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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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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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DATE: 25th May 2020

PLACE: Sydney, Australia

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.

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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