PhD in Information Technology and Electrical Engineering

Università degli Studi di Napoli Federico II

PhD Student: Stefania Zinno

XXX Cycle

Training and Research Activities Report – Third Year

Tutor: Giorgio Ventre– co-Tutor: Stefano Avallone

1. Information

My name is Stefania Zinno and I was awarded the master Science degree in “Ingegneria delle Telecomunicazioni” at University of Naples Federico II. I am a PhD Student in Information Technology and Electrical Engineering, XXX Cycle, Università degli Studi di Napoli Federico II. I completed the industrial master "SIRIO-FORM Servizi per l'Infrastruttura di Rete wIreless Oltre il 3G” held by CNIT - Consorzio Nazionale Interuniversitario per le Telecomunicazioni in partnership with VoiSmart srl and Seconda Università degli Studi di Napoli – Dipartimento di Ingegneria Industriale e dell'Informazione. I work under the supervision of Prof. Giorgio Ventre and Prof. Stefano Avallone.

2. Study and Training Activities

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Cycle XXX

	Credits year 1								Credits year 2								Credits year 3									
		1	2	3	4	5	6			1	2	3	4	5	6			1	2	3	4	5	6			
	Estimated	bimonth	bimonth	bimonth	bimonth	bimonth	bimonth	Summary	Estimated	bimonth	bimonth	bimonth	bimonth	bimonth	bimonth	Summary	Estimated	bimonth	bimonth	bimonth	bimonth	bimonth	bimonth	Summary	Total	Check
Modules			2		3		12	**17**				12		6		**18**								**0**	**35**	**30-70**
Seminars					2,2		1,8	**4**		4	2													**0**	**4**	**10-30**
Research		10	8	10		10		**38**		6	8		10	4	10	**38**		15	10	10	10	10	10	**65**	**141**	**80-140**
	0	10	10	10	5,2	10	14	**59**	**0**	10	10	12	10	10	10	**56**	**0**	15	10	10	10	10	10	**65**	**180**	**180**

3. Research Activity

A)Research Activities:

LTE in Unlicensed Bandwidth

Here an overview of the research work proposing new approaches for a fair coexistence between LTE and Wi-Fi in the unlicensed spectrum is presented. Such works are categorized depending on the main mechanism employed to achieve coexistence, i.e. Listen-Before-Talk, Almost-Blank-Subframe and other minor approaches.

Before presenting the approaches proposed for a fair coexistence of LTE and Wi-Fi, we first discuss about the fairness criteria adopted by such proposals. Most of the works refer to the 3GPP definition of fairness: *the capability of an LAA network not to impact Wi-Fi networks active on a carrier more than an additional Wi-Fi network operating on the same carrier, in terms of both throughput and latency.* Accordingly, most of the works focus on throughput and QoS metrics such as latency. Some other papers, however, evaluate the fairness in terms of airtime, i.e., the amount of time each technology accesses the wireless channel to transmit. While most of the papers just present a comparison of the selected performance indicator (throughput, airtime or latency) with or without an LTE cell operating in the unlicensed bands, a few works at- tempt to quantify the fairness achieved by their solution. Most often, Jain's fairness index is used. The larger the Jain's index is, the fairer is the coexistence between Wi-Fi and LTE. The concept of statistical dominance is instead leveraged in to quantify the 3GPP definition of fairness. Basically, the empirical CDF of the throughput is obtained when a Wi-Fi network coexists with an LTE-U network and when it coexists with another Wi- Fi network. Fairness is achieved if the former dominates the latter. Finally, some other works derive a model for the coexistence of Wi-Fi and LTE in unlicensed bands and incorporate the fairness as a constraint in the proposed optimization model. Therefore a number of approaches proposed for a fair coexistence of LTE and Wi-Fi in unlicensed bands is described.

Table 3: Taxonomy of research works

Paper	CAT	Threshold	CW	Scenario	Model	PTX	Note
[38]	CAT 4	CCA-ED: -62dBM CCA-PD: -82dBM	CW_min 16, CW_max 1024	Indoor	FTP 2	18 dBm	CAT 4 Comparison
[39]	CAT 3		Fixed	LAA-LAA LAA-Wi-Fi			MARKOV
[40]	CAT 1			Indoor Single and Multi-Floor	Full buffer	23 dBm	
[41]	CAT 3	CCA-ED:-82 dBm Indoor -62 dBm Outdoor	Fixed CW and freeze period of 11 OFDM Symbol	2 x Wi-Fi vs Wi-Fi-LTE DL LAA vs DL Wi-Fi (DL+UL) Wi-Fi vs DL LAA	FTP 0.5 Mbyte - Non full buffer		
[42]	CAT 1	CCA-ED: -70 dBm	Fixed 18 micro sec	Office Indoor 3GPP Scenario		15 dBm	Channel Selection with Q-LEARNING
[22]	CAT 2?	CCA-ED: 62 dBm		Indoor LTE-U femtocell, outdoor LTE-U picocell vs Wi-Fi indoor		23 dBm	Channel Selection with MATLAB
[37]	CAT 3	CCA-ED: (-52,-62,-72,-82,-92)dBm	Fixed (32,128)	Outdoor/Mixed standalone plain coexistence	FTP 1 0.5 Mbyte	enodeB 30 dBm AP 20 dBm STA 17 dBm	
[32]	CAT 2	CCA-ED: Adaptive in [-82 dBm, -58 dBm]		Indoor Office	Full Buffer Data	24 dBm BS-AP 23 dBm Ue-STA	
[43]	CAT 3	CCA-ED: -82dBm	Fixed (32,128)	Outdoor - Mixed indoor outdoor - standalone plain coexistence	FTP 1	enodeB 30 dBm AP 20 dBm STA 17 dBm	No licensed band simulated RTS CTS self CTS
[44]	CAT 1			indoor scenario			Channel selection with Q-LEARNING
[45]	CAT 3	CCA-ED: Adaptive in [-30 dBm,-80 dBm]	Fixed 32	2xWi-Fi 2xLAA Wi-Fi vs LAA [indoor, outoor]	FTP 3 0.5 Mbyte	23 dBm	
[46]	CAT 3,4	CCA-ED: -55dBm	QoS Adaptive	Outdoor Indoor only coexistence 3GPP 1,2,3	FTP 3 0.5 Mbyte	18 dBm	
[47]	CAT 3,4	CCA-ED: -62dBm CCA-PD: -82dBm	Adaptive	Indoor standalone plain coexistence	FTP 0.5 Mbyte	18 dBm with LBT 23 dBm Without LBT	WaLT simulator CTS to self
[34]	CAT 2	CCA-ED: -62 dBm, -72 dBm		Outdoor - Mixed Indoor Outdoor [LTE vs Wi-Fi compared to 2x LTE or 2x Wi-Fi]		30 dBm	Channel selection STOCHASTIC 40MHz Bandwidth
[48]	CAT 2						LBT MARKOV
[49]	CAT 3	CCA-ED: -82 dBm E-CCA: 16 SLOTS	indoor building 2xWi-Fi Wi-Fi vs LAA	FTP 3 0.5 Mbyte		23 dBm	COT
[31]							MARKOV
[50]	CAT4	CCA-ED: -62 dBm	Adaptive on Channel Load	3GPP Indoor 2xWi-Fi LAA vs Wi-Fi	FTP 1 0.5 Mbyte	18 dBm	
[51]	CAT 4	CCA-ED: -77 dBm , -82 dBm	Dynamic [0,1] [0,2]	2x Wi-Fi vs Wi-Fi -LTE	Poisson	23 dBm AP and eN-odeB	STOCHASTIC
[33]	CAT 2					UE 20 dBm STA 15 dBm	800 MhZ Bandwidth STHOCASTIC
[36]	CAT 3	CCA-ED: -62 dBm	32	Outdoor, indoor2xLAA- 2xWi-Fi, Wi-Fi vs LAA 3GPP 2,3	FTP 1 0.5 Mbyte	eNB 18dBm	BWSIM
[52]	CAT 4	CCA-ED: -62 dBm,-72 dBm,-82 dBm	[15,63] doubled with 80% of NACK	Indoor scenario Single Floor Building	FTP 3 0.5 Mbyte	18dBm	MCOT
[17]	CAT 1			Standalone, Wi-Fi +LTE-U 21-cell wrap-around dense hotspot		27 dBm	ABS - 40 MHz Bandwidth
[53]	CAT 1						ABS
[54]	CAT 1						ABS
[55]	CAT1				FTP 2 - Non full buffer Traffic Data	23 dBm	ABS
[56]	CAT 1						ABS 40 MHz Bandwidth
[57]	CAT 1						ABS
[58]	CAT 1						ABS Monte carlo MATLAB
[59]	CAT 1						ABS Monte carlo MATLAB

LTE Radio Optimisation: a smartphone approach

LTE technology gives access to higher bandwidth and assures efficiency at network level for telecommunication operators, providing a reliable and continuous data traffic ow that allows data transmission at extremely high bit-rates. The aim of this chapter is to evaluate LTE network performance in an actual urban environment, with emphasis on the downlink channel throughput. The use of statistical methods shows how standard expectations are too high with respect to a real scenario. Also, an analysis is carried out with reference to key parameters for radio optimization that are not defined in the standard and are implemented and defined differently by each vendor. Beside a theoretical approach which resorts to network numerical simulation and emulation tools, or to experiments run in a controlled environment, most of the mentioned topics require an experimental approach under real-case conditions.

A measurement campaign was conducted in a real-world scenario adopting a drive test methodology by mean of smartphone-based measurement tool. Sessions were conducted over a 9.75 km extra-city route in the area of Naples, Italy. The campaign was carried out along such area to ensure homogeneous propagation conditions along the route. Measurement device was put in a vehicle moving with an average speed of 49 km/h in a completely *outdoor* scenario. The device used for the measurement session implements LTE-Advanced standard and operates in the 20th band (800 MHz, FDD) with 10 MHz channels.

LTE standard do not de ne how to compute CQI value, even if several times it has been stated that SINR plays a major role into link adaption procedure. But SINR itself does not represent a comprehensive channel state representation. This first analysis we present is able to show the strong relationship between SINR, RSRP and CQI. It is very interesting to characterize which combination of SINR and RSRP values lead to a specific CQI value. In fig.1 CQI evolution is shown based on RSRP and SINR. RSRP values are represented by the different colors in each point in the plane. Generally, a first investigation let us conclude that a certain CQI value leads to a wide range of SINR and RSRP values. Also, it is quite noticeable that a high SINR values correspond high RSRP values.

Figura 1

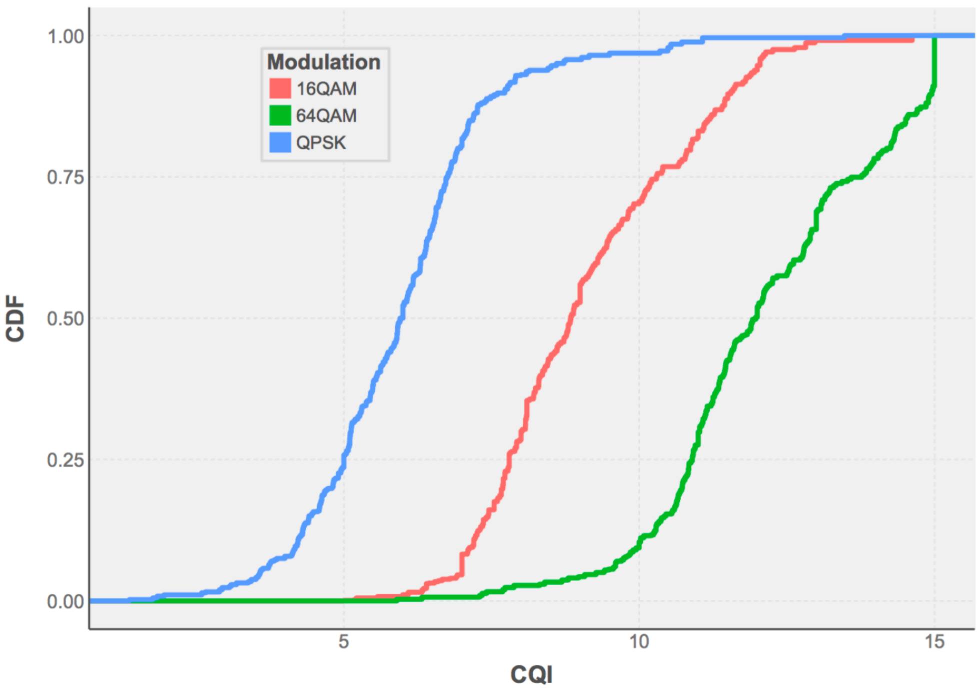

Figura 2

CQI role is fundamental for Adaptive Modulation and Coding Mechanism. The choice of which modulation to use in fact, is up to the CQI value. In Fig. 2 CQI CDF is shown. Measurement are conducted based on the PCC related to primary MIMO stream Generally different stream could use different modulation code scheme in order to exploit different propagation channel features. In this case, to obtain a meaningful analysis, only values related to MIMO streams using the same modulation scheme were evaluated.

LTE Radio Optimisation: MIMO techniques Assessment

MIMO has been deployed since years in Wireless LAN, Wi-Fi standards in fact incorporated this technology since 802.11n.

MIMO stands for *Multiple-Input Multiple-Output*, meaning that it allowed to transmit at faster speeds by sending data through multiple receiving and transmitting antennas.

Using MIMO enhances the performance and enriches network connections compared to those adopting with single-antenna techniques. Although its development date back at ten years ago, only recently LTE networks involved it in its architecture. 3GPP technology in fact, has lastly evolved from the original Single-User transmission to a Single User MIMO (SU-MIMO) and a Multi User MIMO (MU-MIMO). LTE standard supports multi- antenna technologies that improve both link- and system-level performance in a wide range of scenario.

Multi-antenna technologies for reception and transmission at the eNodeB and in UEs in LTE today are a key enabler of the high performance offered by 3rd Generation Partnership Project (3GPP) LTE. MIMO in fact, enables radio systems to achieve significant performance gains by using multiple antennas at their transmitters and receivers. Since Release 10 up to eight antennas are possible in the downlink.

Since maximum throughput using a given modulation scheme increases linearly at low SINR but logarithmically at higher SINR, increasing SINR of the low-SINR layer at the expense of the high-SINR layer increases total throughput. At a basic level, however, the goal is to ensure that each layer can be decoded at an acceptable error rate of 10% or less, allowing the UE to take advantage of the spatial multiplexing.

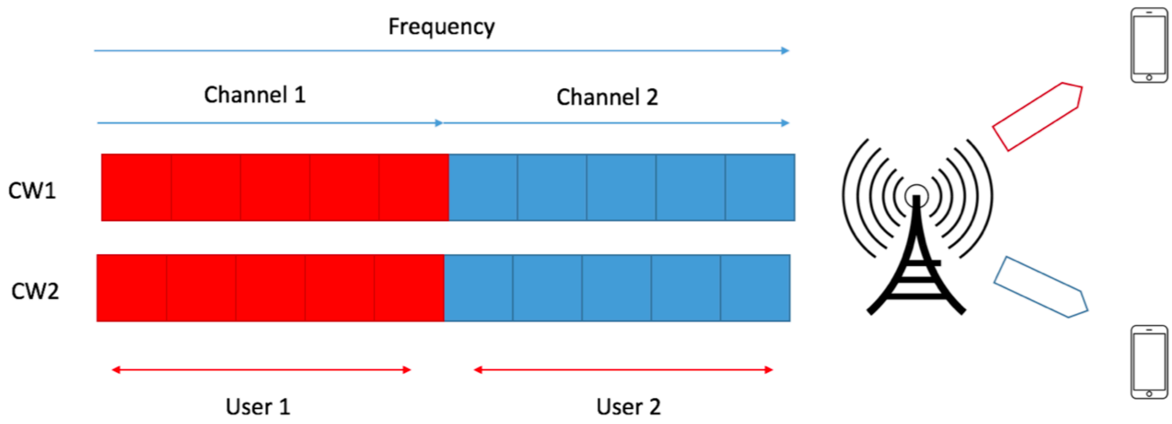

Fig. 5.1 SU-MIMO

The basic idea is to transmit multiple code-word to a single user in the same time-frequency interval so there is only one scheduled user per sub-band or channel. A Code Word is de ned as a *Coded Transport Block*, but in a wider sense we consider it as a single independently data stream.

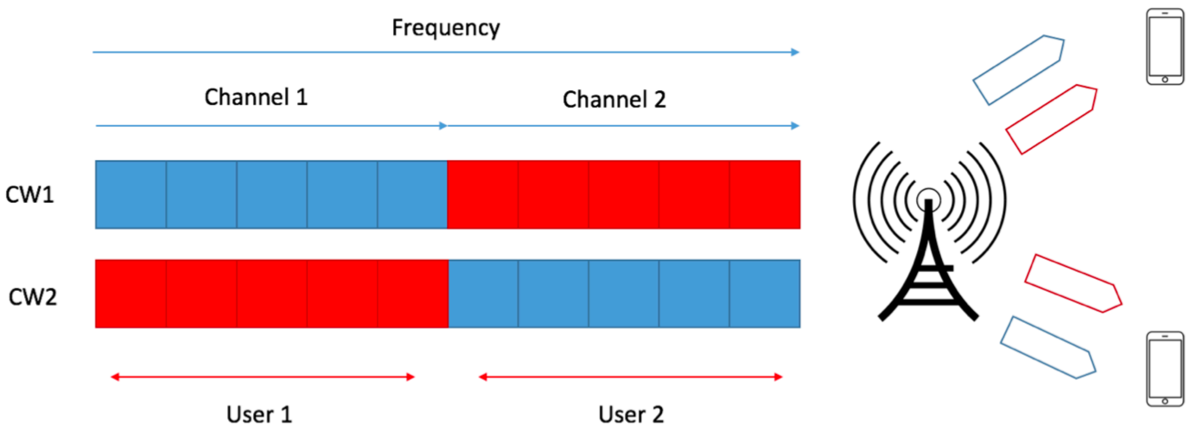

Fig. 5.2 MU-MIMO

In MU-MIMO, separate data streams are sent to spatially separated UEs over the same sub-channel. Each UE serving has multiple Rx antennas. With this technique, the overall system capacity is increased, though it does not increase throughput for individual UEs. To achieve MU-MIMO better performances rich scattering conditions are necessary for each UE in order to decode the data stream meant for that particular UE.

Measurement campaign was conducted using *Nemo Analyzer* as a tool. The tool was installed at the radio interface of an eNodeB. The software provides a complete automated data processing chain from raw measurement data to automatically generated results in workbook format. Nemo is an event based measurement suite which acts like a Live Network Monitor at every eNodeB desired level. For each event occurring it collects data.

B) Collaborations:

Programma per il finanziamento della ricerca di Ateneo *"Radio optImization and human Exposure assessMent for LTE AdvaNced Networks - RIEMANN":* LTE (Long Term Evolution) mobile system is one of the most promising technologies for fast and reliable mobile communication and data streaming, allowing for an impressive down- and up-link channel throughput typically reaching 300 Mbps and 75 Mbps rates, respectively.

Given the larger and larger spread expected for such mobile system, efforts are required to fully characterize its propagation characteristics, and more specifically how propagation impacts on signal strength, which in turn affects the system's quality of service (QoS) indicators and the human exposure to electromagnetic fields.

More specifically, the proposed research project deals with:

A. the analysis of time and space dependence of exposure levels to high frequency electromagnetic fields, through an extensive experimental activity and data analysis by advanced statistical methods. The main purpose is to validate the hypothesis made in the measurement standard and, consequently, suggest potential changes to reduce measurement uncertainty [1].

B. Optimization of network coverage and capacity, interference reduction algorithms and radio channel adaptivity according to channel variations based on user measurements. The main goal is to achieve efficiency in network optimization procedures, to improve throughput and reduce latency.

To achieve the mentioned results, the project will focus on the *physical* layer (i.e., the propagation channel) and the radio *optimization* of the LTE system: on the *physical* side, the methodologies for the measurement of the human exposure to the electromagnetic field will be investigated in order to determine which one results in the lowest uncertainty level [2], and the best approach to estimate the covered area by identifying which spatial interpolation algorithm best matches propagation will also be researched. On the *optimization* side, the investigated propagation characteristics will be used to optimize *coverage shaping* and *load balancing* procedures, and interference reduction algorithms [3]. Coverage and capacity requirements, just like any other network resource that must be efficiently deployed, require that the configuration policies be based on actual radio conditions, propagation environment and traffic load.

We strongly believe that the outcomes of the research undertaken will be of interest to the scientific community as well as the professional and industrial world that will be benefit from the reduced-uncertainty measurement procedures and optimized network configuration, respectively.

4. Products

1. "A Load Balancing Algorithm against DDoS attacks in beyond 3G wireless networks" **- Stefania Zinno, Giovanni Di Stasi, Stefano Avallone, Giorgio Ventre** published in Euro Med Telco Conference (EMTC), 2014

2. "Smartphone-based Measurements of LTE Network Performance" **- Stefano Avallone, Nicola Pasquino, Stefania Zinno and Domenico Casillo** pubblicato in International Instrumentation Measurement Conference (IMTC), 2017

3. "Experimental characterization of LTE Adaptive Modulation and Coding scheme under actual operating conditions" **- Stefano Avallone, Nicola Pasquino, Stefania Zinno and Domenico Casillo** in 2017 IEEE International Workshop on Measurements and Networking (M&N)

4. "VERIFICA SPERIMENTALE DELLE PRESTAZIONI DELLA RETE LTE MEDIANTE MISURE BASATE SU SMARTPHONE" **- Stefano Avallone, Nicola Pasquino, Stefania Zinno and Domenico Casillo** sottomesso in GMEE, **I Forum Nazionale delle Misure** XXXIV Congresso Nazionale di **Misure Elettriche ed Elettroniche** XXV Congresso nazionale di **Misure Meccaniche e Termiche, (2017)**

5. "On a Fair Coexistence of LTE and Wi-Fi in the Unlicensed Spectrum: A Survey " -**Stefania Zinno, Giovanni Di Stasi, Stefano Avallone, Giorgio Ventre** *accettato* in Computer Communications - Journal - Elsevier, (2017)

6. “Radio Optimisation and Measurement Procedure in LTE “
7. **Stefania Zinno - MOBILE SYSTEM TECHNOLOGIES (MST2017) October 27 2017**

8. **"La verifica sperimentale delle prestazioni del sistema LTE Il cellulare come strumento di misura"** accettato per la pubblicazione su TUTTO MISURE - Rivista Nazionale (2017)

9. *"Experimental Assessment of LTE performance through measurements in urban environments" - **Stefania Zinno, Nicola Pasquino, Stefano Avallone, Giorgio Ventre** in preparazione*

5. Conferences and Seminars

1. **Speaker at:** MOBILE SYSTEM TECHNOLOGIES (MST2017) October 27 2017, Milan: Architectures, technology trends and memory solutions
2. **Speaker at:** Instrumentation Measurement Conference (IMTC), 2017
3. **Speaker at:** IEEE International Workshop on Measurements and Networking (M&N)
4. University Representative at University Fair - Fondazione O.M.C. Collegio Vescovile Pio X 25th November 2017

6. Tutorship

1. I am teaching assistant for the courses of: ***"Reti di Calcolatori I"***, Bachelor's degree in Computer Engineering, and ***"Computer Networks II"***, Master's degree in Computer Engineering, Scuola Politecnica delle Scienze di Base, Università degli Studi di Napoli Federico II.
2. I was teacher for **"Percorsi Abilitanti Speciali (PAS) per il conseguimento dell'abilitazione all'insegnamento per le scuole secondarie Sessione suppletiva - Classi aggregate A042-C300"**

october november 2016

3. Programma per il finanziamento della ricerca di Ateneo**:** ***"Radio optImization and human Exposure assessMent for LTE AdvaNced Networks - RIEMANN"*** with Prof. Stefano Avallone and Prof. Nicola Pasquino.

4. I was teaching three afternoon laboratories about Scratch programming for ***"Web e Nuove Tecnologie"*** *UniSob* - Prof. Ventre

5. I was involved in ***"*Laboratori territoriali *Fab Lab Cond*"** promoted by *"Istituto superiore Grottaminarda I.T.I.S – I.T.C. – L.A- L.U- L.S.U."* together with CINI and Prof. Ventre

6. Tutoring on basic concept for LTE Architecture