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PhD proposal:
Environment aware radio resource optimization in next generation radio access networks

Context

The Radio Environmental Map [1][2] is a promising concept for storing radio environmental information that can be used to enhance radio resource management in wireless networks. The concept of REMs has been first proposed by the Virginia Tech team [1]. They define REM as a database that contains information on the radio environment, including geographical features, available services, spectrum policies and regulations, location and activities of radio devices, past experiences etc. This database can be located anywhere in the network with different possible architectures: centralized, distributed or hybrid. Related with the architectural aspects, the amount of signalling overhead needed to disseminate the REM is of concern and treated in [4].

The REM proposed as such, has been mainly considered for IEEE 802.22 WRAN scenarios and applications [4][5][6] where the focus is on opportunistic spectrum access on TV whitespaces.
Our conception of REM is more general than the existing database approach described above. We define REM as an intelligent entity which stores incoming radio environmental data but also *interpolates* this data to benefit from the spatial correlation that exists in the data. The concept of collecting geo-localized information on the radio environment and constructing a *map* using this information has also been investigated and developed further by other research groups [2][7][8]. In these works, REMs have been handled in a more general Cognitive Radio (CR) context than TV whitespaces and it is considered as a mean to represent spatio-temporal characteristics of the radio environment by using concepts and tools from spatial statistics, like point processes, spatial random fields, pair correlation functions, point interaction models, spatial interpolation techniques, etc.

With the fast standardization of Minimization of Drive Tests (MDT) in 3GPP, which is a framework for geo-located measurement reporting for 3G and 4G, the first MDT solutions have already started to appear in vendor equipments. It is estimated that MDT-capable mobile penetration will increase rapidly between 2012 and 2015, reaching more than half of the existing mobile devices in 2015. Besides, geo-location information is gaining momentum and popularity in the wireless arena with the flood of geo-location based applications on smartphones and tablets. Due this trend, conventional network planning and optimization vendors are converging towards geo-located measurement processing; and new actors and businesses that propose geo-location based solutions/applications are emerging.

The topics covered by this PhD thesis will allow us to:
- ✓ catch the above-mentioned geo-location train for radio resource management and optimization
- ✓ optimally benefit from the rich source of information provided by the combination of network measurements and the associated geo-location information, in order to achieve operator goals (such as OPEX reduction via reduction of drive tests for example, QoS improvement, optimized network operation etc.
- ✓ promote operator-oriented solutions for the geo-location based features in next generation network equipment releases.
- ✓ impact standardization on geo-located measurements related features, particularly on MDT, which has a high priority for all the operators due to the promising OPEX gains
- ✓ have cost-effective and innovative solutions for optimized radio engineering and radio resource management, which allows us to achieve our technical radio network operation and management targets.

[1] B. A. Fette and B. Fette, *Cognitive Radio Technology (Communications Engineering)*. Newnes, 2006.

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[3] S. Grimoud, S. Ben Jemaa, B. Sayrac, and E. Moulines, "A REM enabled soft frequency reuse scheme," *GLOBECOM, BWA Workshop*, December 2010.

Orange Labs

38-40, rue du Général-Leclerc
92794 Issy Moulineaux Cedex 9
Téléphone : 01 45 29 44 44

[4] Y. Zhao, et.al., “Overhead analysis for radio environment map-enabled cognitive radio networks,” *1st IEEE Workshop on Networking Technologies for Software Defined Radio Networks, pp.18-25*, 2006.

[5] Y. Zhao et.al., “Development of radio environment map enabled case- and knowledge-based learning algorithms for ieee 802.22 wran cognitive engines,” *2nd International Conference on Cognitive Radio Oriented Wireless Networks and Communications, (CrownCom), pp.44-49*, 2007.

[6] Y. Zhao et al., “Applying radio environment maps to cognitive wireless regional area networks,” *2nd IEEE International Symposium on New Frontiers in Dynamic Spectrum Access Networks (DySPAN), pp.115-118*, 2007.

[7] J. Riihijarvi, P. Mahonen, M. Wellens, and M. Gordziel, “Characterization and modelling of spectrum for dynamic spectrum access with spatial statistics and random fields,” *Personal, Indoor and Mobile Radio Communications, 2008. PIMRC 2008. IEEE 19th International Symposium*.

[8] M. Petrova, V. Kolar, J. Riihijarvi, P. Mahonen, “Enhancing cognitive radios with spatial statistics: From radio environment maps to topology engine,” *4th International Conference on Cognitive Radio Oriented Wireless Networks and Communications (CROWNCOM)*, 2009.

Thesis objectives and expected results

The PhD thesis activity will investigate two axes related to the REMs construction and exploitation.

- ✓ REM Construction: The REM information is built based on the terminals’ measurement data, combined with location information and reported to a functional entity. This entity exploits this information to build a complete map by interpolating the geolocalized measurements. Because measurement reporting is costly in terms of signalling overhead and battery consumption, the main challenge while building a REM is to find the optimal trade-off between the REM quality, i.e. the REM information accuracy and the measurements requested from the terminals.
- ✓ Performance evaluation of REM use cases: In cellular networks, the REM can be used to improve the network performances [3], or to minimize the operational costs. We have identified several use cases where using REMs may improve the network management and optimisation. This task will give a quantitative performance evaluation of the REM introduction for identified radio resource management use cases in terms of implementation costs and enhancement of key performance indicators.

Required skills and techniques

Required skills and techniques:

- ✓ Knowledge on radio access networks (3G, LTE, LTE-A), particularly on radio network optimization, radio resource management, architectural aspects (this knowledge also involves a standardization component, namely 3GPP).
- ✓ Knowledge on geo-location (techniques)
- ✓ Spatial statistics (spatial interpolation)
- ✓ Optimization and learning basics (statistical/stochastic optimization)
- ✓ Basic knowledge on probability and stochastic processes (Bayes theory, stochastic processes)

Global planning of the thesis timeline

The research approach to be followed in the thesis comprises the following steps:

- ✓ State of the art in 3G and LTE radio access network measurements, with a focus on the limitations of the existing measurements in terms of precision, periodicity and impact of velocity
- ✓ State of the art in geo-location and geo-location based network optimization solutions
- ✓ State of the art in MDT
- ✓ Scenario definitions
- ✓ Requirement work
- ✓ REM construction (precision, tempo-spatial granularity, update rate, choice of the geographical zone, non-uniform data handling, indoor measurements, architectural choices)
- ✓ REM for network optimization (performance and cost evaluations)
- ✓ Dissemination (NGMN and probably 3GPP on MDT)

Contact: Berna Sayrac (berna.sayrac@orange.com)

Place: Issy les Moulineaux (Paris region) / France
Duration : 3 years