1. Introduction and Motivation

1.1 Multiple Input Multiple Output System

In the last decades, wireless systems have evoked a great deal of interest in communication engineering researches field. The detriment of wired systems becomes the most fundamental reason to exploit the wireless systems. At the beginning, many researchers paid a lot of intention to develop single output single input (SISO) wireless systems. The reason is regarding to affordable complexity of SISO systems [7]. However, as time goes by, the users increases significantly, moreover it demands a higher rates and source reliability. This matter becomes the nascence of the multiple input multiple output (MIMO) systems. The configuration of antennas systems [8] in wireless communication is depicted in Figure 1.1.

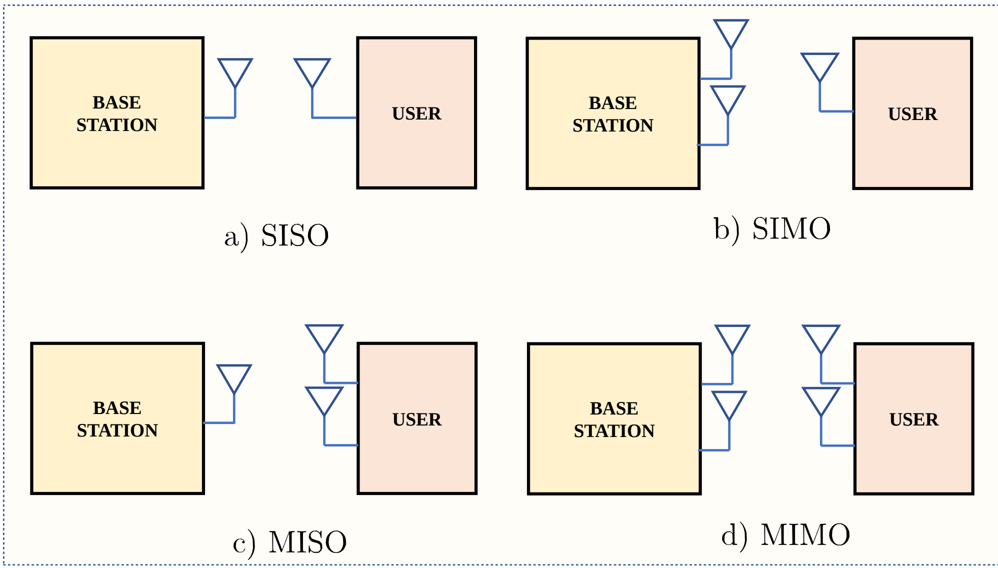

Figure 1.1. Antennas Systems Configuration in uplink scheme

In MIMO systems, maximization of spectral efficiency (SE) and larger channel capacity are investigated as the key advantages [1], [2]. Furthermore, the recent wireless technology, such as long term evolution (LTE) [9], standardize for WI-FI [10], and even next generation of wireless technology (5G) [11] place the MIMO technology at their core systems. It indicates that, MIMO systems plays an important role in near future wireless technologies. Nevertheless, the use of hundreds or even thousands antennas in massive MIMO systems causes a lot of challenges.

Wireless systems face many challenges during the process of transmitting and receiving data. Reflection, scattering, diffraction, pathloss, shadowing, fading are the common challenges in wireless signal propagation. The challenges causes an extremely performance degradation in wireless communication. Therefore, many techniques have been proposed to overcome the signal disturbances particularly for massive MIMO systems. For example, maximum likelihood (ML) detector, which is able to deal with the impairment of the signals and approximate the transmitted signals with an outstanding performance.

However, those techniques will lead to the computational complexity problem. The complexity problem poses a serious challenge in practical MIMO systems implementations. Specifically, if the complexity problem remains, massive MIMO systems cannot be implemented in practical scenery. Obviously, it is due to the unaffordable computational complexity.

In this thesis, we focus on exploiting the spatial multiplexing (SM) of MIMO systems and reducing the signal processing complexity at receiver unit. SM uses the demultiplexing techniques to increase the transferred data rate. As the antennas grow large (massive MIMO systems), the signal processing in transceiver unit becomes prohibitive because of the complexity problem. Hence, we adopt a low complexity algorithm named expectation propagation algorithm (EPA) to solve the complexity problems especially in massive MIMO uplink symbols detection.

1.2 Symbol Detection in Massive MIMO Systems

As mentioned in above, we focus on exploring the massive MIMO signal processing, particularly in uplink detection scheme. In a common term, it is called symbols detection, uplink receiver side. Considering a massive MIMO systems, where the users are sharing time and frequency resources, the transmitted signals will arrive at the receiver side as a linear superposition. The received signals will be equal to the vector multiplication of channel gain and signals, added by noise.

Symbols detection is a process to estimate the transmitted signals by normalizing its noise. In this thesis we assume that channel gain has already been known. Thus, the detection process only focus on fixing the impairment of the received signals caused by fading and the other noise.

An approach to solve the detection problem with an outstanding performance is using optimal symbol detection algorithm. However, as mentioned before, it is prohibitive due to the complexity problem. Therefore, in order to support the implementation of massive MIMO systems, 1) we apply the EPA for sparse code multiple access (SCMA) which is known as a promising candidate of 5G modulation technique, 2) we propose a novel algorithm named decentralized EPA which is successfully reduce the complexity of EPA itself.

1.3 Thesis Organization

The background and motivation, of studying on Expectation Propagation as a low complexity detector algorithm have been described in this chapter. The remainder of this thesis is proceeded as follows. In Chapter 2, a comprehensive discussion about EP and MU-MIMO systems are presented. At the beginning, the single loop EPA is presented. Next, the analysis of EPA complexity and future works for EP, include the double loop EPA are described. Lastly, the theoretical verification method is discussed. A brief explanation about massive MU-MIMO systems is also provided.

The implementation of EPA for 5G wireless system are discussed in Chapter 3. It is consist of twofold. First, we apply EPA for SCMA in order to solve the complexity problem of the conventional MPA SCMA. Second, we proposed novel algorithm which is named decentralized EPA in order to improve the performance of previous decentralized algorithm [6]. Furthermore, our algorithm successfully reduce the complexity of EPA itself. In addition, we provide the theoretical analysis for each application of EPA.

The experimental result and its discussions are presented in Chapter 4. We focus on proving that our algorithms work well and outperform the prior art. Therefore, chapter 4 will clearly flaunt our contributions. Finally, the conclusion drawn from our contributions are presented in Chapter 5.