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Quantum-Assisted Multi-User Wireless Systems

by

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ABSTRACT

FACULTY OF PHYSICAL SCIENCES AND ENGINEERING
SCHOOL OF ELECTRONICS AND COMPUTER SCIENCE

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The high complexity of numerous optimal classical communication schemes, such as the Maximum Likelihood (ML) and Maximum *A posteriori* Probability (MAP) Multi-User Detector (MUD) designed for coherent detection or the ML and MAP Multiple-Symbol Differential Detectors (MSDD) conceived for non-coherent receivers often prevents their practical implementation. In this thesis we commence with a review and tutorial on Quantum Search Algorithms (QSA) and propose a number of hard-output and iterative Quantum-assisted MUDs (QMUD) and MSDDs (QMSDD).

We employ a QSA, termed as the Dürr-Høyer Algorithm (DHA) that finds the minimum of a function in order to perform near-optimal detection with quadratic reduction in the computational complexity, when compared to that of the ML MUD / MSDD. Two further techniques conceived for reducing the complexity of the DHA-based Quantum-assisted MUD (QMUD) are also proposed. These novel QMUDs / QMSDDs are employed in the uplink of various multiple access systems, such as Direct-Sequence Code Division Multiple Access systems, Space Division Multiple Access systems as well as in Direct-Sequence Spreading and Slow Subcarrier Hopping SDMA systems amalgamated with Orthogonal Frequency Division Multiplexing and Interleave Division Multiple Access systems.

Furthermore, we follow a quantum approach to achieve the same performance as the optimal Soft-Input Soft-Output (SISO) classical detectors by replacing them with a quantum algorithm, which estimates the weighted sum of all the evaluations of a function. We propose a SISO QMUD / QMSDD scheme, which is the quantum-domain equivalent of the MAP MUD / MSDD. Both our EXtrinsic Information Transfer (EXIT) charts and Bit Error Ratio (BER) curves show that the computational complexity of the proposed QMUD / QMSDD is significantly lower than that of the MAP MUD / MSDD, whilst their performance remains equivalent. Moreover, we propose two additional families of iterative DHA-based QMUD / QMSDDs for performing near-optimal MAP detection exhibiting an even lower tunable complexity than the QWSA QMUD. Several variations of the proposed QMUD / QMSDDs have been developed and they are shown to perform better than the state-of-the-art low-complexity MUDs / MSDDs at a given complexity. Their iterative decoding performance is investigated with the aid of non-Gaussian EXIT charts.

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DECLARATION OF AUTHORSHIP

I, **Panagiotis Botsinis**,

declare that the thesis entitled

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and the work presented in the thesis are both my own, and have been generated by me as the result of my own original research. I confirm that:

- this work was done wholly or mainly while in candidature for a research degree at this University;
- where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated;
- where I have consulted the published work of others, this is always clearly attributed;
- where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work;
- I have acknowledged all main sources of help;
- where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself;
- parts of this work have been published as: [1–6].

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List of Publications

Journal Papers:

1. D. Alanis, **P. Botsinis**, Z. Babar, S. X. Ng, and L. Hanzo, "Non-Dominated Quantum Iterative Routing Optimization for Wireless Multihop Networks," *IEEE Access*, *(in preparation)*

2. Z. Babar, **P. Botsinis**, D. Alanis, S. X. Ng, and L. Hanzo, "The Realm of Quantum LDPC Codes: A Survey & Improved Decoding Strategies," *IEEE Access*, *(in preparation)*

3. **P. Botsinis**, D. Alanis, Z. Babar, S. X. Ng, and L. Hanzo, "Iterative Quantum-Assisted Multi-User Detection for Multi-Carrier Interleave Division Multiple Access Systems," *IEEE Transactions on Communications*, *(submitted)*

4. **P. Botsinis**, D. Alanis, Z. Babar, S. X. Ng, and L. Hanzo, "Non-Coherent Quantum Multiple Symbol Differential Detection for Wireless Systems," *IEEE Access*, vol. 3, pp. 569–598, 2015

5. Z. Babar, **P. Botsinis**, D. Alanis, S. X. Ng, and L. Hanzo, "The Road From Near-Capacity Classical to Quantum Concatenated Code Design," *IEEE Access*, vol. 3, pp. 146–176, 2015

6. D. Alanis, **P. Botsinis**, S. X. Ng, and L. Hanzo, "Quantum-Assisted Routing Optimization for Self-Organizing Networks," *IEEE Access*, vol. 2, pp. 614–632, 2014

7. **P. Botsinis**, D. Alanis, S. X. Ng, and L. Hanzo, "Low-Complexity Soft-Output Quantum-Assisted Multi-User Detection for Direct-Sequence Spreading and Slow Subcarrier-Hopping Aided SDMA-OFDM Systems," *IEEE Access*, vol. 2, pp. 451–472, 2014

8. **P. Botsinis**, S. X. Ng, and L. Hanzo, "Fixed-Complexity Quantum-Assisted Multi-User Detection for CDMA and SDMA," *IEEE Transactions on Communications*, vol. 62, no. 3, pp. 990–1000, 2014

9. **P. Botsinis**, S. X. Ng, and L. Hanzo, "Quantum Search Algorithms, Quantum Wireless, and a Low-Complexity Maximum Likelihood Iterative Quantum Multi-User Detector Design," *IEEE Access*, vol. 1, pp. 94–122, 2013

Conference Papers:

1. **P. Botsinis**, S. X. Ng, and L. Hanzo, "Low-Complexity Iterative Quantum Multi-User Detection in SDMA Systems," *IEEE International Conference on Communications (ICC)*, June 2014

Contents