ETSI TR 103 542 V1.1.1 (2018-06)

Environmental Engineering (EE);
Study on methods and metrics to evaluate energy efficiency for future 5G systems

Reference

DTR/EE-EEPS31

Keywords

5G, energy efficiency, energy management, KPI, metrics, mobile, radio

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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Environmental Engineering (EE).

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Executive summary

The present document analyses the impacts that the introduction of the new mobile system "5G" will bring to the Energy Efficiency methods and metrics as already standardized for the legacy systems. The report is a first view on this topic towards the future developments that will be carried on in next years, to properly amend the current standards.

1 Scope

The present document analyses the energy efficiency issues for the future 5G systems, object of standardization in 3GPP and ITU and foreseen to be available from 2018 in various countries. The focus is about methods and metrics to measure energy efficiency in 5G systems, considering the degree of stability of the systems known so far and the experience of the legacy systems and the related measurement procedures.

In this approach, the present document will rely on the existing standards for legacy radio systems, especially ETSI ES 202 706 [i.1] and [i.2] for single base station measurements in a laboratory environment and ETSI ES 203 228 [i.3] for access network aggregate measurements of energy efficiency. These standards are currently studying 2G, 3G and 4G energy efficiency topics. Moreover, the present document considers also the state of the art in 5G energy efficiency studies to elaborate a first view on 5G, to be further agreed for the possible future development towards a new standard of Energy Efficiency evaluation for 5G future systems.

2 References

2.1 Normative references

Normative references are not applicable in the present document.

2.2 Informative 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.

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 ES 202 706-1: "Environmental Engineering (EE); Metrics and measurement method for energy efficiency of wireless access network equipment; Part 1: Power Consumption - Static Measurement Method".

[i.2] ETSI ES 202 706-2: "Environmental Engineering (EE); Metrics and Measurement Method for Energy Efficiency of Wireless Access Network Equipment; Part 2: Energy Efficiency - dynamic measurement method".

[i.3] ETSI ES 203 228: "Environmental Engineering (EE); Assessment of mobile network energy efficiency".

[i.4] ETSI TR 138 913: "5G; Study on Scenarios and Requirements for Next Generation Access Technologies (3GPP TR 38.913 Release 14)".

[i.5] 3GPP TR 21.866: "Technical Specification Group Services and System Aspects; Study on Energy Efficiency Aspects of 3GPP Standards (Release 14)".

[i.6] ITU-R IMT-2020.TECH PERF REQ: "Minimum requirements related to technical performance for IMT-2020 radio interface(s)".

[i.7] Recommendation ITU-R M.2083-0: "IMT-Vision - Framework and overall objectives of the future development of IMT for 2020 and beyond".

[i.8] ITU-T Technical Paper Series L: "Study on methods and metrics to evaluate energy efficiency for future 5G systems".

[i.9] ETSI EN 305 174-2: "Access, Terminals, Transmission and Multiplexing (ATTM); Broadband Deployment and Lifecycle Resource Management; Part 2: ICT Sites".

[i.10] ETSI EN 305 200-1: "Access, Terminals, Transmission and Multiplexing (ATTM); Energy management; Operational infrastructures; Global KPIs; Part 1: General requirements".

[i.11] ETSI EN 305 200-2-1: "Access, Terminals, Transmission and Multiplexing (ATTM); Energy management; Operational infrastructures; Global KPIs; Part 2: Specific requirements; Sub-part 1: ICT Sites".

[i.12] ETSI EN 305 200-3: "Access, Terminals, Transmission and Multiplexing (ATTM); Energy management; Operational infrastructures; Global KPIs; Part 3: ICT Sites; Sub-part 1: DCEM".

[i.13] ETSI EN 303 470: "Environmental Engineering (EE); Energy Efficiency measurement methodology and metrics for Servers".

[i.14] ETSI EN 305 200-2-2: "Access, Terminals, Transmission and Multiplexing (ATTM); Energy management; Operational infrastructures; Global KPIs; Part 2: Specific requirements; Sub-part 2: Fixed broadband access networks".

[i.15] ETSI ES 205 200-2-4: "Integrated broadband cable telecommunication networks (CABLE); Energy management; Global KPIs; Operational infrastructures; Part 2: Specific requirements; Sub-part 4: Cable Access Networks".

[i.16] ETSI EN 305 200-2-3: "Access, Terminals, Transmission and Multiplexing (ATTM); Energy management; Operational infrastructures; Global KPIs; Part 2: Specific requirements; Sub-part 3: Mobile broadband access networks".

[i.17] ETSI EN 303 472: "Environmental Engineering (EE); Energy Efficiency measurement methodology and metrics for RAN equipment".

[i.18] ETSI EN 305 174-5-1: "Access, Terminals, Transmission and Multiplexing (ATTM); Broadband Deployment and Lifecycle Resource Management; Part 5: Customer network infrastructures; Sub-part 1: Homes (single-tenant)".

[i.19] ETSI EN 305 174-1: "Access, Terminals, Transmission and Multiplexing (ATTM); Broadband Deployment and Lifecycle Resource Management; Part 1: Overview, common and generic aspects".

[i.20] ETSI EN 303 471: "Environmental Engineering (EE); Energy Efficiency measurement methodology and metrics for Network Function Virtualization (NFV)".

[i.21] ETSI EN 305 174-8: "Access, Terminals, Transmission and Multiplexing (ATTM); Broadband Deployment and Lifecycle Resource Management; Part 8: Management of end of life of ICT equipment (ICT waste/end of life)".

[i.22] METIS-II Deliverable D2.1: "Requirement analysis and design approaches for 5G air interface".

NOTE: Available at https://www.metis2020.com/wp-content/uploads/deliverables/METIS_D2.1_v1.pdf.

[i.23] METIS-II Deliverable D2.3: "Components of a new air interface - building blocks and performance".

NOTE: Available at https://www.metis2020.com/wp-content/uploads/deliverables/METIS_D2.3_v1.pdf.

[i.24] Recommendation ITU-R M.2083: "IMT Vision - Framework and overall objectives of the future development of IMT for 2020 and beyond".

3 Definitions and abbreviations

3.1 Definitions

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

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

Base Station (BS): 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 radio heads (RRH) close to the antenna element and a central element connecting BS to network infrastructure

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

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 (RAN): 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

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

3.2 Abbreviations

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

3GPP	3G (mobile) Partnership Project
AMF	core Access and mobility Management Function
BH	BackHaul
BS	Base Station
BW	BandWidth

CoA	Coverage Area
CS	Circuit Switched
DL	Down Link
DP	Dominant Penetration
DTX	Discontinuous Transmission
DU	Dense Urban
DV	Data Volume
EC	Energy Consumption
EDGE	Enhanced Data rate GSM Evolution
EE	Energy Efficiency
eMBB	extreme/enhanced Mobile BroadBand
EMF	Equipment Management Function
eNB	E-UTRA BS
E-UTRA	Evolved UMTS Terrestrial Radio Access
GERAN	GSM/EDGE Radio Access Network
GSM	Global System for Mobile communication
GSMA	GSM Association
HSDPA	High Speed Downlink Packet Access
HSPA	High Speed Packet Access
HW	HardWare
IAT	Inter-Arrival Time
ICT	Information Communications Technology
IMT	International Mobile Telecommunications
IoT	Internet of Things
KPI	Key Performance Indicator
LCA	Life Cycle Assessment
LTE	Long Term Evolution
LTE-A	LTE (Long Term Evolution)-Advanced
MDT	Minimization of Drive Tests
MIMO	Multiple Input Multiple Output
MME	Mobility Management Entity
mMTC	massive Machine Type Communications
MN	Mobile Network
MNO	Mobile Network Operator
MP	Minor Penetration
MTC	Machine Type Communications
NDP	Non Dominant Penetration
NFV	Network Function Virtualization
NGMN	Next Generation Mobile Networks
NR	New Radio
O&M	Operation & Maintenance
PDF	Probability Distribution Function
PS	Packet Switched
PSL	Packet Switched Large packages dominating
PSS	Packet Switched Small packages dominating
QoE	Quality of Experience (end-user)
QoS	Quality of Services
RAN	Radio Access Network
RAT	Radio Access Technology
RC	Remote Controller
RF	Radio Frequency
RNC	Radio Network Controller
RRC	Radio Resource Control
RRH	Remote Radio Head
RU	RUral
RX	Receiver
SA	Service and System Aspects
SCH	Signalling CHannel
SI	Site Infrastructure
SINR	Signal to Interference plus Noise Ratio
SME	Session Management Entity
STF	Specialist Task Force

SU	Sub Urban
SW	SoftWare
TCH	Traffic CHannel
TCO	Total Cost of Ownership
TCP	Transmission Control Protocol

NOTE: ACK, SYN and FIN are signalling in the TCP session.

TMA	Tower Mounted Amplifier
TRX	Transceiver
TX	Transmitter
U	Urban
UE	User Equipment
UL	UpLink
UMTS	Universal Mobile Telecommunications System
UN	United Nations
URLLC	Ultra-Reliable and Low Latency Communications
UTRAN	UMTS Terrestrial Radio Access Network
V2V	Vehicle to Vehicle
V2X	Vehicle to everything
VNF	Virtualised Network Function
WCDMA	Wideband Code Division Multiple Access
WI	Work Item
X2	Interface allowing interconnecting eNBs with each other

4 Introduction of 5G systems

4.1 The 5G systems

The world of mobile telecommunications experiences the introduction of a new system with the time frame of ten years generally from one to the next. From 2G GSM systems in the 90 s to the 3G UMTS in the first decade of the XXI century to the 4G LTE nowadays. Each time a new system is specified new services emerge and characterize such system:

- GSM was considered as the standard for "voice everywhere";
- UMTS as a first introduction of "data" into a voice oriented approach;
- LTE as the massive explosion of data traffic everywhere.

In this context, the research community started working on 5G systems since many years already and the first question that was raised was about the "main feature" of the new system. Three were the areas to which the new 5G system is dedicated: "extreme/enhanced Mobile Broadband" (eMBB) to further extend the data capacity and the user experienced throughput of LTE in selected environments, "massive machine type communications" (mMTC) to connect an extremely high number of equipment, "ultra-reliable and low latency communications" (URLLC) to ensure a dramatic increase in reliability in all the connections. The usual representation of the new system is given by means of the well-known triangle of 5G services.

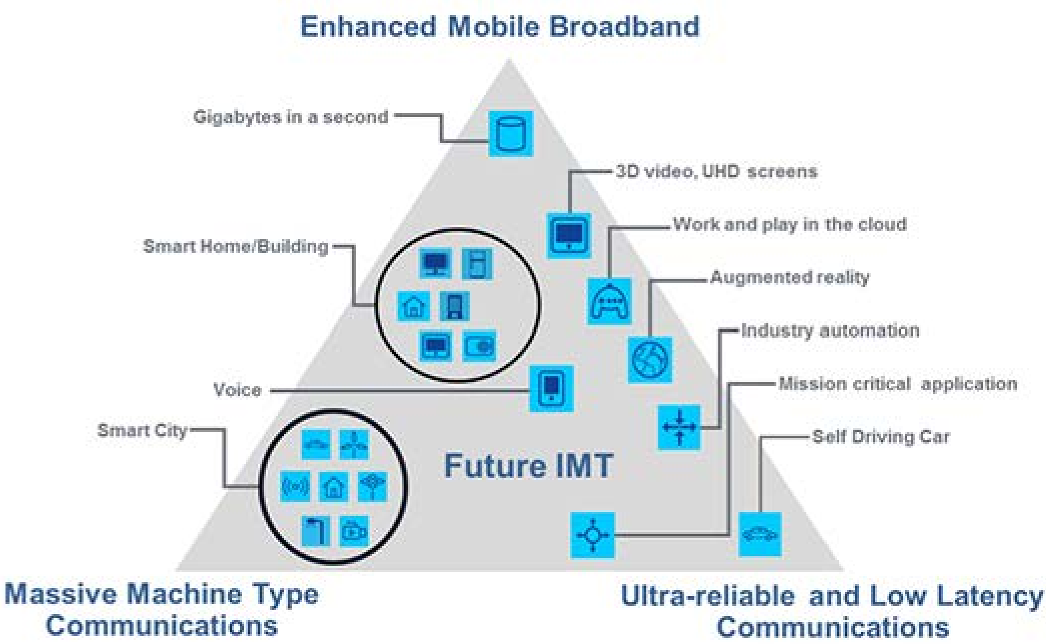

Figure 1

- eMBB: Today LTE offered capacity is already very high, but there are some services and some applications that require even more traffic to be managed (4K videos, virtual reality, etc.) and some specific environments (offices, shopping malls, very crowded events, etc.) where the existing capacity could become an issue. To ensure the performance required by eMBB new modulation schemes and new spectrum allocations will be adopted, together with Massive MIMO, network coding and new interference management solutions.

- mMTC: Even if the so-called "Internet of Things" is already a topic in current networks deployments, the new system will bring a dramatic increase in the number of equipment connected and will play an essential role in ensuring the proper connection among sensors and machines. In this area the so-called "vertical" industries could play a significant role in extending the telecommunications market, especially in the automotive area (V2V, V2X, connected cars and so on).

- URLLC: Previous systems did not consider reliability and safety in the transmissions as a prominent topic, but now new applications and services, such as tele-surgery, road safety and industry automation could require a huge effort in this area. This will open a significant challenge in the layout of the new system, that will have to ensure the above services and also and meanwhile a significant reduction in the latency of the transmission. To ensure this, the so-called "network slicing" will be probably introduced, enabling different networks implementations according to the different services and requirements.

In this context, the 5G system will then represent at the same time an evolution of the current legacy systems and a revolution to satisfy the new needs of the innovative services offered by the inclusion of new "vertical" areas in the telecommunications environment. Also in the present document this two-facets aspect of 5G is reflected in a time-wise approach, that will start with a "Release 15" new system, essentially based on an evolution of LTE, and a "Release 16" that will take care of the new vertical services and applications.

Both steps in 5G will be managed having in mind a set of requirements and KPIs to be satisfied (see in particular ETSI TR 138 913 [i.4] also described in clause 4.1 of the present document) and Energy Efficiency is among those, from the very beginning of the 5G introduction. This is because this new system by its own nature represents a challenge in terms of both offered traffic and energy consumed to provide it, as well as a complete reshaping of the traditional mobile radio access concept and layout.