LEXNET
Low EMF Exposure Future Networks

D2.3 Scenarios

Contractual delivery date: M12
Actual delivery date: M12

Document Information

Version	V2	**Dissemination level**	PU
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Abstract	The Exposure Index (EI) defined within the LEXNET project [1] is an exposure metric which combines both downlink and uplink exposure to assess and to optimize the global exposure in an environment. This deliverable D2.3 Scenarios defines five exposure scenarios representing typical exposure in an environment with one or more wireless communication networks. The first scenario is a basic scenario as it only considers 2G wireless communication in a macro-cell environment. The other four scenarios focus on different environments (office, outdoor, outdoor-indoor) and network deployments (varying network technologies, different type of cells, etc.). This deliverable also provides generic parameters for radio access technologies, environments, and usage profiles.
Keywords	Exposure scenarios

Project Information

Grant Agreement n°	318273
Dates	1st November 2012 – 31th October 2015

Document approval

Name	Position in project	Organisation	Date	Visa
Joe Wiart	Coordinator	Orange	15/11/2013	OK

Document history

Version	Date	Modifications	Authors
V0.1	30/09/2013	Initial draft	Günter Vermeeren
V0.2	23/10/2013	Included the tablet and the laptop for the scenarios where wifi and 3G (or beyond) networks are considered for data Version for internal review	Günter Vermeeren
V0.3	13/11/2013	Revision after internal review	Günter Vermeeren
V1	15/11/2013	Final Version	Francois Bourdel
V2	30/6/2014	Update after EU review	Günter Vermeeren, Massinissa Lalam, Nadège Varsier

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LIST OF ABBREVIATIONS

AP	Access Point
BS	Base Station
DL	Downlink
EI	Exposure Index
GSM	Global System for Mobile communications
LTE	Long Term Evolution
RAT	Radio Access Technology
SNR	Signal-to-Noise Ratio
UE	User Equipment
UL	Uplink
UMTS	Universal Mobile Telecommunications System
WSN	Wireless Sensor Networks

Executive Summary

The Exposure Index (EI) defined within the LEXNET project [1] is an exposure metric which quantifies the combined downlink and uplink exposure of wireless communication networks in an environment. This exposure index can be minimised by modifying network parameters. This deliverable D2.3 Scenarios defines five exposure scenarios representing typical exposure in an environment with one or more wireless communication networks. The first scenario is a basic scenario as it only considers 2G wireless communication in a macro-cell environment. The other four scenarios focus on different environments (office, outdoor, outdoor-indoor) and network deployments (varying network technologies, different type of cells, etc.). This deliverable also provides reference values for parameters of radio access technologies, environments, and load profiles.

1 INTRODUCTION

The Exposure Index (EI), defined in [1], is an exposure metric which combines both downlink and uplink exposure to assess the global exposure in an environment. This deliverable defines five exposure scenarios representing typical exposure from wireless networks in an environment. The first scenario is a basic scenario that only considers 2G wireless communication in a macro cell environment. The other scenarios take into account different environments (office, outdoor, outdoor-indoor) and network deployments (varying network technologies, different type of cells, etc.). These exposure scenarios will assist in evaluating measurement equipment and methodologies for assessing the exposure index, and evaluating different network aspects on the exposure index within the different work packages of the LEXNET project.

Section 2 recapitulates the Exposure Index defined in [1]. Section 3 describes five exposure scenarios representing common daily exposure situations. Section 0 provides an overview of the reference values for radio access technologies (RATs), environments, and load profiles, which can be used when no other data is available. Section 5 concludes this deliverable.

2 EXPOSURE INDEX

The Exposure Index (EI) is defined in [1] and aims at providing a metric for estimating (and thus to be used to minimize) the global exposure in a network. The EI takes into account both uplink (UL) and downlink (DL) exposure:

$$EI_{[\mathrm{J/kg}]} = \sum_{t}^{N_T}\sum_{p}^{N_P}\sum_{e}^{N_E}\sum_{r}^{N_R}\sum_{c}^{N_C}\sum_{u}^{N_U}\left[\sum_{l}^{N_L}\left(d^{UL}_{t,p,l,e,r,c,u\left[\frac{s}{kg}\right]}\overline{P}_{TX[W]}\right) + d_{t,p,e,r,c,u\left[\frac{s}{kg}\right]}\overline{P}_{RX[W]}\right] \quad (1)$$

where:

- N_T is the number of Time periods of the day;
- N_P is the number of Population segments;
- N_L is the number of user Load profiles;
- N_E is the number of Environments;
- N_R is the number of Radio access technologies;
- N_C is the number of Cell types;
- N_U is the number of Usages with devices;
- $\overline{P}_{TX}$ is the mean TX power by the users' devices during the period t, for the segment of population p, in usage mode u, connected to RAT r, in environment e.
- $\overline{P}_{RX}$ is the mean received power by the users' devices during the period t, for the segment of population p, connected to RAT r, in environment e.

- $d^{UL}_{t,p,l,e,r,c,u}$ and $d^{DL}_{t,p,e,r,c,u}$ are the normalised raw Specific Absorption Rate (SAR) values for UL and DL, respectively weighted by the time spent in the configuration.

An exposure scenario is the set of networking, environmental and usage parameters which determines the exposure of people to wireless networks in an environment. Exposure scenarios can be graphically represented by a tree of exposure as shown in Figure **1**. Possible scenarios can include one, several or all branches of the tree. Different exposure scenarios are considered and aggregated by putting weights on each configuration, thereby determining the Index.

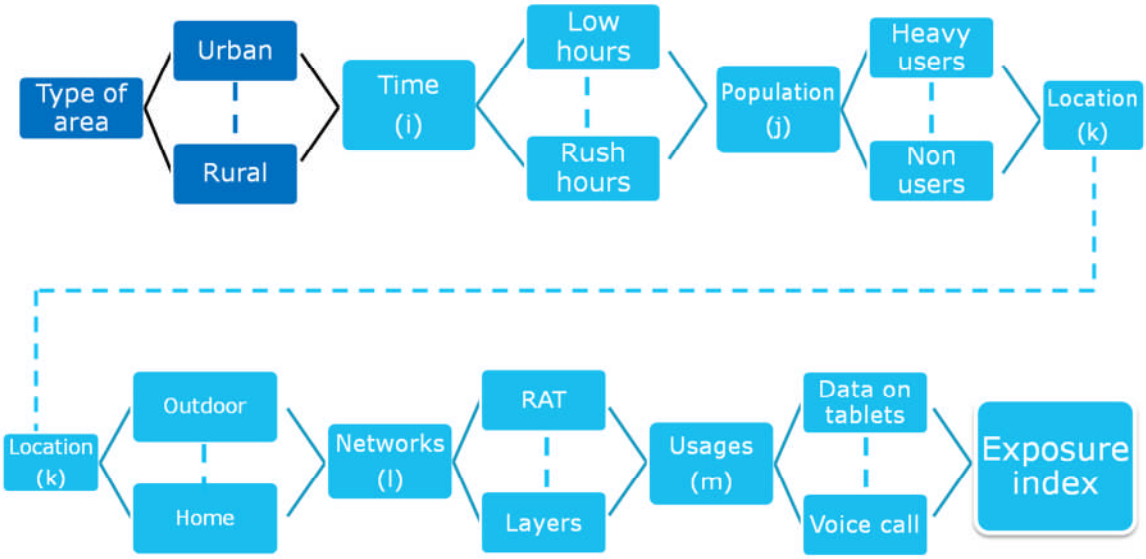

Figure 1: Tree of exposure

3 SCENARIOS

In this section five generic scenarios are presented for which the exposure index will be evaluated within the LEXNET project. These scenarios cover different network deployments in outdoor and indoor (e.g., office building, train) environments but they do not define network topologies and the usage within an environment. This degree of freedom allows the project partners to use their own data available and the evaluation of the EI for different network settings. The five scenarios are: a basic scenario (2G in urban-macro cell environment), an office or wireless sensor network scenario (indoor), an outdoor scenario with only macro cells, an indoor-outdoor scenario with micro cells, an indoor-outdoor scenario with micro cells and WiFi off-loading. For a comprehensive overview of the parameters of the EI, we refer to [1]. In this section the variables or parameters are listed together with the assigned values for the scenarios. For each scenario the parameters will be presented as follows:

- Time period (t): a day can be split in several periods.
  - Day-night: in this deliverable D2.3 we will only consider two periods in a day: day and night.
    - Day: 8:00am – 6:00pm (10 hours)
    - Night: 6:00pm – 8:00am (14 hours)
- Population (p):

    - Category (children, students, adults, seniors)
        - Depend on the environment (school, office, etc.)
- Load profiles (l):
    - Distinction between heavy, medium, light, and non-users.
    - Defined in terms of duration for voice and amount of data for data
- Environment (e)
    - Distinction between indoor, outdoor, moving
- Radio Access Technologies (RATs) (r):
    - Type: e.g., 2G, 3G, 4G, and WiFi
- Cell type (c): s
    - Distinction between macro, micro, pico, and femto
- Usage (u):
    - Usage (voice or data)
    - Device (mobile, smartphone, and tablet)
    - Posture (standing or sitting)

Deliverable D2.4 [1] includes two examples on how to calculate the EI in an environment based on two of the scenarios presented in this section.

3.1 2G scenario: 2G in an urban environment with macro cells

The first scenario considers voice and data in a 2G (GSM) network deployed in an urban macro cell environment.

Table 1: 2G scenario in an urban environment with macro cells.

Parameter	Value
Time periods	Day - Night
Population	Adult, children
Load profile	Variable; categories defined in Section 4.3
Environment	Outdoor
RATs/Cell Types	
• **Type**	2G (see Section 4.1)
• **Cell size**	Variable
• **Cell type**	Macro (see Section 4.1)
User	
• **Usage**	Voice - data
• **Equipment**	Smartphone
• **Posture**	Standing, sitting

3.2 Indoor scenario: office in an urban environment

This scenario is composed by an indoor office environment with surrounding macro base stations.

Table 2: Indoor scenario: office in an urban environment.

Parameter	Value
Time periods	Day, Night
Population	Adult, children

Load profile	Variable; categories defined in Section 4.3
Environment	Office (indoor)
RATs/Cell Types	
• **Type**	3G, 4G, WiFi, WSNs (e.g., Zigbee (see Section 4.1))
• **Cell size**	Variable
• **Cell type**	Macro, femto (see Section 4.1)
User	
• **Usage**	Voice, data
• **Equipment**	Smartphone, tablet, laptop
• **Posture**	Standing, sitting

3.3 Outdoor scenario: macro cells

This scenario is composed by multiple systems' macro cells and some WiFi hotspots.

Table 3: Outdoor scenario with macro cells.

Parameter	Value
Time periods	Day, Night
Population	Adult, children
Load profile	Variable; categories defined in Section 4.3
Environment	Outdoor
RATs/Cell Types	
• **Type**	2G, 3G, 4G, WiFi (see Section 4.1)
• **Cell size**	Variable
• **Cell type**	Macro (see Section 4.1)
User	
• **Usage**	Voice, data
• **Equipment**	Smartphone, tablet, laptop
• **Posture**	Standing, sitting

3.4 Outdoor-indoor scenario: micro cells

This scenario is composed by a combination of both macro and micro cells with users being indoors.

Table 4: Outdoor-indoor scenario with micro cells.

Parameter	Value
Time periods	Day, Night
Population	Adult, children
Load profile	Variable; categories defined in Section 4.3
Environment	Outdoor, indoor, commuting (e.g., train, bus)
RATs/Cell Types	
• **Type**	2G, 3G, 4G (see Section 4.1)
• **Cell size**	Variable
• **Cell type**	Macro, micro (see Section 4.1)
User	
• **Usage**	Voice, data

• **Equipment**	Smartphone, tablet
• **Posture**	Standing, sitting

3.5 Outdoor-indoor scenario with WiFi off-loading

This scenario is similar to the above, with outdoor macro and micro cells, with indoor users, but considering network offloading.

Table 5: Outdoor-indoor scenario with WiFi off-loading.

Parameter	Value
Time periods	Day, Night
Population	Adult, children
Load profile	Variable; categories defined in Section 4.3
Environment	Outdoor, indoor, commuting (e.g., train, bus)
RATs/Cell Types	
• **Type**	2G, 3G, 4G, WiFi (see Section 4.1)
• **Cell size**	Variable
• **Cell type**	Macro, micro (see Section 4.1)
User	
• **Usage**	Voice, data
• **Equipment**	Smartphone, tablet, laptop
• **Posture**	Standing, sitting

4 REFERENCE VALUES

This section provides reference values for RATs, environments and load profiles. These values can be used if no other values are available. Some of the parameters depend on the specific case considered. These parameters will be assigned the value “variable” (see Section 3). One should highlight that these are only reference values.

4.1 Radio Access Technologies

4.1.1 GSM

Table 6: Reference values for GSM.

Parameter	Value
Node/Terminal Sensitivity	-110 dBm
Micro BS Power	0.1 – 5 W
Macro BS Power	40 W
BS Antenna Gain	Macro: 14 dBi Micro: 5 dBi
BS Antenna Type *(e.g., Omni)*	Macro: directive Micro: omni or directive
Frequency Band	900 MHz
UE antenna gain	0 dBi

4.1.2 UMTS

Table 7: Reference values for UMTS.

Parameter	Value
Node/Terminal Sensitivity	-110 dbm
Micro BS Power	0.1 – 5 W
Macro BS Power	40 W
BS Antenna Gain	Macro: 14 dBi Micro: 5 dBi
BS Antenna Type *(e.g., Omni)*	Macro: directive Micro: both omni or directive
Frequency Band *(e.g., 2100 MHz)*	2100 MHz
UE antenna gain	0 dBi

4.1.3 LTE

Table 8: Reference values for LTE.

Parameter	Recommended value	Comments
Frequency Band [MHz]	800 MHz, 1800 MHz, 2600 MHz	See [2] for details
"Physical Profile"	FDD 10 MHz – 20 MHz TDD 10 MHz – 20 MHz	
Macro Base stations		
Max DL transmit power	40 W	Per antenna port
Antenna type	Directive	3GPP pattern [2], including downtilt (typically 6° in urban areas)
Antenna Gain	15 dBi Except for urban 800 MHz: 12 dBi	[2]
#antennas	2 – 4	
UL noise figure	2 dB – 5 dB	[2]: 5 dB Typical in studies: 2.5 dB
Micro Base station		
Max DL transmit power	0.1 W – 6.3 W	Per antenna port Max power compliant with [3]
Antenna type	Directive or Omni	For directive antenna: 3GPP pattern
Antenna Gain	15 dBi (directive) or 5 dBi (omni)	[2]
#antennas	2	
UL noise figure	2 dB – 5 dB	
Femto Base station		

Max DL transmit power	0.005 W – 0.05 W	Per antenna port Max power compliant with [3]
Antenna type	Omni	Half-wavelength dipole radiation pattern
Antenna Gain	5 dBi	[2]
#antennas	2	
UL noise figure	2 dB – 5 dB	
UE		
UL transmit power	[3GPP1]: 10^{-6} W – 0.25 W [3GPP2]: 10^{-7} W – 0.2 W	Adjusted via power control
Antenna Type	Omni	[2]
Antenna Gain	0 dBi	[2]
#antennas	2	
DL noise figure	9 dB	Note from [4]: UTRA TDD UE will have a relatively lower Noise Figure since it does not have a duplexer. However, for simulation alignment purpose, a Noise Figure of 9 dB will be used.
SNR mapping	[2], [5]	

4.1.4 WiFi at 2.4 GHz and 5 GHz bands

Table 9: Reference values for WiFi at 2.4 GHz and 5 GHz bands.

Parameter	Value
Node/Terminal Sensitivity	-110 dBm
AP Power	[2.4 GHz] 0.1 W [5 GHz] 0.2 W to 1 W
AP Antenna Gain	2.2 dBi
AP Antenna Type	Omni
Frequency Band	2400 MHz 5160-5340 MHz 5480-5720 MHz
UE Antenna Gain	0 dBi
UE Power (maximum)	[2.4GHz] 20 dBm [5160-5340 MHz] 23dBm [5480-5720 MHz] 30dBm

4.1.5 Zigbee

Table 10: Reference values for Zigbee.

Parameter	Value
Node/Terminal Sensitivity	-95 dBm
Node Power	0.1 W
Antenna Gain	2.2 dBi
Antenna Type	Omni
Frequency Band	2400 MHz

4.2 Environment

A distinction is made between different environments. The project LEXNET will use the classification of local administrative units defined by the statistical office of the European Union, EuroStat [6]. The degree of urbanization (DEGURBA) is defining three categories of populated area:

1. Densely populated area (called Urban): area with a density of at least 1 500 inhabitants per km² and a minimum population of 50 000.
2. Intermediate populated area (called sub-urban): density of at least 300 inhabitants per km² and a minimum population of 5 000.
3. Thinly populated area (called rural): area outside dense and intermediate areas

It is clear that the typical densities of population in each category are depending on the country.

The classification of each local administrative unit in each European country is available through EuroStat [6].

The median values in France for the three categories called Urban, Suburban and Rural are given as example in Table 11.

Table 11: Density of people living in an environment.

Environment	Living population density (persons/km^2)
Urban	2800
Suburban	525
Rural	35

4.3 Load profiles

The usage profile categorises the duration of voice communications and the duration or amount for data communications. Several categories can be defined; initially, we distinguish four categories: heavy, moderate, light, and non-user. Once the categories of the usage profiles are defined, the proportion of the population for each category can be derived. The proportion of people assigned to each category will depend on the population category (adult, children, seniors, etc.), the time of the day, and the environment.

5 CONCLUSIONS

We proposed exposure scenarios representing common daily exposure in realistic environments. Besides a basic scenario limited to 2G wireless communications, four scenarios are defined covering different environments and different network deployments. These scenarios will be used throughout the LEXNET project for evaluating measurement devices, evaluating assessment methodologies of the exposure index, and investigating the influence of network settings on the exposure index in an environment.

6 REFERENCES

[1] E. Conil, *D2.4 Global wireless exposure metric definition v1*, LexNet project, 2013.
[2] 3GPP, *TR 36.942 - Radio Frequency (RF) system scenarios*, 2012.
[3] 3GPP, *TS 36.104 - Base Station (BS) radio transmission and reception*, 2013.
[4] 3GPP, *TS36.10 - User Equipment (UE) radio transmission and reception*, 2013.
[5] C. Mehlführer, M. Wrulich, J.C. Ikuno, D. Bosanska, and M. Rupp, “Simulating the long-term evolution physical layer,” *Proceedings of 17th European Signal Processing Conference (EUSIPCO 2009)*, Glasgow, Scotland: 2009, pp. 1471–8.
[6] E. Commission, “http://ec.europa.eu/eurostat.”

7 APPENDIX 1: INTERNAL REVIEW

	Reviewer 1: Milos Tesanovic			Reviewer 2: Daniel Sebastião		
	Answer	**Comments**	**Type***	**Answer**	**Comments**	**Type***
1. Is the deliverable in accordance with						
(i) the Description of Work?	☒ Yes ☐ No		☐ M ☐ m ☐ a	☒ Yes ☐ No		☐ M ☐ m ☐ a
(ii) the international State of the Art?	☒ Yes ☐ No		☐ M ☐ m ☐ a	☒Yes ☐ No		☐ M ☐ m ☐ a
2. Is the quality of the deliverable in a status						
(i) that allows to send it to EC?	☒ Yes ☐ No	But it is hoped that issues identified will be resolved beforehand.	☐ M ☐ m ☐ a	☒ Yes ☐ No		☐ M ☐ m ☐ a
(ii) that needs improvement of the writing by the editor of the deliverable?	☒ Yes ☐ No	Please see my detailed comments above.	☐ M ☒ m ☐ a	☒ Yes ☐ No		☐ M ☒ m ☐ a
(iii) that needs further work by the partners responsible for the deliverable?	☐ Yes ☒ No		☐ M ☐ m ☐ a	☐ Yes ☒ No		☐ M ☐ m ☐ a

* Type of comments: M = Major comment; m = minor comment; a = advice