

**SEVENTH FRAMEWORK PROGRAMME**

**THEME 3**

**Information and Communication Technologies**

**Small or medium-scale focused research project**

***Year 2 - "Periodic Report" - D1.4***



Project acronym: HARP

Project full title: **High capacity network Architecture with Remote radio heads & Parasitic antenna arrays**

Grant agreement no.: 318489

Version number: V1

Date of preparation of periodic report (latest version): 31/12/2014

Date of approval of periodic report by Commission: .....

# PROJECT PERIODIC REPORT

**Grant Agreement number: 318489**

**Project acronym: HARP**

**Project title: High capacity network Architecture with Remote radio heads & Parasitic antenna arrays**

**Funding Scheme: FP7 – Call 8 – STREP**

**Date of latest version of Annex I against which the assessment will be made:**

**Periodic report:**                    1<sup>st</sup>     2<sup>nd</sup>     3<sup>rd</sup>     4<sup>th</sup>

**Period covered:**                    from 1<sup>st</sup> November 2013 to 31<sup>st</sup> October 2014

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**Project website<sup>1</sup> address:** <http://www.fp7-harp.eu/>

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<sup>1</sup> The home page of the website should contain the generic European flag and the FP7 logo which are available in electronic format at the Europa website (logo of the European flag: [http://europa.eu/abc/symbols/emblem/index\\_en.htm](http://europa.eu/abc/symbols/emblem/index_en.htm) logo of the 7th FP: [http://ec.europa.eu/research/fp7/index\\_en.cfm?pg=logos](http://ec.europa.eu/research/fp7/index_en.cfm?pg=logos)). The area of activity of the project should also be mentioned.

## Declaration by the scientific representative of the project coordinator

I, as scientific representative of the coordinator of this project and in line with the obligations as stated in Article II.2.3 of the Grant Agreement declare that:

- The attached periodic report represents an accurate description of the work carried out in this project for this reporting period;
- The project (tick as appropriate) <sup>2</sup>:
  - has fully achieved its objectives and technical goals for the period;
  - has achieved most of its objectives and technical goals for the period with relatively minor deviations.
  - has failed to achieve critical objectives and/or is not at all on schedule.
- The public website, if applicable
  - is up to date
  - is not up to date
- To my best knowledge, the financial statements which are being submitted as part of this report are in line with the actual work carried out and are consistent with the report on the resources used for the project (section 3.4) and if applicable with the certificate on financial statement.
- All beneficiaries, in particular non-profit public bodies, secondary and higher education establishments, research organisations and SMEs, have declared to have verified their legal status. Any changes have been reported under section 3.2.3 (Project Management) in accordance with Article II.3.f of the Grant Agreement.

Name of scientific representative of the Coordinator: T.Ratnarajah.....

Date: 05/01/2015

For most of the projects, the signature of this declaration could be done directly via the IT reporting tool through an adapted IT mechanism and in that case, no signed paper form needs to be sent

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<sup>2</sup> If either of these boxes below is ticked, the report should reflect these and any remedial actions taken.

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## 1 Publishable summary



[www.fp7-harp.eu](http://www.fp7-harp.eu)

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**HARP** (FP7 call 8 project # 318489, <http://www.fp7-harp.eu/>) is a 3-year collaborative research project, which is funded by the FP7 Programme of the European Commission.

### Project vision

The project's main goal is to bring distributed multi-antenna wireless access to reality by combining two powerful emerging technologies:

1. radio remote heads (RRHs), which allow for widely geographically distributed access via radio-over-fibre connections to a central base station; and
2. electronically steerable passive array radiators – ESPARs, which provide multi-antenna-like functionality with a single active RF chain only

### Project consortium

The project's Consortium consists of a number of well-recognized researchers in the field of wireless communication, belonging to HARP' four academic (Imperial College London (IMPERIAL), Norwegian University of Science and Technology (NTNU), Technical University of Denmark (DTU) and the University of Edinburgh (UEDIN)), three industrial (MTI Radiocomp (RADIOCOMP), Alcatel Lucent Bell Labs (ALU), Orange Labs, France Telecom R&D (FT)) and two research center (Athens Information Technology (AIT) and Eurecom Institute (EUR)) partners. UEDIN is the project coordinator.

### Main scientific concept

The current state of the art of dense radio networks follows two common assumptions.

- From the antenna design and the air interface point of view, multiple radio frequency (RF)-chains are required to drive the available antenna elements that should also retain a large enough inter-element spacing in order to provide the necessary fading properties.
- From the network infrastructure point of view, the intelligence that coordinates the transmission among adjacent cells could be located either in the central processing unit or at the individual base station itself.

### Project goals

The HARP project envisions to overcome these two limitations by combining advantageously two recently emerged technology innovations, i.e.

- **Remote radio heads (RRHs)**

They are compact radio architectures that are connected with a central base station via optical fibres and have been recently proposed as a way to share multiple geographically dispersed sets of wireless users. RRH reduce substantially the network cost and also allow the implementation of a distributed multiple-input multiple-output (MIMO) transmission, thus improving network throughput.

- **Single RF compact array radiators**

This term refers to antenna arrays with very small inter-element spacing that are fed with only a single RF chain. The apparent cost, hardware and size savings make those lightweight arrays an ideal candidate for RRHs radio equipment. This entails an important increase of the network throughput without making the base stations bulkier and without increasing the cost and implementation complexity.

An overview of the architecture that benefits from the combination of these two approaches is shown in Fig. 1. Therefore, the HARP's objectives can be listed as follows:

- To define an end-to-end architecture, including both wireless access and backhaul network, based on RRHs and single RF compact arrays that can deliver substantially higher over-the-air capacity
- To explore the fundamental limits (bandwidth / power efficiency) of distributed multi-antenna wireless access networks as the one shown in Fig.1.
- To develop efficient transceiver techniques (both single and multi-user) for single RF compact arrays that enable them to emulate spatial multiplexing / beamforming / diversity communication, which comply with the requirements of the LTE Advanced and related next generation wireless systems
- To develop appropriate channel estimation and channel feedback techniques, as required for the developed transceiver techniques and as dictated by the distributed mobile access network parameters. This will be an important catalyst for the envisioned intelligent interference management

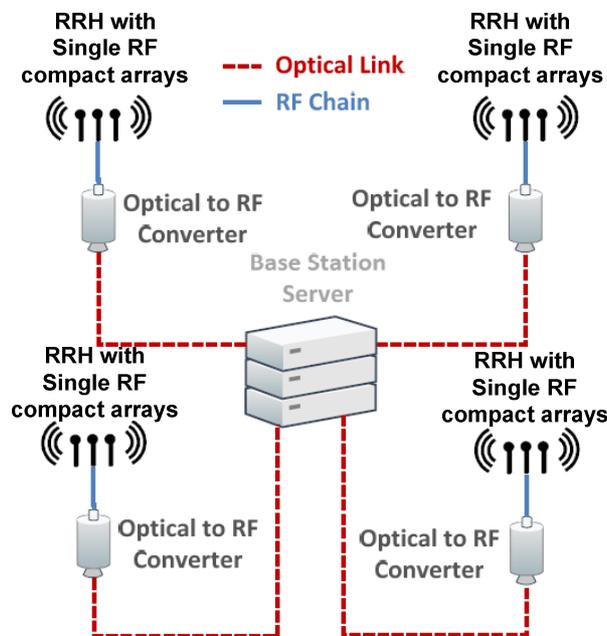


Fig. 1: HARP's RRH distributed wireless network architecture with single RF compact arrays

- To extend the above-mentioned transceiver and channel feedback techniques to corresponding cooperative transmission and channel sharing techniques for efficient distributed wireless access

- To define, model and optimise the aggregation network between the RRH-based wireless access nodes and the central processing stations (building upon the existing common public radio interface (CPRI) & OBSAI protocol structures) so as to best serve the requirements in both data traffic and channel distribution of the developed wireless access techniques
- To demonstrate the key HARP concept by building an end-to-end demonstration that will include both LTE-compliant base stations and prototyped electronically steerable parasitic antenna radiator (ESPAR)-equipped radio heads, thus showcasing the validity of the approach over the air towards the end user

### Highlights of results

Along these lines, some concrete results obtained during the 2<sup>nd</sup> year of HARP are listed below:

1. We have provided new results on the channel capacity of MIMO system with bounded inputs.
2. We have proposed a new modulation technique, referred to as Multi-dimensional Continuous Phase Modulation (M-CPM). It was shown that the capacity of M-CPM with fixed constellation is close the capacity of MIMO with Gaussian inputs even for a few number of antennas.
3. It was shown that energy efficiency does not increase infinitely in a massive MIMO system when the increasing number of antennas is to be accommodated within a fixed physical space and the total power consumed is considered to be a function of the antennas.
4. CRAN with large antenna arrays at RRHs was considered and effects of mutual coupling and spatial correlation were investigated.
5. We have presented design methodologies for arbitrary precoding with ESPARs. The proposed methodologies are used for arbitrary channel-dependent precoding in the following system setups: *i*) the 3-user 2x2 MIMO interference channel (IFC); *ii*) maximal ratio transmission (MRT) and Alamouti space-time precoding with a macro base station (BS) equipped with an ESPAR RRH.
6. We have presented a modulation scheme for single-RF MIMO systems (M-CPM) that keeps the peak to average ratio (PARP) at the sole central power amplifier at the single-RF TX to the minimum.
7. We have presented a simple signal transmission strategy for the downlink of a multi-user system that does not require accurate channel estimation and builds on the low-dimensionality of the signal subspace.
8. We have presented the error rate performance of a two-user two transmit antenna MISO broadcast channel with perfect but outdated CSI.
9. A simple feedback scheme based on the Grassmann manifold was developed and we characterized the proper scaling of the number of feedback bits with the transmit power in order to preserve the multiplexing gain achievable using perfect CSI.
10. A new relative calibration method, immune to frequency offset, is introduced and validated through bi-directional channel measurements.
11. We proposed a modified VP technique where the search of perturbing vectors is limited to the area in the symbol constellation which is constrictive to the information symbols, i.e., the area where the distances from the decision thresholds are increased with respect to a distance threshold.
12. We have examined the leading models for CSI acquisition and distribution for a multi-RRH network with CPRI-based fronthaul connecting the RRH to the BBU pool.
13. We have investigated beyond state-of-the-art data and CSI exchange models.
14. We investigated the inter-tier interference coordination scheme based on global perfect channel state information.

15. A 2-stage precoding strategy based on statistical and instantaneous CSI was proposed.
16. We optimized the design of the statistical precoder, assuming the instantaneous precoder is a classical Zero-Forcing (ZF) precoder and evaluated its performance improvement.
17. We evaluated the conditions that impact the statistical multiplexing gain in the Baseband Unit (BBU) Pool.
18. We evaluated conditions under which C-RAN or Base station with RRH should be deployed.
19. A computer model of the HARP network has been developed.
20. An operational gateway (or bridge) was implemented using the Zynq platform (Zynq 706, a Soc combining an FPGA and 2 ARM cores clocking at 800MHz) and the corresponding development environment based on Vivado HLS.
21. We developed and built the ESPAR-equipped transmitters that will be used in the project's over-the-air demonstration for RRH wireless access.

The project's progress is ongoing, placing it well in line with its final aim of identifying winning combinations of network setups and transmission methodologies that may offer unprecedented gains in terms of spectral efficiency to emerging and future wireless networks.

The address of the project public website is <http://www.fp7-harp.eu>

The Consortium partners are:

- The University of Edinburgh (UEDIN) (UK, Co-ordinator)
- Athens Information Technology (AIT) (Greece, Technical Leader)
- Eurecom Institute (EUR) (France)
- Imperial College London (IMPERIAL) (UK)
- Norwegian University of Science and Technology (NTNU) (Norway)
- Technical University of Denmark (DTU) (Denmark)
- MTI Radiocomp (RADIOCOMP) (Denmark)
- Alcatel Lucent Bell Labs (ALU) (France)
- Orange Labs (ORANGE) (France)

## 2 Project objectives for the period

In the following, we give a concise overview of the project objectives for the work packages that have been active in the second year of the HARP project.

### **WP3: Network requirements & fundamental limits**

Herein we will investigate and evaluate the network requirements for the HARP architecture taking into consideration the entire value chain, which includes the end users, the network operators, the equipment manufacturers and the component industry. The network architecture will be first defined in terms of its topology and components. Performance metrics and service / user requirements will be also defined. Moreover, we will study the power vs. bandwidth trade-offs for several distributed multi-antenna configurations as well as other related fundamental performance limits. These will be later used for benchmarking in WP4, WP5 and WP6.

### **WP4: Single-point ESPAR-enabled RRH access**

In this WP we will develop transceiver techniques for single-point ESPAR-enabled RRHs which comply with the defined network architecture taken from WP3. Initially, we will assume perfect channel knowledge at the receiver and no or perfect channel knowledge at the transmitter. The user dimension will be also explored for both single and multi-user techniques. We will also deal with the inaccurate channel state information. Special attention will be given to the issue of channel feedback by considering partial channel feedback.

### **WP5: Multi-point ESPAR-enabled RRH access**

In this WP we will identify and develop cooperative techniques for multi-point ESPAR-enabled RRHs which comply with the network architecture developed in WP3. We will also exploit both the local beamforming capability and the cooperative joint processing by identifying an optimal regime of information exchange between ESPAR-enabled RRHs. Moreover, we will study the optimal transmission schemes, precoding techniques and resource allocation schemes. Finally, we will investigate how the ESPAR-based RRH cooperative techniques can be implemented on a cloud RAN.

### **WP6: Aggregation network**

In WP6 we will define, model, optimise and implement the HARP's multi-cell aggregation network. After providing a network architecture that ensures end-to-end connectivity, this will be further optimised in order to meet the requirements specified in WP3. The existing CPRI and OBSAI aggregation protocols will be adopted and further developed to comply with the needs of the ESPAR-based RRH cooperative access network. Flexible protocol extensions will be derived and the Cloud RAN architecture will be adopted for multi-cell network aggregation. These techniques will feed into WP7 for the aggregation network protocol verification and overall system integration and demonstration.

### **WP7: Experimentation and Demonstrations**

In this WP we will validate the feasibility of the ESPAR based RRH network by prototyping and experimentation. The validation will be done using an agile approach and incremental complexity, starting from the single elements (ESPAR, RRH) and leading to multiple elements (RRH network and a cloud RAN). An end-to-end demo from an LTE compliant base station through the fibre backhaul to the RRH and the end user will be provided.

### 3 Work progress and achievements during the period

#### 3.1 Progress Overview

The project progress has in general followed the planned work schedule, and we have produced significant and novel results in the field. We have exceeded our own expectations in some areas, for example WP3 and WP4 (e.g., single RF compact multiport antenna arrays), which place the HARP project in the front line of research in the field, and demonstrate the world-leading quality of the research in the project.

#### 3.2 Work Packages Progress

In the following sections, we detail the achievements, progress towards each task’s objectives and the resources used for each of the active work packages.

##### **WP3: Network requirements & fundamental limits**

The technical work in this WP is split into two main actions, which are the following:

###### *Network requirements and metrics*

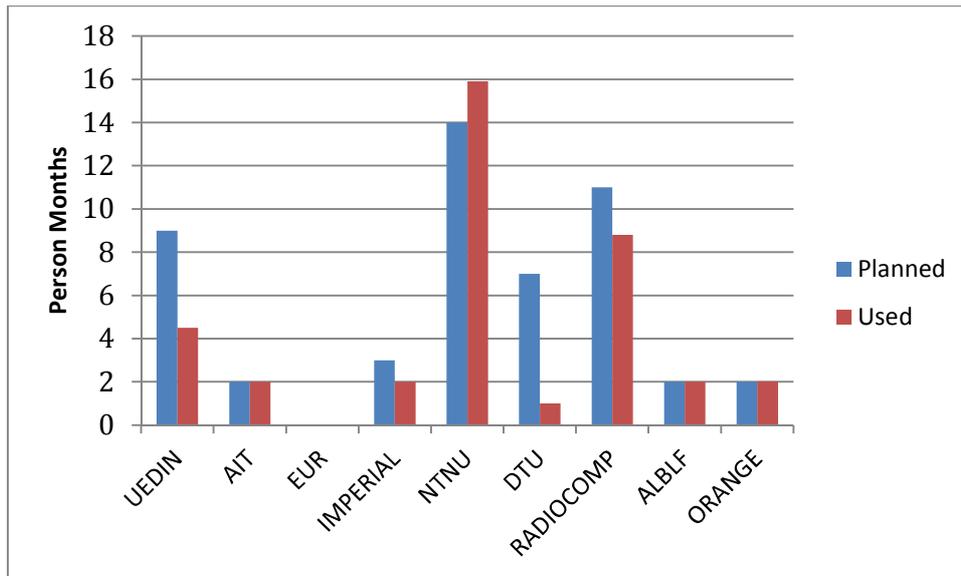
At the end of the year 1 of the project, a number of candidate network architectures and technologies were evaluated and compared. Several definitions and metrics were agreed upon. We were able to validate and to provide results of the proposed solutions. This work was completed and was reported in Year I.

###### *Fundamental Limits*

In this work in year 2, we have investigated the fundamental limits of ESPAR-MIMO systems proposed in the project. This work also investigates both the bandwidth and the power efficiency that can be achieved by means of ESPAR-based MIMO given a certain demand on throughput, as well as the associated EMF radiation savings. We have presented the update on channel capacity of MIMO system with bounded inputs. We have proposed a new modulation technique called Multi-dimensional Continuous Phase Modulation (M-CPM) and derived channel capacity of M-CPM modulation in a vector Gaussian channel. We have also derived some bounds for the capacity of MIMO systems with bounded inputs. We have also investigated effects of mutual coupling and spatial correlation in CRAN with large antenna arrays at RRHs.

	<b>UEDIN</b>	<b>AIT</b>	<b>EUR</b>	<b>IMPERIAL</b>	<b>NTNU</b>	<b>DTU</b>	<b>RADIOCOMP</b>	<b>ALBLF</b>	<b>FT</b>
<b>Planned</b>	9	2	0	3	14	7	11	2	2
<b>Used</b>	4.5	2	0	2	15.91	1	8.8	2	2.02
<b>Total</b>	14	2	0	5	21	10	12	2	2

**Table 3.2.1: Person Month Resources for WP3 (Year I and II)**



**Figure 3.2.1 Person Month Resources for WP3 (Year I and II)**

#### **WP4: Single-point ESPAR-enabled RRH access**

The technical work in this WP can be split into three main actions, which are the following:

##### *Transceiver design*

In this work in year 2, we have presented design methodologies for arbitrary precoding with remote radio heads (RRHs) equipped with ESPARs. The proposed methodologies are used for arbitrary channel-dependent precoding in the following system setups: i) the 3-user 2x2 MIMO interference channel (IFC); ii) maximal ratio transmission (MRT) and Alamouti space-time precoding with a macro base station (BS) equipped with an ESPAR RRH. We also presented a modulation scheme for single-RF MIMO systems that keeps the peak-to-average power ratio (PAPR) at the sole central power amplifier at the single-RF TX to the minimum. In addition, we investigated the optimum input signal distribution for RRHs equipped with either LMAs or single-RF ESPARs and studied the maximum achievable rate and its impact on the transceiver design in terms of suboptimal modulations. In parallel, we also focus on power efficient modulation schemes that are adequate for the considered antennas arrays at the RRHs. We also presented a simple signal transmission strategy for the downlink of a multi-user system that does not require accurate channel estimation and builds on the low-dimensionality of the signal subspace. Details of this work can also be found in the deliverable D4.1.

##### *Channel estimation*

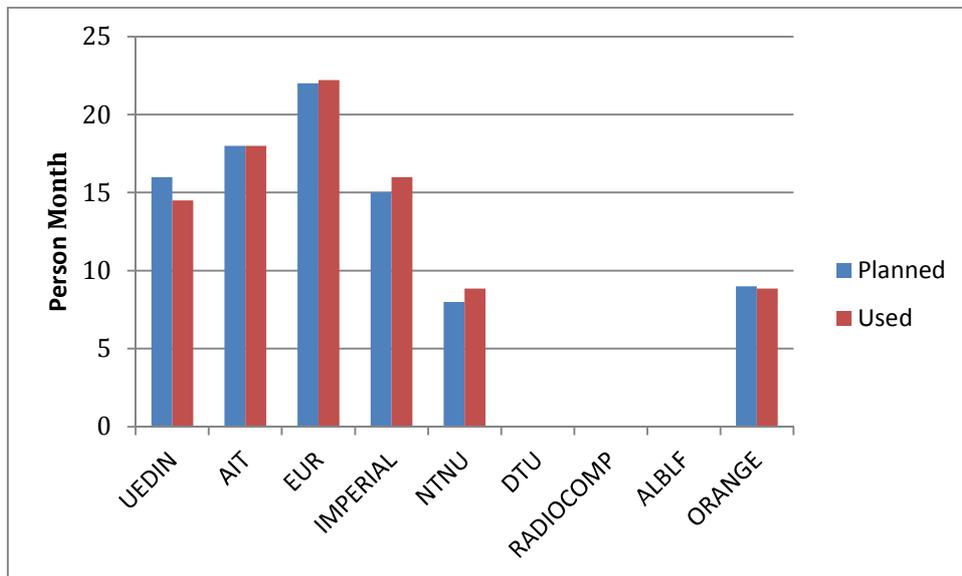
In this work in year 2, we have addressed the problems in channel estimation in MIMO systems equipped with single-RF transmitters. We investigated channel modeling in MIMO systems with single-RF transmitters, channel estimation in ESPAR as one of the candidates of single-RF MIMO transmitters and pilot contamination. We also worked on the design of pilots for channel estimation purpose in ESPAR configuration and investigated problem of pilot contamination in multiuser MIMO systems. Details of this work can also be found in the deliverable D4.2.

### CSI Feedback

In this work in year 2, we studied the CSI feedback techniques including use of channel reciprocity, limited feedback in the form of quantised values, precoder values and use of statistical CSI. We have first investigated the impact of short-term and long-term delay on the CSI in MU-MIMO system and presented the error rate performance of a two-user two transmit antenna MISO broadcast channel with perfect but outdated CSI. We developed a simple feedback scheme based on the Grassmann manifold and characterized the proper scaling of the number of feedback bits with the transmit power in order to preserve the multiplexing gain achievable using perfect CSI. We also investigated on how the CSI feedback results could be extended to the scenario of CSI exchange over the backhaul, for the purpose of calculating IA precoders. We evaluated the performance of interference management techniques under CSI mismatch for three different scenarios, a multiuser downlink scenario with channel inversion (CI), MIMO interference channel (IFC) with interference alignment (IA), MIMO interference broadcast channel (IBC) with IA. We also investigated adaptive Max-SINR algorithms for both the MIMO IC and IBC that can handle the CSI mismatch effects more effectively than the corresponding standard versions. We investigated a low-complexity vector precoding (VP) scheme for the downlink of multi-user multiple input single output (MU-MISO) systems with limited feedback. Details of this work can also be found in the deliverable D4.3.

	UEDIN	AIT	EUR	IMPERIAL	NTNU	DTU	RADIOCOMP	ALBLF	FT
<b>Planned</b>	16	18	22	15	8	0	0	0	9
<b>Used</b>	14.5	18	22.21	16	8.86	0	0	0	8.85
<b>Total</b>	16	18	22	15	8	0	0	0	9

**Table 3.2.2: Person Month Resources for WP4 (Year I and II)**



**Figure 3.2.2: Person Month Resources for WP4 (Year I and II)**

### WP5: Multi-point ESPAR-enabled RRH access

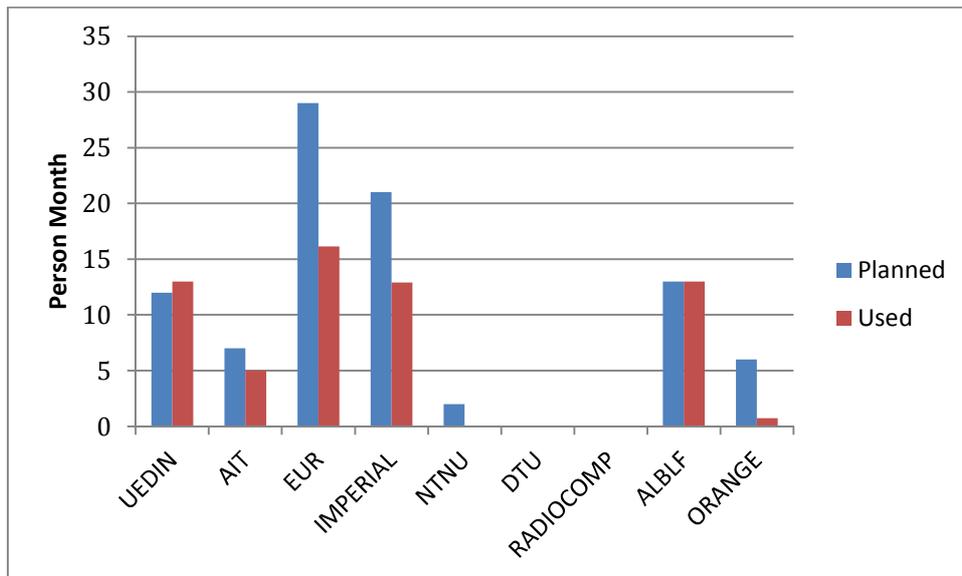
The technical work in this WP can be split into three main actions, which are the following:

*CSI and user plane data distribution techniques*

In this work in year 2, we have presented a classification of CSI data types and showed the assumptions made in terms of CSI and user-plane data exchange under some of the antenna combining and interference cooperation methods presented in HARP and show possible approaches developed under HARP to strike a good balance between interference cooperation gains and data sharing overhead. We have presented the leading data and CSI exchange models for CSI and data sharing and investigated the relevance of a subset of the classes of imperfect CSI in the context of HetNet interference coordination involving a macro base and one of more RRH. We have also investigated the case of joint processing (downlink) CoMP, a.k.a network MIMO, with several RRH cooperating to serve a group of user terminals and examined the leading models for CSI acquisition and distribution for a multi-RRH network with CPRI-based fronthaul connecting the RRH to the BBU pool. We also reviewed the CSI and data distribution assumptions for a study of downlink joint processing CoMP among RRH located randomly in a network following a Poisson point process and developed more efficient channel representation methods and techniques to reduce the amount of CSI overhead on the RRH fronthaul as well as fronthaul capacity provisioning. Details of this work can also be found in the deliverable D5.1.

	UEDIN	AIT	EUR	IMPERIAL	NTNU	DTU	RADIOCOMP	ALBLF	FT
<b>Planned</b>	12	7	29	21	2	0	0	13	6
<b>Used</b>	13	5	16.14	12.92	0	0	0	13	0.72
<b>Total</b>	16	9	33	25	3	0	0	18	9

**Table 3.2.3: Person Month Resources for WP5 (Year I and II)**



**Figure 3.2.3: Person Month Resources for WP5 (Year I and II)**

### *Cooperative techniques*

In this work in year 2, we have addressed the problem of cooperative techniques and gains of the ESPAR-enabled remote radio heads (RRH) with perfect channel state information (CSI). Several transmission and interference coordination schemes have been proposed and compared in terms of cell-level throughput (i.e., sum rate) and individual user constraints (i.e., outage probability). We first investigated the inter-tier interference coordination scheme based on global perfect channel state information in downlink multi-antenna heterogeneous network and compared the outage probability of the user under several cooperative techniques in a CRAN system where a user is served by a central intelligence unit and a group of RRHs distributed randomly over a circular region. We have proposed the utilization of compact single-RF electronically steerable parasitic (passive) array radiators (ESPARs) at the cooperating transmitters (TXs) and described a signal model capable of capturing the characteristics of the considered ESPARs. We have introduced a general precoding design methodology for the tunable parasitic loads at the TXs' ESPARs. Specific precoding techniques and an indicative ESPAR design have been presented for a 3-user 2x2 MIMO IFC with one ESPAR TX. We have also optimized the design of the statistical precoder, assuming the instantaneous precoder is a classical Zero-Forcing (ZF) precoder and evaluate its performance improvement. Details of this work can also be found in the deliverable D5.2.1.

### *CRAN implementation of proposed cooperative techniques*

In this work in year 2, we have worked on the implementation of ESPAR-based RRH cooperative techniques on a cloud RAN. The idea is to be able to deploy some of the cooperative techniques identified in T5.1 and T5.2 in order to have a proof of concept tested in WP6. This is a work in progress and will continue in year 3. In year 2, we have studied how a candidate cooperative technique could be implemented on the Open Air Interface based CRAN. We have also investigated how the CSI could be efficiently be distributed over a fronthauling network to serve this cooperation technique using a so-called "CPRI gateway" and how the ESPAR antenna could be efficiently be configured by the CRAN with 2 options for the control, either a signal sent via the CPRI connection (in-band signal) or via a separate Ethernet connection (out-of-band signal). Details of this work can also be found in the deliverable D5.3.1.

## **WP6: Aggregation network**

The technical work in this WP can be split into four main actions, which are the following:

### *Aggregation network definition & modelling*

In this work in year 2, we have defined the architecture and the details of the RRH aggregation network. We have studied the various alternative approaches in RRH aggregation network and the pros and cons of packet-based fronthaul networks. Details of this work can also be found in the deliverable D6.1.

### *Aggregation network optimization*

In this work in year 2, we have investigated to what extent the aggregation network can be optimized to meet the requirements specified by the HARP project. We have optimized CAPEX of C-RAN deployment by maximizing multiplexing gain achievable in BBU pool and smart network planning and evaluated the

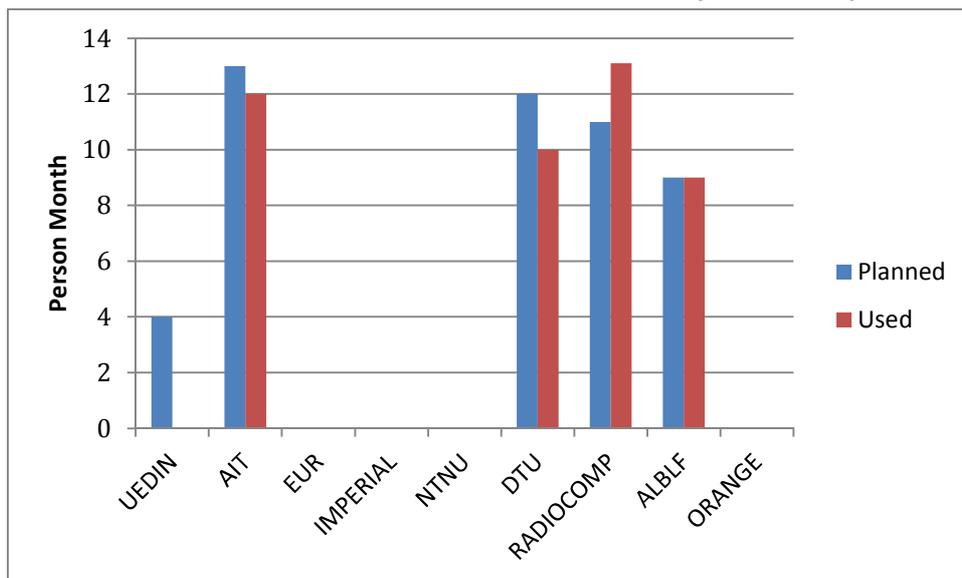
conditions that impact the statistical multiplexing gain in the Baseband Unit (BBU) Pool. We have found the set of parameters that maximize the statistical multiplexing gain, leading to the highest potential cost savings and evaluated conditions under which C-RAN or Base station with RRH should be deployed. We also planned and optimized the cost of C-RAN deployment by reducing fiber associated CAPEX. We investigated deployment a scenario in which not only fibers, but also Microwave (MWR) is used. We also considered the case with multiple BBU-pools as one C-RAN can cover only a limited area and investigated requirements and researching on solutions for synchronization in CPRI over Ethernet transport. We also analysed requirements and possible solutions for synchronization for this scenario and measured the performance of CPRI and OBSAI over OTN transmission thereby understanding challenges associated with synchronization.

*Protocol extensions design and implementation*

In this work in year 2, we have been working on develop protocols for the aggregation network. We have already developed a computer model of the full HARP network, which can be used for evaluation. The model was created by using the tool OPNET modeler. The model implements (i) Core network that focuses on an application server used as a traffic generator (ii) Backhaul network in BBU pool with BBUs connected via P2P links that implement the X2 interface (iii) Fronthaul network connecting the BBUs to the RRHs on the cells (iv) RRHs for urban macro scenario with omnidirectional antennas covering a cell each (v) Mobile pedestrian UEs (with speed 3 km/h) uniformly distributed in the network.

	UEDIN	AIT	EUR	IMPERIAL	NTNU	DTU	RADIOCOMP	ALBLF	FT
<b>Planned</b>	4	13	0	0	0	12	11	9	0
<b>Used</b>	0	12	0	0	0	10	13.1	9	0
<b>Total</b>	6	17	0	0	0	18	17	18	0

**Table 3.2.4: Person Month Resources for WP6 (Year I and II)**



**Figure 3.2.4: Person Month Resources for WP6 (Year I and II)**

### *Cloud RAN for multi-cell network aggregation*

In this work in year 2, we have been working to achieve the integration of Cloud RAN in the RRH aggregation network. We have implemented an operational gateway using the Zynq platform (Zynq 706, a Soc combining an FPGA and 2 ARM cores clocking at 800MHz) and the corresponding development environment based on Vivado HLS and connected the gateway: (i) with existing RRH using the CPRI interface (ii) with existing VRAN using 10GbEthernet interface. This work will continue in year 3 of the project.

#### **WP7: Experimentation and demonstrations**

The technical work in this WP is split into three main actions, which are the following:

##### *ESPAR Prototyping*

In this work in year 2, we are investigating ESPAR-equipped transmitters that will be used in the project's over-the-air demonstration for RRH wireless access. We first identify the combination of ESPAR array topology and transmission technique that will be chosen for the demonstration. Then we will build the ESPAR array taking into account, besides the transmission constraints, also the radiation power and circuit energy consumption of the devices to be built, as these constitute important metrics for Future Networks.

##### *Verification of aggregation network protocols*

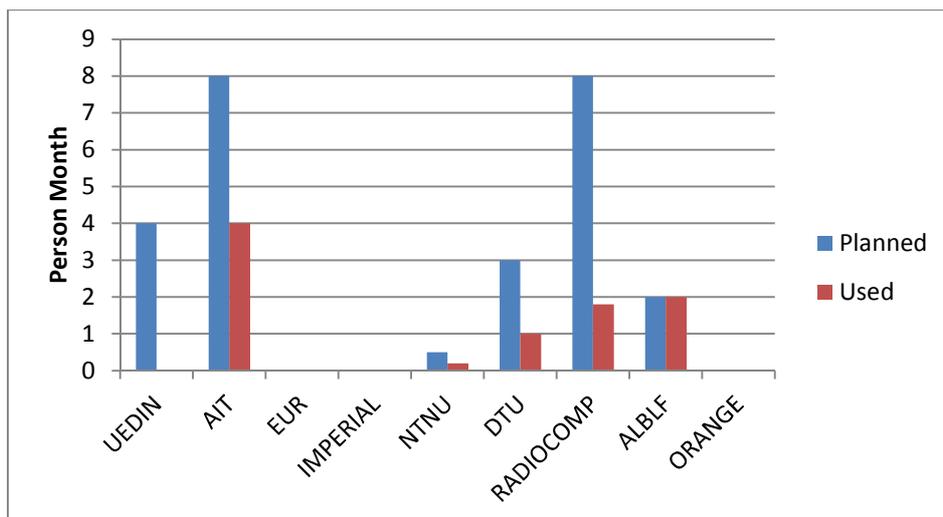
In this work in year 2, we will design, implement and finally verify the extensions to the protocol used in the aggregation network. The main activity so far in this task has been to decide on a method for verification. Computer simulation is the main method being used. We are developing prototype of a flexible radio platform which will support different wireless standards and will achieve over-the-air transmission making use of an ESPAR antenna technology.

##### *Radio head prototype*

In this work in year 2, we are working on the development of remote radio head prototype. We are currently working on a solution based on commercial 4G RRH. However the demonstration will showcase the advanced features of the ESPAR antennas integration.

	<b>UEDIN</b>	<b>AIT</b>	<b>EUR</b>	<b>IMPERIAL</b>	<b>NTNU</b>	<b>DTU</b>	<b>RADIOCOMP</b>	<b>ALBLF</b>	<b>FT</b>
<b>Planned</b>	4	8	0	0	0.5	3	8	2	0
<b>Used</b>	0	4	0	0	0.2	1	1.8	2	0
<b>Total</b>	6	12	0	0	1	9	15	18	0

**Table 3.2.5: Person Month Resources for WP7 (Year I and II)**



**Figure 3.2.5: Person Month Resources for WP7 (Year I and II)**

### Reasons for change in plan for WP 7.2 and D 2.1.3 from Annex I

Please note that WP 7.2 was supposed to start on month M13 with RADIOCOMP, leading this work. Due to unforeseen business circumstances at RADIOCOMP, they were unable to lead this WP and informed the consortium about it. The original plan then had to be changed. While we will be using ALBLF's own commercial RRH instead of our own RRH prototype, we have invested significantly more efforts in ESPAR and CPRI prototyping. The released person months from RADIOCOMP were then redistributed to AIT and ALBLF who will be putting additional efforts on ESPAR and CPRI prototyping. The change in WP7 plan amounted to release of 11 person month from RADIOCOMP (EUR 63,480) that was distributed in AIT and ALBLF for the additional work they will be doing for ESPAR and CPRI prototyping.

Redistribution of person month for partners	WP2	WP7
UEDIN	2 (11240)	
AIT	1.5 (8430)	5.5 (31740)
EUR	2 (11240)	
IMPERIAL	1.5 (8430)	
NTNU	1.5 (8430)	
DTU	1.5 (8430)	
RADIOCOMP		
ALBLF	1.5 (8430)	5.5 (31740)
ORANGE	1.5 (8430)	

The deliverable D 2.1.3 Report on dissemination and exploitation planning activities that was originally allocated to RADIOCOMP will now be worked on by UEDIN. WP2 work, released from RADIOCOMP amounted to 13 person month from RADIOCOMP (EUR – 73,140) that was distributed amongst all partners.

### Response to Recommendations concerning future work from Technical Review Report Year 1

The following is the response to the reviewers' recommendations concerning future work from technical review report of year 1.

1. As per recommendation, we have incorporated in all second year deliverables, the contribution to overall HARP objectives and relationship/interdependency to other activities within the project as much as possible.
2. We have reduced the amount of technical work details in the scientific report as per reviewers' recommendation and summarised the work and activities as briefly as possible. Much lesser technical details are included in scientific report than the submitted deliverables.
3. As per recommendation, we have now made D5.1 as one public deliverable in WP5. This WP only started in year 2 and good progress has been made.
4. It is to be mentioned that consortium partners ALBLF and AIT are in touch with outside industrial partners in the cloud-RAN area to gather more requirements and know-how of cloud-RAN technology.
5. An updated plan has already been submitted as deliverable for exploitation strategy for all partners in the consortium.

### Interactions with other FP7 projects

HARP consortium organised an international workshop on “*Wireless Optical Network Convergence in support of Cloud Architectures*” in IEEE Globecom conference on 12 December 2014, held in Austin, USAGlobecom. In particular, the above workshop provided a special research session where MTI Radiocomp presented the preliminary results accomplished by the HARP consortium during the first year of the project. This event is in collaboration with other FP7 Call 8 projects: **CROWD, Tropic and iJOIN.**

## 3.3 Collaboration in the HARP Project

There have been several inter-partner collaborations in the Year I of the HARP project:

- **NTNU-UEDIN-IMPERIAL:** WP3-Fundamental limits
- **NTNU – EUR:** WP4 – channel estimation
- **UEDIN-IMPERIAL:** WP4 – CSI feedback
- **EUR – ALBLF:** Transmitter cooperation with distributed CSIT]
- **FT-ALBLF:** WP5- CRAN implementation
- **DTU – RADIOCOMP:** WP3 & WP6
- **AIT – NTNU:** Single RF CMAs
- **DTU, RADIOCOMP & ALBLF :** WP7

We expect these interactions to continue and increase in the Year III.

## 3.4 HARP Publications

Table 1 below maps the publishable works resulting from HARP to the work packages and consortium partners.

	UEDIN	AIT	EUR	IMPERIAL	NTNU	DTU	RADIOCOMP	ALBLF	ORANGE
WP3	<b>P20</b>		<b>P4</b>		<b>P17</b>				
WP4	<b>P1, P2, P3, P12, P13, P15, P16</b>	<b>P10, P21,</b>	<b>P14, P18, P22</b>		<b>P5</b>				
WP5		<b>P7</b>	<b>P6</b>						
WP6						<b>P19</b>	<b>P8, P9, P11</b>		
WP7		<b>P21, P23</b>							

**Table 3.4.1: Publication distribution across partners and work packages (bold indicates a collaboration)**

#### HARP Project Y2 Publications

##### Journal papers

- P1. C. Masouros, M. Sellathurai and T. Ratnarajah, "**Vector Perturbation Based on Symbol Scaling for Limited Feedback MISO Downlinks**," *IEEE Trans. on Signal Processing*, Vol. 63, Issue 3, pp. 562-571, Feb.1, 2014.
- P2. C. Zhong, T. Ratnarajah, Z. Zhang, K-K Wong and M. Sellathurai, "**Performance of Rayleigh Product MIMO Channels with Linear Receivers**", *IEEE Trans. on Wireless Communications*, pp. 2270-2281, Vol. 13, No. 4, April 2014.
- P3. C. Masouros, M. Sellathurai and T. Ratnarajah, "**Maximizing Energy-Efficiency in the Vector Precoded MU-MISO Downlink by Selective Perturbation**," *IEEE Trans. on Wireless Communications*, June 2014.
- P4. X. Yi, S. Yang, D. Gesbert, and M. Kobayashi, "**The degrees of freedom region of temporally correlated MIMO networks with delayed CSIT**," *IEEE Transactions on Information Theory*, vol. 60, no. 1, pp. 594-614, January 2014.
- P5. Ralf Müller, Laura Cottatellucci, and Mikko Vehkaperä, "**Blind pilot decontamination**," *IEEE Journal of Selected Topics in Signal Processing*, vol. 8, October 2014.
- P6. Haifan Yin, David Gesbert, and Laura Cottatellucci, "**Dealing with Interference in Distributed Large-scale MIMO Systems: A Statistical Approach**," *IEEE Journal of Selected Topics in Signal Processing*, vol. 8, October 2014.

- P7. V. I. Barousis and C. B. Papadias, "**Arbitrary precoding with single-fed Parasitic arrays: Closed-form expressions and design guidelines,**" *Wireless Communications Letters, IEEE*, vol. PP, no. 99, pp. 1–4, 2014.
- P8. A. Checko, H. L. Christiansen, Y. Yan, L. Scolari, G. Kardaras, M. S. Berger, L. Dittmann, "**Cloud RAN for Mobile Networks - a Technology Overview**". *To Appear in IEEE Communications Surveys and Tutorials journal*.
- P9. Checko, Aleksandra; Kardaras, Georgios; Lanzani, Christian Fabio Alessandro; Temple, Dan; Mathiasen, Carsten; Pedersen, Lars A.; Klaps, Bert, "**Transport of Baseband Radio Serial Protocols in C-RAN Architecture for Mobile Network Applications**" *White Paper OTN, Altera*, 2014. 9 p.

## Conferences

- P10. V. Barousis, C. Papadias, R. Müller, "**A New Signal Model for MIMO communication with Compact Parasitic Arrays.** *International Symposium on Communications, Control and Signal Processing*, Athens, Greece, May 2014.
- P11. Checko, H. Holm, and H. Christiansen, "**Optimizing small cell deployment by the use of C-RANs,**" *Proc. of European Wireless 2014 (EW 2014)*, May 2014, Barcelona.
- P12. A Papazafeiropoulos and T Ratnarajah, "**Uplink Performance of Massive MIMO Subject to Delayed CSIT and Anticipated Channel Prediction,**" *IEEE 39th International Conference on Acoustics, Speech and Signal Processing*, Florence, Italy, May 4-9, 2014.
- P13. C. Masouros, M. Sellathruai and T. Ratnarajah, "**Bridging the Gap Between Linear and Non-Linear Precoding in Small- and Large-Scale MIMO Downlinks,**" *In Proc. the IEEE International Conference on Communications*, Sydney, Australia, June 10-14, 2014.
- P14. Haifan Yin, D. Gesbert, and L. Cottatellucci, "**A Statistical Approach to Interference Reduction in Distributed Large-Scale Antenna Systems,** *IEEE International Conference on Acoustics, Speech, and Signal Processing (ICASSP)*, May 2014, Florence, Italy.
- P15. A. Papazafeiropoulos and T. Ratnarajah, "**Precoding for Downlink Massive MIMO with Delayed CSIT and Channel Prediction,**" *In Proc. the IEEE Wireless Communications and Networking Conference*, Istanbul, Turkey, April 6-9, 2014.
- P16. A. Papazafeiropoulos and T. Ratnarajah, "**Ergodic Channel Capacity for Generalized Fading channels,**" *In Proc. the IEEE Wireless Communications and Networking Conference*, Istanbul, Turkey, April 6-9, 2014.
- P17. A. Sedaghat, R. R. Muller, and G. Fischer, "**A Novel Single-RF Transmitter for Massive MIMO,**" *ITG Workshop on Smart Antennas (WSA)*, March 2014.
- P18. Laura Cottatellucci, "**Spectral Efficiency of Extended Networks with Randomly Distributed Transmitters and Receivers,**" *2nd IEEE China Summit and International Conference on Signal and Information Processing (ChinaSIP14)*, Xi'an China, July 9--13, 2014.

- P19. M. Artuso, H. Christiansen, "**Discrete-Event Simulation of Backhaul Impact on Coordinated Multi-Point in LTE-Advanced**", *11<sup>th</sup> International Symposium on Wireless Communication System*, Barcelona, August 2014.
- P20. Sudip Biswas, Christos Masouros, Tharmalingam Ratnarajah, "**On the effect of Antenna Correlation and Coupling on Energy-Efficiency of Massive MIMO Systems**," *IEEE 25th International Symposium on Personal Indoor and Mobile Radio Communications* , PP 472-476, Sept. 2014.
- P21. G. C. Alexandropoulos, V. I. Barousis, and C. B. Papadias, "**Precoding for multiuser MIMO systems with single-fed parasitic antenna arrays**," in *Proc. IEEE GLOBECOM*, Austin, USA, 8–12 December 2014.
- P22. Laura Cottatellucci, "**Capacity per Unit Area of Distributed Antenna Systems with Centralized Processing**," *Proc. of IEEE Global Communications Conference (GLOBECOM)*, December 2014.
- P23. C. B. Papadias, G. C. Alexandropoulos, V. I. Barousis, and E. I. Roumpakias, "**Design of parasitic antenna arrays & experimentation at AIT's B-WiSE lab**," *Scandinavian workshop on testbed based wireless research*, Stockholm, Nov. 27, 2013.

## 4 Deliverables and milestones tables

### 4.1 Deliverables (excluding the periodic and final reports)

The deliverables due in the second year of the project were D1.3, D1.4, D1.5, D2.1.1, D2.2, D3.2.2, D4.1, D4.2, D4.3, D5.1, D5.2.1, D5.3.1 and D6.1. These have all been delivered on schedule, as shown in Table 4.1.1 below.

Del. no.	Deliverable name	WP no.	Lead beneficiary	Nature	Dissemination level	Delivery date from Annex I (proj. month)	Delivered Yes/No	Actual / Forecast delivery date	Comments
D1.1	Project Website	1	UEDIN	O	PU, CO	3	YES	Jan 2013	Approved
D1.2	Quarterly progress reports	1	UEDIN	R	CO	3, 6, 9, 15, 18, 21, 27, 30, 33	YES	Jan 2013, April 2013, July 2013	M3, 6, 9 are approved
D3.1	Requirements, metrics and network definition	3	FT	R	CO	8	YES	June 2013	Approved
D1.3	Yearly progress report	1	AIT	R	CO	12, 24	YES	Dec 2013	M12 is approved
D3.2.1	Candidate ESPAR Designs and Modelling	3	AIT	R	CO	12	YES	Dec 2013	Approved

D1.4	Interim and final cost claims	1	UEDIN	R	CO	12, 24, 36	YES	Jan 2014	M12 is approved
D1.5	Final plan for the use and dissemination of foreground	1	UEDIN	R	CO	18	YES	Apr. 2014	
D3.2.2	Single point ESPAR limits	3	NTNU	R	PU	18	YES	Apr. 2014	
D6.1	Aggregation network definition	6	AIT	R	PU	18	YES	Apr. 2014	
D4.2	Channel estimation techniques	4	NTNU	R	PU	21	YES	Jul. 2014	
D2.1.1	Proceedings of first Special Session	2	RADIOCOMP	O	PU	24	YES	Oct. 2014	
D2.2	Report on Exploitation Strategy	2	IMPERIAL	R	CO	24	YES	Oct. 2014	
D4.1	Transceiver techniques	4	AIT	R	CO	24	YES	Oct. 2014	
D4.3	CSI feedback techniques	4	UEDIN	R	CO	24	YES	Oct. 2014	
D5.1	CSI and user plane distribution techniques	5	EUR	R	CO	24	YES	Oct. 2014	
D5.2.1	Cooperative techniques with perfect CSI	5	IMPERIAL	R	CO	24	YES	Oct. 2014	
D5.3.1	Efficient CSI distribution algorithm	5	FT	R	CO	24	YES	Oct. 2014	

D6.2	Aggregation network optimisation	6	DTU	R	CO	27			
D1.6	Report on awareness and wider societal implications	1	UEDIN	R	PU	30			
D5.2.2	Cooperative techniques under realistic CSI conditions	5	EUR	R	CO	30			
D5.3.2	Prototype of a cloud RAN cluster implementing selected techniques	5	ALBLF	R	CO	30			
D7.1	ESPAR prototypes	7	AIT	P	CO	30			
D7.2	Radio head prototypes	7	RADIOCOMP	P	CO	30			
D6.3	RAN protocol extensions	6	RADIOCOMP	R	CO	33			
D1.7	Final project report	1	UEDIN	R	PU	36			
D2.1.2	Proceedings of Second Special Session	2	AIT	O	PU	36			
D2.1.3	Report on dissemination and exploitation planning activities	2	RADIOCOMP	R	PU	36			
D3.2.3	Fundamental limits	3	NTNU	R	PU	36			

D6.4	Eth2CPRI prototype implementation	6	ALBLF	R	CO	36			
D7.4	Final end-to-end demo	7	ALBLF	D	PU	36			

## 4.2 Milestones

Several milestones were completed in the first year of HARP. They are detailed in Table 4.2.1 below. All Milestones were achieved on schedule.

<b>TABLE 4.2.1 MILESTONES</b>							
<b>Milestone no.</b>	<b>Milestone name</b>	<b>WPs no's.</b>	<b>Lead beneficiary</b>	<b>Delivery date from Annex I</b>	<b>Achieved Yes/No</b>	<b>Actual / Forecast achievement date</b>	<b>Comments</b>
MS1	Consortium Agreement	1		0	YES	6	The Consortium Agreement has been signed among all partners
MS2	Project Website online and secure	1		3	YES	3	Web site available and receiving hits; interest in the project's public mailing list
MS8	Service scenarios and requirements completed	3		4	YES	4	Reviewed and approved by the Project Steering Board (PSB)
MS12	Requirements for CSI and user plane distribution methods	4, 5		12	YES	12	Reviewed and approved by the PSB
MS9	Transceiver techniques for single user links	4		15	YES	15	Reviewed and approved by the PSB

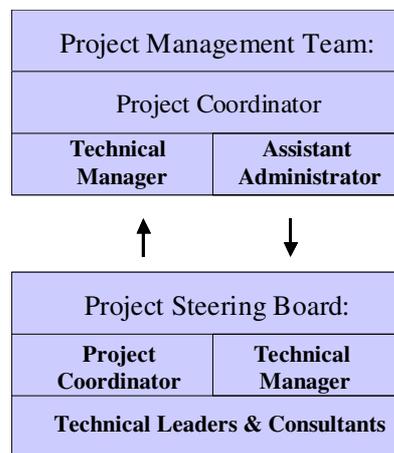
MS3	Organisation of technical workshop / special session	2		18	YES	26	Organised at GLOBECOM 2014
MS6	Identification of relevant standardisation activities	2		18	YES	18	ALBLF identified and working on the standardisation activities
MS13	Cooperative techniques with perfect CSI	4, 5		18	YES	18	Reviewed and approved by the PSB
MS14	Requirements of CSI and user-plane data exchange to balance cooperation and overhead	4, 5		18	YES	18	Reviewed and approved by the PSB
MS10	Transceiver techniques for multi user access	3, 4		20	YES	20	Reviewed and approved by the PSB
MS11	Transceiver techniques with imperfect CSI	3, 4		24	YES	24	Reviewed and approved by the PSB
MS16	ESPAR prototype design	3, 4, 5, 7		24	YES	24	Reviewed and approved by the PSB
MS17	Radio head prototype design	3, 4, 5, 7		24			Plan changed

MS18	Test procedure and methodology for aggregation network protocol verification	3, 5, 6, 7		24	YES	24	Reviewed and approved by the PSB
MS15	Specification of the Eth2CPRI gateway	3, 5, 6		27			
MS4	Participation in International forum / congress	2		30			
MS7	Suggested exploitation plan	2		30			
MS19	Demonstration Design and Setup	7		30			
MS20	Aggregation network protocol verification	3, 5, 6, 7		32			
MS5	Organisation of demo-related workshop	2		34			

## 5 Project management

The **Project Management Team (PMT)** is in charge of the day-to-day monitoring of this collaborative project and its administrative management. This includes the Project Coordinator, Dr. Ratnarajah, the scientific manager, Prof. Papadias and a part-time project administrator. The *Project Management Team* coordinates the daily operations and the timely production of deliverables and acts as liaison with IST and other EU bodies, as necessary. Tasks within project coordination are divided between the strategic management and communication issues, coordinated by Dr. Ratnarajah; technical / scientific management, co-ordinated by Prof. Papadias; and purely operational issues, handled by the project administrator. This structuring has been successful in not only avoiding any conflicts but in fact fostering multiple collaborations.

The project's management structure is schematically shown in the figure below.



**Figure 6.1: Project's management structure**

The management tasks during the period focused on tracking all defined deliverables, coordinating tasks and meetings as well as bi-monthly conference calls, providing the interface between the project and the European Commission etc. Specific consortium management tasks given below were successfully carried out.

- **Project Monitoring:** There was regular monitoring of project progress during the period by ensuring regular interaction through meetings, conference calls and email communication.

The details of the project meetings are given as follows:

Project Meeting during the period	Date	Venue
Kick-off meeting	Nov. 9, 2012	IMPERIAL, London, UK
1 <sup>nd</sup> Progress Meeting	March 18-19, 2013	ALU, Paris, France

2 <sup>rd</sup> Progress Meeting	July 15-16, 2013	EUR, Sophia Antipolis, France
3 <sup>rd</sup> Progress Meeting	Oct. 15-16, 2013	DTU, Copenhagen, Denmark
Year 1 Review	Jan. 14-15, 2014	EC, Brussels, Belgium
4 <sup>th</sup> Progress Meeting	April 1-2, 2014	AIT, Greece
5 <sup>th</sup> Progress meeting	July 7-8, 2014	UEDIN, Edinburgh
6 <sup>th</sup> Progress meeting	Oct. 13-14, 2014	ALBLF, Paris

**Table 5.1: Project Meeting Schedule**

In addition, bi-monthly tele-conferences were held regularly to discuss the progress.

Other management tasks included as following

- Consortium agreement was prepared and signed by all partners
- Work packages were synchronized so that the desired targets for the period were definitely achieved.
- Management of the knowledge and intellectual property
- Preparation of the annual project reports
- Communication with the FP7 central office of the European Commission
- Updating the work plan for the next year
- Selection of technical alternatives where required

**Achievements:** Throughout HARP' 2<sup>nd</sup> year, we pursued targeted opportunities for disseminating the project's core ideas and early results to the scientific, engineering and regulatory communities. Specific dissemination actions include:

- **Laura Cottatellucci (EURECOM)** organised a one day workshop on "Wireless Optical Networks in support of Cloud Architectures", at *IEEE Global Communications Conference (GLOBECOM)* which was held in Austin, Texas, USA on December 12, 2014. (<http://www.fp7-harp.eu/globecom-2014wonc.html>).
- **Tharmalingam Ratnarajah (UEDIN), Constantinos Papadias (AIT) and Bruno Clerckx (IMPERIAL)** will organise a one day workshop at *IEEE VTC Spring Conference* which will be held in Glasgow, UK in May, 2015. The workshop title is "Emerging MIMO Technologies in Wireless Cellular Networks (EMT5G)" (<http://www.fp7-harp.eu/vtc-spring-2015emt5g.html>).
- Stephane Senecal and Jean-Marc Kelif, delivered a talk on "HARP project", at Computation and Simulation Institute of Pierre&Marie Curie University, Paris, March 2014.
- Stephane Senecal and Jean-Marc Kelif, delivered a talk on "HARP project", at Orange internal TOOS project seminars, Paris, December 2013.

- David Gesbert, delivered a talk on “A statistical approach to interference management in large scale antenna systems”, KTH, Stockholm, March 2014.
- Laura Cottatellucci, delivered a talk on “Low complexity pilot decontamination via blind signal subspace estimation”, at CEFIPRA workshop, IISC Bangalore, January 2014.
- Mohammad Ali Sedaghat, participated Poster in IEEE Workshop on Advanced Information Processing for Wireless Communication Systems, Aalborg
- Mohammad Ali Sedaghat and Ralf Müller presented “Load Modulated Massive MIMO”, at Communication Theory Workshop 2014
- Henrik Christiansen, presented “Traffic Adaptive Base Station Management Scheme for energy-aware Mobile networks”, EUCNC conference, Bologna, June 2014
- Tharmalingam Ratnarajah, delivered a talk on “HARP project”, at Future Network and Mobile Summit, Lisbon, July 2013
- **Project Website:** A website dedicated to the HARP project has been created (<http://www.fp7-harp.eu/>) which is updated on a regular basis.
- **Project publications:** In Year 2, 4 IEEE Journal papers and 14 IEEE International Conference papers has been published and many publications have been submitted.
- **Project planning and status:** The structure of the work in Year I & II of the HARP project has closely followed the objectives set in the DoW.

The work in Year 3 of the project will focus on the development and implementation of the single and multi-point ESPAR-enabled RRH transceiver architectures. Particular focus will be placed on addressing the challenges of the implementation of single RF chain compact antenna designs in platforms compatible to down-selected scenarios and existing communication standards and solving issues such as channel estimation, channel feedback, and the transceiver designs.

## 6 Explanation of the use of the resources

Table 6.1 below shows the total person month usage in Year 1 by each partner.

	UEDIN	AIT	EUR	IMPERIAL	NTNU	DTU	RADIOCOMP	ALBLF	FT	Totals
WP1: Project Management	3 / 18	4 / 10	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	7 / 28
WP2: Dissemination Activities and Exploitation Plan	0 / 2	0 / 2	.2 / .5	0 / 4	.14 / 2	0 / 3	.23 / 13	0 / 2	2.18 / 2	2.75 / 30.5
WP3: Network requirements & fundamental limits	2 / 14	2 / 2	0 / 0	2 / 5	10.36 / 21	1 / 10	8.5 / 12	1.5 / 2	2.02 / 2	29.38 / 68
WP4: Single-point ESPAR-enabled RRH access	2 / 16	8 / 18	17.21 / 22	4 / 15	.57 / 8	0 / 0	0 / 0	0 / 0	1.43 / 9	33.21 / 88
WP5: Multi-point ESPAR-enabled RRH access	0 / 16	0 / 9	3 / 33	3.36 / 25	0.03 / 3	0 / 0	0 / 0	0 / 18	0 / 9	6.39 / 113
WP6: RRH aggregation network	0 / 6	1 / 17	0 / 0	0 / 0	0 / 0	1 / 18	4 / 17	2.9 / 18	0 / 0	8.9 / 76
WP7: Experimentation & demonstrations	0 / 6	0 / 12	0 / 0	0 / 0	0 / 1	0 / 9	2.34 / 15	2 / 18	0 / 0	4.34 / 61
<b>Totals</b>	<b>7 / 78</b>	<b>15 / 70</b>	<b>20.41 / 55.5</b>	<b>9.36 / 49</b>	<b>11.11 / 35</b>	<b>2 / 40</b>	<b>15.07 / 57</b>	<b>6.4 / 58</b>	<b>5.63 / 22</b>	<b>91.98 / 464.5</b>

**Table 6.1: Total Person Month Usage in Y1**

Table 6.2 below shows the total person month usage in Year 1 & Year 2 by each partner.

	UEDIN	AIT	EUR	IMPERIAL	NTNU	DTU	RADIOCOMP	ALBLF	FT	Totals
WP1: Project Management	5 / 18	4 / 10	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	9 / 28
WP2: Dissemination Activities and Exploitation Plan	1 / 2	0 / 2	.2 / .5	0 / 4	.14 / 2	0 / 3	.23 / 13	0 / 2	2.18 / 2	3.75 / 30.5
WP3: Network requirements & fundamental limits	4.5 / 14	2 / 2	0 / 0	2 / 5	15.91 / 21	1 / 10	8.8 / 12	2 / 2	2.02 / 2	38.23 / 68
WP4: Single-point ESPAR-enabled RRH access	14.5 / 16	18 / 18	22.21 / 22	16 / 15	8.86 / 8	0 / 0	0 / 0	0 / 0	8.85 / 9	88.42 / 88
WP5: Multi-point ESPAR-enabled RRH access	13 / 16	5 / 9	19.14 / 33	16.28 / 25	0.03 / 3	0 / 0	0 / 0	13 / 18	0.72 / 9	67.17 / 113
WP6: RRH aggregation network	0 / 6	12 / 17	0 / 0	0 / 0	0 / 0	10 / 18	13.1 / 17	11.9 / 18	0 / 0	47 / 76
WP7: Experimentation & demonstrations	0 / 6	4 / 12	0 / 0	0 / 0	0.02 / 1	1 / 9	4.14 / 15	4 / 18	0 / 0	13.16 / 61
<b>Totals</b>	<b>38 / 78</b>	<b>45 / 70</b>	<b>41.55 / 55.5</b>	<b>34.28 / 49</b>	<b>24.96 / 35</b>	<b>12 / 40</b>	<b>26.27 / 57</b>	<b>30.9 / 58</b>	<b>13.77 / 22</b>	<b>266.73 / 464.5</b>

**Table 6.2: Total Person Month Usage in Y1 & Y2**

# FP7 - Grant Agreement - Annex VI - Collaborative project

## Summary Financial report - Collaborative project

Project acronym	HARP	Project nr	318489	Reporting period from	01/11/2013	to	31/10/2014	Page	1/1
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Funding scheme		CP		Type of activity								Total		Req. EC Contrib.	Receipts	Interest
Benef. nr	If 3rd Party, linked to benef.	Adjustment (Yes/No)	Organisation Short Name	RTD (A)		Demonstration (B)		Management (C)		Other (D)		Total (A+B+C+D)				
				Total	Max EC Contrib.	Total	Max EC Contrib.	Total	Max EC Contrib.	Total	Max EC Contrib.	Total	Max EC Contrib.			
1		No	UEDIN	212,531	159,398	0	0	11,812	11,812	0	0	224,343	171,210	171,210	0	0
1		Yes (1)	UEDIN	-16	-12	0	0	0	0	0	0	-16	-12	-12	0	0
2		No	AIT	170,743	128,057	0	0	16,447	16,447	0	0	187,190	144,504	144,504	0	0
2		Yes (1)	AIT	5,203	3,902	0	0	1,893	1,893	0	0	7,096	5,795	5,795	0	0
3		No	EUR	165,328	123,996	0	0	0	0	2,037	2,037	167,365	126,033	126,033	0	0
3		Yes (1)	EUR	4,354	3,265	0	0	0	0	314	314	4,668	3,579	3,579	0	0
4		No	IMPERIAL	167,740	125,805	0	0	0	0	0	0	167,740	125,805	125,805	0	0
5		No	NTNU	170,307	127,730	54	27	1,528	1,528	0	0	171,889	129,285	129,285	0	0
6		No	DTU	168,205	126,153	0	0	0	0	0	0	168,205	126,153	126,153	0	0
6		Yes (1)	DTU	-2,053	-1,539	0	0	0	0	0	0	-2,053	-1,539	-1,539	0	0
7		No	RADIOCOMP	74,857	37,428	0	0	5,552	5,552	0	0	80,409	42,980	42,980	0	0
8		No	ALBLF	114,830	57,415	0	0	0	0	0	0	114,830	57,415	57,415	0	0
8		Yes (1)	ALBLF	2,265	1,132	0	0	0	0	0	0	2,265	1,132	1,132	0	0
9		No	FT	84,480	42,240	0	0	0	0	0	0	84,480	42,240	42,240	0	0
<b>Total</b>				<b>1,338,774</b>	<b>934,970</b>	<b>54</b>	<b>27</b>	<b>37,232</b>	<b>37,232</b>	<b>2,351</b>	<b>2,351</b>	<b>1,378,411</b>	<b>974,580</b>	<b>974,580</b>	<b>0</b>	<b>0</b>

# FP7 - Grant Agreement - Annex VI - Collaborative project

Form C - Financial Statement (to be filled in by each beneficiary)

Project Number	318489	Funding scheme	Collaborative project
Project Acronym	HARP		
Period from	01/11/2013	Is this an adjustment to a previous statement ?	No
To	31/10/2014		
Legal Name	THE UNIVERSITY OF EDINBURGH	Participant Identity Code	999974941
Organisation Short Name	UEDIN	Beneficiary nr	1
Funding % for RTD activities (A)	75.0	If flat rate for indirect costs, specify %	N/A

## 1. Declaration of eligible costs/lump sum/flat-rate/scale of unit (in €)

	Type of Activity				Total (A+B+C+D)
	RTD (A)	Demonstration (B)	Management (C)	Other (D)	
Personnel costs	110,425	0	5,071	0	115,496
Subcontracting	0	0	0	0	0
Other direct costs	26,655	0	3,483	0	30,138
Indirect costs	75,451	0	3,258	0	78,709
<b>Total costs</b>	<b>212,531</b>	<b>0</b>	<b>11,812</b>	<b>0</b>	<b>224,343</b>
Maximum EU contribution	159,398	0	11,812	0	171,210
Requested EU contribution					171,210

## 2. Declaration of receipts

Did you receive any financial transfers or contributions in kind, free of charge from third parties or did the project generate any income which could be considered a receipt according to Art.II. 17 of the grant agreement ?  
If yes, please mention the amount (in €)

No

## 3. Declaration of interest yielded by the pre-financing (to be completed only by the coordinator)

Did the pre-financing you received generate any interest according to Art.II.19 ?

If yes, please mention the amount (in €)

No

## 4. Certificate on the methodology

Do you declare average personnel costs according to Art.II.14.1 ?

Is there a certificate on the methodology provided by an independent auditor and accepted by the Commission according to Art.II.4.4 ?

No

Yes

Name of the auditor	KPMG	Cost of the certificate (in €), if charged under this project	0
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## 5. Certificate on the financial statements

Is there a certificate on the financial statements provided by an independent auditor attached to this financial statement according to Art.II.4.4 ?

No

Name of the auditor		Cost of the certificate (in €)	
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## 6. Beneficiary's declaration on its honour

We declare on our honour that:

- the costs declared above are directly related to the resources used to attain the objectives of the project and fall within the definition of eligible costs specified in Articles II.14 and II.15 of the grant agreement, and, if relevant, Annex III and Article 7 (special clauses) of the grant agreement;
- the receipts declared above are the only financial transfers or contributions in kind, free of charge, from third parties and the only income generated by the project which could be considered as receipts according to Art.II.17 of the grant agreement;
- the interest declared above is the only interest yielded by the pre-financing which falls within the definition of Art.II.19 of the grant agreement;
- there is full supporting documentation to justify the information hereby declared. It will be made available at the request of the Commission and in the event of an audit by the Commission and/or by the Court of Auditors and/or their authorised representatives.

Beneficiary's Stamp	Name of the Person(s) Authorised to sign this Financial Statement
	William Bruce
	Date & signature

# FP7 - Grant Agreement - Annex VI - Collaborative project

Form C - Financial Statement (to be filled in by each beneficiary)

Project Number	318489	Funding scheme	Collaborative project
Project Acronym	HARP		
Period from	01/11/2013	Is this an adjustment to a previous statement ?	Yes
To	31/10/2014	Adjustment relates to Period :	1
Legal Name	THE UNIVERSITY OF EDINBURGH	Participant Identity Code	999974941
Organisation Short Name	UEDIN	Beneficiary nr	1
Funding % for RTD activities (A)	75.0	If flat rate for indirect costs, specify %	N/A

## 1. Declaration of eligible costs/lump sum/flat-rate/scale of unit (in €)

	Type of Activity				Total (A+B+C+D)
	RTD (A)	Demonstration (B)	Management (C)	Other (D)	
Personnel costs	0	0	0	0	0
Subcontracting	0	0	0	0	0
Other direct costs	-16	0	0	0	-16
Indirect costs	0	0	0	0	0
Total costs	-16	0	0	0	-16
Maximum EU contribution	-12	0	0	0	-12
Requested EU contribution					-12

## 2. Declaration of receipts

Did you receive any financial transfers or contributions in kind, free of charge from third parties or did the project generate any income which could be considered a receipt according to Art.II. 17 of the grant agreement ?  
If yes, please mention the amount (in €)

No

## 3. Declaration of interest yielded by the pre-financing (to be completed only by the coordinator)

Did the pre-financing you received generate any interest according to Art.II.19 ?

If yes, please mention the amount (in €)

No

## 4. Certificate on the methodology

Do you declare average personnel costs according to Art.II.14.1 ?

Is there a certificate on the methodology provided by an independent auditor and accepted by the Commission according to Art.II.4.4 ?

No

Yes

Name of the auditor	KPMG	Cost of the certificate (in €), if charged under this project	0
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## 5. Certificate on the financial statements

Is there a certificate on the financial statements provided by an independent auditor attached to this financial statement according to Art.II.4.4 ?

No

Name of the auditor		Cost of the certificate (in €)	
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## 6. Beneficiary's declaration on its honour

We declare on our honour that:

- the costs declared above are directly related to the resources used to attain the objectives of the project and fall within the definition of eligible costs specified in Articles II.14 and II.15 of the grant agreement, and, if relevant, Annex III and Article 7 (special clauses) of the grant agreement;
- the receipts declared above are the only financial transfers or contributions in kind, free of charge, from third parties and the only income generated by the project which could be considered as receipts according to Art.II.17 of the grant agreement;
- the interest declared above is the only interest yielded by the pre-financing which falls within the definition of Art.II.19 of the grant agreement;
- there is full supporting documentation to justify the information hereby declared. It will be made available at the request of the Commission and in the event of an audit by the Commission and/or by the Court of Auditors and/or their authorised representatives.

Beneficiary's Stamp	Name of the Person(s) Authorised to sign this Financial Statement
	William Bruce
	Date & signature

# FP7 - Grant Agreement - Annex VI - Collaborative project

Form C - Financial Statement (to be filled in by each beneficiary)

Project Number	318489	Funding scheme	Collaborative project
Project Acronym	HARP		
Period from	01/11/2013	Is this an adjustment to a previous statement ?	No
To	31/10/2014		
Legal Name	RESEARCH AND EDUCATION LABORATORY IN INFORMATION TECHNOLOGIES	Participant Identity Code	999582382
Organisation Short Name	AIT	Beneficiary nr	2
Funding % for RTD activities (A)	75.0	If flat rate for indirect costs, specify %	N/A

## 1. Declaration of eligible costs/lump sum/flat-rate/scale of unit (in €)

	Type of Activity				Total (A+B+C+D)
	RTD (A)	Demonstration (B)	Management (C)	Other (D)	
Personnel costs	103,862	0	10,216	0	114,078
Subcontracting	0	0	0	0	0
Other direct costs	3,525	0	0	0	3,525
Indirect costs	63,356	0	6,231	0	69,587
<b>Total costs</b>	<b>170,743</b>	<b>0</b>	<b>16,447</b>	<b>0</b>	<b>187,190</b>
Maximum EU contribution	128,057	0	16,447	0	144,504
Requested EU contribution					144,504

## 2. Declaration of receipts

Did you receive any financial transfers or contributions in kind, free of charge from third parties or did the project generate any income which could be considered a receipt according to Art.II. 17 of the grant agreement ?  
If yes, please mention the amount (in €)

No

## 4. Certificate on the methodology

Do you declare average personnel costs according to Art.II.14.1 ?

No

Is there a certificate on the methodology provided by an independent auditor and accepted by the Commission according to Art.II.4.4 ?

No

Name of the auditor		Cost of the certificate (in €), if charged under this project	
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## . Certificate on the financial statements

Is there a certificate on the financial statements provided by an independent auditor attached to this financial statement according to Art.II.4.4 ?

No

Name of the auditor		Cost of the certificate (in €)	
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## 6. Beneficiary's declaration on its honour

We declare on our honour that:

- the costs declared above are directly related to the resources used to attain the objectives of the project and fall within the definition of eligible costs specified in Articles II.14 and II.15 of the grant agreement, and, if relevant, Annex III and Article 7 (special clauses) of the grant agreement;
- the receipts declared above are the only financial transfers or contributions in kind, free of charge, from third parties and the only income generated by the project which could be considered as receipts according to Art.II.17 of the grant agreement;
- the interest declared above is the only interest yielded by the pre-financing which falls within the definition of Art.II.19 of the grant agreement;
- there is full supporting documentation to justify the information hereby declared. It will be made available at the request of the Commission and in the event of an audit by the Commission and/or by the Court of Auditors and/or their authorised representatives.

Beneficiary's Stamp	Name of the Person(s) Authorised to sign this Financial Statement
	DIDOE PREVEDOUROU
	Date & signature

# FP7 - Grant Agreement - Annex VI - Collaborative project

Form C - Financial Statement (to be filled in by each beneficiary)

Project Number	318489	Funding scheme	Collaborative project
Project Acronym	HARP		
Period from	01/11/2013	Is this an adjustment to a previous statement ?	Yes
To	31/10/2014	Adjustment relates to Period :	1
Legal Name	RESEARCH AND EDUCATION LABORATORY IN INFORMATION TECHNOLOGIES	Participant Identity Code	999582382
Organisation Short Name	AIT	Beneficiary nr	2
Funding % for RTD activities (A)	75.0	If flat rate for indirect costs, specify %	N/A

## 1. Declaration of eligible costs/lump sum/flat-rate/scale of unit (in €)

	Type of Activity				Total (A+B+C+D)
	RTD (A)	Demonstration (B)	Management (C)	Other (D)	
Personnel costs	4,355	0	1,584	0	5,939
Subcontracting	0	0	0	0	0
Other direct costs	0	0	0	0	0
Indirect costs	848	0	309	0	1,157
<b>Total costs</b>	<b>5,203</b>	<b>0</b>	<b>1,893</b>	<b>0</b>	<b>7,096</b>
Maximum EU contribution	3,902	0	1,893	0	5,795
Requested EU contribution					5,795

## 2. Declaration of receipts

Did you receive any financial transfers or contributions in kind, free of charge from third parties or did the project generate any income which could be considered a receipt according to Art.II. 17 of the grant agreement ?  
If yes, please mention the amount (in €)

No

## 4. Certificate on the methodology

Do you declare average personnel costs according to Art.II.14.1 ?

No

Is there a certificate on the methodology provided by an independent auditor and accepted by the Commission according to Art.II.4.4 ?

No

Name of the auditor		Cost of the certificate (in €), if charged under this project	
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## . Certificate on the financial statements

Is there a certificate on the financial statements provided by an independent auditor attached to this financial statement according to Art.II.4.4 ?

No

Name of the auditor		Cost of the certificate (in €)	
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## 6. Beneficiary's declaration on its honour

We declare on our honour that:

- the costs declared above are directly related to the resources used to attain the objectives of the project and fall within the definition of eligible costs specified in Articles II.14 and II.15 of the grant agreement, and, if relevant, Annex III and Article 7 (special clauses) of the grant agreement;
- the receipts declared above are the only financial transfers or contributions in kind, free of charge, from third parties and the only income generated by the project which could be considered as receipts according to Art.II.17 of the grant agreement;
- the interest declared above is the only interest yielded by the pre-financing which falls within the definition of Art.II.19 of the grant agreement;
- there is full supporting documentation to justify the information hereby declared. It will be made available at the request of the Commission and in the event of an audit by the Commission and/or by the Court of Auditors and/or their authorised representatives.

Beneficiary's Stamp	Name of the Person(s) Authorised to sign this Financial Statement
	DIDOE PREVEDOUROU
	Date & signature

# FP7 - Grant Agreement - Annex VI - Collaborative project

Form C - Financial Statement (to be filled in by each beneficiary)

Project Number	318489	Funding scheme	Collaborative project
Project Acronym	HARP		
Period from	01/11/2013	Is this an adjustment to a previous statement ?	No
To	31/10/2014		
Legal Name	EURECOM	Participant Identity Code	999606147
Organisation Short Name	EUR	Beneficiary nr	3
Funding % for RTD activities (A)	75.0	If flat rate for indirect costs, specify %	N/A

## 1. Declaration of eligible costs/lump sum/flat-rate/scale of unit (in €)

	Type of Activity				Total (A+B+C+D)
	RTD (A)	Demonstration (B)	Management (C)	Other (D)	
Personnel costs	99,635	0	0	1,273	100,908
Subcontracting	0	0	0	0	0
Other direct costs	5,789	0	0	0	5,789
Indirect costs	59,904	0	0	764	60,668
<b>Total costs</b>	<b>165,328</b>	<b>0</b>	<b>0</b>	<b>2,037</b>	<b>167,365</b>
Maximum EU contribution	123,996	0	0	2,037	126,033
Requested EU contribution					126,033

## 2. Declaration of receipts

Did you receive any financial transfers or contributions in kind, free of charge from third parties or did the project generate any income which could be considered a receipt according to Art.II. 17 of the grant agreement ?  
If yes, please mention the amount (in €)

No
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## 4. Certificate on the methodology

Do you declare average personnel costs according to Art.II.14.1 ?

No
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Is there a certificate on the methodology provided by an independent auditor and accepted by the Commission according to Art.II.4.4 ?

No
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Name of the auditor		Cost of the certificate (in €), if charged under this project	
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## . Certificate on the financial statements

Is there a certificate on the financial statements provided by an independent auditor attached to this financial statement according to Art.II.4.4 ?

No
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Name of the auditor		Cost of the certificate (in €)	
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## 6. Beneficiary's declaration on its honour

We declare on our honour that:

- the costs declared above are directly related to the resources used to attain the objectives of the project and fall within the definition of eligible costs specified in Articles II.14 and II.15 of the grant agreement, and, if relevant, Annex III and Article 7 (special clauses) of the grant agreement;
- the receipts declared above are the only financial transfers or contributions in kind, free of charge, from third parties and the only income generated by the project which could be considered as receipts according to Art.II.17 of the grant agreement;
- the interest declared above is the only interest yielded by the pre-financing which falls within the definition of Art.II.19 of the grant agreement;
- there is full supporting documentation to justify the information hereby declared. It will be made available at the request of the Commission and in the event of an audit by the Commission and/or by the Court of Auditors and/or their authorised representatives.

Beneficiary's Stamp	Name of the Person(s) Authorised to sign this Financial Statement
	Thierry BONARDI
	Date & signature

# FP7 - Grant Agreement - Annex VI - Collaborative project

Form C - Financial Statement (to be filled in by each beneficiary)

Project Number	318489	Funding scheme	Collaborative project
Project Acronym	HARP		
Period from	01/11/2013	Is this an adjustment to a previous statement ?	Yes
To	31/10/2014	Adjustment relates to Period :	1
Legal Name	EURECOM	Participant Identity Code	999606147
Organisation Short Name	EUR	Beneficiary nr	3
Funding % for RTD activities (A)	75.0	If flat rate for indirect costs, specify %	N/A

## 1. Declaration of eligible costs/lump sum/flat-rate/scale of unit (in €)

	Type of Activity				Total (A+B+C+D)
	RTD (A)	Demonstration (B)	Management (C)	Other (D)	
Personnel costs	2,535	0	0	195	2,730
Subcontracting	0	0	0	0	0
Other direct costs	283	0	0	0	283
Indirect costs	1,536	0	0	119	1,655
<b>Total costs</b>	<b>4,354</b>	<b>0</b>	<b>0</b>	<b>314</b>	<b>4,668</b>
Maximum EU contribution	3,265	0	0	314	3,579
Requested EU contribution					3,579

## 2. Declaration of receipts

Did you receive any financial transfers or contributions in kind, free of charge from third parties or did the project generate any income which could be considered a receipt according to Art.II. 17 of the grant agreement ?  
If yes, please mention the amount (in €)

No

## 4. Certificate on the methodology

Do you declare average personnel costs according to Art.II.14.1 ?

No

Is there a certificate on the methodology provided by an independent auditor and accepted by the Commission according to Art.II.4.4 ?

No

Name of the auditor		Cost of the certificate (in €), if charged under this project	
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## . Certificate on the financial statements

Is there a certificate on the financial statements provided by an independent auditor attached to this financial statement according to Art.II.4.4 ?

No

Name of the auditor		Cost of the certificate (in €)	
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## 6. Beneficiary's declaration on its honour

We declare on our honour that:

- the costs declared above are directly related to the resources used to attain the objectives of the project and fall within the definition of eligible costs specified in Articles II.14 and II.15 of the grant agreement, and, if relevant, Annex III and Article 7 (special clauses) of the grant agreement;
- the receipts declared above are the only financial transfers or contributions in kind, free of charge, from third parties and the only income generated by the project which could be considered as receipts according to Art.II.17 of the grant agreement;
- the interest declared above is the only interest yielded by the pre-financing which falls within the definition of Art.II.19 of the grant agreement;
- there is full supporting documentation to justify the information hereby declared. It will be made available at the request of the Commission and in the event of an audit by the Commission and/or by the Court of Auditors and/or their authorised representatives.

Beneficiary's Stamp	Name of the Person(s) Authorised to sign this Financial Statement
	Thierry BONARDI
	Date & signature

# FP7 - Grant Agreement - Annex VI - Collaborative project

Form C - Financial Statement (to be filled in by each beneficiary)

Project Number	318489	Funding scheme	Collaborative project
Project Acronym	HARP		
Period from	01/11/2013	Is this an adjustment to a previous statement ?	No
To	31/10/2014		
Legal Name	IMPERIAL COLLEGE OF SCIENCE, TECHNOLOGY AND MEDICINE	Participant Identity Code	999993468
Organisation Short Name	IMPERIAL	Beneficiary nr	4
Funding % for RTD activities (A)	75.0	If flat rate for indirect costs, specify %	60

## 1. Declaration of eligible costs/lump sum/flat-rate/scale of unit (in €)

	Type of Activity				Total (A+B+C+D)
	RTD (A)	Demonstration (B)	Management (C)	Other (D)	
Personnel costs	98,019	0	0	0	98,019
Subcontracting	0	0	0	0	0
Other direct costs	6,819	0	0	0	6,819
Indirect costs	62,902	0	0	0	62,902
<b>Total costs</b>	<b>167,740</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>167,740</b>
Maximum EU contribution	125,805	0	0	0	125,805
Requested EU contribution					125,805

## 2. Declaration of receipts

Did you receive any financial transfers or contributions in kind, free of charge from third parties or did the project generate any income which could be considered a receipt according to Art.II. 17 of the grant agreement ?

If yes, please mention the amount (in €)

No

## 4. Certificate on the methodology

Do you declare average personnel costs according to Art.II.14.1 ?

Is there a certificate on the methodology provided by an independent auditor and accepted by the Commission according to Art.II.4.4 ?

No

No

Name of the auditor		Cost of the certificate (in €), if charged under this project	
---------------------	--	---	--

## . Certificate on the financial statements

Is there a certificate on the financial statements provided by an independent auditor attached to this financial statement according to Art.II.4.4 ?

No

Name of the auditor		Cost of the certificate (in €)	
---------------------	--	--------------------------------	--

## 6. Beneficiary's declaration on its honour

We declare on our honour that:

- the costs declared above are directly related to the resources used to attain the objectives of the project and fall within the definition of eligible costs specified in Articles II.14 and II.15 of the grant agreement, and, if relevant, Annex III and Article 7 (special clauses) of the grant agreement;
- the receipts declared above are the only financial transfers or contributions in kind, free of charge, from third parties and the only income generated by the project which could be considered as receipts according to Art.II.17 of the grant agreement;
- the interest declared above is the only interest yielded by the pre-financing which falls within the definition of Art.II.19 of the grant agreement;
- there is full supporting documentation to justify the information hereby declared. It will be made available at the request of the Commission and in the event of an audit by the Commission and/or by the Court of Auditors and/or their authorised representatives.

Beneficiary's Stamp	Name of the Person(s) Authorised to sign this Financial Statement
	Mr Shaun Power
	Date & signature

# FP7 - Grant Agreement - Annex VI - Collaborative project

Form C - Financial Statement (to be filled in by each beneficiary)

Project Number	318489	Funding scheme	Collaborative project
Project Acronym	HARP		
Period from	01/11/2013	Is this an adjustment to a previous statement ?	No
To	31/10/2014		
Legal Name	NORGES TEKNISK-NATURVITENSKAPELIGE UNIVERSITET NTNU	Participant Identity Code	999977851
Organisation Short Name	NTNU	Beneficiary nr	5
Funding % for RTD activities (A)	75.0	If flat rate for indirect costs, specify %	60

## 1. Declaration of eligible costs/lump sum/flat-rate/scale of unit (in €)

	Type of Activity				Total (A+B+C+D)
	RTD (A)	Demonstration (B)	Management (C)	Other (D)	
Personnel costs	88,576	34	955	0	89,565
Subcontracting	0	0	0	0	0
Other direct costs	17,866	0	0	0	17,866
Indirect costs	63,865	20	573	0	64,458
<b>Total costs</b>	<b>170,307</b>	<b>54</b>	<b>1,528</b>	<b>0</b>	<b>171,889</b>
Maximum EU contribution	127,730	27	1,528	0	129,285
Requested EU contribution					129,285

## 2. Declaration of receipts

Did you receive any financial transfers or contributions in kind, free of charge from third parties or did the project generate any income which could be considered a receipt according to Art.II. 17 of the grant agreement ?

If yes, please mention the amount (in €)

No

## 4. Certificate on the methodology

Do you declare average personnel costs according to Art.II.14.1 ?

Is there a certificate on the methodology provided by an independent auditor and accepted by the Commission according to Art.II.4.4 ?

No

No

Name of the auditor		Cost of the certificate (in €), if charged under this project	
---------------------	--	---	--

## . Certificate on the financial statements

Is there a certificate on the financial statements provided by an independent auditor attached to this financial statement according to Art.II.4.4 ?

No

Name of the auditor		Cost of the certificate (in €)	
---------------------	--	--------------------------------	--

## 6. Beneficiary's declaration on its honour

We declare on our honour that:

- the costs declared above are directly related to the resources used to attain the objectives of the project and fall within the definition of eligible costs specified in Articles II.14 and II.15 of the grant agreement, and, if relevant, Annex III and Article 7 (special clauses) of the grant agreement;
- the receipts declared above are the only financial transfers or contributions in kind, free of charge, from third parties and the only income generated by the project which could be considered as receipts according to Art.II.17 of the grant agreement;
- the interest declared above is the only interest yielded by the pre-financing which falls within the definition of Art.II.19 of the grant agreement;
- there is full supporting documentation to justify the information hereby declared. It will be made available at the request of the Commission and in the event of an audit by the Commission and/or by the Court of Auditors and/or their authorised representatives.

Beneficiary's Stamp	Name of the Person(s) Authorised to sign this Financial Statement
	Andreas Vatne Ellefsen
	Date & signature

# FP7 - Grant Agreement - Annex VI - Collaborative project

Form C - Financial Statement (to be filled in by each beneficiary)

Project Number	318489	Funding scheme	Collaborative project
Project Acronym	HARP		
Period from	01/11/2013	Is this an adjustment to a previous statement ?	No
To	31/10/2014		
Legal Name	DANMARKS TEKNISKE UNIVERSITET	Participant Identity Code	999990655
Organisation Short Name	DTU	Beneficiary nr	6
Funding % for RTD activities (A)	75.0	If flat rate for indirect costs, specify %	N/A

## 1. Declaration of eligible costs/lump sum/flat-rate/scale of unit (in €)

	Type of Activity				Total (A+B+C+D)
	RTD (A)	Demonstration (B)	Management (C)	Other (D)	
Personnel costs	73,022	0	0	0	73,022
Subcontracting	0	0	0	0	0
Other direct costs	22,161	0	0	0	22,161
Indirect costs	73,022	0	0	0	73,022
<b>Total costs</b>	<b>168,205</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>168,205</b>
Maximum EU contribution	126,153	0	0	0	126,153
Requested EU contribution					126,153

## 2. Declaration of receipts

Did you receive any financial transfers or contributions in kind, free of charge from third parties or did the project generate any income which could be considered a receipt according to Art.II. 17 of the grant agreement ?  
If yes, please mention the amount (in €)

No

## 4. Certificate on the methodology

Do you declare average personnel costs according to Art.II.14.1 ?

No

Is there a certificate on the methodology provided by an independent auditor and accepted by the Commission according to Art.II.4.4 ?

No

Name of the auditor		Cost of the certificate (in €), if charged under this project	
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## . Certificate on the financial statements

Is there a certificate on the financial statements provided by an independent auditor attached to this financial statement according to Art.II.4.4 ?

No

Name of the auditor		Cost of the certificate (in €)	
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## 6. Beneficiary's declaration on its honour

We declare on our honour that:

- the costs declared above are directly related to the resources used to attain the objectives of the project and fall within the definition of eligible costs specified in Articles II.14 and II.15 of the grant agreement, and, if relevant, Annex III and Article 7 (special clauses) of the grant agreement;
- the receipts declared above are the only financial transfers or contributions in kind, free of charge, from third parties and the only income generated by the project which could be considered as receipts according to Art.II.17 of the grant agreement;
- the interest declared above is the only interest yielded by the pre-financing which falls within the definition of Art.II.19 of the grant agreement;
- there is full supporting documentation to justify the information hereby declared. It will be made available at the request of the Commission and in the event of an audit by the Commission and/or by the Court of Auditors and/or their authorised representatives.

Beneficiary's Stamp	Name of the Person(s) Authorised to sign this Financial Statement
	Minna Dahl Nielsen
	Date & signature

# FP7 - Grant Agreement - Annex VI - Collaborative project

Form C - Financial Statement (to be filled in by each beneficiary)

Project Number	318489	Funding scheme	Collaborative project
Project Acronym	HARP		
Period from	01/11/2013	Is this an adjustment to a previous statement ?	Yes
To	31/10/2014	Adjustment relates to Period :	1
Legal Name	DANMARKS TEKNISKE UNIVERSITET	Participant Identity Code	999990655
Organisation Short Name	DTU	Beneficiary nr	6
Funding % for RTD activities (A)	75.0	If flat rate for indirect costs, specify %	N/A

## 1. Declaration of eligible costs/lump sum/flat-rate/scale of unit (in €)

	Type of Activity				Total (A+B+C+D)
	RTD (A)	Demonstration (B)	Management (C)	Other (D)	
Personnel costs	0	0	0	0	0
Subcontracting	0	0	0	0	0
Other direct costs	0	0	0	0	0
Indirect costs	-2,053	0	0	0	-2,053
Total costs	-2,053	0	0	0	-2,053
Maximum EU contribution	-1,539	0	0	0	-1,539
Requested EU contribution					-1,539

## 2. Declaration of receipts

Did you receive any financial transfers or contributions in kind, free of charge from third parties or did the project generate any income which could be considered a receipt according to Art.II. 17 of the grant agreement ?

If yes, please mention the amount (in €)

No

## 4. Certificate on the methodology

Do you declare average personnel costs according to Art.II.14.1 ?

Is there a certificate on the methodology provided by an independent auditor and accepted by the Commission according to Art.II.4.4 ?

No

No

Name of the auditor		Cost of the certificate (in €), if charged under this project	
---------------------	--	---	--

## . Certificate on the financial statements

Is there a certificate on the financial statements provided by an independent auditor attached to this financial statement according to Art.II.4.4 ?

No

Name of the auditor		Cost of the certificate (in €)	
---------------------	--	--------------------------------	--

## 6. Beneficiary's declaration on its honour

We declare on our honour that:

- the costs declared above are directly related to the resources used to attain the objectives of the project and fall within the definition of eligible costs specified in Articles II.14 and II.15 of the grant agreement, and, if relevant, Annex III and Article 7 (special clauses) of the grant agreement;
- the receipts declared above are the only financial transfers or contributions in kind, free of charge, from third parties and the only income generated by the project which could be considered as receipts according to Art.II.17 of the grant agreement;
- the interest declared above is the only interest yielded by the pre-financing which falls within the definition of Art.II.19 of the grant agreement;
- there is full supporting documentation to justify the information hereby declared. It will be made available at the request of the Commission and in the event of an audit by the Commission and/or by the Court of Auditors and/or their authorised representatives.

Beneficiary's Stamp	Name of the Person(s) Authorised to sign this Financial Statement
	Minna Nielsen
	Date & signature

# FP7 - Grant Agreement - Annex VI - Collaborative project

Form C - Financial Statement (to be filled in by each beneficiary)

Project Number	318489	Funding scheme	Collaborative project
Project Acronym	HARP		
Period from	01/11/2013	Is this an adjustment to a previous statement ?	No
To	31/10/2014		
Legal Name	RADIOCOMP APS	Participant Identity Code	956130359
Organisation Short Name	RADIOCOMP	Beneficiary nr	7
Funding % for RTD activities (A)	50.0	If flat rate for indirect costs, specify %	N/A

## 1. Declaration of eligible costs/lump sum/flat-rate/scale of unit (in €)

	Type of Activity				Total (A+B+C+D)
	RTD (A)	Demonstration (B)	Management (C)	Other (D)	
Personnel costs	59,841	0	5,552	0	65,393
Subcontracting	0	0	0	0	0
Other direct costs	3,819	0	0	0	3,819
Indirect costs	11,197	0	0	0	11,197
<b>Total costs</b>	<b>74,857</b>	<b>0</b>	<b>5,552</b>	<b>0</b>	<b>80,409</b>
Maximum EU contribution	37,428	0	5,552	0	42,980
Requested EU contribution					42,980

## 2. Declaration of receipts

Did you receive any financial transfers or contributions in kind, free of charge from third parties or did the project generate any income which could be considered a receipt according to Art.II. 17 of the grant agreement ?  
If yes, please mention the amount (in €)

No

## 4. Certificate on the methodology

Do you declare average personnel costs according to Art.II.14.1 ?

Yes

Is there a certificate on the methodology provided by an independent auditor and accepted by the Commission according to Art.II.4.4 ?

No

Name of the auditor		Cost of the certificate (in €), if charged under this project	
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## . Certificate on the financial statements

Is there a certificate on the financial statements provided by an independent auditor attached to this financial statement according to Art.II.4.4 ?

No

Name of the auditor		Cost of the certificate (in €)	
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## 6. Beneficiary's declaration on its honour

We declare on our honour that:

- the costs declared above are directly related to the resources used to attain the objectives of the project and fall within the definition of eligible costs specified in Articles II.14 and II.15 of the grant agreement, and, if relevant, Annex III and Article 7 (special clauses) of the grant agreement;
- the receipts declared above are the only financial transfers or contributions in kind, free of charge, from third parties and the only income generated by the project which could be considered as receipts according to Art.II.17 of the grant agreement;
- the interest declared above is the only interest yielded by the pre-financing which falls within the definition of Art.II.19 of the grant agreement;
- there is full supporting documentation to justify the information hereby declared. It will be made available at the request of the Commission and in the event of an audit by the Commission and/or by the Court of Auditors and/or their authorised representatives.

Beneficiary's Stamp	Name of the Person(s) Authorised to sign this Financial Statement
	Janne Erwolter
	Date & signature

# FP7 - Grant Agreement - Annex VI - Collaborative project

Form C - Financial Statement (to be filled in by each beneficiary)

Project Number	318489	Funding scheme	Collaborative project
Project Acronym	HARP		
Period from	01/11/2013	Is this an adjustment to a previous statement ?	No
To	31/10/2014		
Legal Name	ALCATEL - LUCENT BELL LABS FRANCE	Participant Identity Code	996377696
Organisation Short Name	ALBLF	Beneficiary nr	8
Funding % for RTD activities (A)	50.0	If flat rate for indirect costs, specify %	N/A

## 1. Declaration of eligible costs/lump sum/flat-rate/scale of unit (in €)

	Type of Activity				Total (A+B+C+D)
	RTD (A)	Demonstration (B)	Management (C)	Other (D)	
Personnel costs	77,476	0	0	0	77,476
Subcontracting	0	0	0	0	0
Other direct costs	1,280	0	0	0	1,280
Indirect costs	36,074	0	0	0	36,074
<b>Total costs</b>	<b>114,830</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>114,830</b>
Maximum EU contribution	57,415	0	0	0	57,415
Requested EU contribution					57,415

## 2. Declaration of receipts

Did you receive any financial transfers or contributions in kind, free of charge from third parties or did the project generate any income which could be considered a receipt according to Art.II. 17 of the grant agreement ?

If yes, please mention the amount (in €)

No

## 4. Certificate on the methodology

Do you declare average personnel costs according to Art.II.14.1 ?

Is there a certificate on the methodology provided by an independent auditor and accepted by the Commission according to Art.II.4.4 ?

No

No

Name of the auditor		Cost of the certificate (in €), if charged under this project	
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## . Certificate on the financial statements

Is there a certificate on the financial statements provided by an independent auditor attached to this financial statement according to Art.II.4.4 ?

No

Name of the auditor		Cost of the certificate (in €)	
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## 6. Beneficiary's declaration on its honour

We declare on our honour that:

- the costs declared above are directly related to the resources used to attain the objectives of the project and fall within the definition of eligible costs specified in Articles II.14 and II.15 of the grant agreement, and, if relevant, Annex III and Article 7 (special clauses) of the grant agreement;
- the receipts declared above are the only financial transfers or contributions in kind, free of charge, from third parties and the only income generated by the project which could be considered as receipts according to Art.II.17 of the grant agreement;
- the interest declared above is the only interest yielded by the pre-financing which falls within the definition of Art.II.19 of the grant agreement;
- there is full supporting documentation to justify the information hereby declared. It will be made available at the request of the Commission and in the event of an audit by the Commission and/or by the Court of Auditors and/or their authorised representatives.

Beneficiary's Stamp	Name of the Person(s) Authorised to sign this Financial Statement
	D.JONQUAIS
	Date & signature

# FP7 - Grant Agreement - Annex VI - Collaborative project

Form C - Financial Statement (to be filled in by each beneficiary)

Project Number	318489	Funding scheme	Collaborative project
Project Acronym	HARP		
Period from	01/11/2013	Is this an adjustment to a previous statement ?	Yes
To	31/10/2014	Adjustment relates to Period :	1
Legal Name	ALCATEL - LUCENT BELL LABS FRANCE	Participant Identity Code	996377696
Organisation Short Name	ALBLF	Beneficiary nr	8
Funding % for RTD activities (A)	50.0	If flat rate for indirect costs, specify %	N/A

## 1. Declaration of eligible costs/lump sum/flat-rate/scale of unit (in €)

	Type of Activity				Total (A+B+C+D)
	RTD (A)	Demonstration (B)	Management (C)	Other (D)	
Personnel costs	0	0	0	0	0
Subcontracting	0	0	0	0	0
Other direct costs	0	0	0	0	0
Indirect costs	2,265	0	0	0	2,265
<b>Total costs</b>	<b>2,265</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>2,265</b>
Maximum EU contribution	1,132	0	0	0	1,132
Requested EU contribution					1,132

## 2. Declaration of receipts

Did you receive any financial transfers or contributions in kind, free of charge from third parties or did the project generate any income which could be considered a receipt according to Art.II. 17 of the grant agreement ?  
If yes, please mention the amount (in €)

No
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## 4. Certificate on the methodology

Do you declare average personnel costs according to Art.II.14.1 ?

No
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Is there a certificate on the methodology provided by an independent auditor and accepted by the Commission according to Art.II.4.4 ?

No
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Name of the auditor	Cost of the certificate (in €), if charged under this project
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## . Certificate on the financial statements

Is there a certificate on the financial statements provided by an independent auditor attached to this financial statement according to Art.II.4.4 ?

No
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Name of the auditor	Cost of the certificate (in €)
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## 6. Beneficiary's declaration on its honour

We declare on our honour that:

- the costs declared above are directly related to the resources used to attain the objectives of the project and fall within the definition of eligible costs specified in Articles II.14 and II.15 of the grant agreement, and, if relevant, Annex III and Article 7 (special clauses) of the grant agreement;
- the receipts declared above are the only financial transfers or contributions in kind, free of charge, from third parties and the only income generated by the project which could be considered as receipts according to Art.II.17 of the grant agreement;
- the interest declared above is the only interest yielded by the pre-financing which falls within the definition of Art.II.19 of the grant agreement;
- there is full supporting documentation to justify the information hereby declared. It will be made available at the request of the Commission and in the event of an audit by the Commission and/or by the Court of Auditors and/or their authorised representatives.

Beneficiary's Stamp	Name of the Person(s) Authorised to sign this Financial Statement
	D.JONQUAIS
	Date & signature

# FP7 - Grant Agreement - Annex VI - Collaborative project

Form C - Financial Statement (to be filled in by each beneficiary)

Project Number	318489	Funding scheme	Collaborative project
Project Acronym	HARP		
Period from	01/11/2013	Is this an adjustment to a previous statement ?	No
To	31/10/2014		
Legal Name	ORANGE SA	Participant Identity Code	999908981
Organisation Short Name	FT	Beneficiary nr	9
Funding % for RTD activities (A)	50.0	If flat rate for indirect costs, specify %	N/A

## 1. Declaration of eligible costs/lump sum/flat-rate/scale of unit (in €)

	Type of Activity				Total (A+B+C+D)
	RTD (A)	Demonstration (B)	Management (C)	Other (D)	
Personnel costs	52,597	0	0	0	52,597
Subcontracting	0	0	0	0	0
Other direct costs	1,903	0	0	0	1,903
Indirect costs	29,980	0	0	0	29,980
Total costs	84,480	0	0	0	84,480
Maximum EU contribution	42,240	0	0	0	42,240
Requested EU contribution					42,240

## 2. Declaration of receipts

Did you receive any financial transfers or contributions in kind, free of charge from third parties or did the project generate any income which could be considered a receipt according to Art.II. 17 of the grant agreement ?

If yes, please mention the amount (in €)

No

## 4. Certificate on the methodology

Do you declare average personnel costs according to Art.II.14.1 ?

Is there a certificate on the methodology provided by an independent auditor and accepted by the Commission according to Art.II.4.4 ?

No

No

Name of the auditor		Cost of the certificate (in €), if charged under this project	
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## . Certificate on the financial statements

Is there a certificate on the financial statements provided by an independent auditor attached to this financial statement according to Art.II.4.4 ?

No

Name of the auditor		Cost of the certificate (in €)	
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## 6. Beneficiary's declaration on its honour

We declare on our honour that:

- the costs declared above are directly related to the resources used to attain the objectives of the project and fall within the definition of eligible costs specified in Articles II.14 and II.15 of the grant agreement, and, if relevant, Annex III and Article 7 (special clauses) of the grant agreement;
- the receipts declared above are the only financial transfers or contributions in kind, free of charge, from third parties and the only income generated by the project which could be considered as receipts according to Art.II.17 of the grant agreement;
- the interest declared above is the only interest yielded by the pre-financing which falls within the definition of Art.II.19 of the grant agreement;
- there is full supporting documentation to justify the information hereby declared. It will be made available at the request of the Commission and in the event of an audit by the Commission and/or by the Court of Auditors and/or their authorised representatives.

Beneficiary's Stamp	Name of the Person(s) Authorised to sign this Financial Statement
	Nicolas DEMASSIEUX
	Date & signature