5G Wireless Networks: Requirements and Improve Capacity with Massive MIMO System

Abubakr Wsu Muhammed

University of Raparin, Engineering and Project Directorate, Sulaimanyah, IRAQ

**Corresponding author:* Abubakr Wsu Muhammed. Tel.: +964-750-1132122 E-mail address: abobakrwm@gmail.com

Abstract

The 5G technology standards guarantees to afford a mobile wireless communication revolution, delivering enhanced wideband and high-speed connection for a broad number of subscribers. Next generation mobile needs a paradigm shift that carries extremely frequency spectrum, greatest data capacity, very low latency to minimize time response and unprecedented amounts of MIMO antenna to support a huge boost in the volume of mobile traffic with beam steering technology. with the approaching the release 5G in future, most telecommunication researchers are debating the 5G standards, requirements, key factors, challenges, network architecture and impact on industries.

This article presents some general properties and several improvements that will be 5G deliver to customers of the wireless networks. also, present the important technologies to advance the capacity of the 5G system and acquire spatial multiplexing which knows as a multi-user massive MIMO system in the context of future 5G wireless technology, in addition, discusses some simulation results that implemented by Matlab program.

Keywords: 5G technology; Massive MIMO; 5G Requirements; Data Rate

1. Introduction

Wireless mobile technology has been one of the most successful technological inventiveness in recent history. The last decade testified enormous development in mobile networks. Mobile technology has greatly participated in the economic and civilization development of both developing and developed society, The history of wireless mobile technology is not far away, the 1G analogue system started from 1979 until today 4G (LTE/LTE-Advanced), 4G started in 2010 and deployed quickly around the world [1]. Generally, the new generation of the mobile system launched in the markets about every 10 years, the researchers in this field are expected 5G mobile technology which commercially deployed in markets at 2020 and beyond [2].

The number of mobile network users rises every day, in 2012 mobile subscribers more than 4 billion and expected by 2020 increased to 7 billion users. Furthermore, more than 50 billion machines and wireless devices connected around the world through the envision Internet of Things (IoT) by 2020 [3]. The mobile traffic on wireless networks is expected to increase more than 1000 times in 2020 compared to the year 2010, this significant increase in mobile traffic will need an important improvement in the capacity of the mobile network. These requirements are supposed to be a decisive challenge towards 5G technology [4].

To solve the 5G challenges, it is necessary to utilize a network infrastructure that can integrate different wireless technologies of existing and new technologies.

Especially, the 5G mobile should allow the subscriber to achieve the really networked society with limitless access to data for anyone, anytime, and anywhere. Also enable subscribers to boost different smart cities and infrastructures that are reliable, green and transportable [5]. To achieve this aim, it is important to establish a network with various models of cells, massive MIMO at a base station and/or mobile station, multiple radio access technologies (RATs), and utilization of both the mm-wave and microwave frequency bands.

2. Key Requirements of 5G Wireless Technology

Combining the different study initiatives by academia, several groups special mobile organization and industries working to the ultimate designing of 5G mobile and wireless communication system, several key requirement and features that provide a significant effect on the expected next generation system improvement, network architectures and evolution of technology, The requirements and visions for 5G technology are identified as:

Peak data rate

5G system should practically supply higher data rates compared to existing networks 4G and LTE-A. Also, 5G required the guarantee a certain QoS for subscribers at low and high mobility travelling such as (high-speed trains at 500 km/h) wherever the current systems cannot agreeably support users, (existing networks can support mobility of up to 300 km/h.). The data rate will reach 1 ∼ 15 Gbps or higher, this is approximately 100 times enhance from the existing networks that theoretical higher data rate of 150 Mbps [6, 7].

Millimeter-wave radio spectrum

The capacity for wireless telecommunication system relies on the amount of bandwidth and spectral efficiency. to provide an important increase in mobile traffic and the increase of devices and services, for 5G wireless communication suggest frequency bands above 6 GHz, wherever the high-frequency mm Wave spectrum ranging (3∼300 GHz) with wavelengths that range of 1 to 100 mm. The use of millimeter-wave spectrum bands is a possible candidate to allows transmission at wider bandwidths than conventional transmission 20 MHz channels for the 4G system and increased the bandwidth for more than 500 MHz Contiguous Spectrum above 6 GHz [7, 8].

The important advantage of mm Waves that have a very short wavelength it possible to package a massive number of small antenna size elements into a small area at both the BSs and MS [E].

5G system capacity

It is expected that the amount of mobile traffic in the 2020 increase on the order of 1,000 times compared to practice in 2010. Therefore, to satisfy that exciting traffic growth next generation must be able to manage traffic volumes, also required to perform a 1,000-fold capacity gain compared to the 4G mobile network.

The main technique for performing the required gain and increased capacity of the wireless system is improving the air-interface, acquiring new spectrum efficiency, upgrades in devices and develop the network architecture. This will be a big challenge for 5G mobile technology [1, 9].

Power consumption and battery life

Improve energy efficiency and minimize the Power consumption in 5G technology requires to achieving longer battery life especially in user equipment and massive machine communication (MMC), in the expected design for 5G, there has been a powerful vision of interest in the issue of energy saving to produce a “green communications” system through saving energy by 90% [10].

Massive Machine Connectivity and IoT

With the significant increase number of machines that to be connected simultaneously to the wireless network as expected in future, the network system will be overcrowded. 5G will need to manage and support more connectivity and reliable connection link for a different enormous set of devices, furthermore, next generation will

need to be able to support all-time connection for more machine that services of healthcare, automation, transportation, agriculture, and other industrial sectors, based for the Internet of Everything (IoE) that known as vision Internet of Things (IoT) [11].

Minimum latency

Latency is the time that needs to complete a full signal communication, latency reduction become important to enable energy savings and long battery life. Also, several potential application requires a lower latency such as the tactile Internet [12], virtual reality (VR), augmented reality (AR), Emergency/Disaster system, Machine-to-Machine (M2M) communication, and IoT. Also the 5G low latency can cause autonomous vehicles out of the lab and make smart home smarter. These applications cannot be satisfied fully by the existing 4G latency which is about 15 ms. besides, provide high data rates, future 5G technology should support minimum latency about 1ms, which will have important implications on design and allow to driven those applications across all sectors and industries [13].

Moreover, there are more requirement and challenges that will be progress and development in 5G technology such as nearly 100% coverage, Multiple-radio access technology (RAT), Ultra-reliable Networks (URN) and Ultra-dense Networks (UDN) [14].

Six key requirements and research areas will have the largest effect on progressing 5G are summarized in Figure 1.

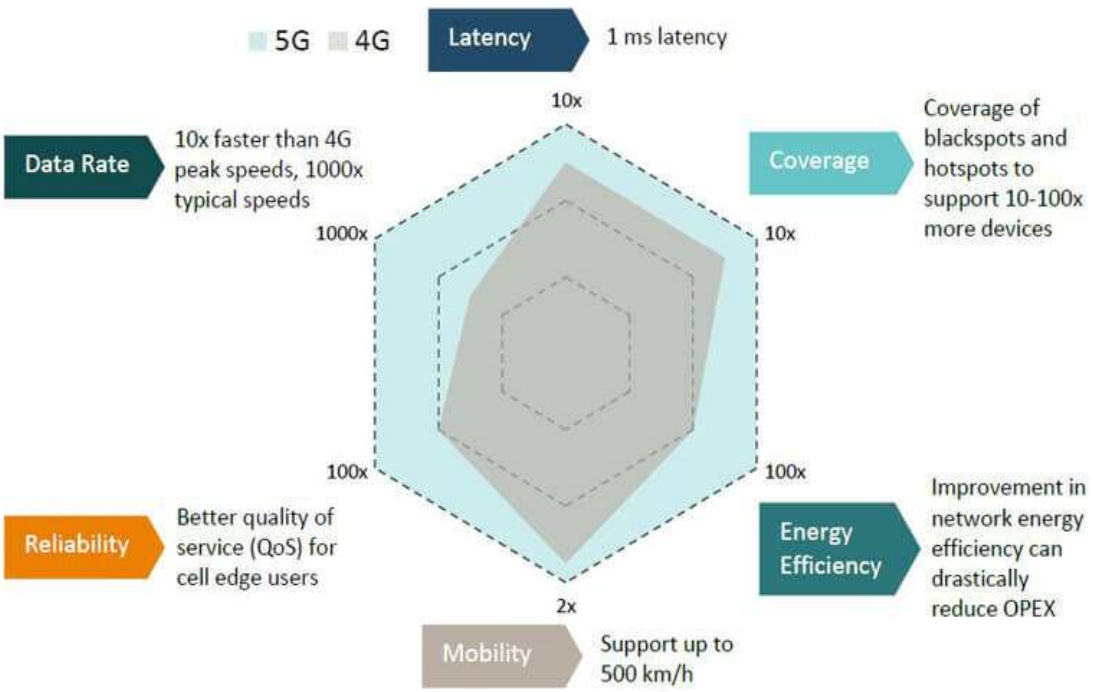

Figure 1. Key performance indicators for the development from 4Gto 5G [2, 7]

3. Massive MIMO System

Most of the organizations and featured companies that leading in 5G technologies such as METIS, IMT 2020, NTT DoCoMo, Ericsson, Huawei and Intel etc. suppose that massive MIMO will be a key factor in supporting the dramatically increase the demands and mobile traffic on wireless mobile network in the next decade, massive MIMO able to significantly enhance the reliability and capacity for 5G wireless mobile technology, also MIMO is expected to be an essential milestone in the evolution of 5G mobile networks. Massive MIMO (multi-input multi-output) antennas use multiple elements or links to send and receive large data simultaneously [15]. Massive MIMO has the ability to integrate up to hundreds of antennas at a base station, also User Equipment (mobile phones and devices) in the 5G system could combine a massive number of antenna elements that formed into the devices for the mm-Wave frequency with the small size antenna element.

The main improvements of massive MIMO in a future wireless system can be described on two fronts:

- **Spectral & Energy Efficiency**

Massive MIMO obviously Increase spectral efficiency and great energy efficiency [6]. Compared to a single-antenna system. The massive MIMO able to reduce antenna transmit power at the BS with perfect channel state information (CSI), this is drives to greater energy efficiency that is very important for the future wireless generation, where unnecessary power consumption is an increasing concern [16].

- **Spatial multiplexing**

Massive MIMO can increases capacity by several times above traditional MIMO, with spatial multiplexing can transmit and receive a different data stream at the same time and bandwidth together, also M-MIMO has the ability to perform very big data rates and high quality of service to each user. Further, decreased spatial interference for a new massive MIMO design by combining an electromagnetic lens with a big antenna array [17, 18].

4. RESULT AND DISCUSSION.

The improvement of capacity and increase data rate with massive MIMO antenna configurations are studied, also the massive MIMO with conventional MIMO system and other antenna configuration are compared. In addition, the effect of the kind of precoding scheme with massive MIMO for increasing data rate is illustrated. The simulations and computations are implemented by the "MATLAB 2018 a".

4.1. Simulation of Ergodic Capacity

In this section, the comparison between various antenna systems such as MIMO, SIMO, MISO and SISO system is performed, also the impact of increasing number of antenna from 64x64 to 128x128 MIMO system is implemented by plotting among ergodic capacity versus a number of the antenna at the constant value of SNR equal to 0 dB. There are two different statuses which are shown in Figures 1 and 2.

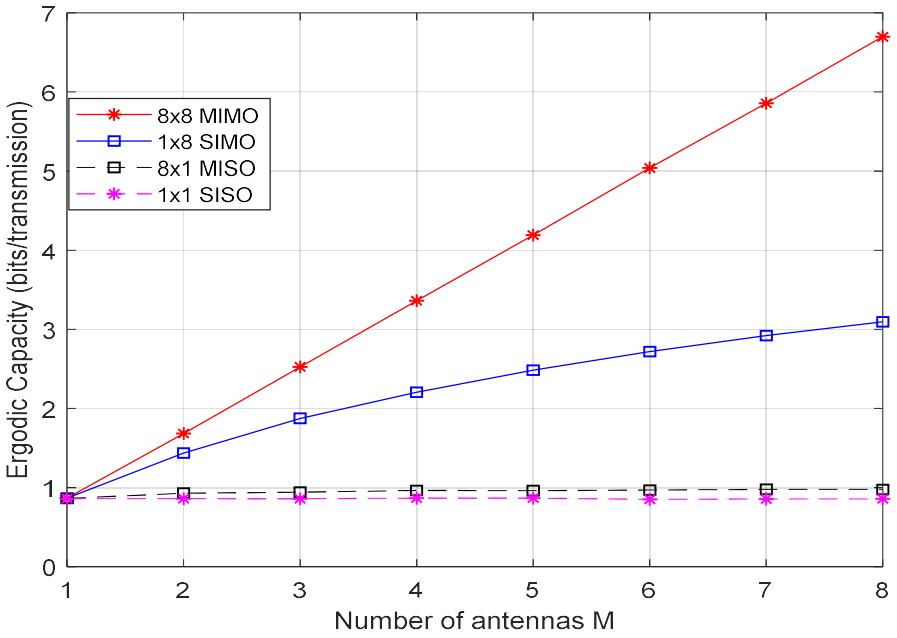

Figure 2. Ergodic Capacity for MIMO, SIMO, MISO, SISO i.i.d. Rayleigh fast fading channel - SNR=0dB.

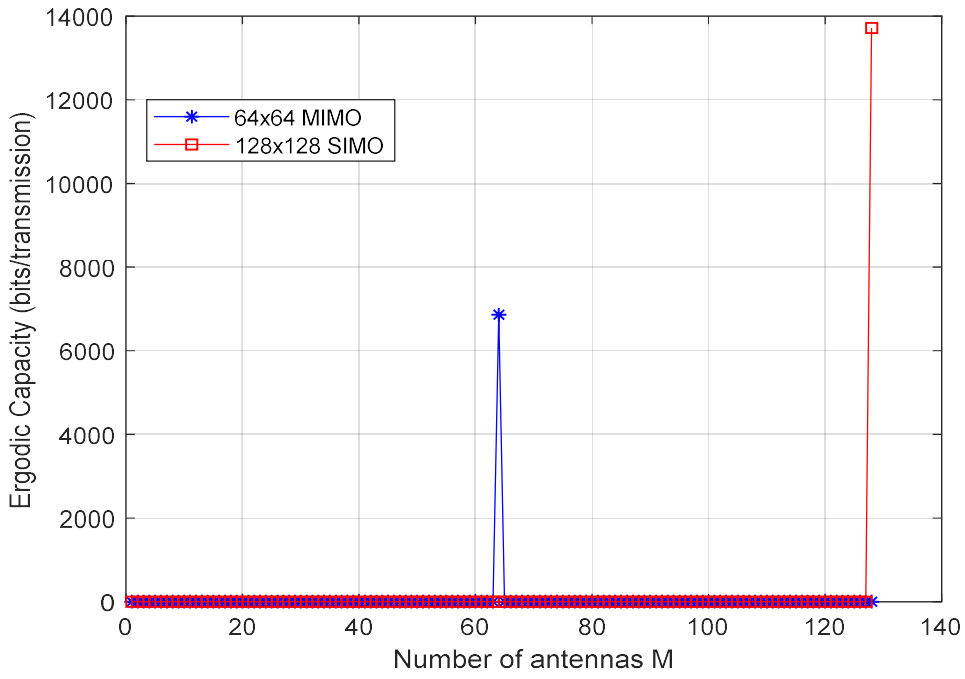

Figure 3. Ergodic Capacity for MIMO i.i.d. Rayleigh fast fading channel - SNR=0dB

Figure 2. displayed the capacity of four types of the antenna system, as noted the increasing the transmitter antenna without increasing the receiver antenna could not greatly influence the capacity, but by the increased in both transmitter and receiver or only in receiver side a significant improvement capacity was found, also the capacity of the MIMO system is much better than other systems.

Figure 3 shows the results gained in increasing the number of antennae raised the ergodic capacity significantly and channel capacity increases rapidly.

In contrast, in MISO and SIMO technologies, by increasing the number of antennas the ergodic capacity was slowly developed.

4.2. Simulation of M-MIMO using (MMSE and SIC) pre-coding scheme

To illustrated the achievable sum rate (bits/transmission) for MIMO system and shown the effect of the increasing number of antenna with MMSE and SIC pre-coding as a function of raising SNR for M= 64, 128 respectively.

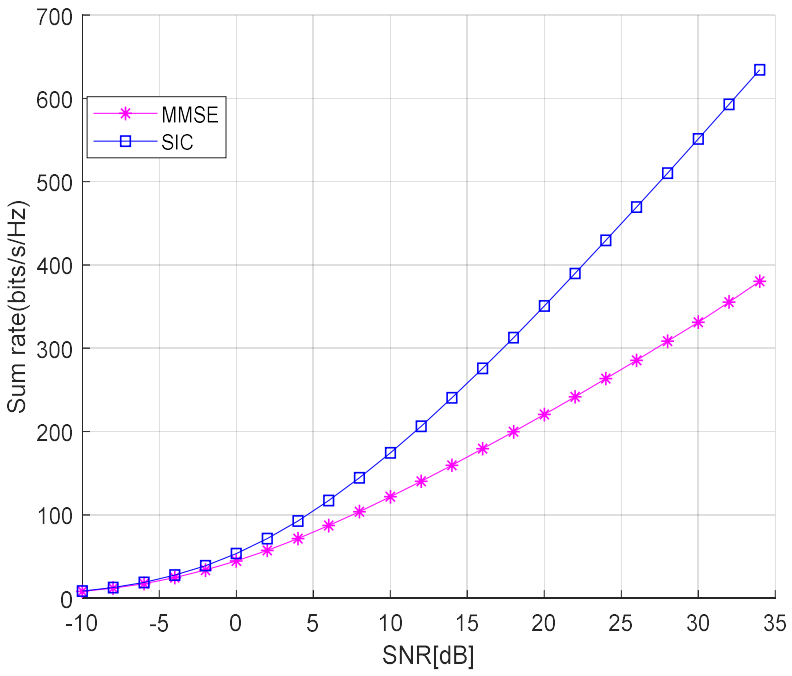

Figure 4. Achievable rate of MIMO 64×64 receivers for i.i.d. fast fading channel.

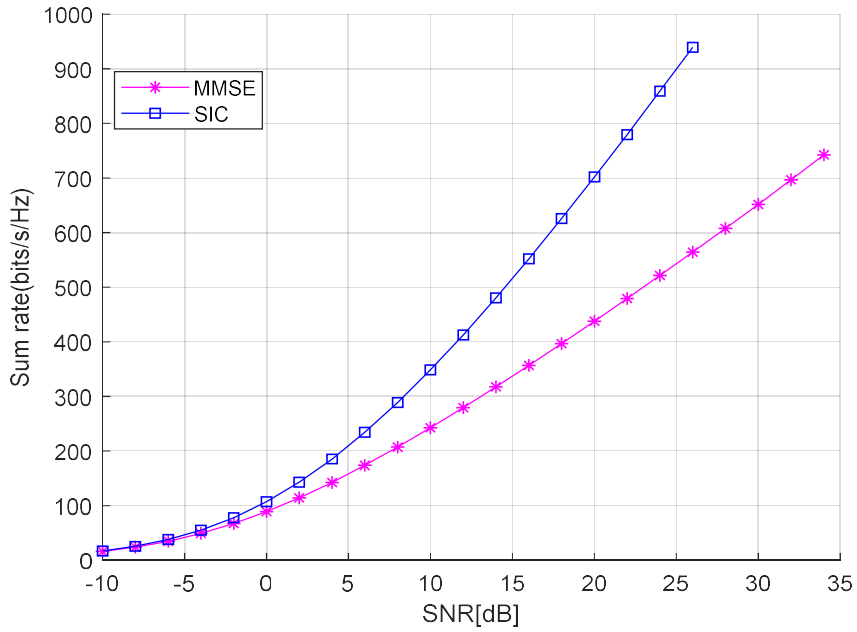

Figure 5. Achievable rate of MIMO 128×128 receivers for i.i.d. fast fading channel.

Figure 4 and 5 shows the comparison of 64x64 and 128x128 MIMO system with MMSE linear and SIC non-linear pre-coding scheme.

It is an expression through increase SNR values, the SIC was recorded larger value than MMSE precoding at any value of SNR. In Figure 4, the curves show SIC performance gained over MMSE about 8 to10 dB at 400 bits/s/Hz, also it can be seen in Figure 5 the advantages of SIC over MMSE it is receiving 10 to15 dB at 700 bits/s/Hz.

Consequently, the data rate gain of the 128x128 MIMO over 64x64 MIMO clearly can be seen at all value of SNR. Thus, the achievable rate gets more improved due to increase in the number of multiple antennas.

5. Conclusion

The critical requirements for 5G networks already release a set of innovative thinking and a feeling of importance in delivering innovative new technologies to reality. In this article, 5G wireless technology was presented, this generation plays a fundamental role in the development of all sectors of the technology and telecommunications industry.

Massive MIMO techniques are considered to be one of the key technologies in origination 5G that nearly inevitable, This article has shown the spatial multiplexing including increase capacity and data rate using massive MIMO techniques.

Computing results prove that a large scale antenna such as 128x128 MIMO firmness the channel performance much better than other MIMO configurations that simulated at this study, which can accomplish a high capacity and data rate connection without increase frequency bandwidth and raising signal power.

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