Deanship of Graduate Studies
AL - Quds University

# Channel-Aware Decision Fusion for Distributed Classification in MIMO Wireless Sensor Networks

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M.Sc. Thesis

Jerusalem - Palestine

1440 - 2019

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A thesis submitted in partial fulfillment of the requirements for the master degree of Electronics and Computer Engineering/ Faculty of Engineering/ Graduate Studies

1440 - 2019

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# Thesis Approval

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# Dedication

*To the memory of my father (may Allah grant him His Mercy), to my mother who has been supporting and encouraging me all the way, to my beloved wife, for her outstanding and highly appreciated patience day and night throughout the time of my study, to my son and daughter, to my brother and sister.*

*friends and all of my family*

# Declaration

I certify that this thesis submitted for the degree of Master is the result of my own research, except where otherwise acknowledged, and that this thesis (or any part of the same) has not been submitted for higher degree to any other university or institution.

Signed:.......................

Rushdi Nadi Mahmoud AbuAwad

Date:19/5/2019

# Acknowledgements

First of all, I thank God for every thing.

I am very grateful to my supervisor Dr. Ali Jamoos. I feel it is a great fortune to be supervised by Dr. Ali. Dr. Ali is a knowledgeable scholar, deep thinker and hard worker. He has a keen insight into the research topics and gives very helpful instructions to me. Besides, his enthusiasm, responsibility and rigor make him a role model to my future career. I could not have obtained this degree in such an enjoyable way, nor would I have the same strong motivation and interest toward research, if not for Dr. Ali. In addition to academics, he gave me many personal helps when I was in need, which I am equally, or even more, thankful to him.

As always, I am thankful to my parents for supporting me to pursue my academic goal. Their encouragement and support through all these years meant more than what I can express in words.

Last but by no means least, I am thankful to all my teachers and friends. Their support is indispensable to my completing the master degree.

# Abstract

Wireless sensor networks (WSNs) have become a rich research area through the last few years. That is because of its high flexibility, mobility and cost efficiency. WSNs have many application such as security, surroundings and battlefield monitoring. The very important part must be investigate in the design of WSN is how to transact with the observed information at the decision fusion center (DFC) so as to obtain the final decision about a certain phenomena.

We study several fusion rules such as optimum rule, maximum ratio combiner (MRC), equal gain combiner (EGC), max-log rule, chair varshney-maximum likelihood (CV-ML) and chair varshney-minimum mean square error (CV-MMSE) applied at the DFC for one hypothesis which requires both the channel state information (CSI) and the sensors indices. The need of these information is assumed as an overhead in power and bandwidth obliged systems such as WSNs. The above rules used to fixed the matter about implementations and give a wide spectrum of choices for reducing complication and minimal system knowledge. All these rules still significantly interest from adding several antennas at the DFC.

We study in this thesis the fusion of decisions in distributed multiple input multiple output (MIMO) WSN with $M$-ary hypothesis and binary local decisions, where M is the number of hypothesis to be classified. The detection of distributed schemes for testing of $M$-ary hypothesis often assume that for every observed phenomena the local detector transmits at least $log_2 M$ bits to DFC. We formulate three fusion rules for the DFC such as Optimum maximum a posteriori (MAP) rule, Augmented Quadratic Discriminant Analysis (A-QDA) rule and MAP Observation bound.

A comparison performance has been obtained through simulation between three different fusion rules, optimum (MAP), MAP observation bound, augmented quadratic discriminant analysis (A-QDA) applied at MIMO WSN system model. We assumed Rayleigh fading and additive white Gaussian noise (AWGN) channels between the local detectors (sensors) and the DFC. We investigate the system parameters effect on the system performance at the DFC. We study the effect of the local detector (sensors) performance indices in the case in which all indices are identical. also investigate the effect of the total number of antenna at the DFC, the number of local detectors, the number of hypothesis and the effect of the value of channel signal to noise ratio (SNR) between the sensing elements and the DFC. Results obtained by simulation show that the MIMO WSN system model provide a relatively good performance in terms of detection performance when increasing the number of antenna at the DFC with lower number of hypothesis for the applied fusion rules. In addition, simulation results show that the optimum (MAP) rule has the best performance than A-QDA rule, also the A-QDA needs higher signal to noise ratio to obtain suitable performances comparable with the optimum (MAP) rule.

**Keywords**: Wireless Sensor Networks (WSNs), Distributed hypothesis testing, Decisions fusion, fading channels, distributed detection, MIMO, Optimum (MAP) classifier, Augmented Quadratic Discriminant Analysis (A-QDA).

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# Acronyms and Abbreviations

| | |
|---|---|
| A-QDA | Augmented Quadratic Discriminant Analysis |
| BPSK | Binary Phase Shift Keying |
| AWGN | Additive White Gaussian Noise |
| CSI | Channel State Information |
| CV-ML | Chair Varshney-Maximum Likelihood |
| CV-MMSE | Chair Varshney-Minimum Mean Square Error |
| DaF | Decode-and-Fuse |
| DFC | Decision Fusion Center |
| DtF | Decode-then-Fuse |
| EGC | Equal Gain Combiner |
| LDs | Local Detectors |
| LLR | Log Likelihood Ratio |
| LRT | Likelihood Ratio Test |
| MAC | Multiple Access Channel |
| MAP | Maximum A Posteriori |
| MIMO | Multiple Input Multiple Output |

| | |
|---|---|
| MMSE | Minimum Mean Square Error |
| MRC | Maximum Ratio Combiner |
| PAC | Parallel Access Channel |
| PMF | Probability Mass Function |
| ROC | Receiver Operating Characteristics |
| SNR | Signal to Noise Ratio |
| WSN | Wireless Sensor Network |

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