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*Perceptive Mobile Network Based on Joint
Communication and Radio Sensing*

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**Perceptive Mobile Network Based on Joint
Communication and Radio Sensing**

*Dissertation submitted in fulfilment of the requirements
for the degree of*

Doctor of Philosophy in Electrical Engineering

by

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May 25, 2020

Certificate of Original Authorship

I, *Md Lushanur Rahman* 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, Faculty of Engineering and IT* at the University of Technology Sydney (UTS), Australia.

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.

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Dedication

To my beloved wife and my parents

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Abstract

Radio networks have been evolving from communication-only wireless connectivity to a network for services, which will enable new business models and user experiences for emerging industrial applications. Many of these applications, including automotive, industrial automation, public safety and security tasks, will require information retrieval relating to mobile devices and objects through radio sensing. Radio sensing here refers to the process of information extraction for objects of interest in the surrounding environment that is covered by radio signals. We call the evolutionary mobile network with both communication and radio sensing functions as a perceptive mobile network. Such joint functions can be promoted as one of the core components in future 5G/6G standards.

The parametric values regarding moving objects, human movement, and any change in the environment surrounding the user equipment are embedded with the wireless signal and this enables the possibility of using the cellular signal for information extraction. As both wireless communication and radar system exhibit similar receiver front-end architecture at high frequency, it triggers the concepts of joint communication and radio sensing (JCAS) operation. In that circumstance, a unified platform can introduce shared hardware between two functions, which eventually implies reduced size, cost and weight. The main purpose of this doctoral study is to analyse the radio sensing capability of a mobile network and design the framework for joint operation. The thesis aims to design advanced signals and protocols that allow communications and sensing to be better implemented jointly and benefit from each other efficiently. An additional goal is to investigate the existing sensing parameter estimation processes and their suitability in signal processing for JCAS operation.

The thesis provides a general framework for the envisioned perceptive mobile networks that enable radio sensing using downlink and uplink mobile signaling, by considering future mobile network architecture and components, practical sophisticated communication signal format, and complicated signal propagation environment. The thesis discusses the required modifications and upgrades to existing mobile networks to facilitate JCAS functionalities. One and multi-dimensional compressive sensing techniques are successfully employed for estimating the parameters of the sensed scene, following the state of the art, by applying orthogonal frequency-division multiplexing (OFDM) based multi-user multiple-input multiple-output (MIMO) signal model. The simulated results presented here demonstrate reasonable performance in radio sensing using perceptive mobile networks. The research works shown in this thesis indicate the feasibility of the perceptive mobile network and provide a way to proceed.

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List of Publications

PUBLICATIONS PUBLISHED AND UNDER REVIEW RELATED TO THE THESIS:

M. L. Rahman, J. A. Zhang, X. Huang and Y. J. Guo, Analog antenna array based sensing in perceptive mobile networks, IEEE-APS Topical Conference on Antennas and Propagation in Wireless Communications (APWC), Verona, 2017, pp. 199-202.

J. A. Zhang, X. Huang, Y. J. Guo and **M. L. Rahman**, Signal stripping based sensing parameter estimation in perceptive mobile networks, IEEE-APS Topical Conference on APWC, Verona, 2017, pp. 67-70.

M. L. Rahman, J. A. Zhang, X. Huang, Y. J. Guo, and R. W. Heath Jr, "Perceptive Mobile Network Using Joint Communication and Sensing", in IEEE Transactions on Aerospace and Electronic Systems (TAES), pp. 1-1, 2019.

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M. L. Rahman, J. A. Zhang, X. Huang, Y. J. Guo and Z. Lu, "On Joint Communication and Radar Sensing in 5G Mobile Network by Compressive Sensing", submitted for review in the IET Communications, 2020.

M. L. Rahman, J. A. Zhang, X. Huang, Y. J. Guo and Z. Lu, "Gaussian-Mixture-Model Based Clutter Mitigation in Perceptive Mobile Networks", submitted for review in the IEEE Communication Letters, 2020.

M. L. Rahman, J. A. Zhang, K. Wu, X. Huang, Y. J. Guo, S. Chen and J. Yuan, "Enabling Joint Communication and Radio Sensing in Mobile Networks - A Survey", submitted to IEEE Communications Surveys & Tutorials, 2020.

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Abbreviations

AoA	Angle of Arrival
AoD	Angle of Departure
AWGN	Additive White Gaussian Noise
BSBL	Block Sparse Bayesian Learning
BBU	Baseband Units
CDF	Cumulative Distribution Functions
CRAN	Cloud Radio Access Network
CS	Compressive Sensing
DDCE	Decision Directed Channel Estimation
DMRS	Demodulation Reference Signals
EM	Expectation Maximization
GMM	Gaussian Mixture Model
JCAS	Joint Communication and Radio Sensing
MIMO	Multiple-Input Multiple-Output
MU-MIMO	Multiuser Multiple-Input Multiple-Output
MMV	Multi-Measurement Vector
OFDM	Orthogonal Frequency Division Multiplexing
OFDMA	Orthogonal Frequency Division Multiple Access
OMP	Orthogonal Matching Pursuit
PDF	Probability Density Function
PDSCH	Physical Downlink Shared Channel
PRB	Physical Resource Block
PUSCH	Physical Uplink Shared Channel
RMSE	Root Mean Square Error
RRU	Remote Radio Unit
SDMA	Spatial Division Multiple Access
SNR	Signal to Noise Power Ratio

