

ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

L.1331

(04/2017)

SERIES L: ENVIRONMENT AND ICTS, CLIMATE
CHANGE, E-WASTE, ENERGY EFFICIENCY;
CONSTRUCTION, INSTALLATION AND PROTECTION
OF CABLES AND OTHER ELEMENTS OF OUTSIDE
PLANT

Assessment of mobile network energy efficiency

Recommendation ITU-T L.1331

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ITU-T L-SERIES RECOMMENDATIONS

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Recommendation ITU-T L.1331

Assessment of mobile network energy efficiency

Summary

Recommendation ITU-T L.1331 aims to provide a better understanding of the energy efficiency of mobile networks. The focus of this Recommendation is on the metrics and methods of assessing energy efficiency in operational networks.

The networks considered are those whose size and scale could be defined by topologic, geographic or demographic boundaries.

This Recommendation explains how to extrapolate the measurements made on partial networks to the level of the total network. Such a simplified approach is proposed as a way of making approximate energy efficiency evaluations at the level of network elements, and cannot therefore be considered sufficient for the entire network operation including, for example, transport.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T L.1331	2017-04-06	5	11.1002/1000/13147

Keywords

Energy efficiency, metrics, mobile, networks.

* To access the Recommendation, type the URL <http://handle.itu.int/> in the address field of your web browser, followed by the Recommendation's unique ID. For example, <http://handle.itu.int/11.1002/1000/11830-en>.

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Introduction

Recommendation ITU-T L.1331 considers the definition of metrics and methods used to measure energy efficiency performance of mobile radio access networks and adopts an approach based on the measurement of such performance on small networks, for feasibility and simplicity purposes. Such a simplified approach is proposed for approximating energy efficiency evaluations and cannot be considered as a reference for planning evaluation purposes throughout the network operation process. The same approach was introduced in ETSI TR 103 117; the measurements in testing laboratories of the efficiency of the base stations is the topic treated in ETSI ES 202 706.

The measurement of this performance is useful for many reasons, and implementation guidelines are given in clause 11.

Recommendation ITU-T L.1331 also provides an extrapolation method to extend the applicability of the assessment of energy efficiency to wider networks.

The general outcome of the application of the method specified is based on the "Assessment report" introduced in clause 10. An example of an application of the method is given for better readability and ease of use in Appendix I.

Recommendation ITU-T L.1331 was developed jointly by ETSI TC EE and ITU-T Study Group 5 and published by ITU and ETSI as Recommendation ITU-T L.1331 and ETSI Standard ETSI ES 203 228 respectively, which are technically equivalent.

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Recommendation ITU-T L.1331

Assessment of mobile network energy efficiency

1 Scope

This Recommendation aims to provide a better understanding of the energy efficiency of mobile networks. The focus of this Recommendation is on metrics for energy efficiency and methods of assessing (and measuring) energy efficiency in operational networks.

This Recommendation defines the topology and level of analysis needed to assess the energy efficiency.

The analysis includes radio base stations, backhauling systems, radio controllers (RCs) and other infrastructure radio site equipment. The technologies involved are global system for mobile communication (GSM), universal mobile telecommunications service (UMTS) and long term evolution (LTE) (including LTE advanced (LTE-A)).

Both homogeneous and heterogeneous networks are considered, whose size and scale could be defined by topologic, geographic or demographic boundaries. An example of a network defined by topologic boundaries consists of a control node (whenever applicable), its supported access nodes and related network elements. Networks could also be defined by geographic boundaries, such as city-wide, national or continental, or they could be defined by demographic boundaries, such as urban or rural networks.

This Recommendation also applies to so-called "partial" networks, where energy efficiency is measured in some recommended way. The specification extends the measurements made in partial networks to the wider, so-called "total" network energy efficiency estimation, such as the network in a geographical area, the network in an entire country or the network of a mobile network operator (MNO).

Terminal (end-user) equipment is outside the scope of this Recommendation and is not considered in the energy efficiency measurement.

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.

- [ITU-T L.1330] Recommendation ITU-T L.1330 (2015), *Energy efficiency measurement and metrics for telecommunication networks*.
- [ITU-T Q.1742.1] Recommendation ITU-T Q.1742.1 (2002), *IMT-2000 references to ANSI-41 evolved core network with cdma2000 access network*.
- [ETSI ES 202 336-12] ETSI ES 202 336-12 V1.1.1 (2015), *Environmental Engineering; Monitoring and control interface for infrastructure equipment (power, cooling and building environment systems used in telecommunications networks); Part 12: ICT equipment power, energy and environmental parameters monitoring information model*.

- [ETSI TS 123 203] ETSI TS 123 203 V12.7.0 (2015), *Digital cellular telecommunications system (Phase 2+); Universal Mobile Telecommunications System (UMTS); LTE; Policy and charging control architecture (3GPP TS 23.203 version 12.7.0 Release 12).*
- [ETSI TS 125 104] ETSI TS 125 104 V11.3.0 (2012), *Universal Mobile Telecommunications System (UMTS); Base Station (BS) radio transmission and reception (FDD) (3GPP TS 25.104 version 11.3.0 Release 11).*
- [ETSI TS 132 405] ETSI TS 132 405 V11.1.1 (2013), *Digital cellular telecommunications system (Phase 2+); Universal Mobile Telecommunications System (UMTS); LTE; Telecommunication management; Performance Management (PM); Performance measurements; Universal Terrestrial Radio Access Network (UTRAN) (3GPP TS 32.405 version 11.1.1 Release 11).*
- [ETSI TS 132 412] ETSI TS 132 412 V11.1.0 (2013), *Digital cellular telecommunications system (Phase 2+); Universal Mobile Telecommunications System (UMTS); LTE; Telecommunication management; Performance Management (PM) Integration Reference Point (IRP): Information Service (IS) (3GPP TS 32.412 version 11.1.0 Release 11).*
- [ETSI TS 132 425] ETSI TS 132 425 V12.0.0 (2014), *LTE; Telecommunication management; Performance Management (PM); Performance measurements Evolved Universal Terrestrial Radio Access Network (E-UTRAN) (3GPP TS 32.425 version 12.0.0 Release 12).*
- [ETSI TS 136 104] ETSI TS 136 104 V11.2.0 (2012), *LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); Base Station (BS) radio transmission and reception (3GPP TS 36.104 version 11.2.0 Release 11).*
- [ETSI TS 136 314] ETSI TS 136 314 V11.1.0 (2013), *LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); Layer 2 – Measurements (3GPP TS 36.314 version 11.1.0 Release 11).*
- [ETSI TS 152 402] ETSI TS 152 402 V11.0.0 (2012), *Digital cellular telecommunications system (Phase 2+); Telecommunication management; Performance Management (PM); Performance measurements – GSM (3GPP TS 52.402 version 11.0.0 Release 11).*
- [ISO/IEC 17025] ISO/IEC 17025:2005, *General requirements for the competence of testing and calibration laboratories.*

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

- 3.1.1 backhaul equipment:** See [ITU-T L.1330]
- 3.1.2 base station U:** See [ITU-T L.1330]
- 3.1.3 distributed RBS:** See [ITU-T L.1330]
- 3.1.4 energy efficiency (EE):** See [ITU-T L.1330]
- 3.1.5 energy saving feature:** See [ITU-T L.1330]
- 3.1.6 integrated BS:** See [ITU-T L.1330]
- 3.1.7 mobile network (MN):** See [ITU-T L.1330]

- 3.1.8 mobile network coverage energy efficiency:** See [ITU-T L.1330]
- 3.1.9 mobile network data energy efficiency:** See [ITU-T L.1330]
- 3.1.10 mobile network energy consumption:** See [ITU-T L.1330]
- 3.1.11 mobile network energy efficiency:** See [ITU-T L.1330]
- 3.1.12 mobile network operator (MNO):** See [ITU-T L.1330]
- 3.1.13 mobile network operator penetration ratio:** See [ITU-T L.1330]
- 3.1.14 mobile network performance delivered:** See [ITU-T L.1330]
- 3.1.15 power consumption:** See [ITU-T L.1330]
- 3.1.16 radio access network:** See [ITU-T Q.1742.1]
- 3.1.17 telecommunication network:** See [ITU-T L.1330]
- 3.1.18 virtualized network function (VNF)** [b-ETSI GS NFV 003]: Implementation of an NF that can be deployed on a Network Function Virtualisation Infrastructure (NFVI).

3.2 Terms defined in this Recommendation

This Recommendation defines the following term:

3.2.1 site energy efficiency (SEE): A metric used to determine the energy efficiency of a telecom site. SEE is defined by the ratio of "IT equipment energy" and "Total site energy", which generally includes rectifiers, cooling, storage, security and IT equipment.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

3GPP	3G (mobile) Partnership Project
BH	Backhaul
BS	Base Station
CC	Central Cloud
CoA	Coverage Area
CoA_geo	total geographical area under investigation and within the operators' license agreement
CoA_des	designated coverage area as designed by network planning
CoA_qdes	quality factor describing how well users are covered within the coverage area
CR	Coverage Ratio
CRAN	Cloud Radio Access Network
CS	Circuit Switched
DCA	Designed Coverage Area
DL	Downlink
DP	Dominant Penetration
DU	Dense Urban
DV	Data Volume
DV _{MN}	Data Volume of the Mobile Network
EC	Energy Consumption

EC _{MN}	Energy Consumption of the Mobile Network
EDC	Edge Cloud
EE	Energy Efficiency
EE _{MN}	Energy Efficiency of the Mobile Network
E-UTRA	Evolved UMTS Terrestrial Radio Access Network
FAO	Food and Agriculture Organization
GERAN	GSM/EDGE Radio Access Network
GHG	Greenhouse Gas
GSM	Global System for Mobile communication
GSMA	GSM Association
ICT	Information Communications Technology
KPI	Key Performance Indicator
LTE	Long Term Evolution
MDT	Minimization of Drive Tests
MJ	MegaJoule
MN	Mobile Network
MNO	Mobile Network Operator
MP	Minor Penetration
NA	Not Applicable
NDP	Non-Dominant Penetration
OAM	Operations and Maintenance
PDF	Probability Distribution Function
PS	Packet Switched
PSL	Packet Switched Large packages dominating
PSS	Packet Switched Small packages dominating
PUE	Power Usage Effectiveness
QCI	QoS Class Identifier
QoS	Quality of Service
RAB	Radio Access Bearer
RAN	Radio Access Network
RAP	Remote Access Point
RAT	Radio Access Technology
RC	Radio Controller
RF	Radio Frequency
RNC	Radio Network Controller
RRC	Radio Resource Control
RRH	Remote Radio Head

RU	Rural
SCH	Signalling Channel
SEE	Site Energy Efficiency
SI	Site Infrastructure
SINR	Signal to Interference plus Noise Ratio
SU	Suburban
TCH	Traffic Channel
TCO	Total Cost of Ownership
TMA	Tower Mounted Amplifier
U	Urban
UE	User Equipment
UE-BS	User Equipment to Base Station
UL	Uplink
UMTS	Universal Mobile Telecommunications Service
UN	United Nations
UTRAN	UMTS Terrestrial Radio Access Network
VNF	Virtualized Network Function
VoLTE	Voice over LTE
X2	Interface allowing to interconnect eNBs with each other

5 Conventions

None.

6 Network under test definition

6.1 Introduction

The mobile radio access network under investigation includes all the equipment that is necessary to run a radio access (RA) network or sub-network (see Figure 1 as a reference to the elements considered in this Recommendation).

- base stations (BSs) (see [ETSI TS 125 104] and [ETSI TS 136 104]):
 - wide area BS;
 - medium range BS;
 - local area BS;
 - home BS;

NOTE – Home BS (and Wi-Fi access points) are not considered in this Recommendation, and are for further study.

- site equipment (e.g., air conditioners, rectifiers/ batteries, fixed network equipment);
- backhaul (BH) equipment required to interconnect the BS used in the assessment with the core network;
- radio controller (RC).

Power consumption and energy efficiency measurements of individual mobile network elements are described in several standards (e.g., [b-ETSI ES 202 706] for radio base stations). This Recommendation describes the energy consumption (EC) and mobile network (MN) energy efficiency measurements in operational networks.

As a comprehensive and detailed energy consumption measurement of the complete network of a country or mobile network operator (MNO) may not be viable, the total network is split into a small number of networks with limited size (i.e., "sub-networks").

These sub-networks are defined to represent specific characteristics, for example:

- capacity-limited networks representing urban (U) and dense urban (DU) networks;
- suburban (SU) networks with high requirements for coverage and capacity;
- rural (RU) networks, which are usually coverage limited.

The size and scale of the sub-networks are defined by topologic, geographic or demographic boundaries. For networks defined by topologic boundaries, an example could include: a radio controller, its supported access nodes and related network elements. Networks could also be defined by geographic boundaries, such as city-wide, national or continental networks. Networks could also be defined by demographic boundaries, such as urban or rural networks.

The sub-networks analysed might consist of macro-only base stations (BSs) or heterogeneous networks or what is actually implemented in real-world networks.

The tests defined in this Recommendation for sub-networks provide the basis to estimate energy efficiency for large networks of one MNO or within an entire country, applying the extrapolation methods described in clause 9.

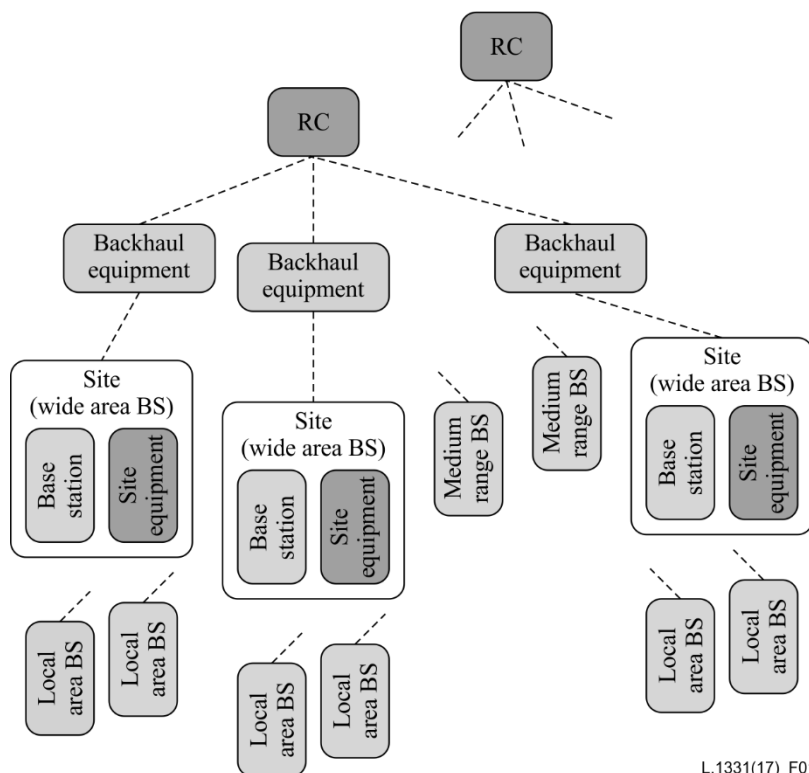


Figure 1 – Network under test definition

The functions outlined in Figure 1 could also be implemented in a cloud radio access network (CRAN). The first details of assessing energy efficiency in CRAN networks are outlined in Appendix II, but further investigated is needed.

6.2 Test parameter categorization

Metrics used for the energy efficiency assessment of mobile networks require the definition and collection of a range of parameters and variables. These are separated into two categories:

- 1) parameters and variables required to calculate the network energy efficiency;
- 2) parameters needed to allow network energy efficiency evaluation.

The first category describes a set of network variables as described in clause 7 (energy consumption, delivered bits, coverage) to be used to calculate the energy efficiency.

The second category includes parameters which are not directly required in the energy efficiency calculation. These parameters describe the network characteristics, such as geographical conditions, population density, coverage area, targeted data rates and climate zones, and are used to interpolate from the measured sub-network to a larger network as described in clause 9. These parameters can be used to interpret variations in energy efficiency results of different networks. Test parameters are listed in Table 1.

Table 1 – Test parameter categorization

Category	Parameter	Remarks
1	EC_{MN}	Measured network energy consumption
1	Capacity	As defined in clause 7.1
1	Coverage area	As defined in clause 8.3.3
2	Coverage ratio	As defined in clause 8.3.3
2	Demography	Population density as defined in clause 6.3.2
2	Topography	As defined in clause 6.3.3
2	Climate zones	As defined in clause 6.3.4
2	Informative classes	As defined in clause 6.3.5
2	Circuit switched/packet switched data ratio	Describes the fraction of circuit switched traffic vs. packet switched traffic in the network

6.3 Network classification

6.3.1 Introduction to network classification

To allow an extrapolation from the measured sub-networks (i.e., "partial" networks) to a complete network (i.e., "total" or "overall" networks), the test areas shall be classified into different categories as described in this clause.

The environmental classes used for network classification are: demography, topography and climate zones and are described in the following clauses.

6.3.2 Demography

For the test purposes defined in this Recommendation the mobile network is split into domains depending on the population density. The following population density values per domain categories are recommended, as reported in Table 2.

Table 2 – Sub-network demography classes

Demography class	Typical population density (inhabitants/km ²)	Population range (inhabitants/km ²)
Dense urban (DU)	20000	> 10000
Urban (U)	2000	1000-10000
Suburban (SU)	300	200-1000
Rural (RU)	30	20-200
Unpopulated	0	< 20

Some references to databases where the demography distribution classes are reported can be found at [b-European Eurostat], [b-UN Reference] and [b-USA Reference].

6.3.3 Topography

The following topography classes shall be used, as reported in Table 3.

Table 3 – Sub-network topography classes

Topography classification		Examples
ETSI class	Median slope	
1 Flat (FAO 1-3)	0-5%	Denmark, Netherlands
2 Rolling (FAO 4-6)	> 5-30%	France, Italy
3 Mountainous (FAO 7-8)	> 30%	Norway, Switzerland

Information on the median slope gradient distribution in the world can be found in the Food and Agriculture Organization (FAO) of the United Nations (UN) world median slope distribution information database [b-FAO].

6.3.4 Climate zones

The following climate zones are identified as reported in Table 4.

Table 4 – Sub-network climate classes

Climate class	Subclass	Explanation
A: Tropical	<i>Temperature of the coldest month: > 18 °C</i>	
	Af	No dry season, at least 60 mm of rainfall in the driest month
	Am	Monsoon type, short dry season but sufficient moisture to keep ground wet throughout the year
	Aw	Distinct dry season, one month with precipitation < 60 mm
B: Dry	<i>Arid regions where annual evaporation exceeds annual precipitation, marked dry season</i>	