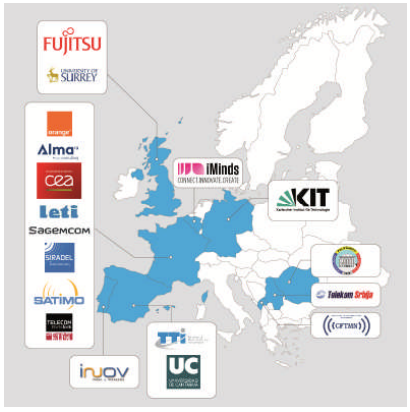
1 PUBLISHABLE SUMMARY

Wireless communications systems based on electromagnetic fields have been increasingly used over the past 30 years. Nowadays, the versatile use of new mobile phones, the development of home wireless LANs and the emergence of all-pervasive wireless communication systems are strengthening this tendency. This intensive use and the present trends have also created a public risk perception about possible health impact of EMF.

To protect the public from sanitary health impact induced by EMF, the International Commission on Non Ionising Radio Protection (ICNIRP) has established guidelines defining basic restrictions that limit the specific absorption rate (SAR), expressed in Watt/kilogram, and characterising the RF human absorption. ICNIRP defines also the reference levels that are limiting the incident field strength to the level inducing an exposure compliant with the basic restrictions. The European Council adopted in 1999 a recommendation (1999/519/CE based on ICNIRP guidelines) on the limitation of the exposure of the general public to electromagnetic field. Today in Europe, telecommunications have to comply with the RTTE directive that requires products to comply with the European Council recommendation. In spite of these existing protection limits, public concern still exists. In 2010, a survey performed by the European Commission through the Euro-barometer has shown that about 70% of the respondents believed that EMF can have maybe an impact on health.

To respond to this risk perception, some countries have tried to minimize the exposure, but most of the time these initiatives have been dedicated to base stations emission. Since the day-to-day exposure is a combination of uplinks and downlinks, to focus only on the downlink can unexpectedly lead to raise the uplinks emissions and therefore increase the exposure. Focus only on base stations can also lead to reject some innovations in network technologies and architecture even if they can reduce the global exposure. Unfortunately, most of the works dedicated to EMF exposure were dedicated to compliance tests using worst cases scenarios, considering separately the mobiles and base stations. A key challenge is to change the paradigm and create a new acceptable metric able to quantify the global exposure of a population exposed to the emission of a wireless network.

The strategic goal of LEXNET is to take into account the public concern and improve the acceptability of existing and future wireless systems through low exposure systems, reducing the human exposure without compromising the user's perceived quality. The project use a holistic approach targeting innovative low radiation exposure solutions at many levels, ranging from the radio devices and the radio link, to the network architecture, topologies, management and the provision of services. To assess the human exposure, metrics and tools are being defined and built. The project is composed of 17 network providers, manufacturers, research centres and universities from 9 European countries.



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The project is divided in 7 Work Packages (WP).
WP1 is dedicated to the project management.
WP2 is dealing with "Socio-economic analysis, EMF exposure metrics, and reduction

targets". The objective of this WP is to design a human exposure index combining exposure induced by access points or base stations and the exposure induced by the devices (mobile, laptop). Its objective is also to analyse people's exposure beliefs, risk perceptions and attitudes towards acceptance of exposures in order to take into account these aspects in the exposure index and in the planned communication efforts.
WP3 is working on "Efficient EMF Measurement and Assessment of the Exposure Index". Its objective is to design a dosimeter that provides 'in situ' and real time measurements of the EMF and to design an expert system that combines the distributed time-domain dosimeter and network measurements to calculate the exposure index.
WP4 is dealing with "Smart Low EMF Radio". Its objectives is to focus on Innovations for Radio techniques, at component, device level (HW), but also from a Radio Transmission System standpoint, that could optimise and minimize indices of Exposure.
WP5 is working on "Smart Low EMF Architectures". The objectives of this work package is to design effective network topologies that will further reduce the ubiquitous and ever-increasing electromagnetic radiation to acceptable levels, while also maintaining low cost, efficient communication and required Quality of Service and Quality of Experience. The objective is also to produce analysis and solutions of the network management associated with such topologies as well as existing network topologies, which can be later output to networking demonstrators.
WP6 is dedicated to "Validation and assessment of the objectives". Its objectives are the validation of the low EMF radio and network solutions developed in the project by means of real-world prototypes, system level simulators and lab demonstrator. The objectives are also to deploy wideband EMF dosimeters over a Smart City scenario, which enable the creation of an exposure index map available to all involved stakeholders (citizens, authorities, network operators, etc.) within a field trial.
The last work package, WP7, is dedicated to "Standardisation and dissemination". It disseminates the work performed in LEXNET in the general public, the scientific community and in standardisation and regulatory bodies.

WP2
In the framework of WP2, a first survey had been launched during the first year of the project, aiming to conduct a comprehensive analysis of the public's view regarding RF EMF exposure. A first draft of a new exposure metric called Exposure index (EI) had also been developed. This new exposure metric is assessing the average EMF exposure of a population in a given geographical area to a network as a whole, combining exposure from access points and base stations and exposure from personal wireless devices.

During the second year, as for the socio-economic analysis part, WP2 partners focused their efforts on the design of a second survey aiming to test the understandability of the EI and to test the social acceptance of such an index combining both downlink and uplink exposures and averaging the exposure of a population in a given geographical area over space and over time. The analysis of the results confirmed the tendency of people to overestimate the exposure to base-stations while underestimating the exposure to personal wireless devices. This second survey has also demonstrated that the risk perception is mostly affected by the exposure perception and to some extent by moral judgments. But the major result is that the majority of the survey respondents support LEXNET project aims. When asked about adding up the exposure from personal wireless devices and the exposure from base stations when evaluating the exposure of people to EMF, more than 60% of respondents agreed on the fact that both downlink and uplink exposures should be considered when evaluating the population exposure to EMF.

A large percentage of respondents also agreed when asked if it makes sense to characterize the day-to-day exposure to EMF by averaging it over time or if they think that an individual exposure to EMF can be approximated by measuring the exposure over a large population.

Concerning the human exposure index design, large efforts were carried out during the second year in order to consolidate the EI concept and formula as well as collect and calculate all the parameters that are necessary to the EI effective evaluation. This EI evaluation relies indeed on the collection of a wide range of data.
Up-to-date life segmentation surveys collected in the different participated countries were used to extract information on how different categories of population segment their daily lifes. ICT Usage data (usage of mobile phones for voice call or data, usage of tablets, PC…) were obtained through measurements of Key Performance Indicators (KPIs) by sensors inside the network. The network operators involved in the LEXNET project, i.e. Orange (France) and Telekom Serbia (Serbia), as well as the operators from Montenegro being partners of University of Montenegro, provided such data.
Reference Specific absorption rate (SAR) values were computed using 3D electromagnetic simulation platforms based on the Finite Difference Time Domain (FDTD) method. SAR values were calculated for far-field and near-field exposure for two anatomical human body models, one adult and one child model. Two postures (standing and sitting) and three usages (mobile phone close to the head, mobile phone or tablet for data and laptop usage) were selected.
But the main achievement of this second year is the EI integration on a few scenarios (see Figure 1).

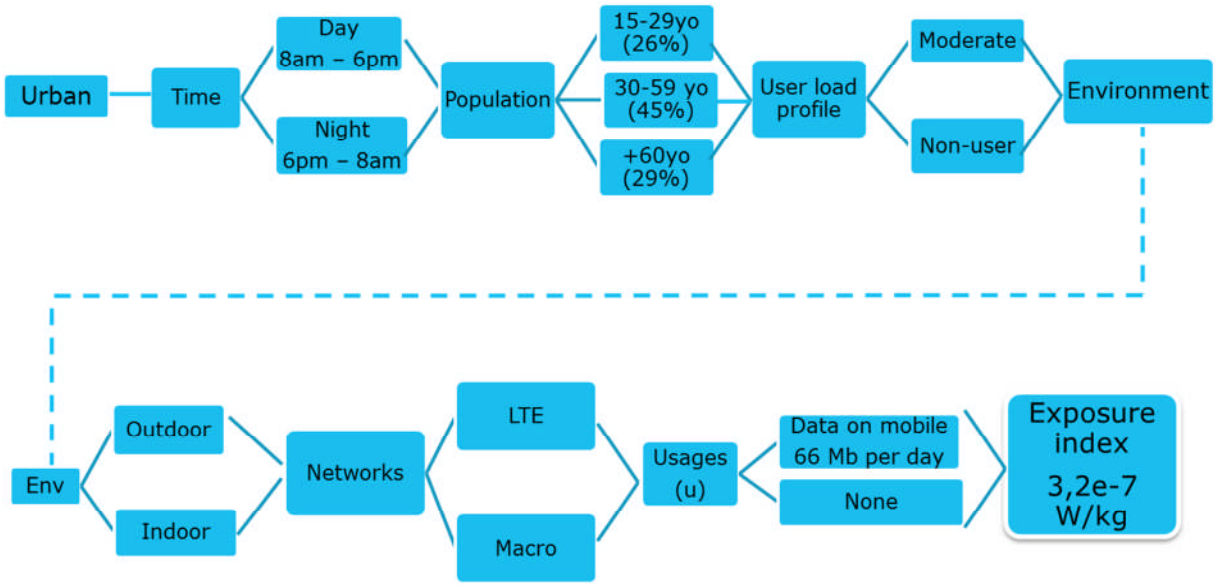

Figure 1 EI integration on a urban macro LTE scenario

WP3
The principal outcome from first year's work in WP3 was the specifications for the wearable LEXNET dosimeter and some initial work on the architecture of the system. Two different topologies were considered in parallel.
During the second and final year of the WP, the work can be divided into four principal activities. The first part was the design and validation of the new dosimeter. A flexible and

robust dosimeter architecture was identified, which is expected to overcome the limitations of the existing solutions and reply to the needs of the project. Each component of the architecture was individually tested and validated. The mechanical design of the final dosimeter was also addressed proposing a slimmer and more robust body comparable to a smartphone format. The work on the dosimeter design was presented at the European Microwave Week Conference in Rome in October 2014.
The second principal activity during the second year was regarding the impact of human body and network parameters on dosimeter measurements. With the help of exhaustive simulations and measurement campaigns, the impact of dosimeter measurements with the presence of human body in controlled and real environment was evaluated, and two corrections schemes were proposed. The work resulted in several articles in the conferences and scientific reviews.
The third principal work done in WP3 was regarding the evaluation of different network parameter variations in several scenarios and their impact on EMF measurements, uncertainty calculations for LEXNET dosimeter measurements, and on the estimation of isotropic EMF levels from mono-axial measurements.
A proposal for an expert system and definition of the methodology to assess the Exposure Index (EI defined in WP2) constituted the fourth main activity for this WP. A Decision Tree has been defined to identify the available data and tools coming from network simulation, E field measurements and network measurement, specifying the capacity to assess the DL and UL exposure. A processing method of the different inputs and calculation of the EI in several different scenarios was the main outcome of this work, providing the basis for demonstrator in WP6. The aim of this expert system is also to propose an EI assessment methodology to the different stakeholders as operators, regulators and public agencies.

WP4
During the first year; WP4 had addressed the review and the identification of a dozen of promising low EMF technologies from hardware components to radio link technics. Their exposure reduction principles are either based on modifying EMF spatial distribution, reducing the transmitted power or its duration. Scenarios and concept of exposure reduction had also been detailed.
The second year has been focused on the evaluation of each solution regarding exposure reduction based on a common 5-step methodology. Initial performance assessments of the innovative solutions considered within WP4 are carried out through a ratio of the Exposure Index (EI). The proposed intermediate performances assessments show a large range of exposure reduction from non-significant to 75% reduction considering in each case a specific scenario, while ensuring a constant QoS. Despite a large diversity of solutions, the adopted methodology makes possible a fair comparison of their effectiveness but also allows to highlight some compatibility or at the opposite some conflicts between these solutions. This last point is a mandatory step to prepare solution prioritization and global exposure reduction assessment planned for the last year of the project. The proposed exposure evaluation methodology has been discussed with the EU project MIWAVES partners.

WP5
In Year One of the project, WP5 provided a comprehensive overview of the EMF footprint of existing and emerging wireless networks, and the impact of most common network management techniques on EMF, which resulted in a clearly-defined way forward for Year Two. The following are key achievements of WP5 in Year Two of the project:

1. Preliminary measurements on a live network were carried out which show that available cellular technologies, current traffic conditions and user context, including services used, are main points to be taken into account when designing low-EMF solutions
2. Based on LTE simulations it was shown that Small Cell densification in urban areas allows for significant exposure reduction; however, it was also shown that power consumption and EMF exposure optimizations often conflict each other, and that a compromise between both is required
3. A tool was developed for the prediction of whole-body and localized SARs for indoor wireless network deployments
4. Adaptation of techniques belonging to the link and transport layers was shown to reduce EMF exposure whilst retaining the required QoE for the case of video by decreasing the maximum number of RLC frame retransmissions for non-critical frames
5. Work on routing in multi-hop networks has demonstrated that LEXNET-developed reward-based routing protocol proposed for multi-hop networks reduces exposure since it is able to fairly distribute it by lowering the corresponding peak values compared to the traditional protocols

In addition to key technical achievements summarised above, it is worth noting some additional activities carried out by WP5 in Year Two of LEXNET:
• An assessment of the impact on communications standards of the WP5 work was provided;
• Numerous publications were produced, many of which included multiple partners highlighting the cross-partner collaboration WP5 relies on and fosters;
• Organisation of a low-EMF workshop by WP5, accepted from an open call as part of IEEE ISWCS conference held in Barcelona in August 2014;
• Contribution by WP5 to a systematic methodology to assess the real exposure levels which leverages a large-scale deployment of low-complexity dosimeters exploiting an IoT testbed.

WP6
The work-package WP6 aims at experimenting the most promising techniques proposed by LEXNET to assess and reduce the EMF exposure in wireless communication networks, leading to demonstration, validation and evaluation of those techniques. The main characteristics of the measurement tools and testbeds to be developed and/or exploited into the WP6 validation platform were identified at the end of year 1 (after 6 months activity), while the second year was mainly dedicated to the platform development and definition of the evaluation scenarios.
The deliverable D6.1 entitled Validation platform framework and initial assessment, and delivered in May 2014, introduces the various components of the validation platform that are being developed with a two-fold objective: to study the feasibility of the low-EMF solutions (both within radio link components and network management entities); and demonstrate the EI assessment over real indoor and outdoor networks. Beside the tools devoted to the measurements of the DL power density (dosimeters) and UL transmit power, the WP6 validation platform is composed of two laboratory testbeds for evaluation of antennas and receiver components; several WLAN testbeds for demonstration of design and network management techniques; a real multi-RAT cellular network with advanced measurement facilities; the smart-city testbed where the exposure from real cellular networks will be continuously monitored by a fixed dosimeters deployment; and a

simulator for e.g. analysis of various offloading techniques in heterogeneous networks. Most the evaluation and demonstration scenarios are perfectly identified at the end of the second year. And the main part of WP6 resources is still dedicated to the platform development, including the development of the testbeds themselves, EI implementation, low-EMF techniques integration and the wearable-dosimeter prototyping.

The low-cost simplified dosimeter to be installed in the smart-city testbed is validated (from a prototype) and is today under production. A first set of such dosimeters has already been produced and will be integrated in the downtown sensor network beginning of 2015. Besides, the partners are working on an optimized deployment strategy, which takes into account together the terrain constraints, simulation results and iterative measurements.

WP7
In the first year, main activities were the definition and implementation of Standardisation/Regulation and Dissemination strategies.

During the second year, main Standardisation/Regulation objectives were focused on the presentation of LEXNET in standardisation bodies and the proposal of a New Work item (NWI) in CENELEC. Regarding dissemination special emphasis was given to the dissemination of LEXNET preliminary results in workshops and conferences, as well as specific training activities. Additionally, special emphasis was given to the identification and definition of actions concerning inter-project collaboration and other contacts.

During the third year special attention will be given to inter-project collaboration, interaction with public bodies and standardisation entities and to additional workshops and training activities. Dissemination and Standardisation impact will be reported in Deliverable D7.4 (Dissemination & standardisation impact). At the end of the project a final workshop will be organised and reported in D7.5 (Workshop 2).

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