UNIVERSITY OF TECHNOLOGY SYDNEY

School of Electrical and Data Engineering
Faculty of Engineering and Information Technology

A Dissertation submitted in fulfilment of the requirements for the degree of Doctor of Philosophy

D2D Communications in 5G Mobile Cellular Networks

We propose and validate a novel approach to mobility management

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To my lovely parents...

Declaration

To the best of my knowledge and belief this work was prepared without aid from any other sources except where indicated. Any reference to material previously published by any other person has been duly acknowledged.

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Abstract

Fifth Generation (5G) stands for future fitness combined with flexible technical solutions that combine with the latest wireless technology. 5G is expected to multiply a thousand times (1000x) in data speed with 20.4 billion devices (IoT) connected to the network by 2020. This literally means everything connecting to everything. From the network point of view, lower latency along with high flexibility is not limited just to 5G. It is already being implemented in real networks. The number of wireless devices connected to networks has increased remarkably over the last couple of decades. Ubiquitous voice and data connections are the fundamental requirements for the next generation of wireless technology.

Device-to-Device communication is widely known as D2D. It is a new paradigm for cellular communication. It was initially proposed to boost network performance. It is considered to be an integral part of the next generation (5G) of telecommunications networks. It takes place when two devices communicate directly without significant help from the base station. In a cellular network, Device-to-Device communication has been viewed as a promising technology overcoming many existing problems. These include capacity, quality and scarce spectrum resources. However, this comes at the price of increased interference and complex mobility issues, even though it was proposed as a new paradigm to enhance network performance. Nevertheless, it is still a challenge to manage devices that are moving. Cellular devices without well-managed mobility are hardly acceptable. Considering in-band underlay D2D communication, a well-managed mobility system in cellular communication should have lower latency, lower power consumption and higher data rates. In this dissertation, we review existing mobility management systems for LTE-Advanced technology and propose an algorithm to be used over the current system so that lower signalling overheads and less delay, along with uninterrupted D2D communication, are guaranteed. We model and simulate our algorithm, comparing the results with mathematical models based on Markov theory.

As in other similar communication systems, mobility management for D2D communication is yet to be explored fully. There are few research papers published so far. What we can say is that the intention of such systems in cellular networks are to enable lower latency, lower power consumption, less complexity and, last but not least, uninterrupted data connections. Our simulation results validate our proposed model and highlight D2D communication and its mobility issues.

An essential element of our proposal is to estimate the user's location. We can say that a mobility management system for D2D communication is hardly workable if the location of the users is not realisable. This dissertation also shows some latest techniques for estimating the direction of arrival (DOA) with mathematical models and simulation results. Smart antenna systems are proposed. It is possible to determine the location of a user by considering the uplink transmission system. Estimating the channel and actual path delay is also an important task, which might be done by using 1D uniform linear array (ULA) or 2D Uniform Rectangular (URA) array antenna systems. In this chapter, 1D ULA is described utilising some well-known techniques. The channel characteristics largely determine the performance of an end-to-end communication system. It determines the signal transformation while propagating through the channel between receivers and transmitters. Accurate channel information is crucial for both the transmitter and receiver ends to perform at their best. The ultimate focus of this part is to estimate the channel based on 2D parameter estimation. Uniform Rectangular Array (URA) is used to perform the 2D parameter estimation. It is possible to estimate azimuth and elevation of a source by using the URA model.

The problem of mobility in this context has been investigated in few papers, with no reliable solutions as yet. We propose a unique algorithm for mobility management for D2D communications. In this dissertation, we highlight and explain the mobility model mathematically and analytically, along with the a simulation of the Markovian model. A Markov model is essentially a simplified approach to describing a system that occupies a discrete state at any point in time. We also make a bridge between our mobility algorithm and a Markovian model.

Research Structure

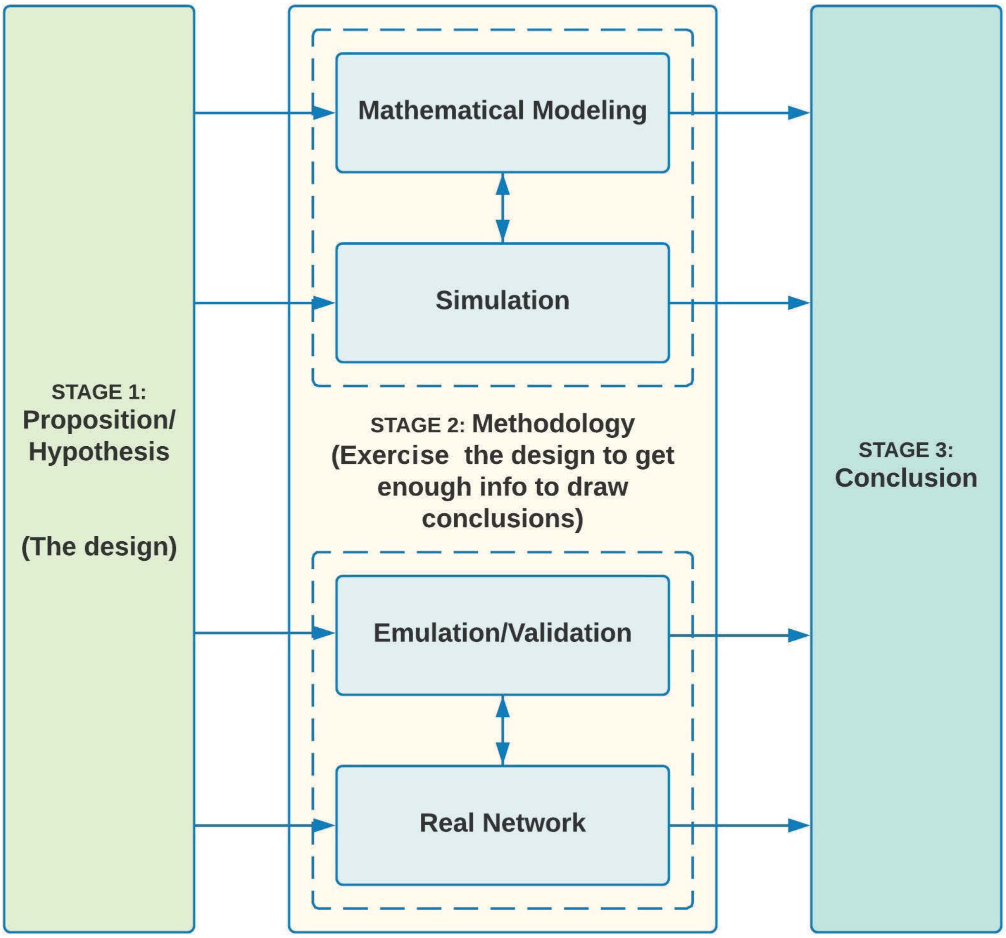

Figure 1: Stages and structure of the overall research

List of Publications

Most of the theories, technical discussions and contributions in this dissertation are based on the following publications written by the author in which others are the co-authors.

A. International Conference Publications:

[$C1$] S. Barua and R. Braun, "Mobility management of D2D communication for the 5G cellular network system: A study and result," 2017 17th International Symposium on Communications and Information Technologies (ISCIT), Cairns, QLD, 2017, pp. 1-6. doi: 10.1109/ISCIT.2017.8261187, IEEE.

[$C2$] S. Barua and R. Braun, "A novel approach of mobility management for the D2D communications in 5G mobile cellular network system," 2016 18th Asia-Pacific Network Operations and Management Symposium (APNOMS), Kanazawa, 2016, pp. 1-4. doi: 10.1109/APNOMS.2016.7737272, IEEE.

[$C3$] S. Barua and R. Braun, "A Markovian Approach to the Mobility Management for the D2D Communication in 5G Cellular Network System," 2017 5th Asia Pacific International Conference on Computer Assisted and System Engineering (APCASE 2017) ISBN 978-0-9924518-0-6.

[$C4$] S. Barua, Sinh Cong Lam, P. Ghosa, Shiqi Xing and K. Sandrasegaran, "A survey of Direction of Arrival estimation techniques and implementation of channel estimation based on SCME," 2015, 12th International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology (ECTI-CON), Hua Hin, 2015, pp. 1-5. doi: 10.1109/ECTICon.2015.7206986, IEEE.

[$C5$] S. C. Lam, R. Subramanian, K. Sandrasegaran, P. Ghosal and S. Barua, "Performance of well-known frequency reuse algorithms in LTE downlink 3GPP LTE systems," 2015, 9th International Conference on Signal Processing and Communication Systems (ICSPCS), Cairns, QLD, 2015, pp. 1-5. doi: 10.1109/ICSPCS.2015.7391766, IEEE.

[$C6$] Daeinabi, A., K. Sandrasegaran, and S. Barua. "A dynamic almost blank subframe scheme for video streaming traffic model in heterogeneous networks." 2015, 12th International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information

Technology (ECTI-CON), IEEE.

B. International Book Chapter Publications:

[*B*1] S. Barua and R. Braun, "*Direction of Arrival (DOA) and Channel Estimation*." Self-Organized Mobile Communication Technologies and Techniques for Network Optimization. IGI Global, 2016. 216-235.

C. International Journal Publications:

[*J*1] S. Barua, F. Afroz, S. S. Islam, A. U. Ahmed, P. Ghosal, and K. Sandrasegaran. "Comparative study on priority based QOS aware MAC protocols for WSN." International Journal of Wireless and Mobile Networks 6, no. 5 (2014): p175.

[*J*2] G, Pantha, S. Barua, R. Subramanian, S. Xing, and K. Sandrasegaran. "A novel approach for mobility management in LTE femtocells." International Journal of Wireless and Mobile Networks 6, no. 5 (2014): p45.

[*J*3] K. Haider Ali, S. Barua, P. Ghosal, and K. Sandrasegaran. "Macro with Pico Cells (HetNets) System Behavior Using Well-known scheduling Algorithms." arXiv preprint arXiv:1411.2140 (2014).

[*J*4] F. Afroz, S. Barua, and K. Sandrasegaran. "Performance analysis of FLS, EXP, LOG AND M-LWDF packet scheduling algorithms in downlink 3GPP LTE system." International Journal of Wireless and Mobile Networks 6, no. 5 (2014): p77.

[*J*5] X. Shiqi, P. Ghosal, S. Barua, R. Subramanian, and K. Sandrasegaran. "System level simulation for two tier macro-femto cellular networks." International Journal of Wireless and Mobile Networks 6, no. 6 (2014): p1.

[*J*6] D. Suman, S. Barua, and J. Sen. "Auto default gateway settings for virtual machines in servers using default gateway weight settings protocol (DGW)." International Journal of Wireless and Mobile Networks 6, no. 5 (2014): p133.

[*J*7] S. Ramprasad, S. Barua, S. C. Lam, P. Ghosal, and K. Sandrasegaran. "Group Based Algorithm to Manage Access Technique in the Vehicular Networking to Reduce Preamble ID Collision and Improve RACH allocation in ITS." International Journal of Wireless and Mobile Networks 6, no. 5 (2014): p1.

Contents

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Abbreviations and Acronyms

1G	First Generation System
2G	Second Generation System
3G	Third Generation System
3GPP	3rd Generation Partnership Project.
3GPP2	3rd Generation Partnership Project 2
4G	Fourth Generation System
5G	Fifth Generation System
8PSK	8-Phase Shift Keying
AMPS	Advanced Mobile Phone System
BBU	Baseband Unit
BDMA	Beam Division Multiple Access
CA	Carrier Aggregation
CDMA	Code Division Multiple Access
CDMA2000	Code Division Multiple Access 2000
CoMP	Coordinated Multi-point Transmission
CUE	Cellular User's Equipment
D2D	Device-to-Device
DOA	Direction of Arrival
DUE	D2D User's Equipment
EDGE	Enhanced Data rates for GSM Evolution (EDGE)
eNodeB	Evolved NodeB
eNB	Evolved NodeB
EPC	Evolved Packet Core
ESPRIT	Estimation of Signal Parameters via Rotational Invariance Technique
EV-DO	Evolution-Data Optimised
FDD	Frequency Division Duplex
FDMA	Frequency Division Multiple Access
GFDM	Generalized Frequency Division Multiplexing
GPRS	General Packet Radio Service
GPS	Global Positioning System
GSM	Global System for Mobile Communications
GTP-U	GPRS Tunnelling Protocol for User Plane

HDTV	High Definition TV
HO	Handover
HSDPA	High Speed Downlink Packet Access
HSPA+	Evolved High-Speed Packet Access
HSUPA	High Speed UplinkPacket Access
IMT-Advanced	International Mobile Telecommunications Advanced
IoT	Internet of Things
IPV6	Internet Protocol Version 6
ITU-R	International Telecommunications Union-Radio communications sector
KPI	Key Performance Indicator
LAS-CDMA	Large Area Synchronised Code Division Multiple Access
LOS	Line of Sight
LRAPs	Light RAPs
LTE	Long Term Evolution
LTE-A	LTE-Advanced
LTE-Hi	LTE Hotspot Improvement
MC-CDMA	Multi-Carrier Code Division Multiple Access
MDT	Minimisation of Drive Test
MIMO	Multiple Input, Multiple Output
MME	Mobility Management Entity
MMS	Multimedia Message System
MTC	Machine type communication
Multi-RAT	Multiple Radio Access Technology
MUSIC	Multiple Signal Classication
MVDR	Minimum Variance Distortionless Response
NFV	Network Function Virtualisation
NLOS	Non-Line of Sight
NMT	Nordic Mobile Telephone
NTT	Nippon Telegraph and Telephone
OFDM	Orthogonal Frequency Division Multiplexing
OFDMA	Orthogonal Frequency-Division Multiple Access
PAPR	Peak-to-Average Power Ratio
P-GW	Packet Data Network Gateway
PGW-C	Packet Data Network Gateway Control Plane
PGW-D	Packet Data Network Gateway Data Plane
PRBs	Physical Resource Blocks
PSTN	Public Switched Telephone Network
RACE	Random Access Channel
RAPs	Radio Access Points
RAT	Radio Access Technologies

RoF	Radio-over-Fiber
RSRP	Reference Signal Receive Power
RSRQ	Reference Signal Received Quality
RSSI	Received Signal Strength Indicator
SAS	Smart Antenna System
SCMA	Sparse Code Multiple Access
SDN	Software Defined Networking
S-GW	Serving Gateway
SMS	Short Message Services
SMTP	Simple Mail Transfer Protocol
SNR	Signal-to-Noise Ratio
TACS	Total Access Communication System
TDD	Time Division Duplex
TDMA	Time Division Multiple Access
TD-SCDMA	Time Division Synchronous Code Division Multiple Access
UCA	Uniform Circular Array
UCE	Unified Control Entity
UDW	Unified Data Gateway
UE	User Equipment
ULA	Uniform Linear Array
UMTS	Universal Mobile Telecommunication System
URA	Uniform Rectangular Array
V2V	Vehicle-to-Vehicle
VoIP	Voice over Internet Protocol
W-CDMA	Wideband Code Division Multiple Access
WiFi	Wireless Fidelity
WiMAX	Worldwide Interoperability for Microwave Access
ZC	Zado-Chu Sequence.