

MASSIVE MIMO DEPLOYMENT SCENARIOS IN REAL PROPAGATION ENVIRONMENTS FOR GREEN WIRELESS NETWORKS

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Abstract: Design of conventional mobile networks mainly focuses on spectral efficiency, throughput and transmission reliability while minimizing the latency. Off late research prospect has more focus in studying the energy efficiency in next generation wireless networks; associated with this shift is a new point of view that wireless communications are becoming ubiquitous and the energy consumption of embedded devices is gradually increasing. The energy resources are becoming scarce and extinct. So more care should be given to energy management than other resources. The rising carbon footprint of wireless communication networks is expected to reach 58% of the information and communication technology (ICT) industry contribution by 2020. Massive MIMO is a great prospect for improvements in energy and spectral efficiency by incorporating a large number of antennas with reduced RF chains. Massive MIMO has limiting factor like pilot contamination but methods like non universal pilot reuse has been proposed to overcome the problems associated with this. Also short wavelength mm wave frequencies along with small size massive MIMO antennas can be attractive. The concept of Fractional Frequency Reuse (FFR) improves spectral efficiency with the help of high frequency reuse factor. Dirty paper coding (DPC) and Tomlinson Harashima Precoding (THP) further improve spectral efficiency by suppressing interference. It has also been proposed that LT-coded MFSK scheme provides higher energy efficiency over other uncoded and coded schemes due to the flexibility to adjust its rate according to the channel condition leading to green wireless network.

Keywords: LT-coded MFSK, mmwave, ICT, DPC, THP.

1. Introduction

Massive MIMO [8][9] is a great technique for increasing spectral and energy efficiency. But the large number of antennas will lead to issues like system complexity and energy consumption. Reducing RF

chains and also performing antenna selection using suitable simple algorithms can be an effective method to overcome the problem. We will look into different possibilities to find a method for reduced RF chains and better antenna selection in the upcoming sections.

2. Massive MIMO Deployment Scenarios

Today the leading candidate for 5G technologies is massive MIMO [8][9]. But the huge number of antennas associated with very high number of RF chains leads to system complexity and power consumption which is a major challenge for massive MIMO. To address the issue, research should focus on how to reduce the RF chains and to analyze the different deployment scenarios that can be more energy efficient. Due to the complexity in hardware implementation and signal processing, we must ensure whether all the antennas in the massive MIMO setup contribute equally with respect to the overall performance of the system. Experimental results and analysis shows that not all the antennas contribute equally to the overall performance of the system [1]. However different deployment scenarios or antenna configurations deliver different levels of contribution. This leads to the selection of different antenna selection algorithms to be implemented so that the antennas which contribute more will be selected and the remaining will get disconnected, which in turn will reduce the number of RF chains leading to reduced system complexity with respect to spectral and energy efficiency [10][11].

3. Antenna Selection

All the antennas are expected to contribute equally to the system performance with distributed Rayleigh fading channels. In that case, consider a multi-user MIMO-OFDM system with K subcarriers and a base station array with N antennas that serves M users. Denote the $N \times 1$ channel vector for a given user m and a

given subcarrier k . In Rayleigh fading channels, all antennas are equally good and assumed to be

$$\frac{1}{M} \sum_{m=1}^M \frac{1}{K} \sum_{k=1}^K \frac{1}{K} |g_{m,n}(k)|^2 \approx \text{const} \quad \forall n \quad (1)$$

But practical experiments show that this scenario is highly impossible because of the huge variation in the performance of antennas. In such case we may need a RF switch which will be used to toggle between different RF chains. However implementation of antenna selection algorithm will increase the system complexity further. Antenna Selection using Convex Optimization scheme [1] has been analyzed along with antenna selection based on received power, of which the second method proves to be simple and a better choice. By investigating the amount of gain that can be obtained by antenna selection, when compared to random selection, and how many RF transceivers we can switch off while maintaining 90% of full MIMO performance, It has been proved that linear array antennas need 70 percent of the antennas to be active to maintain 90 percent performance whereas cylindrical array requires only 50 to 60 percent antennas to be active to deliver the same performance [1]. Performance analysis of other antenna array configurations like circular, hexagonal, concentric and spherical arrays can be examined and tested for selecting a suitable array pattern. It has been clear from the figure that the aperture area and the physical area coverage of linear array geometry is much higher than rectangular and cylindrical array geometry. Figure 1 depicts 100 element (isotropic) cylindrical array and rectangular array geometry along with 10 element linear array geometry.

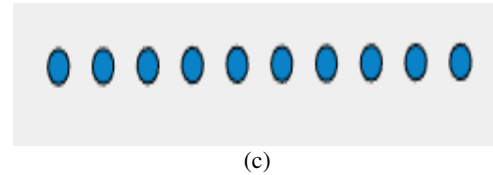
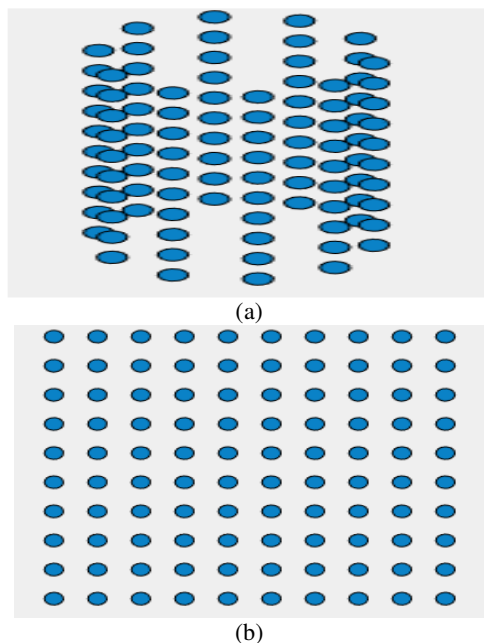


Figure 1. (a) 10X10 Cylindrical array geometry
(b) 10X10 Rectangular array geometry
(c) 10 element Linear array geometry

4. Antenna Architecture

Antenna architecture of wireless communication systems should focus on achieving universal frequency reuse, i.e., reuse factor of 1, is preferred for future broadband wireless communications systems [14]. In the Orthogonal Frequency-Division Multiple Access (OFDMA) systems, which do not have processing gain as the Code-Division Multiple Access (CDMA) systems [16], how to achieve the goal of both universal frequency reuse and reducing intercell interference is a key challenge. To overcome the above challenge a concept called Fractional Frequency Reuse (FFR) [15] has been recommended to improve spectrum efficiency by implementing reuse partition techniques. In FFR scheme the inner region of the cell is assigned with the entire frequency spectrum and the outer region is assigned with a fraction of the frequency spectrum [14-17].

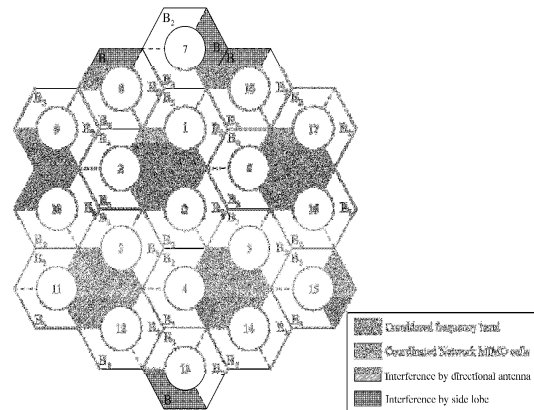


Figure 2. FFR-based three-cell network MIMO systems with interference

Figure 2 shows FFR-based three cell network with interference between two cells since the frequency reuse is not properly arranged. FFR, also called reuse partition, allows different frequency reuse factors to be applied over different frequency partitions during the period of transmission. The FFR partitions the frequency into inner frequency bands fA and outer frequency bands fB , where fB is further partitioned into

three subbands f_{B1} , f_{B2} , and f_{B3} . In general, the inner frequency band f_A adopts a reuse factor of 1 and is used by interior cell users; the outer frequency band f_B adopts a reuse factor of 1/3 for each sector for cell edge users. By means of the tri-sector FFR, the intracell interference can be avoided by the four orthogonal subbands, and the intercell interference can be significantly reduced.

Two types of frequency planning has been in use: 1) Regular and 2) Rearranged frequency partitions. In regular frequency partition, each cell has the same frequency planning in the outer sectors whereas in rearranged frequency partition, each cell has different frequency planning compared with its surrounding cells. FFR is usually integrated with other functions such as power control or antenna technologies for adaptive control. Figure 3 depicts the concept of regular and rearranged frequency partition from which we can clearly understand that rearranged frequency partition will get severely affected by cochannel intercell interference than the regular frequency partition. It is under the assumption of perfect 120° sectoring by directional antenna in the outer region of the cell.

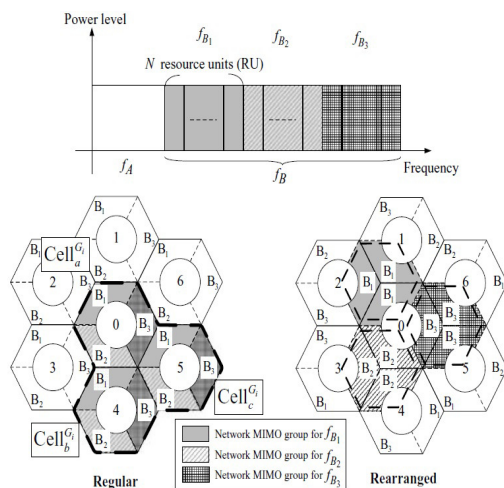


Figure 3. FFR-based three-cell network MIMO systems without interference

5. DPC vs THP

Dirty Paper Coding (DPC) [19] was used to suppress interference from other users. For a more practical approach DPC was replaced with Tomlinson–Harashima precoding (THP) [20]. These coding methods work under the assumption of having single receiver antenna which are not directly applicable to multiple-input multiple-output (MIMO) systems. It is well known that Dirty Paper Coding (DPC) can achieve the capacity of a multiuser MIMO broadcast system.

Due to the high complexity of DPC, some suboptimal but practical schemes were proposed. In this chapter, we consider two suboptimal network MIMO schemes: zero-forcing (ZF) and zeroforcing dirty paper coding (ZF-DPC). Zero Forcing method is used to suppress partial interference. DPC or THP [21][22] is used to eliminate the remaining interference. Table 1 shows the performance of three-cell network MIMO with regular frequency partition in terms of spectral efficiency.

Table 1. Spectral efficiency for three-cell network MIMO with regular frequency partition [19]

Parameters	Reuse 1	Tri-sector FFR	ZFB	ZF-DPC
(bps/Hz)/base Improvement	2.5437	3.7844	2.4977	4.4275
Spectral efficiency		48.78%	-1.81%	74.06%

6. Pilot Contamination

Pilot contamination can be a limiting factor for the performance of massive MIMO. In order to mitigate such phenomenon, non universal pilot reuse has been proposed where neighboring cells use different sets of mutually orthogonal pilots. Under non universal pilot reuse, the total set of available pilot sequences is divided into subgroups, and different subgroups are assigned to adjacent cells. For a pilot reuse factor F , the same subgroup of orthogonal pilot sequences is reused in every F cells.

7. MM Wave Massive MIMO

MM wave frequency may be more useful and effective in association with massive MIMO concept due to the fact that massive MIMO demands large number of antennas whereas mm wave frequency will give the option of integrating a large number of antennas in very small space due to its high frequency range. But there exists problems associated with mmwave like high attenuation with distance due to atmospheric gases, which can be addressed by the high gain achieved by massive MIMO [6][7] and effect of mutual coupling should be reduced due to closely packed antennas [23][24][25]. So the combination of mmwave along with massive MIMO will be a good future prospect in wireless communication.

8. Hybrid Antenna Array for MM Wave Massive MIMO

Massive MIMO is also necessary for mmwave cellular communications. The radiation power is low due to the small antenna size and the propagation attenuation of mmwave is very large. Hence it is necessary to use high-directivity antennas to ensure sufficiently high

signal power received for successful signal detection. Hence, for mmwave cellular communications, massive antenna array is becoming a promising proposition [3][5]. A hybrid array with many analog subarrays and their own respective digital chains turns out to be a more feasible solution. Massive MIMO hybrid array for mmwave communications faces many challenging

design problems in both hardware and signal processing [3]. Figure 4 shows the normalized array factor of a uniform 16×16 square hybrid array with square subarrays in interleaved and localized configuration. Figure 5 depicts the structure of hybrid array system for the transmitter side and it will be the inverse for the receiver side [2][4].

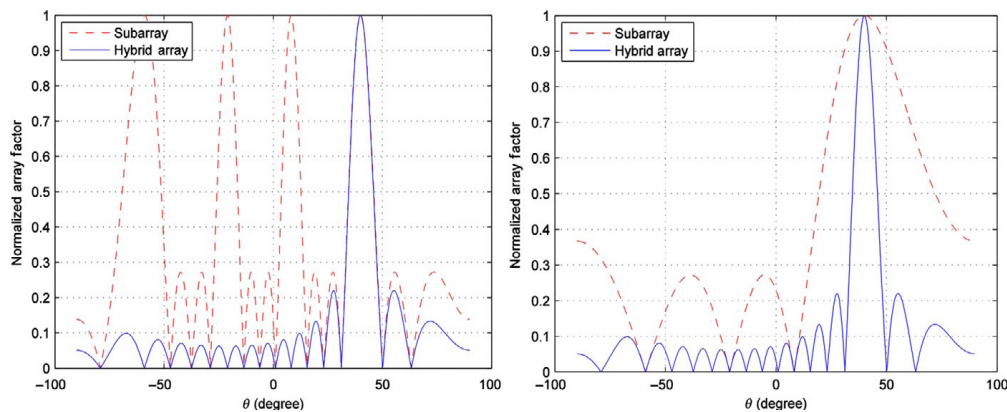


Figure 4. Normalized array factor of a uniform 16×16 square hybrid array with square sub arrays in the interleaved (left) and localized configuration (right)[2][4].

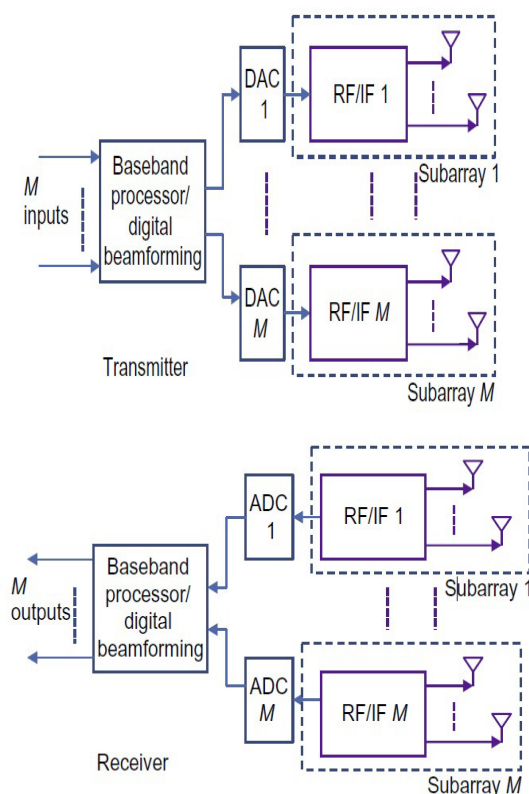


Figure 5. Hybrid antenna array system [2]

Interleaved array is harder to implement due to the space constraint. It offers advantages in beam width, but overall is inferior to localized array [2].

9. Modulation and Coding Schemes

In the previous section we discussed in detail about the antenna structure that can be implemented in mmwave massive MIMO systems due to which there can be reduction in RF chains which in turn improves the energy efficiency. This section focuses on different modulation and coding schemes that can be applied to the above systems so that to make it more energy efficient and to move towards green communication. In recent times, research focus has been moving towards implementing rateless codes (Luby transform Code (LT) code [13] in wireless networks due to their significant advantages in erasure channels [9]. Many transmission environments include significant obstacles such as walls, doors, and furniture which lead to reduced LOS components. This behavior suggests a Rayleigh fading channel model for our system.

A) Uncoded and Coded Schemes

In this section, we analyze the energy and bandwidth efficiency of three popular sinusoidal carrier-based modulations namely MFSK, M-ary Quadrature Amplitude Modulation (MQAM), and Offset Quadrature Phase-Shift Keying (OQPSK), over a Rayleigh flat-fading channel with path loss. MFSK

scheme has a faster start-up time than other schemes. Moreover, for energy-constrained wireless networks, data rates are usually low using M-ary NC-FSK schemes with a small M . The non-coherent M-ary Frequency-Shift Keying (NC-MFSK) provides superior energy-efficiency performance in short-range wireless networks when compared with other sinusoidal carrier-based modulations such as M-ary Quadrature Amplitude Modulation (MQAM), differential Offset Quadrature Phase Shift Keying (OQPSK), and coherent MFSK. MFSK modulation when compared to classical BCH and convolutional-coded modulation as well as uncoded modulation. The LT-coded MFSK scheme provides higher energy efficiency over other uncoded and coded schemes due to the flexibility to adjust its rate according to the channel condition. The authors conclude that LT-coded MFSK modulation is a candidate for green modulation and coding scheme for energy-constrained wireless networks.

10. Conclusion

In this paper we have discussed the various possible antenna deployment scenarios in massive MIMO systems and their performance along with antenna selection methods to improve energy efficiency. It has been shown that antenna architecture for Fractional Frequency Reuse along with precoding schemes like DPC and THP suppress interference from other users leading to improved spectral efficiency. Further the combination of massive MIMO along with mmwave frequency communication has been discussed which leads to very small antenna elements within a small space due to its high operating frequency. Also a hybrid antenna array concept with different modulation and coding schemes will drastically reduce the amount of power consumed by the system which in turn increases the energy efficiency along with spectrum efficiency due to massive MIMO. Finally massive MIMO system together with mmwave communication and hybrid antenna array with suitable coding scheme will lead to green wireless networks which are more energy and spectrum efficient.

References

- [1] X. Gao, O. Edfors, F. Tufvesson, and E. G. Larsson, "Massive MIMO in Real Propagation Environments: Do All Antennas Contribute Equally?," *IEEE Trans. Commun.*, vol. 63, no. 11, pp. 3917–3928, 2015.
- [2] X. Huang, Y. Guo, and J. Bunton, "A hybrid adaptive antenna array," *IEEE Trans. Wirel. Commun.*, vol. 9, no. 5, pp. 1770–1779, 2010.
- [3] J. A. Zhang, X. Huang, V. Dyadyuk, and Y. J. Guo, "Massive hybrid antenna array for millimeter-wave cellular communications," *IEEE Wirel. Commun.*, vol. 22, no. 1, pp. 79–87, 2015.
- [4] Y. J. Guo, X. Huang, and V. Dyadyuk, "A hybrid adaptive antenna array for long-range mm-wave communications," *IEEE Antennas Propag. Mag.*, vol. 54, no. 2, pp. 271–282, 2012.
- [5] T. S. Rappaport et al., "Millimeter wave mobile communications for 5G cellular: It will work!," *IEEE Access*, vol. 1, pp. 335–349, 2013.
- [6] R. Mailloux, *Phased Array Antenna Handbook*, vol. 16, no. 4, 2011.
- [7] W. R. Deal, N. Kaneda, J. Sor, Y. Qian, and T. Itoh, "A new quasi-yagi antenna for planar active antenna arrays," *IEEE Trans. Microw. Theory Tech.*, vol. 48, no. 6, pp. 910–918, 2000.
- [8] L. Lu, G. Y. Li, A. L. Swindlehurst, A. Ashikhmin, and R. Zhang, "An overview of massive MIMO: Benefits and challenges," *IEEE Journal on Selected Topics in Signal Processing*, vol. 8, no. 5, pp. 742–758, 2014.
- [9] T. L. Marzetta, "Massive MIMO: An Introduction," *Bell Labs Tech. J.*, vol. 20, pp. 11–22, 2015.
- [10] O. Blume, D. Zeller, and U. Barth, "Approaches to energy efficient wireless access networks," *Commun. Control Signal Process. (ISCCSP)*, 2010 4th Int. Symp., pp. 2–6, 2010.
- [11] T. L. Narasimhan, P. Raviteja, and A. Chockalingam, "Large-scale multiuser SM-MIMO versus massive MIMO," in *2014 Information Theory and Applications Workshop, ITA 2014 - Conference Proceedings*, 2014.
- [12] M. Feng and S. Mao, "Harvest the potential of massive MIMO with multi-layer techniques," *IEEE Netw.*, vol. 30, no. 5, pp. 40–45, 2016.
- [13] M. Luby, "LT codes," *Annu. Symp. Found. Comput. Sci. - Proc.*, pp. 271–280, 2002.
- [14] H. Fujii and H. Yoshino, "Capacity and outage rate of OFDMA cellular system with fractional frequency reuse," *IEICE Trans. Commun.*, vol. E93–B, no. 3, pp. 670–678, 2010.
- [15] M. Assaad, "Optimal fractional frequency reuse (FFR) in multicellular OFDMA system," in *IEEE Vehicular Technology Conference*, 2008.
- [16] R. Y. Chang, Z. Tao, J. Zhang, and C.-C. Kuo, "A Graph Approach to Dynamic Fractional Frequency Reuse (FFR) in Multi-Cell OFDMA Networks," *2009 IEEE Int. Conf. Commun.*, pp. 1–6, 2009.
- [17] H. Lei, L. Zhang, X. Zhang, and D. Yang, "A novel multi-cell OFDMA system structure using fractional frequency reuse," in *IEEE International Symposium on Personal, Indoor and Mobile Radio*

Communications, PIMRC, 2007.

[18] U. Erez and S. ten Brink, "A close-to-capacity dirty paper coding scheme," *IEEE Trans. Inf. Theory*, vol. 51, no. 10, pp. 3417–3432, 2005.

[19] S. C. Lin and H. J. Su, "Practical vector dirty paper coding for MIMO gaussian broadcast channels," *IEEE J. Sel. Areas Commun.*, vol. 25, no. 7, pp. 1345–1357, 2007.

[20] M. H. M. Huang, S. Z. S. Zhou, and J. W. J. Wang, "Analysis of Tomlinson-Harashima Precoding in Multiuser MIMO Systems With Imperfect Channel State Information," *IEEE Trans. Veh. Technol.*, vol. 57, no. 5, pp. 2856–2867, 2008.

[21] L. Sun and M. Lei, "Tomlinson-Harashima precoding for multiuser MIMO systems: Sum rate analysis with quantized CSI and user scheduling," in *IEEE International Symposium on Personal, Indoor and Mobile Radio Communications, PIMRC, 2012*, pp. 2237–2242.

[22] L. Sun and M. Lei, "Quantized CSI-based tomlinson-harashima precoding in multiuser MIMO systems," *IEEE Trans. Wirel. Commun.*, vol. 12, no. 3, pp. 1118–1126, 2013.

[23] R. Darwin, G. Ishwarya, "Dual Band Mimo Antenna Using Decoupling Slots For WLAN Applications," *Journal of Advanced Research in Dynamical and Control Systems, Special Issue*, pp. 1138-1147, 2017.

[24] L. Charlene Karunya, R. Darwin, "Multiple Input Miniaturized Fractal Antenna for Terrestrial Services", *IEEE Xplore, International Conference on Wireless Communications, Signal Processing and Networking (WiSPNET)*, pp. 2444-2447, 2016.

[25] R Darwin, S David, R Karthikeyan, " High Gain 2.4Ghz Patch Antenna Array For Rural Area Application", *International Journal of Pure and Applied Mathematics, Special Issue, Volume 117 No.8*, 2017, pp.173-176.

[26] A.Jeniffer, S.Haripasath, S.Chinthamani, G.Chitra, V.Karthiga, "An Effective FPGA Implementation of Denoising of Impulse Noise in Images", *International Innovative Research Journal of Engineering and Technology*, Vol 02, No 01, pp.41-48, 2016.

[27] S.V.Manikanthan & K.srividhya "An Android based secure access control using ARM and cloud computing", Published in: *Electronics and Communication Systems (ICECS)*, 2015 2nd International Conference on 26-27 Feb. 2015, Publisher:IEEE,DOI:10.1109/ECS.2015.7124833.

[28] T. Padmapriya, V.Saminadan, "Performance Improvement in long term Evolution-advanced network using multiple input multiple output technique", *Journal of Advanced Research in Dynamical and Control Systems*, Vol. 9, Sp-6, pp: 990-1010, 2017.

