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A New Responsibility Domain Based Architecture for 5G Networks

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ABSTRACT

5G is the world's most advanced wireless mobile communication technology likely to come up with a vision, the vision of providing the best Quality of Service (QOS), explosive data rate of the order of 10Gbps and lowest possible end to end latency. The 5G networks are likely to support completely wireless protocols supporting the world wide wireless web (WWWW) over smart devices and networks. In this paper we discussed the evolution of the mobile communication networks starting from 1G to 5G, their comparisons and the various candidate technologies associated with each of the generations. This paper also takes a review into the emerging technologies and tools for 5G such as Millimeter (Mm) waves, Small cell (SC)concept, Massive Multiple Input Multiple Output (MIMO), Beamforming and Full Duplex (FD). Massive MIMO allows integration of large scale arrays of antennas at the transmitter and the receiver sides of MIMO channel. Massive MIMO has significantly contributed to the channel capacity upsurge for higher orders. We conducted the experiments for channel capacity (bits/sec/hertz) considering 4x4, 8x8, 16x16, 32x32 and 64x64 MIMO systems. The 5G systems will simply overcome the challenges posed by the 4G wireless standards, the challenges include more capacity, advanced data rates, Low latency, Connectivity for gigantic number of devices, reduced cost and energy and Quality of experience (QOE).

Keywords- 5G, Millimeter wave, 5G IOT, Massive MIMO, OFDM, Beamforming.

1. INTRODUCTION

Every fresh generation of the mobile communication networks delivers fastest network speeds and additional functionality to our smartphones. First generation (1G) of analog communication systems were meant mainly for the voice traffic transfer. Second generation (2G)communication systems lets us text for first time. Third generation (3G)communication systems put us online and Fourth generation (4G) wireless systems delivers the fastest speeds that we delight today. Each generation has a key technologies associated with it, like Frequency Division Multiple Access (FDMA) for 1G, Time Division Multiple Access (TDMA) for 2G, Code Division

Multiple Access (CDMA) for 3G and Orthogonal Frequency Division Multiple Access (OFDMA) and (MIMO) for 4G[1][2]. But as more users come online the 4G networks reach the maximum limit what they are capable of, particularly at the spell when users want even more data for the smartphones and other devices. The 5G networks are capable of handling data rates which is about thousand times supplementary than the currently deployed networks. 5G'smotivation tend to be the foundation for virtual reality, autonomous driving, internet of things (IOT) and various other spheres like smart education systems, smart health monitors, electrical energy administration in smart grids etc. IoT interconnect "Things" and enables machine-to-machine (M2M) communication, a means of data communication between heterogeneous devices without human involvement[3][4]. 5G technology is on way to revolutionize the way by which most of the users access their handsets [1]. Today networks that powers our smart devices and internet connected gadgets are mostly centred on 4G wireless systems technology. The high performance 5G is the future technology that promises to take us to future digital world where we had not ever been before. 5G is reflected to be the key wireless communication technology withIOT, which isalabel given to notion of locating each and everything on internet. Billions of sensing devices will be embedded into security systems, appliances, door locks, health monitors, wearables, smart watches, self-driving cars etc. Analysis revealed that number of network connected gadgets will reach up to 25 billion till 2020. The 5G systems provide data rates sixty times faster than the presentlypositioned 4G Systems. Such explosive data rates will help the software controlled self-driving cars to perform time critical decisions where even a single millisecond counts; video chat seems to be talking to a person within the same room. In metropolitan cities the 5G systems will monitor and provide information related to highway vehicular traffic congestion, pollution levels, product demand and feeds the data into your smart car in real time. The users are eagerly waiting for the 5G to be put to use because of reasons like virtual reality, augmented reality, instant gratification, low latency and fast response. The 5G networks for mobile multimedia systems are completely wireless, supporting the world wide wireless web (WWWW) [3][17] without any data and recreational multimedia limitations. The truth behind the 5G technology is that it doesn't have a dedicated infrastructure of its own and experts cannot tell us what 5G is, because they even don't know it yet.

Right now there are five brand new technologies emerging as a foundation of 5G. These are Millimeter (Mm) waves, Small Cells (SC's), Massive MIMO, Beamforming and FD. In this paper we will debate these key technologies and their applications in 5G wireless systems. Massive MIMO allows embedding of large arrays of antenna arrangements to be employed at transmitter and receiver terminals to achieve enormously high data rates in order to serve billions of network connected devices and to provide new services like e-Health, Learning, Vehicle to Vehicle communications (V2V), Device to Device (D2D). D2D communication is a promising technology for 5G which allows multiple devices in close proximity to communicate with each without consuming network resources. D2D reduces indirect computation time, memory, bandwidth and other resources that are required to perform a specific task.In the present age, wireless telecommunication system has gained a huge improvement in both efficiency and cost effectiveness. High data rate and high Quality of Service (QOS) is no more a dream in present wireless systems and this rate has increased quite rapidly in recent past.

(MIMO) and Orthogonal Frequency Division Multiplexing (OFDM) technologies are going to make an evolution in the domain of wireless communication [6]. MIMO employs the concept of multi Antenna systems deployed concurrently at the transmitter and the receiver sides. Such a system has the capability to communicate with different antenna simultaneously which is 2x2, 3x3, 4x4 arrays and even more. Nowadays massive MIMO and OFDM have become the burning issues where hundreds to thousands of antenna can communicate simultaneously [7] using code assignments to different channels. This ensures high data rate required for the 5G communication. Millimeter(Mm) wave can be an important candidate technology to make this system more effective because the wavelength of Mm wave is very low so in that case frequency is very high which are from 30-300 GHz. Massive MIMO promises a huge channel capacity for the consumer which can definitely insure the high data rate. Similarly OFDM is a key broadband wireless technology which supports high data rates about 100 Mbps using the concept of multicarrier transmission.

2. EVOLUTION OF MOBILE COMMUNICATION TECHNOLOGIES FROM 1G TO 5G.

2.1 First generation (1G)

The evolution of the communication systems started in the early 1980’s with the invention of the 1G analog communication systems. This system used FDMA access techniques for voice traffic only [1]. 1G was based on Advanced Mobile Phone System (AMPS), Nordic Mobile Technology (NMT), Improved Mobile Telephone System (IMTS), Push to Talk (PTT) and Total Access Communication System (TACS) technologies, which are capable of wirelessly carrying voice only. It was a narrow band communication system with a carrier frequency of 30 KHz and operating frequency of 800 MHz. 1G was quite unreliable in maintaining handoffs with problems like low capacity, poor voice links and no security [8][6].

2.2 Second generation (2G)

2G started in the 1990’s with a step forward to digitize the already existing 1G analog communication systems and allowing the users to text for the first time in the history of wireless communication. It uses TDMA and CDMA for voice communication rates upto 10kbpsallowing multiple users on the same channel. It is based on the Global System for mobile communications (GSM) and IS-95 standards. General Packet Radio Service (GPRS) and Enhanced Data for GSM evolution (EDGE) were later added with an idea of increasing the data rates over cellular networks upto 144 kbps[2][3] and to provide low speed data access, such as emails, internet etc.to users with mobile devices. It uses circuit switching for Voice and Packet switching for data to provide multimedia features like Short Messaging Service (SMS), Multimedia Messaging service (MMS), internet access and introduced the concept of Subscriber Identity Module (SIM) which provides a unique identity to a mobile user. 2G is a narrow band communication system having bandwidth 0f 25MHz, operating at a frequency of 900-1800 MHz for GSM and 800 MHz for CDMA with a carrier frequency of 200 KHz. Demand for high data rates lead to the development of the 3Gcommunication systems.

2.3 Third generation (3G)

3G started in the year 2000 with the motive of meeting the high data rate requirements of the mobile users. It uses the CDMA techniques to provide advanced multimedia features like video calls, mobile TV, GPS and video conferencing in addition to voice, with a high level of security and international roaming. It sends out data by utilising a digital switching technique called packet switching except for air interface. It is based on International mobile Telecommunications (IMT) 2000 and Wide Band CDMAstandards [9][10]. 3G is a wideband wireless communication technology operating at a frequency of 2100 MHz with a carrier frequency of 5 MHz, providing data rates upto 3.1 Mbps [9].

2.4 Fourth generation (4G)

Long term evolution (LTE) is considered as 4G wireless communication technology.LTE encompasses all the features of 3G and additional high speed features like mobile TV, Wearables, handoffs etc. It is an ultra-wide band wireless communication technology operating at a frequency of 850 – 1800 MHz. with a carrier frequency of 15 MHz, providing ultra-Broadband internet service at a bandwidth of 100MHz [9]. It is based on new emerging technologies likeOFDMA and MIMO offering both cellular and multimedia services at a downloading speed of 100 Mbps. MIMO concept employs use of large antenna arrays giving rise to higher order diversity systems for multipath propagation and OFDM reduces the interference by making two interfered channels orthogonally uncorrelated because of the introduction of the multicarrier systems.

2.5 Fifth generation (5G).

5G would be the future of the wireless communication systems which emerges with a promise, the promise of providing the highest possible data rates, high Quality of Service (QOS) and lowest possible end to end latency [1]. The 5G wireless communication systems will have to feed an unprecedented number of mobile devices, expected to reach 50 billion by the year 2020, satisfying their high volume needs of data and voice traffic [1]. To support such a massive number of connected smart devices and their data needs, the 5G wireless systems are expected to provide a 1000 times increase in capacity enhancement with the same power and spectrum resources currently existing in the performing networks[9]. A close proximity insight into the 5G capabilities and its performance indicators reveals that the current available spectrum resources are insufficient to provide the promised user experienced data rates, connection density, end to end latency, mobility and peak data rates [4] Due to inadequate availability of spectrum, it is recommended to design resource allocation algorithms employing reuse of the spectral resource by multiple communication links [1][3]. The deployment of 5G communication systems employing the current network resources rely on highly efficient technologies like massive (MIMO), cognitive radio (CR) systems, device to device communication and low budget link based cooperative and relay communications[4][17][6]. It is based on millimeter (Mm) wave and FD technology, sending and receiving the data through packet switching achieving data rates upto 10Gbits/s. various emerging technologies that lays the foundation for 5G are Millimeter (Mm) waves, SC's, Massive MIMO, Beamforming and FD. It is an ultra-wide band communication system operating at a frequency of 6 GHz to 30 GHz with carrier frequency of 60 GHz, providing high user experienced data rates at 30 GHz bandwidth for time critical applications like V2V, D2D, virtual reality, augmented reality and instant gratification.Figure1 graphically represents the evolution of mobile communication systems and representative technologies of each generation. Table1 below summarize and compares the important features of all the generations evolved so far.

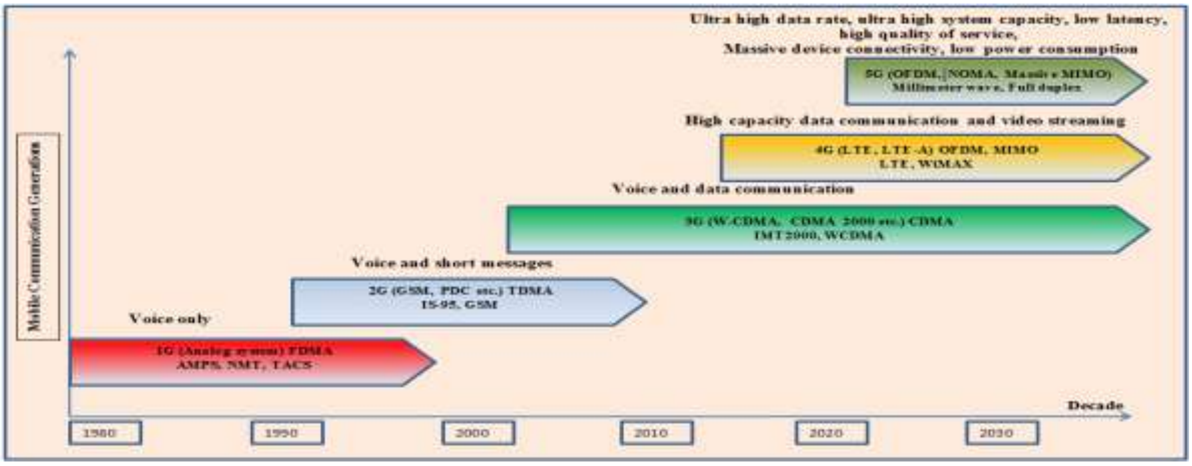

Figure1: Evolution of mobile communication systems and representative technologies of each generation

TABLE 1: Comparison of Different Wireless Communication Systems Generations

Parameters	1G	2G	3G	4G	5G
Technology	AMPS (Advanced Mobile Phone System), NMT, TACS	IS-95, GSM	IMT2000, WCDMA	LTE, WiMAX	Millimeter wave Full duplex
Multiple Address/Access system	FDMA	TDMA, CDMA	CDMA	CDMA	Massive MIMO OFDM, NOMA
Switching type	Circuit switching	Circuit switching for Voice and Packet switching for Data	Packet switching except for Air Interface	Packet switching	Packet switching
Speed (data rates)	2.4 Kbps to 14.4 kbps	14.4 Kbps	3.1 Mbps	100 Mbps	10Gbit/s
Special Characteristic	First wireless communication	Digital version of 1G technology	Digital broadband, speed increments	Very high speeds, All IP	IOT
Features	Voice only	Multiple users on single channel	Multimedia features, Video Call	High Speed, real time streaming	Very High Speed, real time streaming
Supports	Voice only	Voice and Data	Voice and Data	Voice and Data	Voice and Data
Internet service	No Internet	Narrowband	Broadband	Ultra Broadband	Ultra wide Broadband
Bandwidth	Analog	25 MHz	25 MHz	100 MHz	30Ghz
Operating frequencies	800 MHz	GSM: 900MHZ, 1800MHz CDMA: 800MHz	2100 MHz	850 MHz, 1800 MHz	6Ghz – 30Ghz
Band (Frequency) type	Narrow band	Narrow band	Wide band	Ultra Wide Band	Ultra Wide Band
Carrier frequency	30 KHZ	200 KHz	5 MHz	15 MHz	60Ghz
Advantage	Simpler (less complex) network elements	Multimedia features (SMS, MMS), Internet access and SIM introduced	High security, international roaming	Speed, High speed handoffs, MIMO technology, Global mobility	virtual reality, augmented reality, instant gratification
Applications	Voice Calls	Voice calls, Short messages, browsing (partial)	Video conferencing, mobile TV, GPS	High speed applications, mobile TV, Wearable devices	Vehicle to vehicle Device to Device Communications, augmented reality etc.

3. CANDIDATE TECHNOLOGIES FOR 5G

The truth behind the inception of 5G technology is that even experts cannot tell us what 5G is, because they even don't know yet, but there are five brand new technologies emerging as the foundation for 5G, millimeter (Mm) waves, SC's, Massive MIMO, Beamforming and FD. In this section we will be explaining these key technologies and their applications in 5G networks.

3.1 Millimeter (Mm) wave

Various smart devices and other appliances in our homes use specific frequencies in the radio frequency spectrum, typically under 6 GHz [10] as depicted in Figure 2. But these frequencies are starting to get more crowded.With the proliferation of the smart devices day by day on the same network we receive slower service and more connection dropouts. The solution to this problem is to open up some new frequency bands in the radio frequency spectrum above 6GHz. Researchers and scientists are now experimenting and testing broadcasting of data and information on short wavelength waves called millimeter (Mm) waves with frequency between 30GHz – 300GHz [11][12] as depicted in Figure 3. This section of the spectrum has never been used before for the above devices and above all will provide more bandwidth for everyone, but there is a problem that Mm waves cannot ravel through buildings and other obstacles and tend to get absorbed by rain. To overcome this problem we use the technology called small cell technology in 5G networks.

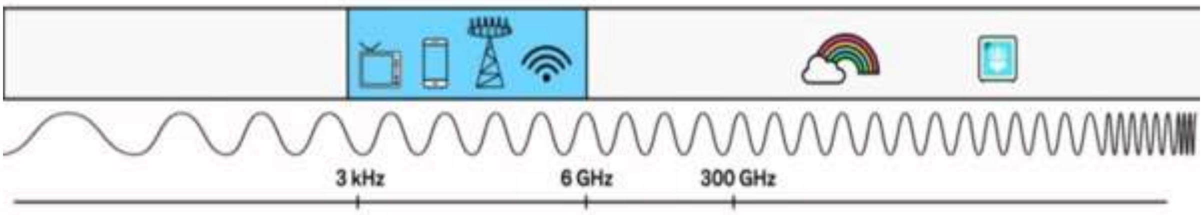

Figure 2: Radio spectrum usage upto 6GHz without Mm wave

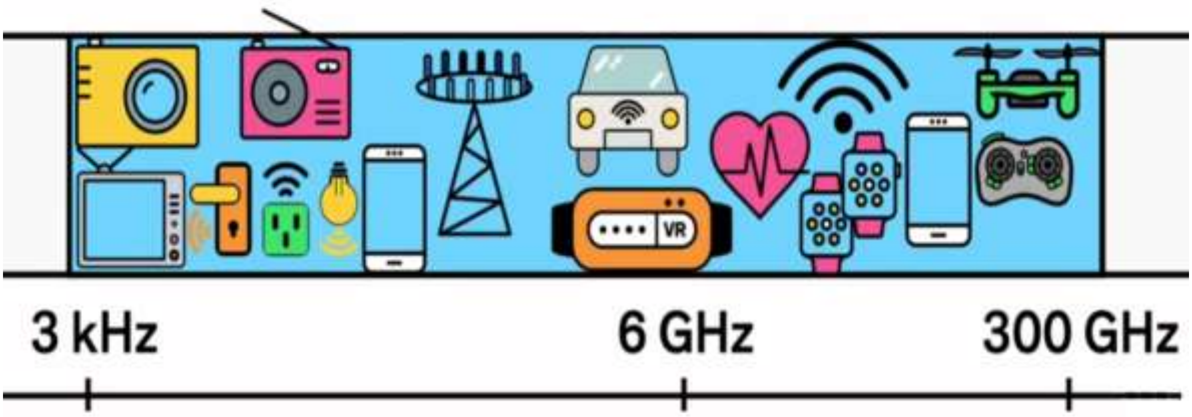

Figure 3: Radio spectrum usage extended to 300GHz wit introduction of Mm waves for 5G

3.2 Small cells (SC's)

Today's network technologies allowed large high power cell towers to broadcast their signals over long distances. High frequency Mm waves have a harder time to travel through obstacles, which means if you are behind Line of Sight, you lose your signal. Small cell technology will solve this problem using thousands of low power mini base stations [12] as shown in figure 4. These base stations will be much identical to traditional mobile towers allowing the mobile user to receive signals even in the presence of obstacles. Small cell networks will be especially useful in cities, as the user may be behind an obstacle, his smartphone would automatically switch to the next base station in better range of his device allowing him to keep his connection using smart handoff techniques.

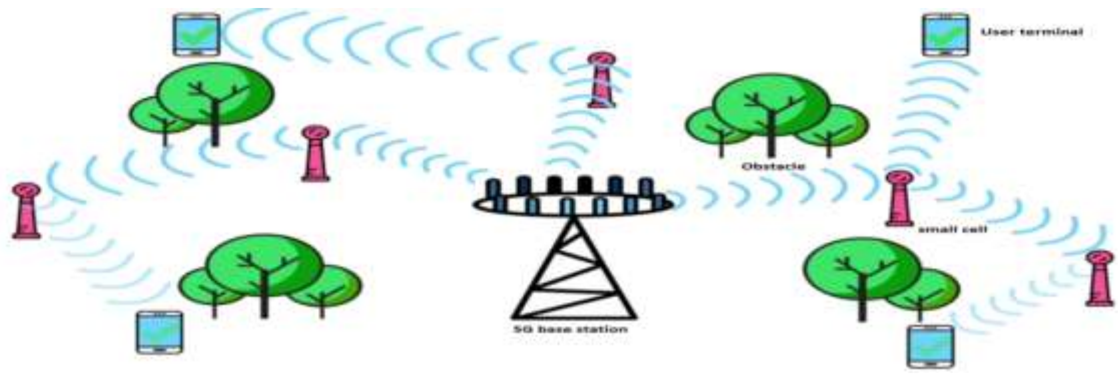

Figure 4:5G Scenario using small cell concept

3.3 Massive MIMO.

Today's 4G base stations have about dozens of ports for antenna that handle all cellular traffic [10]. Massive MIMO base stations can support hundreds of ports/multi-beam antennas [19]. This could increase the capacity of today's networks by a factor of 22 or more, off course Massive MIMO comes with its own complications. Today's cellular antennas broadcast information in every possible direction and all of these crossing signals could cause serious interference both at the base station and at the mobile station. Massive MIMO in collaboration with cooperative communication and Non Orthogonal Multiple Access (NOMA) prove to be a promising candidate technology for the 5G communication systems and networks. In massive MIMO, a large array of high directive/gain antennas are employed both at the base station terminal and the mobile station terminal multiplexed spatially for highly directed Beamforming to efficiently allocate the channel resources and to support the spectrum reuse. With the implementation of the massive MIMO in 5G communication networks, the overall channel capacity of the system increases by a factor of $\min(r, t)$, r being the number of receive antennas and t be the number of transmit antennas.

3.4 Beamforming:

Beamforming is like a traffic signalling system for cellular systems as depicted in figure 5. Instead of broadcasting in every direction, it will allow the base station to send a focussed stream of data to a specific user.

Its precision prevents interference and is very efficient i.e. stations can handle more incoming andoutgoing data streams at once. Let us now see how actually Beamforming works in real world scenario.

Say you are in a cluster of building and you want to make a phone call. Your signal is reflected off and on by the surrounding buildings and crisscrossing with the signals of the other users in the area. A Massive MIMO base station receives all of these signals and keeps track of the timing and the direction of their arrival. It then uses signal processing algorithms to triangulate exactly where the signal is coming from and plots the best transmission round back through the air to each end user. Sometimes relevant bounce of individual packets of data in different directions due to objects and buildings keeps signals from interfering with each other. The resultant is a coherent Data streams sent only to the intended user.

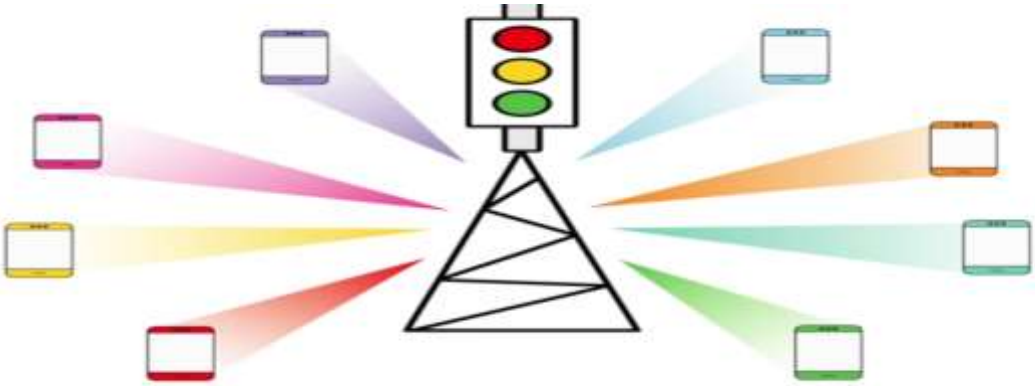

Figure 5:Diagrammatic representation of Beamforming

3.4 Full duplex technology (FD)

FD technology allows both transmitter and receiver to sense and access the spectrum simultaneously; resulting into a time slotted two stage white space exploitation processes [14]. This process senses the spectrum in the first stage and then communicates the data in the second stage. Spectrum sensing enables the connected devices to detect white spaces; therefore, imperfect sensing can result in data loss and harmful interference to primary users (PUs). The transmitter and receiver devices communicate with each other, exchanging data and information for mutual benefit. This practice of exchanging the data and information between the transmitter and the receiver devices accessing a common spectrum for mutual benefit is called reciprocity. Reciprocity is the property of the spectrum by virtue of which the radio frequency can travel backward and forward via the same frequency band. 5G systems employ the use of FD technology, enabling data transmission and reception at the same time.

4. 5G ARCHITECTURE

The 5G wireless mobile networks will be built around the world, the people, and the things and natively will have to provide and meet the requirements of the following use cases [17][10]:

1. Massive broadband (xMBB) that delivers high speed data and gigabytes of bandwidth on demand

2. Massive machine-type communication (mMTC) and device to device communication (D2D) that connects billions of smart sensors and smart machines
3. Critical machine-type communication (uMTC), that handles immediate feedback signals with high reliability of communication links for remote control of robots and autonomous driving, vehicle to vehicle communication (V2V) etc.

4.1 Detailing the core network architecture

With the introduction of cloud technologies, virtualization on network functions and software defined networking, it is now possible to enable transformation of the network architecture towards a software programmable and automated networks giving birth to the 5G wireless mobile communication. Programmability and automation enables flexibility, lower complexity, and lower cost and takes short time to deploy new services. This is enabled by a well-structured architecture whether responsibility domains have well defined interfaces between them as shown in figure 6. System behaviour is captured at low and higher abstraction levels enabling system managers to focus on relevant details. Each responsibility domain is self-contained with the entire necessary domain specific function included such as control, orchestration, management, policy and analytics capabilities. Starting with today's core network, which will see an evolution towards the core network that will support new requirements posed by 5G systems. 5G systems also need to support new businesses establishments. The future core networks will also need to support different types of accesses like legacy accesses, as well as future non licenced and licenced accesses as well as fixed accesses. The future core networks also need to support wide variety of different network functions with optimized characteristics for different services and even dedicated networks like packet core networks, media networks and communication services networks. The requirements for future core networks will not only be to support extreme number of immobile devices [10] but also to support new services, services like industrial applications, media services, sensor networks etc. i.e. all types of services that together form a networked society. The main challenges will be to support the requirement typically with low latency, high capacity, security, robustness and low cost together for new industries and new services. It will also need to support flexible service creation and service activation. The 5G network will be a programmable platform supporting rapid services development. Its service composition features will directly address introduction speed and will enable arbitrary service logic depending on the business case or the customer usage trend. The 5G wireless communications systems will allow operators to quickly put together new services and set things and apply them to a subset of users without impacting the rest. Such experiment ability is the key for deployment flexibility in 5G. Small user groups can provide rapid feedback and measure the quality of service provided, if successful the service can be rolled out to the rest of the users and fine tuning is required only to those experiencing degraded Quality of Service (QOS). Because the 5G platform covers most aspects of the operations, the services developed can access all relevant features from access cell actions, connectivity, compute, communication services and media. The 5G network architecture will have a well-defined user interfaces, clearly separating areas of concerns, allowing independent organizations to operate the different domains. This will open up as a service delivery for network functions and applications either as a whole or software assisted service. The services provided by the 5G network will enable new business models, new network sharing scenarios, increased efficiency and allow individual users to focus on their responsibilities.

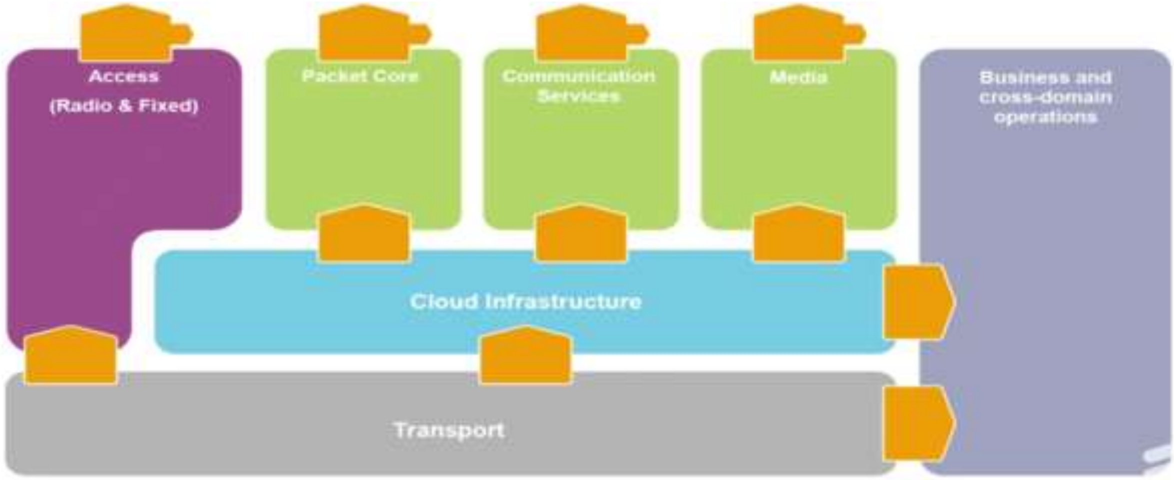

Figure 6:5G network architecture based on responsibility domains

4.2 Network slicing

The simple way to introduce new services into the network is network slicing: either the whole network or just parts of it. The slicing mechanism allows separate networks to be deployed on the infrastructure and having users and devices integrated to them. It allows support for different functions as well as different geographical deployments for different functions [16]. Slicing can also be employed for network sharing, as a service delivery of thenetwork or individual network functions as well as for operational reasons providing access and ability to program the networks at multiple levels with ease to work for service developers. The 5G network platform provides a higher level of abstraction through its management and orchestration functions, hiding unimportant details and automatically managing them. The management and control is always guided by policies which are part of the abstraction. Finally there is extensive domain specific analytics providing support for automation as well as human intervention. Using Software Defined Networks (SDN) and Network Function Virtualization (NFV) to virtualize network functions and to control them to get on the line of infrastructure is really the basis for deployment flexibility in 5G. On one hand virtualizing the functions opens up for new deployment flexibility in terms of logical functions or entities are deployed and on the other hand SDN enables flexible control of this deployment.

5. CHALLENGES FOR 5G

Majority of the network speed gains and capacity improvements made in the last decade were through constant research in the efficiency domain of air-spectrum use such as modulation schemes and channel coding techniques and through spectrum acquisition. Enhancements through thesedomains have now been saturated and are nearing their last limits, so other methods for network enhancement and speed improvement will have to be explored and implemented. Current data rates are 1GB/s for slow or stationary devices, or 100 Mb/s for mobile devices. 5G promises a data rate of 10 GB/s with lowest possible end to end latency and accordingly the current deployed network infrastructure has to change, to meet the explosive data demand.To mitigate the problems of capacity gains and speedfor 5G networksadvanced radio technologies such as OFDM and MIMO antenna arrays were employed to make better use of the current spectrum [15]. Better Quadrature Amplitude Modulation (QAM) techniques will also increase the data throughput over the network channels. These advances brought data transmission speeds into the range high enough for multimedia, especially streaming video. That led to proliferation of smart phone and other devices, and many devices began to be developed. Large format with high-resolution screens nearly always-communicating and always-on with base stations has led to high power usage with battery technologies that have reached their limits. The 5G systems are going to address the following challenges in the near future.

5.1 More capacity

5G network architects predict the need to support a thousand fold increase in voice and data traffic compared to 2010. During the year 2013, the mobile traffic grew nearly 70%, consuming 2.5 exabytes of data a month. In the near future, they expect the data rates to grow by 10 times more than the monthly consumptionby the year 2020. Researchers of the New York University Wireless research centre say 4G "can never accommodate this huge data demand." 4G has reached to the extent, where it is capacity wise fully saturated through radio technology advances and acquisition of new spectrum. Most modulation schemes and channel coding techniques cannot get even more efficient, and the frequency spectra best suited for long distance wireless communications has already been allocated so far. 5G network architects are now planning to make available the additional spectra for use, the advancement in data speed and the improvement in channel capacity are projected to come from other sources [15] (typically from the electromagnetic spectrum above 6GhZ). A modified mathematical expression of the Shannon theory showing the total channel capacity of the system is given as below

$$\boldsymbol{capacity} \approx \sum\nolimits_{\boldsymbol{networks}} \sum\nolimits_{\boldsymbol{channels}} \boldsymbol{B_i} \mathbf{log}\,(\mathbf{1} + \frac{\boldsymbol{P_i}}{\boldsymbol{N_p}})$$

Where subscript $i$is the i^{th} channel, B is channel bandwidth, P is transmitted signal power, and N is noise signal power. The expression reveals that the total channel capacity can be increased via more small networks called SC's, channels with better spectral efficiency, more bandwidth with additional spectrum, and better signal to-noise ratios.

5.2 Higher data rates

5G goals include data rates at least ten times higher than current peak data rates. Current data rates are limited for the same reasons that capacity is limited. Increased usage of the same frequency space limits the required amount of bandwidth that can be put to use per device.The current capabilities of backhaul, backbone, and fronthaul mitigate the amount of data flowthat can pass from base station terminal to mobile devices and vice versa. Solutions for these issues will require expansion beyond current means rather than more efficient usage of the current means to affect data rate.

5.3 Low latency

The IOT is putting up a higher demand on always-on and always–available abilities of wireless networks. Connected devices in autonomous cars, traffic control,industrial automation and healthcare cannot be subjected to latency issues particularly when lives may be on the line. A deadline miss in this case may result into a catastrophic event leading to the loss of lives. This extremely-low latency and extremely-high-reliability requirement is not supportable by the present network models. Past generations of mobile cellular communications and their users primarily used static or latency-independent data, such as websites and email. Higher data rates led then to streaming video, which can be affected by latency, though buffering can prevent that. But the expansion of real-time applications, such as teleconferencing and time-critical communications, such as remote controlled medical robots, cannot suffer the effects of latency to properly function.

5.4 Connectivity for massive number of devices

Not only are the numbers of devices exploding due to IoT, but the different connection needs makes this a colossal challenge. No longer are the needs anticipated to be similar to previous requirements (voice calls, <150 ms latency acceptable.) Devices need to be able to range from sleeping until needed to always-on, yet get the connectivity when required. Handling the enormous number of devices that may pop in and out of connection constantly will be a challenge. 4G is not perfect to handle this because current systems are disconnected, according to Zhiguo Ding of Lancaster University. (Hellemans 2015) Bluetooth, RFID, and other various short-distance communication protocols are not set up to communicate with each other. There is no common system. The test will make a framework that is normal yet ready to help large number of devices with several diverse user cases.

5.5 Reduced cost and energy

Energy storage capabilities are not keeping up with the media abilities of current devices, and the desire to increase those abilities will require a reduction in the amount of energy required in order to communicate with the network. The IoT additionally is influencing this issue because tiny, low-power devices, for example sensors are expected to keep running on a battery for several years. On the provider's side, base station electricity usage and the cost of equipment upgrades to handle the new requirements is a concern that needs to be solved for the business to remain profitable. Current estimates of the percentage of radio network power usage are 70 to 80 percent of total operations energy usage. This is driving costs higher, and future usage will only increase that. Systems will need to change in order to meet service demands yet maintain reasonable costs.

5.6 Quality of experience

Quality of Experience (QoE) is the user's perception of how the experience of using a device meets expectations. It is related to some of the above challenges, such as data rate and latency, but is combined in such a way in that it creates a balance between them. High data rate and low latency may make a streaming video look good, but it is a larger drain on the battery. However, a low QoE will cause a user to become dissatisfied. Due to 4G architecture, it is difficult to maintain consistent experience at all times and in all locations.

6. MASSIVE MIMO CHANNEL CAPACITY MODEL FOR 5G

Massive MIMO refers to large scale antenna systems (LSA) that are operated fully adaptively and coherently to help focussing of transmitted and received signal energy in small regions of space. More number of antennas arrays at the transmitter side means more efficient is the Beamforming at the receiver sideIn this section we will consider a standard MIMO system consisting of $'t'$ transmit antennas at the base station side and$'r'$decentralized receive antennas. The MIMO channel can be equivalently modelled as $\bar{Y} = H\bar{X} + \bar{N}$. Where $\bar{Y} = [y_1 y_2 y_3 \dots y_r]$ is the $'r'$dimensional receive vector at the MIMO receiver, $\bar{X} = [x_1 x_2 x_3 \dots . x_t]$is a't' dimensional transmit vector with each symbol transmitted through each transmit antenna [16]. $\bar{H} = [h_{11} h_{12} h_{13} h_{31} \dots h_{rt}]$ is the $r \times t$ channel coefficient vector and $\bar{N} = [n_1 n_2 n_3 \dots n_r]$ is the $'r'$ dimensional noise vector. The subscripts to the parameters y, x, h, n corresponds to the antenna numbers at transmit and receive sides of the MIMO channel.

The MIMO system introduced represents the parallelization of the MIMO channel with $'t'$symbols transmitted in parallel and spatially multiplexed. The signal power received at the receiver corresponding to each MIMO channel is given as

$$\sigma_i^2 \{E|\bar{X}|^2\}$$

Where σ_i represents the singular values of the channel coefficient matrix $\bar{H}$[14] of the MIMO channel. The SVD of $\bar{H}$ is given below

$$H = U \sum V^H$$

Where the matrices U, $\sum$V are $r \times t$,$t \times t$ and $t \times t$ dimensional respectively [12]

The noise power received at the receiver corresponding to each MIMO channel is given by σ_n^2 computed as the value of the covariance of the noise matrix. Therefore the signal to noise ratio at the input of the receiver is given as

$$\mathrm{SNR} = \frac{\sigma_i^2 \{E|\bar{X}|^2\}}{\sigma_n^2}$$

From the above SNR expression for the i^{th}channel, the Shannon capacityC_i of the channel can be derived as given below

$$C_i = \log_2\left(1 + \frac{P_i \sigma_i^2}{\sigma_n^2}\right)$$

The optimal MIMO power allocation problem can now be formulated as

$$\textbf{maximize.} \sum_{i=1}^{t} \log_2\left(1+\frac{P_i \sigma_i^2}{\sigma_n^2}\right)$$

$$\textbf{subject to} \sum_{i=1}^{t} P_i \leq P$$

Where P is the total transmit power.

The above optimization problem with the given inequality constraint is a non-convex optimization problem and hence the convex optimization techniques cannot be applied directly to obtain the optimal solution for the MIMO power allocation problem [18]. A non-convex optimization problem is transformed into a convex optimization problem by taking the negative sum rate of the non-convex optimization expression. The optimal MIMO power allocation problem can further be modified and formulated as a convex optimization problem by taking the negative sum rate of $.\sum_{i=1}^{t} log_2\left(1+\frac{P_i\sigma_i^2}{\sigma_n^2}\right)$ as under

$$\textbf{Minimize} - \sum_{i=1}^{t} \log_2\left(1+\frac{P_i \sigma_i^2}{\sigma_n^2}\right)$$

$$\textbf{subject to} \sum_{i=1}^{t} P_i \leq P$$

Where P_i is the signal power associated with the i^{th}MIMO channel and $P$is the total transmitted power

7. RESULTS AND DISCUSSIONS

The mathematical model of the proposed technique discussed in section VI has been simulated and the results are plotted in various graphs as:In figure 7, figure 8 and figure 9 we calculated the cumulative distribution function (CDF) of the channel capacity (expressed as bits/second/hertz) for different values of the signal to noise ratios (SNR) at the transmitter side. Figure 7 depicts the CDF’s of the random 4x4, 8x8, 16x16, 32x32 and 64x64 MIMO channel capacities when the SNR = 10dB. Figure 8 and Figure 9 repeats the same process for 4x4, 8x8, 16x16, 32x32 and 64x64 when the SNR = 15dB and 20dB respectively. It is evident from figure 7, figure 8 and figure 9 that the CDF’s of the MIMO channel capacities shifts towards the right, i.e. in the direction of the increase in the number of the bits/sec/hertz with the increase in the number of transmit and receive antennas. On the other hand keeping the number of transmit and receive antennas constant, we find that the channel capacity also improves with the increase in the SNR. The result also reveals that the improvement in MIMO channel capacity is more pronounced due in increase in number of transmit and receive antennas than due to the increase in SNR. Figure 10 shows the channel capacity also called as ergodic capacity of the random MIMO channel as SNR is varied under similar conditions of MIMO arrays. It is clear that channel capacity increases rapidly as the number of transmit and receive antennas are increasing for a particular value of SNR. If the number of transmit and receive antennas are kept constant, we find a similar change in channel capacity as a function of SNR. Once again the improvement in MIMO channel capacity is more pronounced due to increase in number of transmit and receive antennas than due to the increase in SNR.

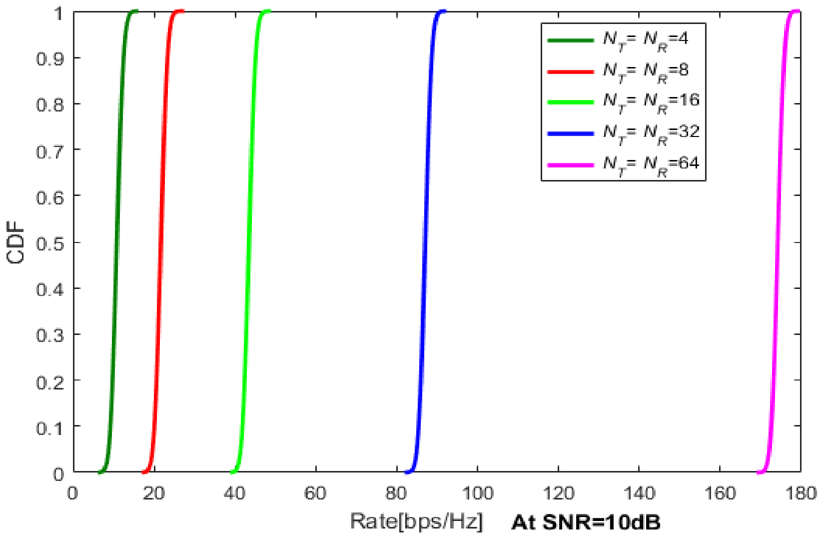

Figure 7: CDF of MIMO channel capacity at SNR = 10dB

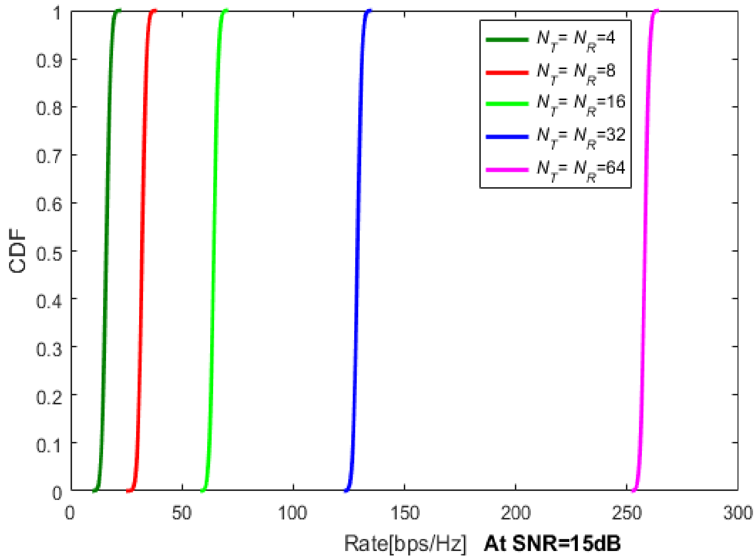

Figure 8: CDF of MIMO channel capacity at SNR = 15dB

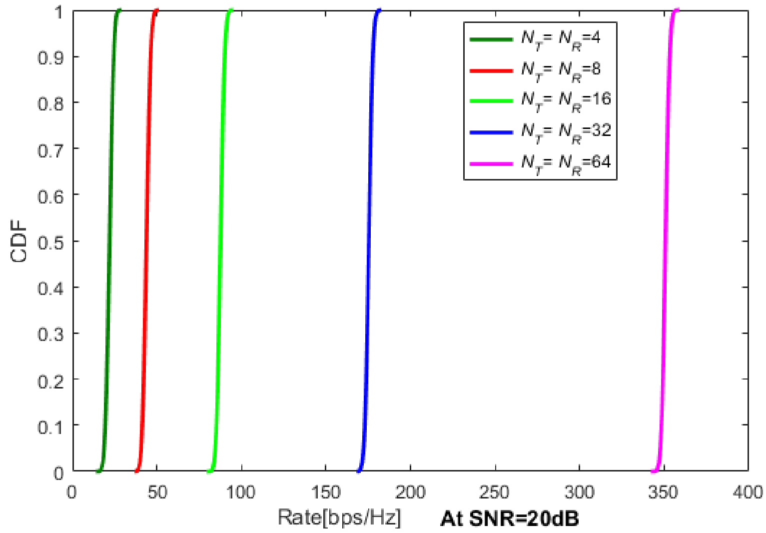

Figure 9: CDF of MIMO channel capacity at SNR = 20dB

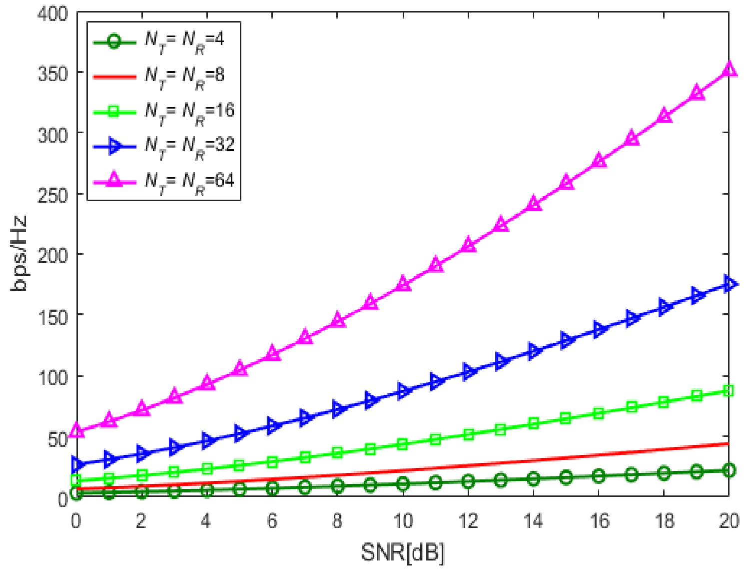

Figure 10: Higher order MIMO channel capacity vs SNR

8.CONCLUSION

This paper is aimed at providing an insight into the review of 5G wireless communication systems. 5G will be the game changing technology in the field of wireless communications ranging from applications like E-Health, V2V, D2D, Smart learning, autonomous driving etc. to proving a high speed data rate of the order of 10Gbps to over 25 billion network connected smart devices. In this paper we have considered Massive MIMO as a key technology responsible for such an enormous data rate. We calculated the cumulative distribution function (CDF) of the channel capacity (expressed as bits/second/hertz) for different values of the signal to noise ratios (SNR) at the transmitter side. The results also reveal that as the number of antennas at the transmitter and receiver sides are increased the capacity of the channel expressed in bits/sec/hertz also increases by the factor of $\min(r, t)$, where r and t represents the number of receive and transmit antennas.

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