PHASED ARRAY ANTENNA DESIGN FOR 5G MOBILE NETWORKS

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ABSTRACT

In the next few years, the demands and challenges for the 4G (and its derivatives ie LTE-A) alternative must be addressed to meet the prime objectives of the upcoming 5G mobile networks such as increased capacity, improved data rate, low latency, and better quality of service. To achieve these objectives, drastic improvements need to be made in cellular network architecture and the antenna configuration that is used for this purpose. This paper presents the results of a detailed survey on the fifth generation (5G) cellular network architecture and some of the key emerging technologies that are helpful in improving the architecture and meeting the evasively increasing demand ofusers. In this detailed survey, the prime focus is on the 5G cellular network architecture, massive multiple input multiple output (MIMO) technology, and millimetre wave beamforming technologies. In this paper, a general probable 5G cellular network phased array antenna concept is proposed, which shows that a combination of multipleinput multiple output and the beamforming can be utilized at the same time to overcome the limitation of either systems.

Keywords: 5G, MIMO, mm Wave, SNR, phased antenna array.

INTRODUCTION

In the near future, to fulfill the presumptions and challenges of the concurrently used wireless based networks will have to evolve in various ways. Recent technology constituent like high-speed packet access (HSPA) and the advanced long-term evolution (LTE-A) will be launched as a part of the evolvement of current wireless based technologies. Despite of the fact that the currently auxiliary components may also be a constitution of future new wireless based technologies, which may be play a supplementary role in the evolvement of the new technologies. These new technology components are different ways of reaching considerably higher frequency ranges and accessing spectrum, one of the most important components of all the deployment of massive antenna array configuration that can overcome the difficulties confronted at the communication medium, direct device-to-device communication (D2D), and ultra-dense deployments while the upcoming 5G network architecture will be femto cell backhauling based [1]. Since the initiation of the mobile wireless communication at the 1970s, it has come across from analog voice calls to current LTE-A 20 Mbps of bandwidth the modern technologies adept of providing high quality mobile broadband services with end-user data rates of even hundreds of megabits per second. The considerable high improvements in terms of potentiality of mobile communication networks, along with the revolutionary types of mobile devices such as smart phones and tablets that have been offered at the market, have led to enormous production of new applications which will be used in cases for mobile connectivity and a resultant evasive growth in network traffic. This paper presents our view on the future of wireless communication for 2020 and beyond, by high lighting the key challenges and obstacles that will be encountered during the design of new phased antenna array that meets the requirements of the upcoming 5G of mobile networks. Along with this, some mmWave beam forming technologies that are being proposed previously for high rate frequencies are reviewed and discussed, and finally, a review is provided for currently architectures that are being proposed recently for the next generation of mobile communications. The remainder of the paper is organized as follows: In Section II, we present a brief evolution of wireless communications systems then a discussion on the requirements and challenges that are facing the next generation of mobile communications. Section III detailed discussion on the currently proposed technologies for millimetre wave communications that will support the 5G. Section IV gives the detailed description of the proposed general 5G cellular network phased antenna design that meets the new generation requirements and the challenges all along. We conclude our paper in Section V.

FIFTH GENERATION OF MOBILE COMUNNICATIONS

Since the first 1G system was introduced at 1981, a new mobile generation has appeared approximately every 10 years to meet the exponential and nonstop increasing demands of the end-users, so, the first 2G system was commercially deployed in 1992, and the first 3G system appeared in 2001. 4G systems fully compliant with IMT Advanced were first standardized in 2012. The development of the 2G (GSM) and 3G (IMT-2000 and UMTS) standards had taken 10 years of development and research, and development of 4G systems began in 2001. The demands that must be fulfilled for the upcoming 5G are data rates of several tens of Mb/s should be supported for tens of thousands of users, 1 Gbit/s to be offered simultaneously to tens of workers on the same office floor, Several hundreds of thousands of simultaneous connections to be supported for massive sensor deployments, spectral efficiency should be significantly enhanced compared to 4G coverage should be improved and signalling efficiency enhanced. In the recent works, an envision for a new architecture which will work with both 3G, 4G and the new 5G mobile telecommunication technologies, by monitoring the efficiency of the centralized approach which is used in the legacy architectures, and then a distributed approach that places the intelligence on the mobile terminal to achieve scalability and efficiency in the upcoming 5G mobile networks [2], in which it provides a stable data path in the face of terminals changing their point of attachment to the network. Another method is called a unified approach which is based on programmable all-SDN architecture with hierarchical network control to ensure different grades of performance for all network functionalities [3] for mobility, routing management proposal, and hand of brings high capacity, agility, and on a low cost. A two layer architecture which is consisting of radio network and a network cloud [5] that provides ultra-dense small cell deployments on licensed and unlicensed spectrum, flexible network deployment by utilizing the NFV and SDN, and facilitates optimal use of network resources by intelligently use of network data, however, further investigations are needed for small cells in different frequency regimes, how to in cooperate them with NFV and SDN, besides the intelligent algorithms that better utilize network resources. The DMM as a suitable candidate framework for mobility management in 5G network, which relies on its [6] robust routing protocol that inherits the issues related to high coverage latency and signalling. A scheduling scheme for inter BS-communications which can be used as a baseline for future improvements, that framework supports in-band, point to multipoint non-line of sight mmWave Backhaul is a cost effective and latency solution, however, more investigations need to be done into SDMA and full duplexing capabilities, and spectral efficiency enhancement [7]. A resource sharing scheme for D2D communications in mmWave 5G networks [8] which improves network capacity while maintaining the network connectivity well, however, the neighbour discovery for frequent handoffs with directional antennas need to be addressed more in the future. For highly challenging wireless environment, a modified CTA-PSO in that reduces its execution time, which makes it suitable to be implemented there [9] This modified CTA-PSO is an alternative resource allocation technique can meet the evasive demanding on higher capacity network, and coverage such as 5G.

MILLIMETER WAVE TELECOMUNICATIONS

The mmWave is a suitable candidate for 5G with its high frequency range from 30 up to 300 Giga hertz per second. But will often be power limited rather than bandwidth limited ,due to much greater spectrum allocations and higher path loss associated with mmWave wavelengths, and will also often be noise limited rather than interference limited due to the use of beamforming to avoid co channel interference while exploiting angle diversity . As mmWave communication systems evolve, they will exploit much wider radio frequency channels having 500 MHz bandwidth or even more, and devices will use dozens of antennas due to the much smaller wavelengths involved. The Hybrid HetNet which is a novel millimetre wave HetNet paradigm, in which, the V-band is used to establish short range links, and the E-Band is used to support links with longer range 70/80 GHz to interconnect cellular [4]. This configuration enhanced the throughput of the millimetre wave network, however, the successful deployment for it requires more modifications to higher layers. More advanced background and the characteristics of propagation for E-band transmissions, focusing on E-band transmissions dependence on how narrow the beam width is, and the directionality of the beamforming used, which increases the effectivity of interference suppression [10]. Also, a several techniques which can be added that can potentially solve the coverage problems at non line of sight scenarios. A new path loss models for the upcoming 5G cellular planning 28 GHz and 38 GHz mmWave bands that are stemming from simple modifications of the concurrent path loss models, which are used in commercial planning tools, in which it estimates accurately mmWave path loss data in both heavy and light urban areas by simulating the RF coverage for the upcoming 5G networks [11] in which a cell radius of 220m simulated. The results shows that with single best beams considered the number of sites needed is times the number of sites needed to be deployed currently at the same coverage area, on the other hand, the random beamforming needs 3 times that number, however, more research needed on the effectiveness of single best beam on the capacity.

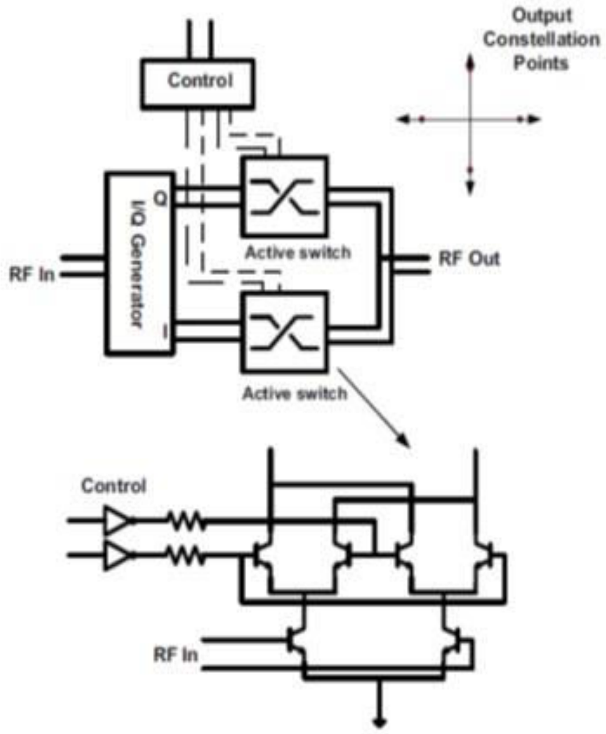

Figure-1. 2 bit phase shifter.

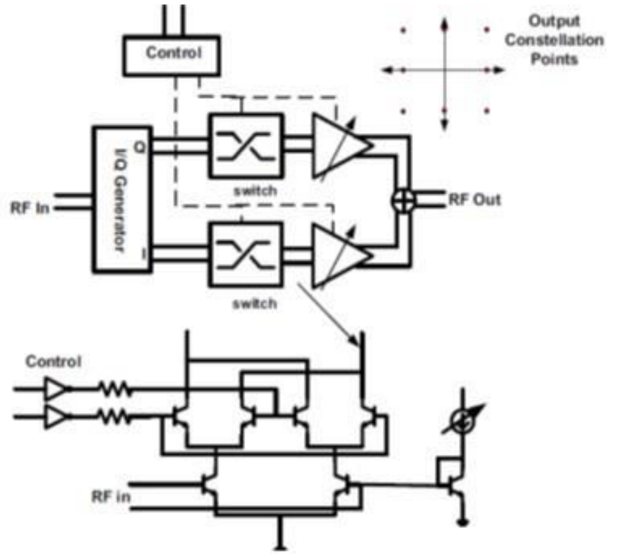

Figure-2. 3 bits phase shifter.

A highly compact integrated circuits in SIGe BICMOS technology for mmWave beamforming, in which the circuits consist of 2 bit RF phase shifter, 3 bit phase shifter as shown in figure 1 and 2 relatively [12], and 4 channel beamforming networks. Phase shifters are for 2 bit RF phase shifter and the four channel of beamforming were measured at the range of 50-60 GHz in which the phase error of 3θ, the 3 bit phase shifter on the hand was measured at the range of 50-70 GHz the RMS amplitude at this case is 1dB and the phase error of 7θ. Their design is feasible and reliable to be used in the upcoming 5G mmWave phased arrays transmitters and receivers, however, it comes on the expense cost.

PHASED ARRAY ANTENNA

The antenna configuration for the upcoming 5G mobile communications must meet certain criterions like the compact size in which it makes it suitable for femtocell backhauling, supporting high bandwidth, high gain, and achieving multiple inputs multiple output spatial multiplexing and beamforming to acquire their benefits and to overcome their limitations. In Figure-3 Radial Line Slot Array (RLSA), which is a low cost antenna with ease of manufacture and installation, that basically consists of two circular conducting surfaces made of copper spaced by dielectric material of height *d*. the excitement is done via a coaxial to waveguide transition feed probe at the center of the lower plate which also act as the ground. The top plate carries the radiating slots which are systematically arranged. The arrangement influences the beamwidth, amount of reflected power from the slots to the feeding point and polarization. A dried region which has no slots is usually left at the center of the radiating surface allowing the wave to stabilize before encountering the slots. A typical RLSA is shown in Figure-1.

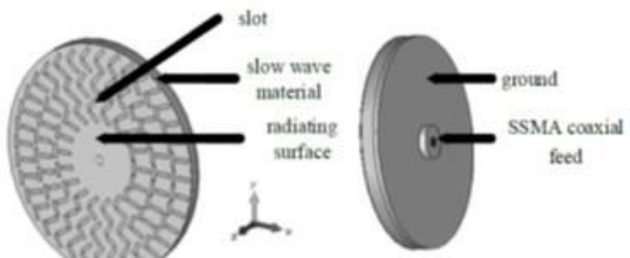

Figure-3. Basic RSLA perspective.

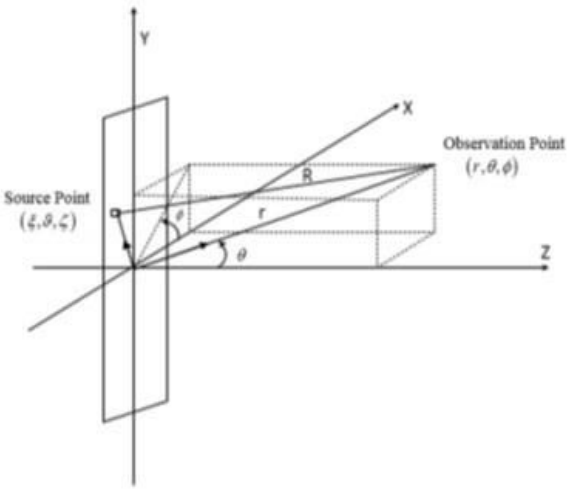

Figure-4. Slot radiated fields evaluation geometry.

$$E_{\theta}(\theta,\Phi) = j\cos\Phi \frac{\cos(kl\sin\theta\sin\Phi)-\cos(kl)}{(1-(\sin\theta)^2(\sin\Phi)^2)} IM \quad (1)$$

$$E_{\Phi}(\theta,\Phi) = -j\cos\theta\sin\Phi \frac{\cos(kl\sin\theta\sin\Phi)-\cos(kl)}{(1-(\sin\theta)^2(\sin\Phi)^2)} IM \quad (2)$$

Where

$$IM = \frac{V_m}{\pi}\frac{\sin x}{x}\frac{e^{-i(\omega t-kr)}}{r}$$

$$x = \frac{ks_w\sin\theta\cos\Phi}{2}$$

$\mathbf{V_m}$slot excitation coefficient

Kfree space wave number

Llength of slot

(θ,)far field region angular coordinate

$\mathbf{S_w}$slot width

The phased antenna array must run an algorithm that runs the antenna in two different modes which based upon the signal to noise ratio values when we have a multipath fading the beamforming configuration will need more power and re transmitting which decreases the spectral efficiency so the antenna start running the spatial multiplexing mode to overcome the multipath fading by assigning a different group of its antennas that are forming

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its array to act as a MIMO configuration as shown in Figure-5 the spatial multiplex in guses multiple streams on a single carrier which increase the capacity per user, but is most effective when radio links operate in a high SNR regime and are bandwidth limited, and not power-limited, moreover it is only effective when the channel provides sufficient diversity or rank, effectively, the number of streams that can be supported by the MIMO H matrix. On the other hand, when SNR is low, the spatial multiplexing has no advantage since the transmitter must split its power across the different spatial streams, which weak each stream and inducing bit errors that limit overall capacity gains. Vice versa, the antenna will switch on beamforming mode in the power-limited regime, in which it can provide greater capacity by increasing SNR to allow the use of higher order modulations. The mmWave systems have no problem operating in either regime. The benefits of spatial multiplexing and beamforming can be achieved at the same time with the proper support of a robust algorithm and the associated hardware. For example, it is possible to use multiple beams in BF to increase SNR in power-limited situations, while also providing unique data streams on each of the beams on the same carrier frequency to increase user data rates, as long as the mmWave channel has enough sufficiently different propagation paths in the spatial and polarization domains. This ability to simultaneously exploit BF and the multiple streams of SM is a wonderful situation not previously available to ultra-high frequencies microwave wireless networks that currently use low-gain or omnidirectional antennas. Furthermore, if the channel can provide multiple spatial degrees of freedom, where each unique beam has both strong propagation path and small root mean square (RMS) delay spread it becomes possible to use both SM and BF with a simplified receiver architecture using simple time domain equalization or rake receivers over very wideband channels at greatly reduced latency. This is in contrast to today's cellular and WLAN modulations, which use multi-carrier frequency domain equalization with small subcarrier spacing to create narrowband flat-fading channels for MIMO exploitation. We now explore the joint use of SM and BF in mmWave channels to provide insight into system performance and challenges. As shown in Figure-5 there are three different beamforming architectures slaved to a two dimensional antenna phased array, the analog beamforming consists ofa single radio frequency chain with $N_x \times N_z$ analog phase weights, the other one I a digital beamforming that needs$N_x \times N_z$ radio frequency chains. Each beamforming per element are weights are applied digitally. The Digital one offers the greatest flexibility, but at the expense of higher power consumption and the fabrication cost, which issues a serious question for designers working on mmWave communication that operates on very wide bandwidths and large numbers of antenna elements normally involved in the system. Implementation of beamforming and spatial multiplexing together is achievable with hybrid beamforming architecture. This method uses N radio frequency chains (N<<Nx×Nz), each connected to N×Nz analog phase weights. Hybrid beamforming reduces the number of required radio frequency chains and enables N multiple data streams to be sent indifferent spatial directions.

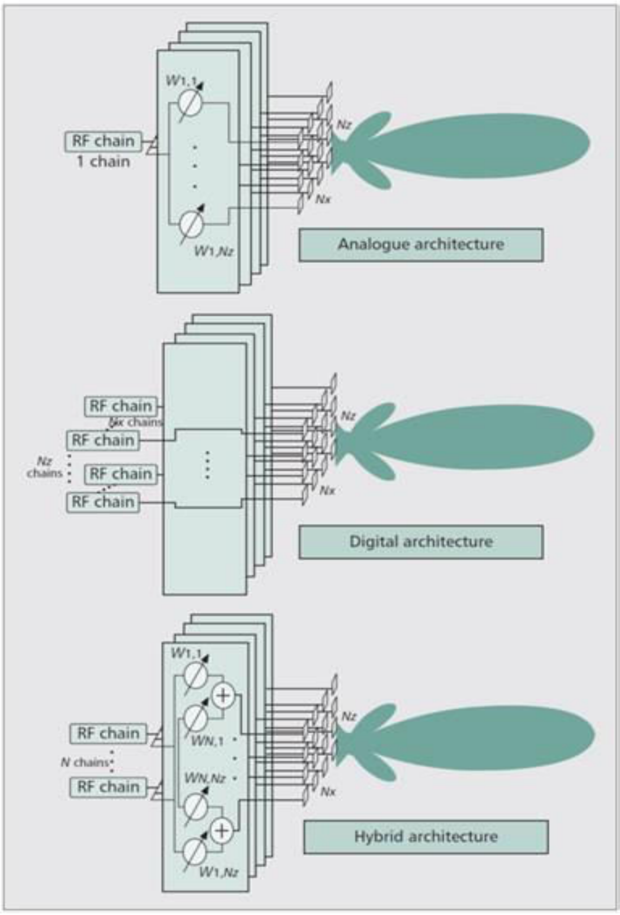

Figure-5. Hybrid architecture.

CONCLUSIONS

The demands for the upcoming 5G are addressed, and the correlated works has been discussed showing in details the merits of each architecture. mmWave communication systems is suitable candidate for 5G but due its limitations they need a special antenna configuration that runs hybrid architectures to overcome them, for future work, the conception phased antenna array will be finalized, then fabricated and measurements will be taken to justify its functionalities.

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