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Assessment of energy consumption of information and communication technology services

ITU-T L-series Recommendations – Supplement 33

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Supplement 33 to ITU-T L-series Recommendations

Assessment of energy consumption of information and communication technology services

Summary

Supplement 33 to ITU-T L-series Recommendations describes a methodology for assessing the energy consumption of an information and communication technology (ICT) service. This assessment is based upon the traffic generated by the service and the equipment through which that traffic propagates.

Methods for assessing the power consumption or efficiency of ICT networks have been studied for some time. In many cases, the assessment is focused on equipment and networks rather than on the services that are conveyed by that equipment. Examples include energy consumption rating (ECR) and telecommunications energy efficiency ratio (TEER). In addition to methods dealing primarily with power consumption, Recommendation ITU-T L.1410 provides a methodology for evaluating the environmental impact of ICT equipment, networks and services objectively and transparently, and is based upon life cycle assessment (LCA) methodology. Recommendation ITU-T L.1410 gives general principles for service level assessments and allocation of network power consumption between services.

This Supplement proposes a more detailed methodology for an assessment of the power consumption of a specific ICT service that shares infrastructure with other services. This enables companies to allocate power consumption of all segments of the network (i.e., the allocation can be made in the customer premises equipment (CPE), access, metro and core networks) to specific services based on throughput.

This Supplement provides an overview of the method and a 'step-by-step' description of the process.

History

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Allocation of power, ICT services, idle power, incremental power, methodology.

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Assessment of energy consumption of information and communication technology services

1 Scope

This Supplement provides a methodology for assessing the power consumption of an information and communication technology (ICT) service for a situation where power consumption scales with traffic or throughput. A formal description of the proposed methodology is presented.

This Supplement describes how to estimate the power consumption of an ICT service based on data from network power consumption measurement. According to [ITU L.1410], which provides high level guidance for service assessment, different network equipment types should be allocated based on different parameters, such as throughput or user time. This Supplement specifically deals with services based on equipment that scales with throughput.

It is recognized that, in the future, most network equipment will have the capability to automatically monitor its power consumption. However, for current generation and legacy network equipment, certain network measurements may be unavailable or missing due to the lack of a network monitoring platform, the lack of an automated data collection platform and corrupted or missing network data. Therefore, this Supplement also outlines the methodology to estimate the missing network data in order to provide a meaningful assessment of service power consumption.

It is important to understand that there are many other ways to assess the power consumption of ICT services and the proposed methodology is not the only way to address this problem. However, the methodology presented in this Supplement provides a clear and justifiable path for the network operator and ICT service provider to understand the allocation of power (and hence greenhouse gas (GHG) emissions) to the provider of services utilizing equipment with a power consumption that scales with throughput.

The value provided by this Supplement is that it enables a service or network provider to assess the specific power consumption for their service traffic though network equipment that their traffic shares with other service providers' traffic. This is important when a service provider desires to determine the power consumption of their services. This, in turn, will be necessary to provide input for assessing or reporting the GHG emissions or costs of the services they provide to their customers.

NOTE – Comparisons of results from environmental assessments of ICT services, which have been performed by different organizations, are beyond the scope of this Supplement, as such comparisons would require that the assumptions and context of each study are equivalent.

2 References

[ITU-T L.1410] Recommendation ITU-T L.1410 (2014), *Methodology for environmental life cycle assessments of information and communication technology goods, networks and services.*

3 Definitions

3.1 Terms defined elsewhere

This Supplement uses the following terms defined elsewhere:

3.1.1 network operator: [ITU-T L.1410].

3.1.2 ICT goods: See clause 3.2.24 of [ITU-T L.1410].

3.1.3 ICT network: See clause 3.2.26 of [ITU-T L.1410].

3.1.4 ICT service (application): See clause 3.2.27 of [ITU-T L.1410].

3.2 Terms defined in this Supplement

This Supplement defines the following terms:

3.2.1 user: Human being, organization, or telecommunications system that accesses the network in order to communicate via the services provided by the network.

3.2.2 ICT service provider: Entity that offers services to users involving the use of network resources.

4 Abbreviations and acronyms

This Supplement uses the following abbreviations and acronyms:

CPE Customer Premises Equipment

ECR Energy Consumption Rating

GHG Greenhouse Gas

ICT Information and Communication Technology

LCA Life Cycle Assessment

TDM Time Division Multiplexing

TEER Telecommunications Energy Efficiency Ratio

VoIP Voice over Internet Protocol

WDM Wavelength Division Multiplexing

5 Conventions

None.

6 Description of the methodology

The power consumption profile of almost all network goods (customer premises equipment (CPE), routers, switches, cross-connects etc.) can be principally described by the linear graph in Figure 1. In reality, different shapes exist. This profile consists of an idle power $P_{\min}$ and an increase in power as the throughput increases from zero to the maximum throughput the equipment can sustain.

The throughput changes as the data size carried by the network equipment over a certain period of time (this can be deduced from port log of the network equipment).

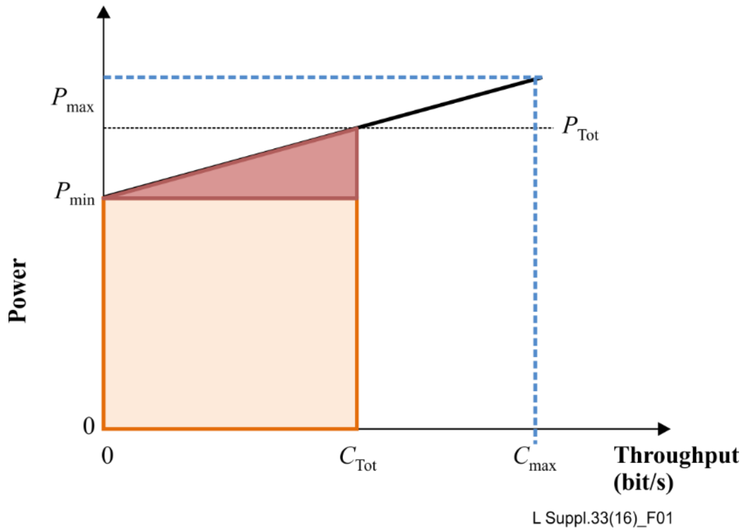

Figure 1 – Power consumption dependence on throughput

The light shaded region corresponds to idle power P_{min}. The dark shaded area corresponds to the incremental power consumption incurred when traffic propagates through the network equipment.

C_{Tot} is defined as the total throughput of the network equipment and P_{Tot} as the operating power consumption of the network equipment corresponding to C_{Tot}.

There are two contributions to the total power consumption of the network equipment: the idle power P_{min} and the "incremental" power incurred, in addition to P_{min}, by the increase in equipment power consumption due to an increase in equipment throughput.

For equipment that scales well with throughput, the difference between P_{min} and P_{max} can be substantial – for other types of equipment the curve may be almost flat.

The purpose of the methodology is to allocate a proportion of the network equipment's total power consumption to an ICT service that is carried by this network equipment. This allocation will apply when that service is one of many simultaneously being propagated through this network equipment unit.

If there is only one service propagating through the network equipment, then the entire power consumption of that network equipment can be allocated to that service.

This Supplement addresses the non-trivial case when multiple services share that network good and these services have different bandwidth requirements. Moreover, each service crosses several telecommunication goods shared with other services.

7 Allocation of power

The main purpose of this Supplement is to assess the power consumption of a telecom service. A service could be voice over Internet protocol (VoIP) or video streaming.

However, this Supplement encompasses more complex services. For example, software-as-a-service where network operators provide cloud services to customers.

Both network operators and customers would like to know the power consumption of cloud services. For infrastructure-as-a-service, the network operator manages the network infrastructure of a customer and again the customer would like to know the power consumption of such network infrastructure. For platform-as-a-service, the network operator provides a network platform for multiple customers to support their businesses and the customers would like to know the power consumption of using the platform to run their businesses.

Furthermore, referring to clause 5.2.3.3.4 of [ITU-T L.1410], the allocation of equipment power consumption to an ICT service is often based on annual data traffic of the service. The service traffic C_j can be estimated by summing the total traffic in a year and dividing by time to get the functional unit of bits per second.

In some cases, time and number of users can be more applicable parameters. However, as this Supplement is intended to assess the power consumption of a service that scales with traffic, the corresponding functional unit for the service would be bits per second.

In this Supplement, the methodology allocates the total power of the network equipment to the service based on the ratio of service traffic to maximum throughput of the network equipment. In other words, the fundamental assumption is that the power allocation to services is based on the principle that each service through the network equipment is allocated an amount of power so that the total allocated power is the total equipment power, P_{Tot}, whereby:

$$P_{\mathrm{Tot}} = \sum_{j=1}^{N} P_j \quad (1)$$

If there are N services each with traffic propagating through the network equipment, the equipment's power to each service (P_j) will be allocated depending on the traffic of the service (C_j).

For cases where a specific ICT service is provided by multiple service providers, the total power of the service is then the sum of all power sources of the same service provided by all service providers.

Therefore, the total traffic through the network equipment is the sum of the traffic of each service:

$$C_{\mathrm{Tot}} = \sum_{j=1}^{N} C_j \quad (2)$$

We focus on assessing the power consumption of the jth service. The same methodology can also be applied to assess the power consumption of the jth service provided by the lth service provider.

Finally, as a specific service does not propagate its traffic through one ICT good only, this assessment should be repeated for all goods used by the service.

8 Allocating incremental power

Using the principles outlined in clause 7, the incremental power for a service is given by the slope of the power profile in Figure 1.

If the slope of the line for the jth service is given by E_j, then the incremental power component for the jth service that has traffic C_j through the network equipment unit is:

$$P_{\mathrm{inc},\,j} = E_j C_j \quad (3)$$

The calculation of E_j is part of the process and is discussed in clause 10.

9 Allocating idle power

The difficulty when allocating power consumption to services is how to equitably allocate the idle power: P_{min}. As explained in Appendix I, a simple allocation of P_{min} in proportion to the C_j/C_{Tot} ratio does not seem appropriate.

Therefore, in this Supplement, two types of calculation method for allocating idle power are considered.

1) Full allocation: the equipment idle power is shared among all services. It should be noted that further research might be necessary to better clarify how the power consumption between services can be split.

2) Maximum throughput based allocation: the allocation of the idle power to the service is based on the ratio of service traffic to maximum throughput.

In the second approach, the sum of power of all services will be less than the total power of the network equipment. Therefore, either the remaining part has to be spread equally between the service operators or the network operator has to be responsible for the remaining parts of the network equipment power consumption.

NOTE 1 – From an LCA perspective, the focus is on services, not organizations, and it is necessary to split the remaining part between the services. If the organizational footprint is targeted, it could be argued that the service power consumption should somehow be split between network operators and service providers. However, there are different ways to handle such allocations. This Supplement looks at a situation when the network operator is allocated the remaining part of the power consumption.

To assess the average service power consumption of a service, the first approach can be used because if the average is taken over a long enough period, (e.g., 1 year), this approach gives an accurate estimate of the service power consumption.

If the network operator would like to know the instantaneous power consumption of the service, the second approach can be used. Using this approach, the network operator can perform fine-grained assessment of a service transaction, e.g., a VoIP call.

The following principles are intended to help avoid this allocation problem.

A network equipment unit is operated at less than its maximum throughput. That is, $C_{Tot} < C_{max}$ as shown in Figure 1. This is because the network operator must ensure that, if a sudden surge in traffic occurs, then no or a minimal number of traffic packets are lost due to the traffic surge being greater than the equipment can handle (i.e., larger than C_{max}).

To limit the amount of lost traffic, a network operator will operate its equipment up to a pre-determined threshold fraction of C_{max}. So the maximum planned traffic through the network equipment unit will be $U_{max}C_{max}$ where U_{max} (<1) is the maximum utilization threshold of the network equipment.

The value of U_{max} is determined by a policy decision of the network operator. If the utilization of the equipment consistently surpasses U_{max}, then more capacity (additional or larger scaled network equipment units or network interfaces) should be deployed.

This means that:

$$C_{\mathrm{Tot}} = \sum_{j=1}^{N} C_j \langle U_{\max} C_{\max} \qquad (4)$$

In this proposal, we allocate traffic to the network operator so that we have:

$$C_{\mathrm{Tot}} = \sum_{j=1}^{N} C_j + C_{\mathrm{Operator}} \qquad (5)$$

where traffic $C_{Operator}$ is allocated to the network operator so that the total traffic through the network equipment unit equals C_{Tot}.

It can be imagined that the network operator "picks up the difference" between the total service providers' traffic through the network equipment unit and the maximum traffic that the network equipment unit is designed to carry. In this case, each service provider's energy allocation of idle power is independent of any traffic changes due to other service providers.

As a consequence, the network operator allocates the idle power to all services and takes a certain responsibility for the idle power of the network equipment. Therefore, the network operator has to choose a reasonable value of U_{max}, which is the average utilization of the network equipment. This could be an average value based on network statistics over a long period of time, e.g., 1 month, 6 months or 1 year.

NOTE 2 – When performing life cycle assessments (LCAs) of services, the full network impact should be allocated to the services, whether it is associated with a network operator or service provider.

Using the approach where the network operator "picks up this difference", the proportionate allocation of $P_{\min,j}$ to each service provider is given by:

$$P_{\min,j} = \frac{P_{\min}}{U_{\max} C_{\max}} C_j \qquad (6)$$

Where $P_{\min}$ is the baseline power (or idle power) of the equipment.

To allocate the idle power of an ICT good to a service, the proposed method allocates $P_{\min}$ to different services based on how much capacity of the equipment is utilized by the service ($C_j/U_{\max}C_{\max}$).

Other approaches were considered such as dividing $P_{\min}$ by total number of services running on the equipment or dividing $P_{\min}$ based on the actual throughput of the equipment (C_j/C_{Tot}) where C_{Tot} is the total throughput of the equipment. This allocation will not change if another service provider changes their traffic load through the network equipment unit.

In this approach, the network operator is allocated power consumption of:

$$P_{\min,\mathrm{Operator}} = \frac{P_{\min}}{U_{\max} C_{\max}} C_{\mathrm{Operator}} \qquad (7)$$

Note that all the idle power is allocated to some responsible party.

Also note that the network operator has picked up a power consumption (and hence carbon footprint) contribution. The network operator's component will change depending upon the total traffic through the network equipment unit. This could be one of the drivers for the network operator to reduce the power consumption of the equipment in its network or increase its utilization. In both cases, the energy efficiency of the network will be increased.

Since increasing utilization may not be optimal for network performance, this Supplement refers to the energy efficiency of network equipment, defined as the ratio of energy (in joules or watt hours) to throughput (in bytes or bits). Therefore, intuitively, increasing the utilization of the network equipment (i.e., increasing data bytes and bits) will decrease this ratio and increase the energy efficiency.

The key parameters that must be measured or otherwise ascertained are:

$P_{\max}$ (W): This can be determined from the network equipment configuration. This information is readily available to the network operator either by measurement or provided by the equipment vendor.

$P_{\min}$ (W): This is the idle power of the network equipment. This information is readily available to the network operator either by measurement or provided by the equipment vendor.

$C_{\max}$ (Gbit/s): This can be determined from the network equipment configuration. This information is easily made available to the network operator by the equipment vendor.

C_j for the service under consideration (Gbit/s): This can be provided by the service provider's specifications of traffic requirements. Typically, if the service provider has a contracted connection speed of x bits/s for the given service, then the traffic allocation will be $C_j = x$ bits/s.

E_j for each service: This is the slope of the line depicted in Figure 1.

10 Determining *Ej*

The determination of E_j depends on the type of network equipment.

There are two cases that may occur:

a) $E_j = 0$

Network equipment types may have $E_j = 0$ or $E_j \approx 0$ for all the service traffic propagating through that network equipment. In these cases, the power of a service is determined by the allocation of the idle power to that service as discussed previously.

b) $E_j \neq 0$

Today many network equipment types have a non-zero E_j that is dependent on the packet size of the traffic. However, real measurements show that this dependency is weak (refer to b-Vishwanath, 2014] for detailed measurement).

In this case, E_j can be determined using the following approaches:

– Direct measurement of the power consumption and traffic load of the network equipment. This will require attaching a power meter to the network equipment to record the power consumption and accessing the traffic logs for the network equipment.

– If it is not practical to use direct measurement, then E_j can be approximated from knowledge of the equipment type. Most modern routers and switches have $P_{\min} \approx 0.8$ to $0.9P_{\max}$. Knowing the approximate proportion gives $E_j \approx 0.1P_{\max}/C_{\max}$ to $0.2P_{\max}/C_{\max}$.

11 Step-by-step process

The steps for implementing this assessment methodology are as follows.

a) Evaluate the values of $P_{\max}$, $P_{\min}$ and $C_{\max}$.

b) Ascertain $U_{\max}$ from company policy.

c) Has $P_{\min}$ been measured?

1 Yes: Use measured value to calculate $E_j = (P_{\max} - P_{\min})/C_{\max}$.

2 No: Use estimate of $P_{\min} \approx 0.85P_{\max}$ to calculate E_j as shown in [b-Vishwanath, 2014]. This estimation gives a guideline for network operators who could not obtain information about the power profile different types of network equipment.

Please refer to [b-Vishwanath, 2014] for detailed measurement.

d) Ascertain C_j from the service agreement between the network operator and service provider.

e) The power of the service provider traffic C_j for the network equipment is given by:

$$P_j = C_j + \frac{P_{\min}}{U_{\max} C_{\max}} C_j \tag{8}$$

f) The power allocation to the network operator for that network equipment is given by equation (7).

g) Repeat this process for all shared network equipment that carries that service provider's traffic based on network statistics collected from the network management and operations platform.

This process only includes network equipment that carries traffic from multiple service providers. To this must be added the power consumption of any equipment that is used solely by the provider.

12 Required data

For all shared items of network equipment, such as switches and routers, the following data are required: $P_{\max}$, $P_{\min}$, C_j, $U_{\max}$ and $C_{\max}$.

For services ex-post, network operators collect data from the network and then perform the calculation of how much energy has been consumed by the service.

If this information is not available, it will need to be determined from the configuration of the network element and consultation of the network element equipment data sheet. The collection of this information is likely to be a time-consuming process, depending on the availability of this information from the network operations data base and a certain number of approximations can be made without impacting the accuracy of the energy service allocation method.

For example, in most metro and core networks, the routers and switches dominate the power consumption of any service carried over the network. Therefore, if only an approximate value for service power consumption is adequate, no data are required on the optical line systems or time division multiplexing/wavelength division multiplexing (TDM/WDM) cross-connects, muxes or demuxes in the network.

This data listed in the preceding text can be provided without any need for any extensive information on the ICT network operator's network architecture. An anonymous naming system can be adopted if the locations of the switches and routers are to be kept confidential.

Appendix I

Alternative method to allocate idle power

The difficulty when allocating power consumption to services is how to equitably allocate the idle power: P_{min}. This power is fixed and, as a consequence, the allocation of this power across multiple services changes depending upon the number of services sharing the network equipment and the traffic of each service. A simple allocation of P_{min} in proportion to the C_j/C_{Tot} is not appropriate because the provider of the jth service will see a change in its allocation even though it has not changed the traffic C_j.

When the idle power of an item of network equipment is allocated using a simple allocation based on the proportion of traffic for each service, the equation becomes:

$$P_{\text{min},j} = P_{\text{min}} \frac{C_j}{C_{\text{Tot}}}$$

This allocation, although simple and direct, has the disadvantage that when one service provider decides to change their traffic, this will change the power consumption allocated to the other service providers using that network equipment. This will occur even if all the other service providers' traffic does not change.

Therefore, the service providers lose control over the power allocation for their service. Service providers would view this situation as unfair and even unacceptable.

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[b-Vishwanath, 2014] Vishwanath, A., Hinton, K., Ayre, R., Tucker, R. (2014). Modeling energy consumption in high-capacity routers and switches. *IEEE Journal on Selected Areas in Communications* **32**, 1524-1532, 10.1109/JSAC.2014.2335312.

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