Improving Energy Efficiency in Massive MIMO system with non-ideal hardware

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***Abstract*- Massive Multiple Input Multiple Output also known as Massive MIMO is promising next generation for wireless network technology, with large number of antenna at base station mean large scale radio frequency chains. It offer higher data rates with low energy consumption for better environment in green technology. This research focus on comparison energy efficiency between ideal hardware and non ideal hardware in Massive MIMO system. In this paper, energy effiency analyzes from N antenna at base station and single antenna user transceiver.Result shows massive MIMO non ideal hardware can achieve energy efficiency.**

Index Terms – Massive MIMO, energy efficiency, non-ideal hardware.

I. INTRODUCTION

Wireless communication system has been evolving from time to time. Lots of technologies have emerged such as Single-input single-output (SISO), Single-input multiple-output (SIMO), multiple-input Single-output (MISO), multiple-input multiple-output (MIMO) and Massive multiple-input multiple-output (MIMO). All of the technologies have their own advantages and disadvantages in term of energy efficiency and spectral efficiency. Massive MIMO is a promising core technology in future wideband wireless communication systems, and has a great potential of high spectral and energy efficiency [2]. Massive MIMO also known as Hyper MIMO is an emerging wireless technology, where each base station is equipped with twenty or hundreds of small active antennas and communicates with single antenna terminals over the same bandwidth frequency at one time. The vision of massive MIMO is new. It processes the signal over the array, uses transmit precoding in the downlink to focus each signal at its desired terminal and receive combining in the uplink to discriminate between signals sent from different terminals [3].

Massive MIMO has been a remarkable potential of increasing the spectral efficiency [4]. The spectral efficiency of a massive MIMO system depends on many characteristic such as the signal-to-noise ratio (SNR), channel estimation accuracy, spatial correlation in the propagation environment, transceiver hardware impairments and signal processing resources.

With the rapid increase in number of users on mobile and wireless communication, number of base station (BS) and the electrical energy consumption increases year by year [5]. This situation draws increasing attention to energy efficiency of wireless communication. In [6], the researcher states that Massive MIMO technology can offer advantages in term of energy and spectral efficient. It allows the expensive and power inefficient hardware to be replaced by massive number of parallel low-cost and low power antenna at the base station and the mobile unit. The research also highlighted the potential of Massive MIMO to become future technology in wireless system, where it is believed to be implemented in fifth generation (5G) standard.

PROBLEM STATEMENT

Nowadays, demand for wireless devices increase rapidly where billion of users need high throughput data to surf the internet, making call even live video call. The demand for wireless communication is expected to continue this trend for many years to come.
There is also demand for green technologies that concern about energy consumption of wireless communication system. It will be the biggest challenge to wireless communication system when energy consumption meets the needs of growing traffic. Energy consumption also becomes the main problem if base station is deployed in rural area where electrical power or grid is not available and base station only relies on batteries or solar panel with limited energy power.

There are three main requirements for massive MIMO to become future wireless system which are having a high throughput and simultaneously serving many users (spectral efficiency) and having less energy (energy efficiency).From the previous research studies covered in the literature review, there are limited researches that have been done to analyze energy efficiency of massive MIMO system with non-ideal hardware.

SCOPE AND LIMITATION OF STUDY

MATLAB (matrix laboratory) will be used as the simulation platform for this research project. The data from simulations will be analyzed.
The main research is to analyze the energy efficiency of massive MIMO with non-ideal hardware through downlink and uplink system model without decreasing the spectral efficiency.

SIGNIFICANCE OF STUDY

Significance of this research is to prove that massive MIMO system with non-ideal hardware can provide energy efficiency. Significance is to optimize energy efficiency of massive MIMO in wireless communication system for reference to other researcher's in the future 5G wireless communication system to stimulate new researches. Also benefit for service providers to save cost on power bills without decreasing the quality of services

The objectives of this paper are as follows :

a) To analyze the energy efficiency of massive MIMO with non-ideal hardware through simulation by using MATLAB.
b) To compare energy efficiency of massive MIMO with ideal and non-ideal hardware.

II. SYSTEM MODEL

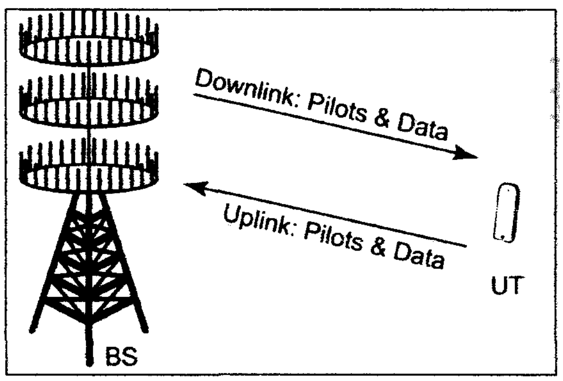

Fig. 1 : Illustration Massive MIMO with non Ideal Hardware model.

Massive MIMO with non Ideal hardware is system model that use hardware impairment at each antenna at the base station. This is contrast with Massive MIMO system with ideal hardware. The system model for Massive MIMO with non ideal hardware consist of base station with N antenna and single antenna UT. The main focus of the study is to analyze the total power consumption to get energy efficiency between an N-antenna and single-antenna UT. Uplink and Downlink transmission are considered to be on the same flat-fading subcarrier.

III. Methodology

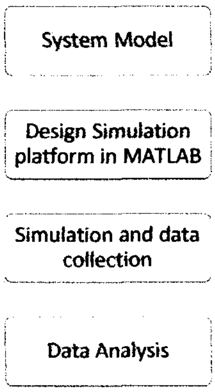

Fig. 2 : Flowchart Research

The flowchart in Figure 2 shows the steps of the research process. The process starts with designed the system model of massive MIMO system with non-ideal hardware. The simulation platform will be built in MATLAB based on the designed system model. Previous equation from others research has been use to modelling this program. Equation 1 has been used to calculate energy efficiency for uplink channel and equation 2 has been use for calculate energy efficiency for downlink channel.

$$\mathrm{EE}^{\mathrm{UL}} = \frac{\mathrm{C}^{\mathrm{UL}}}{\alpha_{\mathrm{UL}}\left(\frac{T^{\mathrm{DL}}_{\mathrm{data}}}{T_{\mathrm{coher}}}\frac{p^{\mathrm{BS}}}{\omega^{\mathrm{BS}}} + \frac{T^{\mathrm{UL}}_{\mathrm{data}}}{T_{\mathrm{coher}}}\frac{p^{\mathrm{UE}}}{\omega^{\mathrm{UE}}} + Np + \mathcal{C}\right) - \frac{T^{\mathrm{UL}}_{\mathrm{pilot}}}{T_{\mathrm{coher}}}\frac{p^{\mathrm{UE}}}{\omega^{\mathrm{UE}}}}.$$

Equation.1 : The defination of energy efficiency for uplink channel

$$\mathrm{EE}^{\mathrm{DL}} = \frac{\mathrm{C}^{\mathrm{DL}}}{\alpha_{\mathrm{DL}}\left(\frac{T^{\mathrm{DL}}_{\mathrm{data}}}{T_{\mathrm{coher}}}\frac{p^{\mathrm{BS}}}{\omega^{\mathrm{BS}}} + \frac{T^{\mathrm{UL}}_{\mathrm{data}}}{T_{\mathrm{coher}}}\frac{p^{\mathrm{UE}}}{\omega^{\mathrm{UE}}} + Np + \mathcal{C}\right) + \frac{T^{\mathrm{DL}}_{\mathrm{pilot}}}{T_{\mathrm{coher}}}\frac{p^{\mathrm{BS}}}{\omega^{\mathrm{BS}}}}$$

Equation.2: The defination of energy efficiency for downlink channel

Tcoher	useful channel
UL	pilot/control signaling (Uplink)
TUL	pilot channel uses
DL	pilot/control signaling (Downlink)
UEs	estimate their effective channel
EE	energy efficiency
PBS	transmit power base station
PUE	Uplink pilot power
N	antenna
WUE	amplifiers efficiency
CDL	Channel Capasity Bound
C	parameter
p	Energy per channel

Fig. 3 Variable define use in energy efficiency

$$\mathrm{C}^{\mathrm{UL}} \geq \mathrm{C}^{\mathrm{UL}}_{\mathrm{lower}} = \frac{T^{\mathrm{UL}}_{\mathrm{data}}}{T_{\mathrm{coher}}}\mathbb{E}\left\{\log_2\left(1 + \mathtt{SINR}^{\mathrm{UL}}_{\mathrm{lower}}(\mathbf{v}^{\mathrm{UL}})\right)\right\}$$

Equation 3 : Theorem for Uplink

$$\mathrm{C}^{\mathrm{DL}} \geq \mathrm{C}^{\mathrm{DL}}_{\mathrm{lower}} = \frac{T^{\mathrm{DL}}_{\mathrm{data}}}{T_{\mathrm{coher}}}\mathbb{E}\left\{\log_2\left(1 + \mathtt{SINR}^{\mathrm{DL}}_{\mathrm{lower}}(\mathbf{v}^{\mathrm{DL}})\right)\right\}$$

Equation4 : Theorem for Downlink

Equation 3 and Equation 4 is theorem applied in massive MIMO system with ideal hardware in [12], also has been use to this study because this theorem is using for lower capasity bound in massive MIMO system.

C + p = 2uJ/channel and C + p = 0.02uJ has been used to represent total circuit power in system with 1 antenna = N. Since the total circuit power for arbitrary N is C+Np, we consider three different splittings between p and C: p/C+p E (0, 0.01, 0.1). From an EE optimization perspective,any scaling of the power amplifier efficiencies is equivalent to an inverse scaling of C and p.To optimizing energy efficiency in massive MIMO system with non ideal hardware, transmit power in both Uplink and Downlink are set to be equal and bounded by Pmax = 0.022uJ. Also consider situation without interference.Energy efficiency in Massive MIMO with non ideal hardware has been analyzed and measured in bit/Joule. Power scaling law show transmit power as 1=Nt, for 0 < t < 1/2 , also achieve an infinitely energy efficiency as N ->∞.

IV. RESULT AND DISCUSSIONS

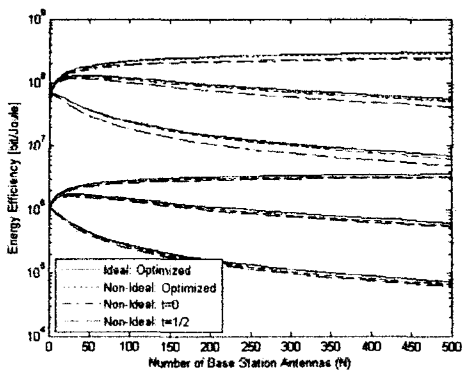

Figure 4 : Achievable energy efficiency with non ideal and ideal hardware for fixed transmit power (t = 0).

Fig. 4 is output from system model by using Matlab to generate grafh, result shows the difference energy efficiency between ideal and non ideal hardware from minimum 1 antenna to maximize 500 antenna on base station. Grafh show energy efficiency massive MIMO non ideal hardware when optimized, t = 0 and t = ½ only had litle different with energy efficiency massive MIMO with ideal hardware. This result proof massive MIMO system with non ideal hardware also energy efficiency just like massive MIMO with ideal hardware.

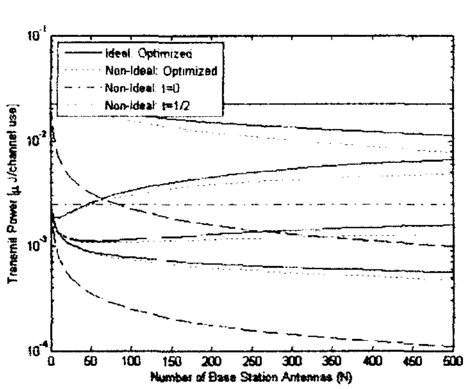

Figure 5 : The transmit powers that correspond to the achiveable energy efficiency in Figure 4

Fig. 5 show the transmit power that correspond to energy efficiency in Fig. 4. Transmit power act differently than energy efficiency when massive MIMO non ideal hardware t = 0 and t = ½. But when massive MIMO non ideal hardware optimized, grafh show litle difference from massive MIMO with ideal hardware. This is because to get higher at spectral we need to increases transmit power at circuit power.

V. CONCLUSION

This paper investigated how to optimize energy efficiency by using non ideal tranceiver hardware on the base station. Result from simulation show energy efficiency with non ideal hardware achive only little bit difference with ideal harware. Dispite these result, massive MIMO with non ideal hardware is less expensive rather than ideal hardware. This mean hardware quality at base station can be decrease as number of antenna grows. overall result shows energy efficiency of massive MIMO with non ideal hardware can be improving without decrease quality of signal. However quality spectral efficiency and technic to implement antenna on base station with non-ideal hardware can be new future research.

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