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ITU-T L.1310 – Supplement on energy efficiency for telecommunication equipment

ITU-T L-series Recommendations – Supplement 1

ITU-T

Supplement 1 to ITU-T L-series Recommendations

ITU-T L.1310 – Supplement on energy efficiency for telecommunication equipment

Summary

Telecommunication technologies play a large and increasing role in modern society; we depend increasingly on constant streams of information in our work and free time for data access and entertainment. Every day, more people access high speed networks via wired and wireless channels, and the amount of energy to deliver all those new services is also growing rapidly.

Without an increase of energy efficiency, this would lead to a dramatic increase in energy use for all new services and customers. Scaling existing technological solutions is not enough. Not only do we need to implement changes in energy efficiency but we also have to implement them rapidly.

This Supplement on energy efficiency for telecommunication equipment reviews the concepts for energy efficiency in application to networking devices; it presents a concept of place in a network as a base for classification, describes a process for creating a single metric for energy efficiency which reflects the qualities of equipment scalability with traffic levels and provides testing topologies and traffic pattern descriptions.

History

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FOREWORD

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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.

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Introduction

Telecommunication technologies play a large and increasing role in modern society; we depend increasingly on constant streams of information in our work and free time for data access and entertainment. Every day, more people access high speed networks via wired and wireless channels, and the amount of energy to deliver all those new services is also growing rapidly. This would lead to a dramatic increase in energy use for all new services and customers. Scaling existing technological solutions is not enough. Not only do we need to implement changes in energy efficiency, but we also have to implement them rapidly. In order to understand if the speed of change is sufficient, we need to evaluate the energy efficiency of the products that are used to build new telecommunication equipment and then compare it to existing solutions. This process highlights the necessity to have reliable and consistent methods and metrics for energy efficiency evaluation.

In recent years, interest in improving energy efficiency of all energy consuming products has become a hot topic for all society and for the business community in particular.

This interest can be attributed to two major factors: concern regarding global warming contributions, and the high price of energy. Both are fair concerns and both require fast action.

Networks have increased significantly in utility and capacity and are now a critical feature of most businesses. However, the energy consumed by networks has also increased, and it is estimated now to represent as much as 10% of all ICT energy usage. Network users, service providers and regulators are looking for ways to reduce or limit the growth of network energy usage without losing critical network functionality. This will require a focus on the energy efficiency of the network installation, with a particular attention to the energy used and the service delivered by the networking products and supporting infrastructure.

The first instinctive action for energy efficiency improvement is to reduce the nameplate power rating for any product. However, while the actual power rating of a product is an important characterization, its use is limited to facility wire provisioning and does not consider what the product actually does. How many useful features does the product have? How does it compare with the previous generation of products? What are the new functions, features, services it brings? What is its power in the real network?

Generally, the first step in improving energy efficiency should always be to define the meaning of energy efficiency and measure current energy usage in order to see where efficiency gains will have most of the impact and to quantify the effects of those efficiency gains. It should be expected that these efficiency gains will be in the production network equipment as well as in the supporting infrastructure and the interactions between the two.

Continuing energy efficiency improvements will require an examination of the procurement and provisioning process to ensure that new equipment that is added to the network or the infrastructure works to maximize the efficiency of the system as a whole. There may be times when particular sets of products must be compared with each other for energy efficiency. It is important that this comparison is made in a manner that demonstrates the best energy efficiency without compromising the critical functions or performance of the network.

Often there is a strong desire to have a single metric that would give a representation for energy efficiency, similar to the miles per gallon for cars. This may be bits per second per watt or an equivalent for networking. The problem with this approach is that a car has only one major function: to take you from one point to another. Networking equipment, on the other hand, not only controls the flow of information, but also performs additional tasks including encryption, packet inspection and quality of service support. Sometimes a metric expressed in watts per port (or similar) is proposed; but again, it does not reflect the nature of the port, its function, its throughput or how it relates to the rest of the network. Does this mean that a single metric is unusable? No, it simply means that both parts of a metric – throughput and power (consumed energy rate) – must be carefully defined for specific network functions and positions in the network and the results compared for similar products only.

Supplement 1 to ITU-T L-series Recommendations

ITU-T L.1310 – Supplement on energy efficiency for telecommunication equipment

1 Scope

This Supplement on energy efficiency for telecommunication equipment reviews the concepts for energy efficiency in application to networking devices; it presents a concept of place in a network as a base for classification, describes a process for creating a single metric for energy efficiency which reflects the qualities of equipment scalability with traffic levels and provides testing topologies and traffic pattern descriptions.

2 Abbreviations and acronyms

This supplement uses the following abbreviations and acronyms:

EER Energy Efficiency Ratio

EUT Equipment Under Test

IMIX Internet Mix

LAN Local Area Network

NAS Network Applications Service

RF Radio Frequency

SNE Small Networking Equipment

TEER Telecommunications Energy Efficiency Ratio

WAN Wide Area Network

3 Definitions

3.1 active mode: Mode in which the equipment is fully functional and can pass traffic. It is also known as On Mode or Ready.

3.2 idle mode: The same as active mode, with no user data traffic.

3.3 stand-by mode: Mode in which the equipment is not functional, only the reactivation option is available.

3.4 networking device: Device with at least two network interfaces and whose primary function is to pass data.

3.5 networked device: Device which uses the network to perform or improve a primary function. Examples are: IP phone, network applications service (NAS).

4 Understand network functionality

Once energy efficiency has been optimized, the next step towards energy conservation is to understand the functionality of the network. Attempting to implement energy savings that compromise the functionality of the network will result in conflicting business objectives. This is especially true as networking functions have become critical to many, or even most businesses. In many cases, network functionality is directly related to the revenue and profitability of the business. If the business goal is to sell network services or services over networks, then any loss of productivity for the network will result directly in lost revenue or customers for the business. The network may be critical to the business functionality in other cases where the business is not directly related to the network because the critical business systems rely on the network. Therefore, it is of utmost importance to understand the productivity and critical requirements of the network to avoid the risk of a major negative impact from (relatively) minor energy savings.

5 Measure energy usage

The most important step is to measure where the energy is being used in the network. How the energy is used will vary not only according to application or network type, but it will also differ from one individual network to the other. These variations can be due to different load requirements, physical infrastructures and environmental factors as well as time of day/week/month/year. Measuring where the energy is being used will highlight the areas where the greatest energy savings may be made, as well as allow accurate cost analysis.

6 Analyse network architecture and components

After analysis of network energy usage and critical functions, enhancements to the network infrastructure, architecture and components may be assessed. At this point, there may be some key components that can be identified as targets for replacement in order to save energy; however, in most cases, significant savings will require evolution of system-wide features. The most important step at this stage is to understand how the interaction of components throughout the network and supporting infrastructure affects overall energy consumption. This will invariably be the most complex step and will require cross-functional expertise. In most cases, this will take the form of multiple initiatives and system-wide feature requirements that will be built into guidelines and component requirements used during the evolution and upgrade process.

7 What is energy efficiency?

Energy efficiency is a widely used term with multiple meanings: for example, one may hear phrases like "use the stairs, be energy efficient", "energy efficient office or house", or many other phrases related to energy efficiency. In referring to electrical devices, it is convenient to start with a generic definition for "Energy Efficiency" that applies to any device that uses energy to do work: "Percentage of total energy input to a machine or equipment that is consumed in useful work and not wasted as useless heat."

This could be expressed as follows:

$$\eta = \frac{\mathrm{Pout}}{\mathrm{Pin}} \tag{1}$$

where P_{out} is the energy needed to do useful work, and P_{in} is the total energy.

Equation 1 can work very well for devices such as power supplies or transformers where input and output can be measured in the same units. By definition, "Energy Efficiency" is always in the range from 0 to 1, or 0 to 100% (if expressed as a percentage).

However, for networking devices pure energy conversion is usually not considered as a useful function, except for some radio frequency (RF) devices. For example, in a typical router or switch, power P_{in} would be in kilowatts (kW) and P_{out} (the signal transmitted) would be in milliwatts (mW). It can be easily seen that power conversion in networking devices is not a major function; data processing, depending on device type, is the major function instead. Therefore, it is necessary to decide what can be used as a representation (or a proxy) for P_{out} (the useful work).

For packet switching equipment, it is very common to represent performance as maximum throughput: i.e., the sum of throughput on all system ports in the egress direction (bit/s). For example, the maximum throughput for Gigabit Ethernet is 1 Gbit/s.

This brings up Equation 2 for energy efficiency calculation:

$$\eta = \frac{System\ Throughput}{System\ Power} \quad (2)$$

Examples of different system performance measures are: RF power, number of calls and connections.

8 Power measurement conditions

Power measurement is an essential part of energy efficiency evaluation. Consequently, a complete definition of all of the factors influencing power is necessary.

First, it is necessary to define environmental factors such as temperature, humidity and barometric pressure which all affect power numbers by increasing or decreasing fan speed, cooling effect of airflow, component power consumption, etc. It is strongly advised to limit the scope of environmental changes to typical laboratory conditions:

Temperature: 25°C ± 3°C

Humidity: 30% to 75%.

Barometric pressure: 1060 and 812 mbar.

The second influencing factor is traffic topology. It is essential to use topologies reflecting real life use and avoid simulations used for testing simplification.

For example, for packet switching devices (such as routers and switches), full mesh traffic where each port talks to all other ports should be used for symmetrical systems and full mesh between uplink and downlink ports, where each downlink port talks to each uplink port (and vice versa), for aggregation-type systems.

A third factor is the packet length mix to use. It can be random, fixed length, or IMIX (Internet mix). In general, IMIX is a close approximation for today's traffic and it would the best choice. It is also important to specify packet content, since all 0 or 1 can change power measurement results, so random code is preferred.

9 Positioning in the network and energy efficiency

Figure 1 shows an exemplification of telecommunication network with an indication of equipment utilization in terms of traffic.

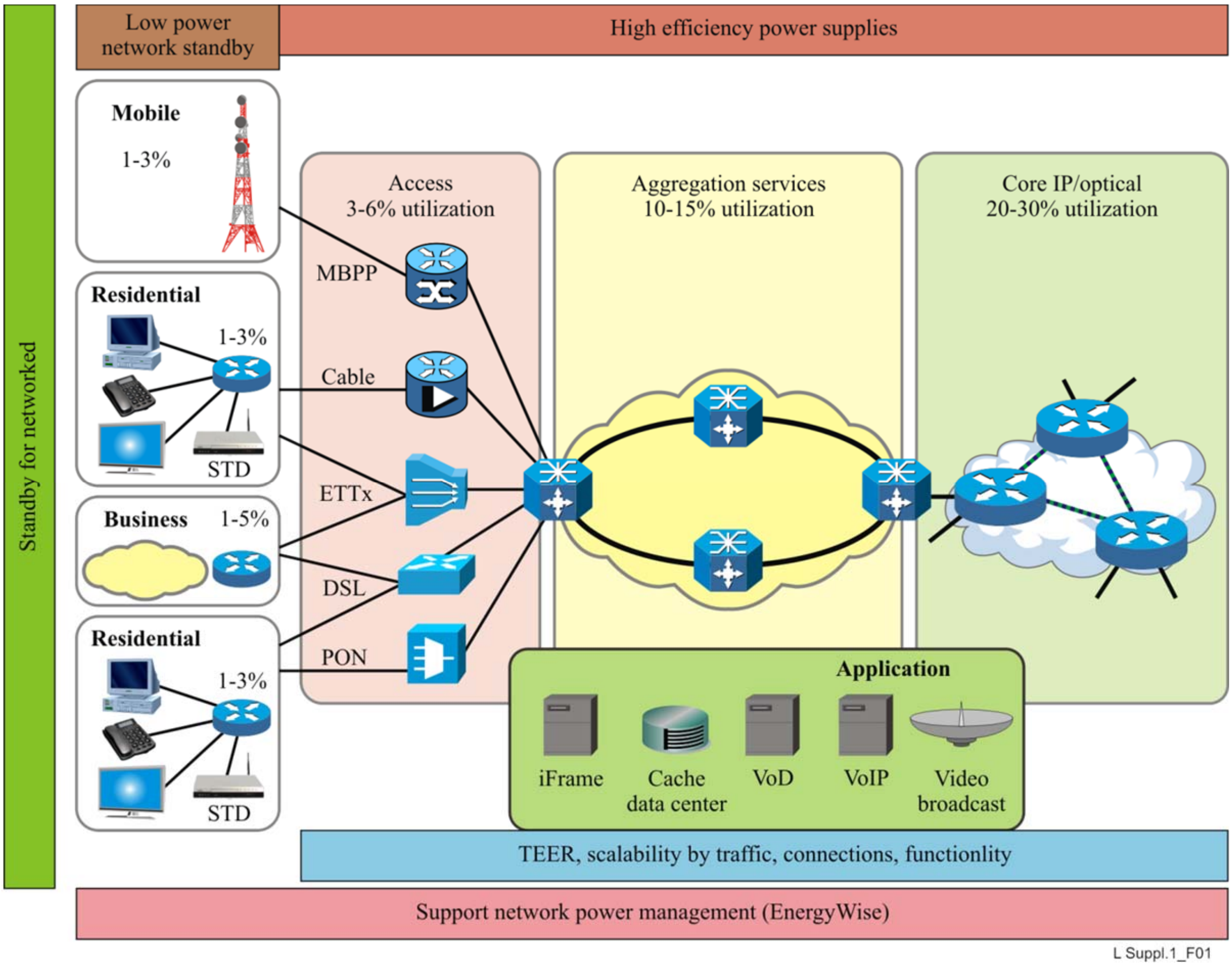

Figure 1 – Positioning in the network and energy efficiency

10 Metric definition: Compare products at points in the network

The next step towards energy conservation in networks is to evaluate the energy efficiency of individual components as part of the selection process during evolution or upgrade. It is important to consider this step after the other three steps, as it is necessary to understand energy use, the critical function and the system-wide impact of the component. Where multiple candidate devices are compared for energy efficiency, this evaluation must be done in the context of the first three steps to avoid negative results that can outweigh the benefits of the energy efficiency assessment.

A successful application of these rules will result in a metric for fair comparison of devices on the basis of energy efficiency. The resultant grading of devices will indicate which devices will most benefit the energy efficiency of real networks and will drive developers to improve their products in a manner that benefits network energy efficiency without degrading the critical network function.

The energy efficiency ratio (EER) is a proposed metric for enterprises and service provider products; it is defined as a ratio of maximum demonstrated throughput (T_d) to weighted power (energy consumption rate) P_w. It reflects both the performance of a system and real-life deployment conditions.

For systems with clear uplink-downlink sides, the maximum throughput, T_d, is generally defined as the maximum rate at which packets can be forwarded from uplink ports to downlink ports and vice versa. For other systems, it is defined as the aggregated maximum rate at which packets can be forwarded between all ports. Internet mix traffic, IMIX, is recommended for throughput testing, specifically the complete IMIX as shown in Table 1:

Table 1 – Simple IMIX traffic definition

Packet size (Bytes)	Proportion of total	Bandwidth (Load)
40	7 parts	6.856%
576	4 parts	56.415%
1500	1 part	36.729%

This set includes a random mix of packet lengths in a flat distribution (equal probability of each size), ensuring that a non-zero number of packets of every size is offered to the equipment under test (EUT). The complete IMIX has an average packet size of 427.0 bytes and a correlation value of 0.985 when compared to realistic Internet traffic.

Weighted power (energy consumption rate) is calculated according to Equation 3:

$$P_w = a \times P_{w1} + \; b \times P_{u2} + c \times P_{u3} \qquad (3)$$

where a, b and c are the traffic profile weights (a, b, c) corresponding to system utilization levels (u1, u2, u3), which vary according to equipment class and position in the network (see Tables 2 and 3). The power measured at each utilization level (u1, u2, u3) is represented by P_{u1}, P_{u2}, $P_{u3,}$ respectively.

The TEER value is then given by:

$$\text{TEER}= \frac{T_d}{P_w}$$

Another metric based on the same measurements, contained in [b-ITU-T L.1310], is energy efficiency rating (EER), which uses in the numerator the weighted throughput in place of the maximum throughput:

$$T_w = 0.1T_{u1} + 0.8T_{u2} + 0.1T_{u3}$$

$$\text{EER}= \frac{T_w}{P_w}$$

Tables 2 and 3 present utilization levels for router and switch as defined in [b-ITU-T L.1310].

Table 2 − Weighs and load profiles for routing equipment based on points in the network

	Representative utilization	% of utilization for energy measurements, u1; u2; u3	Weight multipliers a; b; c	Traffic profile complete IMIX
Access router	1-3%	0; 10; 100	0.1; 0.8; 0.1	(IPv4)
Edge router	3-6%	0; 10; 100	0.1; 0.8; 0.1	IPv4/v6/MPLS (multiprotocol label switching)
Core router	20-30%	0; 30; 100	0.1; 0.8; 0.1	IPv4/v6/MPLS

Table 3 − Weighs and load profiles for Ethernet switching equipment based on points in the network

	Representative utilization	% of utilization for energy measurements, u1; u2; u3	Weight multipliers a; b; c	Traffic profile complete IMIX, unicast
Access	1-3%	0; 10; 100	0.1; 0.8; 0.1	Ethernet
Distribution/ Aggregation	10-15%	0;10;100	0.1; 0.8; 0.1	Ethernet
Core	15-20%	0; 30; 100	0.1; 0.8; 0.1	Ethernet
Data centre	12-18%	0; 30; 100	0.1; 0.8; 0.1	Ethernet

The intent of the small networking equipment (SNE) metric is to provide the ability to compare energy efficiency of similar small networking devices intended for home/domestic or small office use; it is not an absolute metric.

Definitions used for SNE:

Active mode	Each port, WAN, LAN and Wi-Fi, has at least one connection (see [b-Code of Conduct])
Idle mode	The same as the Active mode, except that there is no user data traffic (NOTE – This is not zero traffic, as service and protocol supporting traffic is present.) i.e., device not being used, but ready
Low power mode	WAN port is connected; Wi-Fi is active with no connections, LAN ports not connected (as specified in [b-Code of Conduct])
Stand-by mode	Product is not functional, only reactivation option available (see b-EC 1275/2008])
Throughput	Maximum non-drop data rate between WAN and LAN port in ingress direction
Line rate/speed	The maximum possible bit rate at which it is possible to transmit or receive

$$EER = \frac{0.35 \times Tidle + 0.45 \times Tlowpower + 0.15 \times T\max}{0.35 \times P\,idle + 0.45 \times Plowpower + 0.15 \times P\max} \tag{4}$$

For interfaces with throughput (T) sensitive to distance, T is defined as:

$$T = 0.5\ (T_{20\%\text{ of max distance}} + T_{80\%\text{ of max distance}})$$

Power measured is averaged over five minutes. During the measurement of idle power, an IP ping is sent through the unit under test every 30 seconds.

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