Suitable Beamforming Technique for 5G Wireless Communications

Md. Shoriful Islam*, Kartick Mondal, Tazkia Jessy
Department of Electrical & Electronic Engineering
Uttara University
Dhaka, Bangladesh
*shoriful.eee@gmail.com

Abstract—**5th Generation mobile network (5G) announce the next phase of mobile telecommunications standards beyond the current 4th Generation mobile communication. 5G system will achieve more than 10 Gbps which will implement within 2020. Therefore few major problems have to be solved for getting this super speed. However to achieve this super speed a high frequency wave is required to transmit data through wider bandwidth. Massive MIMO Beamforming (BF) is one of the promising technologies to develop this system and Mm wave can be used to provide higher frequency. Conventional BF is capable to provide CSI (Channel State Information) from the transmitter to the receiver but adaptive BF is not capable to do so. However adaptive BF is very much effective to change it behavior according to the required of the channel. In that case a hybrid BF technology could be very much effective to implement 5G technology which will use both analog and digital BF technology to receive the reference signal without distortion. To find out the best beamforming technique is one the major challenge to implement 5G communication and In this paper the performance of conventional, adaptive and hybrid beamforming technique has been simulated specially for 5G communication to find out the best beamforming technique.**

***Index Terms*— Beamforming (BF), 5G, MIMO, Mm Wave, CSI,**

I. INTRODUCTION

Massive Multiple Input Multiple Output (mMIMO) wireless communication refers to the cellular base station with a very large number of antennas which has been shown to improve the magnitude in spectral and energy efficiency using linier processing. In MIMO system multiple antennas are used at both the transmitter and receiver end. MIMO specifically refers to a technique for sending and receiving more than one data signal on the same radio channel at the same time through multipath propagation [33][34]. The channel capacity of MIMO increased very rapidly with the increase of array antennas which is known as a Shannon capacity [4]. MIMO for 5G is a successful and cost-efficient integration in the overall network concept. The cell is splatted into small cell which are known as phantom cell. A very high frequency, wider bandwidth and even the high Bit Rate is possible in small cell [4]. Fixed BF, which uses the fixed BF weights selected from the BF weight candidates, can be introduced to the signal transmission [35]. For the digital fixed BF, equal number of digital baseband signals and baseband chain which increase the cost of the massive MIMO transceiver remarkably. On the contrary, for the analog fixed BF, the number of the BB chains can be limited for the analog radio frequency (RF) signals compare to the digital preceded outputs, which results in the cost reduction [36]. The analog fixed BF and the digital precoding, which is referred to as hybrid BF, can be effective to reduce the cost of the Massive MIMO transceiver. In the hybrid BF technique an analog fixed BF, codebook-based precoding, the analog BF weights and the preceding matrix are jointly operated to maximize the channel capacity and reduce the cost [22]. The Channel state Information (CSI) is not available in the adaptive BF which is available in the hybrid BF, so it can be assume that the hybrid BF for the transmission suitable for the super high bit rate transmission using multiple streams.

II. RELATED STUDY

A. 5th Generation Communication (5G)

In different analysis papers the term 5G (5th generation mobile networks or fifth generation wireless systems) has been used. Right now, in any written document the term 5G hasn't been formally used rather different telecommunication firms or standardization bodies like 3GPP and WiMAX forums have been publicly utilizing it. Hopefully around the year of 2020 5G would be implemented [1]. With a view of providing hugely increased manageability as well as scalability and also substantial capabilities compared to those of previous generations in 5G era there should have been modification In the architecture of the mobile telecommunication. In order to achieve that a network control structure that is centralized software-based has been introduced. Also different legacy network (i.e 4G or 3G) can also deployed if the performance requirements of 5G is satisfied by the quality of service. [2] For using International Mobile Telecommunications (IMT) evolution as well as air interface technologies which is innovative the necessary solutions will be adaptive. The whole mobile ecosystem will be reshaped by technologies of network service and also functional virtualization. The generation of huge-scale services and applications has been facilitated by 5G. The architecture of 5G has been illustrated below- The architecture consists of 3 layers and an E2E management and also orchestration entity. The 3 layers are

- Infrastructure resource layer
- Business enablement layer

- Business application layer

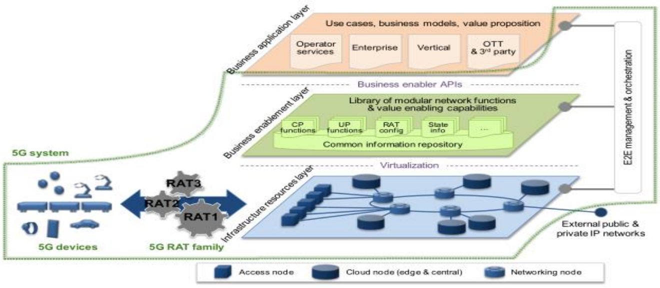

Figure 1: Description of 5G architecture.[2]

One of the biggest European Union 7th Framework Program (FP7) which consists 27 partners is termed as Mobile and wireless communications Enablers for the Twenty-twenty Information Society (METIS) [3-4].

B. Multiple Input Multiple Output (MIMO)

The ultimate actualization and work out of the 5th generation (5G) radio access network with a super high bit rate and high capacity depend on the need of small cells utilizing both higher frequency bands and Massive MIMO technology.

The current advancement of smart phones and the diversity of mobile applications and ministrations have resulted a broad explosion in the amount of mobile data traffic, and higher capacity transmission has turned out an obvious requirement. By 2020, outstanding contribution enhancements in radio access technologies and networks are essential for the 5th generation (5G) mobile communication networks in order to make ready for the 1000 fold rise in the data traffic volume expected over the following 10 years [8], [9]. The proposal of Phantom Cell idea was to materialize the super high bit rates that overcome tens of gigabits per second and high capacity in the 5G networks [10] and furthermore which is distinguished by sum up small cells using higher frequency bands to a macro cell in a present cellular system. Most importantly, macro cell accommodates lower rate communications with high stability and to supply higher frequency bands easily, the small cells provide super high bit rates utilizing a much spacious bandwidth of over hundreds of megahertz. That's why, massive MIMO transmission techniques are needed to place such growing bit rates in small cells. Massive MIMO is an expectant technology that accommodates a very huge number of antennas, e.g., over 100 for 5G super high bit rate radio access [11], [12]. It is given in [13] that, MF-based non-cooperative Massive MIMO systems acquire an average throughput of 730 Mb/s per cell and total spectral efficiency of 26.5 bps/ Hz with a data rate of 17 Mb/ s for each of 40 subscribers in a 20 MHz channel in both uplink and downlink locations under realistic propagation considerations. AS a result, the Massive MIMO provides the higher beam forming (BF) gain that actually makes up the larger propagation loss in the higher frequency bands. Besides, to attain the super high bit rates, Massive MIMO can spatially multiplex a larger number of data streams. In recent past, Massive MIMO has obtained effective momentum to rise capacity in multi-user networks as potential candidate. Within limitations, the system processing gain goes to infinity as the number of base stations (BS) antennas reach to infinity. Because of that, both noise and multi-user effects can be eliminated [14]. Massive MIMO also performs consisting latency reduction on the air surface and in addition to an important feature for delay-constrained applications [15]. Another merit of Massive MIMO is that, the same frequency band can be reused for many users. This plus the channel hardening render frequency domain scheduling no longer needed .

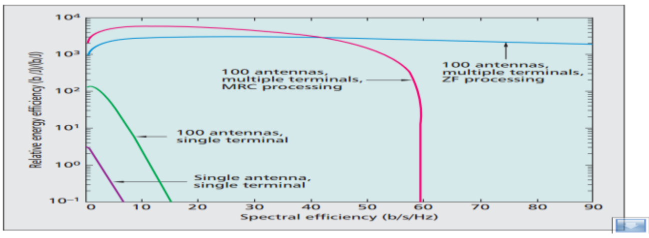

Figure 2: Spectral Efficiency for different number of antenna[15]

Half the power-twice the force (from [9]): Improving uplink spectral efficiency 10 times and simultaneously increasing the radiated power efficiency 100 times with massive MIMO technology, using extremely simple signal processing, taking into account the energy and bandwidth costs of obtaining channel state information.

C. Millimeter Wave (Mm Wave)

The progression of the mm-wave bands is one of the most pressing solutions for 5G mobile radio networks. Nowadays the ever growing use of smart devices and also with the new innovative applications, the demand of data traffic is anticipated to increase over current targets by 1000x in 2020 and 10000x by 2025 [17]. The mm-wave band in the 30-300GHz frequency range is being taken into account for proceeding 5G to achieve 1000 times more data traffic [18]. Due to the advancement of semiconductor technology helps to open scopes for low cost manufacturing and low power consumption of mm-wave components [19]. As a result, mm-wave systems offer a much higher frequency bands and more bandwidth than available in 4G networks. However, the use of mm-wave technology is limited because of harsh propagation conditions. So high path loss happens that reduces receive volume signal because receive antenna size is small to support short wavelength and high thermal noise decreases SNR that brings about from wider bandwidth. Also loss comes about more than that of below 3GHz band by water vapor (H2O), oxygen, rainfall and foliage of signal attenuation [20].

Hence, to minimize these propagation limitations, the system architecture and antenna structure should be effectively planned and also to increase capacity by the utilization of radio resources in the mm-Wave band in 5G mobile communication system. Beam forming technology on patch antenna array can be followed to be a solution for propagation limitations of mm-Wave communication system. 4G small cells will be deployed at street-level using micro/pico base stations deployed on lamp posts and sides of buildings.

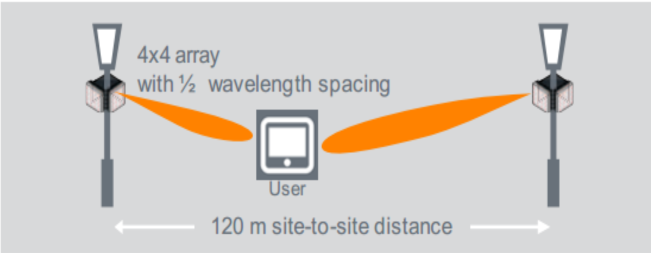

Figure 3: typical mm-wave street level deployment [6]

A pico base station will be deployed every city block or roughly 120 meter site-to-site. The mm-Wave system idea is aimed to work out this small cell deployment by using higher frequency cellular transceivers co-located with the 4G base stations. These mm-Wave transceivers can simultaneously provide backhaul for 4G and also access for 5G [21]. Observation should also be focused on dynamic channel effects which will competent of power for 5G mobile networks due to rise of Doppler influenceat mm-waves. Besides, for moved mobile devices as well as shadowing caused by moving person's impact will require to be measured. These effects introduce a significant time variance to the mm wave channel [22].

D. Beamforming (BF)

Beamforming is a method used to generate the radiation pattern of an array antenna by adding constructively the weights of the signals in the direction of SOI and nulling the pattern in the direction of SNOI (interference).But this array can be antennas in the smart antennas context, or any other types of sensors (radars, medical sensors…etc) can be an array of microphones in the speech signal processing context. Beamforming can be employed at both the transmitting and receiving ends in order to achieve spatial selectivity i.e., an appropriate feeding allows antenna arrays to steer their beam and nulls towards certain directions, this is often referred to as spatial filtering.

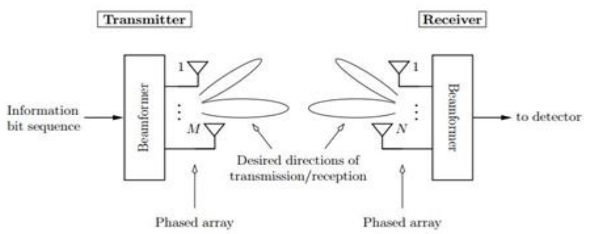

Figure 4: Beamforming Technique.

Smart antennas that can be controlled automatically are normally used according the required performance and the prevailing conditions.

Smart antennas can be divided into two groups:

Phased array systems: Phased array systems are switched and have a number of pre-defined patterns - the required one being switched according to the direction required. ***Adaptive array systems (AAS):*** This type of antenna uses what is termed adaptive beamforming and it has an infinite number of patterns and can be adjusted to the requirements in real time. MIMO beamforming using phased array systems needs the overall system to determine the direction of arrival of the incoming signal and then switch in the most appropriate beam. This is something of a compromise because the fixed beam is unlikely to precisely match the required direction. Adaptive array systems are able to direct the beam in the exact direction needed, and also move the beam in real time - this is a particular advantage for moving systems - a factor that often happens with mobile telecommunications. However, to eliminate the multiuser interference (MUI) in the multiuser multi-input multi-output (MIMO) system, different criteria have been proposed to design transmitter and receiver beamforming algorithms [23-27]. An iterative beamfoming algorithm has been proposed in [6] based on duality relation between downlink and uplink and in [26], by defining the difference between desired signal power and interference plus noise power as an utility function have been proposed for multiuser MIMO downlink systems. In contrast to analog beamforming, the digital beamforming technique can produce a large number of high-gain beams without degradation in signal-to-interference-plus-noise ratio (SINR). A digital beamforming technique can substitute the complex hardware functions of a beamforming network by using software algorithms implementable on digital signal processors. This is especially attractive to satellite communications since only a new suite of software has to be uploaded to the operating satellite if the beams require some modifications. For wireless communications different digital beamforming strategies have been proposed. They can be categorized into two classes: fixed digital beamforming and adaptive digital beamforming. For the fixed digital beamforming technique the weights of the antenna array are designed in advance and kept unchanged during operations.But for the adaptive digital beamforming strategies the weights are adjusted adaptively with the operating conditions. Nevertheless, it is expected that adaptive beamforming algorithms can provide a further enhancement of system capacity because of their adaptive interference nulling capability. In addition, these two major classes can be further divided into four digital beamforming strategies, namely, 1) single fixed beam/single user, 2) single fixed beam/multiple users, 3) single adaptive beam/single user [28], and 4) single Chebyshev dynamic beam/multiple users [28, 29]. While these four schemes are based on either fixed or adaptive beams, their deviation lies in the use of a single beam for multiple users or a single user. On the other hand, many adaptive beamforming algorithms have been developed in the literature. Among them, a popular one is minimizing the system output power subject to multiple linear constraints [30], and a penalty function method can be used to overcome the weight jitter and high sidelobe problems [24].But for large arrays as in satellite communications, techniques such as the contiguous [32] and overlapping [29, 30] subarrays have to be considered. One modern category of adaptive beamforming is neural beamforming where adaptive processes are carried out using neural networks (NN) for real-time parallel processing. Different neural networks (NN) models have been proposed in the literature. For instance, the Hopfield NN (HNN) can realize the minimum mean-square error beamforming based on a neural optimization [31]. Another technique uses a feedforward NN to approximate the input-output relationship for beamforming [32].However; the implementation of digital beamforming in large-scale antenna systems is a great challenge because of its complexity, energy consumption, and cost. So, in a practical large-scale antenna deployment, hybrid analog and digital beamforming structures can be important alternative choices. That’s why, it is expected that large-scale antenna systems with hybrid beamforming structures in the mmWave band can play an important role in 5G.

III. SIMULATION AND RESULTS

In this simulation part a different types of Beamforming technique has been observe such as conventional Beamforming, adaptive Beamforming and hybrid Beamforming. In conventional Beamforming technique, the direction of the desire signal has to be changed according to the model. The whole simulation has been done by using matlab simulation.

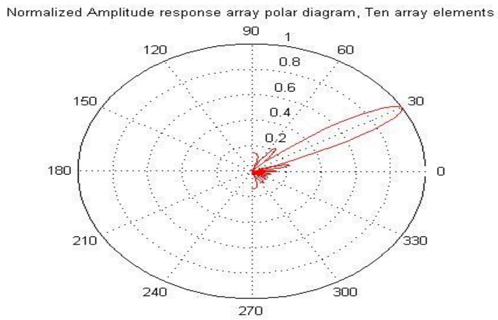

Figure 5: Normalized Amplitude response array polar diagram, Ten array elements

In figure 5, the angle is 30 degree and it is quite clear from the figure that the main lobe is directed in that particular direction.

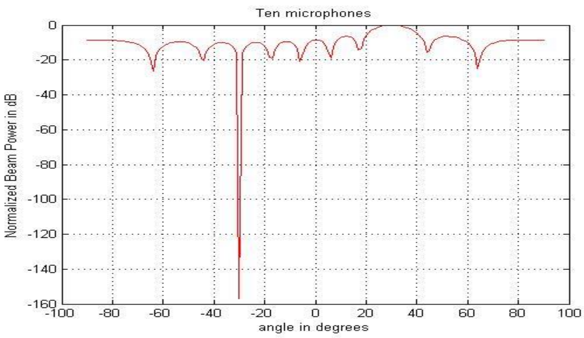

Figure 6: Normalized Beam Power[dB]for 10 microphones.

From figure 6, it can be observed that the beam power is maximum in 30 degree because the main lobe is directed in that particular direction.

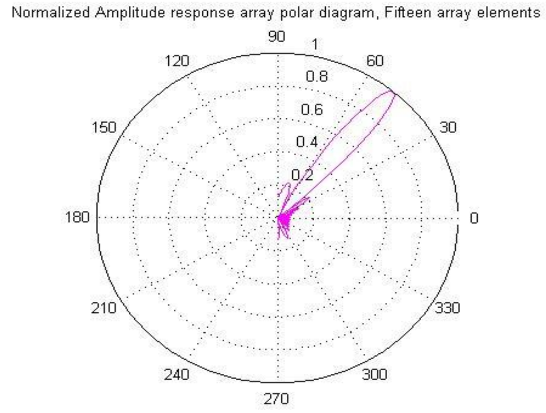

Figure 7: Normalized Amplitude response array polar diagram, fifteen array elements

In figure 7, the angle is 50 degree and it is quite clear from the figure that the main lobe is directed in that particular direction and the side lobe are very small which are located within 0.1 amplitude and the value of main lobe is 1.

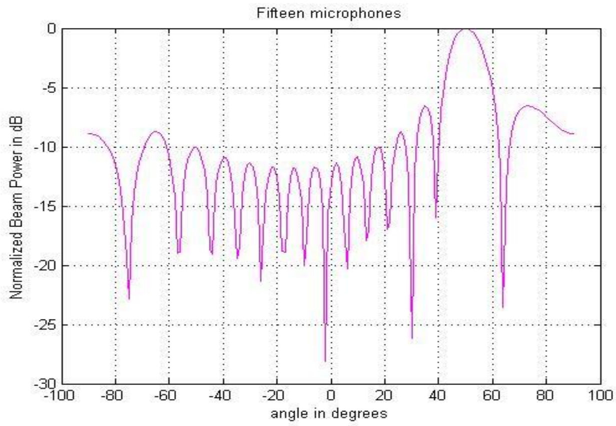

Figure 8: Normalized Beam Power [dB]for 15 microphones.

From figure 8, it can be observed that the beam power is maximum in 50 degree because the main lobe is directed in that particular direction and the number of microphones is fifteen. In conventional beamforming, both the direction of main lobe and the array numbers has to be fixed manually which one of the major disadvantages of this system is.

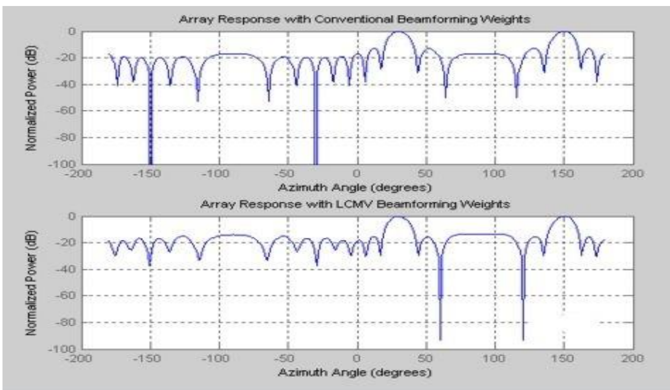

Figure 9: Comparison between conventional and adaptive Beamforming.

In figure 9, conventional and adaptive Beamforming technique has been observed and it is clear that the adaptive Beamforming provided far better spectrum compare to conventional Beamforming..

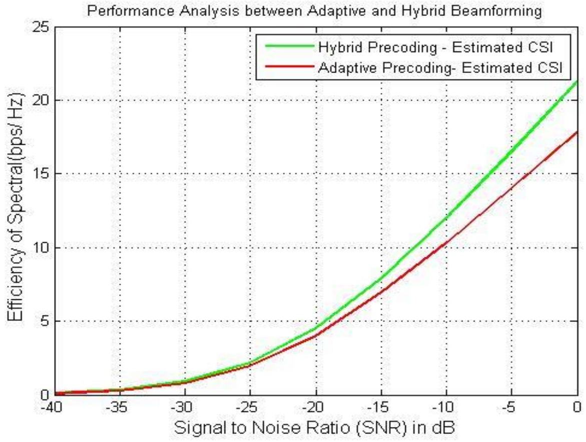

Figure 10: Efficiency of spectrum for both hybrid and adaptive beamforming

In figure hybrid and adaptive precoding technology has been used. For adaptive precoding and Beamforming technology, energy of spectrum is lower than the hybrid precoding system.

IV. CONCLUSION

From the simulation and the results, it can be said that the hybrid Beamforming is more reliable and effective than the adaptive or digital Beamforming technology. Digital Beamforming is also costly because it requires more baseband chain in both transmitter and receiver end compare to analog Beamforming. However analog Beamforming required less BB chain in receiver chain. So the hybrid Beamforming can be very much cost effective. Hybrid Beamforming can provide high data rate with very low BER which can be effective remarkably to implement 5G

ACKNOWLEDGMENT

Special thanks to Uttara University for their heartiest support.

REFERENCES

[1] Reference found on “ARIB 2020 and Beyond Ad Hoc Group White Paper”,Mobile Communications Systems for 2020 and beyond, Version 1.0.0 ,October 8, 2014 . By Association of Radio Industries and Businesses (ARIB) .Web link : http://www.arib.or.jp/english/20bah-wp-100.pdf . Page :35-36

[2] Reference found on “ NGMN 5G White Paper” ,A deliverable by the NGMN(Next Generation Mobile Network)Alliance, Paper_V1_0.pdf . Page :45-46

[3] [3] A. Osseiran, F. Boccardi, V. Braun, K. Kusume, P. Marsch, M. Maternia, O. Queseth, M. Schellmann, H. Schotten, H. Taoka, H. Tullberg, M. A. Uusitalo, B. Timus, and M. Fallgren, “Scenarios for 5G mobile and wireless communications: the vision of the METIS project,” IEEE Commun. Mag., vol. 52, pp. 26–35, May 2014.

[4] [4] FP7 Integrating Project METIS (ICT 317669). [Online]. Available: https://www.metis2020.com/

[5] [5] Pekka Pirinen , “A Brief Overview of 5G Research Activities” , 5GU 2014, November 26-27, Levi, Finland, 2014 ICST, Page :1

[6] [6] Reference found on, “Challenges and Solutions in Prototyping 5G Radio Access Network”, By BEEcube. Weblink:http://www.beecube.com/academics/Challenges%20and%20Solutions%20in%20Prototyping%205G%20Radio%20Access%20Network%20.pdf. Page :2-3

[7] [7] Reference found on “5G: Challenges, Research Priorities, and Recommendations Joint White Paper”, August,2014, by European Technology Platform for Communications Networks and Services, NetWorld2020 ETP,D15Annex4NetworkandServiceVirtualizationwhitepaper.

[8] 3GPP, TR 36. 872 (V0. 3. 0), “Small cell enhancements for E-UTRA and E-UTRAN - physical aspects,” May 2013.

[9] 3GPP, RWS-120010, NTT DOCOMO, “Requirements, candidate solutions & technology roadmap for LTE Rel-12 Onward,” June 2012.

[10] H. Ishii, Y. Kishiyama, and H. Takahashi, “A novel architecture for LTE-B, C-plane/U-plane split and phantom cell concept,” IEEE GLOBECOM2012 Workshop, Dec. 2012.

[11] T. L. Marzetta, “Non-cooperative cellular wireless with unlimited numbers of base station antennas,” IEEE Trans. Wireless Commun., vol. 9, no. 11, Nov. 2010.

[12] F. Rusek, D. Persson, L. K. Buon, E. G. Larsson, T. L. Marzetta, O. Edfors, and F. Tufvesson, “Scaling up MIMO: Opportunities and challenges with very large arrays,”IEEE Signal Processing Magazine, vol. 30, no. 1, pp. 40-60, January 2013.

[13] T. L. Marzetta, “Noncooperative cellular wireless with unlimited numbers of base station antennas,”IEEE Trans. Wireless Commun.,vol.9, no. 11, pp. 3590–3600, Nov. 2010.

[14] T. L. Marzetta, "Noncooperative cellular wireless with unlimited num-bers of base station antennas", iEEE Trans. Wireless Commun., vol. 9, no. 11, pp. 3590-3600, Nov. 2010.

[15] E. G. Larsson, F. Tufvesson, O. Edfors, and T. L. Marzetta, "Massive MIMO for Next Generation Wireless Systems", IEEE Commun. Mag., vol. 52, no. 2, pp. 186-195, Feb. 2014.

[16] H. Q. Ngo, E. G. Larsson, and T. L. Marzetta, “Energy and Spectral Efficiency of Very Large Multiuser MIMO Systems,”IEEE Trans. Commun., vol. 61, Apr. 2013, pp. 1436–49.

[17] M. Cudak, A. Ghosh, T. Kovarik, R. Ratasuk, T. Thomas, F. Vook, P. Moorut, “Moving Towards mmWave-Based Beyond-4G (B-4G) Technology,” in Proc. IEEE VTC-Spring 2013, June 2-5, 2013.B. Raaf, et. al., “Vision for Beyond 4G Braoadband Radio Systems,” in Proc. IEEE PIMRC 2011, September 2011.

[18] F. Khan and Pi Zhouyue, “mmWave Mobile Broadband (MMB): Unleashing the 3-300GHz Spectrum,” in Proc. 34th IEEE Sarnoff Symposium 2011, pp. 1-6, MY 2011.

[19] T.S. Rappaport, J. N. Murdock, and F. Gutierrez, “State of the art in 60-GHz integrated circuits and systems for wireless communications,” Proceedings of the IEEE , vol.99, no.8, pp.1390-1436, Aug. 2011.

[20] Meejoung Kim, Yongsun Kim, and Wooyong Lee, “Resource Allocation Scheme for Millimeter Wave-Based WPANs Using Directional Antennas,” ETRI Journal vol.36, no.3, pp. 385-395, June 2014.

[21] Meejoung Kim, Seung-Eun Hong, Yongsun Kim, and Jinkyeong Kim, “Analysis of Resource Assignment for Directional Multihop Communications in mm-Wave WPANs,” ETRI Journal vol.35, no.1, pp. 120-130, Feb. 2014.

[22] M. Cudak, T. Kovarik, T. A. Thomas, A. Ghosh, Y. Kishiyama,T. Nakamura, “Experimental mmWave 5G Cellular System” Globecom 2014 Workshop - Mobile Communications in Higher Frequency Bands.

[23] R. L. Choi, M. T. Ivrlaˇc, R. D. Murch, and W. Utschick, “On strategies of multiuser MIMO transmit signal processing” IEEE Trans. Wireless Commun., vol. 3, no. 6, pp. 1936–1941, Nov. 2004.

[24] W. Rhee, W. Yu and J. M. Cioffi, “The optimality of beamforming in uplink multiuser wireless systems,” IEEE Trans. Wireless Commun, vol. 3, no. 1, pp. 86-96, Jan 2004.

[25] N. Bonneau, M. Debbeh, E. Altman and A. Hjorungnes, “Nonatomic games for multi-user systems,” IEEE Trans. Commun, vol. 26, no. 7, Sep. 2008.

[26] R. L. Choi, R. D. Murch and K. B. Letaief, “MIMO CDMA antenna system for SINR enhancement,” IEEE Trans. Wireless Commun., vol. 2, no. 2, pp. 240–249, Mar. 2003.

[27] S. Serbetli and A. Yener, “Tranceiver optimization for multiuser MIMO systems ,” IEEE Trans. Signal Process., vol. 52, no. 1, pp. 214–226, Jan. 2004.

[28] Gebauer, T., and Gockler, G. H. (1995) Channel individual adaptive beamforming for mobile satellite communications. IEEE Journal on Selected Areas in Communications, 13 (1995), 439—448.

[29] Horton, A. R., and Abend, K. (1993) Adaptive array antenna for satellite cellular and direct

[30] broadcast communications. InProceedings of the 3rd International Satellite Conference, Pasadena, CA, 1993, 47—52.Safaai-Jazi, A. (1994)

[31] A new formulation for the design of Chebyshev arrays. IEEE Transactions on Antennas and Propagation, 42 (1994), 439—443.

[32] Goldstein, J. S., and Reed, I. S. (1997) Performance measures for optimal constrained beamformers. IEEE Transactions on Antennas and Propagation, 45 (1997), 11—13.

[33] E. G. Larsson, F. Tufvesson, O. Edfors, and T. L. Marzetta, "Massive MIMO for next generation wireless systems," *IEEE Commun. Mag.*, vol. 52, no. 2, pp. 186–195, Feb. 2014.

[34] J. Choi, B. Lee, B. Shim, and I. Kang, "Low complexity detection and precoding for massive MIMO systems," in *Proc. IEEE Wireless Commun. Netw. Conf. (WCNC)*, Shanghai, China, Apr. 2013, pp. 2857–2861.

[35] T. Kim, J. Park, J. Seol, S. Jeong, J. Cho, and W. Roh, "Tens of Gbps support with mmWave beamforming systems for next generation communications," IEEE GLOBECOM2013, Dec. 2013.

[36] X. Huang, Y. Jay Guo, and J. Bunton, "A Hybrid Adaptive Antenna Array," *IEEE Trans. Wireless Commun.*, vol. 9, no. 5, May 2010, pp.1770–79.