

**RESEARCH ON RADIO ENVIRONMENT MAPS FOR  
MOBILITY MANAGEMENT IN 5G NETWORKS**

by  
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## ABSTRACT

One main feature of the fifth generation (5G) of cellular mobile communications is the deployment of an ultra-dense cellular network architecture with much more cell towers. This will construct a multi-tier 5G network, and make ubiquitous access difficult if maintaining the same approaches to mobility management as in previous generations. In recent years, we have witnessed remarkable advancements in cognitive radio, which provides radio-environmental awareness. This awareness can be exploited to improve system performance in various aspects. This thesis studies how to incorporate radio environment maps (REM) into 5G networks with a particular emphasis on mobility management.

Our work begins halfway between Long-Term Evolution (LTE) and 5G. We propose a REM-based handover algorithm that reduces the number of unnecessary handovers in multi-tier networks. The designed handover procedure is fully backward compatible with LTE and exploits the incomplete channel states stored in a REM. We evaluate our method under two different scenarios in which we can deliver the same downlink traffic as current approaches in the literature as well as decrease the overall number of handovers by at least 33% without overloading the backhaul.

We also present a geometric model to derive the handover and handover failure regions taking into consideration imperfect location, by finding the optimal prediction time through numerical optimisation. The effect of multiple mobility-management parameters is investigated as well. The proposed scheme achieves a substantial reduction of up to 30% in the number of un-



necessary handovers in multi-tier networks. We then propose to use REMs for network optimisation in a dense cellular network and obtain the coverage probability for REM cell association using stochastic geometry. The optimal prediction distance maximises the average ergodic rate, including the penalty incurred by the handovers. Our strategy increases the average ergodic rate extensively by 65% across high-mobility users when compared to state-of-the-art strategies found in the literature.

In summary, radio-environmental awareness in mobile cellular networks has not been wholly addressed yet. This thesis introduces REMs as an enabling technology that contributes to the mitigation of the number of unnecessary handovers and capacity growth for mobility management in 5G networks and beyond.



## **CERTIFICATE OF ORIGINAL AUTHORSHIP**

I, Antonio Cristo Suárez Rodríguez declare that this thesis, is submitted in fulfilment of the requirements for the award of Doctor of Philosophy, in the School of Electrical and Data Engineering at the University of Technology Sydney.

This thesis is wholly my own work unless otherwise reference or acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

This document has not been submitted for qualifications at any other academic institution.

This research is supported by the Australian Government Research Training Program.

Signature:

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*To My Parents*

*Eugenia*

*and*

*Antonio.*



“I’ve always been fascinated by maps and cartography. A map tells you where you’ve been, where you are, and where you’re going — in a sense it’s three tenses in one.”

Peter Greenaway

(b. 1942)





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# List of Publications

## Journal publications

- **Cristo Suarez-Rodriguez**, Noman Haider, Ying He and Eryk Dutkiewicz, “Network Optimisation in 5G Networks: A Radio Environment Map Approach”, in *IEEE Transactions on Vehicular Technology*, 2019, major revisions (second round of reviews).
- **Cristo Suarez-Rodriguez**, Ying He and Eryk Dutkiewicz, “Theoretical Analysis of REM-Based Handover Algorithm for Heterogeneous Networks”, in *IEEE Access*, vol. 7, pp. 96719–96731, July 2019.
- Noman Haider, Ahsan Ali, **Cristo Suarez-Rodriguez** and Eryk Dutkiewicz, “Optimal Mode Selection for Full-Duplex Enabled D2D Cognitive Networks”, in *IEEE Access*, vol. 7, pp. 57298–57311, May 2019.

## Conference publications

- **Cristo Suarez-Rodriguez**, Ying He, Beeshanga A. Jayawickrama and Eryk Dutkiewicz, “Low-Overhead Handover-Skipping Technique for 5G Networks”, in *Proc. of IEEE Wireless Communications and Networking Conference (WCNC)*, pp. 1–6, 2019.

- **Cristo Suarez-Rodriguez**, Beeshanga A. Jayawickrama, Faouzi Bader, Eryk Dutkiewicz and Michael Heimlich, “REM-Based Handover Algorithm for Next-Generation Multi-Tier Cellular Networks”, in *Proc. of IEEE Wireless Communications and Networking Conference (WCNC)*, pp. 1–6, 2018.
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