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Deliverable D6.3: First Year Exploitation Plan

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Summary

Exploitation activities of DREAM project outcomes will play a major role both for the industrial, research centers and the academic partners, having a strong mid- and long-term impact on regulation and standardization activities, new products proof-of-concept, IPRs and pre-development activities, as well as on scientific dissemination and education. This document presents the overall exploitation strategy of the DREAM project and the exploitation plan of each consortium member.

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Contents

List of Acronyms and Abbreviations

3GPP	3rd Generation Partnership Project
5GPPP	5G infrastructure Public Private Partnership
ACM	Access Control Manager
AP	Access Point
ATPC	Automatic Transmit Power Control
BiCMOS	Bipolar Complementary Metal-Oxide Semiconductor
BS	Base Station
CMOS	Complementary Metal-Oxide Semiconductor
EC	European Commission
EMF	Electromagnetic Field
FD-SOI	Fully Depleted Silicon On Insulator
FP7	Seventh Framework Program
IC	Integrated Circuit
IoT	Internet of Things
IPC	Institute for Interconnecting and Packaging Electronic Circuits
IPR	Intellectual Property Rights
IQ or I/Q	In-phase/Quadrature-phase
KPI	Key Performance Indicator
LCP	Liquid Crystal Polymer
LTCC	Low Temperature Cofired Ceramic
LTE	Long Term Evolution
LTE-A	Long Term Evolution Advanced
M2M	Machine to Machine
MSE	Mean Square Error
mmWave	Millimeter Wave
PCB	Printed Circuit Boards
QoS	Quality of Service
RAN	Radio Acccess Network
RF	Radio Frequency
RRH	Remote RadioHead
Rx	Receive
SiGe	Silicon Germanium
SME	Small Medium Enterprise
SoC	System on Chip
STO	Standardization Office
TA	Technical Annex
Tx	Transmit
UE	User Equipment
WP	Work Package
WSN	Wireless Sensor Network

1. Introduction

In parallel to the dissemination activities, the exploitation of results plays a major role in the DREAM project, being the ambition of the project having a strong industrial impact towards regulation and standardisation bodies, and fostering a well-ahead of competitors demonstration and pre-development product activities. The exploitation activities of the DREAM consortium will take several forms in order to to best fit the research results and to maximize the impact on the society of the main project outcomes.

The exploitation of the project results started in parallel with the project life-time and will be extended after the project completion. The exploitation strategies vary among the DREAM consortium partners and, in general, can be split in two main branches:

1. On the one hand the academic partners, i.e. both universities and research institutes, that have rather similar interests and exploitation capabilities. In fact they research and develop, for instance, new technologies with the main aim of transferring them to the industry.
2. On the other hand the SMEs and industrial consortium partners, who have specific plans related to their business models and to the potential intercepted market window for each specific product line [1].

The coordination of the activities of the second branch is performed within the Work Package 6 (WP6), "Dissemination, Exploitation and Standardization" and more specifically in Task 6.3 "Exploitation". Confidentiality issues and the different business interests of the partners involved require particular care, in order to handle properly potentially diverging interests. Among the main exploitation activities of the project, the following ones can be mentioned as reference parameters:

- market introduction of products containing some of the mmWave technologies developed during the project lifetime;
- number of patents filed in areas strictly related to the project scope;
- any spin-off coming out of the main outcomes of the project.

Each partner will protect innovations initiated or created in the project according to the rules defined in both the Grant Agreement and the Consortium Agreement.
The purpose of the this document is to present the exploitation strategy of the DREAM project and the plans of each consortium member.The proposed plans are around future activities and therefore are to be taken as indications of the intentions of the project partners, knowing that with time some change or diversion from the original plan can most probably take place.

This report is structured into the following Sections. Section 1 (Introduction), Section 2 elaborates on the objectives, the main concepts, the major expected results and innovations in each WP of the TA project. Section 3 introduces the approach to be followed in the exploitation of the results and how the knowledge and IPR will be managed in the project. The partner-specific plans for the exploitation of results are presented in Section 4. The conclusions are presented in Section 5.

2. Project objectives and main concepts

The objectives and the main concepts of the DREAM project are presented in the following subsections.

2.1 Project strategic and technical objectives

Providing broadband wireless communications to a majority of European citizens is a major objective of the European Commission. With a current annual growth rate in the range of 70%, the mobile data traffic of the smartphones, tablets, machine-to-machine and other portable devices dramatically challenges the 4G wireless cellular network, which is currently under deployment. To sustain this growth, the high data-rate millimeter-wave (mmWave) technologies, that demonstrate striking capabilities for the short- and medium-range wireless communications, can bring a tremendous performance improvement.

The main goal of the DREAM project, through the exploitation of the radio spectrum in D-band (130-174.8GHz) and by the antenna array beam forming technology, is to enable wireless links with data rate exceeding current V-band and E-band wireless backhaul solutions by at least a factor of 10 and thus, to bring wireless systems to the speed of optical systems.

DREAM will develop the key radio, antenna and packaging technologies for the implementation of a mmWave transceiver front end addressing the backhauling links in the future and beyond 5th generation heterogeneous cellular mobile networks. Those technologies will take advantage of the wide unlicensed or light-licensed frequency bands which are available to allow a flexible spectrum usage as well as peak capacities above 100Gbit/s aggregated throughput.

Installed in the dense urban environments, miniature mmWave small-cell access-points connected to the cellular network through the optical fibre or D-band wireless backhaul will support massive data exchanges for mobile users with low latency, low interferences, high QoS and low power consumption per bit. They will also contribute to a reduced exposure of the public to electromagnetic fields (EMF) thanks to lower transmitted power and reduced skin penetration at mmWave, steerable directive antennas focusing the signals in the directions of interest, and reduced data traffic through the lower frequency legacy base stations (BS).

The technical objectives of the project are listed in the following:

1) Technical Objective 1: demonstrate the feasibility of low-cost SiGe BiCMOS transceiver analog front end enabling link data rate up to 100Gb/s in D-band. The project targets to enable innovative mmW systems beyond 100GHz delivering data rate exceeding current V band and E band wireless backhaul solution by at least a factor of 10.

2) Technical Objective 2: provide mobile access to content-rich data using a fast and broadband link, which faces the challenge of bringing mmWave radios to both the access points and the User Equipment (UE) in order to exploit the large bandwidth available. Fast mobile broadband access, with low latency enabling high speed end-to-end connectivity even at the cell edge (100Mb/s minimum), will be enabled by the D-band very high throughput inter-small cell backhauling links.

3) Technical Objective 3: Increase the flexibility and the cost saving of the operator networks. The D-band inter small cell backhauling can route data hungry application traffic to fibre network available close to the access points. In order to optimize the inter-small cell data transferring, to get flexible backhauling and network mesh re-configurability, an important feature of the link solution will be the antenna beam steering functionality.

4) Technical Objective 4: Reduction of the power consumption of the access and small cell backhaul links (green radio): the use of mmWave radios and directive antennas in the short distance links (user access and small cell backhaul) results in a reduced emitted power requirement, more efficient transmitter implementation and a better efficiency of the spectrum usage (higher order modulations with large spectral efficiency can be used due to the more favourable link budget and lower interferences). The project targets to reduce significantly the radios and network power consumption by using mmWave in comparison with existing solutions using lower frequency bands.

In the following sections, the key DREAM project concepts and more detailed descriptions of the expected project results are presented per each technical Work Package.

2.2 Main DREAM concepts

DREAM' vision of 5G mobile networks is a heterogeneous network composed of sub-6 GHz macro-cells overlaid by small cells providing radio access in mmWave frequency bands. These small cells are linked together and to the core network through high data rate wireless backhaul link operating in D-band as well. While macro-cells will provide broadband and high QoS coverage over extended areas and support mobility, mmWave small cells will enable very high data rate radio access to mobile users and extended traffic capacity locally, for instance in areas with a high density of users or with specific needs for high-data rate communications. In this concept, small-cell off-loading technology developed in 3GPP will allow managing the traffic and splitting the data/control traffic when possible to benefit from the improved performances available in mmWave small cells. The mmWave spectrum contains several candidate frequency bands to implement radio access and wireless backhaul, the selection of these bands will be done in the next two to five years by regulation bodies based on various criteria including technical feasibility, commercial opportunities and compatibility with other services; DREAM work is focused on the the 130-174.8GHz band (D band), which is currently available and benefits of a very huge bandwidth and then of a very high data rate potential throughput.

D-band radio equipment can be very compact and low cost thanks to the latest integration technologies enabling full transceiver modules to be integrated in a single package. Such key requirements will enable this technology to be embedded in future mobile UE and in compact and aesthetic Access Points to be installed close together in the urban environment, typically on urban utility poles, street lightings or buildings.

The implementation of this concept requires the development of new D-band radio transceivers front end and antenna systems with high efficiency, beam-steering capability and cost-efficient manufacturability. It will also require new networking functions taking into account the specifics of mmWave communications, which are a relatively short communication range, beamsteering and spatial multiplexing antennas, and the availability of very large frequency resources.

2.3 Major expected results and innovations

The major expected results and innovations are presented in the following sub-sections, elaborating on the technical WPs of the project.

2.3.1 WP1

WP1 (*Applications, Technology Specifications and Architectures)* defines the heterogeneous wireless network with mmWave small cell access and backhauling. From scenarios and use cases, a top-down approach specifies the solution architecture, the system requirements and then the D-band small cells with access point, from which derives a bunch of different transceiver front end architectures and the set of specifications for the chosen solution.

The main outcomes of this WP, described in detail in the deliverables D1.1, D1.2 and D1.3 are the selection and definition of use cases and scenarios, the related KPI definition and the preliminary considerations regarding link budget studies and demonstrator link configuration.

WP1 provides an analysis of D-band frequency arrangement, correspondent regulation and propagation characteristics. The modeling of the whole system and the related specification are then obtained.

2.3.2 WP2

WP2 (*Radio analog front end for antenna beam steering*) will cover the development of all the D-band analog frontend transceiver functional blocks, such as IQ-mixers, low-noise amplifiers, frequency multipliers, and power amplifiers, required to provide cost-efficient, high data rate wireless back- and front haul radio links.

The design rely on the advanced 55nm BiCMOS technology of ST to cope with the integration of the complete D-band frontend on a single chip set to ensure cost effectiveness, compactness and amenability to mass fabrication. The main challenges lay in the achievement of ICs that enable a D-band radio with the bandwidth and performance defined in WP1, in close cooperation with WP3 in IC die-to-antenna feeding line transition co-design. Designed, fabricated and tested chips will be delivered to WP4 for integration, towards the demonstrator implemented within the activity defined in WP5.

2.3.3 WP3

WP3 (*Antenna Technology Including Beam Steering Control*) will specify and design low form factor directive steerable planar antenna array solutions for backhauling, including as a design criteria a minimization of the exposition of EMF inside the small cell environment. This work package will deliver antenna prototypes to be embedded in the WP4 prototype substrate package integration.

The expected results in terms of antenna prototypes are the following:

- Different beam steering techniques such as phased arrays, reflect arrays, transmit arrays and integrated lens antennas will be compared in order to select the most promising technique,
- Mutual coupling reduction between array elements will be studied for optimal beam steering performance,
- Medium-gain beam steering antenna array (phased array) for the access point in V-band,
- Co-simulation of antenna elements with RFICs will be done,
- Digital control interface for the RFICs will be also developed.

Design will be done based on specifications from WP1 in close cooperation with WP2 in RF, LO and IF impedance level. Designed antennas will be delivered to WP4 for integration.

2.3.4 WP4

WP4 (*Subsystem Validation and Integration platform*) will provide D-band radio front end prototype modules to WP5, including the integration of the analog transceiver chip set as well as the beamforming antenna array, the design of power suppliers, the RF and baseband interfaces, integration of RF and DC subsystems and a digital interface for beam steering control. Suitable integration platform technologies will be studied such as low-temperature co-fired ceramics (LTCC), liquid crystal polymers (LCP) and PTFE films and the optimal technology is selected for integration platform. It will house the radio analog building function chip set designed in WP2, and provide support to the WP5 demonstration activities.

2.3.5 WP5

WP5 ((*Proof of Concept, Demonstrator*) is a demonstrator, which is able to show the main KPIs defined in deliverable D1.1. In specific, a real-time base-band unit will be provided, able to handle a high throughput, perform functionalities like ATPC, ACM and channel estimation (MSE) and to optimize connection in a reasonable way. The analog frontend, integrated in WP4, will access the basic functionalities from the base-band unit. Beamforming algorithms will be implemented in the beam foming control. Prototyping will interconnect these parts. A demonstrator with one Tx and one Rx, able to perform beam steering and providing a proper connection will be the result of this WP. Results of the WP5 will be used for standardization activities in D-Band.

3. Plan for the exploitation of project results

In this section, the general approach to the exploitation of the project results and the principles for the management of knowledge and IPR are presented. Regulation and standardisation, which are important ways of impacting the ecosystem, and the proposed plan towards the related standards, is separetly presented in deliverable D6.4. Here, the partner-specific exploitation plans have been described.

3.1 Overall approach to exploitation

Exploitation activities of the DREAM consortium will take several forms in order to leverage at best the obtained project results. Therefore, exploitation activities are structured along several dimensions:

- The exploitation actor will influence the type and target audience of an exploitation activity, where a distinction can be done between the industrial and academic actors of the project;
- The exploitation type depends on the achieved research result and on the time horizon of the exploitation activity. For instance, some activities may have a direct impact within a short time frame on products (pre-)development whereas other activities may leverage research results with a long-term impact on the telecommunications sector through standardisation activities or with the introduction of products targeting more far-ahead market windows;
- The exploitation target is the audience of the obtained result and can either be internal, i.e. related to members of the DREAM consortium, or external, i.e. referring to a broader community, e.g. standardisation bodies.

The exploitation structure is summarised in Figure 1

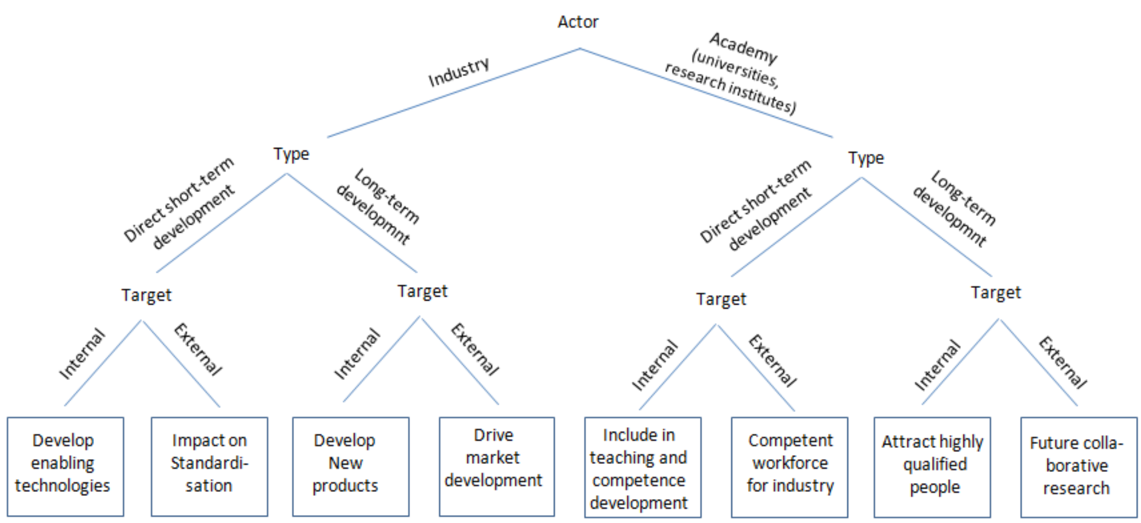

Figure 1: Structure of the exploitation activities

The **industrial partners** (i.e., operators, manufacturers, and SMEs) are focusing their exploitation activities on improving in the mid-long term their market position, with the strong intention to leverage on the project results to obtain leadership positions in the new market segments resulting from the broad deployment of mmwave technologies. Regulation and Standardisation activities, which are an important step of the pre-deployment process, are addressed in the deliverables: D6.4 “Standardization activity”.

Industrial partners usually exploit the newly obtained technical improvements internally, enhancing the existing product lines or even creating new disruptive devices and equipment. A manufacturer uses the acquired know-how to develop new enabling technologies and new products, and to improve its competitive advantage and business position on the markets. Operators and SMEs can speed up the deployment of new network technologies resulting in new usage scenarios and potentially new customers. All the project partners will ensure that the mentioned competitive advantages take place by transferring the results from the research units to the (pre-)development, marketing, and maintenance units. It is seen important that also high-level managers, ranging from board members and Chief Technology Officers to product and marketing managers will be kept posted on the main project results.
Industrial partners will also exploit direct technical improvements externally, the ultimate objective being to improve the competitive advantage and business position on the markets. Here, the timely availability of services and products are the key prerequisites for success. It is also possible to set-up new customer relationships by creating a community around the new offerings and the new enabling technologies coming out of the project results.
DREAM intends to show-case its results to the forthcoming beyond 5G EU-funded projects in order to ensure an early adoption of the main project outcomes within the telecommunications research community, as a solid foundation for future European and world-wide beyond 5G research, innovation and pre-deployment activities.
All in all, the industry-driven exploitation of results is perhaps the most important exploitation aspect of this project. It will shape the forthcoming technological landscape by making DREAM’s outcoms a core ingredient of future networking systems. It will ensure that European companies and markets continue to play a leading role worldwide, thus ensuring (if not even increasing) the number of working places in Europe in key technology areas for the years to come.

The exploitation goals of **academic partners** (i.e., universities and research institutes) are complementary to those of the industrial partners. In the short-term, they will exploit the project results to organise tutorial-style and research seminar-style into training schools of high academic standing. Technical developments will be integrated quickly into the teaching curricula and research agendas, giving themselves as well as their graduates a competitive edge, compared to other universities. Also, the research institutes have the objective of maturing technologies and transfering them to industry.
The academic partners will also be capable to educate a high-skilled workforce for the industry and the academia; this development will be particularly important for SMEs, who are often not able themselves to train personnel in very-advanced and breakthrough new technologies.
The academic exploitation has also a longer time horizon. By publishing high-quality papers, the academic partners will obtain improved international visibility thus being more able of attracting to their institutions and keeping in their ranks the best international Ph.D., M.Sc. and graduate level students. Academic partners will make sure that the main project outcomes will be carried over into future national and international research projects. The academic partners will also exploit the project results to organise tutorial-style and research seminar-style into training schools or summer schools of outstanding academic relevance.

3.2 Management of knowledge and IPR

In the first half of the project there have been no issues among the project partners w.r.t. the availability of the needed background- (when at all needed) and the foreground-IPs.

The principles followed by all the consortium partners have been and will be the ones defined and agreed in the DREAM Consortium Agreement [4], w.r.t. Section 8 'Foreground', Section 9 'Access Rights' and Section 11'Miscellaneous'. No relevant isseus is to be reported on the management of the IP among the project partners.

3.3 Partner-specific plans for exploitation

The current status of DREAM partner's exploitation plan is presented in the following.

3.3.1 ST-I

The exponential grow of data traffic sent over the mobile networks, with the advent of 3G, now the LTE, the LTE-A and in the near future of the 5G and its evolution, will cause the proliferation of distributed RAN (Radio Access Network) architectures and the RRHs, (Remote Radio Heads). Following this very likely market trend, ST is considering adding the D-band transceiver related products to their portfolio as an additional opportunity of increasing their available market by developing a proper BiCMOS based low cost and low power technology well working within the mmWave frequency range. In this way, ST should offer to customers involved in the mmWave backhauling market both an advanced BiCMOS-based technology allowing to develop their own D-band transceiver analog front end architecture solution or a complete ASSP (Application Specific Standard Product) chip set making easy the development of their RRH products as well. Furthermore, ST is planning to extend their System-on-Chip (SoC) portfolio to both the control and data plane layers of the baseband, taking advantage of the latest advances in multicore SoC technology as the nano-scale FDSOI CMOS technology.

ST could also expand its available market by including solutions for mmWave-based small cell backhaul in its portfolio – a market area that is likely to scale up with the increasing demand for data capacity. The requirement for non-crowded spectrum becomes more critical in urban and sub-urban environments, especially as the number of installed links begins to grow as more high-capacity sites at smaller distances are to be served. Since multiple network operators already use the long-established microwave bands in the same area, at some point in time, excessive bandwidth might become more difficult to be sourced at legacy bands to cover their needs adequately. In order to avoid any potential congestion issue, networks operators could turn to mmWave bands, which have not been extensively used, so this part of the electromagnetic spectrum offers an alternative path to evolve wireless transmission networks effectively.

The exploitation activities of the DREAM consortium will take several forms in order to best fit the research results and to maximize the impact on the society of the main project outcomes. Exploitation activities will play a major role both for the industrial and the academic partners, having a strong mid- and long-term impact on standardization activities, new products proof-of-concept and pre-development activities, as well as on disseminating new research results and providing new generations of students with highly competent skills, very much requested from the market of the future.

Among the main exploitation activities of the project, the following three are identified as reference parameters:

- market introduction of products containing some of the mmWave technologies developed during the project lifetime;
- number of patents filed in areas strictly related to the task where ST-I in involved;
- any spin-off coming out of the main outcomes of the project.

Concerning the first parameter, ST-I is leading the WP2 (*Radio analog front end for antenna beam steering*), where it will contribute to a D-band (130GHz-174.8GHz) transceiver front end specifications and will contribute and support the design of some of the main building blocks to improve the transceivers performance in order to allow its integration in the small cell backhaul apparatuses. This work package will deliver chip set prototypes to be used in the antenna and package integration activities handled in WP4.

The RF Business Unit of the DMA division, in ST-I, addresses two business areas: the RF Front End Module of Mobile Devices and the RF Products for Wireless Infrastructure applications.

The RF BU is responsible for the ST COT (Customer-On-Technology) business based on the BiCMOS process technologies. ST's BiCMOS process technology allows a full monolithic integration of all key function of RF Front-end module of mobile devices offering the industry's best in class figure of merit for antenna switch and antenna tuning devices.

The shift from GaAs to BiCMOS process technologies combined with the need to support multiband and multistandard creates growing opportunities in the Cellular phones and WiFi markets.

For the Wireless Infrastructure market the RF BU provide products for Macro to Small cells as well as for mobile Backhauling application. This includes both standard products and ASIC products. COT business is also supported providing advanced BiCMOS process technology to customers developing RF products. The wireless infrastructure, due to the exponential increase in mobile data traffic, is undergoing significant changes toward Heterogeneous Architecture creating new opportunities. The RF BU target is to grow the revenues of the existing standard products and to drive the development of new ones for the emerging opportunities.

The expected planned results and innovations are the following:

- An advanced BiCMOS process platform, based on an higher f_T/f_{MAX} SiGe:C HBT, to enable the high volume production of the future 5G and beyond mmw transceiver front end chip sets,
- Beyond state-of-the-art analog transceiver front end IPs based on the 55nm BiCMOS process, as the D-band frequency synthesizers, the power amplifiers, the up and down converter, the low noise amplifier and the phase shifter,
- Assessment of innovative design technique for mmw LO phase noise reduction in future direct conversion transceiver architecture,
- Assessment of innovative design technique for PA having a mmw output power being comparable with more expensive III-V transistor based technologies,
- 130–174.8GHz backhaul transceiver chip set for beyond 5G mmWave up to 100Gb/s wireless link demonstration.

3.3.2 NOKIA-IT

NOKIA X-Haul portfolio today includes solutions able to transport data rate up to 10Gbps exploiting frequency band up to 86GHz, fitting with the requirements of current mobile backhaul network. The evolution of the network and the forthcoming 5G will reshape the backhaul network scenario, asking, mainly, for more capacity and lower latency. In additional to that, the market is looking for new backhaul solutions that have to be cost effective and more energy efficient. To cope with this scenario, it is generally perceived as mandatory, for a backhaul