A Dissertation submitted in fulfilment of the requirements

for the Degree of Doctor of Philosophy

Scalable MAC Protocol for D2D Communication for future 5G Networks

Bushra Ismaiel

2018

University Of Technology Sydney,

Faculty Of Engineering and Information Technology, School Of Electrical and Data Engineering

Supervisor

Dr.Mehran Abolhasan

Co-Supervisor

Dr.Daniel Franklin

Declaration Of Authorship

I, Bushra Ismaiel, declare that this thesis titled, Scalable MAC Protocol for D2D Communication for future 5G Networks, and the work presented in it are my own. I confirm that:

- The work is done solely while in candidature for a research degree at this University.
- The work done in this thesis has not been previously submitted/published for a degree.
- The work of others have been quoted, the source is always given. With the exception of such quotations, this thesis is entirely my own work.
- Any help that I received in my research work and the preparation of thesis itself has been acknowledged.

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

Signature of Student: Production Note:
Signature removed prior to publication.

Date: 15^{th} October 2018

Table of Contents

List of Figures

List of Tables

List Of Abbreviations

D2D	Device-to-Device
QoS	Quality-of-Service
LTE-A	Long term evolution advance
5G	Fifth generation
MAC	Medium access control
eNB	Evolved node B
PCF	Point coordinated function
DCF	Distributed coordinated function
CP	Contention period
CFP	Contention free period
TDMA	Time division multiple access
FDMA	Frequency division multiple access
CSMA/CA	Carrier sense multiple access collision avoidance
CSMA/CD	Carrier sense multiple access collision detection
RTS	Request-to-send
CTS	Clear-to-send
NAV	Network allocation vector
ACK	Acknowledgement
SIFS	Short Interframe Space
DIFS	DCF short interframe space
PIFS	PCF short interframe space
TXOP	Transmission opportunity
TBTT	Target beacon transmission time

List Of Abbreviations

WLAN	Wireless local area network
SC-MP	Scalable MAC Protocol
LTE-U	Long term evolution unlicensed
LTE-LAA	Long term evolution licensed assisted access
LWA	Long term evolution and Wi-Fi aggregation
SDN	Software defined network
BS	Base station
WBS	Wireless local area base station
HCF	Hybrid coordination function
LBT	Listen before talk

List Of Parameters

r_k	Polling state of user$_k$
v_k	Allocation of time slot to voice traffic of user$_k$
m_k	Time slot is allocated for video/multimedia traffic to a Wi-Fi user after satisfying the channel condition B or allow D2D communication to a Wi-Fi user if the neighbour has already downloaded the video/multimedia file and satisfy the channel condition A
d_k	Allows user to do D2D communication in Markov process.
P_V	Probability for voice traffic
P_M	Probability for video/multimedia traffic
P_N	Probability that video is not downloaded by any neighbour
P_S	Channel condition B is not satisfied to allocate time slot
P_D	Channel condition A is not satisfied for D2D communication
N_n	Total number of neighbours that downloaded the video
t_v	time spent to transmit the voice data
t_m	time spent to transmit the video/multimedia data
t_d	time spent to transmit the D2D data
d_v	data rate for voice
d_m	data rate for video/multimedia
d_d	data rate for D2D communication
$\mathbf{Q}$	Semi-Markov process transition matrix
Γ	Semi-Markov process diagonal matrix
ϕ	eigen value of matrix H
T_r	Duration of r in semi-Markovian model

List Of Parameters

T_v	Duration of voice traffic in semi-Markovian model
T_m	Duration of video/multimedia traffic in semi-Markovian model
T_v	Duration of voice traffic in semi-Markovian model
T_m	Duration of video/multimedia traffic in semi-Markovian model
$M_k(t)$	Moment generating function
$y_{n,k}$	binary variable to select the band
$\mathbf{B}_n$	Total bandwidth
$C_{n,k}$	Effective capacity of licensed/unlicensed band of user$_k$
$\theta_{n,k}$	Quality-of-service of licensed/unlicensed band of user$_k$
$\alpha_{n,k}$	Bandwidth allocated to user$_k$ of licensed/unlicensed band
D_{th}^k	Delay threshold of user$_k$
$\gamma_{n,k}$	Signal-to-interference noise ratio of user$_k$ in licensed/unlicensed band
$\mathbf{R}_k$	Minimum data rate of user$_k$
P_{th}^k	Probability threshold of delay bound
$\mathbf{M}$	Markov process transition matrix

ABSTRACT

Due to the steep growth in mobile data traffic, it will be a challenge for 5G networks to ful-fill the requirement using limited resources in licensed spectrum. However, the joint deployment of smaller cells in the Macro-cell has attempted to overcome this issue. It is observed that users are adversely affected by limited resources in the licensed band. Due to the scarcity of resources in the licensed band, it is better to deploy a small cell operating at an unlicensed spectrum like WLAN. Establishing Device to Device communication (D2D) in the cooperative deployment of cellular networks and WLAN can accommodate the on growing user data demand by intelligently allocating the resources, hence, forming a centralized control in a distributive manner.

This Thesis gives a detailed overview of all the LTE technologies operating in an unlicensed band which includes; LTE-U, LAA, LWA, and MuLTEfire. The technologies are compared with extensive simulation and further D2D communication is applied in these technologies to observe their behaviour.

This Thesis also introduces a three-tier architecture for next generation 5G networks which can offload traffic from cellular networks to WLAN in a dense environment. It proposes a Scalable MAC Protocol (SC-MP) to efficiently allocate resources for Wi-Fi users with D2D communication. SC-MP will allocate WLAN resources to the normal users in a centralized and efficient manner based on a novel PCF strategy, which will develop a centralized control in a distributive manner. The SC-MP is compared to legacy DCF protocol defined in IEEE 802.11 through extensive simulation to evaluate the network performance. The key result is that SC-MP is able to improve the performance compared to DCF for metrics that include; network throughput, network capacity, and network delay.

Furthermore, the thesis gives a detailed mathematical analysis of SC-MP using Markov modelling and semi-Markov modelling. Effective capacity is derived using three-state

semi-Markov modelling for the proposed SC-MP. Analytical results are validated through the simulation results. In addition, an optimal queue scheduling and resource allocation problem with QoS guaranteed between the licensed and unlicensed band is formulated to minimize the bandwidth of licensed spectrum and maximize the aggregated effective capacity of a three-tier network. The results proved that the proposed SC-MP can perform better compared with the state of art.

ACKNOWLEDGEMENTS

I would like to thank God for making the Ph.D journey easy for me. There are so many people that helped me, professionally and personally, through my Ph.D journey. There were many moments that I could not see a light at the end of the tunnel, but I am glad that the support and encouragement that I received along the have brought me to this point. I would like to acknowledge all the people who contributed to this journey.

First, I would like to thank my principal supervisor, Dr. Mehran Abolhasan, who had given me an opportunity to join as a post-graduate researcher. He has always been supportive and a source of encouragement and have an endless source of new ideas to investigate. I would like to thank Wei Ni, for giving me new ideas and helping me through the analytical part and giving me time whenever it was required. I would like to thank David Smith, for all the guidelines he has given me through my Ph.D. tenure. Also, I would like to thank Daniel Franklin, for tirelessly providing guidelines in technical writing.

I would like to thank my parents and my family, especially my kids, who have been supportive throughout my Ph.D. journey. I am thankful for all the sacrifices you have willingly made over the past few years to support me in so many endeavours.

In the end, I would like to thank my colleagues for the interesting discussions, technical support and motivation.