STUDY ON EXPECTATION PROPAGATION AS A LOW COMPLEXITY DETECTOR ALGORITHM FOR 5G WIRELESS SYSTEM

THESIS

ELECTRICAL ENGINEERING
CONTROL SYSTEMS AND ELECTRONICS

Declared qualified to obtain
a Master degree in Engineering

Presented by:

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BRAWIJAYA UNIVERSITY

FACULTY OF ENGINEERING

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STATEMENT OF THESIS ORIGINALITY

I declare that, to the best of my knowledge, this Thesis does not contain scientific article published by other person to gain academic degree in a University or higher institution, as well as ideas or opinions that have been written or published by other person, except the ones written as quotations in this Thesis and mentioned in the sources/Thesis References.

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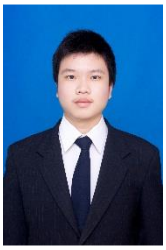

Alva Kosasih, was born in Malang, 1992 March 02. He took formal education from elementary school until senior high school in Malang, Indonesia. After graduated from senior high school in 2009, He began to study in Electronics Electrical Engineering, Faculty of Engineering, Brawijaya University. He graduated from Brawijaya in 2013 with a Cum-laude predicate. In 2014-2015, He worked in PT Sayap Mas Utama as an instrumentation and automation engineer. In 2015, he began to continuing his study in Telecommunication Engineering through the Master Double Degree Program provided by Electrical Engineering, Brawijaya University, Indonesia and Institute of Communication Engineering, National Sun Yat-sen University, Taiwan.

Malang, July 2017

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Karya ilmiah ini kutujukan kepada

Almarhum nenekku tercinta,

Doa dan kasih sayangnya selalu

Menyertaiku meski dia sudah

Tidak bersama-sama lagi denganku.

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ABSTRACT

In near future fifth generation of wireless system (5G), a huge number of transceivers antennas will be employed. Specifically, the 5G system will employ hundreds even thousands antennas that known as massive Multiple-Input Multiple-Output (MIMO) technology. It brings a lot of advantages such as maximization of spectral efficiency (SE) and larger channel capacity [1], [2]. However, the implementation of high dimensional antennas results a technical issue that needs to be solved. This mainly issue regarding unaffordable complexity.

Considering the symbols detection at the massive MIMO receiver side, the conventional symbols detector algorithm such as maximum a posteriori (MAP) can no longer be used due to the unaffordable complexity. The conventional detector algorithm complexity increases exponentially with the dimension of the system because it needs to calculate the feedback loop operation in every iteration. Therefore, a low complexity detector algorithm becomes the main requirement in order to implement the massive MIMO systems.

In this thesis, we propose two major contributions. First, we propose a low complexity detection method for the SCMA detector named the expectation propagation algorithm (EPA). The EPA approximates the marginal distribution of the posterior probability by using an exponential family [3]. Given that the probability in exponential family is easy to compute, the EPA is suitable to deal with high order and dimensional system. We also provide theoretical analysis to evaluate the performance of EPA SCMA. We show that the EPA for SCMA can achieve near optimal detection performance as the numbers of transmit and receive antennas grow. With the theoretical promise, we investigate the necessity of constellation rotation, which is used to increase the degree of freedom [4, 5]. We show that for the uplink scheme, channel responses from different users vary and thus increase the identifiability of each user. Therefore, appending a rotation value in SCMA encoder is unnecessary. The removal of the rotation, value can omit many unnecessary calculations not only in decoding but also in SCMA encoding.

Second, we propose a novel algorithm i.e. decentralized expectation propagation algorithm (EPA) to support massive MU-MIMO system which outperforms decentral- ized AMP [6]. We also investigate the EPA complexity which lies on the dimension of the EP inverse matrix. Originally, the dimension of the EP inverse matrix is equal with the dimension of transmitter antennas. By implementing the partially decentral- ized system, we significantly reduce the dimension of the inverse matrix to become C times smaller than the original one, where C denotes the number of the decentralized system we have. In addition, we provide the theoretical analysis for each decentralized EP systems.

Keywords: Expectation propagation, detector, low complexity, 5G, decentralized.

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NOTATIONS

x	Scalar
$\mathbf{x}$	Vector
x_k	k-th position of vector $\mathbf{x}$
$\mathbf{x}_c$	c-th decentralized of vector $\mathbf{x}$
$\mathbf{x}_{A\to B}$	messages passing $\mathbf{x}$ from module A to B
$\mathbf{x}^{ext}$	extrinsic value of $\mathbf{x}$
$\mathbf{x}^{post}$	posterior value of $\mathbf{x}$
$\mathbf{I}$	Identity matrix
$N(\mathbf{y};\mathbf{x},\mathbf{C})$	Gaussian distribution over $\mathbf{y}$ with mean $\mathbf{x}$ and covariance matrix $\mathbf{C}$
$O(\cdot)$	Computational complexity
^{T}	Transpose
^{H}	Hermitian
$E_{q(\mathbf{x})}$	Expectation with respect to the distribution $q(\mathbf{x})$
$\mathrm{Var}\{\cdot\}$	Variance calculation
$\propto$	Proportional to
Proj	Argument minimum
D_{KL}	Kullback-Leibler Divergence
$\{s\}$	set of $\{1,2,\cdots,s\}$

ABBREVIATIONS

5G	5th Generation of Wireless Systems.
AMP	Approximate Message Passing.
BER	Bit Error Rate.
BL	Baseline.
BP	Belief Propagation.
BS	Base Station.
CDMA	Code Division Multiple Access.
EP	Expectation Propagation.
EPA	Expectation Propagation Algorithm.
HSPA	High Speed Packet Access.
IEEE	Institute of Electrical and Electronics Engineering.
KL	Kullback-Leibler.
LOS	Line of Sight.
LTE	Long Term Evolution.
MPA	Message Passing Algorithm.
MIMO	Multiple-Input Multiple-Output.
MISO	Multiple-Input Single-Output.
ML	Maximum Likelihood.
MM	Moment Matching.
MMSE	Minimum Mean Square Error.
MRC	Maximum Ratio Combining.
MU-MIMO	Multi User Multiple-Input Multiple-Output.
QAM	Quadrature Amplitude Modulation.
RF	Radio Frequency.
SCMA	Sparse Code Multiple Access.

SE	State Evolution.
SIMO	Single-Input Multiple-Output.
SISO	Single-Input Single-Output.
SM	Spatial Multiplexing.
SNR	Signal to Noise Ratio.
WI-FI	Wireless Fidelity.