



**Environmental Engineering (EE);
Mobile Network (MN) Energy Consumption (EC)
estimation method;
Energy estimation method based on statistical approach**

Standard PREVIEW
Full standards catalogue: <https://standards.iteh.ai/catalo...>
Full standards catalogue: <https://standards.iteh.ai/catalo...>
Full standards catalogue: <https://standards.iteh.ai/catalo...>

Reference

DTR/EE-EEPS29

Keywords

access, base station, energy management, GSM,
LTE, network, power measurement, radio, UMTS,
WCDMA**ETSI**

650 Route des Lucioles
F-06921 Sophia Antipolis Cedex - FRANCE

Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Siret N° 348 623 562 00017 - NAF 742 C
Association à but non lucratif enregistrée à la
Sous-Préfecture de Grasse (06) N° 7803/88

Important notice

The present document can be downloaded from:<http://www.etsi.org/standards-search>

The present document may be made available in electronic versions and/or in print. The content of any electronic and/or print versions of the present document shall not be modified without the prior written authorization of ETSI. In case of any existing or perceived difference in contents between such versions and/or in print, the only prevailing document is the print of the Portable Document Format (PDF) version kept on a specific network drive within ETSI Secretariat.

Users of the present document should be aware that the document may be subject to revision or change of status.

Information on the current status of this and other ETSI documents is available at

<https://portal.etsi.org/TB/ETSIDeliverableStatus.aspx>

If you find errors in the present document, please send your comment to one of the following services:

<https://portal.etsi.org/People/CommiteeSupportStaff.aspx>

Copyright Notification

No part may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm except as authorized by written permission of ETSI.

The content of the PDF version shall not be modified without the written authorization of ETSI.

The copyright and the foregoing restriction extend to reproduction in all media.

© ETSI 2018.

All rights reserved.

DECT™, **PLUGTESTS™**, **UMTS™** and the ETSI logo are trademarks of ETSI registered for the benefit of its Members.

3GPP™ and **LTE™** are trademarks of ETSI registered for the benefit of its Members and of the 3GPP Organizational Partners.

oneM2M logo is protected for the benefit of its Members.

GSM® and the GSM logo are trademarks registered and owned by the GSM Association.

Contents

Intellectual Property Rights	5
Foreword.....	5
Modal verbs terminology.....	5
Introduction	5
1 Scope	6
2 References	6
2.1 Normative references	6
2.2 Informative references.....	6
3 Definitions and abbreviations.....	6
3.1 Definitions.....	6
3.2 Abbreviations	7
4 RAN Energy Consumption Estimation Method.....	7
4.1 General description.....	7
4.2 Basic Estimation Method	8
4.2.1 Select a Confidence Level	8
4.2.2 Specify the Sample Size "n"	8
4.2.3 Select the Random Sample of Base Station Sites	9
4.2.4 Choose a Measurement Period.....	9
4.2.5 Measure the Energy Consumption of the Base Station Site Sample.....	10
4.2.6 Estimate the Radio Access Network Energy Consumption.....	10
4.2.7 Calculate the Margin of Error of the Mobile Network Estimate.....	11
4.2.8 State the Radio Access Network Energy Consumption Estimate.....	11
4.3 Stratified Estimation Method	12
4.3.1 General description.....	12
4.3.2 Define the Mobile Network Strata.....	13
4.3.3 Divide the Mobile Network into the Site Strata.....	13
4.3.4 Select a Confidence Level	13
4.3.5 Specify the Sample Size "n"	13
4.3.6 Determine each Stratum's Contribution to the Overall Sample	14
4.3.7 Select the Random Sample of Base Station Sites from Each Stratum	14
4.3.8 Measure the Energy Consumption of each Stratum Sample.....	14
4.3.9 Estimate the Mobile Network Energy Consumption	14
4.3.10 Calculate the Margin of Error of the Mobile Network Energy Consumption Estimate.....	15
4.3.11 State the Mobile Network Energy Consumption Estimate	15
5 Future Estimations and Network Upgrades.....	16
5.1 General description.....	16
5.2 Estimation Method as Path to Full-Network Measurements	16
Annex A: Implementation examples Implementation of Estimation Method Using Statistical Sampling	17
A.1 General description.....	17
A.2 Basic Estimation Method	18
A.2.1 Select a Confidence Level	18
A.2.2 Specify the Sample Size "n"	18
A.2.3 Select the Random Sample of Base Station Sites	18
A.2.4 Choose the Measurement Period.....	20
A.2.5 Measure the Energy Consumption of the Base Station Site Sample	20
A.2.6 Estimate the Mobile Network Energy Consumption.....	20
A.2.7 Calculate the Margin of Error of the Mobile Network Estimate	21
A.2.8 State the Mobile Network Energy Consumption Estimate	22
A.3 Stratified Estimation Method	22

A.3.1	General description.....	22
A.3.2	Define the Mobile Network Strata	23
A.3.3	Divide the Mobile Network into the Site Strata	23
A.3.4	Select a Confidence Level.....	24
A.3.5	Specify the Sample Size "n"	25
A.3.6	Determine each Stratum's Contribution to the Overall Sample	25
A.3.7	Select the Random Sample of Base Station Sites from Each Stratum.....	25
A.3.8	Measure the Energy Consumption of each Stratum Sample	26
A.3.9	Estimate the Mobile Network Energy Consumption.....	27
A.3.10	Calculate the Margin of Error of the Mobile Network Energy Consumption Estimate	28
A.3.11	State the Mobile Network Energy Consumption Estimate	30
Annex B:	Bibliography	31
History		32

iTeh STANDARD PREVIEW
 (standards.iteh.ai)

Full standard:
<https://standards.iteh.ai/catalog/standards/sist/89c32925-9f1b-42f5-9e06-ba2301ec4e05/etsi-tr-103-540-v1.1.1-2018-04>

Intellectual Property Rights

Essential patents

IPRs essential or potentially essential to normative deliverables may have been declared to ETSI. The information pertaining to these essential IPRs, if any, is publicly available for **ETSI members and non-members**, and can be found in ETSI SR 000 314: "*Intellectual Property Rights (IPRs); Essential, or potentially Essential, IPRs notified to ETSI in respect of ETSI standards*", which is available from the ETSI Secretariat. Latest updates are available on the ETSI Web server (<https://ipr.etsi.org/>).

Pursuant to the ETSI IPR Policy, no investigation, including IPR searches, has been carried out by ETSI. No guarantee can be given as to the existence of other IPRs not referenced in ETSI SR 000 314 (or the updates on the ETSI Web server) which are, or may be, or may become, essential to the present document.

Trademarks

The present document may include trademarks and/or tradenames which are asserted and/or registered by their owners. ETSI claims no ownership of these except for any which are indicated as being the property of ETSI, and conveys no right to use or reproduce any trademark and/or tradename. Mention of those trademarks in the present document does not constitute an endorsement by ETSI of products, services or organizations associated with those trademarks.

Foreword

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

The present document has been developed in collaboration with 3GPP SA5 and RAN3; GSMA has given also valuable suggestions and contributions. Moreover, the present document is developed jointly with ITU-T SG5 Q17/5.

Modal verbs terminology

In the present document "**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).

"**must**" and "**must not**" are **NOT** allowed in ETSI deliverables except when used in direct citation.

Introduction

In the absence of direct measurements, a radio access network's energy consumption can be estimated using a simple random sample of base station sites from the mobile network. There are two estimation methods described in the present document which can be used for this purpose: the basic estimation method, and the stratified estimation method.

In the basic estimation method, the sample is created with no consideration for the constitution of the mobile network. This method is well-suited for mobile networks generally characterized as homogenous, with normal statistical distributions of energy-influencing site characteristics across the network (e.g. base stations per site, radios per site).

In the stratified estimation method, the sample is created while taking the constitution of the mobile network into account. This method is well-suited to mobile networks generally characterized as heterogeneous, or mobile networks with non-normal statistical distributions of energy-influencing site characteristics.

An example of application of these two methods is given for better readability and ease of use in annex A.

1 Scope

The present document is aimed to define an estimation method for anticipating the total energy consumption of a radio access network based on measuring energy consumption of a few randomly chosen sites. The present document is used when measuring energy consumption of the whole network is either impossible or costly to an operator. Two different methods have been presented in the present document, one based on Basic Estimation Method and another based on stratified Estimation Method.

The present document deals with any type of radio access network such as homogeneous and heterogeneous network and technologies such as GSM, UMTS and LTE.

The estimation of energy consumption User Equipment (UE) is not within the scope of the present document.

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.

Not applicable.

3 Definitions and abbreviations

3.1 Definitions

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

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

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

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

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

Radio Access Network Energy Consumption (RANEC): overall energy consumption of equipment included in the RAN under investigation

Telecommunication Network (TN): 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
BS	Base Station
CL	Confidence of Level
EC	Energy Consumption
E-UTRA	Evolved UMTS Terrestrial Radio Access Network
GERAN	GSM/EDGE Radio Access Network
GSM	Global System for Mobile communication
GSMA	GSM Association
ICT	Information Communications Technology
ITU	International Telecommunications Union
ITU-T	International Telecommunications Union - Telecommunication
LTE	Long Term Evolution
MN	Mobile Network
PDF	Probability Distribution Function
RAN	Radio Access Network
RF	Radio Frequency
T	Period of Time over the estimate is made
TLAF	Transmission Loss Adjustment Factor
UMTS	Universal Mobile Telecommunication Service
UTRAN	UMTS Terrestrial Radio Access Network

4 RAN Energy Consumption Estimation Method

4.1 General description

A simple random sample of radio access network energy consumption is supported by the following definitions:

- A RAN is a population consisting of "N" base station sites.
- A sample from the RAN population consists of "n" base station sites.
- All possible samples of "n" base station sites from the RAN population are equally likely to occur.
- Each sample of the RAN population has a mean site energy consumption of \bar{x}_i .
- The value of \bar{x}_i serves as an estimate of the true mean site energy consumption for the entire RAN (denoted as μ).
- The size (n) of each RAN sample needs to be sufficiently large such that all possible values of mean site energy consumption (\bar{x}_i) form a normal (or near normal) sample distribution.
- The mean of the sample distribution ($\mu_{\bar{x}}$) is also the true mean of the site energy consumption (μ) for the entire RAN, as shown in figure 1.

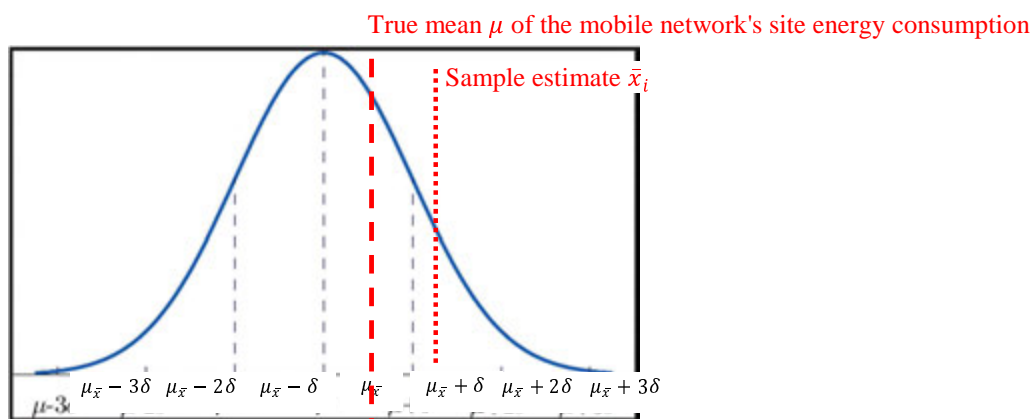


Figure 1: Normal Distribution of a Randomly Sampled Population

Using the above definitions, the radio access network's energy consumption is estimated by multiplying the sample estimate of the mean site energy consumption (\bar{x}_i) by the number of sites in the mobile network population (N).

$$EC_{RAN,\bar{x}} = N \cdot \bar{x}_i$$

The above estimate of RAN energy consumption also includes some indication of its accuracy relative to the true RAN energy consumption value. Therefore, energy consumption estimates are expressed as a confidence interval consisting of:

- The sample estimate of the RAN energy consumption ($EC_{RAN,\bar{x}}$), extrapolated from the sample mean (\bar{x}_i).
- The amount of time (T) covered by the energy consumption estimate.
- A margin of error expressing the maximum expected difference between the true energy consumption of the RAN and the sample estimate.
- The confidence level (CL) in the sampling method. Specifically, it reflects the percentage of sample estimates whose mean energy consumption and margin of error are expected to include the true mean site energy consumption.

Based on the above, a RAN energy consumption estimate is expressed in the following form:

The CL % confidence interval for the mobile network energy consumption over a period of T is $EC_{RAN,\bar{x}} \pm ME$ % Watt · Hours

As an example, an estimate of a mobile network's energy consumption would be expressed as follows:

The 95 % confidence interval for the energy consumed by the mobile network over a one-month period is $1,05 \times 10^{11} \pm 2,4$ % Watt · Hours

4.2 Basic Estimation Method

4.2.1 Select a Confidence Level

The confidence level reflects the confidence that one wants to have in the energy consumption estimate. It is an individual choice not specified by the present document, and it influences the size of the margin of error associated with the energy consumption estimate. It can be any percentage value up to 100 %, with 95 % being a common value. Note that choosing a confidence level of 100 % implies that every site in the network would have to be measured, thus defeating the purpose of the estimation method.

4.2.2 Specify the Sample Size "n"

In order to satisfy the requirements of the central limit theorem, the sample size (n) needs to be large enough to produce a normal sampling distribution. The less "normal" the shape of the network's underlying site energy consumption distribution, the larger the sample size needs to be in order for any estimate and associated margin of error to be valid.

Since the shape of the network is likely an unknown before any measurements take place, it is difficult to predict the sample size required to achieve a certain margin of error. Thus the sample size has to be chosen and measurements made first, with the associated margin of error calculated afterwards.

While the sample size is an individual choice, it is recommended that the sample measurement consist of:

- at least 50 of the network sites, representing at least 5 % of the network

A representative estimate and associated margin of error is more likely if both of these sample size requirements are satisfied.

4.2.3 Select the Random Sample of Base Station Sites

In order to be a truly random sample (n) of base station sites, the site selection needs to be totally blind to such energy consumption influences as data traffic load, climate, site location, site configuration, RF output power, and site capability. This can be achieved using the following site selection procedure:

- Itemize the population of mobile network base station sites in a vertical list consisting of "N" rows (i.e. one row for each base station site in the overall mobile network population). All information regarding the site configuration and environment should be excluded from the list in order to avoid the unconscious introduction of statistical bias.
- Using a random number generator, assign each entry in the site list a random number in the range of 0:1 to at least 6 decimal places. A spreadsheet's rand-function can be useful for this purpose.
- Sort the population site list based on the random number assignments, from the lowest random number to highest, as shown in figure 2.
- The first "n" base station sites in the sorted list (where "n" was determined in the previous step) should serve as the mobile network population sample. These "n" sites will have their energy consumptions directly measured.

Base Station Index	Base Station Name	Location	Random Number
1	BS0043A	MAIN ST	0.615291923
2	BS0043B	MAIN ST	0.627324076
3	BS0044A	MAIN ST W	0.125105478
4	BS0059E	HIGH PARK	0.647086334
5	BS0059F	HIGH PARK	0.752819185
6	BS0069B	REGENT HILLS	0.333481496
7	BS0069C	REGENT HILLS	0.446685252
8	BS0069E	REGENT HILLS	0.808364331
9	BS0083A	KAYVILLE	0.314409428
10	BS0084A	KAYVILLE	0.018700376

Original Base Station List

Base Station Index	Base Station Name	Location	Random Number
10	BS0084A	KAYVILLE	0.018700376
4095	BS4591D	LOWERTOWN	0.018943492
18	BS3401A	BRIDGE ST	0.022231044
10980	BS0321D	UPLANDS	0.023648181
1354	BS3311A	CEDAR HILL	0.027021437
3243	BS7920F	GRASSLAND	0.028293819
459	BS3310A	REDWATER	0.038400109
2944	BS0989A	VALLEY DRIVE	0.039000214
231	BS0943A	GREY ROCK	0.049812901
11231	BS6510B	MAPLE CREEK	0.049843129

Re-Ordered List Using Random Numbering

Use first "n" base station sites in re-ordered mobile network site list population sample

Figure 2: Creating the Random Site Sample

4.2.4 Choose a Measurement Period

The value of the measurement period (T) is an individual choice and is not specified by the present document. However, some consideration needs to be given to the fact that this value also determines the time period (T) over which the estimate applies. For example, if the energy consumption measurements are performed during a two-week period, the resulting estimate for the mobile network's energy consumption can only pertain to the **same** two-week period. The two-week measurement cannot be extrapolated to a year-long measurement, because other factors influencing energy consumption (such as yearly temperature fluctuations) would not be accounted for in the margin of error.

4.2.5 Measure the Energy Consumption of the Base Station Site Sample

The energy consumption measured at each base station site in the mobile network population sample, for measurement period (T), is denoted as:

$$EC_{site,i}$$

These sample energy consumption site values can be obtained from either:

- direct on-site measurements; or
- energy consumption metering information supplied by the electrical utility.

Electrical utility metering is only used for the sample provided the following conditions are met:

- The utility supplies a site energy consumption value in units of Watt-Hours or similar.
- The site energy consumption value is representative of the site only, and only includes equipment which fulfils the site function.
- Any transmission loss adjustment factors (TLAF) applied by the utility are fully quantified and understood.
- TLAFs are removed from the site energy consumption values provided by the electrical utility, since direct energy consumption measurements at the site would not capture the transmission loss effect.
- The energy billing information (i.e. the financial cost of the electricity) is not used to derive a site's energy consumption value.

Having met the above criteria, site energy consumption values based on metering information is calculated as:

$$EC_{site,i} = \frac{EC_{site,i,TLAF}}{TLAF_{utility}}$$

Where:

$EC_{site,i,TLAF}$	The site energy consumption value supplied by the electrical utility which includes a transmission loss adjustment factor (TLAF)
$TLAF_{utility}$	The transmission loss adjustment factor applied by the electrical utility

4.2.6 Estimate the Radio Access Network Energy Consumption

The RAN energy consumption sample estimate ($EC_{RAN,\bar{x}}$) is based on the mean energy consumption (\bar{x}) of the sites in the base station sample calculated as:

$$\bar{x} = \frac{1}{n} \sum_{i=1}^n EC_{site,i}$$

Where:

\bar{x}	Sample estimate of the RAN's mean site energy consumption
n	Number of sites in the mobile network sample
$EC_{site,i}$	Energy consumption of a site within the sample

The mean site energy consumption (\bar{x}) for the sample is then multiplied by the number of sites in the mobile network population (N) to determine the sample estimate for the mobile network energy consumption ($EC_{RAN,\bar{x}}$):

$$EC_{RAN,\bar{x}} = N \cdot \bar{x}$$

Where:

$EC_{site\ i}$	Energy consumption of a site within the sample
$EC_{RAN,\bar{x}}$	Sample estimate of the RAN's total energy consumption
n	Number of sites in the mobile network sample
\bar{x}	Sample estimate of the RAN's mean site energy consumption
N	Total number of base station sites in the mobile network

4.2.7 Calculate the Margin of Error of the Mobile Network Estimate

The margin of error is the maximum difference between the sample estimate and the true value of the radio access network's energy consumption. The confidence in this maximum is described by the confidence level chosen in clause 4.2.1.

As a numerical value, the margin of error is calculated as follows:

$$\text{Margin of Error}_{Num} = N \cdot t_{n-1} \cdot \frac{s}{\sqrt{n}} \cdot \sqrt{\frac{N-n}{N-1}}$$

As a percentage, the margin of error is calculated as follows:

$$\text{Margin of Error}_{\%} = \frac{\text{Margin of Error}_{Num}}{N \cdot \bar{x}} \cdot 100$$

Where:

t_{n-1}	T-score for a sample of size n , determined from an online t-score calculator applying $(n - 1)$ degrees of freedom, and a cumulative probability (CP) calculated as: $CP = 1 - \frac{100 - CL\ \%}{200}$ Where (CL) is the confidence level (in %) chosen in clause 4.2.1.
s	Standard deviation of the site energy consumptions of the mobile network sample

In the above equations, a t-score (rather than a z-score) is used since the standard deviation of the mobile network population is unknown. In addition, the $\sqrt{\frac{N-n}{N-1}}$ term is the finite population correction formula, and is included since the mobile network site population is finite and is being sampled without replacement. Finally, the $\frac{s}{\sqrt{n}}$ term represents the standard error of the sample mean, with the standard deviation (s) of the sample calculated as:

$$s = \sqrt{\frac{\sum_{i=0}^n (EC_{site\ i} - \bar{x})^2}{n - 1}}$$

4.2.8 State the Radio Access Network Energy Consumption Estimate

The resulting radio access network energy consumption estimate includes the chosen confidence level, the measurement period, the estimated mobile network energy consumption, and the associated margin of error. The estimate is expressed in the following form:

The CL % confidence interval for the radio access network energy consumption,
over a period of T is $EC_{RAN,\bar{x}} \pm ME\ \% \text{ Watt} \cdot \text{Hours}$