RGC Ref.: M-HKUST604/12
(please insert ref. above)

The Research Grants Council of Hong Kong
SRFDP & RGC ERG Joint Research Scheme
Completion Report

(Please attach a copy of the completion report submitted to the Ministry of Education by the Mainland researcher)

Part A: The Project and Investigator(s)

1. Project Title

Hierarchical Radio Resource Management for 5G Heterogeneous Networks

5G 異構網絡的分層無線資源管理

2. Investigator(s) and Academic Department/Units Involved

	Hong Kong Team	Mainland Team
Name of Principal Investigator *(with title)*	Vincent LAU	Mugen PENG
Post	Chair Professor	Professor
Unit / Department / Institution	ECE / HKUST	ECE / BUPT
Contact Information	eeknlau@ee.ust.hk	pmg@bupt.edu.cn
Co-investigator(s) *(with title and Institution)*		
PhD student(s) (with period of involvement)	Name: Xiongbin RAO, Junting CHEN, Naeimeh OMIDVAR Institution: HKUST Period from 1st March 2013 to 28 Feb 2016	

Note: The Hong Kong project team must involve at least one research postgraduate student pursuing a Doctor of Philosophy degree at the UGC-funded university (PhD student) at any time throughout the project period.

3. Project Duration

	Original	Revised	Date of RGC/ Institution Approval *(must be quoted*)
Project Start date	1st Mar 2013		
Project Completion date	28 Feb 2016		

Duration *(in month)*	36		
Deadline for Submission of Completion Report	29 Feb 2017		

Part B: The Completion Report

5. Project Objectives

5.1 Objectives as per original application

1. **Objective A: Develop a Novel Hierarchical Stochastic Optimization Framework using Timescale Separation and Stochastic Decomposition**
2. **Objective B: Applications to Practical Systems such as LTE+**

5.2 Revised Objectives

Date of approval from the RGC: _____

Reasons for the change: _____

_____

6. Research Outcome

Major findings and research outcome
(maximum 1 page; please make reference to Part C where necessary)

In this project, we have studied a mixed timescale stochastic optimization problem with target applications in heterogeneous networks for 5G wireless networks. HetNet is considered as one important innovation that can boost the capacity of future wireless systems through more aggressive spatial reuse. However, it also poses great challenges in terms of interference management due to the huge number of small cells involved and the absence of global channel state information. As such, by splitting the control and information into two timescales, we can substantially simplify the fast timescale control solution as well as reducing the signaling overhead to deliver realtime channel state. Using the proposed solution framework and the mixed timescale approach, we have shown that significant gains can still be achieved in HetNet and this is very important because such gains are based on a much more realistic implementation constraint in terms of signaling overheads and complexity. We have applied the solution framework to practical systems such as LTE+ and verified the performance gains of the proposed algorithm through system-level simulations using LTE datapath. As a result of the project, we have published 4 journal papers in IEEE Transactions on Signal Processing, IEEE Journals of Selected Areas on Communications, IEEE Transactions on Wireless Communications as well as IEEE Surveys and Tutorials. Two PhD students have been trained as well.

Potential for further development of the research and the proposed course of action *(maximum half a page)*

The proposed mixed timescale stochastic optimization framework and solution techniques can be applied to other situations such as relay-assisted wireless networks, wireless backhaul optimization as well as other system-level problems such as massive RRM in Cloud RAN.

7. The Layman's Summary

(describe <u>in layman's language</u> the nature, significance and value of the research project, in no more than 200 words)

In this project, we studied the problem of how to address the complicated interference management problem in HetNet of future 5G wireless networks. Conventional approaches of interference management require global knowledge of real-time channel state information of the entire network and this is quite unrealistic in practice. To resolve the signaling burden and the complexity of interference management, we split the control space and the information space into two timescales so that the fast timescale control component is based on real-time local (rather than global) channel conditions and the slow timescale control component is based on global but slow (statistical) channel conditions only. We proposed a solution framework for such mixed timescale optimization and the solution is shown to achieve significant gains under a much more practical implementation constraint.

<u>Part C: Research Output</u>

8. Peer-reviewed journal publication(s) arising <u>directly</u> from this research project

(Please attach a copy of each publication and/or the letter of acceptance if not yet submitted in the previous progress report(s). All listed publications must acknowledge RGC's funding support by quoting the specific grant reference.))

The Latest Status of Publications				Author(s) *(**bold** the authors belonging to the project teams and denote the corresponding author with an asterisk*)*	Title and Journal/ Book *(with the volume, pages and other necessary publishing details specified)*	Submitted to RGC *(indicate the year ending of the relevant progress report)*	Attached to this report *(Yes or No)*	Acknowledged the support of this Joint Research Scheme *(Yes or No)*	Accessible from the institutional repository *(Yes or No)*
Year of publication	Year of Acceptance *(For paper accepted but not yet published)*	Under Review	Under Preparation *(optional)*						
2015				***Mugen PENG**, Jian LI, Hongyu XIANG, Yuanyuan CHENG, **Vincent LAU**	Recent Advances in Underlay Heterogeneous Networks: Interference Control, Resource Allocation, and Self-Organization / IEEE Surveys and Tutorials, vol. 17, no.2, pp 700-729, Mar 2015.	Yes (2014)	Yes	Yes	Yes
2014				***Xiongbin RAO**, **Vincent LAU**	Interference Alignment with Partial CSI Feedback in MIMO Cellular Networks, IEEE Transactions on Signal Processing, vol. 62, no. 8, Apr 2014.	No	Yes	No (student forgot to add acknowledgement in final version)	Yes
2014				**Junting CHEN, Vincent LAU**	Two Tier Precoding for FDD Multi-cell Massive MIMO Time-varying Interference Networks, IEEE Journal on Selected Areas in Communications, vol. 32, no. 6, Jun 2014.	No	Yes	No (student forgot to add acknowledgement in final version)	Yes
2015				***An LIU, Vincent LAU**	Two Stage Subspace Constrained Precoding in Massive MIMO Cellular Systems, IEEE Transactions on Wireless Communications, vol. 14, no. 6, Jun 2015.	No	Yes	Yes	Yes

9. Recognized international conference(s) in which paper(s) related to this research project was/were delivered *(Please attach a copy of each delivered paper. All listed papers must acknowledge RGC's funding support by quoting the specific grant reference.)*

Month/Year/ Place	Title	Conference Name	Submitted to RGC *(indicate the year ending of the relevant progress report)*	Attached to this report *(Yes or No)*	Acknowledged the support of this Joint Research Scheme *(Yes or No)*	Accessible from the institutional repository *(Yes or No)*
05/2014/Florence	Partial CSI Feedback Design for Interference Alignment in MIMO Cellular Networks	International Conference on Acoustic Speech and Signal Processing (ICASSP)	Yes (2014)	No	Yes	Yes
06/2014/Sydney	'Multi-timescale Interference Mitigation for Massive MIMO Cellular Networks	International Conference on Communications (ICC)	Yes (2014)	No	Yes	Yes

10. Student(s) trained *(Please attach a copy of the title page of the thesis.)*

Name	Degree registered for	Date of registration	Date of thesis submission/ graduation
Junting CHEN	PhD	01/09/2010	30/06/2015
Xiongbin RAO	PhD	01/09/2010	30/06/2015
Naeimeh OMIDVAR	Ph.D.	01/01/2013	30/06/2017

11. Other impact *(e.g. award of patents or prizes, collaboration with other research institutions, technology transfer, etc.)*

Workshop Proposal "Second International Workshop on Cloud-Processing in Heterogeneous Mobile Communication Networks (IWCPM 2015)" accepted for IEEE International Conference on Communications (ICC 2015).