TECHNICAL REPORT

# ISO/IEC TR 30132-1

First edition
2016-09-15

# Information technology — Information technology sustainability — Energy efficient computing models —

## Part 1: Guidelines for energy effectiveness evaluation

*Technologies de l'information — Disponibilité des technologies de l'information — Modèles informatisés à efficacité énergétique — Partie 1: Lignes directrices pour l'évaluation de l'effectivité énergétique*



Reference number
ISO/IEC TR 30132-1:2016(E)

# Contents

Page

# Foreword

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The committee responsible for this document is ISO/IEC JTC 1, *Information technology*, Subcommittee SC 39, *Sustainability for and by Information Technology*.



A list of all parts of the ISO/IEC 30132 series can be found on the ISO website.

# Introduction

The world is experiencing explosive growth of data from mobile client devices, cloud services, social networks, online television, the Internet of things, big data and from traditional enterprise computing. The growth of data has been accompanied by a growth in the energy usage and carbon footprint of IT along with increased costs. Much research has been performed regarding energy management for the last two decades, most focusing on the evaluating and improving energy efficiency of individual components or systems such as processors, memory, wireless networks base stations, laptops, supercomputers, data centres, handheld devices and so on. However, several disparate systems, or systems of systems, collectively use energy to accomplish a given task and satisfy service-level expectations. Consider, for example, someone who takes a photo with a smartphone and posts it to a social network for their friends to view. Taking and transmitting the photo consumes energy from the smartphone while the data transfer, processing and storage consumes energy too. Likewise, when friends view the photo, that activity will consume additional energy. To improve energy effectiveness, it is necessary to consider the end-to-end energy use of a task or service involving multiple systems.

The ISO/IEC 30132 series provides guidelines for the end-to-end evaluation of energy effectiveness of a reference computing model and suggestions for determining the energy effectiveness of a computing model. This document comprises guidelines for energy effectiveness evaluation, including a reference computing model that includes end-to-end data transfer, processing and storage.

# Information technology — Information technology sustainability — Energy efficient computing models —

# Part 1:
# Guidelines for energy effectiveness evaluation

## 1 Scope

This document establishes guidelines for improving the energy effectiveness for computing models. Specifically, this document provides

— a reference computing model for evaluating end-to-end energy effectiveness,

— a holistic framework for evaluating the applicability of energy effectiveness improving technologies, and

— guidelines for evaluating energy effectiveness.

## 2 Normative references



There are no normative references in this document.

## 3 Terms and definitions



For the purposes of this document, the terms and definitions given in ISO/IEC 13273-1 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at https://www.iso.org/obp/

**3.1**
**energy effectiveness**
end-to-end total amount of data transferred, processed and stored per unit energy of a computing model

## 4 Abbreviated terms

| | |
|---|---|
| ARP | address resolution protocol |
| BNG | broadband network gateway |
| DHCP | dynamic host configuration protocol |
| DSL | digital subscriber loop |
| DSLAM | DSL access multiplexer |
| FTTN | fibre-to-the-node |
| FTTP | fibres-to-the-premises |

| | |
|---|---|
| HSPA | high speed packet access |
| ICMP | internet control message protocol |
| ICT | information and communication technology |
| ISP | internet service provider |
| NIC | network interface card |
| OLT | optical line terminal |
| ONU | optical network unit |
| PON | passive optical network |
| PtP | point-to-point |
| QoS | quality of service |
| UMTS | universal mobile telecommunications system |
| WDM | wavelength-division multiplexing |

# 5 Reference computing model for end-to-end energy effectiveness evaluation



## 5.1 Overview of computing models

This subclause provides a survey of trends for various computing models.



In the traditional client-server computing model, clients are connected to servers via networks such as the Internet. In this paradigm, a server is a computer system that selectively shares its resources, whereas a client is a computer that initiates requests to a server in order to use its resources.

However, the emergence of new computing models such as cloud computing and the Internet of things, along with new devices such as mobile phones, tablets, wearables and Internet connected sensors introduce new considerations for both computing models and determining energy effectiveness.

Additionally, data is now transported over traditional wired networks and over high- and low-speed wireless networks. Some client devices only support wireless networks.

Energy effectiveness has traditionally been viewed on a per device-category basis, but now it is important to look at energy effectiveness from an end-to-end perspective that includes all the devices, sub-systems and software that delivers a given set of functionalities (also known as a service).

New paradigms for the creation and use of data also affect energy effectiveness end-to-end. For example, many users have their data on multiple devices and synchronization between client devices and servers has become common practice. This means the same data may reside on multiple devices. On the other hand, some applications retrieve and display data on the client device only as needed. This scenario increases loads on networks, servers and storage, which may increase energy consumption.

The shift to mobile client devices and the shift to cloud computing, along with increases in the total number of connected devices have driven a dramatic increase in the number of data centres and faster, higher capacity networks with a corresponding increase in energy use, while client devices continue to improve their energy effectiveness. Customer expectations for highly available, responsive services may cause servers, storage and networking equipment to stay at high power states longer, possibly conflicting with power management schemes and energy effectiveness goals. New technologies such as push notifications also increase data and energy use across systems.

 

Therefore, energy effectiveness assessments should identify all of the energy consuming components in the computing model. The energy effectiveness of networks is calculated using manufacturers' data on equipment energy consumption for a range of typical types of equipment in networks. The manufacturers' data can include the amount of energy consumption in various states of equipment such as idle, active and fully utilized state. This approach enables an overall model of network power consumption to be constructed and provides a platform for predicting the growth in power consumption as the number of users and access rate per user increase[23].

Figure 1 shows a high level representation of the network model of the Internet. In Figure 1, the Internet is segmented into three major components: access network, metro network and core network with data centres. The model is an abstract representation of the Internet and, as such, does not include much of the fine detail of the Internet's true structure and topology. The model does account for the typical hop count for packets that traverse the Internet[24].

The refinement to include a more realistic representation of the Internet's topology is ongoing. The access network connects individual users to their local exchanges. Some of the typical access network technologies, such as digital subscriber loop (DSL) to deliver packets through fixed-line telephone service, fibres-to-the-premises (FTTP) installations to provide shared passive optical network (PON) or a point-to-point (PtP) Ethernet connection. In a PON, a single fibre from the network node feeds one or more clusters of users by using a passive optical splitter. An optical line terminal (OLT) is located at the local exchange to serve many access modems or optical network units (ONUs) located at each user. ONUs communicate with the OLT in a time division multiplexing, with the OLT assigning time slots to each ONU based on its relative demand. In a PtP access network, each ONU is directly connected to the local exchange with a dedicated fibre to the exchange. In areas where the copper pairs are in good condition, a fibre-to-the-node (FTTN) technology may be used. This technology uses a dedicated fibre from the local exchange to a DSL access multiplexer (DSLAM) located in a street cabinet close to a cluster of users. A high-speed copper pair technology, such as very-high-speed DSL, is used from the cabinet to the users. In areas where copper and fibre are not available or feasible, wireless can provide Internet access. Technologies for the wireless access include WiMAX, high speed packet access (HSPA), and universal mobile telecommunications system (UMTS). For wireless access, a wireless modem, located in the user, communicates with a local wireless base station which, in turn, is connected to the central office[23].



The central offices in a city are connected to each other and to other cities via the metro/edge network. This network also provides connection points for Internet service providers (ISPs). The metro and edge network serves as the interface between the access and core networks. The metro and edge network includes edge Ethernet switches, broadband network gateway (BNG) and provider edge routers. Edge Ethernet switches concentrate traffic from a large number of access nodes uplink to two or more BNG routers. The edge switch connects to two or more BNG routers to provide redundancy. The BNG routers perform access rate control, authentication and security services, and connect to multiple provider edge routers to increase reliability. The provider edge routers connect to the core of the network[23].

The core network comprises a small number of large routers in major population centres. These core routers perform all the necessary routing and also serve as the gateway to neighbouring core nodes. The core routers of any one network are often highly meshed, but only have few links to the networks of other providers. High-capacity wavelength-division multiplexed (WDM) fibre links interconnect these routers and connect to networks of other operators[23].

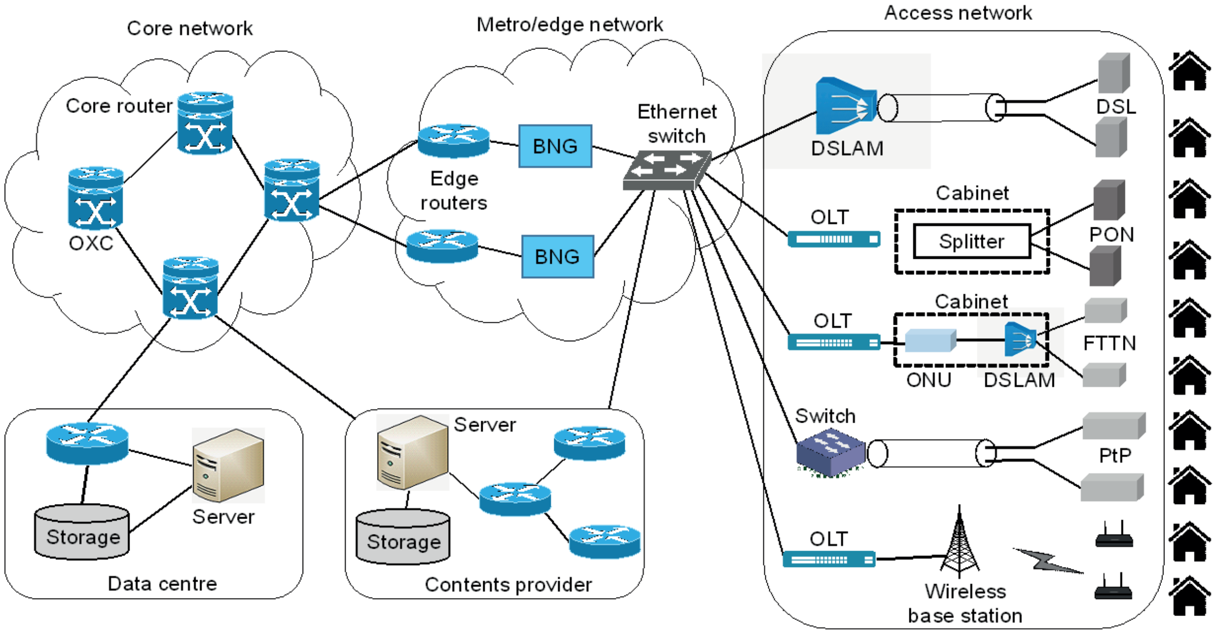


**Figure 1 — High-level network structure for the Internet[23]**



## 5.2 Reference computing model and energy effectiveness evaluation

Since there are many components in modern computing models and each has unique energy effectiveness characteristics, it is difficult to calculate the energy consumption of services. Therefore, this document uses a simplified generic reference computing model consisting of client devices, network equipment and data centre equipment as shown in Figure 2. It is assumed that data centre has computing resources such as server and storage. This document considers the following assumptions for the simple evaluation of energy effectiveness of computing models.



— This document evaluates energy effectiveness of computing models from the view point of end-to-end data creation, processing, storage, consumption and sharing.

— The model also assumes a data-oriented scenario where data moves back and forth between client devices and data centres.

This document considers following components for evaluating end-to-end energy effectiveness while considering application's characteristics:

— client devices;

— network equipment;

— data centre equipment.

For survey for calculating power consumption of the components in computing models, see Annex B.

 

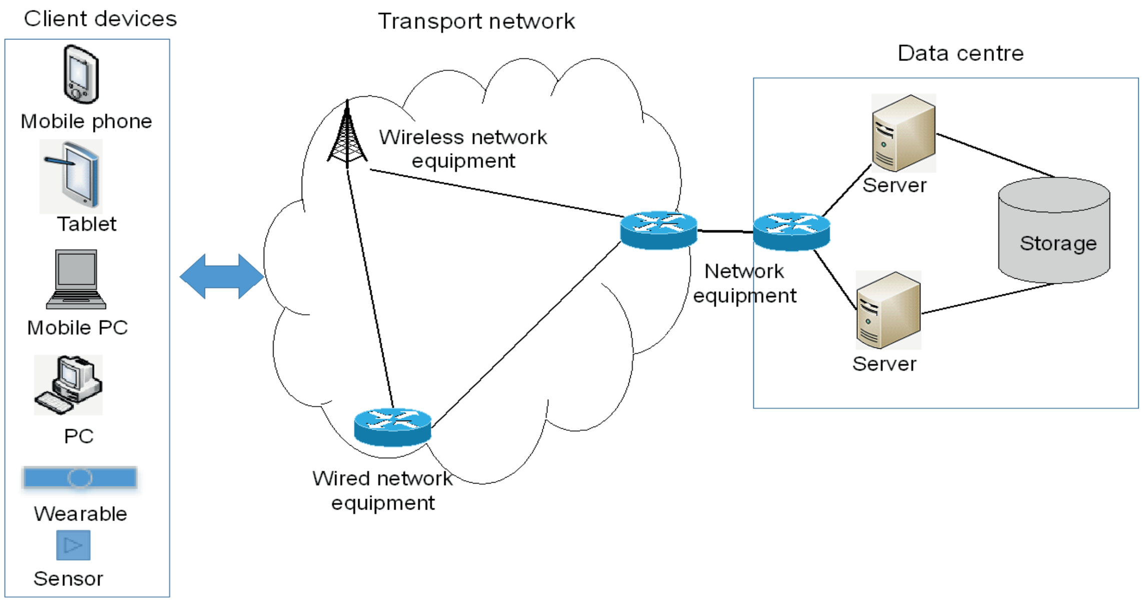


**Figure 2 — Simplified generic reference computing model for energy effectiveness evaluation**

From the perspective of computing the overall energy effectiveness, this document takes a very high-level macroscopic view. At this level, it is considered that the transport network consists of multiple wired and wireless network equipment. Client devices can take many forms including wearable technologies, sensors and controls. It is noted that this document considers network layer equipment in estimating the energy effectiveness of networks because the detail information about networking equipment below network layer is difficult to obtain due to security and confidentiality. Thus, internal network equipment are not taken into account. In case of data centre, border routers that connect data centre to the Internet are taken into account. The internal routers within a data centre are not considered. However, if the internal network information of clients, transport networks and data centre are available, those information may be utilized in order to estimate the energy effectiveness more accurately. Therefore, the end-to-end energy effectiveness evaluation can be performed by calculating the energy effectiveness of the following components:



— client devices;

— transport network: in Figure 2, it is assumed that transport network includes access, metro/edge and core network;

— data centre equipment.

The individual architectures that make up the high level components in the model are much more complicated and the corresponding details and complexities are not within the scope of this document.

The energy consumption (watt-hours) of the end-to-end path in the reference computing model can be calculated as follows:

$$E_{\text{E2E}} = \sum_i E_{\text{client\_device},i} + \sum_j E_{\text{net\_equip},j} + \sum_k E_{\text{datacentre\_equip},k}$$

The energy consumption measurement of components in the reference computing model can be performed as follows.

— Basic assumption: each component is equipped with monitoring function, which can monitor and measure throughput level of target equipment. When the monitoring value reaches a designated threshold value, the amount of consumed energy is measured.

— Client devices and data centre equipment: monitoring function can measure the amount of power consumption at the offered load to the equipment. Calculation of the energy consumption on client device or data centre equipment can be performed by using measurement time, *T*, and power consumption upon offered load as follows:

$$E_{\text{equip}} = \sum_{0}^{T} P_{\text{equip}} \left(\text{offered\_load}\right)$$

— Network equipment: network throughput can be calculated as doing sum of traffic load entered into each network equipment. For this, the monitoring function can collect information about network throughput such as offered load to measure the power information of the equipment. When the network throughput reaches at target threshold value for power measurement, the monitoring function gathers the information upon traffic load on each node and calculates the energy consumption at the target traffic load. The total amount of power consumption on the network equipment can be calculated by using the information upon each traffic load. The consumed power on total network equipment can be the sum of the consumed power on each node. The power measurement can be done depending on different throughput states (e.g. 10 %, 20 %, etc.). When the value of traffic load is known, any network equipment can calculate power consumption value of each node according to traffic load. It is noted that if calculating power consumption of each network equipment, a practical way to calculate the network energy consumption may be to take each segment, measure the total energy consumed over *T*, divide that by the total number of bytes of data that traversed that segment over *T* and then multiply by the number of bytes of data for the service that traversed that network segment over *T*.

$$E_{\text{net\_equip}} = \sum_{0}^{T} P_{\text{net\_equip}} \left(\text{traffic\_load}\right)$$



Since the energy effectiveness evaluation of reference computing model only deals with end-to-end data scenario, the end-to-end energy effectiveness can be calculated as follows.

Comparing product metrics allow consumers, enterprises and carriers to add energy effectiveness to purchase criteria. A straightforward way to estimate the energy effectiveness of a network or telecom system is to normalize its energy consumption to the amount of transmitted data in the test.



Let $B_{\text{E2E}}$ be the end-to-end total amount of data transferred, processed and stored during the measurement time, *T*, in the reference computing model and $\eta_{\text{E2E}}$ be the overall energy effectiveness calculated. Therefore, the end-to-end network energy effectiveness is calculated by dividing the total amount of data, i.e. $B_{\text{E2E}}$ by the total energy consumption of the computing model.

$$\eta_{\text{E2E}} = \frac{B_{\text{E2E}}}{E_{\text{E2E}}}$$

# 6 Holistic framework for evaluating the applicability of energy effectiveness improving technologies

## 6.1 Motivation

As the energy effectiveness of computing systems that use a large amount of electricity becomes an important issue to network providers and operators, there is an increasing demand for developing standards for evaluating and assessing the effectiveness and applicability of various energy effectiveness improving technologies. This clause defines effective and holistic framework for assessing the energy effectiveness improving technologies.

The rapid increase of energy consumption of ICT products accelerates the development of energy efficient technologies. However, since energy efficient technologies in different dimensions may cause unexpected side effects in total energy effectiveness of a computing system, it becomes necessary to develop effective methods for understanding the inter-relationship among multiple energy efficient technologies and evaluating energy effectiveness based on holistic view. This subclause also provides motivation for holistic framework.

 