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OF OUTSIDE PLANT

**Energy efficiency metrics and measurement
methods for telecommunication equipment**

Recommendation ITU-T L.1310

ITU-T



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Energy efficiency metrics and measurement methods for telecommunication equipment

Summary

Recommendation ITU-T L.1310 contains the definition of energy efficiency metrics test procedures, methodologies and measurement profiles required to assess the energy efficiency of telecommunication equipment.

Energy efficiency metrics and measurement methods are defined for telecommunication network equipment and small networking equipment.

These metrics allow for the comparison of equipment within the same class, e.g., equipment using the same technologies.

The comparison of equipment in different classes is out of the scope of this Recommendation.

History

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Introduction

In general, energy efficiency is defined as the ratio of two different energy consumption values bearing the same functional unit (i.e., the ratio of useful work (energy) to total work (energy)). This definition is not easily applied to a telecommunication system, as it does not consider the telecommunication performance of the equipment being measured.

Therefore, for the purposes of this Recommendation, energy efficiency will be defined as the relationship between the specific functional unit for a piece of equipment (i.e., the useful work of telecommunications) and the energy consumption of that equipment. For example, when transmission time and frequency bandwidth are fixed, a telecommunication system that can transport more data (in bits) with less energy (in joules) is considered to be more energy efficient.

For this reason, metrics that can evaluate the performance of a piece of equipment against its energy consumption are to be defined.

To facilitate the measurement of metrics, it is typical to use the measurement of power, rather than energy consumption, as the two quantities are correlated by time.

Recommendation ITU-T L.1310

Energy efficiency metrics and measurement methods for telecommunication equipment

1 Scope

This Recommendation specifies the principles and concepts of energy efficiency metrics and measurement methods for telecommunication network equipment.

This Recommendation also specifies the principles and concepts of energy efficiency metrics and measurement methods for small networking equipment used in the home and small enterprise locations.

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.

- [ATIS-0600015.02.2009] ATIS-0600015.02.2009, *Energy Efficiency for Telecommunication Equipment: Methodology for Measurement and Reporting – Transport Requirements.*
- [ATIS-0600015.03.2013] ATIS-0600015.03.2009, *Energy Efficiency for Telecommunications Equipment: Methodology for Measurement and Reporting for Router and Ethernet Switch Products.*
- [ETSI ES 203 215] ETSI ES 203 215 V1.2.1 (2011), *Environmental Engineering (EE) Measurement Methods and Limits for Power Consumption in Broadband Telecommunication Networks Equipment.*
- [ETSI TS 102 706] ETSI TS 102 706 V1.3.1 (2013-07), *Environmental Engineering (EE) Measurement method for energy efficiency of wireless access network equipment.*
- [ISO 14040] ISO 14040:2006, *Environmental management – Life cycle assessment – Principles and framework.*
- [ISO/IEC 17025] ISO/IEC 17025:2005, *General requirements for the competence of testing and calibration laboratories.*

3 Definitions

3.1 Terms defined elsewhere

None.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 active mode: For small networking equipment, this is the operational mode where all ports (WAN and LAN) are connected, with at least one Wi-Fi connection, if a Wi-Fi function is available.

3.2.2 energy: "The capacity for doing work". In the telecommunication systems, where the primary source of energy is electricity, energy is measured in joules.

3.2.3 functional unit (based on [ISO 14040]): A performance representation of the system under analysis. For example, for transport equipment, the functional unit is the amount of information transmitted, the distance over which it is transported and its rate in Gbit/s. Sometimes the term is used to indicate useful output or work.

3.2.4 idle mode: For small networking equipment, this means the same as active mode, but with no user data traffic (it is not zero traffic, as service and protocol supporting traffic are present) being used, although it is ready to be used (U1 in routers part).

3.2.5 low power (sleep) mode: For small networking equipment, this means a state that happens after the device detects no user activity for a certain period of time and reduces energy consumption. For this state, no user-facing LAN ports are connected; the Wi-Fi is active but no clients are connected. The WAN port may be inactive. The device will reactivate on detecting a connection from a user port or device.

3.2.6 small networking device: A networking device with fixed hardware configuration, designed for home/domestic or small office use, with less than 12 ports. This device can have wireless functionality implemented. Wireless functionality is not considered a port.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

AC	Alternating Current
ADSL2+	Asymmetric Digital Subscriber Line 2 transceiver extended bandwidth
BSC	Base Station Controller
BTS	Base Transceiver Station
CDMA	Code Division Multiple Access
DC	Direct Current
DSLAM	Digital Subscriber Line Access Multiplexer
EDGE	Enhanced Data for GSM Evolution
EER	Energy Efficiency Rating
GEPON	Gigabit Ethernet Passive Optical Network
GPON	Gigabit Passive Optical Network
GSM	Global System for Mobile Communications
HSPA	High Speed Packet Access
IF	Interface
IMIX	Internet MIX traffic
LAN	Local Area Network
LTE	Long Term Evolution

MAC	Media Access Control
MPLS	Multiprotocol Label Switching
MSAN	Multiservice Access Node
NNI	Network-Network Interface
OADM	Optical Add-Drop Multiplexer
OC	Optical Carrier
OLT	Optical Line Termination
ONT	Optical Network Termination
OTN	Optical Transport Network
OTU	Optical Transport Unit
OXC	Optical Cross Connect
P2P	Point-to-Point
PF	Power Factor
PON	Passive Optical Network
PONIF	Passive Optical Network Interface
POTS	Plain Old Telephone Service
PSU	Power Supply Unit
ROADM	Reconfigurable Optical Add-Drop Multiplexer
RBS	Radio Base Station
RNC	Radio Network Controller
SDH	Synchronous Digital Hierarchy
SONET	Synchronous Optical Network
STM	Synchronous Transport Module
SW	Switch
TDM	Time Division Multiplex
TEER	Telecommunications Energy Efficiency Ratio
UNI	User Network Interface
VDSL2	Very high bit rate Digital Subscriber Line
WAN	Wide Area Network
WCDMA	Wideband Code Division Multiple Access
WDM	Wavelength Division Multiplexing
WiMAX	Worldwide Interoperability for Microwave Access

5 Conventions

In this Recommendation, the term "energy consumption" is used to describe the transformation of input energy into the functional unit and waste within telecommunication systems.

For all practical purposes, it is assumed that telecommunication system devices act as single entities, with metrics estimating the total efficiency of input energy within the entire telecommunication device.

In this Recommendation, the term "energy efficiency" is used to describe the ability of a telecommunication system to minimize energy waste, although "power efficiency" could also have been used for the same purpose.

6 Metrics definitions

6.1 General

The energy efficiency metric is typically defined as the ratio between the functional unit and the energy necessary to deliver the functional unit; the higher the value of the metric, the greater the efficiency of the equipment.

The inverse metric, energy divided by functional unit, could be used as an alternative.

The following clauses contain detailed metric definitions and test methodologies for various telecommunication equipment.

The energy efficiency rating (EER) is a metric generally defined as a functional unit divided by the energy used. Various types of equipment have their own EER definitions

6.2 Energy efficiency hierarchy

An energy efficiency metric can be defined at the network level, the equipment/system level and the component level. In this Recommendation, only metrics at the equipment/system level are considered as mandatory; metrics at the component level are given as suggestions only, and are not mandatory.

Metrics at the network level are under study.

6.2.1 Energy efficiency at the network level

Network level metrics are used to evaluate the energy efficiency of an entire network or part of it (e.g., the access network of an operator). They are normally used to evaluate a network for internal operator use or to satisfy an environmental assessment. For this Recommendation, the network level is considered a metric that will cover not only one single product but also a telecommunication network composed of different interworking equipment.

6.2.2 Energy efficiency at the equipment/system level

Equipment/system level metrics are mostly used to compare telecommunication equipment of the same technology. They evaluate the overall energy efficiency performance at the equipment/system level, which is considered as a "single box" or "single entity", from the measurement point of view.

6.2.3 Energy efficiency at the component level

Component-level metrics can be used in the design, development and manufacture of energy efficient equipment. They regard equipment as an "open box" and evaluate the energy efficiency performance of its individual components. Measuring and understanding the energy efficiency or energy consumption of each component within the equipment helps to identify the bottlenecks and key components in a system with regard to energy saving. It should be kept in mind that these kinds of metrics may lead to sub-optimizations unless considered in the context of the overall equipment's energy efficiency.

6.3 Load-proportional efficiency

There are classes of telecommunication equipment (e.g., time division multiplex (TDM) switches), where the functional unit is stationary and does not change through the active-use phase.

However, a vast number of telecommunication devices operate under variable-load conditions, where the measured value of a functional unit can fluctuate based on user demand.

Ideally, telecommunication devices should be able to reduce their energy consumption in proportion to the functional unit produced. However, this goal presents different challenges and opportunities in recognizing and responding to low utilization periods.

In order to capture such capabilities, where available, this Recommendation defines the EER as a weighted, load-proportional metric.

6.4 Metrics robustness

To allow reliable equipment comparisons based on metrics, the metrics should be obtained in strict accordance with ITU-T documentation and the referenced standardization documents.

Whenever the complete application of this Recommendation is not possible for technological reasons (e.g., new technologies may not be covered or may make measurement implementation difficult), manufacturers can declare a metric value. Such declared metrics should be clearly identified and differentiated from a value obtained through standardized measurement methodologies.

6.5 Metrics and equipment modularity

Telecommunication equipment is commonly available in both fixed and modular form factors. In the latter case, telecommunication equipment can be configured in various ways, which may affect its efficiency ratings. Throughout this Recommendation, the following approach to modularity is recommended:

1. Metrics for modular telecommunication systems shall be obtained using the most common set-up and configurations. The metrics shall be reported along with the telecommunication equipment configuration used.
2. Metrics for other telecommunication equipment configurations can be obtained by using metrics obtained from partial configurations. This methodology is described in the relevant measurement procedures. (For example, in [ATIS-0600015.02.2009] this is called the "modular method", and in [ETSI ES 203 215] it is called the "alternative method").

7 General test methodology

7.1 Environmental conditions

7.1.1 Temperature

The equipment should be evaluated at an ambient temperature of $25\pm 3^{\circ}\text{C}$. The equipment itself should stay online or operate at this air temperature for no less than three hours prior to the test. No ambient temperature changes are allowed until the test is complete.

For some types of equipment, additional measurements are required to test the energy efficiency at higher/lower temperatures as reported in the detailed equipment specific requirement.

7.1.2 Humidity

The equipment should be evaluated at a relative humidity of 30% to 75%.

7.1.3 Air pressure

The equipment should be evaluated at a site pressure between 860 to 1'060 hPa. No targeted airflows are allowed except for regular ambient room, data centre or rack cooling.

7.2 Electrical conditions

7.2.1 DC voltage

The direct current (DC) voltage powering the equipment shall be chosen in the range of -55.5 to -52.5 V (-54 ± 1.5 V).

7.2.2 AC voltage and frequency

The input to the equipment (all active feeds) should be the nominal specified voltage $\pm 5\%$ and the specified frequency $\pm 1\%$. If the equipment can work at different nominal voltages, the measurement shall be executed at one of the specified nominal voltages.

An external alternating current (AC)/DC adapter is considered an integral part of the equipment.

NOTE – ITU-T is developing Recommendations on AC/DC adapters; the AC/DC adapter should be in line with these Recommendations if applicable.

7.3 Metrology requirements

Every active power feed should have the power (current) meter installed in the power line with a desired accuracy not less than $\pm 1\%$ of the actual power level. The power meter should include correction for the power factor (PF) on AC feeds; otherwise, it will be necessary to also record the PF in the measurement report. All energy consumption calculations are based on averaging multiple readings over the course of measurements. Power meters should be able to produce no less than 100 evenly-spaced readings in every full test cycle duration.

All measurement instruments used should be calibrated by a counterpart national metrology institute, be within the calibration due date, and the measurement tolerance must be within $\pm 1\%$:

1. Power sources used to provide power to the equipment under test shall be capable of providing a minimum of 1.5 times the power rating of the equipment under test.
2. Power measurement instruments (such as voltmeters and ampere meters or power analysers) shall have a resolution of 0.5% or better. AC power measurement instruments shall have the following minimum characteristics:
 - i) a minimum digitizing sample rate of 40 kHz
 - ii) input circuitry with a minimum bandwidth of 80 kHz
 - iii) capability of accurate readings of waveforms having a crest factor up to at least 5
 - iv) power factor correction and reporting.

8 Reporting format

This Recommendation does not endorse any specific reporting formats. The general requirements for test reports are contained in [ISO/IEC 17025].

However, it is worth noting that any results that are collected under this methodology are intended to be reproducible. For this reason, the minimum set of information (beyond the actual set of measurements) reported should include the following documentation:

- All equipment software versions, hardware board revisions and device configurations used during the test. All commands applied to equipment for the purposes of static reconfiguration or run-time queries performed during the test should be disclosed.

- Traffic generator/measurement tool, actual voltage in power feeds and ambient (environmental) conditions at test site.
- The test set-up should be fully described, including topology, the choice of offered load structure and test actions within a range of possible choices.

9 DSLAM, MSAM GPON GEPON equipment

9.1 Metric for DSLAM, MSAM GPON GEPON equipment

This clause defines the equipment level metrics for digital subscriber line access multiplexer (DSLAM), multiservice access node (MSAN), gigabit passive optical network (GPON) and gigabit Ethernet passive optical network (GEPON) equipment. In particular, this clause covers:

- DSLAM equipment
- MSAN equipment
- GPON and GEPON optical line termination (OLT) equipment.

For these equipment typologies, the most commonly used metric is the P_{port} , which considers the number of ports at a fixed load as a functional unit.

Such a metric is assumed to refer to a fully equipped configuration taking into account the line cards with the same technology (e.g., all asymmetric digital subscriber line 2 transceiver extended bandwidth (ADSL2+) cards, all very high bit rate digital subscriber line (VDSL2) cards, all GPON cards, all plain old telephone service (POTS) cards). Moreover, such line cards must refer to the same profile/state.

Equipment with line cards working at different profiles/states shall be characterized with different metric values for each specific profile/state.

$$P_{\text{port}} = P_{\text{EQ}} / N_{\text{ports}} \text{ [W/port]} \quad (9-1)$$

where:

P_{EQ} is the power (in watts) of a fully equipped wireline network equipment with all its line cards working in a specific profile/state (e.g., all VDSL2 subscriber lines in L0 state, all ADSL2+ subscriber lines in L2 state).

N_{ports} is the maximum number of ports served by the broadband network equipment under test.

9.2 Equipment test methodologies for broadband access technologies

This clause defines measurement procedures for broadband fixed access technologies.

9.2.1 DSLAM and MSAN network equipment

For test methodologies, equipment configuration and set-up, the methodology reported in clause 5.2 of [ETSI ES 203 215] shall apply, with the modification of general measurement conditions presented in clause 7 of this Recommendation.

9.2.2 GPON OLT network equipment

For test methodologies, equipment configuration and set-up, the methodology reported in clause 5.2 of [ETSI ES 203 215] shall apply, with the modification of general measurement conditions presented in clause 7 of this Recommendation.

9.2.3 GEPON OLT network equipment

For OLT, 1 Gbit/s for both the network-network interface (NNI) side and the passive optical network (PON) side is used, and the following three settings for the load factor:

1. 100% load factor: a state where 64-byte frames flow continuously (without interruption)
2. 50% load factor: the state where 512-byte frames flow 50% of the time
3. 0% load factor: the state where frames are not flowing.

Furthermore, in stipulating the load factor, the load factor specified by the data entry side shall be used (NNI or user network interface (UNI)), see Figure 9-1.

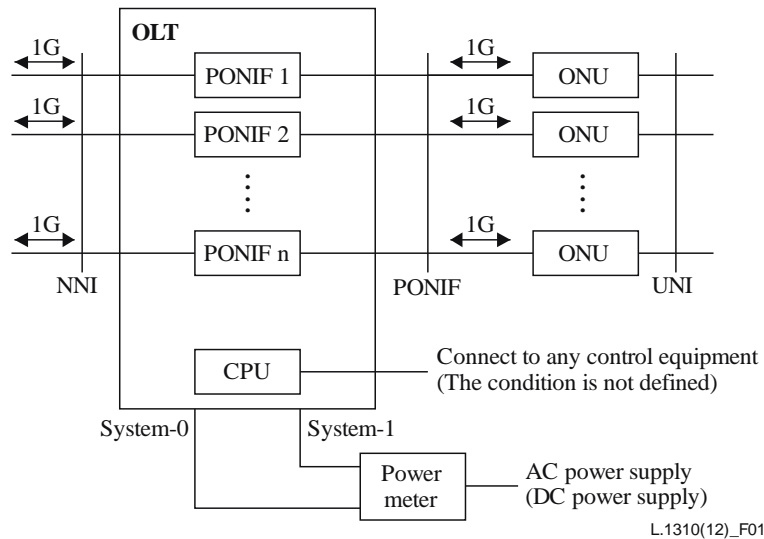


Figure 9-1 – Description of GEPON OLT equipment

$$P_{EQ} = (\text{power at 100\% load} + \text{power at 50\% load} + \text{power at 0\% load}) / 3 \quad (9-2)$$

10 Wireless access technologies

Wireless access technologies cover the following radio access technologies: global system for mobile communications (GSM)/ enhanced data for GSM evolution (EDGE), code division multiple access (CDMA), wideband CDMA (WCDMA), worldwide interoperability for microwave access (WiMAX) and long term evolution (LTE).

A wireless access network consists of more than one element, a radio base station (RBS), a controller, etc.

An RBS is a network component that serves one or more sectors and has radio frequency (RF) interfaces to mobile stations through the air interface, and has metallic or optical interfaces to a wireless network infrastructure (base station controller (BSC), radio network controller (RNC) or mobility management entity). Within this Recommendation, RBS can be a base transceiver station (BTS) (for GSM/EDGE and cdma2000), a NodeB (for WCDMA/ high speed packet access (HSPA)), an eNodeB (for LTE) or a base station (for WiMAX). The controller functionality within an RBS has interfaces to the core network or core network simulator.

As the RBS energy consumption is the dominant part of the total energy consumption of a wireless access network, this Recommendation covers how to calculate RBS energy efficiency which takes into account only RBS energy consumption when defining the total power of wireless access networks.

In this Recommendation only the metric for RBS is considered.

However, since the functionalities located externally to the RBS in the core network can affect the RBS power and "useful unit", these functionalities have also been taken into account.

Low, medium and high load modes have been defined for the RBS usage profile. Idle mode and max load cases have been omitted intentionally for the following reasons:

- Idle mode is a state rarely used in a practical radio network. An RBS transmits, as minimum, a pilot and broadcast channels.
- Max load is typically avoided by network design. It might occur on exceptional events a few times a year. If peak load is reached repeatedly, an operator will do a capacity upgrade.
- Testing of additional modes will increase complexity and testing time without providing significant additional information and will have a low impact on the average power consumption.

10.1 Metrics for wireless access technologies

The metrics for RBSs are defined in terms of coverage or in terms of traffic and are defined in [ETSI TS 102 706].

[ETSI TS 102 706] contains the definition of independent traffic and dependent metrics, called static and dynamic measurement methods, respectively.

10.2 Tests methodologies for wireless access technologies

For test methodologies, equipment configuration and set-up, the methodology reported in [ETSI TS 102 706] shall apply, with the modification of general measurement conditions presented in clause 7 of this Recommendation.

11 Routers, Ethernet switches

11.1 Metrics for routers and Ethernet switches

The metrics adopted for routers and switches depend on the total throughput of the equipment, see [ATIS-0600015.03.2013] for an explanation of the total throughput, testing topologies and traffic patterns.

This clause addresses equipment which are categorized as enterprise, service provider and branch office routers, and Ethernet switch equipment.

The proposed metric is:

$$EER = T_i / P_w \quad [\text{Mbit/ss/W}] \quad (11-1)$$

where:

T_i is weighted throughput

P_w is weighted power (energy consumption rate)

$$T_i = a \times T_{u1} + b \times T_{u2} + c \times T_{u3} \quad (11-2)$$

$$P_w = a \times P_{u1} + b \times P_{u2} + c \times P_{u3} \quad (11-3)$$

where:

(a, b, c) = relative weights for utilization levels, where $a + b + c = 1$; see Tables 11.1 and 11.2.

(P_{u1} , P_{u2} , P_{u3}) = power measured at respective utilization levels

(T_{u1} , T_{u2} , T_{u3}) = throughput measured at respective utilization levels; see Tables 11.1 and 11.2.

Table 11.1 – Class definitions, EER calculation parameters and load profiles for routing equipment

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

Table 11.2 – Class definitions, EER calculation parameters and load profiles for Ethernet switching equipment

Class	Representative utilization	% of utilization for energy measurements, u1, u2, u3	Weight multipliers a, b, c	Traffic profile simple IMIX, unicast
Access	1-3%	0, 10, 100	a=0.1, b=0.8, c=0.1	Ethernet
High speed access	5-8%	0, 10, 100	a=0.1, b=0.8, c=0.1	Ethernet
Distribution/Aggregation	10-15%	0, 10, 100	a=0.1, b=0.8, c=0.1	Ethernet
Core	15-20%	0, 30, 100	a=0.1, b=0.8, c=0.1	Ethernet
Data centre	12-18%	0, 30, 100	a=0.1, b=0.8, c=0.1	Ethernet

Complete methodology for testing is presented in [ATIS-0600015.03.2013]. The weight multipliers a, b, c are established by [ATIS-0600015.03.2013] considering the average traffic distribution during a day.

11.2 Tests methodologies for routers and packet switches (Ethernet, MPLS, etc.)

For test methodologies, equipment configuration and set-up, the methodology reported in [ATIS-0600015.03.2009] shall apply, with the modification of general measurement conditions presented in clause 7 of this Recommendation.

12 Energy efficiency metric for small networking devices

12.1 Metrics for small networking devices

The metrics adopted for small networking devices intended for home/domestic or small office use is:

$$EER = \frac{0.35T_{idle} + 0.5T_{lowpower} + 0.15T_{Maximum}}{0.35P_{idle} + 0.5P_{lowpower} + 0.15P_{Maximum}} \quad (\text{Mbit/s/W}) \quad (12-1)$$

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

$$T = 0.5(T_{20\% \text{ of max distance}} + T_{80\% \text{ of max distance}}) \quad (12-2)$$

Throughput: for small network equipment, this is the maximum non-drop data rate between wide area network (WAN) and local area network (LAN) ports in the ingress direction.

Line rate/speed: for small network equipment, this is the maximum possible number of transmitted/received bits.

Power shall be averaged over 5 minutes, taking measurements every 30 seconds. During idle power, IP ping shall be sent via the user interface.

12.2 Test methodologies for small networking devices

The reference methodology to be used to measure the maximum throughput is reported in clause 6.4.1 of [ATIS-0600015.03.2013] for the "network/uplink" and "access/downlink" configurations.

With reference to clause 6.5 of [ATIS-0600015.03.2009], the test methodology is as follows:

Step 1: Qualification

Small network equipment shall be measured following the method described in clause 6.5.1 of [ATIS-0600015.03.2013].

Step 2: Full load

Small network equipment shall be measured following the method described in clause 6.5.2 of [ATIS-0600015.03.2009].

Step 3: Utilization

This step of [ATIS-0600015.03.2013] shall not be applicable to small network equipment.

Step 4: Idle load

Small network equipment shall be measured following the method described in clause 6.5.3 of [ATIS-0600015.03.2009].

Step 5: Low power (sleep)

Depending on the implementation, the low power (sleep) mode shall be activated. Power will be measured and recorded for a period of 15 minutes after activation of the mode; the average power will then be calculated and used in Equation 12-1.

The manufacturer shall declare how to activate the low power (sleep) mode e.g., disconnect the LAN port.

The activation modality will be recorded in the test report.

13 WDM/TDM/OTN transport MUXes/switches

13.1 Metrics for WDM/TDM/OTN transport MUXes/switches

The metrics for transport equipment excluding microwave radio equipment are defined in [ATIS-0600015.02.2009].

13.2 Test methodologies for WDM/TDM/OTN transport MUXes/switches

For test methodologies, equipment configuration and set-up, the methodology reported in [ATIS-0600015.02.2009] shall be applied, with the modification of general measurement conditions presented in clause 7 of this Recommendation.

14 Converged packet optical equipment

14.1 Metrics for converged packet optical equipment

The metrics for converged packet optical equipment with packet signal and TDM signal functions are defined in Annex A.

The metrics for converged packet optical equipment with packet signal, TDM signal and wavelength division multiplexing (WDM) signal functions are defined in Annex B.

14.2 Test methodologies for converged packet optical equipment

14.2.1 Test methodologies for converged packet optical equipment with packet signal and TDM signal functions

For test methodologies, equipment configuration and set-up, the methodology described in Annex A shall be applied, with the modification of general measurement conditions presented in clause 7.

14.2.2 Test methodologies for converged packet optical equipment with packet signal, TDM signal and WDM signal functions

For test methodologies, equipment configuration and set-up, the methodology described in Annex B shall be applied, with the modification of general measurement conditions presented in clause 7.

Annex A

Metrics and measurement methodologies for converged packet optical equipment with both packet signal and TDM signal functions

(This annex forms an integral part of this Recommendation.)

A.1 Equipment definition

Converged packet optical equipment I refers to a type of transport equipment which transports (switches) multiple types of signals such as packet signals and TDM signals.

The definition of these types of signals shall be as follows:

Packet signals: signals which include a media access control (MAC) address relayed via ISO OSI layer 2 (data link layer) or an IP address relayed via ISO OSI layer 3 (network layer) or a label with routing information.

TDM signals: TDM signals, such as synchronous transport module (STM)-n/OC-n/ optical transport unit (OTU)-n signals defined in synchronous digital hierarchy (SDH)/synchronous optical network (SONET)/ optical transport network (OTN), as well as analogue signals conveying image or voice over telephone lines.

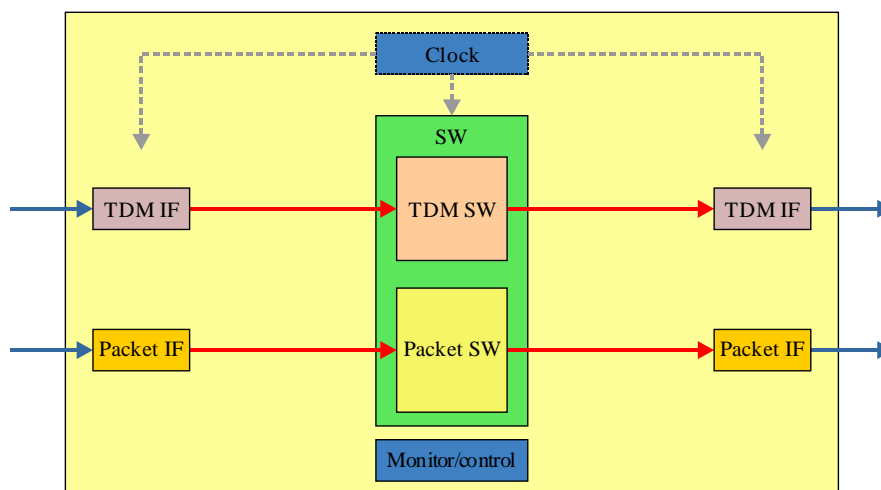
The scope of this Recommendation shall cover the following four configuration models.

Model I: configuration where TDM signals and packet signals in both directions are switched independently.

Model II: configuration where some TDM signals are converted into packets and switched via the packet switch, or some packet signals are depacketed and switched via the TDM switch.

Model III: configuration where all TDM signals are converted into packet signals and switched via the packet switch.

Model IV: configuration where all packet signals are depacketed and switched via the TDM switch.



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Figure A.1 – Converged packet optical equipment I configuration (Model I)

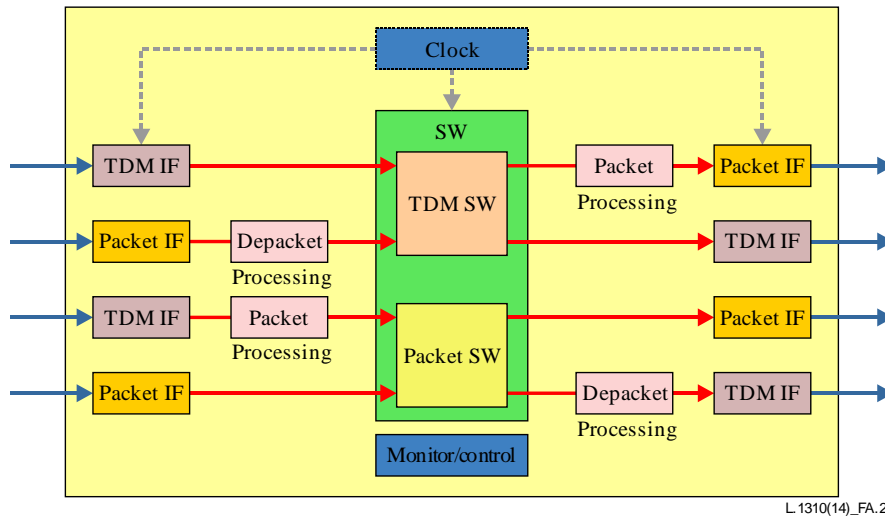


Figure A.2 – Converged packet optical equipment I configuration (Model II)

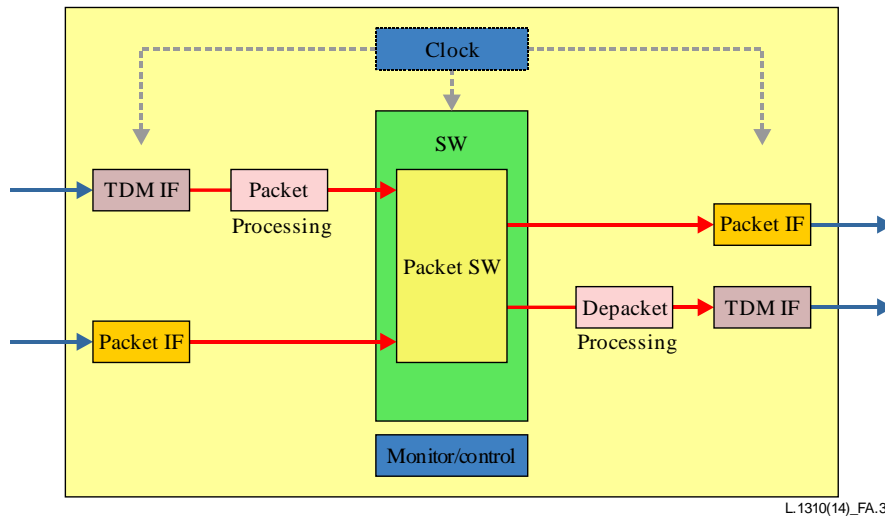


Figure A.3 – Converged packet optical equipment I configuration (Model III)

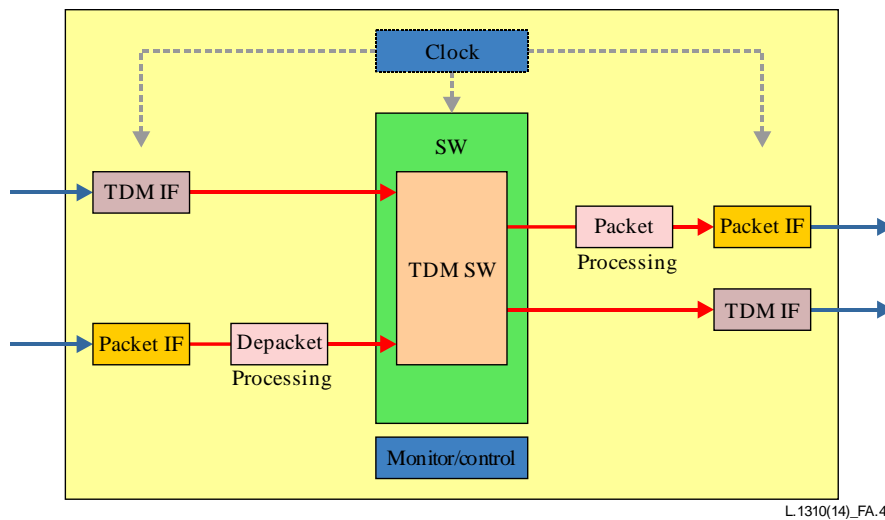


Figure A.4 – Converged packet optical equipment I configuration (Model IV)

A.2 Energy efficiency metrics

The metrics for converged packet equipment shall be the maximum throughput per average power consumption.

The metrics (telecommunications energy efficiency ratio (TEER)) designated by Alliance for Telecommunications Industry Solutions (ATIS) for transport equipment is as follows:

$$\begin{aligned} \text{TEER}_{\text{CERT}} &= D_{\text{TEER}} / P_{\text{TEER-CERT}} \\ &= \Sigma D_i / \{(P_{\text{CERT-0}} + P_{\text{CERT-50}} + P_{\text{CERT-100}})/3\} \end{aligned} \quad (\text{A-1})$$

where:

$\text{TEER}_{\text{CERT}}$: certified TEER measured at a specific configuration

D_{TEER} : total data rate (bps)

$P_{\text{TEER-CERT}}$: measured power consumption (W)

D_i : data rate (bps) at a given interface i

$P_{\text{CERT-0}}$: measured power consumption (W) at a 0% data traffic utilization

$P_{\text{CERT-50}}$: measured power consumption (W) at a 50% data traffic utilization

$P_{\text{CERT-100}}$: measured power consumption (W) at a 100% data traffic utilization

Converged packet optical equipment with packet and TDM functions, interface cards are added depending on the data usage volume. Therefore, in general,

$$(P_{\text{CERT-0}} + P_{\text{CERT-50}} + P_{\text{CERT-100}})/3 \doteq (P_{\text{CERT-0}} + P_{\text{CERT-100}})/2 \quad (\text{A-2})$$

Thus, in practice, $\text{TEER}_{\text{CERT}}$ for converged packet optical equipment shall be as follows:

$$\begin{aligned} \text{TEER}_{\text{CERT}} &= \Sigma D_i / \{(P_{\text{CERT-0}} + P_{\text{CERT-100}})/2\} \\ &= \text{Maximum throughput/average power consumption} \end{aligned} \quad (\text{A-3})$$

a) The maximum throughput for converged packet optical equipment I

$$= \sqrt{(A^2 + B^2)}/2 \quad (\text{A-4})$$

where:

A: maximum throughput (Gbps) of packet functions

(port speed (Gbps) \times number of ports \times number of slots)

B: maximum throughput (Gbps) of TDM functions

(port speed (Gbps) \times number of ports \times number of slots)

b) The average power consumption for converged packet optical equipment I

$$= (P_{\text{idle}} + P_{\text{max}}) / 2 \quad (\text{A-5})$$

where:

P_{idle} : power consumption (W) of total equipment with no data throughput with minimum components and path configuration

P_{max} : power consumption (W) of total equipment during main signal transmission with maximum component configuration

The metric of converged packet optical equipment I is:

$$\text{EER} = \sqrt{(A^2 + B^2)}/2 / \{(P_{\text{idle}} + P_{\text{max}}) / 2\} \quad (\text{A-6})$$

A.3 Measurement methodology

This clause defines measurement procedures for converged optical equipment I.

a) Interface

i) Selection of the interface

Select the interface where the transmission capacity calculated using the following formula will be maximized for TDM and/or packet.

Transmission capacity: port speed (Gbps) × number of ports × number of slots

ii) Function combination patterns

For the TDM interface and packet interface, conduct measurements selecting the configurable pattern at NNI side/user network interface (UNI) side from below:

- TDM (NNI), TDM (UNI)
- TDM (NNI), packet (UNI)
- packet (NNI), TDM (UNI)
- packet (NNI), packet (UNI)

Select the pattern in which maximum throughput will be reached for TDM/packet respectively.

iii) Interface when measuring P_{\max} configuration

Use the interface selected in i), and configure using maximum slot/maximum port.

iv) Interface when measuring P_{idle} configuration

Use the interface selected in i), and configure using 1 slot/1 port I/O.

In the case of ring models, set up with a single-side path or convert the result to 1 slot/1 port configuration.

v) Configuration for redundancy

There is no specification of interface. When using an interface, calculate the transmission capacity with the redundant interface as part of the main unit.

There is no specification for common components (It shall be possible to have no common components).

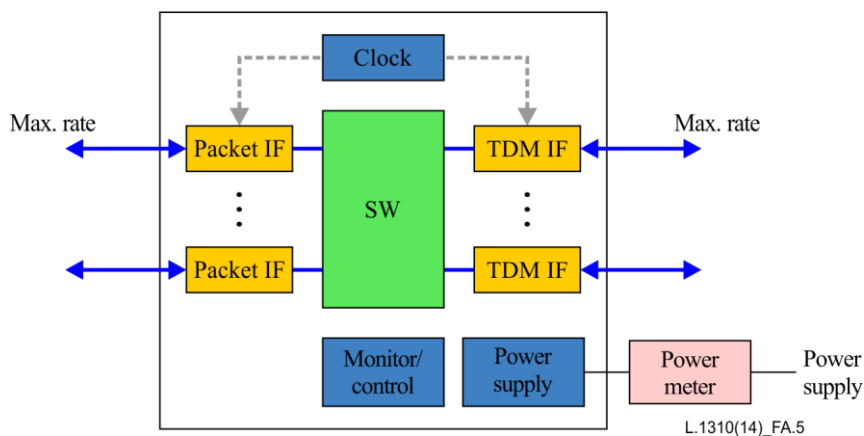


Figure A.5 – Example of maximum component configuration for measuring P_{\max}

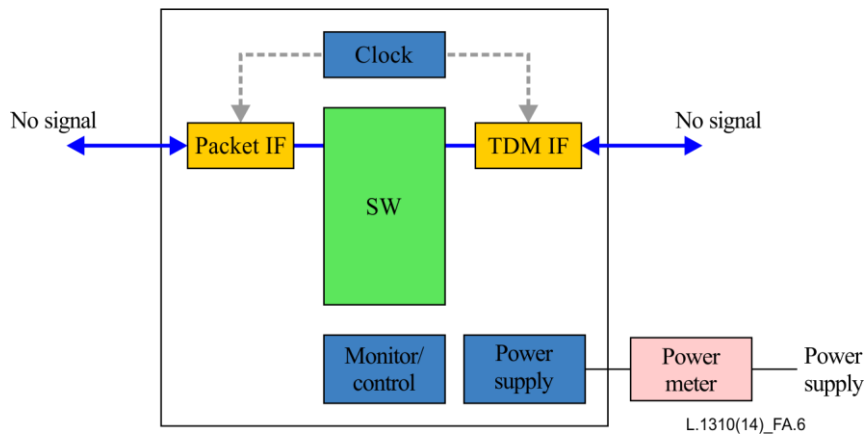


Figure A.6 – Example of minimum component and path configuration for measuring P_{idle}

- b) Transmission load
 - i) Transmission load when measuring P_{max}
Maximum rate when configured at maximum capacity
 - ii) Transmission load when measuring P_{idle}
Non-transmitting state when configured with minimum paths at minimum capacity
- c) Environmental conditions
Environmental conditions are defined in clause 7.
- d) Test voltage
Test voltage is defined in clause 7.
- e) Number of equipment measured
There is no stipulation on number of equipment to be measured, but if multiple equipment is measured, indicate the average value.
- f) Number of measurements
There is no stipulation on number of measurements, but if measurements are taken multiple times, indicate the average value.
- g) Measurement precision
Not stipulated.

Annex B

Metrics and Measurement methodologies for converged packet optical equipment with packet signal, TDM signal and WDM signal functions

(This annex forms an integral part of this Recommendation.)

B.1 Equipment definition

Converged packet optical equipment II refers to a type of transport equipment which transports (switches) multiple types of signals such as packet signals, TDM signals and WDM signals.

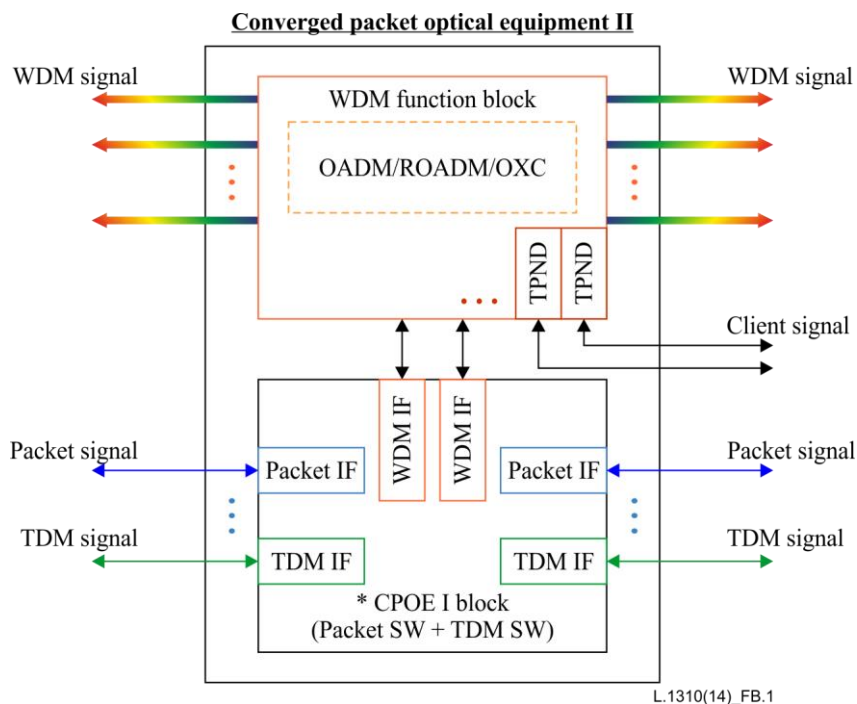
The definition of these types of signals shall be as follows:

Packet signals: signals which include a MAC address relayed via ISO OSI layer 2 (data link layer) or an IP address relayed via ISO OSI layer 3 (network layer) or a label with routing information.

TDM signals: TDM signals, such as STM-n/OC-n/OTU-n signals defined in SDH/SONET/OTN, as well as analogue signals conveying image or voice over telephone lines.

WDM signals: WDM signals, which multiplex multiple optic signals with different wavelengths.

The scope of this Annex shall cover the following configuration model:



*CPOE I : Converged Packet Optical Equipment I

Figure B.1 – Converged packet optical equipment II configuration

Converged packet optical equipment II can be composed of multiple converged packet optical equipment I.

B.2 Energy efficiency metrics

The metrics for converged packet optical equipment shall be the maximum throughput per average power consumption.

The metrics (TEER) designated by ATIS for transport equipment is as follows:

$$\begin{aligned} \text{TEER}_{\text{CERT}} &= D_{\text{TEER}} / P_{\text{TEER-CERT}} \\ &= \Sigma D_i / \{(P_{\text{CERT-0}} + P_{\text{CERT-50}} + P_{\text{CERT-100}})/3\} \end{aligned} \quad (\text{B-1})$$

where:

$\text{TEER}_{\text{CERT}}$: certified TEER measured at a specific configuration

D_{TEER} : total data rate (bps)

$P_{\text{TEER-CERT}}$: measured power consumption (W)

D_i : data rate (bps) at a given interface i

$P_{\text{CERT-0}}$: measured power consumption (W) at a 0% data traffic utilization

$P_{\text{CERT-50}}$: measured power consumption (W) at a 50% data traffic utilization

$P_{\text{CERT-100}}$: measured power consumption (W) at a 100% data traffic utilization

Converged packet optical equipment with packet, TDM and WDM functions, interface cards are added depending on the data usage volume. Therefore, in general,

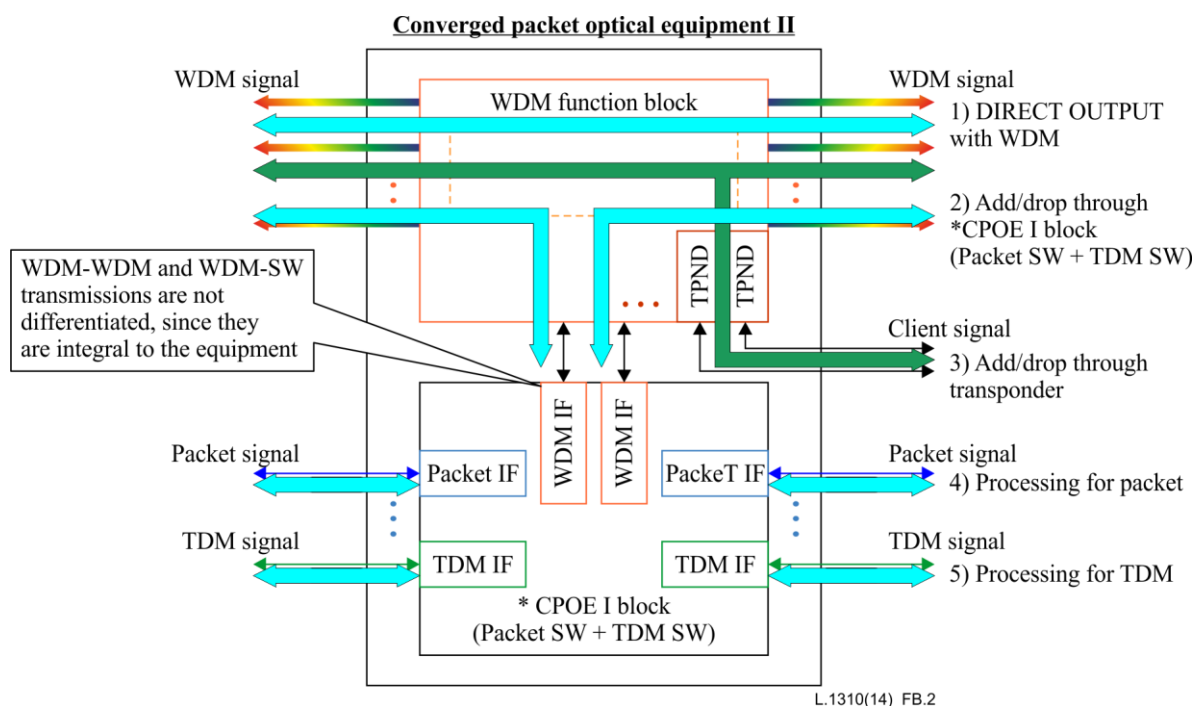
$$(P_{\text{CERT-0}} + P_{\text{CERT-50}} + P_{\text{CERT-100}})/3 \doteq (P_{\text{CERT-0}} + P_{\text{CERT-100}})/2 \quad (\text{B-2})$$

Thus, in practice, $\text{TEER}_{\text{CERT}}$ for converged packet optical equipment with WDM signal function shall be as follows.

$$\begin{aligned} \text{TEER}_{\text{CERT}} &= \Sigma D_i / \{(P_{\text{CERT-0}} + P_{\text{CERT-100}})/2\} \\ &= \text{Maximum throughput/average power consumption} \end{aligned} \quad (\text{B-3})$$

a) The maximum throughput for converged packet optical equipment II

The traffic pattern of converged packet optical equipment is as follows:



*CPOE I: Converged Packet Optical Equipment I

Figure B.2 – Definition of throughput of converged packet optical equipment II

Table B.1 – Characteristic traffic of converged packet optical equipment included in throughput calculations

Pathway	Throughput used for calculating figure of merit	Notes
(1) Transmitted as WDM (unchanged)	–	Not included since power consumption of OADM/ROADM/OXC parts are small
(2) Add/Drop from WDM to packet SW/TDM SW	WDM signal (C) throughput × Add/Drop rate (α)	
(3) Add/Drop from WDM to transponder	–	Not included since not a major function of converged packet optical equipment II
(4) Packet processing part	Packet signal (A) throughput	
(5) TDM processing part	TDM signal (B) throughput	

where:

- A: maximum throughput (Gbps) of packet functions
(port speed (Gbps) × number of ports × number of slots)
- B: maximum throughput of TDM function (Gbps)
(port speed (Gbps) × number of ports × number of slots)
- C: maximum throughput of WDM function (Gbps)
(port speed (Gbps) × number of ports × number of slots)
- α : add/drop rate of WDM function

The add/drop rate will change with operation status, the maximum capacity of the equipment is desired for $\alpha = 1$.

In order to maximize use of converged packet optical equipment II features, the equipment shall be configured so that the traffic of WDM signals flowing into the converged packet optical equipment I part is maximized and the conditions of A, B, C and α are $C \times \alpha = A + B$.

NOTE – Please refer to [b-Ecology Guideline] for further details on formulas.

- Maximum throughput of converged packet optical equipment with packet, TDM and WDM functions.

$$\text{Maximum throughput} = \sqrt{[A^2 + B^2 + (C \times \alpha)^2]/3} \quad (\text{B-4})$$

Furthermore, if packet or TDM functions are not supported, the following shall apply:

- Maximum throughput of converged packet optical equipment with packet and WDM functions.

$$\text{Maximum throughput} = \sqrt{[A^2 + (C \times \alpha)^2]/2} \quad (\text{B-5})$$

- Maximum throughput of converged packet optical equipment with TDM and WDM signal functions.

$$\text{Maximum throughput} = \sqrt{[B^2 + (C \times \alpha)^2]/2} \quad (\text{B-6})$$

- b) The average power consumption for converged packet optical equipment II

$$= (P_{\text{idle}} + P_{\text{max}}) / 2 \quad (\text{B-7})$$

where:

P_{idle} : power consumption (W) of total equipment with no data throughput with minimum components and path configuration (WDM part: 1 wave length, maximum frequency (ex: 1 wave \times 100 Gbps))

P_{max} : power consumption (W) of total equipment during main signal transmission with maximum component configuration (WDM part: full wave length, maximum frequency (ex: 80 wave \times 100 Gbps))

Measurement of the average power consumption shall be taken from power consumption when configured for maximum transmission capacity

The metric of converged packet optical equipment II is:

$$EER = \sqrt{[A^2 + B^2 + (C \times \alpha)^2]/3} / \{(P_{idle} + P_{max})/2\} \quad (B-8)$$

B.3 Measurement methodology

This clause defines measurement procedures for converged optical equipment II.

a) Interface

i) Selection of the interface

Select the interface where the throughput of the WDM part ($C \times \alpha$) is equivalent to the sum of the packet and TDM part throughputs ($A+B$), and as much as possible, WDM signals are added/dropped.

ii) Function combination patterns

For the TDM, packet and WDM interfaces, conduct measurements selecting the configurable pattern at NNI/UNI sides from below

- WDM (NNI), TDM & packet (UNI)
- WDM (NNI), TDM (UNI)
- WDM (NNI), packet (UNI)

iii) Interface when measuring P_{max} configuration

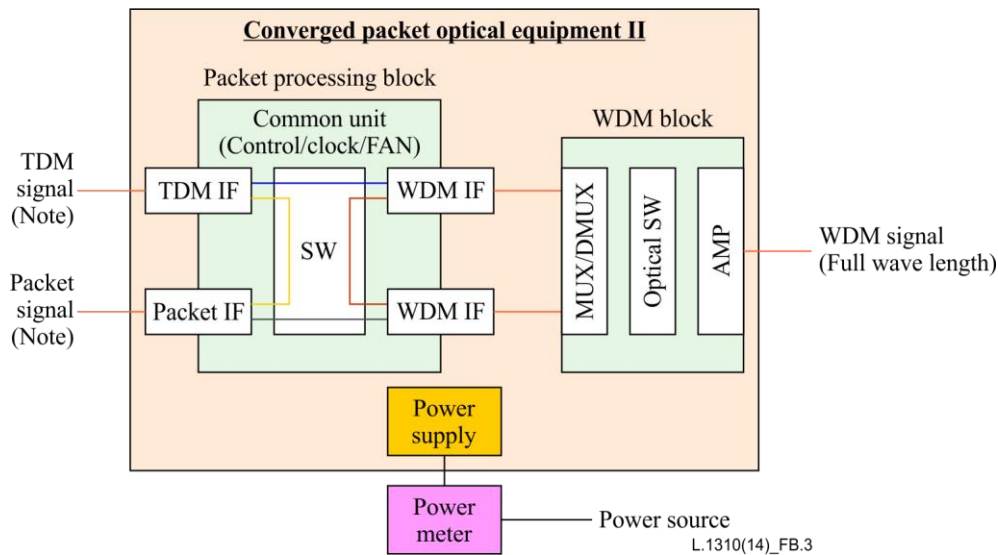
Use the interface selected in i), and configure using maximum throughput.

iv) Interface when measuring P_{idle} configuration

Use the interface selected in i), and configure including 1 path with the WDM part.

v) Configuration for redundancy

There is no specification of interface when configured for redundancy. When configured for redundancy, calculate the figure of merit with the redundant interface as part of the main unit.



NOTE – Throughput of the TDM and packet functions are at its maximum, and all WDM signals can be added/dropped.

Figure B.3 – Example of maximum component configuration for measuring P_{max}

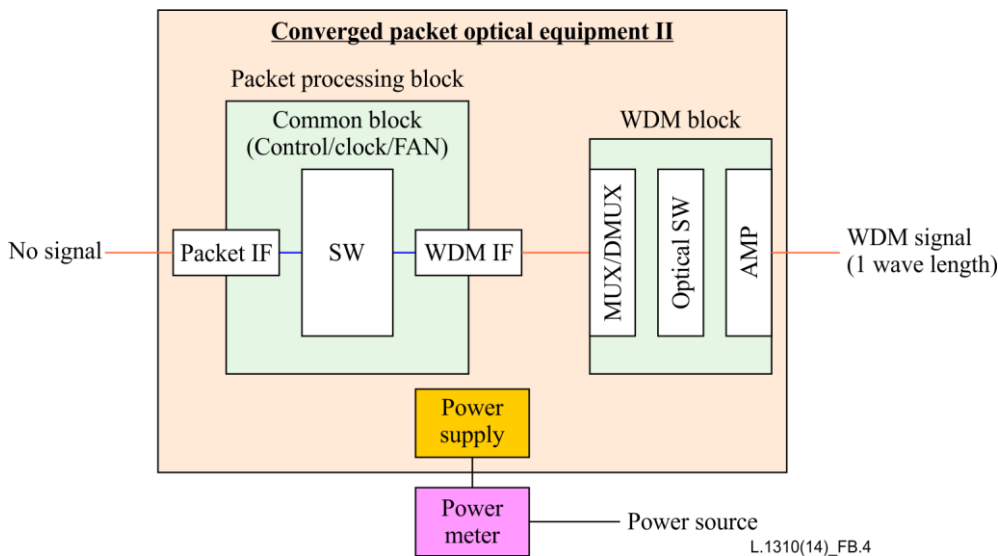


Figure B.4 – Example of minimum component and path configuration for measuring P_{idle}

- b) Transmission load
 - i) Transmission load when measuring P_{max}
Maximum throughput when configured at maximum capacity
 - ii) Transmission load when measuring P_{idle}
Non-transmitting state when configured with minimum paths at minimum capacity
- c) Environmental conditions
Environmental conditions are defined in clause 7.
- d) Test voltage
Test voltage is defined in clause 7.
- e) Number of equipment measured
There is no stipulation on number of equipment to be measured, but if multiple equipment is measured, indicate the average value.

f) Number of measurements

There is no stipulation on number of measurements, but if measurements are taken multiple times, indicate the average value.

g) Measurement precision

Not stipulated.

Appendix I

Alternative metrics for wireline access technologies

(This appendix does not form an integral part of this Recommendation.)

This appendix reports an alternative metric available for wireline access technologies (including MSAN, DSLAM, GPON OLT and GEAPON OLT).

EER: This metric considers the maximum output bit rate per line at different traffic states as a functional unit (variable load → traffic related metric).

$$EER_{avg} = T_{OSavg} / P_{avg} [\text{Mbps/W}] \quad (\text{I-1})$$

where:

T_{OSavg} output bit rate per subscriber line is the weighted output bit rate for the subscriber (in Mbit/s) of the broadband network equipment in possible (if implemented) different operational states (L0, L2, L3).

$$T_{OSavg} = aT_{OS1} + bT_{OS2} + cT_{OS3} \quad (\text{I-2})$$

P_{avg} is the weighted energy consumption (in Watts) per line of the broadband network equipment in possible (if implemented) different states

$$P_{avg} = aP_1 + bP_2 + cP_3 [\text{W}] \quad (\text{I-3})$$

where:

(a, b, c) are weight coefficients that are selected so that $(a + b + c) = 1$

P_1, P_2, P_3 are power measurements (in Watts) of fully equipped broadband network equipment, operating in different traffic conditions as defined below.

I.1 DSLAM and MSAN network equipment

For this equipment, power is measured on a fixed loop length defined for any technology.

The parameters a, b, c values consider the traffic distribution during the day.

These values are established considering the distribution of traffic contained in [ETSI ES 203 215].

P_1, P_2, P_3 are power measurements (in Watts) of fully equipped broadband network equipment operating in L0, L2 and L3 states (respectively) and collected under the terms defined in clause 9.2.1.

The values are reported in Table I.1; they depend on the energy mode available in the equipment.

Table I.1 – Weight factor definition for DSLAM and MSAN

Power mode available	Weight multipliers a, b, c
L0, L2, L3	a=0.15, b=0.06, c=0.79
L0, L2	a=0.2, b=0.8, c=0
L0	a=1, b=0, c=0

The weight multipliers a, b, c are derived from Table B.1 in Annex B of [ETSI ES 203 215] considering the average traffic distribution during a day.

I.2 GPON OLT network equipment

For GPON OLT equipment, EER is an indicator of the amount of traffic transported for each Watt of power in a fully equipped configuration.

Since the power of typical OLT gear is not directly related to optical fibre length, it is not necessary to define a reference optical fibre length.

$$\text{EER} = (\text{Bit rate per port}) / P_{\text{port}} [\text{Gbps/W}] \quad (\text{I-4})$$

where:

"Bit rate per port" is the downstream active data rate expressed in Gbit/s

P_{port} is the associated unit power consumption (in Watt) of the equipment

I.3 GEAPON OLT network equipment

For GEAPON OLT equipment, EER is an indicator of the amount of available port for each Watt of power in a fully equipped configuration.

For OLT, use a value that divides average power consumption for the OLT (at full mounting), measured using DC input if the equipment power source is DC and AC input if the power source is AC, by the total number of lines (Total number of interface (IF) ports \times number of PON branches).

$$\text{EER} = \text{total number of IF ports} / \text{average power} \quad [\text{line/W}] \quad (\text{I-5})$$

where:

Average power = (power at 100% load + power at 50% load + power at 0% load) / 3.

NOTE – It is possible to obtain a metric of the number of subscriber lines by multiplying the defined EER by the number of branches (e.g., 32).

Appendix II

Alternative metrics for routers and switches

(This appendix does not form an integral part of this Recommendation.)

This appendix reports some alternative metrics available for routers and switches.

II.1 Routers and switches supporting sleep (stand by) mode

This metric is applicable only to routers and switches that can change to sleep mode.

The proposed metric is:

$$\text{EER} = T_i/P_i \quad [\text{Mbit/s/W}] \quad (\text{II-1})$$

where:

$$P_i = c \times P_{\max} + b \times P_{\text{typical}} + a \times P_{\text{idle}} + d \times P_{\text{sleep}} \quad [\text{W}] \quad (\text{II-2})$$

T_i is the weighted throughput

$$T_i = c \times T_{\max} + b \times T_{\text{typical}} + a \times T_{\text{idle}} \quad (\text{II-3})$$

(T_{\max} , T_{typical} , T_{idle}) = throughput measured at respective utilization levels

where:

P_{\max} is the power at maximum traffic load in real time; here maximum traffic load is defined as maximum non-drop rate, equivalent to 100% load (u_3 in [ATIS-0600015.03.2013])

P_{typical} is the power at typical traffic load in real time; here typical traffic load is defined as 30% load or 10% load which is dependent on the different equipment types (u_2 in [ATIS-0600015.02.2009])

P_{idle} is the power in idle state in real time; here idle state is defined in 0% load (u_1 in [ATIS-0600015.02.2009])

P_{sleep} is the power in sleep mode in non-real time, applicable only for equipment that offer sleep mode.

c is the weighting multiplier for maximum state in real time,

b is the weighting multiplier typical traffic load in real time,

a is the weighting multiplier for idle traffic load in real time,

d is the weighting multiplier for sleep mode in non-real time,

$$a + b + c + d = 1$$

The values of parameters a , b , c , d , are defined in Table II.1 for routers and in Table II.2 for switches. Such parameters are derived from the contents of [ATIS-0600015.03.2013] adding the "new" state of sleep mode (related to weight d) considering an average distribution of the traffic during the day.

Values for a , b , c and d shall be substantiated with data; sleep/standby mode can be used in a limited number of networking devices, but only if nothing is attached to the device network connection. For this group of routers/switches, expected traffic is close to idle.

Table II.1 – Weight factor definition for routers

Class	Representative utilization	% of utilization for energy measurements, u1, u2, u3	Weight multipliers a, b, c, d
Access router with sleep mode support	1-3%	0, 10, 100	a=0.15, b=0.25, c=0.15, d=0.45

Table II.2 – Weight factor definition for switches

Class	Representative utilization	% of utilization for energy measurements, u1, u2, u3	Weight multipliers a, b, c, d
Access switch with sleep mode support	1-3%	0, 10, 100	a=0.15, b=0.25, c=0.15, d=0.45

II.2 Measurement methodology

Measurement methodology shall be in line with [ATIS-0600015.02.2009], excluding what was reported in clause 7 and the sleep mode defined below.

Power measurement for sleep mode

With each of the equipment's ports operating in sleep mode for 20 minutes, record the average input power over 15 minutes.

II.3 Routers and switches supporting explicit power states

Definitions

Power state: a mode of operation with reduced performance and reduced energy consumption. Power state is a static, not a traffic-dependent, mode of operation. Transition between power states is not instantaneous and may incur a delay during which excess traffic might be lost.

Duty cycle: duration for each power mode to a specific time period, day, week, etc.

EE_{NRT}: energy efficiency for equipment with non-real time adjustment for traffic (explicit power states).

To evaluate EE_{NRT}, three measurement points that may correspond to different power states of unit under test (UUT) are defined:

1. S0 – full performance
2. S1 – 30% performance
3. S2 – 10% performance

A sample duty cycle is defined as a fraction of time during which the planned traffic levels are applicable. Level 0 will be used for 55% of duty period, level 2 for 25% and level 3 for 20% of the duty period.

$$EE_{NRT} = (0.55T_{S0} + 0.25T_{S1} + 0.2T_{S2}) / (0.55P_{S0} + 0.25P_{S1} + 0.2P_{S2}) [\text{Gbps/W}] \quad (\text{II-3})$$

where:

T_{S0}, T_{S1}, T_{S2} is the throughput in the three measurement points

P_{S0}, P_{S1}, P_{S2} is the power in the three measurement points.

Bibliography

[b-Ecology Guideline]

Ecology Guideline For the ICT Industry (Version 5).
http://www.tca.or.jp/information/pdf/eco guideline/guideline_eng_5.pdf

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