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

Distributed Joint Source-Channel Coding and Modulation for Wireless Communications

by

Abdulah Jeza Aljohani
B.Sc.(Eng.), MSc.

A doctoral thesis report submitted in partial fulfilment of
the requirements for the award of Doctor of Philosophy
at the University of Southampton

December 2015

SUPERVISORS:
Dr. Soon Xin Ng
PhD, SMIEEE, MIET, CEng, FHEA
and
Professor Lajos Hanzo
FREng, FIEEE, FIEE, DSc, EIC IEEE Press
Chair of Southampton Wireless Group
Department of Electronics and Computer Science
University of Southampton
Southampton SO17 1BJ
United Kingdom

Dedicated to my family and friends

UNIVERSITY OF SOUTHAMPTON

ABSTRACT

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

Doctor of Philosophy

Distributed Joint Source-Channel Coding and Modulation for Wireless Communications

by Abdulah Aljohani

Distributed Source Coding (DSC) schemes rely on separate encoding but joint decoding of statistically dependent sources, which exhibit correlation. DSC has numerous promising applications ranging from reduced-complexity handheld video communications to onboard hyperspectral image coding under computational limitations. The concept of separate encoding at the first sight compromises the attainable encoding performance. However, DSC theory proves that independent encoding can in fact be designed as efficiently as joint encoding, as long as joint decoding is allowed. More specifically, Distributed Joint Source-Channel coding (DJSC) is associated with the scenario, where the correlated source signals are transmitted through a noisy channel. A series of Turbo Trellis-Coded Modulation (TTCM) aided DJSC-based cooperative transmission schemes are proposed.

An iterative Joint Source-coding, Channel-coding and Modulation (JSCM) scheme relying on the intrinsic amalgamation of Variable Length Code (VLC) and TTCM was proposed for two-way-aided transmission. The system advocated was designed for improving the attainable throughput, reliability and coverage area compared to that of conventional one-way relaying. Briefly, a pair of users exchange their information with the aid of a twin-antenna aided Relay Node (RN). We quantify the Discrete-input Continuous-output Memoryless Channel (DCMC) capacity of the corresponding two-way relay channel. The semi-analytical EXtrinsic Information Transfer Characteristics (EXIT) charts are employed for investigating the decoding convergence of the joint source and channel decoder as well as for assisting the overall system design. Furthermore, our iterative scheme employs a novel low-complexity source coding technique that significantly reduces the number of states in the bit-based trellis before invoking it for robust image and video transmission.

Then, an adaptive DJSC scheme is conceived for the transmission of a pair of correlated sources to a Destination Node (DN). The first source sequence is TTCM encoded and then it is compressed before it is transmitted both over a Rayleigh fading and Nakagami-m fading channels, where the second source signal is assumed to be perfectly decoded side-information at the DN for the sake of improving the achievable decoding performance of the first source. The proposed scheme is capable of performing reliable communications for various levels of correlation near to the theoretical Slepian-Wolf/Shannon (SW/S) limit. Additionally, its encoder is capable of accommodating arbitrary time-variant short-term correlation between the two sources.

Pursuing our objective of designing practical DJSC schemes, we further extended the above-

mentioned arrangement to a more realistic cooperative communication system, where the pair of correlated sources are transmitted to a DN with the aid of a RN. Explicitly, the two correlated source sequences are TTCM encoded and compressed before transmission over a Rayleigh fading Multiple Access Channel (MAC). The RN transmits both users' signal with the aid of a powerful SuperPosition Modulation (SPM) technique that judiciously allocates the transmit power between the two signals. The correlation is beneficially exploited at both the RN and the DN using our powerful iterative joint decoder, which is optimised using EXIT charts. We further conceive a so-called Block Syndrome Decoding (BSD) approach for our DJSC scheme, which reduces the decoding complexity, whilst additionally providing an accurate correlation estimate.

As a further new cooperative technique, our DJSC scheme invokes RN-aided Network Coding (NC) which is capable of improving the overall throughput without increasing the energy dissipation. To investigate our DJSC in the context of diverse environments, our NC-based schemes are also appraised in the context of slow fading effects that might be imposed by obstacles blocking the line-of-sight transmission links. Our proposed scheme is shown to achieve substantial performance gains over its conventional non-cooperative counterpart.

Declaration of Authorship

I, **Abdulah Jeza Aljohani**, declare that the thesis entitled **Distributed Joint Source-Channel Coding and Modulation for Wireless Communications** and the work presented in it are my own and has 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.

Signed: ..... Date: .....

Acknowledgements

I wish to express my heartfelt gratitude to my supervisors Dr. Soon Xin Ng and Professor Lajos Hanzo for their excellent guidance and support throughout my research. I sincerely thank Dr. Ng for the countless research ideas and tools I have learned from him. Without his support and great patience my research would not approach this level.

I would also like to thank Prof. Hanzo for his outstanding guidance and inspiration. His patience, enthusiasm and encouragement have been highly supportive to me. Many thanks to the staff and my colleagues of Southampton Wireless Group, particularly Prof. Sheng Chen, Prof. Lie-Liang Yang, Dr. Rob Maunder, Dr. Mohammed El-Hajjar, Dr. Rong Zhang, Dr. Halil Yetgin, Dr. Hung Viet Nguyen, Dr. Zunaira Babar and Dr. Hua Sun, for their invaluable technical support and collaborative works.

I would also like to express my sincere gratitude to my beloved family, my parents: Jeza Aljohani and Muznah Aljohani, my parents-in-law: Mohammed Alzahrani and Fatimah Alzahrani, my brothers: Captain. Khalid and Dr. Naif, my sisters: Nashmia, Dr. Nouf, Dr. Kholud and Sara. Last but not least heartfelt thanks to my lovely wife Ebtesam Alzahrani and my son Amr (Amoori) for their love, support and care for me.

List of Publications

Journals:

1. **A. J. Aljohani**, S. X. Ng, R. G. Maunder and L. Hanzo,"EXIT-chart Aided Joint Source-Coding, Channel-Coding and Modulation Design for Two-Way Relaying", IEEE Transactions on Vehicular Technology, vol. 62, no. 6, pp. 2496-2506, July 2013.

2. **A. J. Aljohani**, S. X. Ng and L. Hanzo, "TTCM-Aided Rate-Adaptive Distributed Source Coding for Rayleigh Fading Channels", IEEE Transactions on Vehicular Technology, vol. 63, no.3, pp. 126-134, March 2014.

3. **A. J. Aljohani**, S. X. Ng and L. Hanzo, "Distributed Source and Turbo Trellis Coded Modulation Aided Superposition Modulation", *Accepted*, 2016.

4. **A. J. Aljohani**, Z. Babar, S. X. Ng and L. Hanzo, "Distributed Joint Source-Channel coding Using Reduced-Complexity Syndrome-Based TTCM", *submitted* to IEEE Communications Letters, 2016.

5. **A. J. Aljohani**, H. Nguyen, S. X. Ng and L. Hanzo, "TTCM-Aided Distributed Joint Source-Channel coding based Adaptive Dynamic Network Coding", *to be submitted*, 2016.

Conferences:

6. **A. J. Aljohani**, S. X. Ng, R. G. Maunder and L. Hanzo, "Joint TTCM-VLC-Aided SDMA for Two-Way Relaying Aided Wireless Video Transmission", IEEE Vehicular Technology Conference (VTC2013-Fall) 2013.

7. **A. J. Aljohani**, H. Sun, S. X. Ng, and L. Hanzo, "Joint Source and Turbo Trellis Coded Hierarchical Modulation for Context-aware Medical Image Transmission", IEEE HEALTHCOM 2013 - The 1st International Workshop on Service Science for e-Health 2013.

8. **A. J. Aljohani**, S. X. Ng, and L. Hanzo, "TTCM-Assisted Distributed Source-Channel Coding for Nakagami-m Fading Channels", IEEE Vehicular Technology Conference (VTC2014-Fall) 2014.

Poster Presentation:

9. **A. J. Aljohani**, S. X. Ng, and L. Hanzo, "Adaptive Turbo Trellis Coded Modulation For Slepian-Wolf Coding Over A Rayleigh Fading Channel", the 8th Saudi Student Conference, Imperial College London, UK, 31 Jan - 01 Feb 2015.

Contents