# ADDRESSING THE HIDDEN TERMINAL PROBLEM IN MU-MIMO WLANS WITH RELAXED ZERO-FORCING APPROACH


by

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## CERTIFICATE OF ORIGINAL AUTHORSHIP

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of the requirements for a degree to any other university or institution other than University of Technology Sydney, Australia.

I also certify that the thesis is an original piece of research and it has been written by me.

In addition, I certify that all information sources and literature used are indicated in the thesis.

Last but not the least, this research is supported by an Australian Government Research Training Program Scholarship.

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# ABSTRACT

An ever-increasing data rate demand, mainly due to the proliferation of numerous smart devices, enterprises' mission critical networks, and industry automation, has mounted tremendous pressure on today's Wireless Local Area Networks (WLANs). Several avenues such as bandwidth, constellation density, the Multiple Input Multiple Output (MIMO) technique, etc., have been explored, e.g., IEEE802.11n/ac standards, to keep up with the demand. Future WLAN standard, e.g., IEEE802.11ax, with potential technologies such as uplink Multi-User (MU)-MIMO, full duplex transmission, etc., is anticipated by 2019.

Having said that, there has been a strong emphasis on solving the technical issues with WLANs along with the addition of new frontiers in order to cope with the data rate demanded. One such appending decade-long issue is the inevitable Hidden Terminal (HT) problem in a distributive, decentralised and densely deployed WLANs, which fundamentally arises because of the transmission time overlaps between different transmitters operating at a particular frequency. The consequence is that it causes collisions of signals, which sharply reduces the system throughput.

In the context of MU-MIMO based WLANs, several designs for a general network scenario, without the consideration of the HT problem, have been proposed, bringing efficiency by avoiding the collision of signals. However, a dedicated design, which could effectively address the HT problem in MU-MIMO WLANs

and also become interoperable (with legacy standards) and feasible with existing hardware, is lacking to the best of our knowledge.

In this thesis, we propose a solution for the HT problem which has three fundamental attributes.

First, a) at the Physical (PHY) layer, the Zero-forcing (ZF) transmission strategy with fairness and throughput aware precoding is proposed, b) a hybrid scheduling scheme, combining the packet position-based First In First Out (FIFO) and channel quality-based scheme, namely the Best of the Two Choices, is designed, c) at the Medium Access Control (MAC) layer, Degrees-of-Freedom (DoF) based Transmission Opportunity (TXOP) for Access Points (APs) is developed which is backed by an extended Point Coordination Function (PCF), d) an explicit channel acquisition framework is proposed for ZF which has a reduced signaling time overhead of 98.6740 $\mu s$ compared to IEEE802.11ac. e) performance evaluation methodologies are: i) hardware testbed results of the PHY strategy, which shows a received SNR gain of about 6 dB on average, and about 10 dB in comparison to the HT scenario, ii) simulation results of the MAC design, which shows a constant throughput gain of $4-5$ times w.r.t. the popular Request to Send/Clear to Send (RTS/CTS) solution.

Second, to address the interoperability issue, we purposefully use the standard frame format except for some required logical changes. Notably, the transition mechanism of our design, and for any MAC that uses standard frame formats, is investigated meticulously. The transition condition, transition steps and transition frame formats are detailed.

Third, to address a practical constraint of an imperfect Channel State Information (CSI) at APs, a) we incorporate the Finite Rate Feedback (FRF) model in our solution. The effects on system parameters such as quantisation error bounds,

throughput loss w.r.t. perfect CSI, etc., are discussed with closed-form analytical expressions, b) instead of an ideal ZF technique, a Relaxed ZF (RZF) framework is considered, in which the interference and power constraints of the optimisation problem are relaxed to the interference upper bound and to the maximum transmit power respectively. Our results lead to a distributive algorithm for calculating the optimal ZF precoding vector which suits the distributive, decentralised and uncoordinated nature of MU-MIMO WLANs.

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