energy saving policy by manipulating facility and ICT equipment in the data centre as shown in Table 4.

Table 4 – Requirements for conducting energy saving

Requirements	Description	Note
Controlling facility equipment for energy saving	It is necessary to control facility equipment for energy saving. For example, it can change the fan speed of air conditioner based on the environmental conditions.	Mandatory
Controlling ICT equipment for energy saving	It is necessary to control ICT equipment for energy saving. For example, it can change CPU clock speed or migrate virtual machines on a server with low utilization to another server for server consolidation.	Optional

7 Framework of ESMS

This clause presents a framework of ESMS to implement functional requirements of the system described in clause 6. The ESMS consists of following blocks:

1) data collecting block;
2) data storing block;
3) data process and analysis block;
4) external system interfacing block;
5) user interface block;
6) control block.

Figure 1 illustrates the overall block diagram of the ESMS.

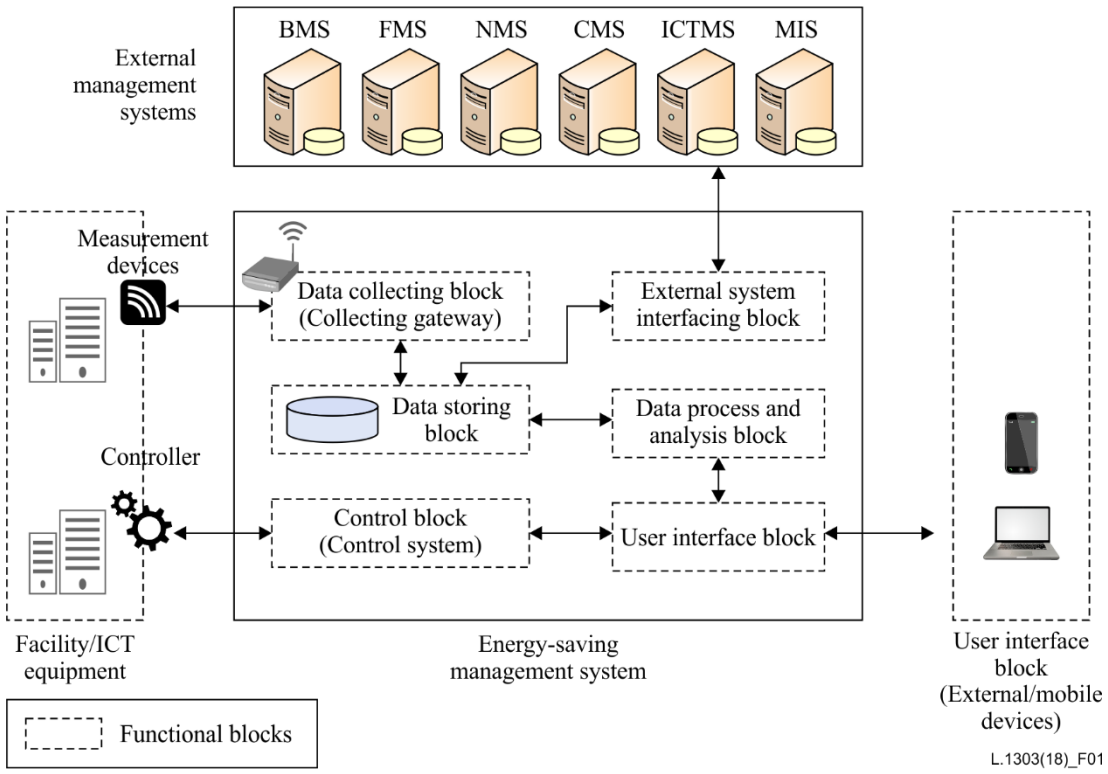


Figure 1 – Functional block diagram of the ESMS

7.1 Data collecting block

The data collecting block performs to collect the measured data related to the energy consumed and environmental conditions in the data centre. The energy consumption can be measured by a measuring device or agent embedded in the equipment. Environmental conditions such as ambient temperate or humidity can be measured by sensors attached on equipment or walls in the building. Resource utilization of ICT equipment can be measured in an agent software program embedded in the equipment. The measured data from the measurement devices are collected to the ESMS through a collecting internal data network or a separate collecting network. There could be a collecting gateway, which acts as a broker to collect the measured data from the measurement devices. The collecting frequency of measured data depends on the importance of the data and their applications. Table 5 presents a functional module of the data collecting block in the ESMS.

Table 5 – Functional modules in the data collecting block

Functional modules	Description	Note
Data collection	This module collects the energy consumption and environmental conditions data from the measurement devices in the data centre. A collecting gateway acts as a broker, collects the data from the measurement devices and relays them to the ESMS. A collecting gateway could be a standalone system or an internal function block in the ESMS. If there is standalone collecting gateway, the ESMS can obtain the data through the interfacing blocks with the gateway as described in Table 2. The collection frequency may vary depending on the characteristics, importance and the applications of the data. The measured data should be collected in specific formats, which are suitable for building the database.	Mandatory

7.2 Data storing block

Based on the collected data, the ESMS builds databases for the applications. The ESMS may build the database for the energy consumption and environmental conditions data, the database of ICT resource utilization, alarms and events, facility equipment, ICT equipment, building management, network management and cable management. Table 6 presents functional modules for a storing block of the ESMS. Each functional module is indicated as mandatory or optional in Table 6.

Table 6 – Functional modules in the data storing block

Functional modules	Description	Note
Database for energy consumption and environmental condition	The database on the energy consumed and environmental conditions in the data centre shall be built and managed. The database record for the energy consumed and environmental conditions may include the measuring point (equipment ID or measurement device ID), location, the specification of equipment, the energy consumption, temperature, humidity and the measurement time.	Mandatory
Database for ICT resource utilization	The database record may include equipment ID, location, the specification of equipment, the utilization of resources such as CPU, memory, and the measurement time. This database may be built to interwork with an ICT equipment management system (ICTMS).	Optional
Database for alarms and events	This database should record the issued alarms and events when the energy consumed, resource utilization, temperature or humidity exceeds their pre-set threshold values. The database record may include items (the energy consumed, the utilization, temperature, or humidity), the measuring point (device ID or equipment ID), the measured value, the threshold, alarm or events issuing time, etc.	Optional
Database for facility management	The database on facility equipment shall be built and managed. The database records may include location, year, the specification of equipment, the manager etc. The facility equipment may include UPS, up to 400VDC system, backup generators, power distribution system, cooling system, CRAC, etc. If the data centre operates a facility management system (FMS), the database on the facility equipment can be obtained from the FMS.	Mandatory
Database for ICT equipment management	It builds and manages the database on servers and storages. The database record may include location, year, the specification of equipment, the manager etc. If the data centre operates an ICT equipment management system (ICTMS), the database on the ICT equipment management can be obtained from the ICTMS.	Optional
Database for building management	It builds and manages the database on building management on building space, security, firefighting equipment, light etc. If the data centre operates a building management system (BMS), the database on the building management can be obtained from the BMS.	Optional

Table 6 – Functional modules in the data storing block

Functional modules	Description	Note
Database for network configuration	It builds and manages the database on the data centre network configuration and the network equipment such as switches and routers. The database may contain the input and output port ID, bandwidth, input and output traffic, the equipment ID, location, the specification of the equipment etc. If the data centre operates a network management system (NMS), the database on the network configuration can be obtained from the NMS.	Optional
Database for cable management	It builds and manages the database on the network cable management. If the data centre operates a cable management system (CMS), the database on the cable management can be obtained from the CMS.	Optional

7.3 Data process and analysis block

From the energy-related data managed in the ESMS, a data centre manager can identify which parts consume energy inefficiently. It is necessary to process and analyse the stored data in the databases for providing the useful information for the data centre manager who plans and executes the energy-saving policy.

The data process and analysis block provides long-term and short-term statistics, the trend analysis and prediction of the consumed energy, and the key performance indicators such as PUE. Table 7 presents the functional modules of the data process and analysis block.

Table 7 – Functional modules in the data process and analysis block

Functional modules	Description	Note
Calculating key performance indicators	This module shall produce PUE to evaluate the energy efficiency of green data centres.	Mandatory
	Data centre infrastructure efficiency (DCIE), water usage effectiveness (WUE), IT equipment efficiency (ITEE), etc. should be provided.	Optional
Statistics	This module provides statistics on the consumed energy in facility equipment and ICT equipment, resource utilization of ICT equipment, and environmental condition such as temperature or humidity. Various statistics on the data may be provided in the average value, the minimum value, the maximum value, or the accumulated value in the period of hour, day, week, month, and year.	Optional
Prediction	This module predicts the future trends of energy-related data based on time-series analysis and statistics models.	Optional

7.4 External system interfacing block

The ESMS may have various interfaces with other external management systems in the data centre in order to collect energy-related data and operational information of facility and ICT equipment, which can be utilized to manage the consumed energy and KPIs. Table 8 presents functional modules in the external system interfacing block of the ESMS. The external systems can be stand alone or be parts of the ESMS. If the external systems are the parts of the ESMS, the interface module is not necessary. Instead, the function on inter-process communication (IPC) inside the ESMS should be provided.

Table 8 – Functional modules in the external system interfacing block

Functional modules	Description	Note
Interface with an energy management system	This module provides an interface with an energy management system, which collects and stores the energy consumed in the data centre. The energy management system manages the energy consumption per each equipment, rack, room, section or area, and the whole data centre. The system can be implemented in a type of gateway to collect the measured data from the measurement devices. Or, it can be a part of the ESMS. If the latter case, the interface module is not necessary. Instead, the function on inter-process communication (IPC) inside the management system should be provided.	Mandatory
Interface with a facility management system	This module provides an interface with a facility management system (FMS) to collect information on facility equipment such as UPS, power feeding systems, cooling systems, etc. The FMS can be a stand-alone system or a part of the ESMS.	Mandatory
Interface with an ICT performance monitoring systems	Server consolidations should be provided by virtualization technology in order to save the energy. For the server migration and integration, it is necessary to monitor the resource utilization of ICT equipment. While the server integration based on the resource utilization can improve the energy efficiency in ICT equipment, higher energy efficiency can be achieved if the server integration or relocation is performed in consideration of power density, power capacity and cooling capacity in racks, containments, rooms, zones and areas.	Optional
Interface with a cable management system	Network cables among various network equipment and power cables occupy many spaces so that they may obstruct cooled and hot air flows. Cable configuration information obtained from a cable management system (CMS) should be applied to identify problems that cause hot spots and hence energy inefficiency. The CMS can be applied to configure an efficient data centre network cooperating with an NMS.	Optional
Interface with a building management system	This module functions to collect the information of facility in the building from BMS. Besides energy-related data and equipment, it would be beneficial to manage facility information in the data centre building in order to operate the data centre in an energy efficient way. Information on space, security, light, firefighting equipment, etc. can be obtained from a building management system (BMS).	Optional
Interface with a management information system	Top level managers or board of directors, who own or manage a data centre, could be able to monitor energy-related data through a management information system (MIS), which overall manages finance, accounting, human resources, inventory of the data centre or the parent company. ESMS should provide energy-related data to the MIS.	Optional
Interface with control systems	This module functions to send commands to control facility equipment, ICT equipment and other management systems in the data centre to save the energy for executing the energy saving policy.	Optional

Table 8 – Functional modules in the external system interfacing block

Functional modules	Description	Note
Interface with a network management system	This module collects the information on the data centre network, which covers switches and routers including ports information, network configuration, etc. Network traffic data on ports of network equipment can be provided to the ESMS through the NMS. Network information can be used to establish and execute an energy-saving policy that includes virtual machine allocation, server migration or integration based on the traffic data among virtual servers or physical servers. By interworking the cable management system and the NMS, the data centre network can be configured in an energy-efficient way.	Optional

7.5 User interface block

A data centre manager should be able to retrieve the information related to the energy consumed and other statistics not only to monitor the operational status of the data centre but also to establish an energy-saving policy. The manager can access the ESMS through a dashboard-style or limited screen size such as on mobile devices. The ESMS is able to set up the different levels of authority to look up the query results.

Table 9 presents the functional modules in the user interface of the ESMS. Each functional module can be implemented as mandatory or optional depending on the operational status of the data centre.

Table 9 – Functional modules in the user interface block

Functional modules	Description	Note
User interface for desktop PCs (dash board)	The dashboard-style user interface for desktop PCs shall provide energy-related facilities and processed data to users. The data that users can query and monitor through the UI is as follows. − Facility equipment, ICT equipment, building information • Equipment ID, location, specification, manager, etc. − The energy consumed, temperature, humidity − The ICT resource utilization (CPU, memory, VMs, storage, etc. − KPIs − Issued events or alarms − Inquiry options • Inquiry target: equipment, rack, room, section or area, the whole data centre • Statistics: the average value, the minimum value, the maximum value, the accumulated value • Inquiry period: real-time(or near real-time such as minutes), hours, days, weeks, months, years	Mandatory (Inquiry options can vary)
User interface for mobile devices	Users may access the ESMS through mobile devices when they are moving or outside the data centre. This module forms the user interface suitable for mobile devices. This can be implemented as a mobile application or a web application. Basically, provided information through the UI would be the same as the dashboard-style UI, but the screen layout may vary depending on the	Optional

Table 9 – Functional modules in the user interface block

Functional modules	Description	Note
	operating systems or environment of the mobile devices.	
Inquiry authority	The ESMS may display the inquiry results differently according to the level of the user's managing authority. Inquiry authority can be classified by a manager and a general user. Another level of authority may be added. A general user may have the authority to query the pre-set inquiry options. A manager may have the authority to query with full inquiry options. In addition, a manager may have the authority to issue commands to control energy systems or other equipment inside the data centre in order to execute the energy-saving policy.	Optional
Reporting	This module prints a formatted report on the energy data. The report may contain facility and ICT equipment data, the energy consumed, the resource utilization of ICT, KPIs, the issued alarms or events and statistics that users can query to the ESMS.	Optional

7.6 Control block

When a data centre manager establishes an energy-saving policy to save energy consumption in the data centre, the manager may issue a command to control facility equipment or ICT equipment. Through a control block in the ESMS, the manager can conduct the energy-saving policy. The control system can be a standalone system or an internal control block in the ESMS.

Table 10 presents the functional modules in the control block.

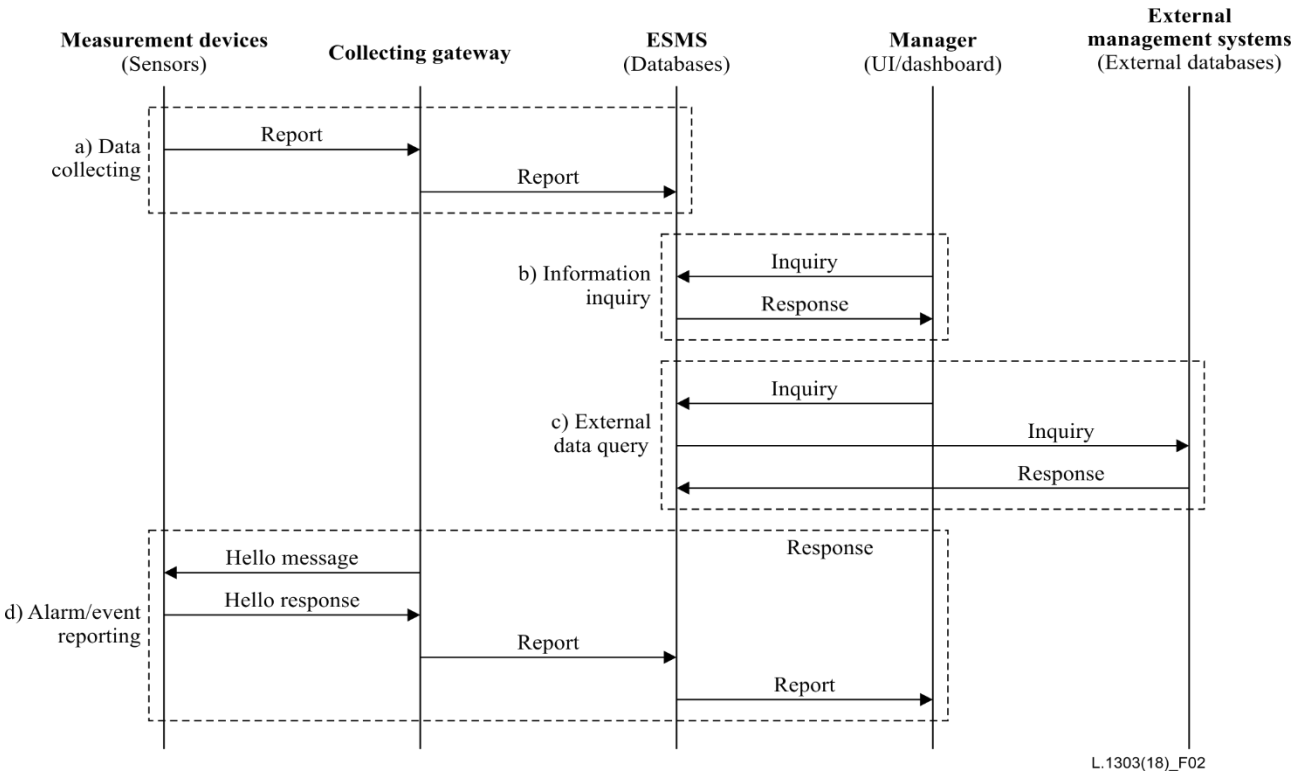
Table 10 – Functional modules in the control block

Functional modules	Description	Note
Equipment control	The purpose of the ESMS is to save energy consumption in a data centre. So, the ESMS may require a control function to manipulate the equipment in the data centre in order to conduct the energy saving policy. The control function should be implemented as a standalone system or an internal control block in the ESMS. Depending on the usage of the ESMS, the control function is optional. There are many different types of equipment to be controlled in a data centre, control commands issued from the ESMS should have a standardized format, which can be applied to the equipment in the data centre.	Optional

8 Operational flow of ESMS

This clause presents how the ESMS operates with its functional blocks. The ESMS first collects energy data in a data centre and stores them with specific format in databases. As illustrated in Figure 2, measurement devices periodically report the measured data to the ESMS. There could be a collecting gateway, which relays the measured data from the measurement devices to the ESMS. The collecting gateway can be implemented in an internal data collecting block in the ESMS. When the ESMS receives the measured data, it then stores the data with specific format in the related databases. When a data centre manager queries the energy data to the ESMS through a dashboard or another user interface, the ESMS provides them. For the information inquiry, ESMS may process and analyse the stored data to produce useful data such as PUE, statistics, long-term predictions. If

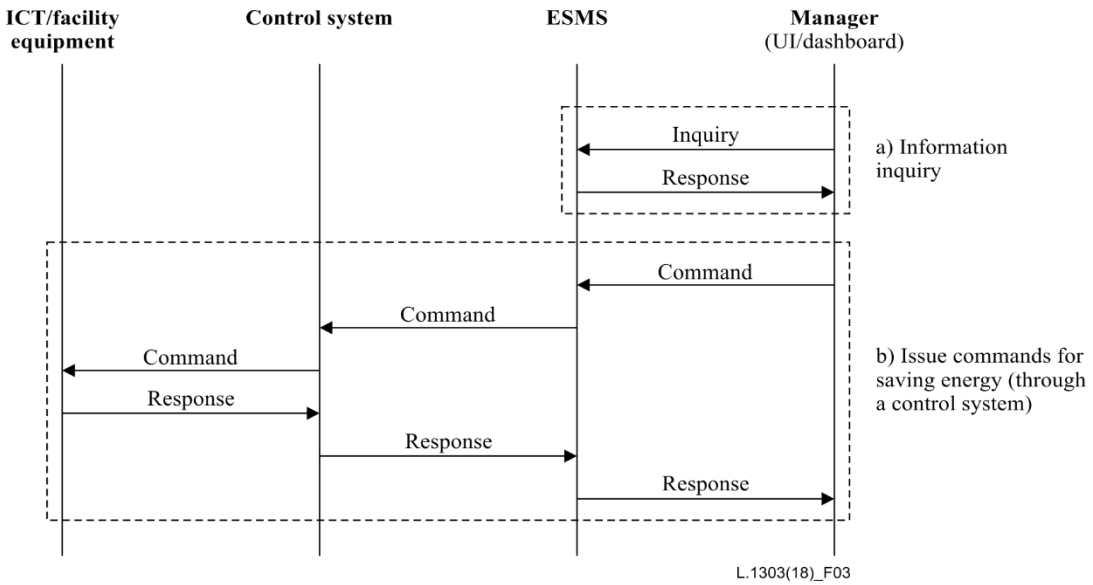
the inquiry needs data managed in external management systems, the ESMS then requests external management systems to provide the data from their databases. The collecting gateway periodically sends a "keep alive" message to the measurement devices to check that the device is operating normally. If the measuring device does not operate normally, the gateway issues an alarm to the ESMS.



NOTE – Functions between brackets at each level (sensors, databases, etc.) are the main functions considered for the operation flow.

Figure 2 – Operational flow for data collection and query

Data centre managers may control facilities in a data center in order to efficiently manage energy consumption. The energy-related data managed in the ESMS helps to identify where energy is consumed inefficiently within the data centre and to establish a policy to improve energy efficiency. As illustrated in Figure 3, a data centre manager gets energy information or alarms from the ESMS. If there is a need to control a facility, the manager issues commands to control them through a control system. The result of the commands is reported from the facility to the ESMS through the control system.



NOTE – Function between brackets (UI/dashboard) is the main function considered for the operation flow.

Figure 3 – Operational flow for energy-saving control

Bibliography

[b-ITU-T L.1330] Recommendation ITU-T L.1330 (2015), *Energy efficiency measurement and metrics for telecommunication networks.*

[b-ETSI ES 202 336-12] ETSI ES 202 336-12 V1.1.1 (2015), *Environmental Engineering (EE); Monitoring and control interface for infrastructure equipment (power, cooling and building environment systems used in telecommunication networks); Part 12: ICT equipment power, energy and environmental parameters monitoring information model.*

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