

International Telecommunication Union

ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

Y.3022

(08/2014)

SERIES Y: GLOBAL INFORMATION
INFRASTRUCTURE, INTERNET PROTOCOL ASPECTS
AND NEXT-GENERATION NETWORKS

Future networks

Measuring energy in networks

Recommendation ITU-T Y.3022



Documents
International
Telecommunication
Union
Document Sharing Hub

ITU-T Y-SERIES RECOMMENDATIONS

GLOBAL INFORMATION INFRASTRUCTURE, INTERNET PROTOCOL ASPECTS AND NEXT-GENERATION NETWORKS

GLOBAL INFORMATION INFRASTRUCTURE

General	Y.100–Y.199
Services, applications and middleware	Y.200–Y.299
Network aspects	Y.300–Y.399
Interfaces and protocols	Y.400–Y.499
Numbering, addressing and naming	Y.500–Y.599
Operation, administration and maintenance	Y.600–Y.699
Security	Y.700–Y.799
Performances	Y.800–Y.899

INTERNET PROTOCOL ASPECTS

General	Y.1000–Y.1099
Services and applications	Y.1100–Y.1199
Architecture, access, network capabilities and resource management	Y.1200–Y.1299
Transport	Y.1300–Y.1399
Interworking	Y.1400–Y.1499
Quality of service and network performance	Y.1500–Y.1599
Signalling	Y.1600–Y.1699
Operation, administration and maintenance	Y.1700–Y.1799
Charging	Y.1800–Y.1899
IPTV over NGN	Y.1900–Y.1999

NEXT GENERATION NETWORKS

Frameworks and functional architecture models	Y.2000–Y.2099
Quality of Service and performance	Y.2100–Y.2199
Service aspects: Service capabilities and service architecture	Y.2200–Y.2249
Service aspects: Interoperability of services and networks in NGN	Y.2250–Y.2299
Enhancements to NGN	Y.2300–Y.2399
Network management	Y.2400–Y.2499
Network control architectures and protocols	Y.2500–Y.2599
Packet-based Networks	Y.2600–Y.2699
Security	Y.2700–Y.2799
Generalized mobility	Y.2800–Y.2899
Carrier grade open environment	Y.2900–Y.2999

FUTURE NETWORKS

Y.3000–Y.3499

CLOUD COMPUTING

Y.3500–Y.3999

For further details, please refer to the list of ITU-T Recommendations.

Recommendation ITU-T Y.3022

Measuring energy in networks

Summary

Recommendation ITU-T Y.3022 describes the measurement of energy in networks and identifies the requirements for energy measurement. Based on this, a reference model, functional architecture, energy efficiency metrics and energy measurement methods are defined. To aid better understanding of energy efficiency metrics, relevant detailed equations are described in the appendices.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T Y.3022	2013-08-13	13	11.1002/1000/11976
2.0	ITU-T Y.3022	2014-08-13	13	11.1002/1000/12208

Keywords

Energy efficiency metrics, energy measurement.

* 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

The International Telecommunication Union (ITU) is the United Nations specialized agency in the field of telecommunications, information and communication technologies (ICTs). The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of ITU. ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

NOTE

In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

Compliance with this Recommendation is voluntary. However, the Recommendation may contain certain mandatory provisions (to ensure, e.g., interoperability or applicability) and compliance with the Recommendation is achieved when all of these mandatory provisions are met. The words "shall" or some other obligatory language such as "must" and the negative equivalents are used to express requirements. The use of such words does not suggest that compliance with the Recommendation is required of any party.

INTELLECTUAL PROPERTY RIGHTS

ITU draws attention to the possibility that the practice or implementation of this Recommendation may involve the use of a claimed Intellectual Property Right. ITU takes no position concerning the evidence, validity or applicability of claimed Intellectual Property Rights, whether asserted by ITU members or others outside of the Recommendation development process.

As of the date of approval of this Recommendation, ITU had not received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementers are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database at <http://www.itu.int/ITU-T/ipr/>.

© ITU 2014

All rights reserved. No part of this publication may be reproduced, by any means whatsoever, without the prior written permission of ITU.

Table of Contents

	Page
1 Scope	1
2 References.....	1
3 Definitions	2
3.1 Terms defined elsewhere	2
3.2 Terms defined in this Recommendation.....	2
4 Abbreviations and acronyms	2
5 Conventions	3
6 Overview of measuring energy consumption in networks	3
7 Requirements for measuring energy consumption in networks	4
8 Reference model and functional architecture for network energy consumption measurement	5
8.1 Reference model for network energy consumption measurement	5
8.2 Functional architecture for measuring energy consumption in networks	5
9 Energy efficiency metrics	7
10 Energy consumption measurement methods	8
10.1 Measurement methods at an interface	8
10.2 Measurement methods at a node	9
10.3 Measurement methods at a server	10
10.4 Measurement methods at a network	11
11 Security considerations and requirements	11
Appendix I – Calculation process for energy consumption at an interface	12
I.1 Switch	12
I.2 Router	13
Appendix II – Calculation process for energy consumption at a node	14
II.1 Energy consumption for wired nodes.....	14
II.2 Energy consumption for wireless nodes.....	17
Appendix III – Calculation process for energy consumption at a server.....	21
Appendix IV – Calculation process for energy consumption at a network	22
IV.1 Energy consumption of TDM-PON	22
Appendix V – Energy management levels on restricted electricity supply	25
Appendix VI – Energy consumption in relation to functional operations	26
Appendix VII – Energy efficiency rating for network equipment.....	27
Appendix VIII – Methods for adjusting the energy measurement time	28
VIII.1 Framework of adjusting the energy measurement time	28
VIII.2 Variation of traffic volume-based adjusting method for the energy measurement time T	28

	Page
VIII.3 Variation of energy consumption based method for adjusting the energy measurement time T	29
Bibliography.....	30

Recommendation ITU-T Y.3022

Measuring energy in networks

1 Scope

This Recommendation describes a reference model and methods for measuring energy in networks to reduce the operating expenditure (OPEX) of telecommunication network equipment. This Recommendation covers the following:

- requirements to measure energy consumption in networks;
- reference model and architecture to build an energy measurement framework;
- energy efficiency metrics of network elements based on a reference model;
- energy consumption measurement methods based on functional architecture.

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 G.8013]	Recommendation ITU-T G.8013/Y.1731 (2013), <i>OAM functions and mechanisms for Ethernet based networks</i> .
[ITU-T L.1310]	Recommendation ITU-T L.1310 (2014), <i>Energy efficiency metrics and measurement methods for telecommunication equipment</i> .
[ITU-T X.805]	Recommendation ITU-T X.805 (2003), <i>Security architecture for systems providing end-to-end communications</i> .
[ITU-T Y.2701]	Recommendation ITU-T Y.2701 (2007), <i>Security requirements for NGN release 1</i> .
[ITU-T Y.3021]	Recommendation ITU-T Y.3021 (2012), <i>Framework of energy saving for future networks</i> .
[ATIS-0600015.03.2009]	ATIS-0600015.03.2009, <i>Energy Efficiency for Telecommunications Equipment: Methodology for Measurement and Reporting for Router and Ethernet Switch Products</i> .
[ETSI ES 203 215]	ETSI ES 203 215 V1.2.1 (2011), <i>Environmental Engineering (EE); Measurement Methods and Limits for Power Consumption in Broadband Telecommunication Networks Equipment</i> .
[ETSI TS 102 706]	ETSI TS 102 706 V1.2.1 (2011), <i>Environmental Engineering (EE); Measurement Method for Energy Efficiency of Wireless Access Network Equipment</i> .

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 network energy efficiency [ITU-T Y.3021]: Throughput of the network divided by the power consumed.

NOTE – It is usually expressed in bps/W.

3.1.2 energy efficiency metrics [ITU-T L.1310]: Ratio between the functional unit and the energy necessary to deliver the functional unit.

NOTE 1 – Functional unit is the amount of information transmitted.

NOTE 2 – It is usually expressed in bits/Joule.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 network energy profile: Energy consumption of network elements versus offered traffic load.

NOTE – Network elements include interfaces, nodes and servers in a network.

3.2.2 power efficiency metrics: Throughput per power calculated by network energy profile.

NOTE – It is usually expressed in bps/W.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

AC	Alternating Current
CDMA	Code Division Multiple Access
CPU	Central Processing Unit
DC	Direct Current
FFT	Fast Fourier Transform
GSM	Global System for Mobile communications
HPA	High Power Amplifier
ICT	Information and Communications Technology
IDC	Internet Data Centre
IFFT	Inverse Fast Fourier Transform
IP	Internet Protocol
LNA	Low Noise Amplifier
LTE	Long-Term Evolution
MSPP	Multi-Service Provisioning Platform
OAM	Operation, Administration and Maintenance
OLT	Optical Line Terminal
ONU	Optical Network Unit
OPEX	Operating Expenditure

OXC	Optical Cross-Connect
PC	Personal Computer
PON	Passive Optical Network
RF	Radio Frequency
RLDRAN	Reduced-Latency Dynamic Random access memory
RN	Remote Node
RRH	Remote Radio Head
RSOA	Reflective Semiconductor Optical Amplifier
TCAM	Ternary Content-Addressable Memory
TDM	Time Division Multiplexing
TDM-PON	Time Division Multiplexing – Passive Optical Network
UMTS	Universal Mobile Telecommunications System
WDM-PON	Wavelength Division Multiplexing – Passive Optical Network

5 Conventions

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 of measuring energy consumption in networks

In response to the demands imposed by climate change, telecommunication networks should reduce energy consumption by utilizing energy saving technologies, see [ITU-T Y.3021]. When considering network energy consumption, network energy efficiency is an important factor. In order to calculate network energy efficiency, the total of transmitted data bits is divided by the energy consumption of the network over a specific time period. The network energy efficiency is measured and then calculated at interfaces, nodes, servers and networks as follows:

- Energy measurement at interfaces: The interface is the module of network equipment that enables communication via various mediums such as copper, optical fibres and air. The measurement of the energy consumption of interfaces is affected by various conditions including traffic load, interface state and packet size.
- Energy measurement at nodes: Nodes operate as switches or routers to exchange data in a network. Energy measurement at the node includes energy measurement at the interfaces and at the non-interfaces. The power consumption at non-interfaces such as fans, central processing units (CPUs) and alternating current (AC) to direct current (DC) converters is generally included in the measurement of energy consumption at the nodes. Depending on the power consumption of the non-interface elements within the node, energy consumption of the node varies according to the manufacturer's product characteristics.

NOTE 1 – Routers equipped with different AC-DC power supply converters can cause the power consumption at the node to vary.

NOTE 2 – For example, the clock rate of a CPU can be controlled at a lower traffic condition to save energy [ITU-T Y.3021].

- Energy measurement at servers: The energy consumption at a server is affected by equipment density and inter-operating relationships. In an Internet data centre (IDC), there are generally numerous air conditioners and dehumidifiers that enable large numbers of servers to operate normally. These external devices operating next to servers and

controlling temperature and humidity indirectly induce additional energy consumption in networks. Energy measurement at the server takes into account both energy consumption from the network equipment such as personal computer (PC)-type or rack-type servers and the non-network equipment such as air conditioners or humidifiers. The energy measurement for network equipment at the server considers the processing power required to generate service traffic as well as the server interfaces.

- Energy measurement at the network: A network is comprised of sets of nodes and servers with interfaces. Energy measurement for networks includes the energy consumption of nodes and servers with interfaces and non-network equipment.

7 Requirements for measuring energy consumption in networks

The following are high-level requirements for network energy consumption measurement:

- It is recommended for network energy consumption measurement to measure energy consumption according to traffic load, which is dependent on interface, node and server states.
- It is recommended for network energy consumption measurement to include external devices such as air-conditioning devices operating next to network equipment as sources of energy consumption.
- It is recommended for network energy consumption measurement to include measurement time and packet size with protocols in [b-IETF RFC 1944].
- It is recommended for network energy consumption measurement to include the effects of the load distribution of routing protocols which significantly impact energy consumption.
- It is recommended for network energy consumption measurement to use all measurement functional entities to gather information on all nodes and servers in the network.
- It is recommended for network energy consumption measurement to store and manage information related to network energy profiles in a database.
- It is recommended that network energy consumption measurement be done several times in order to reduce tolerance.

8 Reference model and functional architecture for network energy consumption measurement

8.1 Reference model for network energy consumption measurement

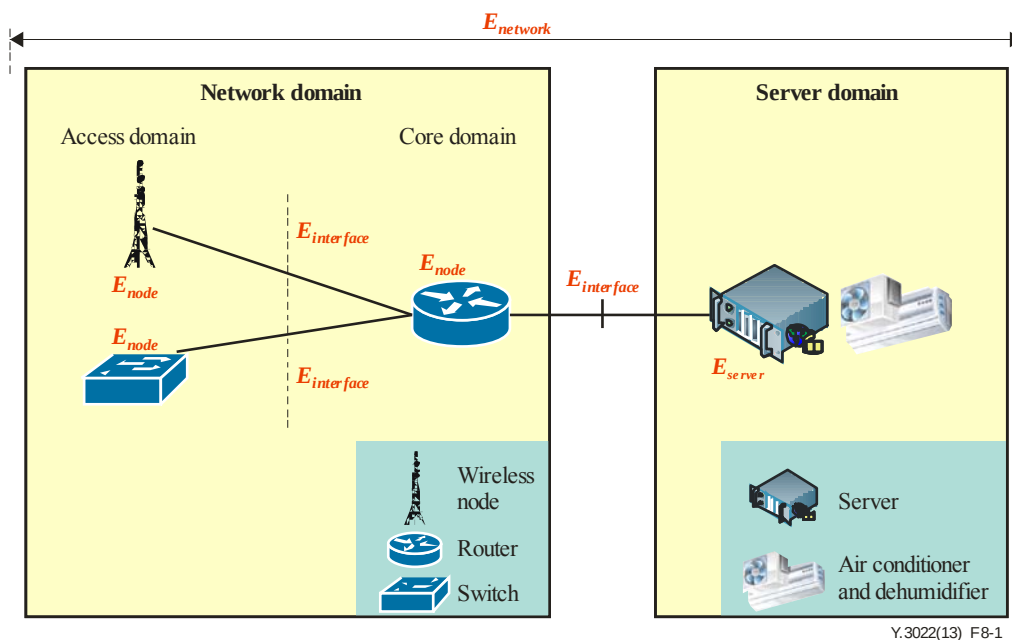


Figure 8-1 – Reference model for measuring energy consumption in networks

The reference model for network energy consumption measurement consists of the network domain and the server domain as shown in Figure 8-1.

The network domain has various nodes (e.g., a switch, a router and a wireless node) in the access domain and core domain. The nodes communicate with each other via wireless and wired interfaces. The server domain includes a number of servers and the non-network equipment. In order to measure the energy consumption of networks, it is important to be aware of network and system configurations, traffic loads of nodes and the number of interfaces both in the network domain and the server domain.

In the network domain, the energy consumption of the interface ($E_{interface}$) and the energy consumption of the node (E_{node}) are measured and calculated from their network energy profiles and traffic loads.

In the server domain, the energy consumption of the server (E_{server}) is measured and calculated according to server configuration, including the non-network equipment (e.g., an air conditioner and a dehumidifier). The server domain may have a centralized or distributed configuration. For example, distributed servers incorporating the cloud computing concept can be configured at the server domain. The energy consumption of a network ($E_{network}$) is the combined energy consumptions of all interfaces, nodes and servers within the defined area of the network.

8.2 Functional architecture for measuring energy consumption in networks

Functional architecture for network energy consumption measurement consists of energy measurement functions and transport functions as shown in Figure 8-2. Transport functions include both domains of the reference model for network energy consumption measurement shown in Figure 8-1.

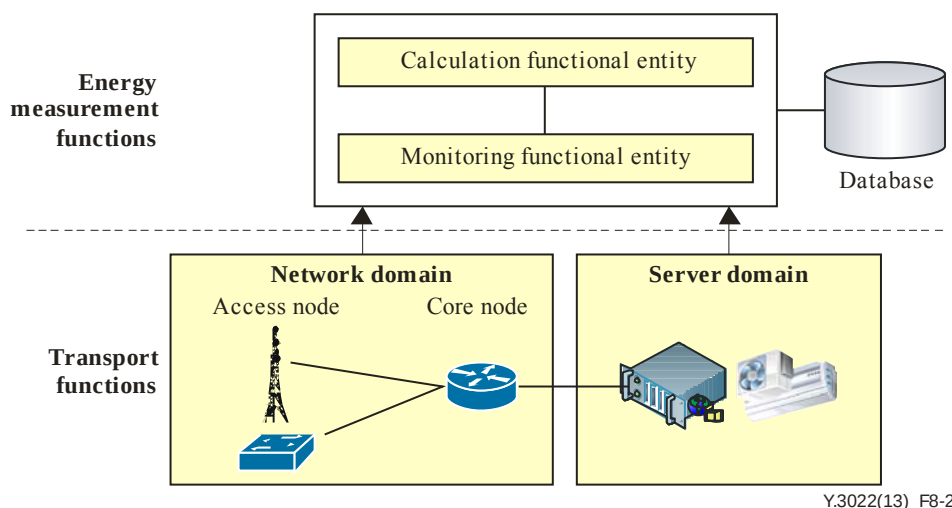


Figure 8-2 – Functional architecture for measuring energy consumption in networks

The network energy consumption measurement functions include two functional entities. The functional entities interact with each other for network energy consumption measurement as follows:

- **Monitoring functional entity:** This functional entity monitors required information about networks such as traffic load, which can be obtained from transport functions in nodes and servers.

The monitoring functional entity also performs measurement of energy consumption such as interface states (e.g., on, off and sleep) and packet size on each interface, node and server when traffic load reaches a target value of for example 0%, 10% or 100%, which can be decided by the network manager. The monitoring functional entity delivers information such as throughput, state and packet size on each interface, node and server to the calculation functional entity. In order to calculate the energy consumption and the network energy efficiency, the monitoring functional entity operates in association with the calculation functional entity.

NOTE – If a node is turned on and a port cable is connected to an interface of the node, the interface's state is on. If a node is turned on and traffic load is zero (0%), the interface's state is changed to sleep as a power saving mode. If a port cable is disconnected, the interface's state is off, regardless of whether the node is turned on or off.

- **Calculation functional entity:** This functional entity calculates the energy consumption and network energy efficiency by using traffic load and network energy profiles, which contain the measured information in a database. The energy consumption can be calculated according to measurement time and power consumption. This functional entity operates in association with the monitoring functional entity and database.

A database stores the network energy profiles, which combine the energy consumptions of interface, node and server in both the network domain and the server domain.