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5G ENABLING TECHNOLOGIES: A BRIEF OVERVIEW

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Abstract

The objective of this paper is to introduce the concept of 5G Communication, its comparison with previous technologies, and mainly to discuss various enabling technologies required for 5G Communication. These technologies include Massive MIMO, use of Cognitive Radio & Networks, Implementation of Millimetre Waves, and Non Orthogonal transmission. This paper also describes the importance of Device to Device communication in 5G, especially when it is implemented in Internet of Things. This paper also discusses why these technologies will play a major role when the fifth generation of standards for wireless communication is implemented.

Keywords: *5G, MIMO, Millimetre waves, Cognitive Radio, Non-orthogonal transmission, Device to Device communications.*

1. INTRODUCTION

Mobile and wireless communications have undergone a remarkable evolution in the last three decades. With the advent of new technologies, new standards were defined. Since wireless communications were upgraded, each set of standards defined a generation. The first generation or 1G used Frequency Domain Multiple Access (FDMA) and was based on analog communication. The second generation or 2G used digital radio signal and was based on Time Division Multiple Access (TDMA). It added the concept of transmitting data along with voice wirelessly. Code Division Multiple Access (CDMA) and turbo codes enabled the third generation which ushered in the transmission of rich multimedia content. 4G systems use Orthogonal Frequency Division Multiplexing (OFDM) along with Multiple-Input Multiple-Output (MIMO) and link adaptation technologies. 4G wireless networks can support data rates of up to 1 GB/s for low mobility, such as nomadic/local wireless access, and up to 100Mb/s for high mobility such as mobile access. [1]

However, more and more people with more powerful wireless gadgets are demanding advanced multimedia capabilities. They crave faster internet and information access as well as instant communication, while on the move. Wireless World Research forum predicts that by 2017, 7 billion people will be served by 7 trillion wireless devices. On one hand, cellular service providers are facing an ever increasing demand for higher data rates. New wireless applications also require a larger network capacity, higher spectral and energy efficiency and higher mobility. On the other hand, 4G networks have reached the theoretical limit as far as current technologies are concerned.

It is time to therefore begin structuring the fifth generation of standards for wireless communications. 5G will be a global standard, similar to 4G, dominated by LTE-Advanced. Worldwide, many countries and regions are already setting up detailed plans for 5G study and promotion, such as METIS project ofEurope Union, IMT-2020 of China, 5G Forum of Korea and ADWICS of Japan. [2]

Unlike the previous four generations, the application scenarios will be much more diverse in 5G. The user peak data rate and average cell efficiency are no longer the only requirements. System design will have to be based on high reliability, latency, number of connections, user experience rate, energy efficiency, etc. The five words 'anybody, anything, anywhere, anytime and anyhow' will be the basis of 5G. The aim is to achieve seamless and ubiquitous communication between anybody or anything (people to people, people to machine or machine to machine), whenever they want (anytime), at whichever place they are (anywhere) using whichever device they possess and the service they subscribe to (anyhow).

So, the question arises, what will the 5G network be defined as? It is too early to predict the standards, but what can be said with certainty that with such diverse scenarios that 5G is expected to cater to, technologies for 5G will be multi-fold. It cannot be represented by one dominant single technology.

In this paper, we will discuss the key technologies which will individually and together as a group enable the implementation of an evolutionary as well as revolutionary set of standards for the next generation of wireless devices and communications. We will start with a discussion on MIMO, and then proceed to discuss cognitive radio, millimetre waves, device to device communication and finally Non-Orthogonal transmission.

2. PROMISING TECHNOLOGIES

There are several technologies which will help in the implementation of fifth generation standards. We will discuss a few of them in this paper.

2.1. Massive MIMO

Multiple antennas at both the transmitter and receiver constitute the MIMO (Multiple Input Multiple Output) system. In addition to time and frequency domains, multiple antennas offer more freedom in wireless channels to accommodate more information. Hence, reliability, and spectral and energy efficiency improves significantly.

To a large extent, this is facilitated by OFDM in 4G. The much simpler processing at the receiver compared to coded-division multiple access makes MIMO an attractive and effective way in improving both the peak rate and system capacity of cellular networks. [2]

Massive MIMO is also called Large Scale Antenna Systems. In this system, the number of antennas at base station is much larger than the number of devices per signalling resource. [3] The transmit antennas can be co-located or distributed in different applications. Similarly, the huge number of reception antennas can be possessed by a single device or distributed for multiple devices.

Unlike in single-user MIMO (SU-MIMO), in which a mobile device can accommodate a limited number of antennas, multi-user version of MIMO lets each BS communicate with several users concurrently by effectively pulling together the antennas at those users.

MIMO offers many benefits. First, without the need for increased BS densification, it provides significantly great enhancements in spectral efficiency. Second, it results in a smoothed out channel response because of vast spatial diversity. Third, the effects of noise, fast fading and intracell interference are diminished using simple linear precoding and detection method.

Spatial modulation has been proposed for the low complexity implementation of MIMO models, without the degradation of system performance. Instead of simultaneously transmitting multiple data streams from the available antennas, SM encodes part of the data to be transmitted onto the spatial position of each transmit antenna in the antenna array.[1] This increases data rate with respect to single antenna wireless systems. One transmits antenna remains active while others remain idle. The receiver may then use the optimal Maximum Likelihood (ML) detection for decoding purposes.

2.2 Cognitive Radio and Networks

Cognitive radio is an intelligent communication system that is aware of its surrounding environment. It learns from its environment and changes its internal states according to the incoming RF stimuli. This is achieved by changing certain operating parameters like carrier frequency, transmit power, etc. in real time. This methodology ofunderstanding by building is implemented with two objectives in mind: highly reliable communication at anytime and anyplace along with efficient utilization of radio spectrum.

Cognitive terminal therefore has the intelligence to choose the best network among those available. Information such as time, demand and resource will determine the choice. Therefore, with the use of cognitive radio 5G can achieve interoperability and still have good quality of service. [4] By interoperability we mean, that different systems using different technologies will be able to communicate with each other.

The 5G technology needs a universal terminal, with all of the radio predecessors featuring into a single device. This convergence meets the users' demands and needs. Therefore cognitive radio is one of the key technologies to implement 5G.

The use of cognitive radio networks is motivated by the fact that the RF spectrum is under-utilized most of the time. The CR network is an innovative software based radio technique in which a secondary system can share spectrum bands with licensed primary system. This maybe done either in interference free basis or an interference tolerant basis.

The CR network should regulate its transmissions based on the surrounding radio environment's status quo. IN interference free networks, CR users can employ spectrum resources only when the primary users are not using them. In interference tolerant CR networks, CR users can share the spectrum with the primary users as long as the threshold is below a certain limit. In general interference tolerant CR systems utilize the spectrum more efficiently as well as provide higher efficiency.

2.3 Millimetre Waves

Wireless systems have been employing a slim range of microwave frequencies corresponding to wavelengths in the range of a few centimetres to a meter. This spectrum is nearly fully occupied, especially at peak times and in peak markets. With the internet services increasing with a tremendous rise in the number of gadgets, much more bandwidth is needed. To increase bandwidth, there is only one way: to increase frequency. Fortunately, the mmWave range of 1-10mm wavelengths is lying relatively idle.

Until recently, this mmWave spectrum was deemed unsuitable for mobile communications due to many reasons. First, it had hostile propagation qualities resulting in strong pathloss, atmospheric and rain absorption, low diffraction around obstacles and penetration through objects. Second, there was strong phase noise. Also, the equipment had exorbitant costs.

The free space loss between transmit and receive antennas grows with f_c^2. However, if the antenna aperture at one end of the link is held constant as the frequency increases, then the free space pathloss remains unchanged. Further if both transmit and receive antenna apertures are held constant, then free space loss actually diminishes with f_c^2. [5] As antennas shrink in size with frequency, more of them must be added within the original area to maintain the aperture. Therefore, path loss in the spectrum can be reduced using arrays.

The absorption due to air and rain is noticeable, especially the 60 GHz unlicensed band, but it is insignificant where BS spacings might be of the order of 200m, like in urban deployments. In fact, such absorption becomes beneficial, since it further attenuates interference from more distant BSs.

Therefore we can say, that the propagation losses can be overcome, but require large antenna arrays to steer the beam and collect it coherently. A challenge for narrow beams is establishing associations between users and BSs, both for initial access and handoffs. The notion of "Phantom cells" is the solution. In this concept, mmWave frequencies will be employed for payload data transmission from small cell BSS while microwave frequencies from macro BSS will be used at the control plane. Fast data transmissions could then be arranged over mmWave links, as control links would remain in place for retransmission of lost data, overcoming the problem of sporadic interruptions of mmWave links.

2.4 Device to Device Communication

Direct device to device (D2D) communication between devices can be defined as the direct communication between devices, without involving any network infrastructure.

In voice centric systems it was implicitly accepted that two parties in close proximity will not establish a call. But now, in the new age of data transmission, several co-located devices are willing to share multimedia content or interact say for the purpose of gaming or social networking. There are inefficiencies at various levels, when such a connection is made.

Multiple wireless hops are used to achieve what requires fundamentally a single hop. This results in wastage of signalling resources as well as higher latencies. Transmit powers of a fraction of a watt (in downlink) and several watts (in uplink) are consumed to achieve what fundamentally requires a few mWatts. Consequently there is unnecessary battery drain. Spectral efficiencies are also lower given that path losses to possibly distant BSs are much stronger than direct link ones.

Although, other radio access technologies such as Bluetooth or WifiDirect, cases requiring a mixture of local and non local content for example interaction of users via augmented reality represent more compelling reasons to use D2D. Therefore, D2D natively supported in 5G is a sine qua non.

2.5 Non Orthogonal Transmission

OFDM system has a simple receiver implementation due to orthogonal resource allocation, especially for MIMO. However, orthogonal systems are sub-optimum in nature especially when SNRs of co-scheduled users are different. The drawbacks of OFDM include its and peak-to-average-power ratio (PAPR). Another problem is the applicability of OFDM to mmWave spectrum, given the enormous bandwidths therein and the difficulty of developing power amplifiers at such high frequencies. [5]

The simplest form of non orthogonal transmission is direct superposition of modulation symbols. However, it requires full-blown successive interference (SIC) at the receiver that can be a serious issue for mobile terminals. [2]

Code structures can be used to either improve the system robustness when resource collisions occur, or provide more flexibility in pairing the users for simultaneous transmissions. They can also reduce receiver complexity.

There are three ways to implement more advanced non orthogonal transmission schemes using code structures. They are spread sequence based, sparse code based and bit division based.

In spread sequence based code structure, the sequences have low cross correlation and hence can easily facilitate SIC at the receiver. Sparse code based implementation can reduce receiver complexity with a well designed matrix. Both these methods are suitable for grant free uplink transmission. Code superposition at bit level can be used to reduce receiver complexity of downlink.

3. CONCLUSION

It is a revolutionary time for wireless industry. The requirements and expectations from the fifth generation of wireless communication standards are many. In this paper we have presented five key technologies that will play a major role in implementation of 5G. Massive MIMO will help improve reliability of networks, their energy and spectral efficiencies. Millimeter waves will solve the problem of a huge demand for bandwidth. Cognitive radio will provide interoperability and cognitive radio networks will further improve spectral utilization. Device to Device communication will improve latency and data rates between co-located devices. Finally non orthogonal transmission will enable communication at mmWave frequencies and offer further optimization. These technologies might as well be the foundation on which 5G will be build.

References:

[1] Cheng-Xiang Wang, Haider F., Xiqi Gao, and Xiao-HuYou "Cellular Architecture and Key Technologies for 5G Wireless Communication Networks" in Communications Magazine, IEEE (Volume:52 , Issue: 2) Feb 2014.

[2] Yuan Yifei and Zhu Longming "Application Scenario and Enabling Technologies of 5G" in Next-generation Wireless Innovation Program, ZTE, Beijing, China

[3]Boccardi, F ; Heath, R.W. ; Lozano, A. ; Marzetta, T.L. "Five Disruptive Technology Directions for 5G",Communications Magazine, IEEE (Volume:52 , Issue: 2)

[4] Felita, C. and ; Suryanegara, M. "5G Key Technologies: Identifying Innovation Opportunity" in QiR (Quality in Research), International Conference in June 2013

[5] Andrews, J.G., ; Buzzi, S. ; Wan Choi ; Hanly, S.V. "What will 5G be?" Selected Areas in Communications, IEEE Journal on (Volume:32 , Issue: 6) July 2014