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Assessment of mobile network energy efficiency
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Contents

Intellectual Property Rights	5
Foreword.....	5
Modal verbs terminology.....	5
Introduction	6
1 Scope	7
2 References	7
2.1 Normative references	7
2.2 Informative references.....	8
3 Definition of terms, symbols and abbreviations.....	9
3.1 Terms.....	9
3.2 Symbols.....	10
3.3 Abbreviations	10
4 Network under test definition.....	12
4.1 Introduction	12
4.2 Test parameter categorization.....	13
4.3 Network classification	14
4.3.0 Introduction of network classification	14
4.3.1 Demography	14
4.3.2 Topography.....	15
4.3.3 Climate zones.....	15
4.3.4 Additional classification classes	16
5 Metrics for energy efficiency assessment.....	16
5.0 Introduction of clause.....	16
5.1 Energy Consumption metrics	16
5.2 Performance metrics.....	19
5.2.1 Data Volume.....	19
5.2.2 Coverage Area	19
5.2.3 Latency	20
5.2.4 Massive machine type networks	20
5.3 Mobile Network Energy efficiency metrics	20
6 Measurement of energy efficiency	21
6.0 Introduction of clause.....	21
6.1 Time duration of the measurement.....	21
6.2 Measurement procedures.....	22
6.2.1 Measurement of Energy Consumption	22
6.2.2 Measurement of capacity	22
6.2.3 Determination of coverage area.....	23
6.2.3.0 Introduction	23
6.2.3.1 Geographic coverage area	23
6.2.3.2 Designated coverage area.....	23
6.2.3.3 Coverage quality	23
6.2.4 Measurement of latency.....	26
6.2.5 Measurement of the number of subscribers	26
7 Extrapolation for overall networks.....	26
7.0 Extrapolation approach.....	26
7.1 Extrapolation method	27
7.1.0 Introduction of extrapolation method	27
7.1.1 Statistical information about Demography	27
7.1.2 Statistical information about Topography.....	27
7.1.3 Statistical information about Climate zones	28
7.2 Extrapolation reporting tables	28
7.2.0 Introduction of extrapolation reporting tables.....	28

7.2.1	Reporting extrapolation based on Demography.....	28
7.2.2	Reporting extrapolation based on Topography.....	29
7.2.3	Reporting extrapolation based on Climate zones.....	29
8	Assessment report	29
8.0	Introduction of assessment report.....	29
8.1	Report of Network Area under test	29
8.2	Report of sites under test.....	31
8.3	Report of Site measurement	32
9	Implementation guidelines	33
Annex A (informative): Implementation examples		34
A.1	Implementation examples.....	34
A.2	Examples of reporting data.....	34
History		39

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[ETSI ES 203 228 V1.4.0 \(2022-02\)](https://standards.iteh.ai/catalog/standards/sist/3bface2-71cd-45a4-b0cd-07ae052d23d3/etsi-es-203-228-v1-4-0-2022-02)
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Foreword

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This final draft ETSI Standard (ES) has been produced by ETSI Technical Committee Environmental Engineering (EE), and is now submitted for the ETSI standards Membership Approval Procedure.

The present document was developed jointly by ETSI TC EE and ITU-T Study Group 5. It will be published respectively by ITU and ETSI as Recommendation ITU-T L.1331 [i.4] and ETSI ES 203 228 (the present document), which are technically-equivalent.

Moreover the present document has been developed in collaboration with 3GPP SA5 and RAN3; GSMA has also given valuable suggestions and contributions.

Modal verbs terminology

In the present document "**shall**", "**shall not**", "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the [ETSI Drafting Rules](#) (Verbal forms for the expression of provisions).

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Introduction

The present document deals with the definition of metrics and methods to measure energy 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 simplified approach is proposed for approximate energy efficiency evaluations and cannot be considered as a reference for planning evaluation purposes throughout the network operation process. The same approach was introduced also in ETSI TR 103 117 [i.1]; the measurements in testing laboratories of the efficiency of the Base Stations is the topic treated in ETSI ES 202 706 [i.2].

The present document provides also a method to extrapolate the assessment of energy efficiency to wider networks (clause 7).

The general outcome of the application of the method specified in the present document is based on the "Assessment report" introduced in clause 8. An example of application of the method is also given in annex A.

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1 Scope

The present document is aimed at defining the topology and level of analysis to assess the energy efficiency of mobile networks. Within the scope of the present document there is the radio access part of the mobile networks, and namely there are radio base stations, backhauling systems, radio controllers and other infrastructure radio site equipment. The covered technologies are GSM, UMTS, LTE and 5G New Radio (NR). In particular the present document defines metrics for mobile network energy efficiency and methods for assessing (and measuring) energy efficiency in operational networks. The purpose of the present document is to allow better comprehension of networks energy efficiency, in particular considering the networks' evolution in different periods in time.

Aiming to consider also the slicing approach of the networks from 5G onwards the metrics are extended to the latency of the network itself related to the energy consumed, additionally to the metrics based on traffic and on coverage, already existing for legacy networks and still valid.

The present document deals with both a homogeneous and heterogeneous "network" considering a network whose size and scale could be defined by topologic, geographic or demographic boundaries. For networks defined by topologic boundaries, a possible example of a network covered by the present document consists of a control node (whenever applicable), its supported access nodes as well as the related network elements. Networks could be defined by geographic boundaries, such as city-wide, national or continental networks and could be defined by demographic boundaries, such as urban or rural networks.

The present document applies to the so-called "partial" networks for which a measurement method is also recommended. The specification extends the measurements in partial networks to wider so-called "total" networks energy efficiency estimations (i.e. the network in a geographic area, the network in a whole country, the network of a MNO, etc.).

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

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2 References

2.1 Normative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

Referenced documents which are not found to be publicly available in the expected location might be found at <https://docbox.etsi.org/Reference/>.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

The following referenced documents are necessary for the application of the present document.

- [1] ETSI TS 125 104: "Universal Mobile Telecommunications System (UMTS); Base Station (BS) radio transmission and reception (FDD) (3GPP TS 25.104)".
- [2] ETSI TS 136 104: "LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); Base Station (BS) radio transmission and reception (3GPP TS 36.104)".
- [3] ETSI TS 132 425 (V12.0.0): "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)".
- [4] ETSI TS 132 412 (V11.1.0): "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)".

- [5] ETSI TS 123 203 (V12.7.0): "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)".
- [6] ETSI TS 136 314: "LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); Layer 2 - Measurements (3GPP TS 36.314)".
- [7] ETSI TS 152 402 (V11.0.0): "Digital cellular telecommunications system (Phase 2+); Telecommunication management; Performance Management (PM); Performance measurements - GSM (3GPP TS 52.402 version 11.0.0 Release 11)".
- [8] ETSI TS 132 405 (V11.1.1): "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)".
- [9] ETSI ES 202 336-12: "Environmental Engineering (EE); Monitoring and control interface for infrastructure equipment (power, cooling and building environment systems used in telecommunication networks); Part 12: ICT equipment power, energy and environmental parameters monitoring information model".
- [10] ISO/IEC 17025 (2005): "General requirements for the competence of testing and calibration laboratories".
- [11] ETSI EN 303 471: "Environmental Engineering (EE); Energy Efficiency measurement methodology and metrics for Network Function Virtualisation (NFV)".
- [12] Report ITU-R M.2410: "Minimum requirements related to technical performance for IMT-2020 radio interface(s)".
- [13] ETSI TS 128 554: "5G; Management and orchestration; 5G end to end Key Performance Indicators (KPI) (3GPP TS 28.554)".
- [14] ETSI TS 128 552 (V16.6.0): "5G; Management and orchestration; 5G performance measurements (3GPP TS 28.552 version 16.6.0 Release 16)".

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NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

- [i.1] ETSI TR 103 117: "Environmental Engineering (EE); Principles for Mobile Network level energy efficiency".
- [i.2] ETSI ES 202 706 (all parts): "Environmental Engineering (EE); Measurement method for power consumption and energy efficiency of wireless access network equipment".
- [i.3] ETSI GS NFV 003: "Network Functions Virtualisation (NFV); Terminology for Main Concepts in NFV".
- [i.4] Recommendation ITU-T L.1331: "Assessment of mobile network energy efficiency".
- [i.5] FAO Soils Portal.

NOTE: Available at <http://www.fao.org/soils-portal/soil-survey/soil-maps-and-databases/harmonized-world-soil-database-v12/en/>.

[i.6] Jürgen Grieser, René Gommès, Stephen Cofield and Michele Bernardi: "Data sources for FAO worldmaps of Koeppen climatologies and climatic net primary production", 2006.

NOTE: Available at http://www.fao.org/nr/climpag/globgrids/KC_commondata_en.asp.

3 Definition of terms, symbols and abbreviations

3.1 Terms

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

backhaul equipment: equipment used to connect base stations to the core network, or to other BSs (like X2 in LTE)

Base Station (BS): generic term used for network component which serves one cell or more cells and interfaces the user terminal (through air interface) and a radio access network infrastructure

distributed RBS: BS architecture which contains Remote Radio Heads (RRH) close to the antenna element and a central element connecting BS to network infrastructure

end-to-end latency: time that takes to transfer a given piece of information from a source to a destination, measured at the communication interface, from the moment it is transmitted by the source to the moment it is successfully received at the destination

Energy Efficiency (EE): relation between the useful output and energy/power consumption

energy saving feature: feature which contributes to decreasing the energy consumption compared to the case when the feature is not implemented

integrated BS: BS architecture in which all BS elements are located close to each other for example in one or two cabinets

NOTE: The integrated BS architecture may include TMA close to antenna.

Mobile Network (MN): set of equipment from the radio access network or sub-network that are relevant for the assessment of energy efficiency

mobile network coverage energy efficiency: ratio between the area covered by the network in the Mobile Network under investigation and the energy consumption

mobile network data energy efficiency: ratio between the performance indicator based on Data Volume and the energy consumption when assessed during the same time frame

mobile network energy consumption: overall energy consumption of equipment included in the MN under investigation

mobile network energy efficiency: energy efficiency of a mobile network

Mobile Network Operator (MNO): operator that manages one or more mobile networks

mobile network operator penetration ratio: percentage of traffic served by an MNO in the area where it is active

mobile network performance delivered: performance indicator of the MN under investigation, defined as the data volume delivered by the mobile network under investigation during the time frame of the energy consumption assessment

power consumption: power consumed by a device to achieve an intended application performance

radio access network: telecommunications network in which the access to the network (connection between user terminal and network) is implemented without the use of wires and that is part of GERAN, UTRAN or E-UTRA networks defined by 3GPP

Site Energy Efficiency (SEE): metric used to determine the energy efficiency of a telecommunication site

NOTE: SEE is defined by the ratio of "IT equipment energy" and "Total site energy", which generally includes rectifiers, cooling, storage, security and IT equipment. For datacentres, the "Total site energy" more globally includes building load, powering equipment (e.g. switchgear, uninterruptible power supply (UPS), battery backup), cooling equipment (e.g. chillers, Computer Room Air Conditioning unit (CRAC)) and IT equipment energy.

telecommunication network: network operated under a license granted by a national telecommunications authority, which provides telecommunications between Network Termination Points (NTPs)

Virtualised Network Function (VNF): See ETSI GS NFV 003 [i.3].

3.2 Symbols

Void.

3.3 Abbreviations

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

3GPP	3G (mobile) Partnership Project
BH	Backhaul
BS	Base Station
CC	Central Cloud
CoA	Coverage Area
CoA_des	designated coverage area as designed by network planning
CoA_geo	total geographical area under investigation and within the operator's license agreement
CoA_Qdes	quality factor describing how well users are covered within the coverage area
CoA _{MN}	Coverage Area Mobile Network
CRAN	Cloud Radio Access Network
CS	Circuit Switched
CS/PS	Circuit Switched/Packet Switched
DC	Data Center
DCA	Designed Coverage Area
DL	DownLink
DP	Dominant Penetration
DU	Dense Urban
DV	Data Volume
DV _{MN}	Data Volume of the Mobile Network
E2E	End To End
EC	Energy Consumption
EC _{MN}	Energy Consumption of the Mobile Network
EC _{SI}	Energy Consumption of the Site
EDC	Edge Cloud
EDGE	Enhanced Data rates for GSM Evolution
EE _{MN}	Energy Efficiency of the Mobile Network
E-RAB	E-UTRAN Radio Access Bearer
E-UTRA	Evolved UMTS Terrestrial Radio Access
E-UTRAN	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
HARQ	Hybrid Automatic Repeat Request
ICT	Information Communications Technology
IP	Ingress Protection
ITU	International Telecommunications Union

ITU-T	International Telecommunications Union - Telecommunication
KPI	Key Performance Indicator
LC	Local Cloud
LTE	Long Term Evolution
MDT	Minimization of Drive Tests
MJ	MegaJoule
MMTC	Massive Machine Type Communication
MN	Mobile Network
MNO	Mobile Network Operator
MP	Minor Penetration
NA	Not Applicable
NDP	Non Dominant Penetration
NR	New Radio
O&M	Operation & Maintenance
PDCP	Packet Data Control Protocol
PDF	Probability Distribution Function
PofP	Point of Presence
PS	Packet Switched
PSL	Packet Switched Large packages dominating
PSS	Packet Switched Small packages dominating
QCI	QoS Class Identifier
QoS	Quality of Services
RA	Radio Access
RAB	Radio Access Bearer
RAN	Radio Access Network
RAP	Radio Access Point
RAT	Radio Access Technology
RC	Remote Controller
RF	Radio Frequency
RNC	Radio Network Controller
RRC	Radio Resource Control
RRH	Remote Radio Head
RU	Rural
SDU	Service Data Unit
SE	Switching Equipment
SEE	Site Energy Efficiency
SI	Site Infrastructure
SINR	Signal to Interference plus Noise Ratio
SU	Sub Urban
TCO	Total Cost of Ownership
TE	Telco Equipment
TMA	Tower Mounted Amplifier
U	Urban
UE	User Equipment
UE-BS	User Equipment to Base Station
UL	UpLink
UP	User Plane
UMTS	Universal Mobile Telecommunication Service
UN	United Nations
URLLC	Ultra Reliable Low Latency Communications
USA	United States of America
UTRAN	UMTS Terrestrial Radio Access Network
VNF	Virtualised Network Function
VNFS	Virtualised Network Function Servers
X2	Interface allowing to interconnect eNBs with each other

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4 Network under test definition

4.1 Introduction

The Mobile Network (MN) for Radio Access (RA) under investigation shall include all the equipment that is necessary to run a radio access network or sub-network. Equipment to be included in the Mobile Network under investigation:

- Base Stations (see ETSI TS 125 104 [1] and ETSI TS 136 104 [2]):
 - Wide area BS.
 - Medium range BS.
 - Local Area BS.
 - Home BS.

NOTE: Home BS (and Wi-Fi access points) are not dealt with in the present document, being possibly considered for future versions.

- Site equipment (air conditioners, rectifiers/batteries, fixed network equipment, etc.).
- Multi-Access EDGE equipment.
- Backhaul equipment required to interconnect the BS used in the assessment with the core network.
- Radio Controller (RC).
- Gateways to connect to the Cloud.

Power consumption and energy efficiency measurements of individual mobile network elements are described in several standards (for example ETSI ES 202 706-1 and ETSI ES 202 706-2 [i.2] for radio base stations). The present document describes energy consumption and MN energy efficiency measurements in operational networks.

As a complete and detailed energy consumption measurement of the complete network of a country or MNO is in most cases impossible or economically not viable, the total network is split into a small number of networks with limited size ("sub-networks").

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

- capacity limited networks representing urban and dense urban networks;
- sub-urban networks with high requirements for coverage and capacity;
- rural 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, a possible example of a network covered by the present document consists of a Radio controller (whenever applicable), its supported access nodes as well as the related network elements. Networks could be defined by geographic boundaries, such as city-wide, national or continental networks and could be defined by demographic boundaries, such as urban or rural networks.

The sub-networks analysed might consist of macro-only base stations or heterogeneous networks or whatever is actually implemented in real networks. A description of the sub-network general layout is represented in the figure 1.

The tests defined in the present document 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 7.