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Case Study of Energy Efficiency in Massive MIMO System

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Abstract— By using large-scale antenna arrays, considerable enhancement in energy and spectral efficiency is accomplished. What will be the optimum number of antennas, active users and transmit power? In single cell consequence Zero Forcing (ZF) processing is used to know how the constraints interact. A conjoint belief is transmitter power is enlarged with large number of antennas that means EE-systems can operate in high Signal to noise ratio systems where interference-suppressing signal processing is mandatory. Systematic and arithmetical results show that, Massive MIMO is the solution to get maximum energy efficiency. A combination of Massive MIMO and Small cell access point is also anticipated to increase the energy proficiency at the UEs, without losing the Quality of Service (QoS). If latter are operator positioned, a spatial soft cell tactic can be used at the multiple transmitters to oblige the users by non-coherent beam forming, overall power ingestion can be diminished without losing QoS restraints.

Keywords— Multi input Multi output, Single input single output, Single input Multiple output, Multiple input Single output, Multi-User Multiple input multiple output, space-division multiple access, Media Access Control, Channel State Information, Time Division Duplex, Frequency Division Duplex

I. INTRODUCTION (HEADING 1)

Multiple-antenna (MIMO) technology is fetching matured for wireless communications and has been merged into wireless broadband standards like LTE and Wi-Fi [1][2][3]. Ultimately, the more antennas the transmitter/receiver is equipped with, the more the possible signal paths and the better the performance in terms of data rate and link reliability. The price to pay is increased complexity of the hardware and the complexity of energy consumption of the signal processing at both ends.

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Multiple-input and multiple-output, or MIMO, Means using several antennas at both the transmitter and receiver to advance communication performance [4]. To accomplish an array gain that incrementally advances the spectral proficiency and/or accomplishing a diversity gain that advances the link consistency, multiple antennas can be used to accomplish smart antenna functions. Though, currently the term "MIMO" generally states to a scheme for enlarging the capacity of a radio link by manipulating multipath propagation [5].

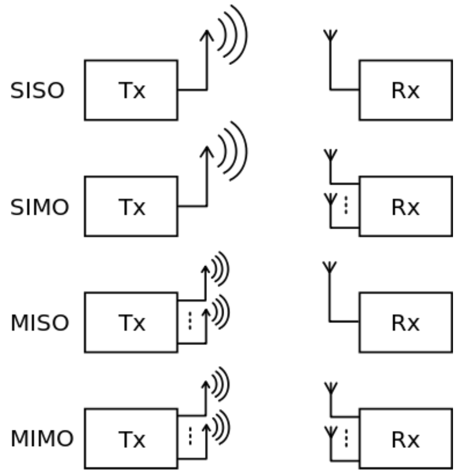

Fig. 1 Understanding of SISO, SIMO, MISO and MIMO

According to MIMO systems, a transmitter drives numerous streams by numerous transmit antennas. Those transmitted streams pass over a matrix channel that contains of all $N_t N_r$ paths among the N_t transmit antennas at the transmitter and N_r receive antennas at the receiver. After that the receiver collects the signal vector and decodes that collected signal to get the original evidence. A narrowband flat fading MIMO system is demonstrated as

$$\mathbf{y} = \mathbf{H}\mathbf{x} + \mathbf{n}$$

Where $\mathbf{y}$ and $\mathbf{x}$ represents the receiver and transmitter vectors, and $\mathbf{H}$ and $\mathbf{n}$ represents the channel matrix and the noise vector, respectively.

Multi-user MIMO (MU-MIMO) is the advanced form of MIMO, in multiple-input and multiple-output, technologies' the available antennas are spread above a multitude of independent access points and independent radio terminals, all having one or multiple antennas. While comparing, single-user MIMO uses a single multi-antenna transmitter that communicate with a single multi-antenna receiver. To improve the communication competencies of all terminals, MU-MIMO uses an comprehensive form of (SDMA) to permit multiple transmitters to send distinct signals and multiple receivers to collect separate signals instantaneously in the same band [6].

MU-MIMO is the advanced form of MIMO that can be used in different ways as a multiple access strategy. A prominent alteration is, the performance of MU-MIMO depend on precoding competency than OFDMA, if the transmitter does not use precoding, the performance benefit of MU-MIMO is not attainable.

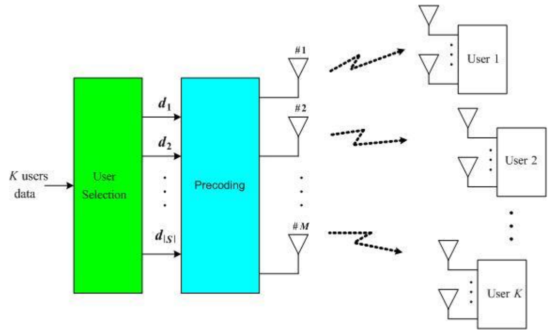

Fig. 2 Multiuser MIMO System

Massive MIMO (also acknowledged as Large-Scale Antenna Systems, Very Large MIMO, Hyper MIMO, Full-Dimension MIMO and ARGOS) creates a big difference with conventional MIMO systems by using large number of antennas (e.g., hundreds or thousands) which are functioned entirely coherently and adaptively [7]. To focus the signal transmission and reception energy into smaller regions of space, spare antennas are helpful. That fetches massive enhancements in throughput and energy efficiency, when predominantly joined with instantaneous scheduling of a large number of user terminals (e.g., tens or hundreds). Massive MIMO was formerly proposed for (TDD) operation, but now potentially can also be functional in (FDD) operation.

Some other advantages of massive MIMO are, the broad use of low-cost low-power equipment, reduced latency, generalization of the (MAC) layer, and robustness to interference and intentional jamming [8]. The estimated throughput depends on the propagation environment providing asymptotically orthogonal channels to the terminals, and experimentations have not revealed any restrictions till now in this respect. Whereas massive MIMO condenses many traditional research problems inappropriate, and exposes completely new complications that immediately need consideration; for example, the challenging task of making several low-cost low-precision components that work efficiently together, the need for efficient acquisition scheme for channel state information, resource allocation for newly-joined terminals, the manipulation of additional degrees of freedom given by spare service antennas, reducing internal power consumption to attain overall energy efficiency reductions, and finding new placement situations.

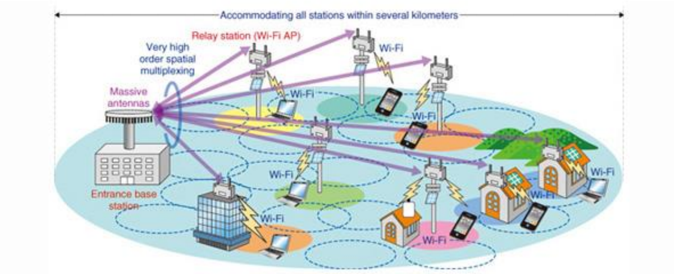

Fig. 3 Massive MIMO Technology

II. BACKGROUND

A. 1G(First Generation) (Heading 2)

1G (or 1-G) states the first generation of wireless telephone technology (mobile telecommunications). 1G is the analog telecommunications standards that was presented in the 1980s and sustained till being substituted by 2G digital telecommunications. The key variance among the two mobile telephone systems (1G and 2G), is that the radio signals used by 2G are digital, while the signals used by 1G are analog. 1G is only moderated to higher frequency, characteristically 150 MHz and up.

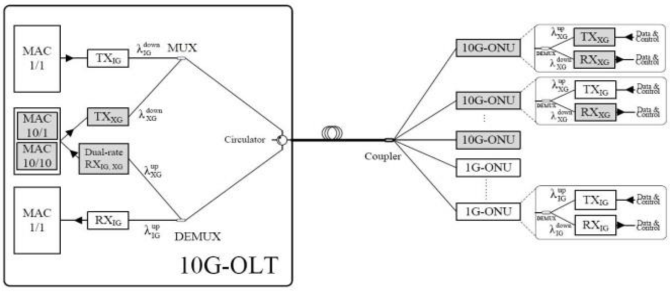

Fig. 4 A typical network architecture for the co-existence of 1G

B. GSM (Global System for Mobile Communication)

GSM , is a standard recognized by the European Telecommunications Standards Institute (ETSI) to describe protocols for second generation (2G) digital cellular networks used by mobile phones. GSM is the default worldwide standard for mobile communications, and is accessible in more than 219 countries and regions [9][10].

GSM standard was established to replace the first generation (1G) analog cellular networks, and described a digital, circuit-switched network improved for full duplex voice telephony. GSM technology was extended with time to include data communications, initially by circuit-switched transport, later packet data transport via GPRS (General Packet Radio Services) and EDGE (Enhanced Data rates for GSM Evolution or EGPRS) [11].

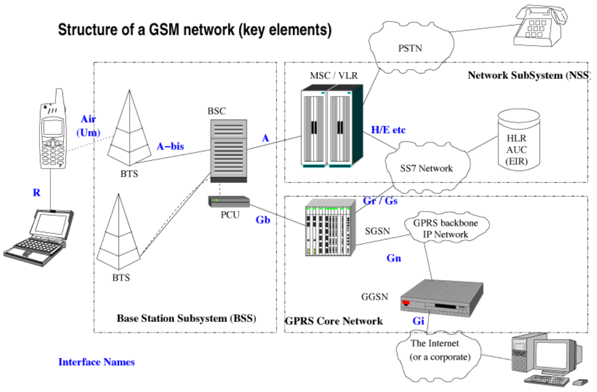

Fig. 5 Structure of GSM Network

C. 3G (Third Generation)

3G, third Generation, is the third generation of mobile telecommunications technology[3]. 3G is introduced on the base of standards used for mobile devices and mobile telecommunications use facilities and networks that fulfill the International Mobile Telecommunications-2000 (IMT-2000) specifications by the International Telecommunication Union [4]. 3G is mostly used with mobile phones and handsets as a means to connect the phone to the Internet or other IPnetworks in order to make voice and video calls, to download and upload data and to surf the net.

a. How is 3G Better?

3G has the following enhancements over 2.5G and previous networks:

- Several times higher data speed;
- Enhanced audio and video streaming;
- Video-conferencing support;
- Web and WAP browsing at higher speeds;
- IPTV (TV through the Internet) support.

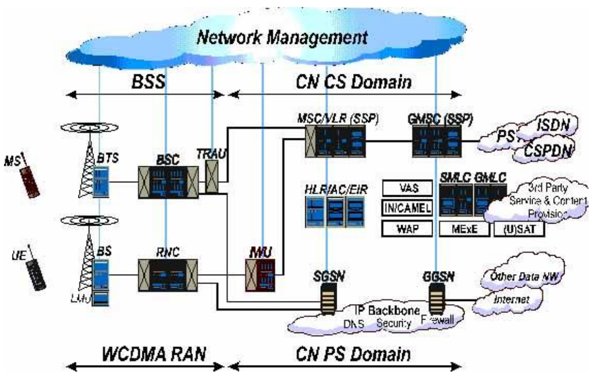

Fig. 6 Structure of 3G (third Generation)

D. 4G (Fourth Generation)

4G, fourth generation, is the fourth generation of mobile telecommunications technology, advanced form of 3G and foregoing 5G. A 4G systemchave some similar applications same as 3G [12] for example the voice and other services, offers mobile broadband Internet access, for example to laptops with wireless modems, to smartphones, and to other mobile devices.

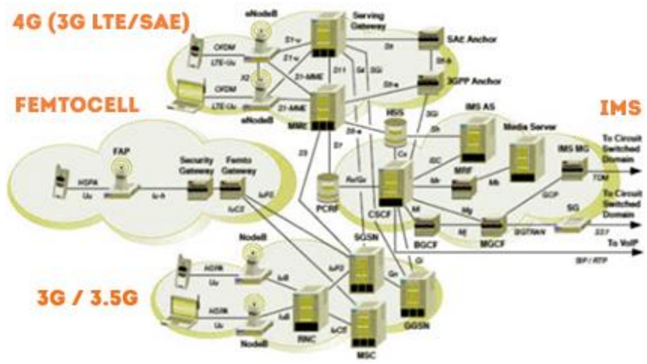

Fig. 7 3G/4G Service Structure

E. MIMO (Multiple Input Multiple Output)

When talk about more than one antenna at both transmitter and receiver, that system is known as MIMO system. MIMO stances for Multiple-Input, Multiple-Output can be used to provide improvements in both channel robustness as well as channel throughput [13].

MIMO is an important factor of wireless communication standards such as IEEE 802.11n (Wi-Fi), IEEE 802.11ac (Wi-Fi), 4G, 3GPP Long Term Evolution, WiMAX and HSPA+.

Fig. 8 MIMO - Multiple Input Multiple Output

There are different types of MIMO Configurations that we can use, named as, SISO, SIMO, MISO and MIMO. These formats requires different number of antennas and have different complexity level.

Hence the altered forms of single / multiple antenna links are :

- SISO - Single Input Single Output
- SIMO - Single Input Multiple output
- MISO - Multiple Input Single Output
- MIMO - Multiple Input multiple Output

MU-MIMO is also used for a multiple user type of MIMO .

a. SISO

The modest form is known as SISO - Single Input Single Output [14]. This is commendably a standard radio channel. The transmitter and receiver both operates with one antenna, and no diversity and additional processing is required.

Fig. 9 SISO - Single Input Single Output

b. Advantages and Disadvantages:

The advantage of a SISO system, it does not requires processing in various forms of diversity, also the SISO system is very simple. Whereas SISO system has limited Performance, fading and interference affect the system, also its Bandwidth is limited by Shannon's law.

c. SIMO

SIMO(Single Input Multiple Output) is also a form of MIMO, having single antenna at transmitter and multiple antennas at receiver, which is recognized as receive diversity. SIMO systems are helpful up to some extent to conquer the fading effects [15].

Two forms of SIMO that can be used:

- *Switched diversity SIMO:* This form of SIMO appearances for the resilient signal and switches to that antenna.
- *Maximum ratio combining SIMO:* This form of SIMO receives both signals and adds them to give a combined result.

Fig. 10 SIMO - Single Input Multiple Output

d. Advantages and Disadvantages

The advantage of SIMO is that it is comparatively easy to implement. SIMO also have some disadvantages, such as needs processing at the receiver. SIMO can be used in many applications but in case of mobile phones where receiver is positioned, processing is limited because of size and also drains the battery.

e. MISO

MISO(Multiple input single output) also known as transmit diversity. In MISO systems, same data are transmitted excessively from both transmit antennas, and the receiver receives the optimal signal to obtain the desired information.

Fig. 11 MISO - Multiple Input Single Outputs

F. *MU-MIMO*

Multi-user MIMO or MU-MIMO is an improved form of MIMO technology, gains approval. MU-MIMO permits multiple autonomous radio terminals to access a system improving the communication competencies of each distinct terminal.

MU-MIMO manipulates the extreme system capacity by arranging multiple users to be capable of concurrently access the equivalent channel using the spatial degrees of freedom presented by MIMO.

f. MU- MIMO Advantages

MU-MIMO has some substantial advantages compared to other techniques:

- MU-MIMO systems allow a level of direct gain to achieve in a multiple access capacity rising from the multi-user multiplexing schemes, and are proportional to the amount of base station antennas engaged.
- MU-MIMO seems to be less affected from propagation problems that distress single user MIMO systems. Which consist of channel rank loss and antenna correlation, while channel correlation still affects diversity on a per user basis.

G. Massive MIMO

Massive MIMO also known as Very large MIMO have a major difference by using a large number of antennas above active terminals and time division duplex operation. Spare antennas help to focus energy in small regions of space to carry massive enhancement in throughput and radiated energy efficiency. Additional advantages of massive MIMO comprise the widespread use of low-cost low-power components, reduced latency, generalization of the media access control (MAC) layer, and robustness to purposeful jamming. Massive MIMO systems have excessive potential for grasping Gigabit data rates in the next generation wireless networks [16]. When networks install massive MIMO-based base stations (BS), they will be able to increase their data rate many times as compared to current networks/technology. Extra number of antennas can be used to enhance the present system capability and can bring more users into the system.

Fig. 12 shows a downlink massive MIMO system. Though such a remarkable increase in the number of antennas presents new encounters for transceiver design and employment, and has certain fascinating benefits for signal processing and communication. Lets have an example, if the amount of base station antennas is much greater than the number of users in the system, simple conjugate beam forming (BF) precoding (downlink) and matched filter (MF) detection (uplink) at the base station lead to close-to-optimal performance enabling low complication signal processing at mutually the base station and the user terminals. Moreover, casual impairments known as small-scale fading and noise are averaged out as the number of base station antennas increases. To preserve the signaling above for channel state information (CSI) procurement in massive MIMO systems controllable, time division duplex (TDD) operation is favored, subsequently for frequency division duplex (FDD) systems the amount of CSI feedback raises with the number of base station antennas [12]. A most important weakening in massive MIMO systems is the so-called pilot contamination. Pilot contamination is triggered by the reprocess of the identical pilot sequences in altered cells. This reprocess is inevitable as, for a specified pilot sequence length; the number of linearly autonomous pilot sequences is restricted. Though, in recent times numerous effective techniques have been suggested to overwhelm pilot contamination. While massive MIMO communication systems have been first proposed in 2010 , and have engrossed significant attention from both academic circles and business sectors in a very limited time. Consider an example, a 2013 distinct subject of the IEEE Journal on Nominated Regions in Communications was committed exclusively to massive MIMO systems and massive MIMO plays a vital part in GreenTouch'squest to increase the energy efficiency of communication networks by 2015 by a aspect of 1000 compared to the 2010 levels. Actually, if NT raises large and all other system parameters are supposed constant, the transmit power per user in multi-user massive MIMO systems can be condensed equivalently to 1/NT and 1/NT−−−√ for flawless and flawed CSI information at the base station, correspondingly, deprived of disturbing throughput and reliability. Therefore, massive MIMO systems compromise a humble path to additional energy efficient and "greener" communication networks. Bearing in mind the promising possessions of and large concern in massive MIMO systems, we presume them to come to be an essential part of upcoming wireless communication systems [18]. While a significant exploration struggle has by this time been focused towards massive MIMO systems, numerous significant signal processing and signal design complications persist to be resolved.

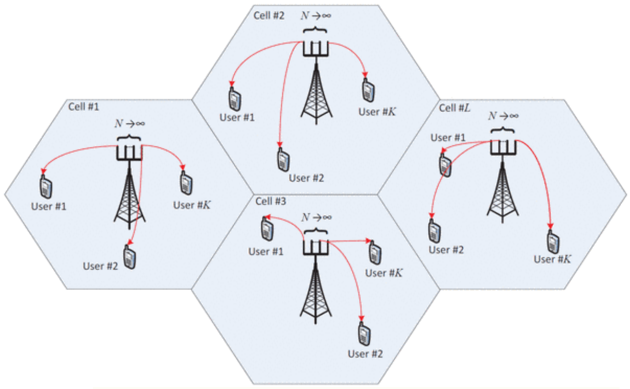

Fig. 12 Downlink of a multi-cell massive MIMO system.

b. BENEFITS

Some initial advantages from the massive MIMO systems are stated as:

i. Inter-user interference is simply diminished by the extraordinary beam forming determination.

ii. Low-complexity signal processing processes are asymptotically optimal.

iii. Propagation damages are diminished by a large array gain due to coherent beam forming/combining.

iv. Interference-leakage because of channel estimation blunders is exterminated asymptotically in the large-dimensional vector space.

III. CONCLUSION

In this paper we reviewed the two methods for improving energy efficiency of a cellular network. Energy efficiency of a cellular network can be improved by retaining Massive MIMO at the base station or by draping current arrangement by a layer of SCAs. This exploration ponders mutually dynamic emitted power and static hardware consumption. The overall power consumption can be significantly enhanced by merging Massive MIMO and small cells. Most of the benefits are also attainable by low intricacy beam forming.

Also if we employ 100-200 antennas to oblige a comparatively huge number of UEs is the optimum explanation using present circuit equipment. Energy Efficient systems consequently not functioning in the low SNR system, but in a system where appropriate interference-suppressing processing (e.g., ZF or MMSE) is extremely preferably over interference snubbing MRT/MRC processing. Mathematical results displays that the power per antenna is in the range of 10-100 mW, which specifies that Massive MIMO can be constructed by low power consumer-grade transceiver equipment at the BSs in its place of conservative industry-grade high power equipment. The circuit power coefficients will drop over time, which infers the Energy Efficiency optimum operating point will get a greater value and can be accomplished using less UEs, less BS antennas, less RF power, and further advanced processing.

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