ICT-215282 STP ROCKET

Reconfigurable **O**FDMA-based **C**ooperative Networ**K**s **E**nabled by Agile Spec**T**rum Use

1M2

Intellectual Property Strategy

Contractual Date of Delivery to the CEC:	**June, 30. 2008**
Actual Date of Delivery to the CEC:	**August, 11. 2008**
Author(s):	**Sebastien Simoens, Patrick Labbe (MOT), Antonis Valkanas, Ilias Pamagiotopoulos, Nikos Skentos, Christos Antonopoulos (ICOM), Lionel Rudant, Cédric Dehos, Patrick Rosson, (CEA), Zdenek Becvar (CTU), Benedikt Wolz, Klaus Sambale (RWTH), Roberto Gimenez (GOW), Shyamalie Thilakawardana, Reza Hoshyar (UniS), Olga Muñoz, Josep Vidal, Adrian Agustin (UPC), Enrico de Marinis, Giampaolo Imponente (DUN)**
Participant(s):	**MOT, UPC, RWTH, CEA, ICOM, UniS, CTU, GOW, DUN**
Workpackage:	**1**
Est. person months:	**5**
Security:	**Internal**
Dissemination Level:	**CO (Public Version)**
Version:	**10.0**
Total number of pages:	**37**

Abstract:

This milestone report represents a part of the deliverable D5 "1D3-Standardization and Dissemination Strategy". This deliverable has been restructured including sections containing information that can become available and useful to the general public. In this report, IPR issues relevant to ROCKET investigations are presented and have been used for the identification of the IPR strategy of the ROCKET project. First, the 4G standardization landscape is briefly described and the target standard bodies for ROCKET are identified as being 3GPP-LTE-A and IEEE802.16m. The IPR situation in these standard bodies is then analyzed and compared to the current situation of 3G in terms of e.g. royalty rates, IPR players, patent pool initiatives, etc. In the third part of this report, IPR creation opportunities are identified for each of these topics, as well as relevant standards and related prior art. Reference is made to relevant patents, patent applications and publications which are obtained from a recent scan performed in FIREWORKS and from a new exhaustive search in the framework of ROCKET.

Keyword list: IPR, patents, royalty, 4G, essential, patent pool, LTE, WiMax, 802.16m, 3G

Executive Summary

This report describes Intellectual Property Rights (IPR) matters relevant to the ROCKET project. The ROCKET approach aims at designing and demonstrating novel techniques in a set of technological areas that are considered key for next generation BWA systems. These areas include base stations coordination, cooperative transmission, flexible spectrum usage, MAC signaling efficiency, antenna design and linearization of amplifiers. The techniques designed during the course of the project shall be protected, either by patent filing or by publication. These two forms of protection have to be sought in a very competitive landscape, both in the academia and among industrial partners in standard bodies. It is therefore critical to preliminary address the following questions before starting the technical investigations:

- **Which 4G standards are expected to dominate the market, and in which time frame?**

The first bullet is addressed by sections 2.1and 2.2 of this report. It seems clear that the dominant standards will be 3GPP-LTE and IEEE802.16/WiMax, while Qualcom's UMB seems stalled. While LTE is supported by the largest operators, its commercial rollout is expected in the 2010-2012 timeframe, which corresponds to the expected time frame for WiMax release 2 (i.e. 802.16m). In contrast, the commercial deployment of WiMax release 1.0 started in Asia in 2007 and national roll-out should occur in the U.S. in the second half of 2008.

- **Who are the IPR players? What is the nature and value of the IPR already claimed? How does the 4G IPR landscape differ from 3G?**

These questions are addressed in section 2.3. Overall, major cellular manufacturers (Nokia, Ericsson, Motorola, Qualcomm,…) have the lion's share of IPR for 3G. In 3G-WCDMA, the total royalty rate for a company that does not hold any patent is around 25% of the wholesale price. This clearly represents a barrier to entry for small players entering the cellular market. Moreover, out of these 25%, Qualcomm is said to charge a royalty rate of 4-5% of the sale price. In 4G the situation is not yet clarified. First, it seems that the patent situation is more fragmented than in 4G, with a large number of companies claiming patents for WiMax and LTE. The essentiality and commercial value of these patents remain however to be assessed. Several initiatives have been taken (e.g. NGMN, LTE patent pool initiative) in an attempt to limit the royalty rate of WiMax and LTE. However, some important 4G IPR players (e.g. Qualcomm, Motorola, Nortel) are not involved in these initiatives and therefore it remains uncertain at this point whether the royalty rate of WiMax and LTE can be significantly lowered compared to 3G. Meanwhile, each player is trying to build the largest possible patent portfolio in order to be in a favorable position to negotiate bilateral agreements in case patent pool initiatives fail.

- **For each technical area (i.e. Workpackage) of ROCKET, which specific topics are especially promising in terms of IPR generation? What is the prior art (patents and publications) for these topics?**

In section 3, reference is made to some patents and publications in the literature that may constitute prior art for this topic. Previous patent and publications search performed in FIREWORKS project is leveraged, and additional new references are also provided. At this stage the limits of a microscopic approach to IPR analysis appear: for many topics, a large number of patent applications are filed and we cannot list them all. Often, these applications have vague or excessively broad claims. Sometimes these applications even claim things that seem obvious from the existing literature. It is therefore difficult for the engineer to assess the actual relevance of these patent applications. Yet, a prior art search gives an idea of how broad/narrow claims in such topics can be expected.

DISCLAIMER

The work associated with this report has been carried out in accordance with the highest technical standards and the ROCKET partners have endeavoured to achieve the degree of accuracy and reliability appropriate to the work in question. However since the partners have no control over the use to which the information contained within the report is to be put by any other party, any other such party shall be deemed to have satisfied itself as to the suitability and reliability of the information in relation to any particular use, purpose or application.

Under no circumstances will any of the partners, their servants, employees or agents accept any liability whatsoever arising out of any error or inaccuracy contained in this report (or any further consolidation, summary, publication or dissemination of the information contained within this report) and/or the connected work and disclaim all liability for any loss, damage, expenses, claims or infringement of third party rights.

Table of Contents

References & Standards

[ETSI07] ETSI Directives, ETSI IPR Policy (Annex 6 of the Rules of Procedure) ETSI IPR Policy - Extracted from the ETSI Rules of Procedure, 29 March 2007), Annex 6: ETSI Intellectual Property Rights Policy

[Fir-IPR] IST-27675 STP FIREWORKS FlexIble RElay Wireless OFDM-based networks, Amendment on 6D1 "IPR Portfolio Analysis" Feb 2008.

[Gab08] Caroline Gabriel, Rethink Research in ArcChart BluePrint "LTE patent situation remains fragmented, threatening no-subsidy handset" http://www.arcchart.com/blueprint/show.asp?id=474&qtabs=99999

[Good05] David J. Goodman and Robert A. Myers, Dept. of Electr. & Comput. Eng., Polytech. Univ. Brooklyn, USA; "3G Cellular Standards and Patents", Wireless Networks, Communications and Mobile Computing, 2005 International Conference on. 13-16 June 2005

[Lte06] 3GPP TR 25.814 V7.1.0 (2006-09), Technical Report, 3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Physical layer aspects for evolved Universal Terrestrial Radio Access (UTRA), (Release 7)

[Mar07] Donald L. Martin and Carl De Meyer, Qualcomm Inc., "Patent Counting, A Misleading Index of Patent Value: A Critique of Goodman & Myers and Its Uses" – Qualcomm white paper, January 2007

[Reu06] Reuters, "Nokia says patent row to determine wireless future " Nov 30, 2006

[Syp07] Robert Syputa "WiMAX/LTE 4G Intellectual Property Rights (IPR) Policy & Market Report" Maravedis, Feb 2007.

[Yos99] Junko Yoshida "3G intellectual property licensing strategy comes under fire" in EETimes, 11/27/1999.

[Wat07] Wateen WiMax Commercial Service in Pakistan http://www.wateen.com/HomeUsers.aspx?HomeTreeID=16

[Wav0] Wavecom, France Telecom, "Advantages of using OFDM for enhancing UTRAN", Tdoc R1-02-1256, 3GPP RAN1 Meeting #28 bis, Espoo, Finland, October 7th-9th 2002

[WSJ08] The Wall Street Journal, 9 Jun 2008 (Don Clark) "WiMAX Patent Pool Is Planned --- Firms Aim to Spur Use by Limiting Royalty Payments"

[WWiSE04] EN-Genius Network Guest Column: The WWiSE Proposal For The 802.11n Standard (Jim Zyren, Conexant Systems, Inc. September 20, 2004).

List of abbreviations & symbols

AF	Amplify-and-Forward
ARQ	Automatic Repeat Request
BS	Base Station
BWA	Broadband Wireless Access
CF	Compress-and-Forward
CR	Cognitive Radio
CSI	Channel State Information
DF	Decode-and-Forward
FEC	Forward Error Control
IP(R)	Intellectual Property (Rights)
LTE	Long-Term Evolution (3GPP)
LUT	Look-up Table
MIMO	Multiple Input Multiple Output
MS	Mobile Station
MU	Multi-User
NG-BWA	Next Generation Broadband Wireless Access
NGMN	Next Generation Mobile Networks
OFD(M/MA)	Orthogonal Frequency Division (Multiplexing /Multiple Access)
PA	Power Amplifier
PD	Pre-Distortion
RS	Relay Station
SINR	Signal to Interference plus Noise Ratio
STBC	Space-Time Block Coding
TPRC	Two-Path Relay Channel
TWRC	Two-Way Relay Channel
EGF	Extended Gaussian Function
OQAM	Offset QAM
IOTA	Isotropic Orthogonal Transform Algorithm
Tx	Transmitter
Rx	Receiver
TIA	Telecommunication Industry Association
HSDPA	High Speed Downlink Packet Access

1 INTRODUCTION

1.1 Foreword

It is commonly envisaged by the global research community that the Intellectual Property Rights (IPRs) and in general the 'intangible resources' are becoming a strategic source of revenues and competitive advantage on the market. Through IPRs, knowledge in any form is considered as private property and is protected against unauthorised use. In this respect, publication such as journal and conference papers can be viewed as a defensive IPR: it prevents other companies from patenting the technique, or at least force them to narrow their claims. Such considerations form the basis for the profitable use of IPR ownership. However, the inherent monopolistic nature of IPRs may in some circumstances restrict technology deployment and creativity. Therefore, standardization bodies, industrial and academic organizations (ETSI, WiMAX, Wi-Fi, IEEE) actively respond, (e.g. ETSI is strengthening its policy regarding IPRs by forcing the IPR holders to declare the terms and conditions attached to their IPR ahead of the standardization of a new technology, see also section 2.3 of this document). Recently, advanced communication technologies, systems and services are competing across a range of both technical merits and techno-economic considerations like IPR distribution etc.

1.2 Scope of this document

The main objective of the present document is to identify IPR elements addressing the context of the ROCKET project, which aims at creating and developing key technology for NG-BWA systems meeting the IMT-Advanced Requirements. The ROCKET project leverages the FIREWORKS project, in which technology was created for OFDMA-based relay systems. Therefore, it seemed natural for us to leverage on the IPR portfolio analysis performed within this project [Fir-IPR]. In particular, the general IPR landscape in standards such as WiMax has not significantly evolved since the release of [Fir-IPR]. However, some noticeable context differences exist between the present document and [Fir-IPR]: the latter was written at the end of the project, and therefore was already able to identify in details the actual IPR contributions of the project, whereas in ROCKET we are just starting the technical investigations and it is all the more important to identify the domains in which IPR generation shall focus. Another key difference is the technological scope of the project: some novel topics are addressed in ROCKET, such as Base Stations coordination or Flexible Spectrum Usage. The ROCKET IPR strategy shall consider these new domains. Note that IPR ownership and licensing issues will be managed by the consortium according to the Consortium Agreement that is already signed by all partners upon the project start. The implementation of the IPR strategy of ROCKET partially issued from this document aims at preventing future licence cost for used technology, strengthening the position of the ROCKET consortium in the targeted standards, providing competitive advantage to ROCKET industrial partners on their markets and assuring a prominence of the consortium within the academic community.

2 LEGACY AND EMERGING SYSTEMS

IT IS STATED HERE EXPLICITLY BY THE AUTHORS THAT THE CONTENTS AND INFORMATION PRESENTED THROUGHOUT THE SECTION 2 "LEGACY SYSTEMS" OF THIS DOCUMENT IS BASED ON COMPILATIONS AND REPRODUCTIONS OF INFORMATION GATHERED SOLELY FROM FREE PRESS RELEASES AND OTHER PUBLICLY AVAILABLE SOURCES. THEREFORE, THE IDEAS AND RELIABILITY OF THE INFORMATION OF THIS SECTION DO NOT NECESSARLY REFLECT THE OPINIONS OF THE AUTHORS AND THE ROCKET CONSORTIUM.

2.1 BWA Systems Towards 4G

The evolution of BWA systems will eventually lead to an official definition of wireless 4G technologies. That definition is not expected to be released before the 2008/09 timeframe in the form of the International Telecommunication Union's (ITU) IMT-Advanced requirements; however, there are certain objectives that are projected for 4G, e.g.: ITU set the target of peak useful data rates at 100 Mbit/s for mobility and 1 Gbit/s speeds for fixed/portable (both indoors and outdoors) radio access.

Currently the main candidate technologies striving for designation as the official 4G are:

- The Ultra Mobile Broadband (UMB) advocated by the 3GPP2 CDMA Development Group (CDG),
- The 3GPP Long Term Evolution (LTE) project aiming to improve the UMTS mobile phone standard to cope with future requirements,
- The mobile iterations of IEEE 802.16e/m, i.e.: WiMAX.

Large-scale commercial deployment of Mobile WiMax (based on Mobile Wimax release 1.0) is expected in 2008. FDD profiles will be included in the 1.x release (expected during 2009). The certification of 802.16m shall correspond to WiMax release 2 (which shall not be mistaken with waves 1 and 2 of the Mobile Wimax release 1.0 certification process). **The rollout of LTE and WiMax release 2 are expected to start in the 2010-2012 timeframe**. Drivers of LTE, UMB and 802.16m WiMAX adoption are likely to herald the re-allocation of older spectrum for 4G technologies, the resolution of any WiMAX IPR issues, and the creation of FDD profiles for 802.16e WiMAX (release 1.x). Realistically, initial implementations of LTE, UMB and 802.16m WiMAX may fall short of throughput and other expectations, with later enhancements, or even some type of technology combination, actually bringing real 4G to the table.

2.1.1 Ultra Mobile Broadband (UMB)

UMB is considered as an evolutionary upgrade within the family of CDMA2000 standards that can be deployed in existing or new spectrum allocations using scalable bandwidths up to 20 MHz. UMB technology incorporates the benefits of OFDMA, CDMA and other air interface techniques with MIMO and advanced antenna technologies, to offer features such as support for broadband speeds, greater capacity and coverage, and an enhanced user experience for a wide range of interactive services and mobile services. The technology is expected to be commercially available by mid-2009, but, no operator has yet announced any plans for trials or deployment of UMB. Several of the major CDMA operators in the two primary markets are migrating to other technologies, e.g. Verizon Wireless. Verizon historically has built networks based on the CDMA migration path, including EV-DO networks for 3G (EV-DO can't scale up to near-4G speeds to bridge the G gap the same way HSPA can -where for a given 10 MHz, it has a maximum throughput of 7.2 Mb/s downloading and 2.2 Mb/s uploading- hence the need of immediate 4G delivery). Instead of opting for UMB - the 4G technology for CDMA-based carriers - Verizon chose LTE, which is the 4G technology being used by most GSM-based carriers and also points out that it will continue to use its CDMA network and likely will have dual-mode CDMA/LTE devices. Vendors cannot move forward with development unless their customers commit to trial this technology. It is also said that the biggest potential market for UMB is in Asia, but many operators there are considering WiMAX or are still focused on 3G. So, UMB is unlikely to make much progress or significant revenue there. In general, if carrier plans are any indication, **Ultra Mobile Broadband, the upgrade technology for CDMA networks, is quickly becoming a non-factor, leaving what it calls a true battle for 4G between mobile WiMAX and LTE**.

2.1.2 3GPP Long Term Evolution (LTE) Project

LTE prototypes with data rates above 100 Mbps are already being demonstrated, and plans to have standard-compliant equipment are targeting 2009. At the 3GSM World Congress in Barcelona, using a live system at 144Mpbs, Ericsson showed customers that it is able to provide a bit pipe large enough for video-conferencing and HDTV applications, and to allow fast file-downloading. To promote further the technology an initiative called "LTE/SAE (Long Term Evolution/System Architecture Evolution) Trial Initiative (LSTI)" was founded by leading telecommunications companies Alcatel-Lucent, Ericsson, France Telecom/Orange, Nokia, Nokia Siemens Networks, Nortel, T-Mobile and Vodafone, and was recently expanded with China Mobile, Huawei, LG Electronics, NTT DoCoMo, Samsung, Signalion, Telecom Italia, Motorola and ZTE joining as new members. The LTE/SAE Trial Initiative (LSTI) is divided into three main phases: Proof of concept, Interoperability and Trial. Nokia announced recently that the LSTI had met lab and field test goals of 100 Mbps on the downlink and 50 Mbps on the uplink. Joint testing, and reporting of ongoing results will continue out to the end of 2009. **Initial LTE system deployments may not be ready for commercial use until 2011-2012 time frame**. Many carriers favour LTE for their plans to rollout 4G networks on the exciting 700MHz band e.g AT&T, Verizon, Vodafon (although not committed to it yet) etc. 3GPP-backed LTE is progressing quickly toward standardisation. Additionally, LTE is seeing early trials take place while moving into TDD (as well as FDD) spectrum territory. LTE has intrinsic advantages, being an extension of the existing GSM-based networks used at over 80% of the installed base of telecoms base stations worldwide. However, China and India, have not yet decided about their 3G/4G destiny and so an open question remains for the market. As more carriers opt for LTE, the equipment makers can start planning for scale and thus bring down the cap-ex costs for these carriers. Lower pricing may have a domino effect, so we could see smaller carriers start to opt for LTE as well.

2.1.3 Mobile WiMAX

While commercial Mobile WiMax service is effective in some countries since 2007 (e.g. [Wat07]), the start of commercial service by Sprint Nextel of its 'Xohm' service in the U.S. is expected only in the second half of 2008. Xohm is a joint venture with Clearwire that will be funded by Intel, Google, Comcast, Time Warner Cable, and Bright House Networks. Such partnership between WiMAX and also Cable broadband operators will potentially create a simpler subscription model where consumers and businesses can get both fixed and mobile broadband as part of one package. This is the most significant WiMax-related deal to be struck in the developed world.

Sprint Nextel and Samsung are just confirming that they are happy with the performance of the 'Xohm' WiMax network in the lab and in the Baltimore/Washington area. This means they have tested the overall network performance, including WiMax's ability to hand off signals when units move between base stations, and they like the results. But the operator is still saying its initial market launches will happen "later this year" rather than the original April'08 kick-off date. Provisioning of backhaul is the primary hold-up to the operator's nationwide deployment of mobile WiMAX. Sprint, is having difficulty finding high-capacity transport links to connect cell sites as typical T-1 lines that feed today's mobile networks are inefficient for high-speed wireless broadband data.

Still, another broadband operator TowerStream may become the first service provider to commercially deploy mobile WiMax technology in the U.S. However, TowerStream has no intention of using 802.16e for mobile services. Instead, the company believes it can improve its existing fixed wireless broadband services using the new technology.

Other indicative investments on the WiMax technology include India's Reliance Globalcom that seeks to become one of the developing world's leading providers of WiMax and provide internet access in developing countries. Reliance Globalcom target countries that are scattered across Africa, Asia, Eastern Europe and Latin America, where fixed line phone infrastructure is weak or non-existent, and WiMax could be a cost-effective way of providing wireless connections to the Internet.

Furthermore, **Intel, the most prominent backer of WiMax, is planning to integrate the technology into its upcoming Centrino 2 platform by the end of this year**, since it expects WiMax to be commercially deployed in the second or third quarter this year in the US and that infrastructure in Asia should be ready by between 2009 and 2010. Samsung also reminds that it has a WiMax PC card and an "Ultra Premium Mobile PC" waiting for when the networks get up and running.

2.2 The evolution of IEEE 802.16 and mobile WIMAX

The IEEE Standards Board established the IEEE 802.16 Working Group on BWA Standards in 1999, and the first 802.16 standard was approved in December 2001. In 2004, the 802.16d project concludes with the release of 802.16-2004, known as 'Fixed WiMAX' that supersedes the earlier 802.16 documents (including the a/b/c amendments) and harmonizes the standard with ETSI HIPERMAN. Prior to the emergence of WiMAX, proprietary technologies such as LMDS and MMDS occupied the segment on Metropolitan Area Network (MAN) trying to provide connectivity, with varying degrees of success due to lack of client device installations, high base station costs, and the general barrier-to-market-entry encumbering all proprietary solutions in a new market. Further on, the IEEE 802.16e project issued the IEEE 802.16e-2005 standard that includes better support for QoS and the use of Scalable OFDMA. IEEE 802.16e-2005 emerged as an amendment to 802.16-2004 that is addressing mobility, and therefore it is often called 'Mobile WiMAX', after the WiMAX forum for interoperability. Other amendments are either in progress like 802.16j concerning "Multihop Relay Specification", and 802.16m that aims to deliver downstream speeds of 100 Mb/s for high-mobility and up to 1 Gb/s for low-mobility systems in a "nomadic" mode over the air. This standard is intended for incorporation into the IMT-Advanced standardization activity of ITU-R that performs as an umbrella to 4G systems. The amendment provides continuing support for legacy subscriber stations.

2.2.1 IEEE 802.16e standard

Based on the IEEE 802.16e standard, Mobile WiMAX will provide personal broadband at up to 150 km/hour. With a legacy in the initial IEEE 802.16-2004 and later 802.16e-2005 standards, Mobile WiMAX has its basis in firm standards and gives a clear path for achieving truly interoperable technology. Its true differentiation is on OFDMA Physical Layer. IEEE 802.16e-2005 is the first widely embraced standard to be based on OFDMA, which in turn, is a multiple access transmission format that can supply significant gains in spectral efficiency, with particular advantages in mobile applications. Unlike legacy OFDM applications (e.g. 802.11a/g, 802.16d etc.), its key offspring like OFDMA utilizes on-the-fly allocation of subcarriers and timeslots to individual subscribers based on bandwidth needs and dynamic signal and noise conditions and offers higher bandwidths over less spectrum. Yet, high speed dynamic modulation and scalable OFDMA capabilities were first defined by the Mobile Broadband Wireless Access (MBWA) technology developed by IEEE 802.20 Working Group. Unfortunately, the associated Working Group was temporarily suspended in mid 2006 by the IEEE-SA Standards Board. Later in September 2006 a new plan was approved to enable the working group to continue and the 802.20 standard is now expected to finalize by Q2 2008.

2.2.2 Prior Art

In fact, the development of wireless systems employing the basic OFDM PHY concept and its variants does not restrain to Wireless MAN IEEE 802.16 based WiMAX technologies. Besides, it spans to Wireless LAN standards such as Wi-Fi IEEE 802.11a/g, ETSI HiperLAN/2, ETSI HiperMAN and many other. As a result these technologies may share the common essence of OFDM employment. Interestingly enough, in its infancy the initial IEEE 802.16 based WiMAX technologies also borrowed many basic ideas also from DOCSIS/HFC technology; a cable modem technology developed by Multi Cable Service Operators (MSOs) motivated by the lack of progress on IEEE 802.14 standard. In particular the DOCSIS MAC is ingrained in the WiMAX 802.16 standards making it at an early stage almost an evolution of the DOCSIS MAC specifications, e.g.: WiMAX QoS granularity mimics on DOCSIS 1.1 release.

However what technologies exactly constitute the legacy systems that WiMAX family is building upon is difficult to distinguish without receiving considerable amount of criticism.

2.3 IPR Landscape in 3G, WiFi and 4G

The General Assembly of ETSI has established [ETSI07] an Intellectual Property Rights Policy (Annex 6 of the Rules of Procedure of 29 March 2007) where "essential" as applied to IPR means that *it is not possible on technical (but not commercial) grounds, taking into account normal technical practice and the state of the art generally available at the time of standardization, to make, sell, lease, otherwise dispose of, repair, use or operate equipment or methods which comply with a standard without infringing that IPR. For the avoidance of doubt in exceptional cases where a standard can only be implemented by technical solutions, all of which are infringements of IPRs, all such IPRs shall be considered essential*".

2.3.1 Industrial Debate on the Essentiality of IPR

According to the above definition, essential patents for WiMAX are understood to be issued patents that have one or more claims that would necessarily be infringed by the implementation or use of the WiMAX related standards. Yet, in the IT business many areas of patent holders rights remains rather grey despite a multitude of settled claims and disputes, as it is less obvious that any particular patent is indeed 'essential'. There are many paradigms of crucial industry debates on patents 'essentiality' and the value placed on them. The latest paradigm is the Qualcomm-Nokia debate. Qualcomm issued a white paper [Mar07] entitled "Patent Counting, A Misleading Index of Patent Value: A Critique of Goodman & Myers and Its Uses" where it strongly criticizes both David J. Goodman and Robert A. Myers, authors of [Good05] the paper "3G Cellular Standards and Patents" that was presented on March 17, 2005, at an IEEE Infocom Conference Poster/Demonstration Session entitled "Analysis of Intellectual Property for Third Generation Cellular Technology" and also at the WirelessCom Conference held on June 13-16, 2005. Qualcomm further censures and cast doubt on their paper's scientific independence since they failed to disclose the fact that their paper was funded solely by Nokia, which in turn constitute a potential conflict of interest.

According to analysts, there will be no resolution soon to this situation without outside influence because the two companies are negotiating from fundamentally opposite positions - Qualcomm values quality while Nokia points to quantity. Qualcomm sees the worth of its core W-CDMA IP as far more valuable than the number of patents it holds, while Nokia contends that its volume of patent activity in recent years should be recognized by lower royalty fees. A recent research report found that Qualcomm holds a collection of the most frequently cited patents for the W-CDMA standard. This is generally accepted as the best measure of patent portfolio quality. Correspondingly, Nokia has sunk billions of dollars into improving its patent position regarding W-CDMA, and it is a given that they now own more patents relating to the technology than when the original license agreements were negotiated.

2.3.2 Patent Trolls and Patent Pools

It is true that the value of patent essentiality is critical since such value would reflect the IP's contribution to a standard giving the holder a return on investment. Hence, a recent phenomenon is the presence of 'patent trolls'. Patent Trolls, are a new breed of companies that acquire ownership of a patent without the intention of actually using it to produce a product. Instead, it licenses the technology to an entity that will incorporate the patent into a product, or it sues an entity it believes has already incorporated the technology in a product without permission. Although the common complaint is that patent trolls stunt innovation and spur unnecessary litigation, some suggest that trolls are actually beneficial for the natural evolution of the patent market by realigning market participant incentives, making patents more liquid, and clearing the patent market.

On the other hand the recent re-emergence of the formation of 'patent pools' suggests that the benefits of such arrangements outweigh their costs. A patent pool is a consortium of at least two companies agreeing to cross-license patents relating to a particular technology. Very often, the patents that each party owns covers different essential aspects of a given commercial product and this benefits competition by allowing each party more freedom to design products covered by the others patents without provoking a patent infringement lawsuit. Yet, patent pools do not eliminate risk, they only temper it. Criticism is that the patent pools have several anticompetitive effects, they shield invalid patents, and they eliminate competition by encouraging collusion and price fixing. So, if it is found that a patent pool harms competition and reduces further innovation, then the members of that pool may face antitrust violations, which should discourage the formation of anticompetitive patent pools.

2.3.3 IPR Landscape in 3G

In [Good05], Goodman and Myers published a quantitative analysis of 3G patents. They found that about 7000 patents (including applications) were declared by companies as "essential" in 3GPP on the ETSI web site. Because a single invention can give rise to several patent applications (in order to protect the invention in the various regions of the world), the patents can be grouped into about 700 "patent families", i.e. 700 "inventions". However, based upon an "independent" study reported in [Good05], only 150 of these 700 patents would actually be "essential". The paper [Good05] states that some companies tend to "overdeclare" essential patents, and explicitly points Qualcomm as an example, with 279 patents declared as essential, versus only 30 patents actually matching the criteria for essentiality. As explained in section 2.3.1 of this report, Qualcomm reacted to [Good05] by criticizing its approach.

In terms of royalty rates, the situations seems quite intricate. In [Yos99], it is stated that the royalty rate in GSM handsets was about 20%. However, in [Reu06] the GSM royalty rate is said to be no higher than 8.5%. For 3G-WCDMA, it is stated in [Reu06] that the total royalty rates for a company that holds no patent is around 25% of the wholesale price. This clearly represents a barrier to entry for competitors of the giant manufacturers. Qualcomm is said to charge a royalty rate of about 4-5% of the sale price.

2.3.4 IPR Landscape in IEEE802.11n

The IEEE requires companies and individuals holding essential patents to issue a Letter of Assurance (LoA) stating that they will license their IP under Reasonable And Non-Discriminatory terms (RAND). In the IEEE802.11n standardization process, the WWiSE consortium which was backing one of the three competing proposals [WWiSE04] went even further and proposed both RAND and RAND-Z, which means that any company joining the consortium and choosing the RAND-Z option would offer its IPR for free to other members that opted for the RAND-Z, and in return would not have to pay license fees to these members. However, this was an initiative that came from a consortium outside the IEEE, and to the best of our knowledge **the position of the IEEE for the final 802.11n standard remains RAND**.

2.3.5 IPR Landscape in WiMax and LTE

2.3.5.1 The WiMAX Forum Position on IPR

In its Mobile WiMAX whitepaper, the WiMAX Forum states: "a less onerous IPR model will lead to a substantial reduction in equipment prices and fair treatment of vendors without essential IPR, which in turn will increase competition in the market and the attractiveness of WiMAX to network operators". It is not currently known if the WiMAX Forum's aim will be delivered, and therefore it is vital for vendors to understand the patent landscape at present and the likely behaviours of the key players in the near future, as they feared that an unexpected license requirement could increase the cost for vendors to build their equipment, a cost that would likely be passed on to end users.

According to WiMAX Forum the IPR for WiMAX technology is at present adequately distributed throughout the industry. An IPR study, conducted by IPR law firm Schwegman, Lundberg, Woessner and Kluth, showed that as of September 2006 there were more than 1,500 patents distributed among 330 companies on WiMAX technologies. Of the 23 companies that hold more than ten patents, 74% are WiMAX Forum members. However, according to Robert Syputa [Syp07], a Senior Analyst of Maravedis Inc., "WiMAX/LTE 4G Intellectual Property Rights (IPR) Policy & Market Analysis, 1st Edition, Release 2" the number of individuals, institutions and companies that hold patents on WiMAX, LTE and related technology is over 400, where the essential patents to WiMAX are almost 550 and held by a large number of companies.

Even so, for the moment at least, it is unclear precisely who owns what and how they will choose to negotiate the royalties, yet it is expected that the essential IPRs (patents) for WiMAX technology as being held by different and non-dominant companies will provide WiMAX the opportunity to emerge as being a lower cost technology. Recently, on January 15, 2007, Ron Resnick, president and chairman of the WiMAX Forum, share his belief that WiMAX can get IPR close to 3% to 5% of equipment costs and such percentage makes the equipment significantly cheap.

To conclude, the WiMAX Forum, has asked the members to disclose any relevant patents they have in an effort to control the patent licensing cost for vendors making WiMAX equipment. If all IPR holders conform to that directive, a clear picture would emerge of the essential patents and their owners, and so players could make a realistic assessment of likely royalties and avoid nasty surprises later on. Yet, this remains to prove in practice.

2.3.5.2 Trends, Patent Activity and Ownership in WiMax and LTE

The conceptualisation of WiMAX among the leading companies and industry groups has shifted over the past few years from being considered an alternative for fixed broadband wide area connectivity to embracing hand-held device mobility. This is from one hand a major concession that IEEE 802.16 development has been on the right track and on the other it unveils the rational behind the fact that the activity on MIMO-OFDM/OFDMA technology – which in turn advocates mobile WiMAX conception – has dominated recent patent application and publishing.

Using solely publicly available information, gathered from press releases and other public patent-related sources it is found that there is a considerable growth in innovative WiMAX activity. It is likely that WiMAX patent filings and grants will continuously rise over the next years.

There are many firms around the globe that struggle on the WiMAX patent arena to obtain ownership of essential IPR. Some are being truly innovative, while others may be acquiring patents to defend themselves against possible litigation and to bargain effectively in cross-licensing agreements. This makes it very difficult for new entrants to gauge costs for entering a market or for carriers to identify specifically which companies are responsible for the majority of royalty rates associated with products. The recent creation of the Next Generation Moblile Networks (NGMN) initiative on intellectual property rights and the move [WSJ08] - led by Intel and Samsung - to create a patent pool for 4G could lead to some significant changes. The smaller vendors in the more diffuse 4G IP space will be keen to join those like Intel and Samsung that have much to gain, but the real question is how many of the major IP holders will be attracted to the pool. The key concepts here revolve around the independent reporting of royalty rates to the NGMN and also the ability of a patent pool to report en masse. In this way there will be an evident divide between the patent pool rates reported, and royalty rates reported from the rest players. This will expose the position of any big player (and those of any others not in the pool) to the public gaze.

To obtain a broad understanding of the up-to now WiMAX patent landscape, the position of few sporadically selected active players is briefly outlined below in a compilation of most relevant recent free press releases.

On Feb. 2007, MOSAID Technologies Incorporated, which is self-described as is one of the world's leading intellectual property (IP) companies, announced that it has won a competitive bid for a

portfolio of 20 essential WiFi and WiMAX patents from Agere Systems. The portfolio includes patents that are essential to the 802.11 family of WLAN (or WiFi) standards, and the 802.16 family of WiMAX standards. MOSAID believes that the licensing revenue from these WiFi and WiMAX patents has the potential to surpass the revenues that the Company has earned to date from its DRAM memory patents.

Among other WiMAX players, it seems that Samsung Electronics Co Ltd of Korea can compete on a global scale and especially in Asia for example where a lot of its own mobile WiMAX flavor, WiBRO initial deployments are being placed. The intellectual property development of WiMAX and its cousin WiBRO is to some extent dominated by Samsung that opted to commercialize WiBRO in response to a slight inability to gain momentum behind its network architecture proposals in the IEEE WiMAX groups. Based on recent analysis of ABI's research, it is likely that Samsung will soon hold close to 30% of the essential IP regarding WiMAX, although in total there over 350 companies that also own essential IP in WiMAX technology. Yet such estimation it is not widely approved.

US wireless vendor Qualcomm, a consistently virulent critic of WiMAX that is not a WiMAX forum member and known for its vigorous defence of patents on CDMA, has already raised the contention that it owns OFDM-based essential IPR in WiMAX acquired along with Flarion Technologies and Airgo Networks. To understand the implication of such contention, one may just have to notice that after Sprint-Nextel (a long-time licensee of Qualcomm's CDMA technology) prior announcement that it will upgrade its network based to WiMAX infrastructure and devices technology of Samsung, Motorola and Nokia, thereby freeing itself from Qualcomm's patents, Qualcomm stock fell about 4%. Qualcomm's counterclaim was that their patents cover WiMAX technology, so Sprint will still have to pay royalties. The stakes here are enormous. Yet, other industry leaders, including Intel, believe that Qualcomm's patents aren't relevant to the WiMAX standards. At a point where WiMAX hype is just about peaking and questions about the technology and market are beginning to emerge, Qualcomm's position in 802.16e-2005 is considered limited; however, due to cash potential, Qualcomm is hurrying to boost its patent portfolio for OFDMA as patent trends indicate a stronger position for a few areas of development that will become increasingly important.

Wi-Lan, a Canadian IPR corporate licensor, believes its portfolio of 220 patents, are necessary for the implementation of devices using the IEEE 802.16 and ETSI HiperMAN as well as CDMA, DOCSIS, DSL, Wi-Fi variants 802.11a and 802.11g and ETSI HiperLAN/2 and has decided to assert its patent rights by attacking a total of 22 separate companies, claiming patent infringement. Written in the company's "Licensing Program" on its Web site is the passage: "Like most lawsuits, well over 90% of patent litigation cases never proceed to trial because the parties agree to conclude a settlement agreement." So, Wi-Lan had early agreements for WiMAX and related licenses with Redline, Cisco and Nokia, which set some benchmarks for commercial precedents of IPR agreements. By suing the networking giant Cisco, Wi-Lan gained licensing agreements with its key technology partner, Fujitsu Microelectronics, with whom it co-developed the Fujitsu WiMAX system on a chip. However, despite some licensing wins, Wi-Lan did not succeed in gaining the universal recognition of its WiMAX patents that it had hoped for. This represents the limited direct commercial or legal precedent yet available for establishing IPR licensing trends in the emerging field.

Cisco, on the other hand, after seeing that ITU is adopting WiMAX as an IMT standard by designating radio frequencies used for WiMAX as IMT frequencies, it seeks to augment its mobile IP and OFDM patent portfolio. Thus, it came to a settlement with Wi-Lan and licensed all the smaller company's patents and, significantly, acquired some of them for itself, in the WiMAX and smart antenna areas. Furthermore, on October 23, 2007 Cisco announced a definitive agreement to purchase Richardson, TX-based Navini Networks, Inc. a leader in the Mobile WiMAX 802.16e-2005 broadband wireless industry, which holds 13 patents and has 14 more pending. Cisco acquired Navini that focuses on advanced smart antenna techniques and asserts leadership in Beamforming which in turn means increased range, less base stations and increased capacity, driving compelling savings in site acquisition costs and ongoing OPEX. Like Qualcomm with the acquisition of Flarion and Airgo, Cisco is methodically building up its solution and patent stores in key technology areas.

In China’s mainland, ZTE Corporation, China's largest listed telecommunications manufacturer and Huawei Technologies are also considered key WiMAX developers. ZTE began to do research on OFDM technology in 2000, and became officially involved in WiMAX product development in 2003. It has since then raised more than 100 proposals and obtained 14 WiMAX patents. Huawei, in turn, as of the end of 2006, has already obtained about 100 patents in WiMAX technology. To what extend these patents are considered essential is not easily to answer.
Finally, a patent pool initiative was announced in LTE [Gab08], gathering several important players including Nokia and Ericsson, with the official goal to reduce the royalty rate on devices. However, some other players like Nortel, Motorola and Qualcomm did not join.

3 BACKGROUND IPR

In this section, relevant standards and some existing prior art in which we identify some potential room for IPR generation are referred to.

3.1 Patents (including patent applications)

Table 1: Potentially relevant Patents identified by IST FIREWORKS project

Patent Title	Number	Date	Related Technical Area	Holder
METHOD AND ARRANGEMENT FOR IMPROVED RELAYING	WO20070 64252	2007	Claims the combination of OFDM with repeaters that amplify and forward the signal fast-enough so that the interference at the destination is constructive	ERICSSON TELEFON AB L M; LARSSON PETER
HYBRID FORWARDING APPARATUS AND METHOD FOR COOPERATIVE RELAYING IN AN OFDM NETWORK	US200700 86512	2007	Claims the adaptive selection of AF and DF.	SAMSUNG ELECTRONICS CO LTD
COOPERATIVE RELAY TRANSMISSION TECHNIQUE FOR WIRELESS COMMUNICATION SYSTEM	US200700 2766	2007	Claims setup of the cooperative DF in uplink and diversity combining	SAMSUNG ELECTRONICS CO LTD
APPARATUS AND METHOD FOR COOPERATIVE MAXIMUM RATIO TRANSMISSION IN A BROADBAND WIRELESS ACCESS COMMUNICATION SYSTEM	US200707 52046	2007	Claims Cooperative DF with multiple relays in downlink based on protocol II (phase I: BS-RS, phase II: (BS,RS)- SS)	SAMSUNG ELECTRONICS CO LTD
COOPERATIVE MULTIPLE-ACCESS USING USER-CLUSTERING AND SPACE-TIME-FREQUENCY CODING TECHNIQUES FOR HIGHER RELIABILITY RECEPTION	US200801 4884	2008	Claims clustering of cooperation set and distributed space-time-frequency block coding with vertical encoding	OYMAN OZGUR (US); SANDHU SUMEET (US)
METHODS AND SYSTEMS FOR SPACE-TIME CODING FOR DISTRIBUTED COOPERATIVE COMMUNICATION	WO20071 40437	2007	Claims a new method for distributed space-time block coding with identical coding rules for all participating relays and no need for central code allocation	CORNELL RES FOUNDATION INC (US); SIRKECI BIRSEN (US); SCAGLIONE ANNA (US)

Patent Title	Number	Date	Related Technical Area	Holder
METHOD AND SYSTEM FOR WIRELESS COMMUNICATION NETWORKS USING COOPERATIVE RELAYING	EP 1852984	2007	Claims an efficient and low complexity method for assignment of relays to user terminal and conflict resolution	ERICSSON TELEFON AB L M (SE)
METHOD FOR CHANNEL ESTIMATING OF MOBILE COMMUNICATION SYSTEM FOR COOPERATIVE DIVERSITY	KR100728 640B	2007	Claim is on channel estimation for cooperative relaying	SK TELECOM CO LTD (KR)
A METHOD OF TRANSMITTING DATA IN CELLULAR NETWORKS USING COOPERATIVE RELAYING	WO20070 37638	2007	Claims cooperative communication using frequency domain duplexing	LG ELECTRONICS INC (KR); YOON YOUNG CHEUL (US); WANG SHU (US); KIM SANG GOOK (US)
MULTI-HOP RELAY SYSTEM AND DATA TRANSMISSION METHOD EMPLOYED BY THE SAME	US200800 19321	2008	A data transmission method employed by a multi-hop relay system comprising a base station, one or more relay stations in a cell of the base station, and one or more mobile stations connected to the relay stations	LOWE HAUPTMAN HAM & BERNER, LLP, KIM, JUHEE, KIM, KYUNG
METHOD AND SYSTEM FOR GENERIC MULTIPROTOCOL CONVERGENCE OVER WIRELESS AIR INTERFACE	US200800 08159	2008	Data packets of multiple different protocols are transmitted over a broadband wireless air interface between network stations subscribing to the broadband wireless access service.	PROCOPIO, CORY, HARGREAVES & SAVITCH LLP, BOURLAS, YAIR, WANG, LEI, PETRY, BRIAN D.
SYSTEM AND METHOD FOR RELAYING DATA	US200800 25280	2008	Claims a data communication relaying system with a protocol data unit being capable of identifying the connection identifier assigned to the mobile station without identifying the connection identifier assigned to the at least one relay station	INDUSTRIAL TECHNOLOGY RESEARCH INSTITUTE (CHUTUNG, TW)
RELAYING METHOD OF A MOBILE COMMUNICATION SYSTEM AND SYSTEM THEREOF	US200800 13459	2008	Claims a method for setting a path, by measuring and comparing the quality of the direct link and the quality of the entire relaying path while taking quality of two hops into account.	SAMSUNG ELECTRONICS CO., LTD.
METHOD FOR RELAYING DATA PACKET FOR DOWNLINK IN WIRELESS COMMUNICATION SYSTEM	US200700 15461	2007	A method for relaying data packets, where each SS determines whether the SS receives the data packet directly from the BS or via an RS, based on signal intensities obtained through pilots sent from the BS and RS.	SAMSUNG ELECTRONICS CO., LTD.

Patent Title	Number	Date	Related Technical Area	Holder
METHOD AND APPARATUS FOR RELAYING SPATIALLY-MULTIPLEXED SIGNALS	US20080002601	2008	A method to design jointly the relay receiving matrix and the destination receiving matrix that reduces the minimum square error between the source data and the output data at the receiver, in a MIMO relaying system.	IBM CORPORATION, T.J. WATSON RESEARCH CENTER - YORKTOWN HEIGHTS, NY, US
DYNAMIC CHANNEL ALLOCATION METHOD IN AN OFDMA MOBILE COMMUNICATION SYSTEM	US20070015469	2007	A method of sending feedback information used for dynamic channel allocation, and allocating resources based on the feedback information in an OFDMA mobile communication system.	SAMSUNG ELECTRONICS CO., LTD.
MULTI-ANTENNA RELAY WITH SELF-INTERFERENCE CANCELLATION	WO2006SE829A	2008	A wireless relay node comprises a receiving side and a transmitting side adapted for concurrent reception and transmission of an information stream, and at least one of the two sides has multiple antennas for multi-antenna operation.	ERICSSON TELEFON AB L M; LARSSON PETER; PRYTZ MIKAEL
METHOD AND SYSTEM FOR WIRELESS COMMUNICATION NETWORKS USING COOPERATIVE RELAYING	EP2004809191A	2007	The present invention relates to relay supported wireless communication to enhance communication performance.	ERICSSON TELEFON AB L M LARSSON, PETER
METHOD AND SYSTEM FOR ESTIMATING AND COMPENSATING IQ IMBALANCE	US20049996192A	2007	A method of determining IQ imbalance introduced on an RF multicarrier signal received via a channel on a direct conversion analog receiver is disclosed.	IMEC INTER UNI MICRO ELECTR; KATHOLEIKE UNIVERSITEIT LEUVEN; SONY CORP
RECEIVER ARCHITECTURE HAVING A LDPC DECODER WITH AN IMPROVED LLR UPDATE METHOD FOR MEMORY REDUCTION	US20066557491A	2006	The present invention provides a reduced memory implementation for the min-sum algorithm compared to traditional hardware implementations.	LEGEND SILICON ZHONG, YAN PRABHAKAR, ABHIRAM VENKATACHALAM, DINESH
SYSTEMS, METHODS, AND APPARATUS FOR MITIGATION OF NONLINEAR DISTORTION	WO2006IB3070A	2007	A method among the embodiments includes calculating a value of a parameter of a nonlinear model of a signal as transmitted into a transmission channel, and applying the calculated value to obtain an estimate of data values carried by the signal. Applications to multicarrier signals are described.	ADVANCED MICRO DEVICES INC; MA YIAOQIANG; TOUZNI AZZEDINE

Patent Title	Number	Date	Related Technical Area	Holder
HANDOVER PROCEDURES IN A WIRELESS COMMUNICATIONS SYSTEM	WO/2007/ 109720	2007	Various techniques for handover	QUALCOMM INCORPORATED, KATAZOE, MASATO
METHOD OF HARD HANDOVER IN A WIRELESS COMMUNICATION SYSTEM	WO/2007/ 008465	2007	Method for seamless wireless communication between a mobile unit and multiple base stations	LUCENT TECHNOLOGIES INC, BOSCH, PETER, MULLENDER, SAPE, JURRIEN, RANA, ANIL, SAMUEL, LOUIS, GWYN
METHOD OF PERFORMING PROCEDURES FOR INITIAL NETWORK ENTRY AND HANDOVER IN A BROADBAND WIRELESS ACCESS SYSTEM	WO/2007/ 133034	2007	methods for network entry and handover in a broadband wireless access system	LG ELECTRONICS INC, KIM, YONG HO, RYU, KI SEON, KIM, JEONG KI

The table below provides a selection of patents that may be relevant to the activities of ROCKET.

Table 2: Potentially relevant patents additionally identified by ICT ROCKET

#	Patent Title	Number	Date	Related Technical Area	Holder
1	Polarization diversity multi-antenna system	WO2008028892	2007	Claims a compact co-located multi antenna subsystem	L. Rudant, C. Delaveaud (CEA Commissariat à l'énergie atomique)
2	Method of digital compensation of nonlinearities in a communication system and receiver device	EP1887749 A2	Feb. 13, 2008	A method for estimate and compensate for non linearities in the receiver of a wireless system	C. Dehos, T. Schenk, M. Dominique (CEA Commissariat à l'énergie atomique)
3	Digital Predistortion for Amplifiers	US6304140 B1	Oct. 16, 2001	The look-up table for the predistorter is computed using power values of digital input signal samples as look-up values. The calibration power values and corresponding amplitude/phase predistortion calibration values are interpolated to provide amplitude/phase predistortion values of the LUT.	C. P. Thron, M. B. Thomas, D. J. Anderson (MOTOROLA)
4	Baseband Predistortion System for the Adaptive Linearization of Power Amplifiers	US5524286	June. 4, 1996	A method for updating the error tabels of a digital predistorter. The content of the tables is obtained by accumulating the difference, suitable weighed, between the sampling entering the predistortion device and the demodulated feedback.	R. D. Chiesa, A. Guido, M. Stanzani, (Alcatel Italia S.p.A)
5	System and Method for Relaying Signal in a Communication System	US2007/0223374 A1	March 2006	This patent claims a coding strategy in which two messages are transmitted by the relay using superposition coding. During the first slot the destination decodes the first layer. The relay decodes the first layer and forwards the second layer to the destination during the second slot.	Samsung
6	Coverage improvement in wireless systems with fixed infrastructure	US20070010196 A1	November, 3rd, 2005	Infrastructure relays are used to relay signals to multi-antenna receivers where the received signals are then processed using MIMO processing. The transmissions can use spatial multiplexing and/or space time block coding.	Nortel networks
7	Method of providing cooperative diversity in a MIMO wireless network	US20060239222 A1	April, 20, 2006	Claims the relaying of multiple streams with ARQ	SAMSUNG ELECTRONICS CO LTD

#	Patent Title	Number	Date	Related Technical Area	Holder
8	Method for Transmitting and Receiving Signals in Cooperative Mulituser Multiple Input Multiple Output Network	WO 2007/123029 A1	November 1st , 2007	A method transmits and receives signals in a cooperative multiuser MIMO network. The network includes BSs and MSs. Each BS has at least 2 antennas and each MS has at least one antenna. The BSs cooperate to transmit jointly a plurality of data streams synchronously to certain MS using linear precoding matrices. Then the BSs transmit in similar manner to a second MS. Joint BS transmissions to different MSs are asynchronous.	MITSUBISHI ELECTRIC COORDINATION
9	COORDINATED TRANSMISSIONS IN WIRELESS NETWORKS	US 2007102322 35 A1	Oct., 4, 2007	Overall network throughput may be increased in a wireless network through coordinated transmission between wireless network stations. A wireless network station selects beamforming information based at least in part on interference to other wireless network stations.	Guoqing Li, Qinghua Li, Xintian E. Lin
10	Method and system for wireless communication networking using cooperative relaying	US 2007/016001 4 AI	July, 12, 2007	The present invention relates to relay supported wireless communication to enhance communication performance. In the wireless communication system according to the invention neighboring relay stations are arranged with substantially overlapping coverage.	Larson, (ERICSSON)
11	RELAYING IN WIRELESS COMMUNICATION SYSTEMS	WO2008002 717 A1	Apr. 26, 2007	Claims the adaptive quantization of sample streams in a cooperative MIMO uplink configuration with joint receiver processing. This patent application was filed in FIREWORKS.	Motorola Inc
12	Method of semidynamic centralized interference coordination for cellular systems	EP20060290 045	2007	A method where each BS area is statically divided into a plurality of spatial subsectors. A subset of the time-frequency domain of the resource domain is allocated to each of the subsectors by a central base station controller based on each subsector information, comprising interference conflict scenarios and traffic load.	Assignee: Alcatel Lucent Inventors: Münzner, Dr. Roland; Cesar, Bozo

#	Patent Title	Number	Date	Related Technical Area	Holder
13	DOWNLINK COORDINATED TRANSMISSION IN OFDMA SYSTEMS	WO/2007/109296	2007	In an embodiment, a set of terminals is designated a coordinated-transmission group. The set of terminal is chosen such that the slot-allocations of the set are given special treatment to alleviate interference from other sectors or cells. All terminals within a coordination group generally use the same slot, but embodiments are not so limited.	BECEEM COMMUNICATIONS, INC., GARRETT, David; HOCHWALD, Bertrand, M. ; PAULRAJ, Arogyaswami TUJKOVIC, Djordje; JALLOUL, Louay
14	SIGNALING REQUIREMENTS TO SUPPORT INTERFERENCE COORDINATION IN OFDMA BASED SYSTEMS	WO/2007/090115	2007	The invention provide methods for classifying user equipments (UEs) communicating with a serving base station (Node B) according to their experienced average interference in subsets of frequency or time resources. By capturing this average interference and SINR, a reference Node B can apply interference co-ordination through fractional frequency reuse or fractional time reuse.	TEXAS INSTRUMENTS INCORPORATED PAPASAKELLARIOU, Aris
15	Method for coordinated control of radio resources in a distributed wireless system	USPTO Application #: 20070225003		A method is provided for coordinating distributed radio resource management. The method comprises communicating information between a plurality of units having radio resource management responsibilities, wherein the communicated information is related to radio resources associated with each unit.	Fang-Chen Cheng, Shupeng Li, Lei Song

#	Patent Title	Number	Date	Related Technical Area	Holder
16	METHOD AND SYSTEM FOR INTERFERENCE MITIGATION IN A MOBILE COMMUNICATIONS SYSTEM	WO/2008/022887	2008	A method and system for inter- cell interference coordination during random access in a mobile communications system. The method comprises the following steps: In a first step, the user equipment executes downlink measurements. In a second step, an interference mitigation algorithm is executed using results of said downlink measurements as input for assigning time/frequency resources for said random access of said user equipment. In a third step, said time/frequency resources for said random access of said user equipment are assigned.	NOKIA SIEMENS NETWORKS GMBH & CO. KG [DE/DE]; St. Martin Str. 76, 81541 München (DE) (All Except US). CHMIEL, Mieszko [PL/PL]; Powstancow Slaskich 50/23, PL-48-340 Glucholazy (PL) (US Only).
17	METHODS AND SYSTEMS TO MITIGATE INTER-CELL INTERFERENCE	WO/2007/022631	2007	The present invention provides methods and devices for mitigating inter-cell interference in communication environments having a plurality of cells.	NORTEL NETWORKS LIMITED MA, Jianglei JIA, Ming . TONG, Wen ZHU, Peiying LE STRAT, Evelyne [BOUMENDIL, Sarah [FR/FR]; 82
18	METHOD FOR RESOURCE PARTITION, ASSIGNMENT, TRANSMISSION AND RECEPTION FOR INTER-CELL INTERFERENCE MIGRATION IN DOWNLINK OF OFDM CELLULAR SYSTEMS	WO/2007/0299	2007	A resource division, allocation, and transmitting/receiving method of downlink for reducing inter-cell interference in an orthogonal frequency division multiplexing system are provided.	ELECTRONICS AND TELECOMMUNICATIONS RESEARCH INSTITUTE AHN, Jae-Young [LEE, Hee-Soo [KWON, Jae-Kyun
19	IMPROVED RADIO RESOURCE ALLOCATION MECH	WO/2008/003815	2008	Radio resource of the plurality of cells is divided into more than one-radio resource blocks. User equipment is allocated a radio resource from one of the radio resource blocks on the basis of the determined effective interference to be generated to the defined group of neighboring cells.	NOKIA CORPORATION TIIROLA, Esa PAJUKOSKI, Kari HORNEMAN, Kari

#	Patent Title	Number	Date	Related Technical Area	Holder
20	Method and Apparatus for Overhead Reduction of Signaling Messages	USPTO Application #: 20070097961	2007	A method and apparatus to reduce the overhead of frequently sent signaling messages is provided. Various methods are presented which facilitate conveying information that is unchanged from information in the earlier part of the message, or in a previous signaling message, without sending the previous information in its entirety.	LG Electronics Inc.: Li-Hsiang Sun, Young C. Yoon, Suk Woo Lee
21	Method, Apparatus and Computer Program to Dynamically Adjust Segmentation at a Protocol Layer, Such as at The Medium Access Control (MAC) Layer	USPTO Application #: 20060245452	2006	In one exemplary aspect thereof the invention provides a method that operates to receive information through at least one input of a protocol layer packet segmentation unit and to dynamically vary packet segment size in accordance with the received information prior to transmission to a receiver. The information received through the at least one input may include information related to channel quality for a channel through which packet data are transmitted to the receiver. The information received through the at least one input may also be or may include information received from at least one of a higher protocol layer or a lower protocol layer.	Nokia Cooperation: Frank Frederiksen, Preben Mogensen, Jussi Kahtava, Mika P. Rinne
22	SPECTRUM UTILIZATION IN A RADIO SYSTEM	WO/2007/127250	2007	Claims a multi-user scheme allowing for a number of users, sets of user, or carriers to share one or more channels. As in the standard OFDM the total channel bandwidth is subdivided into a number of equal-bandwidth sub-channels. These sub-channels need not be contiguous in the spectrum or belong to the same channel.	MICROSOFT CORPORATION [US]

#	Patent Title	Number	Date	Related Technical Area	Holder
23	FACILITATING REUSE OF FREQUENCIES BY UNLICENSED COGNITIVE DEVICES	WO/2007/100809	2007	Claims decentralized spectrum management to dynamically control power level for each channel in a transmission system. The decentralized spectrum management uses a common reference signal received from a TV station to select a channel and coordinate the transmitter power to mitigate interference. The decentralized spectrum management ensures that the propagation loss between the desired and interfering transmitters exceeds a desired power ratio in order to facilitate frequency reuse on non-interfering basis.	INTEL CORPORATION [US]
24	SPECTRUM UTILIZATION IN A RADIO SYSTEM	WO/2007/122297	2007	The invention relates to sharing a radio spectrum between a first radio system and a second radio system which co-exist so that the radio spectrum is shared at least locally. A radio access point of the first radio system is provided with information on the co-existing second radio system and the constraints it causes to user terminals operating in the service area of the radio access point. Based on the information the radio access point creates and broadcasts beacon or control information to user terminals operating in the service area of the radio access point, to thereby enable the user terminals to adjust their operation so that they can co-exist with the second radio system.	NOKIA CORPORATION [FI]

#	Patent Title	Number	Date	Related Technical Area	Holder
25	OFDM-OQAM MULTICARRIER TRANSMISSION SYSTEMS	EP1032174	2000	An OFDM-OQAM digital base band transmission and reception system with filters for the multiplexing of N complex sequences each with symbol frequency F/2 and spacing F between the frequencies of the adjacent subcarriers is embodied with f0=0 where f0 means the frequency of the subcarrier of order 0. An OFDM-OQAM digital pass band transmission and reception system with filters for the multiplexing of N complex sequences each with symbol frequency F/2 and spacing F between the frequencies of the adjacent subcarriers is embodied with f0=0 where f0 means the base band equivalent frequency of the subcarrier of order 0.	Vangelista, Lorenzo Laurenti, Nicola
26	METHOD FOR PULSE SHAPE DESIGN FOR OFDM	USPTO Application 20060039270	2006	A computationally efficient pulse shaping method for OFDM that produces mutually orthogonal transmission pulses having fast spectral decay is provided. The pulse shaping method comprises an iterative method for designing OFDM transmission pulses that satisfy prescribed time-frequency localization conditions. The iterative method may be implemented in a computationally efficient way and can be used to adapt the transmission pulses to time-varying channel conditions in real-time, thereby maximizing the bit-error performance of an OFDM system while maintaining high data rates in wireless transmission.	Thomas Strohmer, Paulraj Arogyaswami

#	Patent Title	Number	Date	Related Technical Area	Holder
27	MULTI-CARRIER MODULATION METHOD, AND TRANSMISSION DEVICE AND RECEPTION DEVICE USING THE METHOD	WO/2007/080745	2007	Intended is to generate a pilot signal for estimating the transmission characteristics of a transmission channel, which are suited for OFDM/OQAM type multi-carrier modulations. A phase reference pilot symbol having a modulation amplitude suppressed to 0 and an amplitude reference pilot signal modulated at a receiving end with a known amplitude are transmitted from a sending end, and the transmission characteristics of the transmission channel are estimated and compensated at the receiving end with the phase reference pilot signal and the amplitude reference pilot signal. Thus, it is possible to simplify a frame constitution of the sending end and to reduce the sending power on the phase reference pilot signal.	MATSUSHITA ELECTRIC INDUSTRIAL CO., LTD. (JP)

3.2 Publications

Table 3. List of relevant publications identified by IST-FIREWORKS Project

Ref #	Publication Title	Publisher	Date	Technical Area	Author
1	MAC Frame Concepts to Support Multihop Communication in IEEE 802.16 Networks	Wireless World Research Forum (WWRF)	2006	Relaying	C. Hoymann, K. Klagges
2	Proposed Relay Method With P-MP Structure of IEEE802.16-2004	PIMRC	2005	Relaying	S. Kaneko, K. Saito, H. Izumikawa, T. Matsunaka
3	A PMP-Friendly MANET Networking Approach For WIMAX/IEEE 802.16TM	MILCOM	2006	Relaying	M. Sherman, K. M. McNeill, K. Conner, et al.
4	CoopMAC: A Cooperative MAC for Wireless LANs	Selected Areas in Com. IEEE Journal on Vol 25, Issue 2, pp: 340 – 354	2007	Cooperative	P. Liu, Z. Tao, S. Narayanan, et al.
5	New Approaches for Relay Selection in IEEE 802.16 Mobile Multi-hop Relay Networks	Springer (ISBN: 978-3-540-74465-8)	2007	Relaying	D. M. Shrestha, S-H. Lee, S-C Kim, Y-B. Ko, et al.
6	An Adaptive Frame Resource Allocation Strategy for TDMA-Based Cooperative Transmission	Com. Letters, IEEE Vol 11, Issue 5, pp: 417 – 419	2007	Cooperative	Y. Ning, T. Hui, Ch. Shasha, Z. Ping
7	Source and Channel Coding for Cooperative Relaying	IEEE Trans. Inf. Theory, vol. 53, No. 10, pp. 3454 – 3475	2007	Cooperative Relaying	D. Gunduz, and E Erkip,
8	Hybrid Forwarding Scheme for Cooperative Relaying in OFDM Based Networks	IEEE ICC 2006, vol. 10, pp. 4520 – 4525	2006	Cooperative Relaying	C. Basak, Y. Hiroyuki, and E. D. Carvalho
9	Bandwidth-Efficient Coded Cooperative Relaying in Wireless Networks	MILCOM	2006	Cooperative Relaying	Kim, S.W
10	Cooperative relay broadcast channels," International	Conference on Wireless Networks, Com. and Mobile Computing, vol. 2, pp. 1449 – 1454.	2005	Cooperative Relaying	L. Yingbin, and V. V. Veeravalli,
11	Minimum Error Probability Cooperative Relay Design	IEEE Trans. Signal Processing vol. 55, no. 2, pp. 656 – 664	2007	Cooperative Relaying	L. Bin, C. Biao, and R. S. Blum
12	Throughput Gains Using Rate and Power Control in Cooperative Relay Networks	IEEE Trans. Commun. Vol. 55, no. 4, pp. 656 – 660	2007	Cooperative Relaying	N. Ahmed, and B. Aazhang
13	Power allocation for cooperative relaying in wireless networks	IEEE Com. Letters, vol. 9, no. 11, pp. 994 – 996	2005	Cooperative Relaying	D. Xitirnin, and A. M. Haimovich

Ref #	Publication Title	Publisher	Date	Technical Area	Author
14	Throughput gains with limited feedback in cooperative relay networks	Wireless Networks, Communications and Mobile Computing, vol. 2, pp. 1489 – 1490	2005	Cooperative Relaying	N. Ahmed, and B. Aazhang
15	Compress-And-Forward Cooperative Relaying in MIMO-OFDM Systems	IEEE 7th Workshop, SPAWC.pp. 1 – 5	2006	Cooperative Relaying	S. Simoens, J. Vidal, and O.Munoz,
16	Exploiting the finite-alphabet property for cooperative relays	IEEE Proceedings. ICASSP, vol. 3, pp. iii/357 – iii/360	2005	Cooperative Relaying	L. Bin, C. Biao, and R. S. Blum
17	Optimal power allocation for multiple-input-multiple-output relaying system	IEEE VTC2004-Fall, vol. 2, pp. 1405 – 1409	2004.	Relaying	J. Zhang, C. Shao, Y. Wang, and P. Zhang,
18	Reliable Cooperative Source Transmission with Side Information	IEEE Workshop on Information Theory for Wireless Networks, pp. 1 – 5	2007	Cooperative	D. Gunduz, and E. Erkip
19	Capacity Theorems for Cooperative Relay Broadcast Channels	Conference on Information Sciences and Systems, pp. 1719 – 1724	2006	Cooperative Relaying	Y. Liang, and G. Kramer
20	Cooperative Communications with Outage-Optimal Opportunistic Relaying	IEEE Trans. Wireless Com. vol. 6, no. 9, pp. 3450 – 3460	2007	Cooperative	Bletsas, S. Hyundong, M. Z. Win
21	On the Performance of Distributed Space-Time Block Codes in Cooperative Relay Networks	IEEE Com. Letters, vol. 1, no. 5, pp. 411 – 413	2007	Cooperative Relaying	T. Unger, and A. Klein
22	Achievable diversity-multiplexing-delay tradeoff in half-duplex ARQ relay channels	ISIT Proceedings, pp. 1828 – 1832	2005	Relaying	T. Tabet, S. Dusad, and R. Knopp
23	Capacity bounds and power allocation for wireless relay channels	IEEE Trans. Information Theory, vol. 51, no. 6,	2005	Relaying	A.Høst-Madsen, J.Zhang
24	Gaussian Orthogonal Relay Channels: Optimal Resource Allocation and Capacity	IEEE Trans Inf Theory, vol. 51, no. 9	2005	Relaying	Y. Liang, V. Veeravalli
25	Cooperative Wireless Communications: A Cross-Layer Approach	IEEE Wireless Com. pg. 84-92	2006	Cooperative	Pei Liu, et al.
26	Joint optimization of relay strategies and resource allocations in cooperative cellular networks	IEEE Journal on Selected Areas in Com. Vol. 25, Issue 2 Page(s): 328 – 339	2007	Cooperative Relaying	Ng, T.C.-Y, et al.
27	The P802.16j Baseline Document for Draft Standard for Local and Metropolitan Area Networks	The Relay Task Group of IEEE 802.16 IEEE 802.16j-06/026r1	2006	Cooperative Relaying	

Ref #	Publication Title	Publisher	Date	Technical Area	Author
28	New Approaches for Relay Selection in IEEE 802.16 Mobile Multi-hop Relay Networks	Euro-Par 2007, LNCS 4641, pp. 950–959	2007	Relaying	Deepesh Man Shrestha, Sung-Hee Lee, et al.
29	An Adaptive Frame Resource Allocation Strategy for TDMA-Based Cooperative Transmission	IEEE Com. Letters, vol. 11, no. 5	2007	Cooperative Relaying	Yang Ning, Tian Hui, Chen Shasha, and Zhang Ping
30	Adaptive Space-Time Sectorization for Interference Reduction in Smart Antenna Enhanced Cellular WiMAX Networks	VTC Fall	2006	MAC, SDMA	Hoymann, C. and Wolz, B
31	Evaluation of Grouping Strategies for an Hierarchical SDMA/TDMA Scheduling Process	IEEE International Conference on Communications 2007, Jun., Glasgow, UK	2007	RRM	Hoymann, C. and Ellenbeck, J. and Pabst, R. and Schinnenburg, M.
32	Dimensioning Cellular WiMAX Part II: Multihop Networks	European Wireless, Apr. 2007 Paris	2007	Relaying	Hoymann, C. and Dittrich, M. and Göbbels, S
33	IEEE 802.16 Wireless Metropolitan Area Networks	in Walke, Mangold, Berlemann, IEEE 802 Wireless Systems, November Wiley & Sons, pp. 147-195, ISBN 0-470-01439-3	2006	MAC Access, RRM	Hoymann, Walke
34	Multihop Communication in Relay Enhanced IEEE 802.16 Networks	PIMRC September, Helsinki, Finland	2006	Relaying	Hoymann, C. and Klagges, K. and Schinnenburg, M.
35	MAC Frame Concepts to Support Multihop Communication in IEEE 802.16 Networks	WWRF 16, April, 2006, Shanghai, China	2006	MAC	Hoymann, C. and Klagges, K.
36	Unlicensed Operation of IEEE 802.16: Coexistence with 802.118(a) in Shared Frequency Bands	PIMRC September, Helsinki, Finland	2006	Hybrid systems, coexistence	Berlemann, L. and Hoymann, C. and Hiertz, G. and Walke, B.
37	Overview of the proposal for MS MAC handover procedure in a MR Network.	IEEE C802.16j-06/217	2006	Handover procedure	H. Lee, W.C. Wong, J. Sydir, K. Johnsson, S. Yang, M. Lee
38	MS MAC handover Procedure in an MR Network – Network Topology Advertisement	IEEE C802.16j-06/218	2006	Network topology advertisement, MS scanning	H. Lee, W.C. Wong, J. Sydir, K. Johnsson, S. Yang, M. Lee
39	Comparison of empirical propagation path loss models for fixed wireless access systems	VTC	2005	Channel path models	V.S. Abhayawardhana, I.J. Wassell, D. Crosby, M.P. Sellars, M.G. Brown

Ref #	Publication Title	Publisher	Date	Technical Area	Author
40	Performance Analysis for the IEEE 802.16 Wireless Metropolitan Area Network	DFMA Conference pp(s): 130 - 136	2005	System performance	Cho, D. H., Song, D. H., Kim, M. S., Han, K. J.
41	On the Optimal Number of Hops in Infrastructure-based Fixed Relay Networks	GLOBECOM Vol 6, Issue, 28 pp(s): 6 pp.	2005	Multihop communication	Florea, A. - Yanikomeroglu, H

The table below provides a selection of publications that may be relevant to the activities of ROCKET.

Table 4: Relevant publications identified by ICT ROCKET Project

Ref #	Publication Title	Publisher	Date	Technical Area	Author
42	HETEROGENEOUS COMBINATION FOR COMPACT INTEGRATED DIVERSITY MULTI-ANTENNA SYSTEM	Antennas and Propagation, 2007. EuCAP 2007. The Second European Conference on	November 2007	A compact co-located multi-antenna system is compared with canonical solutions for polarization diversity and shows better diversity performances for mitigating fading or MIMO schemes.	L. Rudant and C. Delaveaud
43	A Block Based Predistortion for High Power Amplifier Linearization	IEEE Transactions on Microwave Theory and Techniques	June 2006	A new PD scheme based on block estimation suitable for burst-type communication since it doesn't suffer from bad performance during training	Nima Safari, Joar Petter Tanem, and Terje Røste
44	RF Power Amplifier Linearization Through Amplitude and Phase Predistortion	IEEE Transactions on Communications	November 1996	A LUT based PD scheme whose AM/AM and AM/PM responses are separately implemented as polynomial approximations of the respective responses of the ideal linearizer.	Aldo N. D' Andrea, Vincenzo Lottici, and Ruggero Reggiannini

Ref #	Publication Title	Publisher	Date	Technical Area	Author
45	Amplifier Linearization Using a Digital Predistorter with Fast Adaptation and Low Memory Requirments	IEEE Transactions on Vechular Technology	November 1990	An adaptive predistorter with little memory requirments, small convergence time and robust in channel flactuations	James K. Cavers
46	Compensation of Nonlinear Distortion During Transmission Based on the Adaptive Predistortion Method	IEICE Trans. Electron., Vol. E80-C, NO. 6,	June 1997	Combination of polynomial approximation of the inverse PA characteristics and LUT-based techniques for high-order polynomials.	Takashi Matsuoka, Masayuki Orihashi, Morikazu Sagawa, Hikaru Ikeda, Kouei Misaizu
47	Receiver-Based Compensation of Transmitter-Incurred Nonlinear Distortion in Multiple-Antenna OFDM Systems	66th IEEE Vehicular Technology Conference, 2007. VTC-2007 Fall.	Sept. 30 2007-Oct. 3 2007	Methods for adaptive compensation of PA nonlinearities in the receiver of a MIMO-OFDM system	Schenk, T.C.W.; Dehos, C.; Morche, D.; Fledderus, E.R.;
48	Spectral efficient protocols for half-duplex fading relay channels	IEEE Journal on Selec. Areas in Comm., vol. 25, no. 2	February 2007	A half-duplex relay is assumed in the two-way relay channel.	B.Rankov, A.Wittneben
49	MIMO two-way relaying with transmit CSI at the relay	Proc. 8th IEEE Workshop on Signal Processing Advances in Wireless Communications (SPAWC-20007), Helsinki, Finland	June 2007	The TWRC is analyzed when the terminals are equipped with multiple antennas (MIMO) and there is channel state information (CSI) at the transmitters.	I.Hammerström, M.Kunhn, C.Esli, J.Zhao, A.Wittneben, G.Bauch,
50	Bidirectional regenerative half-duplex relaying using relay selection	IEEE Trans. Wireless Communications, vol.7, no.5, part 2, pp. 1879-1888	May 2008	The problem of relay selection is tackled for the TWRC. The optimal selected relay depends on the achievable rate region to be covered by the nodes.	T.J.Oechtering, H.Boche,

Ref #	Publication Title	Publisher	Date	Technical Area	Author
51	Coded bi-directional relaying	Proc. IEEE Vehicular Technology Conf. (VTC-FALL-2006), Melbourne, Australia	May 2006	In this paper a transmission protocol where each node can combine the transmissions from two paths is presented.	P.Larsson, N.Johansson and K.E. Sunell,
52	Spectral efficient protocols for half-duplex fading relay channels	IEEE Journal on Selec. Areas in Comm., vol. 25, no. 2	February 2007	The two-path relay channel (TPRC) is also investigated in this paper in order to combat the spectral efficiency loss due to the half-duplex relays.	B.Rankov, A.Wittneben,
53	Recovering multiplexing loss through successive relaying using repetition coding	IEEE Trans. on Wireless Communications, vol. 6, no. 12	December 2007	This work takes into account the possibility that the destination receives the transmissions from the source and relays.	Y.Fan, C.Wang, J.Thompson, H.Vincent Poor
54	Cooperation in a Half-duplex Gaussian Diamond Relay channel	IEEE Trans. on Information Theory, vol. 53, no.10, pp. 3806-3814	October 2007	This works analyzes the diamond channel which consists of a source, two relays and destination.	F.Xue, S.Sandhu
55	Rate Bounds for MIMO Relay Channels Using Precoding	Proc. IEEE Globecom'05	November 2005	This paper describes coding strategies for the MIMO relay channel. (including superposition coding of two messages).	C.K. Lo, S. Vishwanath, R.W. Heath Jr.
56	BS cooperation for multi user MIMO: joint transmission and BS selection	Conference on Information Sciences and Systems, Princeton University, 2004	March, 2004	A common framework is proposed to study base stations cooperation using MU diversity and BS selection.	H. Zhang, H. Dai, Q. Zhou

Ref #	Publication Title	Publisher	Date	Technical Area	Author
57	Interaction of transmit diversity and proportional fair scheduling.	In Proceedings of the IEEE Vehicular Technology Conference, Spring, volume 4, pages 2423–2427, JeJu, Korea,	April 2003	Explanation on the competition between multi user scheduling and tranmit diversity	Lars T. Berger, Troels E. Kolding, Juan Ramiro-Moreno, Pablo Ameigeiras, Laurent Schumacher, and Preben E. Mogensen.
58	On the combination of spatial diversity and multiuser diversity	IEEE Communication Letters, 8(8):517–519,	August 2004	Explanation on the competition between multi user scheduling and transmit diversity	Eric G. Larsson
59	On multicell cooperative transmission in backhaul-constrained cellular systems	Springer Paris, Annals of Telecommunications	February 2008	This paper proposes an optimization framework and algorithm for multicell downlink signal processing of a subset of users under a constrained backhaul.	P. Marsch, G. Fettweis
60	Overcoming Interference in Spatial Multiplexing MIMO Cellular Networks	IEEE Wireless Communications Magazine, Vol. 14, No.6	December 2007	This paper reviews approaches for handling interference in multicell MIMO networks including BS coooperation and distributed antenna architectures.	J.G. Andrews, W. Choi, R.W.Heath Jr
61	On The Fundamentally Asynchronous Nature of Interference in Cooperative Base Station Systems	IEEE International Conference on Communications 2007	2007	Impact of asynchronous multi user interference on linear precoding.	H. Zhang, N. Mehta, A.F. Molisch, J. Zhang, H. Dai
62	Multi cell downlink capacity with coordinated processing	International Symposium on Information Theory 2007, Nice, France	2007	Study of the potential base station cooperation for downlink transmission in a multi cell networks.	S. Jing, D. Tse, J. Soriaga, J. Hou, E. Smee, R. Padovani

Ref #	Publication Title	Publisher	Date	Technical Area	Author
63	Uplink Macro Diversity with Limited Backhaul Capacity	International Symposium on Information Theory 2007, Nice, France	2007	Achievable rates are derived for multiple single-antenna cooperating BSs with limited backhaul rate constraint, using compress-and-forward, local decoding and inter-cell time-sharing.	A. Sanderovich, O. Somekh, S. Shamai
64	Interference avoidance through dynamic downlink OFDMA subchannel allocation using intercell coordination	IEEE VTC2008–Spring	2008	Inter-cell coordination	Mahmudur Rahman and Halim Yanikomeroglu
65	Inter-cell coordination in wireless data networks	European Transactions on Telecommunication ISSN 1124-318X	2006	Inter-cell coordination	BONALD Thomas (1) ; BORST Sem (2 3) ; PROUTIERE Alexandre
66	Adaptation, Coordination, and Distributed Resource Allocation in Interference-Limited Wireless Networks	Proceedings of the IEEE	2007	Inter-cell coordination	David Gesbert, Saad Ghazanfar Kiani, Anders Gjendemsjø and Geir Egil Øien
67	Asynchronous Interference Mitigation in Cooperative Base Station Systems	IEEE TRANSACTIONS ON WIRELESS COMMUNICATIONS, VOL. 7, NO. 1	2008	Inter-cell cooperation	Hongyuan Zhang, Neelesh B. Mehta, IEEE, Andreas F. Molisch,Jin Zhang, and Huaiyu Dai,
68	Dynamic Load Balancing Through Coordinated Scheduling in Packet Data Systems	INFOCOM	2003	Inter-cell coordination	Suman Das, Harish Viswanathan, Gee Rittenhouse
69	QoS Provisioning in the Absence of ARQ in Cellular Fixed Relay Networks through Inter-Cell Coordination	Global Telecommunications Conference, GLOBECOM	2006	Inter-cell coordination	Rahman, Mahmudur; Yanikomeroglu, Halim;
70	Inter-Cell Packet Scheduling In OFDMA Wireless Network	Vehicular Technology Conference, 2007. VTC2007-Spring. IEEE 65th	2007	Inter-cell coordination	Xu Kai; Tao Xiaofeng; Wang Ying; Zhang Ping

Ref #	Publication Title	Publisher	Date	Technical Area	Author
71	A low complexity distributed multibase transmission scheme for improving the sum capacity of wireless networks	Signal Processing Advances in Wireless Communications, 2007. SPAWC 2007. I	2007	Inter-cell coordination	Skjevling, H.; Gesbert, D.; Hjorungnes, A.;
72	Improving base station coordination based packet scheduling schemes in fixed broadband wireless access networks	International Conference on Communications, ICC	2005	Inter-cell coordination	Rahman, M.; Yanikomeroglu, H.; Ahmed, M.H.; Mahmoud, S.;
73	Inter-Cell Coordination, Opportunistic Beamforming and Scheduling	International Conference on Communications, ICC	2006	Inter-cell coordination	Vemula, M.; Avidor, D.; Ling, J.; Papadias, C.;
74	Optimal and Distributed Scheduling for Multicell Capacity Maximization	IEEE TRANSACTIONS ON WIRELESS COMMUNICATIONS, VOL. 7, NO. 1,	2008	Inter-cell coordination	Saad G. Kiani and David Gesbert
75	Structured semi-blind interference rejection in dispersive multichannel systems	IEEE Transactions on Signal Processing	2002	STBC with interference cancellation	Klang, G.; Ottersten, B.
76	Interference robustness aspects of space-time block code-based transmit diversity	IEEE Transactions on Signal Processing	2005	STBC with interference cancellation	Klang, G.; Ottersten, B.
77	Frame Descriptor Tables for Minimized Signaling Overhead in Beyond 3G MAC Protocols	Proceedings of Symposium on Trends in Communications, Bratislava, Slovakia	2006	Signaling Overhead Reduction	Klein, O. and Einhaus, M. and Federlin, A. and Weiss, E.
78	Effects of Frame Descriptor Tables in Beyond 3G Systems	Proceedings of 13th International Conference on Telecommunications, Funchal, Portugal	2006	Signaling Overhead Reduction	Klein, O. and Einhaus, M. and Federlin, A. and Weiss, E.
79	Reduction of Signaling Overhead in Beyond 3G MAC-Protocols using Frame Descriptor Tables	Proceedings of 11th European Wireless Conference, Nicosia, Cyprus	2005	Signaling Overhead Reduction	Klein, O. and Einhaus, M. and Federlin, A.
80	Cognitive radio: brain-empowered wireless communications	IEEE Journal on Selected Areas Communications	2005	Cognitive Radio	S. Haykin

Ref #	Publication Title	Publisher	Date	Technical Area	Author
81	Achievable rates in cognitive radio	IEEE Transactions on Information Theory	2006	Capacity enhancement in increased spectrum	N. Devroye, P. Mitran and V. Tarokh
82	Multi-Band Scheduler for Future Communication Systems	WiCom2007	2007	Spectrum Scheduling concepts between relay and BS in flexible spectrum assignement	K. Doppler, C. Wijting, J.P. Kermoal

4 GENERAL CONCLUSIONS

The ROCKET project aims at designing technology for next-generation BWA systems, for which possible standardization landing zones are IEEE802.16m and 3GPP-LTE-Advanced. For these standards, the IPR landscape has evolved compared to 3G: several standards are competing, the number of patent applications has undergone (and is still undergoing) a significant growth, the number of players has also increased, and some patent pool initiatives have also been announced. At the macroeconomic level, this makes it difficult to predict the relative strengths that will drive the final 4G royalty rates. At the microscopic level of patent creation and defensive publication, this makes it difficult for the inventor to assess the breadth and commercial value of his invention. Yet, a list of patents and publications is provided in this report in which we identify room for potential IPR creation. The topics of these patents and publications will be investigated in the technical workpackages of the project and hopefully several patent filings and defensive publications can be generated.