Vetenskapsrådet

Application

2015-03-31

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Information about applicant

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Project site: Data- och informationsteknik, inst för

Information about application

Call name: Forskningsbidrag Stora utlysningen 2015 (Naturvetenskap och teknikvetenskap)

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Focus: Fri

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Project title (english): "Integration of Proposed Transmission Protocols for Phantom Cells in 5G/LTE Networks" "Creating a Smart Network that is Flexible and Robust"

Project start: 2016-01-01

Project end: 2017-12-31

Review panel applied for: NT-13, NT-14, NT-2

Classification code: 20204. Telekommunikation, 20203. Kommunikationssystem

Keywords: 5G, Interference, MIMO

Funds applied for

Year:	2016	2017
Amount:	0	0

Descriptive data

Project info

Project title (Swedish)*

"Integration av föreslagna överföringsprotokoll för Phantom Celler i 5G / LTE-nätverk" "Skapa en Smart Network som är flexibel och robust"

Project title (English)*

“Integration of Proposed Transmission Protocols for Phantom Cells in 5G/LTE Networks” “Creating a Smart Network that is Flexible and Robust”

Abstract (English)*

In this proposal we aim to design a new framework for network architecture of future 5G/LTE wireless networks, including different transmission protocols. The proposed design is based on performance analysis of ‘Phantom Cell’ classification of 5G/LTE networks. The splitting plane classification i.e. C/U-plane makes it very interesting and ultra efficient in terms of resource allocation purpose. 5G wireless networks give a promising solution for the future wireless communication by exploiting high speed, higher capacity and much efficient systems. The key potential technologies for further spectrum efficiency enhancements include Massive MIMO/beam-forming, receiver interference cancellation, and dynamic TDD, and for integrating local area with wide area assuming the frequency-separated scenario using the proposed macro-assisted small cell that is termed as a ‘Phantom cell’. This proposal includes the implementation of the proposed protocols in order to mitigate interference issues in the 5G network for phantom cells, the resource allocation and optimization problem in order to make design more efficient.

Popular scientific description (Swedish)*

I detta förslag vill vi utforma en ny ram för nätverksarkitektur för framtida trådlösa 5G / LTE-nät, inklusive olika överföringsprotokoll. Den föreslagna konstruktionen är baserad på resultatanalys av "Phantom Cell" klassificering av 5G / LTE-nät. Klyvningen planet klassificering dvs C / U-planet gör det mycket intressant och ultra effektiv när det gäller resursfördelningen ändamål. 5G trådlösa nätverk ger en lovande lösning för framtiden trådlös kommunikation genom att utnyttja höghastighets, högre kapacitet och mycket effektiva system. De viktigaste potentiella tekniker för ytterligare spektrum effektiviseringar inkluderar Massive MIMO / balk bildande, mottagare störningsupphävning och dynamisk TDD, och för att integrera lokalt med stort område förutsatt frekvensseparerade scenario med den föreslagna makro assisterad småcellig som benämns som en "Phantom cell". Förslaget omfattar genomförandet av de föreslagna protokollen för att lindra störningsproblem i 5G nätverk för fantomceller, resursallokeringen och optimeringsproblem för att göra designen mer effektiv.

Project period

Number of project years*

2

Calculated project time*

2016-01-01 - 2017-12-31

Classifications

Select a minimum of one and a maximum of three SCB-codes in order of priority.

Select the SCB-code in three levels and then click the lower plus-button to save your selection.

SCB-codes*

2. Teknik > 202. Elektroteknik och elektronik > 20204. Telekommunikation

2. Teknik > 202. Elektroteknik och elektronik > 20203. Kommunikationssystem

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Enter a minimum of three, and up to five, short keywords that describe your project.

Keyword 1*

5G

Keyword 2*

Interference

Keyword 3*

MIMO

Keyword 4

Keyword 5

Research plan

Ethical considerations

Specify any ethical issues that the project (or equivalent) raises, and describe how they will be addressed in your research. Also indicate the specific considerations that might be relevant to your application.

Reporting of ethical considerations*

-

The project includes handling of personal data

No

The project includes animal experiments

No

Account of experiments on humans

No

Research plan

Post-Doc Research Proposal

"Integration of Proposed Transmission Protocols for Phantom Cells in 5G/LTE Networks"

"Creating a Smart Network that is Flexible and Robust"

Author
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Abstract

In this proposal we aim to design a new framework for network architecture of future 5G/LTE wireless networks, including different transmission protocols. The proposed design is based on performance analysis of 'Phantom Cell' classification of 5G/LTE networks. The splitting plane classification i.e. C/U-plane makes it very interesting and ultra efficient in terms of resource allocation purpose. 5G wireless networks give a promising solution for the future wireless communication by exploiting high speed, higher capacity and much efficient systems. The key potential technologies for further spectrum efficiency enhancements include Massive MIMO/beam-forming, receiver interference cancellation, and dynamic TDD, and for integrating local area with wide area assuming the frequency-separated scenario using the proposed macro-assisted small cell that is termed as a 'Phantom cell'. This proposal includes the implementation of the proposed protocols in order to mitigate interference issues in the 5G network for phantom cells, the resource allocation and optimization problem in order to make design more efficient.

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1 Background and Problem Statement

Small cells that are deployed as a part of Long Term Evolution (LTE) for indoor coverage extension gives the promising solution under heterogeneous networks termed as femto-cell. In order to maintain reliable service of macro-cells, it is important to mitigate destructive femto-femto (co-channel) and femto-macro (adjacent or cross channel) cell interference respectively. Novel cooperative, distributive, femto cooperative (Fe-COPE) [8] and femto adjacent (Fe-ADJ) transceiver design protocols are proposed for multiple femto-macro cell systems with the mitigation of co-channel and cross-channel interference in various fading channel environments respectively. The significant advantage of the proposed scheme is the exploitation of the user as a relay network with feedback cancellation to acquire diversity gain from the interferer user of the femto COPE system. Fe-ADJ scheme for the cross-channel interference approach works with the coordination of femto and macro base stations by using wired back-haul whereas, another protocol (Fe-COPE) for mitigating the co-channel interference issue needs no feedback information or back-haul connection.

This proposal discusses the evolution concept and candidate technologies for future steps of 3GPP LTE-Advanced (LTE-A), which was the first major step in the continuous evolution of LTE. In the future steps of LTE-A, there is a need to ensure the sustainability of 3GPP radio access technologies in order to respond to the anticipated challenging requirements in the future. Taking into account the ever-increasing importance of local area (small cells) and the need for further spectrum extension in particular, a common evolution concept for the future steps of LTE-A (referred to as LTE-B, C, and so on) known as "5G/LTE" Networks.

In wireless systems, higher data rates are always a biggest challenge to achieve for the higher generation. The next generation mobile broadband technology is LTE (Long Term Evolution). LTE is the latest standard in the mobile network technology tree that previously realized th GSM/EDGE and UMTS/HSxPA network technologies that now account for over 85% of all mobile subscribers. LTE will ensure 3GPP's competitive edge over other cellular technologies. The motivation for LTE includes the need for higher data rates and greater spectral efficiency, that can be achieved with HSDPA/HSUPA and new air interface defined by 3GPP LTE. The need for high quality of services that can be achieved by use of licensed frequencies to guarantee quality of service and reduce round trip delay. The advantages of LTE includes high network throughput, low latency, low operating cots and simplified upgrade path from 3G networks from network operator's point of view. LTE-Advanced, which is an evolution of LTE and a “true 4G” mobile broadband, is under development and its initial services roll-out is expected in 2015. Amid such a situation, the anticipated challenges of the future are so tremendous that there is a vastly increased need for a new mobile communications system with even further enhanced capabilities, termed as a fifth generation (5G) systems. Having the goal to provide a revolution of the telecommunication environment, the 5G

system includes the design and development of a new radio network, of a comprehensive convergence core and back-haul infrastructure, of customization and parallelization mechanisms and of novel management and automation technology [1].

What is 5G? 5G represents the wireless ecosystem beyond LTE/EPC. It aims to provide a new radio access network [2-4] with ultra-high capacity, low delay and energy efficiency for an extremely high number of diversified devices and applications. 5G research directions include lots of different clusters, for instance: wireless system convergence, Massive MIMO, security issues for wireless sensor networks etc. For a coherent architecture, the 5G environment should consider, from the beginning, such a heterogeneous wireless ecosystem and afterwards develop the specific core network functionality in a harmonized manner including access control and security, mobility, session, resource management, RAN sharing [5] and network controlled multi-homing [6]. For bridging with the physical wireless research activities, which represent a research area on their own, Open5GCore implements the subscriber oriented radio access network functionality. Through this means, new radio resource scheduling and integration with radio PHY can be easily achieved and demonstrated into a comprehensive environment as well as novel research into the area of flexible radio access network architectures such as C-RAN, integration of small cells, local coordination of access network selection, etc. To concretize this evolution concept, potential spectrum-efficiency enhancing candidate technologies on both transmitter and receiver sides are identified for both wide area and local area. In addition, frequency-separated deployment between wide and local areas is considered as an important scenario towards the efficient utilization of higher frequency bands. For this scenario, a macro-assisted small cell, called “Phantom cell,” as a key solution for further network densification and spectrum extension in the future is proposed [7]. The Phantom cell solution brings with it many important benefits ranging from system capacity and data rate boosting to network cost reduction, mobility robustness, and energy savings.

Considering small cells, interference is one of the major issue that needs to be addressed before their deployment. The novel transmission protocols are proposed to mitigate interference issues in femto cells and exploit the better BER curves under different fading environments [8]. To the best of the knowledge, no one yet has considered Fe-COPE and Fe-ADJ protocols in Phantom cells for 5G/LTE networks. The idea is to analyze the integration of these transmission protocols upon Phantom User (U)-plane/ Control (C)-plane concept, where C-plane is provided by a macro-cell in lower frequency band to maintain a good connectivity and mobility. On the other hand, U-plane is provided by a small cell, i.e. a Phantom cell using a higher frequency band in order to boost the user data rate. The future research directions include the interference management in 5G/LTE networks by assuming certain limitations and conditions in order to achieve desired/expected results. Different performance parameters such as BER, channel capacity, outage, and optimization of power allocation for the Phantom cells will be the key objectives to be highlighted. The performance can be analyzed under different fading scenarios using different modulation techniques. It is expected that by utilizing the different transmission protocols for phantom cells in MIMO structure will not

only help to mitigate interference issues but will acquire the better BER vs SNR curves in terms of performance evaluation.

2 Literature Survey

2.1 Femto Cells

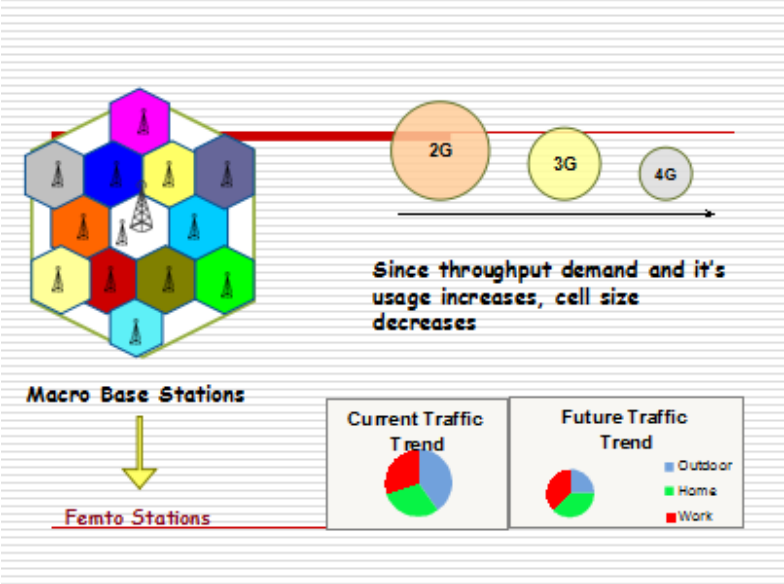
In wireless systems, coverage and capacity is a major challenge especially in high buildings. Femtocells have gained a lot of attention recently due to their advantages in terms of infrastructure cost saving and improved user experience in indoor environments. Several standards bodies, such as 3GPP, WiMAX Forum, and IEEE 802.16, have started to develop standard solutions to enable and optimize femtocells operation. A new technique and alternative approach that bears less expense than the existing techniques since in this approach, the distance between the transmitter and the receiver is so minimized that the access points are easily to access in and to achieve good performance in an indoor voice and high data rate of coverage. Such a concept is known as: femto-cells or also known as, home base stations [9]. In femto-cell systems, there are tiers or cells in a combination of network like a hot spot. Due to limited size between transmitter and receiver, the most prominent issue comes in one's mind is the interference issue. There is a cross-tier interference always present in the network. In [10], researchers have analyzed a system in which in a two-tier networks, a network is overlaid comprises with a conventional wireless network i.e. that can be a hot spot, distributed antennas technique, femto-cell systems or can be a wired system scenarios.

2.2 COPE Topology

The idea of cooperative network coding (CNC) to exploit spatial diversity is proposed in [11] that is based on COPE: a technique introduced by [12] for the wireless mesh networks. the performance have been evaluated that demonstrates that a CNC-aware route selection scheme that leverages cooperative communication to improve coding opportunity leads to higher end-to-end throughput comparing with the coding-oblivious and traditional coding-aware schemes. There is no consideration of femto scenarios and the performance measure of BER analysis using moment generation function (M.G.F.) based approach [13]. [14] focused on analyzing the performance of spatial channel separation method to mitigate the interference experienced by the macro user equipment (MUE) trapped inside a closed access femto cell for a Long Term Evolution (LTE) system. There is no mathematical derivation provided and the authors have considered the path loss model effect and simulation is given to facilitate the scheme in terms of BER. The authors presented advanced interference mitigation schemes for user equipment (UE), such as the received-power dependent interference cancellation (IC), decision-directed channel estimation and IC-assisted channel estimation, there is no mathematical expression for BER is provided, scheme is supported with the aid of simulation results in terms of BER. Fe-COPE and Fe-ADJ protocols are implemented over femto cells scenarios in order to mitigate co-channel and cross-channel interference issues and by exploiting the diversity gain ends in having good BER curves.

2.3 Massive MIMO in 5G Networks

'5G' is something of a misnomer: the standard doesn't exist yet but as the cell size decreases throughout demand increases as shown below. It will be months, likely years, before it's finally defined. In the meantime, organization, governments, and academics are working on the technologies that will form the standard, but today, 5G is purely a concept, and one that needs to go from vaporware to real-world roll-out in the next six years. According to prevailing wisdom, the first networks built on the standard will be rolled out in 2020. In order to meet that deadline, most of the hard yards in the 5G standardization process will have to be completed over the next two to three years, with standards bodies including the 3GPP, ITU, and IEEE, as well as universities, public bodies, and special interests groups, all having their input.



Evolution of Cellular Systems

MIMO is another technology likely to arrive in a big way with 5G. Rather than having a single antenna in the receiver and one in the transmitter as is the case now, MIMO (which stands for multiple input, multiple output) envisages a scenario where both sets of equipment have tens, or even a hundred, antennas or more. That translates into better data rates for users, and helps with both spectral and energy efficiency for operators. It should work in concert with millimeter wave and small cells too. "Massive MIMO base stations and small-cell access points are two promising approaches for future cellular. Massive MIMO base stations allocate antenna arrays at existing macro base stations, which can accurately concentrate transmitted energy to the mobile users. Small cells offload traffic from base stations by overlaying a layer of small cell access points, which actually decreases the average distance between transmitters and users, resulting in lower propagation losses and higher data rates and energy efficiency [15].

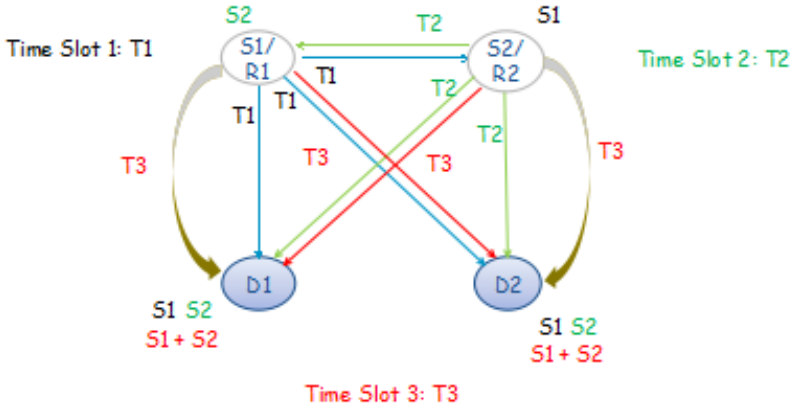
Considering 5G technical components, Phantom cells play the vital role. Network densification using small cells with low power nodes is a promising solution to cope with mobile traffic explosion, especially in high traffic areas (hot spot). DOCOMO has defined the concept of C-plane and U-plane for splitting up the bands on the frequency basis and utilize the resources [16].

The main idea is to implement the proposed protocols on Phantom cells in order to analyze the system behavior in terms of different performance parameters and mitigate the interference issues in both C/U-planes. Considering massive MIMO, in single cell aspect following will be the areas to be focused: channel estimation with basic considerations, impact of channel state information (CSI) errors on massive MIMO performance, a coordinated resource allocation solution based on random access for crowd scenarios in massive MIMO case. The optimization problem is to minimize the total transmitted power subject to the fixed signal to interference plus noise ratio (SINR) constraints, can be solved in a centralized or decentralized manner.

3 Research Design and Methods

This section includes few categories in order to well define the purpose of this research to be carried out. The methodology includes the discussion of design and system model to be considered. The system model consists of macro base station, phantom cells with C/U-plane. The different transmission protocols discussed in detail are implemented on 5G Phantom cells. Optimization problem can be defined for better resource allocation in Phantom cells. Massive MIMO techniques can be considered with some new protocol design in order to exploit the efficiency of the system.

In the proposed Fe-COPE scheme [8], the user one (S1) will broadcasts it's information to user two (S2), destination one (D1) and destination two (D2). Similarly, user two (S2) will perform the similar action in the next time frame by sending it's information to user one (S1), destination one (D1) and destination two (D2) respectively. In the third time slot, both users i.e. S1 and S2 containing each others signal information will forward the data at the destinations i.e. D1 and D2. In the Fig. below, the whole idea is depicted and it is evident to see the diversity gain at the destinations after retrieving the desired signal.



Fe-COPE Proposed Scheme

The input-output relationship can be mathematically expressed as follows:

$$y_{F-BS1}^{(1)} = \sqrt{E_{s_1}} h_{11} S_1 + n_{F-BS1}^{(1)}$$

$$y_{F-BS1}^{(2)} = \sqrt{E_{s_2}} h_{12} S_2 + n_{F-BS1}^{(2)}$$

$$y_{F-BS1}^{(3)} = \sqrt{E_{s_1}} h_{11} S_2 + \sqrt{E_{s_2}} h_{12} S_1 + n_{F-BS1}^{(3)}$$

Considering transceiver formulation at femto base station (F-BS1), the condition is checked if |h12| > |h11|, choose and detect S2 coming from the second slot, else Case B will hold true. After condition becomes true, the first detection is valid from the second time slot of y(2)-FBS1 gives good strength of the signal S2. So the interfered signal can be mitigated by using the following matrix technique:

$$\begin{bmatrix} y_{F-BS1}^{(3)} \\ y_{F-BS1}^{(1)} \end{bmatrix} = \begin{bmatrix} h_{12} & h_{11} \\ h_{11} & 0 \end{bmatrix} \begin{bmatrix} S_1 \\ S_2 \end{bmatrix} + \begin{bmatrix} n_{F-BS1}^{(3)} \\ n_{F-BS1}^{(1)} \end{bmatrix}$$

Now in order to get the desired signal S1 at F-BS1 and cancel the unwanted signal: S2(hat), the detection of S1(hat) is done as:

$$\widehat{S}_1 = \begin{bmatrix} h_{12}^* & h_{11}^* \end{bmatrix} \left\{ \begin{bmatrix} y_{F-BS1}^{(3)} \\ y_{F-BS1}^{(1)} \end{bmatrix} - \begin{bmatrix} h_{11} \\ 0 \end{bmatrix} \widehat{S}_2 \right\}$$

After some mathematical computing, the instantaneous signal to noise ratio (SNR) for the user 1 at F-BS1

is as:

$$\overline{\gamma}_{F-BS1} = \frac{(|h_{12}|^2 + |h_{11}|^2)\sigma_{S_1}^2}{\sigma_n^2}$$

whereas, $\sigma_{S_1}^2$ and σ_n^2 are the variance for the source signal and the noise variance respectively and their ratio provides SNR.

Similarly, case B in otherwise is functioned to obtain instantaneous SNR. Using different fading channels and M.G.F. Approach, the final expressions for SER is as follows:

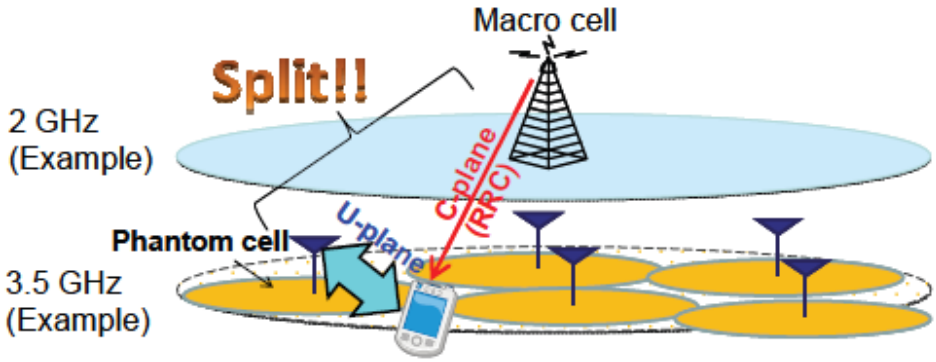
$$P_{R_s} = \left[G_1 B\left(\frac{5}{2}, \frac{1}{2}\right)\ {}_2F_1\left(2, \frac{5}{2}; 3, \frac{-10}{\beta\Omega}\right)\right] - \left[G_2 \int_0^{\frac{1}{2}} v^{\frac{3}{2}}(1-v)^{-\frac{1}{2}}\left(1 + \frac{10v}{\Omega\beta}\right)^{-2} dv\right]$$

Whereas, β is the SNR and $G_1 = \frac{150}{\beta^2 \times \Omega^2 \times \pi}$. Similarly using Rician fading environment, the final SER expression computed is as:

$$P_{Ric_s} = G_3 \int_0^1 v^{\frac{3}{2}}(1-v)^{-\frac{1}{2}} \frac{e^{\frac{20K(1+K)v}{\beta\Omega+10v(1+K)}}}{(\beta\Omega + 10v(1+K))^2} dv - G_4 \int_0^{\frac{1}{2}} v^{\frac{3}{2}}(1-v)^{-\frac{1}{2}} \frac{e^{\frac{20K(1+K)v}{\beta\Omega+10v(1+K)}}}{(\beta\Omega + 10v(1+K))^2} dv$$

By Using Mathematica, helps in obtaining the theoretical results for the average BER for the Rician-K fading environment, in order to solve the complex integral.

Now considering the Phantom cell concept, the proposed protocols will be integrated under C/U-plane concept as follows:



C-plane/U-plane split and Phantom Cell [7]

The proposed protocols have some limitations as the 2x2 user case is considered. So for sake for simplicity, two user scenario is considered for future research. But the extension of the scheme to MIMO based Phantom cells and Massive MIMO technique will be exploited for the simulated based results. The minimum time frame to carry out the research activity in order to fulfill the tasks will take about 16 months to 18 months depending upon the extension of the project. As the topic under consideration is very hot and have lots of potential, so most likely there will be lots of new directions while performing the objectives will be kept under consideration.

Genetic Algorithm (GA) will be used as optimization method for determination of appropriate values for weights of different criteria in multi-criteria decision making approach for resource allocation. The goal of the GA is to optimize the weights upon locations of the users and their demands to the network (which is dependent upon service type initiated by each user). With this approach, the GA can assign weighting coefficient to provide best user satisfaction. In our analysis we use 200 iterations, which is based on the fact that there is no improvement after successive 100 generations in most cases.

Nokia is actively driving 5G collaborative research; Brooklyn Summit focuses on antennas, propagation, channel modeling and measurements. The ongoing project includes: novel radio architecture, and cognitive radio. The future research focuses on ultra dense small cells, wide area networks, and there architecture design.

4 Project Plan and Tasks

The two investigators will carry out the project cooperatively with the possible help of a research assistant. The project progress and development is divided into four main phases spanning the 18 months. The project phases are as follows:

4.1 Phase I (4 months) – Literature Survey:

- Performing a comprehensive and elaborate literature review: This step involves the gathering and reading of up to date literature and resources in the field. The team should focus on cutting-edge network technologies and up to date literature that is directly applicable to the problems of interest. Grouping and classification of solutions found in the literature will aid in the analysis phase to follow.
- The team will also attempt to obtain literature in regard to evolution and expansion plans of the current on-going research project i.e. Horizon 202, that are available for public.

4.2 Phase II (6 months) – Analysis and Evaluation:

- Identification of most promising solutions using criteria that include but not limited to:

classification of objectives into sub-classes, deep analysis of Phantom cells in terms of interference alignment and its performance analysis in massive MIMO technique.

- Potential candidate architecture and network evolution paths shall be analyzed and evaluated in terms of their relevance to the current network infrastructure and the expected betterment in efficiency.
- Formulation of one of few winner solutions i.e., to implement different designed transmission protocols in Phantom cells and in order to have maximum benefit of the resources, optimization problem will be considered.

4.3 Phase III (4 months) – Case Study:

- Using the analysis and results obtained in phase II, the team will assume a hypothetical scenario where the collaboration can be made with some industry i.e. IMEC where a big project is going on Massive MIMO under EU project titled: 'Horizon 2020'. The task is to provide a comprehensive plan for introducing such service including all architectural changes and new network entities needed with consensus of the industrial applications.

4.4 Phase IV (4 months) – Project Documentation:

- This task involves providing a detailed document with the following major sections: Comprehensive literature review of 5G/LTE networks and it's architecture found and their analysis, a list of potential solutions for mitigating the interference issues in Phantom cells in splitting up of the two (2) planes. The report will include a case study analysis for a typical integration scenario and the required infrastructure.

5 Summary of Deliverables

Hopefully few publications focusing on the implementation details of proposed protocols in Phantom cells architecture and on the massive MIMO. By the mid of the project, few papers could be submitted in some reputable conferences that focus on applied research and real world 5G/LTE wireless applications. More specific in conferences with proceedings relevant to 5G architecture issues and cross later accept or mobile computing and the interconnection of heterogeneous wireless networks.

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Interdisciplinarity

My application is interdisciplinary

☐

An interdisciplinary research project is defined in this call for proposals as a project that can not be completed without knowledge, methods, terminology, data and researchers from more than one of the Swedish Research Councils subject areas; Medicine and health, Natural and engineering sciences, Humanities and social sciences and Educational sciences. If your research project is interdisciplinary according to this definition, you indicate and explain this here.

Click here for more information

Scientific report

Scientific report/Account for scientific activities of previous project

Erasmus Mundus EXPERTS-III Project:

PhD exchange fellowship for 10 months

Amount awarded: 15,000 Euros

Insurance, Travel Allowance and Research allowance was covered.

Output:

Research Assistant, Teaching Courses, 2 research publications and international collaboration.

Budget and research resources

Project staff

Describe the staff that will be working in the project and the salary that is applied for in the project budget. Enter the full amount, not in thousands SEK.

Participating researchers that accept an invitation to participate in the application will be displayed automatically under Dedicated time for this project. Note that it will take a few minutes before the information is updated, and that it might be necessary for the project leader to close and reopen the form.

Dedicated time for this project

	Role in the project	Name	Percent of full time
1	Applicant	Zuhaib Ashfaq Khan	

Salaries including social fees

Role in the project	Name	Percent of salary	2016	2017

Other costs

Describe the other project costs for which you apply from the Swedish Research Council. Enter the full amount, not in thousands SEK.

Premises

Type of premises	2016	2017

Running Costs

Running Cost	Description	2016	2017

Depreciation costs

Depreciation cost	Description	2016	2017

Total project cost

Below you can see a summary of the costs in your budget, which are the costs that you apply for from the Swedish Research Council. Indirect costs are entered separately into the table.

Under Other costs you can enter which costs, aside from the ones you apply for from the Swedish Research Council, that the project includes. Add the full amounts, not in thousands of SEK.

The subtotal plus indirect costs are the total per year that you apply for.

Total budget

Specified costs	2016	2017	Total, applied	Other costs	Total cost
Salaries including social fees			0		0
Running costs			0		0
Depreciation costs			0		0
Premises			0		0
Subtotal	0	0	0	0	0
Indirect costs			0		0
Total project cost	0	0	0	0	0

Explanation of the proposed budget

Briefly justify each proposed cost in the stated budget.

Explanation of the proposed budget*

Project Plan and Tasks

The two investigators will carry out the project cooperatively with the possible help of a research assistant. The project pro

***4.1 Phase I (5 months) – Literature Survey*:**

- Performing a comprehensive and elaborate literature review: This step involves the gathering and reading of up to d edge network technologies and up to date literature that is directly applicable to the problems of interest. Grouping
- The team will also attempt to obtain literature in regard to evolution and expansion plans of the current on-going research project i.e. Horizon 202, that are available for publi

4.2 Phase II (7 months) – Analysis and Evaluation:

- Identification of most promising solutions using criteria that include but not limited to:classification of objectives in classes, deep analysis of Phantom cells in terms of interference alignment and its performance analysis in massive M
- Potential candidate architecture and network evolution paths shall be analyzed and evaluated in terms of their relev
- Formulation of one of few winner solutionse., to implement different designed transmission protocols in Phantom ce

4.3 Phase III (6 months) – Case Study:

- Using the analysis and results obtained in phase II, the team will assume a hypothetical scenario where the collabor

4.4 Phase IV (6 months) – Project Documentation:

This task involves providing a detailed document with the following major sections: Comprehensive literature review of 5G

Amount (SEK) Granted per year:

2016: 1,050,000
2017: 1,050,000

Other funding

Describe your other project funding for the project period (applied for or granted) aside from that which you apply for from the Swedish Research Council. Write the whole sum, not thousands of SEK.

Other funding for this project

	Funder	Applicant/project leader	Type of grant	Reg no or equiv.	2016	2017	Total
1	Vetenskapsrådet	Zuhaib Ashfaq Khan	Project Research	ÄR-NT - UNGA FORSKARE	1,050,000	1,050,000	2,100,000
	Total				1,050,000	1,050,000	2,100,000

CV

europass Curriculum Vitae

PERSONAL INFORMATION

Zuhaib Ashfaq Khan

House No. D-5 Street No. 3 Phase # 1 Officers Colony, Wah Cantt (Pakistan)

+923345312369

znarjuit@hotmail.com

PERSONAL STATEMENT

Area of Research:

Wireless Communication (Physical Layer)

Research Interests:

Wireless Communications, MIMO Femto Cells, Cooperative Networks, Interference Mitigation Protocols, 5G/LTE Networks, Phantom Cell, Massive MIMO.

Teaching Interests:

Signal Processing, DSP, DLD, Wireless Communications, Data Communicatons.

WORK EXPERIENCE

01/12/2014–Present

Assistant Professor

COMSATS (CIIT) University
Kamra Road, Attock (Pakistan)
http://www.ciit-attock.edu.pk/comsats/facultyprofile.php?id=zuhaibkhan@ciit-attock.edu.pk

Assistant Professor.

Research Area: Wireless Communications, MIMO Femto Cells, Cooperative Networks, Interference Mitigation Protocols, 5G/LTE Networks, Massive MIMO etc.

Teaching Courses: Signal Processing, DSP, DLD, Wireless Communications, Electronics Engineering etc.

Business or sector Education

15/09/2013–14/07/2014

PhD Exchange Student

Katholieke University Leuevn (KUL), Leuven (Belgium)
http://www.esat.kuleuven.be/telemic/people/index.php?puc=101

Positions Held:

Katholieke University Leuevn (KUL), Belgium

Doctoral Fellow, Sep 2013 - Juy 2014

IMEC, Belgium (http://www2.imec.be/be_en/home.html)

Research Assistant (Internship)- Dec 2013 - June 2014

Katholieke University Leuven, Belgium

Teaching Assistant (http://www.esat.kuleuven.be/telemic/people/index.p...

Course: Avionics Telemic Engineering

Nov 2013 - July 2014.

Business or sector Information and communication

20/02/2012–15/01/2013

Doctoral Exchange Fellow

Yuan Ze University (YZU), Neili (Taiwan)
http://www.comm.yzu.edu.tw/teacher/cn_jhdeng.htm

Positions Held:

PhD. Exchange Fellow

Yuan Ze University (YZU), Taiwan

Department of Communications Engineering

(http://www.comm.yzu.edu.tw/english/)

Research Assistant- 22 Feb 2012 - 15 Jan 2013

Teaching Courses:

Introduction to Cooperative Communications

Network Coding

Performance Analysis and Interference Mitigation Protocols

Basic Introduction to Latex

Business or sector Professional, scientific and technical activities

14/08/2007–20/02/2012

Telecommunications engineer

Asian Institute of Technology (AIT), Rangsit (Thailand)
http://www.set.ait.ac.th/page.php?fol=tc&page=tc

Scholarship Award:

Masters Leading to PhD Degree

Asian Institute of Technology (AIT), Thailand

Masters Degree- Telecommunications Engineering

Teaching Assistant: 20 Aug 2007 - 15 June 2009

Master Research Area: MIMO Cooperative Networks, V-BLAST Algorithm, Performance Analysis, Cooperation Gain Protocols.

Award:

Masters Dual Degree Fellowship

Telecom SudParis (http://www.telecom-sudparis.eu/fr_accueil.html)

PhD Doctor Degree in AIT, Thailand

15 June 2009 - Dec 2014

Research Assistant: 20 June 2009 - 20 Feb 2012

Teaching Assistant for courses: Signals and Systems, Advanced Digital Signal Processing, Error Control Coding, Teletraffic Engineering, Data Communications etc.

Awards:

PhD Dual Degree Program to Oulu, Finland

PhD Exchage Fellowship to YZU, Taiwan

PhD Erasmus Mundus Exchange Program to KUL, Belgium

Business or sector Education

25/12/2006–01/08/2007

Electronics engineer

Heavy Industries Taxila (HIT), Taxila Cantt, Taxila (Pakistan)

Works as an Junior Works Manager. Main responsibility includes to perform tasks of the on-going

projects related to electronics engineering.

Team Leader for AARDIC research unit. Focal person for research collaborations with AWC, NDC, and other defense organizations.

EDUCATION AND TRAINING

14/08/2007–08/08/2014

Ms Leading to PhD Degree

PhD in Telecommunications Engineering

Asian Institute of Technology (AIT), Rangsit (Thailand)

Masters: Telecommunications Engineering

MS Thesis Area: MIMO Cooperative Networks, Network Coding, Wireless Comm.

Master Thesis Title: "Performance Analysis of MIMO Based Cooperation Diversity System using Hybrid FDMA-TDMA Technique"

Research Output: Two publications in reputable conferences

PhD: Telecommunications Engineering

Dissertation: Femto Cells, Interference Alignment, 5G/LTE.

Title: "Performance Analysis of MIMO Based Femto-Cell Networks Using Interference Mitigation Protocols"

Research Output: Three research papers in reputable Journals and two papers are in progress.

PERSONAL SKILLS

Mother tongue(s): Urdu

Other language(s)

	UNDERSTANDING		SPEAKING		WRITING
	Listening	Reading	Spoken interaction	Spoken production	
English	C2	C2	C2	C2	C2

Levels: A1/A2: Basic user - B1/B2: Independent user - C1/C2: Proficient user
Common European Framework of Reference for Languages

Communication skills

-good communication skills gained through my experience as a Doctor

-good presenter

Organisational / managerial skills

- leadership (currently responsible for a team of 10 people)
- good organisational skills gained as a volunteer of TSF French NGO
- responsible for booking speakers and promoting events
- good team-leading skills gained as football volunteer coach

Job-related skills

- good command of quality control processes (currently responsible for quality audit)
- mentoring skills (as a Doctor I was responsible for the training and induction of new research topics among the students)

Computer skills

Awards, Honors, Scholarships:

1. HEC Approved Supervisor, December 2014.
2. EXPERTS Erasmus Mundus PhD exchange program awarded for ten months of duration.

3. Representative of ESAT-TELEMIC research group to IMEC, Belgium for collaboration.

4. PhD exchange fellowship awarded for an year at YZU, Taiwan.

5. Dual degree for PhD being awarded at CWC, Oulu, Finland.

6. Winner of National Institute of Informatics International Internship Program (scholarship awarded to the best doctoral student in the School of Engineering and Technology, AIT), Tokyo, Japan, March 2012.

7. Professional Volunteer for TSF French NGO for emergency deployments worldwide. Letter of appreciation being awarded for Asia-Pacific region by TSF director at AIT, Bangkok Thailand.

8. Scholarship for the Masters and PhD studies awarded by the Higher Education Commission of Pakistan, August 2007 Dec 2012.

9. Scholarship for Bachelor of Engineering (Honors) Program in Electronics Engineering awarded by Air Force University (Air Uni), Pakistan, 2004-2006 upon excellent performance.

10. Winner of many sports and extra co-curricular activities i.e. Football, Basketball and Volleyball champion. Gold Medal in Mini-Marathon at university and graduate level.

Professional Activities:

1. Member Ph.D. Club, Cancer Care Hospital and Research Center, Lahore, Pakistan (Sep 2014 Present).

2. Reviewer: Journal of Communications (JoCM).

3. Reviewer: International Conferences, ICC, Globecom etc.

4. University Research Satcom Project Analysis to Identify Research Strengths of Yuan Ze University March 2012.

5. International Conference on 5G LTE Networks 2014. Attended as a representative of ESAT-TELEMIC. Member of FITCE.be.

6. Workshop on Research Performance Evaluation and Support of Communication Networks: ESAT KUL, Belgium 2014.

7. International Conference (ICWCMC) in Penang, Malaysia 2012. Novel design of MIMO cooperative protocol, (third prize)

8. Conference MC & member organizing committee: 10th International Conference of Mobile Computing and Wireless Networks, Bangkok, Thailand, January 2009.

Projects:

1. National Taiwanese Government Funded Program- The main objectives include to cope with interference issue. EU collaboration for massive MIMO techniques implementation in real time scenario.

2. Horizon 2020. Considering small cells and there critical issues. Collaborative work with IMEC, Belgium and CWC Oulu, Finland.

3. METIS 2020 project. Designing of innovative techniques to cope issues in wireless sensor networks. EU collaborative work is going with cooperation of many European universities. The key role in physical layer is to interface cross later Femto cell concepts and perform interference alignment technique in collaboration with Prof. Nandana Rajatheva CWC Oulu, Finland. Aug 2014-present.

Seminars, Conferences, Books, Journal Publications:

A separate sheet is attached with CV for reference.

Computer Skills

Matlab

Latex

EDP (Electronic Data Processing)

DOS (Disk Operating System)

MS-Windows

MS-Office, MS-Word

Introduction to Internet

SPSS

Experiences

Teaching experience at KUL, Belgium. Teaching Bachelor and Masters Degree students the course titled: Avionics Telemic for a year.

Exchange program and research (on-going) at KUL, Belgium TELEMIC Lab for a year.Exchange program to YZU, Taiwan for a year to carry out PhD research under supervision of enthusiastic researchers.

Having experience on Electric Trainers and Power Control at ESBI Rousch Power

Plant, Abdul Hakim.

Having experience on Lathe Machine and different tools.

Having knowledge of GSM, CDMA etc in Communication Side.

Having knowledge of languages like Matlab, C++, Assembly Language, VHDL etc.

Having experience of using softwares like Electronic Work Bench (EWB), Circuit Maker, PSPICE, Matlab, PRO-E, AVR Studio4 etc.

Study Projects

Study on Introduction to GSM

Study Project on GSM Channels

Study on new Technologies e.g. 3G, Bluetooth, CDMA etc.

Survey of different BTSs and BSCs in Communication Sector

Semester Projects (Undergraduate)

Project on Fleet System Based on C++.

A.C. Control System based on C language.

Many mini projects related to field and DLD etc.

16-Bit ALU (Arithmetic Logic Unit).

Final project based on Control System named as Linear Motion Control System Design and Fabrication (Sponsored by PIEAS).

ANNEXES

- List of Publications.pdf

List of Publications.pdf

List of Publications

Journal Papers:

- Zuhaib Ashfaq Khan, Nandana Rajatheva, and Juinn-Horng Deng, ``Performance Analysis of Novel Interference Mitigation Schemes in Heterogeneous Networks over Rayleigh and Rician Fading Channels". JOCM- Journal of Communications, vol. 8, no. 6, pp. 359-371, 2013. Doi: 10.12720/jcm.8.6.359-371 ETP 2013. June 2013.
- Zuhaib Ashfaq Khan, Muhammad Hasanain Chaudary, and Juinn-Horng Deng, ``Moment Generating Function (M.G.F.) based Performance Analysis of Network Coding Two-way Relaying Using Alamouti Scheme over Various Fading Channels". BUJICT- Bahria University Journal of Information & Communication Technologies, vol. 5, no. 1, pp. 11-18, 2012. December 2012.
- Zuhaib Ashfaq Khan, Juinn-Horng Deng, and Nandana Rajatheva, ``Novel Femto Cooperative Scheme (Fe-COPE) with Interference Mitigation and Performance Analysis under Different Fading Channels". JCIE- Journal of the Chinese Institute of Engineers, Vol, 2014 Thomson Reuters ScholarOne. Accepted: 17 March 2014.
- Zuhaib Ashfaq Khan, Muhammad Hasanain Chaudary, Nandana Rajatheva, Sofie Pollin, and Juinn-Horng Deng, ``A MIMO Based Interference Mitigation Protocol for Femto Cells and Performance Analysis using Alamouti Coding Gain for Different Fading Scenarios". EURASIP Journal on Wireless Communications and Networking, Springer, 2014. [In Progress]
- Zuhaib Ashfaq Khan, Rodolfo Torrea Duran, Fernando Rosas, Marc Moonen, Nandana Rajatheva, and Sofie Pollin, ``A Power-Enhanced Cooperative Scheme in OFDMA Heterogeneous systems for 5G Networks". J-SAC IEEE Journal on Selected Areas in Communications, IEEE Communications Society, 2014. [To be Submitted]

Conference Papers:

- ✓ Zuhaib Ashfaq Khan, Imran Khan, and Nandana Rajatheva, ``Performance Analysis of MIMO Based Multi-User Cooperation Diversity System using Hybrid FDMA-TDMA Technique". IEEE ECTI-CON, Chiang Mai, Thailand May 2010.
- ✓ Zuhaib Ashfaq Khan, Imran Khan, and Nandana Rajatheva, ``Performance Analysis of Multi-User Cooperation Diversity System using MIMO Approach Over Various Fading Channels". ICWCMC WASET Penang, Malaysia February 2010.
- ✓ Zuhaib Ashfaq Khan, Rodolfo Torrea Duran, and Sofie Pollin, ``A Power-Enhanced Femto Cooperative Scheme (Fe-COPE) in OFDMA Heterogeneous systems using Interference Mitigation for 5G Networks". 35th and 4th Joint WIC/IEEE Symposium on Information Theory and Signal Processing in the Benelux, May 2014.

Publication list

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Journal Papers:

- Zuhaib Ashfaq Khan, Nandana Rajatheva, and Juinn-Horng Deng, ``Performance Analysis of Novel Interference Mitigation Schemes in Heterogeneous Networks over Rayleigh and Rician Fading Channels". JOCM- Journal of Communications, vol. 8, no. 6, pp. 359-371, 2013. Doi: 10.12720/jcm.8.6.359-371 ETP 2013. June 2013.
- Zuhaib Ashfaq Khan, Muhammad Hasanain Chaudary, and Juinn-Horng Deng, ``Moment Generating Function (M.G.F.) based Performance Analysis of Network Coding Two-way Relaying Using Alamouti Scheme over Various Fading Channels". BUJICT- Bahria University Journal of Information & Communication Technologies, vol. 5, no. 1, pp. 11-18, 2012. December 2012.
- Zuhaib Ashfaq Khan, Juinn-Horng Deng, and Nandana Rajatheva, ``Novel Femto Cooperative Scheme (Fe-COPE) with Interference Mitigation and Performance Analysis under Different Fading Channels". JCIE- Journal of the Chinese Institute of Engineers, Vol, 2014 Thomson Reuters ScholarOne. Accepted: 17 March 2014.
- Zuhaib Ashfaq Khan, Muhammad Hasanain Chaudary, Nandana Rajatheva, Sofie Pollin, and Juinn-Horng Deng, ``A MIMO Based Interference Mitigation Protocol for Femto Cells and Performance Analysis using Alamouti Coding Gain for Different Fading Scenarios". EURASIP Journal on Wireless Communications and Networking, Springer, 2014. [In Progress]
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- ✓ Zuhaib Ashfaq Khan, Imran Khan, and Nandana Rajatheva, ``Performance Analysis of Multi-User Cooperation Diversity System using MIMO Approach Over Various Fading Channels". ICWCMC WASET Penang, Malaysia February 2010.
- ✓ Zuhaib Ashfaq Khan, Rodolfo Torrea Duran, and Sofie Pollin, ``A Power-Enhanced Femto Cooperative Scheme (Fe-COPE) in OFDMA Heterogeneous systems using Interference Mitigation for 5G Networks". 35th and 4th Joint WIC/IEEE Symposium on Information Theory and Signal Processing in the Benelux, May 2014.

CV

Name: Zuhaib Ashfaq Khan	**Doctorial degree:** 2009-05-22
Birthdate: 19850322	**Academic title:** Doktor
Gender: Male	**Employer:** Comsats Institute of Information Technology

Research education

Dissertation title (swe)

Dissertation title (en)

"Performance Analysis of MIMO Based Femto-Cell Networks Using Interference Mitigation Protocols"

Organisation	Unit	Supervisor
Asian Institute of Technology, Thailand Not Sweden - Higher Education institutes	Telecommunication Engineering	Nandana Rajatheva (RMAP)

Subject doctors degree	ISSN/ISBN-number	Date doctoral exam
20204. Telekommunikation		2014-08-08

Publications

Name: Zuhaib Ashfaq Khan	**Doctorial degree:** 2009-05-22
Birthdate: 19850322	**Academic title:** Doktor
Gender: Male	**Employer:** Comsats Institute of Information Technology

Khan, Zuhaib Ashfaq has not added any publications to the application.

Register

Terms and conditions

The application must be signed by the applicant as well as the authorised representative of the administrating organisation. The representative is normally the department head of the institution where the research is to be conducted, but may in some instances be e.g. the vice-chancellor. This is specified in the call for proposals.

The signature*from the applicant*confirms that:

- the information in the application is correct and according to the instructions form the Swedish Research Council
- any additional professional activities or commercial ties have been reported to the administrating organisation, and that no conflicts have arisen that would conflict with good research practice
- that the necessary permits and approvals are in place at the start of the project e.g. regarding ethical review.

The signature *from the administrating organisation* confirms that:

- the research, employment and equipment indicated will be accommodated in the institution during the time, and to the extent, described in the application
- the institution approves the cost-estimate in the application
- the research is conducted according to Swedish legislation.

The above-mentioned points must have been discussed between the parties before the representative of the administrating organisation approves and signs the application.

Project out lines are not signed by the administrating organisation. The administrating organisation only sign the application if the project outline is accepted for step two.

Applications with an organisation as applicant is automatically signed when the application is registered.