Prof. L. Hanzo FREng, FIEEE, FIET, DSc
Chair of Telecommunications

University of Southampton
Highfield
Southampton
SO17 1BJ United Kingdom

T +44 (0)23 8059 3125
F +44 (0)23 8059 4508
E lh@ecs.soton.ac.uk
www.wireless.ecs.soton.ac.uk

UNIVERSITY OF Southampton
School of Electronics and Computer Science

1st of May 2022

External Examiner's Review

on

Bartosz Bossy

ENERGY-EFFICIENT RESOURCE ALLOCATION IN OFDM SYSTEMS WITH COMPUTATIONAL AWARENESS

Overview

A range of issues related to the optimal design of Orthogonal Frequency Division Multiple Access (OFDM) techniques is investigated in the context of both single-link as well as multi-user and relay-aided systems. The motivation of the thesis is to design energy-efficient techniques relying on adaptive modulation and coding arrangements, while optimizing both the transmit power and the signal processing power dissipation. This holistic power optimization is the over-arching novelty of the thesis.

To expound a little further, in **Chapter 1** the state-of-the-art is critically appraised and the pivotal issues of energy-efficient resource allocation are highlighted with special emphasis on OFDM systems. The specific energy efficiency metric to be optimized is also introduced in this chapter along with the associated power consumption estimation techniques. Their pros and cons are weighed up before their employment for the systems investigated. The chapter is concluded with a brief tour of the optimization methods to be employed, where the challenge is that they have to handle a mixture of continuous and discrete-valued variables.

Chapter 2 solves the energy-efficient resource allocation problem of a single OFDM link, commencing with a state-of-the-art survey of a single-link OFDM scenario. Again, the holistic

energy efficiency metric takes into account both the transmit power as well as the power consumption of the Adaptive Modulation and Coding (AMC) mode selection. Specifically, the resultant optimization problem is a Mixed Integer Nonlinear Fractional Programming (MINLFP) problem associated with a mixture of continuous and discrete values. The candidate solves this challenging problem by harnessing a sophisticated combination of Dinkelbach's popular method, the classic dual decomposition method, Lagrange multipliers and the Karush-Kuhn-Tucker (KKT) conditions. His research goes beyond the existing state-of-the-art constituted by references [23, 24, 44, 47], because he considers adaptive modulation and coding, which is more intelligent than fixed-mode schemes, since it does not aim for the wasteful power-boosting of the attenuated low-quality subcarriers. The chapter is well illustrated with perfoamnce results, but it appears that the legend 'Shannon limit' should be removed from Fig. 2.6, since this limit is not included in the figure.

Chapter 3 extends the energy efficiency maximization problem to multiuser OFDMA networks. Initially both the throughput and power dissipation aspects as well as the multiuser network optimization solutions found in the open literature are reviewed. An iterative algorithm is conceived for maximizing the overall energy efficiency in the OFDMA downlink by judiciously allocating both the resource blocks and the transmit power to the users. Similarly to the single-link scenario of Chapter 2, the resultant optimization problem becomes again a challenging Mixed Integer Nonlinear Fractional Programming problem. This chapter uses the same system model as [13,14], but instead of maximizing the throughput, it maximizes the energy efficiency and attains gains between 10 and 60 %.

In **Chapter 4** the system's architecture is evolved further to a relay-aided multiuser OFDMA system. In the state-of-the-art references [68,70,75,95] the authors refrain from using the same subcarrier at the source and relay, which necessitates the employment of two time-slots. By contrast, the candidate added a transmission mode, in which the source transmits to another user on the same subcarrier, as the relay, which however creates extra interference. The candidate proposed to adaptively activate one of the above-mentioned soure-, relay- as well as source-and-relay transmission modes for every user. The chapter is concluded by a well-illustrated results section for substantiating the candidate's claims.

School of Electronics and Computer Science, University of Southampton, Highfield Campus, Southampton SO17 1BJ, UK.
Tel:+44(0)23 8059 2909 Fax:+44(0)23 8059 6881 www.ecs.soton.ac.uk

In the brief **Chapter 5** a number of practical aspects of energy-efficient OFDM resource allocation are highlighted and the impact of nonlinear distortions imposed on OFDM signals is alluded to. Finally, **Chapter 6** concludes the thesis and provides a few suggestions for future work.

Assessment

The candidate employed a wide variety of optimizations techniques, demonstrating his capability to conduct independent research. Indeed, these sophisticated optimization techniques are widely applicable to diverse wireless communications problems. The literary standard of the thesis is high and the calims are richly illustrated with perfomance results for diverse application scenarios. The candidate has made prolific contributions to the international research literature, including seven journal papers as well as seven conference papers, in addition to a range of national publications. Hence he demonstrated his ability to disseminate his research results for further exploitation by the scientific community. A welcome improvement would be to combine Chapters 5 and 6 into an inspirational longer chapter, which should be richly illustrated with numerous citations from the recent years of 2020-2022 to outline a range of open research problems.

In conclusion, based on the above evidence, I recommend the award of PhD with distinction.

Prof. L. Hanzo

School of Electronics and Computer Science, University of Southampton, Highfield Campus, Southampton SO17 1BJ, UK.
Tel:+44(0)23 8059 2909 Fax:+44(0)23 8059 6881 www.ecs.soton.ac.uk