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Metrics and Measurement Methods of Telecommunication Equipments: IP Routers

(Draft)



The present document has been developed within GISFI and may be further elaborated for the purposes of GISFI.

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Contents

Foreword 4

Introduction 4

1 Scope 5

2 References 5

3 Definitions, symbols and abbreviations 5

3.1 Definitions 5

3.2 Symbols 5

3.3 Abbreviations 6

4 Equipment Category Description 7

5 Metric Definition 8

6 Traffic Profile and Parameters 11

7 General Requirements for Lab Setup 13

7.1 Environmental Requirements 13

7.2 Electrical Requirements 13

7.3 Metrology Requirements 14

8 Test Procedure 15

8.1 Measurement Condition 15

8.2 Equipment Configuration 16

8.2.1 Integrated Configuration 16

8.2.2 Modular Configuration 17

8.3 Traffic Topology 18

8.4 Traffic Generation 19

Dual-group partial mesh: 20

8.5 Measurement Procedure 20

8.5.1 Qualification of Maximum Load 20

8.5.2 Full Load 21

8.5.3 Utilization 21

8.5.4 Idle Load 22

8.6 Alternative / Modular Measurement Procedure 23

8.7 Traffic Profiles 25

9 Reporting Format 26

10 Conclusion 28

Annex <A>: <Annex title> 29

A.1 Heading levels in an annex 29

# Foreword

This Technical Report has been produced by GISFI.

The contents of the present document are subject to continuing work within the Technical Working Group (TWG) and may change following formal TWG approval. Should the TWG modify the contents of the present document, it will be re-released by the TWG with an identifying change of release date and an increase in version number as follows:

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x the first digit:

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# Introduction

This clause is optional. If it exists, it is always the second unnumbered clause.

# 1 Scope

The present document surveys the global standards on metrics and measurement methods for energy efficiency of Internet Protocol (IP) based telecommunication equipments; specifically IP routers. There are several classes of IP routers such as those deployed in the access, edge and core network. This technical report provides a detailed comparison of the specifications on metrics, lab setup requirements, traffic generation, measurement methodology and report formats.

# 2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

[1] ETSI ES 203 136 V1.0.0 (2013-03) Environmental Engineering (EE); Measurement methods for energy efficiency of router and switch equipment

[2] ITU recommendation: L.1310; (11/2012); Energy efficiency metrics and measurement for telecommunication equipment

[3] ATIS-0600015.03.2009; (07/2009): Energy efficiency for telecommunication equipment: Methodology for measurement and reporting for router and Ethernet switch products3 Definitions, symbols and abbreviations

[4] ECR Initiative - Network and Telecom Equipment - Energy and Performance (Assessment Metrics, Test Procedure and Measurement Methodology), Draft 3.0.1, December 14, 2010

[5] ISO 14040:2006, Environmental management − Life cycle assessment − Principles and framework.

[6] ISO/IEC 17025:2005, General requirements for the competence of testing and calibration laboratories

[7] ATIS-0600015-2009, Energy efficiency for telecommunication equipment: Methodology, Measurement and Reporting- general requirements.

# 3 Definitions, symbols and abbreviations

## 

## 3.1 Definitions

Definition format (Normal)

**<defined term>:** <definition>.

**example:** text used to clarify abstract rules by applying them literally.

## 3.2 Symbols

For the purposes of the present document, the following symbols apply:

Symbol format (EW)

<symbol> <Explanation>

## 3.3 Abbreviations

ARP Address Resolution Protocol

ATIS Alliance for Telecommunications Industry Solutions

CUT Component under Test

ECR Energy Consumption Rating

ECR-EX Energy Consumption Rating – Extended Idle Load Cycle

ECR-VL Energy Consumption Rating – Variable Load

EEER Energy Efficiency Ratio of Equipment

EER Energy Efficiency Ratio

ETSI European Telecommunications Standards Institute

EUT Equipment under Test

IMIX Internet Mix Traffic

ITU International Telecommunication Union

MAC Medium Access Control

MPU Main Processing Unit

NDR Non Drop Rate

OSI Open Systems Interconnection

PAR Peak to Average Ratio

PF Power Factor

PoE Power over Ethernet

SUT System under Test

# 4 Equipment Category Description

Routers are typical packet switching equipment running at the network layer of OSI layer 3. The router selects the optimal route according to the destination address of the received packet through a network and forwards the packet to the next router. Based on their deployment and capabilities, they may be categorized as Core, Edge and Access routers [3]. This document provides a detailed comparison of standards from ETSI [1], ITU [2], ATIS [3] and ECR [4] with a focus on IP router equipments.

Table 1: Comparison of the equipments covered under the energy efficiency standards

|  |  |  |  |
| --- | --- | --- | --- |
| ETSI [1] | ITU [2] | ATIS [3] | ECR [4] |
| Core, edge and access routers and Ethernet Switch | Core, edge and access routers and Ethernet Switch | Core, edge and access router and Ethernet Switch | Packet-oriented network and  telecom equipment, including, but not limited to, core and edge routers, L2/L3  switches, packet-optical equipment, security devices, load balancers, etc. |

It is observed that all the global standards (ETSI/ATIS/ITU and the ECR document) address the energy efficiency metrics and measurement methods for switching and routing equipments deployed in the core, edge and access networks.

# 5 Metric Definition

In this section, a detailed comparison of the metrics used to compute the energy efficiency of IP equipments is provided. Specifically, the definition, units of measurement and method of computation are compared.

Table 2: Comparison of energy efficiency metrics for IP equipments

|  |  |  |  |
| --- | --- | --- | --- |
| ETSI [1] | ITU [2] | ATIS [3] | ECR [4] |
| Definition:  Energy Efficiency Ratio of Equipment (EEER) is defined as the throughput forwarded by 1 watt, | Definition: | Definition:  TEER is defined as a ratio of maximum demonstrated throughput ( to weighted power | Definition: |
| Units: Gbps/Watt | Units : Mbit/ss/W | Units: Gbps/Watt | Units: Watts/Gbps |
| Computation:  The weighted power is calculated as:  : Weight multipliers for different traffic level;  The summation of to equal to 1.  : Total capacity of the interfaces for a fixed configuration model (the sum of interface bandwidth). | Computation:  is weighted throughput    is weighted power (energy consumption rate)    (a, b, c) = relative weights for utilization levels, where  () = power measured at respective utilization levels  () = throughput measured at respective utilization levels | Computation:  Weighted energy consumption  Where,  = Weighted power  a,b,c = weighting for power at each utilization level  ,= Power at system utilization level | Computation:  = energy consumption (watts)  = maximum throughput (Gbps) achieved in the measurement cycle  T50 = Tf \* 0.5  T30 = Tf \* 0.3  T10 = Tf \* 0.1  E100 = energy consumption (watts) measured during step 2, Test Procedure 1  E50 = energy consumption (watts) measured during step 3, Test Procedure 1  E30 = energy consumption (watts) measured during step 4, Test Procedure 1  E10 = energy consumption (watts) measured during step 5, Test Procedure 1  Ei = energy consumption (watts) measured during step 6, Test Procedure 1 |
| No separate definition. Procedure outlined in Subsection 8.6 | No separate definition. Procedure outlined in Subsection 8.6 | TEER Metric Definition (Modular)  TEER for modular packet based network systems can also be estimated as throughput measured for components/modules () divided by the sum of weighted components/modules power consumption  Where  = Individual Module throughput  = Modular weighted energy consumption | No separate definition. Procedure outlined in Subsection 8.6 |
| No Support | Routers and switches supporting sleep (stand by) mode    is the weighted throughput    () = Throughput measured at respective utilization levels | No Support | No support |
| No support | Routers and switches supporting explicit power states  Definitions:Power stateis a mode of operation with reduced performance and reduced energy consumption.  Duty cycle: Duration for each power mode to a specific time period, day, week, etc.  EENRT: Energy efficiency for equipment with non-real time adjustment for traffic (explicit power states).  Three measurement points that may correspond to different power states of EUT:  - full performance  - 10% performance  - 30% performance  Sample duty cycle:  Fraction of time during which the planned traffic levels are applicable.  Level 0 will be used for 55%, Level 1 for 25% and Level 2 for 20% of duty period.    , , is the throughput in the three measurement points  , , is the power in the three measurement points  Power state is a static, not a traffic dependent, mode of operation. Transition between power states is not instant and may incur a delay, during which excess traffic might be lost. | No support | Supported by ECR-EX metric |

It is seen from Table 2 that the ECR/ETSI/ATIS metric does not incorporate support for low power states such as sleep mode. However the ITU specification considers such a low power state in real time. The ECR, ECR-VL metrics do not incorporate the variations due to explicit switching into low power states in non-real time by the router hardware.

# 6 Traffic Profile and Parameters

This section compares the global standards in terms of the recommended traffic profile, load conditions and parameters to be used for the computation of the energy efficiency metrics as defined in Section 5.

Table 3: Traffic profile and parameters as per ITU specification [1]

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Class | Representative utilization | % of utilization for energy measurements, u1, u2 and 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 4: Parameters as per ITU specification for access router with sleep mode support [1]

|  |  |  |  |
| --- | --- | --- | --- |
| 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 5: Traffic profile and parameters as per ETSI [2] specification

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Traffic load level percentage of maximum load | | | Weight factor | | |
| Equipment type | High | Medium | Low | B1 | B2 | B3 |
| Core equipment | 100% | 30% | 0% | 0.1 | 0.8 | 0.1 |
| Edge/Access | 100% | 10% | 0% | 0.1 | 0.8 | 0.1 |

Table 6: Traffic profile and parameters as per ATIS [3] specification

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Class | Representative utilization | % of utilization for energy measurements, u1, u2 and 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=0.15;b=0.75;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 |

ECR [4]: Not defined

It may be observed from Tables 3, 4, 5 and 6 that the traffic profile and utilization levels at which the computation of energy efficiency metric is performed is the same for all the standards. However, in addition to the three utilization levels at which the computation is performed for the router energy consumption, a separate utilization level for sleep mode is recommended by the ITU metric [2] along with the weight multiplier parameters.

# 7 General Requirements for Lab Setup

This section provides a detailed comparison of the general requirements for the test and measurement lab setup for energy efficiency of IP equipments. In particular, this section addresses the environmental, electrical and metrology requirements of the lab setup.

## 7.1 Environmental Requirements

In Table 7, a comparison of the environmental requirements while performing the measurements over the IP equipments is provided. Recommendations from all global standards are in agreement.

Table 7: Comparison of environmental requirements

|  |  |  |  |
| --- | --- | --- | --- |
| ETSI [1] | ITU [2] | ATIS [3] | ECR [4] |
| Room Temperature:  23 °C to 27 °C. | Ambient temperature:  25°±3°C. | Temperature:  25 +/- 3 °C (77 +/- 5 °F) | Ambient temperature:  25° ±3°C. |
| Room Relative Humidity: 25 % to 75 % | Relative humidity of 30% to 75% | Humidity: 30% to 75 % | Relative humidity of 30% to 75% |
| Atmospheric pressure: 86 kPa to 106 kPa. | Site pressure between 860 to 1060 hPa. | Barometric Pressure: 1020 to 812 mbar | Site pressure between 860 to 1060 mbar. |

## 7.2 Electrical Requirements

The electrical requirements for the measurement setup and equipment under test are listed in the Table 8.

Table 8: Comparison of electrical requirements for the measurement setup

|  |  |  |  |
| --- | --- | --- | --- |
| ETSI [1] | ITU [2] | ATIS [3] | ECR [4] |
| DC Powered Equipment:  With a nominal voltage of -48 V DC according to EN 300 132-2, shall be tested with a test voltage of -54,5 V ±1,5 V. Equipment using voltage other than -48 V DC shall be tested at ±1 % of the nominal voltage. | DC Powered Equipment:  The DC voltage powering the equipment shall be chosen in the range of - 55.5 to -52.5 V (54±1.5 V). | DC Powered Equipment:  DC Voltage -53 V +/- 1V | DC Powered Equipment:  The input to the SUT (all active feeds) should be at a nominal DC voltage ±5%. This corresponds to -53 ±2.65 V for typical telecom facilities. |
| AC Powered equipment:  Equipment with a nominal voltage of 230 V shall be tested with a test voltage of 230 V ±5 % and at 50 Hz ±1 % of frequency. | AC powered equipment:  The input to the equipment (all active feeds) should be the nominal specified voltage ±5% and the specified frequency ±1%. | AC powered equipment:  Total harmonic distortion </=2% up to and including the 13th harmonic  115 VAC +/- 1 %, 60 Hz +/- 1 %  230 VAC +/- 1 %, 50 or 60 Hz +/- 1 % | AC powered equipment:  AC voltage and frequency  The input to the SUT (all active feeds) should be the specified voltage ±1% and the specified frequency ±1% |

## 7.3 Metrology Requirements

Accuracy and calibration of metrology equipments is essential for fair comparison amongst power consumption of equipments. The Table 9 provides a detailed comparison of these requirements as specified by the standards.

Table 9: Comparison of the metrology requirements of the measurement setup

|  |  |  |  |
| --- | --- | --- | --- |
| ETSI [1] | ITU [2] | ATIS [3] | ECR [4] |
| Power Source:  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. | Power Source:  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. | Power Source:  DC 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 | Power Source:  Not Defined |
| Power Measurement Instrument:  Power measurement instrument (such as voltmeter and amperometer or power analyzer) shall have a resolution of 0.5 % or better. AC power measurement instrument shall have the following minimum characteristics:  1) A minimum digitizing sample rate of 40 kHz.  2) Input circuitry with a minimum bandwidth of 80 kHz.  3) It shall be capable of accurate readings of waveforms having peak to average ratio (PAR) factors up to at least 5. | Power Measurement Instrument:  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:  1) A minimum digitizing sample rate of 40 kHz.  2) Input circuitry with a minimum bandwidth of 80 kHz.  3) Capability of accurate readings of waveforms having a crest factor up to at least 5.  4) Power factor correction and reporting. | Power Measurement Instrument:  1) A minimum digitizing sample rate of 40 kHz.  2) Input circuitry with a minimum bandwidth of 80 kHz.  3) Ability to log data over time and store the total measurement period  4) Overall measurement accuracy should be within +/1 1% | Power Measurement Instrument:  Every active power feed should have the power (amp) meter installed in line with desired accuracy no less than ±1% of the actual power consumption. This should include correction for power factor (PF) on AC feeds.  Sampling frequency:  1) All energy consumption calculations are based on averaging multiple readings over the course of measurements.  2) Power meters should be able to produce no less than 100 evenly-spaced readings in every full test cycle |

It can be observed that all standards except the ECR document consider the DC 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. Further, a minimum digitizing sample rate of 40 kHz and input circuitry with bandwidth of 80 kHz is recommended for such power sources.

# 8 Test Procedure

This section deals with the details of the test procedures recommended by global standards for measurement of energy efficiency of IP equipments. Further, the recommendations on measurement conditions, equipment configurations, traffic topology, traffic profiles and measurement procedure are compared in detail.

## 8.1 Measurement Condition

In Table 10, a comparison of the baseline measurement conditions of the IP equipments is provided. Specifically, the requirement for equipment stabilization is provided. It is observed that except for the ECR recommendation, other global standards require the equipment under test to be operated for a minimum duration of 15 minutes.

Table 10: Conditions for measurement recommended by standards

|  |  |  |  |
| --- | --- | --- | --- |
| ETSI [1] | ITU [2] | ATIS [3] | ECR [4] |
| Stabilization:  The equipment shall be operated for at least 15 minutes for initialization until equipment run stable | Stabilization:  For test methodologies, equipment configuration and set-up, the methodology reported in ATIS- 0600015.03.2009 [3] shall apply, with the modification of general measurement conditions presented in clause 7 of this document. | Stabilization:  The equipment is to be powered and placed into the relevant operating mode.  Allow the equipment to stabilize in this mode for 15 minutes. | Stabilization:  System under test (SUT) is configured according to class requirements and offered load defined in the class requirements (Appendix B of [4]).  Prior to the actual test, the SUT has to be exposed to environmental conditions for at least four hours to settle the potential temperature difference. |
| Other considerations: | Other considerations:  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. | Other considerations:  Measure the power for a period of 15 minutes.  If the power varies over the 15 minute measurement time interval, an average of the measurement will be calculated. | Other considerations:  Router tester equipment is used to simulate the load and collect the performance related results. |

## 8.2 Equipment Configuration

### 8.2.1 Integrated Configuration

Table 11 provides comparison of requirements for configuration of IP equipments. In particular, the recommendation for baseline, auxiliary configurations and the restriction on change of configuration during measurements is outlined.

Table 11: Comparison of requirements for test and measurement of IP equipments in integrated configuration

|  |  |  |  |
| --- | --- | --- | --- |
| ETSI [1] | ITU [2] | ATIS [3] | ECR [4] |
| Base Configuration:  ATIS | Base Configuration:  ATIS | Base Configuration:  All testing shall be performed on a fully loaded chassis as defined by the referenced application | Base Configuration:  The SUT is configured according to class requirements and offered the load as defined in the class requirements (Appendix B of [4]).  Typically, the SUT is a reference system fully outfitted with hardware and software suitable for class requirements. |
| Redundancy and auxiliary configuration:  Equipment shall be tested with all redundancies in place and corresponding functions shall be activated, the redundancy modules including but not limited to power supply unit redundancy, Main Processing Unit (MPU), redundancy, etc. | Redundancy and auxiliary configuration:  ATIS | Redundancy and auxiliary configuration:  If there are customer specific applications defining redundancy requirements, they should be clearly documents in the report. | Redundancy and auxiliary configuration:  For the purposes of testing, all redundant components (fabric, routing engines, power supplies, memory cards, etc.) should be present in the system |
| Other configurations:  For the equipment supporting PoE power supply, the PoE power supply modules shall be disabled. No PoE power is supplied.  For optical ports, 10 Km optical modules need to be used for FE, GE and 10 GE ports; for the electrical and optical multiplexing ports, the electrical ports need to be tested.  The capacity of the equipment shall be obtained from traffic generator, unit is Gbps, the sum of bandwidth of all the ports calculated cannot be used in EEER calculation. | Other configurations:  ATIS | Other configurations:  All ports shall be in an active state and passing or ready to pass traffic.  System software shall be properly configured prior to the test and all the necessary HW components installed. HW and SW shall be representative of a production unit. | Other configurations:  For the purposes of public testing, all platforms should be tested with publicly available (shipping) software images, publicly available (shipping) board hardware revisions and fully documented and supported configurations. |
| Configuration Change:  It is not allowed to change the software and hardware configurations of the equipment under test respect to the normal commercial software and configuration. | Configuration Change:  ATIS | Configuration Change:  There is no EUT configuration change allowed any time beyond preparation phase. This includes external configuration commands, scripts executing configuration commands on EUT during testing etc. | Configuration Change:  There is no SUT configuration change allowed any time beyond preparation phase. All energy savings adjustments (if done) by the SUT should be automatic. |

It is observed that all the standards agree on the baseline configuration of the equipment under test to be a fully loaded chassis as defined by the referenced application. Moreover configuration change is prohibited during the measurement process.

### 8.2.2 Modular Configuration

Table 12 provides comparison of requirements for configuration of IP equipments. In particular, the recommendation for baseline and modular configurations during measurements is outlined.

Table 12: Comparison of requirements for test and measurement of IP equipments in modular configuration

|  |  |  |  |
| --- | --- | --- | --- |
| ETSI [1] | ITU [2] | ATIS [3] | ECR [4] |
| Modular Configuration:  This type of equipment could be configured to provide similar functionality with different board types and different compositions in the same rack/box. To reduce the test timing an alternative method is proposed that can provide an estimation of the EER in conservative mode. | Modular Configuration:  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. (In ATIS e.g. [ATIS-0600015.02.2009] this is called the “modular method” e.g. and in ETSI e.g.. [ETSI ES 203 215] it is called “Alternative methods”.) | Modular Configuration:  If the vendor chooses to provide the modular TEER estimates, it may be required to build more than one setup of the number of modules exceeds the number of available slots in a chassis. | Modular Configuration:  A modular SUT is configured with hardware, software and connection topology relevant for its class of operation including the component (or module) under test (CUT). |
| Base configuration:  In this case, the "base" system configuration is defined as a common system part, used by all modules. It may include chassis, fan tray, routing engine, etc.  Common system is equipment with no service board installed and including main processing boards, fan tray, power input boards, etc., which is used by all service boards. | Base configuration:  ATIS | Base configuration:  In this case, the “base” system configuration is defined as a common system parts, used by all modules. It may include chassis, fan tray, routing engine, etc.  At this time, all other system slots should be fully populated with function modules, not necessary the same, all passing traffic at the same rate: idle, representative, or maximum NDR. | Base configuration:  The SUT is not required to be fully loaded and is not required to bear all modules of the same type.  However, it is beneficial to make sure that the energy and traffic impact of the CUT is minimized compared to the rest of the system, which is best achieved in higher-end configurations. |

## 8.3 Traffic Topology

This subsection provides the comparison of the recommendations by global standards regarding the traffic topology under which the equipment under test is subjected to during the measurement procedure.

Table 13: Comparison of traffic topology under which the equipment is tested

|  |  |  |  |
| --- | --- | --- | --- |
| ETSI [1] | ITU [2] | ATIS [3] | ECR [4] |
| Full Mesh:  for a core functionality mode: total weighted throughput is the sum of all interface throughputs measured in full mesh traffic topology. | ATIS | Full Mesh:  If the ports on EUT can be grouped into “network/uplink” and “access/downlink” sides, according to vendor discretion, then traffic shall be run from every “network” side port to every “access” side port and vice-versa, thus forming full mesh traffic between two groups. All streams originated from every port shall be the same capacity.  If all ports on EUT have identical roles, then full mesh traffic with identical capacity streams between  all ports shall be used. | Symmetric full-mesh topology:  Same-bandwidth traffic stream from every port to every port. This topology is applicable to equipment with equal port roles and minimal internal oversubscription, such as core routers and carrier Ethernet switches |
| Partial Mesh:  for an aggregation mode: the weighted sum of uplink port throughputs, measured in uplink/downlink mesh configuration. | ATIS | Partial Mesh:  Not Described | Dual-group partial mesh  This topology is applicable to various aggregation and edge transport devices where traffic from one side (user or access) is groomed or tunnelled over to the other side (network). |
| Throughput calculation:  The capacity of the equipment shall be obtained from traffic generator, unit is Gbps, the sum of bandwidth of all the ports calculated cannot be used in EEER calculation. | ATIS | Throughput calculation:  The system throughput is computed as sum of throughputs on all the system ports in the egress direction. | Throughput calculation for partial mesh:  In this topology, the sum of face values of the “user side” ports can be significantly higher than sum of “network side” ports due to oversubscription.  However, for purposes of throughput calculation, only sustained egress data rates are accounted for. |

It is observed that full mesh and partial mesh are the two classes of traffic topologies recommended for throughput measurements. The decision to use one of the two applicable topologies is taken based on the functionality of the router either in the core mode or the aggregation mode.

## 8.4 Traffic Generation

Table 14 depicts the various recommended topologies for carrying out the tests in the laboratory that includes the use of a suitable traffic generator. The traffic generator must be capable of generating uniform or variable sized IP packets as outlined in Section 8.6.

Table 14: Comparison of topology and traffic generator configuration for tests

|  |  |  |  |
| --- | --- | --- | --- |
| ETSI [1] | ITU [2] | ATIS [3] | ECR [4] |
| Full Mesh:  Traffic  Gen  Ports  Ports  UUT  Partial Mesh:  User Ports  Traffic  Gen  Uplink Ports  UUT | ATIS | Mesh Topology:  Downlink Ports  EUT  Traffic Generator  Uplink Ports | Full mesh  Traffic  Generator  SUT  AC/DC  Metering System Dual-group partial mesh: User side  Network side  Traffic  Generator  SUT  AC/DC  Metering System |

## 8.5 Measurement Procedure

This subsection provides the detailed measurement procedure for computation of energy consumption at various pre determined load conditions. In particular, procedures are outlined for qualification of maximum load, full load and idle load tests.

### 8.5.1 Qualification of Maximum Load

Table 15: Comparison of procedures for preparing the equipment for test at maximum traffic load

|  |  |  |  |
| --- | --- | --- | --- |
| ETSI [1] | ITU [2] | ATIS [3] | ECR [4] |
| Qualification:  The equipment shall be operated for at least 15 minutes for initialization until equipment run stable, after that, configure the equipment according to clause 6.2 of [1] and make the data rate of all ports reach to the rate with no packet loss, measure the capacity of all in egress direction and record them, this capacity is the maximum capacity () for each port. If some ports reach to line rate but lose packet, adjust the capacity of those ports until no packet loss, record the capacity of each egress port, calculate the total capacity () of all ports. | Qualification:  ATIS | Qualification:  The first run determines the maximum load that can be sustained at Non Drop Rate (NDR). Any methodology is suitable, including binary search (similar to RFC2544), heuristics, or known maximum load values. There is no time limit for this run. The run is complete after a maximum (lossless) line rate is determined. | Qualification:  First run determines the maximum load that can be sustained at zero packet loss. Any methodology is suitable, including binary search (similar to RFC2544), heuristics or known maximum load values. There is no time limit for this run. The run is complete after a maximum (lossless) load is determined. |
| Idle Time:  Not Defined | Idle Time:  ATIS | Idle Time:  The following three runs should be separated with idle time of 300 seconds or less  If the test class requires the EUT to be “primed” with control plane information (ARP/MAC/route learning, etc.), this shall be completed within the idle time window. | Idle Time:  The following three runs should be separated with idle time of 300 seconds or less.  If the test class requires the SUT to be “primed” with control plane information (ARP/MAC/route learning etc), it should be done within the idle time window. |

### 8.5.2 Full Load

Table 16: Comparison of procedures for equipment test at full load

|  |  |  |  |
| --- | --- | --- | --- |
| ETSI [1] | ITU [2] | ATIS [3] | ECR [4] |
| With all equipment ports operating stably under maximum traffic load () for 5 minutes, record the average input power over 5 minutes, this value is P1. | ATIS | The second run applies the NDR (identified at step 1: Qualification) to the EUT for period of 15 min. Power shall be sampled for the entire period, and average consumption P100 recorded. | Second run offers the load Lmax (identified at step 1) to SUT for period of 1200 seconds. Energy consumption is being sampled for the entire period, and average consumption Ef calculated. |

### 8.5.3 Utilization

Table 17: Comparison of procedures for equipment test at maximum traffic load

|  |  |  |  |
| --- | --- | --- | --- |
| ETSI [1] | ITU [2] | ATIS [3] | ECR [4] |
| 50% Load – Not defined | ATIS | 50% Load – Not defined | Step 3 (50% load)  Third run reduces the load Lmax twice (Lhalf = 0.5 x Lmax) and runs for another 1200 seconds.  Energy consumption is being measured for the entire period, and average consumption Eh calculated.  Load reduction is achieved by reducing packet rate on all configured ports. |
| 30% Load – Only for Core Network  Power Consumption Measurement for 30 % traffic loads (only core equipment)  With all equipment ports operating stably under 30 % of maximum traffic load (30%\*) for 5 minutes, record the average input power over 5 minutes, this value is P2 for core equipment. | ATIS | 30% Load – Only for Core Network - Step 3 (u2 load)  The third run reduces the line rate to utilization (u2) and runs for another 15 min.  Power shall be sampled for the entire period, and average consumption Pu recorded.  Load reduction is achieved by reducing the line rate on all configured ports.  Packet loss during any run (if seen) invalidates the measurement and resets testing to the qualification run to provide a better NDR estimate. | 30% Load – Step 4  This test run further reduces the load to L30 (L30= 0.3 x Lmax) and runs for another 1200 seconds. Energy consumption is being measured for the entire period and average consumption E30 calculated. Load reduction is achieved by reducing the packet rate on all configured ports. (Load reduction by means of idling or disconnecting ports is not acceptable.) |
| 10% Load – Only for Access/Edge Equipment –  Power Consumption Measurement for 10 % traffic loads (only access/edge equipment)  With the equipment operating stably under 10 % of maximum traffic load (10%\*) for 5 minutes, record the average input power over 5 minutes, this value is P2 for access/edge equipment.  NOTE:  Burst traffic model is used for 10 % traffic load, and the cycle of Burst is 20 milliseconds. To obtain the 10 % traffic load, the packets shall be sent in 100 % traffic at the first 2 milliseconds of cycle and then no packets (0 % traffic) are sent in remaining 18 milliseconds and this process is repeated periodically in 20 milliseconds cycles. | ATIS | 10% Load – Only for Access/Edge Equipment - Step 3 (u2 load)  The third run reduces the line rate to utilization (u2) and runs for another 15 min.  Power shall be sampled for the entire period, and average consumption Pu recorded.  Load reduction is achieved by reducing the line rate on all configured ports.  Packet loss during any run (if seen) invalidates the measurement and resets testing to the qualification run to provide a better NDR estimate. | 10% Load - Step 5  This test run further reduces the load to L10 (L10= 0.1 x Lmax) and runs for another 1200 seconds. Energy consumption is being measured for the entire period and average consumption E10 calculated. Load reduction is achieved by reducing the packet rate on all configured ports. (Load reduction by means of idling or disconnecting ports is not acceptable.) |

### 8.5.4 Idle Load

Table 18: Comparison of procedures for equipment test at idle load

|  |  |  |  |
| --- | --- | --- | --- |
| ETSI [1] | ITU [2] | ATIS [3] | ECR [4] |
| With all equipment ports operating stably under 0 % traffic load for 5 minutes, record the average input power over 5 minutes, this value is P3. | ATIS | Run the EUT idle for another 15 minutes. Power shall be measured for the entire period, and the average value shall be recorded. Load reduction is achieved by setting line data rate of 0% on all configured ports. | Idle run removes the load and runs for another 1200 seconds. Energy consumption is being measured for the entire period, and average consumption Ei calculated. Load reduction is achieved by idling packet rate on all configured ports, or disabling ports on packet tester side, at vendor discretion. |

Tables 15, 16, 17 and 18 detail the procedure of measurement at predefined load levels. All the applicable standards mandate the measurements to be recorded at zero packet loss (NDR) conditions. Apart from the maximum load tests, all the applicable standards recommend measurements to be carried out at 50%, 30% and 10% of maximum load.

## 8.6 Alternative / Modular Measurement Procedure

Modern IP routing equipments have modular configurations and may be operated with full or partial combinations of service boards. Since the number of possible combinations of such modules could be large, a simpler method to approximate the power consumptions of individual modules is recommended as the alternative measurement procedures. Each test performed on complete system and then without one module at a time. Table 19 provides the comparison of the recommended procedure to compute the modular energy efficiency metrics.

Table 19: Comparison of alternate procedures for equipment test

|  |  |  |  |
| --- | --- | --- | --- |
| ETSI [1] | ITU [2] | ATIS [3] | ECR [4] |
| **Step 1**: Configure the system with the all service boards to obtain a full chassis and set the system at the traffic load defined in clause 6.2 within the boards, and test the power used .  **Step 2:** Remove one service board and test the power used of this configuration .  **Step 3:** Calculate the power used by the service board: = ().  **Step 4**: Repeat steps 1 and 2 with other traffic load.  **Step 5:** According to above steps, test the power used by other service boards, , ,  **Step 6:** Calculate the power used by the common system; this power is determined by subtracting the power used by different service boards present in the system from the power measured in the initial configuration during step 1 at maximum traffic .  Where is the number of service present in the initial configuration and is the power used by service identified during step 3.  **Step 7:** The weighted power of the board is calculated using the following formula:  is the weighted power of board 1….n  is the power of the estimated configuration with traffic  is the weighted factor depending on traffic load and equipment type see clause 5.  The estimated EEER is:  Where:  is the weighted Throughput of any service board calculated as in clause 6.3.  is the total weighted power of the board. | ATIS | Each test performed on complete system and then without one module at the time, following steps in 6.5.  The power for each “function” module is the difference between total system power, with and without this “function” module.  NOTE: Throughput and energy consumption may be affected by interaction between the system and module under test, so total calculated numbers may be not exactly the same as in representative test results. | A modular SUT is configured with hardware, software and connection topology relevant for its class of operation including the component (or module) under test (CUT).  **Step 1 (qualification):** The first run determines the maximum load (Lmax +) that the SUT can be sustain at zero packet loss. It is recommended to design Lmax + to exercise all SUT components (including CUT) to the highest possible throughput. A failure to do so might significantly affect test results.  **Step 2 (full load):** The second run offers the load Lmax + (identified in step 1) to the SUT for a period of 1200 seconds. Energy consumption is being sampled for the entire period and average system footprint F+ calculated.  **Step 3 (CUT removal):** The CUT should be removed from the SUT at this step. The SUT and test system configurations might need to be readjusted to compensate for component removal. The third run determines the new maximum load (Lmax -) the SUT can be sustained at zero packet loss. It is recommended to design Lmax - to exercise all remaining SUT components to the highest possible throughput. A failure to do so can significantly affect test results.  **Step 4 (Final measurement):** At this step, the load Lmax - (identified in step 3) is offered to the SUT for a period of 1200 seconds. Energy consumption is being sampled for the entire period and average system footprint F- calculated. At this point, the energy footprint of the CUT can be approximated:  Fc = F+ - F-  The same procedure (Steps 1 to 4) can be repeated as many times as needed to build a component footprint library. |

## 8.7 Traffic Profiles

In Table 20, a short description of traffic profiles recommended to carry out the tests on IP equipments is provided. Simple IMIX traffic is recommended by all global standards to test the equipments.

Table 20: Traffic profiles recommended for equipment test

|  |  |  |  |
| --- | --- | --- | --- |
| ETSI [1] | ITU [2] | ATIS [3] | ECR [4] |
| |  |  |  | | --- | --- | --- | | Package Size (Bytes) | Proportion of Total | Bandwidth | | 64 | 7 parts | 10.3 | | 594 | 4 parts | 54.7 | | 1518 | 1 parts | 35 |   Simple IMIX Traffic | ATIS, Simple IMIX | Simple IMIX Traffic   |  |  |  | | --- | --- | --- | | Packet Size (Bytes) | Proportion of Total | Bandwidth (local) | | 40 | 7 parts | 6.856% | | 576 | 4 parts | 56.415% | | 1500 | 1 parts | 36.729% | | Simple IMIX average of 340 Bytes size packets |

# 9 Reporting Format

In Table 21, a comparison of recommended reporting formats for the energy efficiency metrics is provided. The ITU specification recommends ISO/IEC 17025 General requirements for the competence of testing and calibration laboratories [5] as a general basis for reports along with minimum requirement for content of the test reports. The ATIS standard ATIS-0600015-2009 [7] describes the general requirements for reporting the energy efficiency test results.

Table 21: Comparison of recommended reporting formats

|  |  |  |  |
| --- | --- | --- | --- |
| ETSI [1] | ITU [2] | ATIS [3] | ECR [4] |
| Not Specified | This Recommendation does not endorse a specific reporting format. The general requirements for a test report 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:  1. 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.  2.Traffic generator/measurement tool, actual voltage in power feeds and ambient (environmental) conditions at test site.  3. 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. | Contains the following minimum information:  1. Any relevant supplemental standard used  2. Date and location of test.  3. Physical equipment configuration including physical dimensions and mounting used for testing  4. Software version operating on the system  5.Activated features and functions during testing  6. Explanation of configuration chosen/tested  7. Method used to validate stated traffic flow under specified conditions.  8. Support equipment used to verify operation of equipment  9. Description of test equipment used for making measurements with calibration dates  10. A block diagram with connection information. It is recommended that traffic flow be indicated.  11. Energy measurement results for all applicable test conditions as defined in the relevant supplemental standard. (MSS, Maximum, alternate configuration etc)  12. Duration of actual energy measurement tests  13. Identification of environmental conditions  14. TEER  15. Report of any engineering judgement used during the evaluation  16. EUT information  The test report shall contain complete information about the EUT, software version, EUT configuration information, hardware serial numbers, and test instruments’ models and serial numbers. The equipment class shall be included in the reporting description. | This document does not endorse a specific reporting format.  However, it is worth noting that any results that are collected under this methodology are intended to be fully reproducible by independent test laboratories. For this reason, the minimum set of results (beyond the actual measurements) is required to include the following documentation:  1. All SUT software versions, hardware board revisions and device configurations used during the test. All commands applied to SUT for purposes of static reconfiguration (Test Procedure 2) or run-time queries (Test Procedure 4) should also be provided.  2.Traffic generator/measurement tool passports, actual voltage in power feeds and ambient (environmental) conditions at test site.  3. The test setup should be fully described, including topology, the choice of offered load structure and test actions within a range of possible choices. |

# 10 Conclusion

In summary, the following significant observations have been made while comparing the global standards on energy efficiency of IP equipments such as ATIS/ITU/ETSI and the ECR document [1, 2, 3 and 4]:

1. Units of the ECR metric are defined in Watts/Gbps. This is not in agreement with the generic definition of energy efficiency of telecom equipments as defined by ITU “The energy efficiency metric is typically defined as the ratio between the functional unit and the energy necessary to deliver the functional unit. In this recommendation the term functional unit is considered a performance representation of the system under analysis, for example, transport equipment is the quantity of information transmitted and the distance at which the information is transported for other equipment Gbit/sec. Sometimes the term is used with the same meaning to indicate useful output or work.” see ISO 14040 [5] section 3.20. At the same time, ATIS/ITU/ETSI definitions of energy efficiency for IP equipments comply with the general definition.

2. Weight multipliers for throughput and power computation at various utilization levels are not defined. are the weight multiplier coefficients defined in the ECR document [4]. However, the values of these multipliers are not specified and left open for the vendors to choose. This is a major drawback as compared to other international standards like ATIS/ITU/ETSI, since choosing weights in such a way so as to inefficient states of operation can produce misleading results. All major standards on energy efficiency of equipments define the coefficient values to be utilized for computations.

3. The ECR metric does not incorporate support for low power states such as sleep mode of the IP router equipment. Though, it accounts for the idle state where there could be a lower power consumption when no packets are processed over the ports; it does not explicitly consider a state where the router could move to a very low power sleep mode [Mainly access routers] in real time while waiting for new packets to arrive for processing. The ITU specification, for example considers such a low power state in real time.

4. The ECR, ECR-VL metrics [4] do not incorporate the variations due to explicit switching into low power states in non-real time by the router hardware [Mainly in the edge and core routers]. These power states need not necessarily be activated on zero throughput level. They may also be activated at various intermediate utilization levels. The ECR-EX metric accounts for such variations; however the same is not considered in the current document for comparison. The ETSI/ATIS specifications also do not address the explicit low power states in routers.

5. The ECR document [4] does not detail the characteristics of the DC power source used to power the equipment under test conditions. All other standards consider the DC 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. Such a protection against surges is very essential to dimension the power source capabilities under lab test conditions. Further, a minimum digitizing sample rate of 40 kHz and input circuitry with bandwidth of 80 kHz is recommended for such power sources by other standards.

6. It is mentioned in the ECR document [4] prior to the actual test, the equipment has to be exposed to environmental conditions for at least four hours to settle the potential temperature difference. This period appears to be too long and unreasonable considering the modern lab equipments capable of maintaining the temperatures. A period of maximum 15 minutes is recommended by all other global standards for stabilization period.

7. Simple IMIX average of 340 Bytes size packets is suggested for ECR computation in [4]. This is too simplistic assumption considering the complex traffic profiles seen by the equipment in real deployment conditions. It is recommended that atleast a simple IMIX traffic mix with packet sizes and proportion of the total traffic be defined as per relevant global specification to obtain realistic traffic loads for measurement purposes.

8. ITU specification recommends ISO/IEC 17025 General requirements for the competence of testing and calibration laboratories [5] as a general basis for reports along with minimum requirement for content of the test reports. However, the ECR document [5] does not endorse a specific reporting format and neither provides details of contents of such a test report. The ETSI document also does not specify any requirements for the reporting format of measurements. The ATIS standard ATIS-0600015-2009 [7] however provides details of general requirements for reporting the energy efficiency test results.

Annexes are only to be used where appropriate:

Annex <A>:  
<Annex title>

Annexes are labelled A, B, C, etc. and are "informative"(3G TRs are informative documents by nature).

# A.1 Heading levels in an annex

Annex <1>:  
Change history

It is usual to include an annex (usually the final annex of the document) for reports under TSG change control which details the change history of the report using a table as follows:

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Change history** | | | | | | | |
| **Date** | **TSG #** | **TSG Doc.** | **CR** | **Rev** | **Subject/Comment** | **Old** | **New** |
| 2013-07 |  |  |  |  | TOC for TR on Energy Efficiency of IP equipments. |  | 0.0.0 |
| 2013-08 |  |  |  |  | Content updated |  | 0.0.1 |
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