INTL JOURNAL OF ELECTRONICS AND TELECOMMUNICATIONS, 2020, VOL. 66, NO. 3, PP. 529-535
Manuscript received May 1, 2020; revised July, 2020. DOI: 10.24425/ijet.2020.134009

Power Scaling and Antenna Selection Techniques for Hybrid Beamforming in mmWave Massive MIMO Systems

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***Abstract*— With the advent of massive MIMO and mmWave, Antenna selection is the new frontier in hybrid beamforming employed in 5G base stations. Tele-operators are reworking on the components while upgrading to 5G where the antenna is a last-mile device. The burden on the physical layer not only demands smart and adaptive antennas but also an intelligent antenna selection mechanism to reduce power consumption and improve system capacity while degrading the hardware cost and complexity. This work focuses on reducing the power consumption and finding the optimal number of RF chains for a given millimeter wave massive MIMO system. At first, we investigate the power scaling method for both perfect Channel State Information (CSI) and imperfect CSI where the power is reduced by $\frac{1}{N_r}$ and $\frac{1}{\sqrt{N_r}}$ respectively. We further propose to reduce the power consumption by emphasizing on the subdued resolution of Analog-to-Digital Converters (ADCs) with quantization awareness. The proposed algorithm selects the optimal number of antenna elements based on the resolution of ADCs without compromising on the quality of reception. The performance of the proposed algorithm shows significant improvement when compared with conventional and random antenna selection methods.**

***Keywords*—Antenna Selection, Massive MIMO, millimeter Wave, 5G, Hybrid Beamforming, Power Scaling**

I. INTRODUCTION

MILLIMETER-WAVE (mmWave) technology has been considered to be a dominant enabler for the success of next-generation cellular networks. Massive MIMO antenna systems have gained considerable attention as a key candidate in mmWave communications because they render significantly enhanced spectral efficiency [1-3]. In mmWave massive MIMO systems, Beamforming (HBF) is a primary signal processing technique to compensate for the higher path loss in mmWave propagations [4-6]. Beamforming (BF) enables the antennas to form directional beams focusing on the desired spatial directions allowing to serve the terminals located in different spots. Thus beamforming technique significantly contribute to improve spectral efficiency in massive MIMO systems. Due to a large number of antennas in massive MIMO, there arise the practical challenges such as power consumption, hardware cost and complexity [7].

One way to reduce the hardware cost and complexity is by adopting hybrid beamforming designs that use smaller number of radio frequency (RF) chains than the number of antennas in massive MIMO array. The analog-to-digital converters (ADCs) used in the RF chains consume significant power. The power consumption in ADCs scales exponentially concerning their resolutions (number of quantization bits). Hence, use of low resolution (1 to 3 bits) ADCs could be a possible solution.

Power scaling analysis for massive MIMO system is well presented in [8], they assume a relay fading channel with arbitrary rank mean, but do not address the overheads on ADCs. In [9], authors describe the energy efficient law for massive MIMO and address the issues with eavesdroppers and other security constraint rather not concerning the reduction in hardware cost and its complexity. In [10] and [11], power scaling methods for massive MIMO are presented, however they do not touch upon the hybrid beamforming aspect. The work in [12] illustrates the spectral and energy efficiency of multi-pair Massive MIMO with Hybrid Processing without considering antenna selection aspect. Until recently, most of the previous works have presented the significance of low-resolution ADCs considering the same number of RF chains as number of antennas in MIMO array [13-16] without presenting the trade-off in number of RF chains and the number of quantization bits. The reduced number of RF chains with low resolution ADCs has been investigated in [17-19] using analog phase shifter with analog processing. However, the analog phase shifters require additional power and hardware cost.

For massive MIMO receivers, processing with analog phase shifters and analog processing using switches was compared and the selection of antennas to reduce the number of RF chains is discussed in [20]. For mmWave channels, it is proven in [20] that, system with reduced number of RF chains can provide equal spectral efficiency as it could achieve with analog processing and analog phase shifters. The antenna selection scheme in [20] does not exploit the sparsity characteristics whereas the analog processing with phase shift does. Hence the channel do not put much limit on the antenna selection. The concept of antenna selection becomes very important in mmWave massive MIMO receivers. Indeed, for mmWave channels a greater number of RF chains could be reduced by the advent of antenna selection mechanism thereby reducing the significant amount of power consumption and hardware complexity [21 - 24]. To the author's best knowledge, there has been no work in the literature which has discussed power scaling in arena of massive MIMO, hybrid beamforming and antenna selection. In this paper, we present i) A power scaling models for massive MIMO receivers for perfect and imperfect CSI. ii) The capacity achieved by hybrid

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beamforming system with reduced number of RF chains. iii) Also, we propose an optimal quantization error aware antenna selection algorithm.

II. BACKGROUND

Increasing smartphone usage has led to an exponential increase in the transmission of multimedia content over mobile networks. This has, in turn, led to significant growth in global mobile traffic. Apart from handling the enormous wireless traffic, mobile networks should also be feasible to realize the exciting applications in new domains, such as Augmented/Virtual reality (AR/VR), Internet of thing(IoT), Internet of Vehicles(IoV), Device to Device(D2D) communication, Machine to Machine communication (M2M) to name a few. The legacy wireless networks cannot potentially support the exponentially increased mobile traffic and a large number of network services envisioned in the aforementioned new domains. The fifth-generation (5G) cellular networks promise to meet these demands, aiming to achieve nearly 10 Gbps data rates, to connect 1 million devices per square km, targets 1 millisecond round trip latency and 1000x bandwidth per unit area required to support the future applications.

A. Physical layer Technologies for 5G

The new physical layer technologies like millimeter wave, massive MIMO and Beamforming are considered as key enablers majorly contributing to realize the goals of 5G networks. The 5G systems operate in two frequency bands namely, sub-6 GHz (<6GHz) also referred as frequency range 1(FR-1) and frequency range 2 (FR-2; 24GH to 56 GHz) falls in mmWave band (30 GHz to 300 GHz). The available bandwidth in the mmWave band plays a key role in determining the larger data rates. In contradiction, the propagation loss at mmWave frequencies is substantial due to higher carrier frequencies. Their week diffraction ability renders it very sensitive to blockage by obstacles.

The smaller wavelengths of mmWave band allow to pack a large number of antennas in the same physical area. When the number of antenna elements is large (nearly 100 to 200), it is referred to as a massive MIMO antenna. A large number of antennas in massive MIMO results in huge spatial multiplexing gains thereby increasing the capacity of the network by several fold. Massive MIMO technology leads to reduced radiated power and greater simplicity in signal processing. Millimeter wave communication systems inherently use massive MIMO antennas. However the higher propagation loss and reduced scattering of mmWave lead to significantly different physical channels that require intelligent signal processing to exploit the changed propagation scenario. Millimeter wave communications have highly directional characteristics due to large antenna arrays. Hence spatial multiplexing and frequency reuse coupled with beamforming hold the key to improve network capacity.

The advantage of the MIMO system can be leveraged by a powerful technique called beamforming (directing the transmitting beam of an antenna in a particular direction). BF saves power, offers frequency reuse while increasing coverage. The analog type of BF contains a single RF chain connected to all the antenna elements through the analog phase shifters, while the digital BF has a separate RF chain for an individual antenna element. In the former category, the analog phase-shifters would influence to steer the signal emitted by the array in the desired direction. In the latter category, different signals are designed for each antenna in the digital domain. Digital beamforming also referred to as precoding, deals with creating multiple beams to multiplex several data streams, choosing the steering direction and choosing the transmit power (power allocation). Hybrid beamforming, is the compromise between the two (analog beamforming and digital beamforming). The number of RF chains used in HBF is smaller than the number of antennas thereby reducing the cost and complexity of the hardware.

B. Millimeter wave Hybrid Beamforming Technique

Beamforming with large antenna arrays is key for recognizing the gains in mmWave MIMO (mmWave massive MIMO)[25]. Naturally, optimal beamforming, precoder/combiner design strategies will play a critical role in the implementation of mmWave systems [26]. There is a vast difference among MIMO architectures at FR-1 and FR-2 bands [27]. In the FR-1 regime, complete signal processing action carried out in baseband digitally by assuming an individual RF chain, ADC /DAC for every antenna. But this model does not suite for FR-2 due to three main hardware constraints: First, Each RF chain requires a power amplifier, low noise amplifier, therefore its implementation becomes significantly difficult at mmWave as there would be large number of antennas. Second, the power consumption of the large number of ADCs/DACs would be substantially increased by the high sampling rate in mmWave regime (Giga samples per second) [28], and third, since antennas are closely spaced, the physical space limitation itself prohibits using a complete RF chain per antenna. These severe hardware restrictions have to lead to the development of new architectures specific to mmWave MIMO where signal processing is accomplished by a mixture of analog and digital domains, this is termed as hybrid analog-digital signal processing. Analog beamforming (RF beamforming) is the easiest signal processing approach deployed either transmitter or/and receiver [29]. It is considered as a suitable solution supported in IEEE 802.11ad standard. RF beamforming is implemented using a digitally controlled phase shifters, where all the antenna elements are connected to a single RF chain via these phase shifters. It can only support a single user with the single-stream transmission (multi-user, multi-stream benefits of MIMO could not be realized). The hybrid analog-digital architecture shown in Fig.1 uses a small number of transceivers of RF chains N_t^{RF}employed at the transmitter and RF chains at the receiver N_r^{RF}such that $N_s < N_t^{RF} < N_t$ and $N_s < N_r^{RF} < N_r$ respectively. N_s denotes the number of streams, N_t and N_r represents the number of antennas at transmitter and receiver respectively. In contrast to analog beamforming, hybrid architecture enables both spatial multiplexing and multiuser MIMO in mmWave. The hybrid structure allows fully-connected architecture where all antennas connected to each RF chain and partially connected architecture where the antenna array gets divided into sub-arrays, each sub-array connected to its RF chain, the later architecture of hybrid beamforming reducing the hardware complexity at a cost of less flexibility. Hybrid architectures can also be based on switching networks

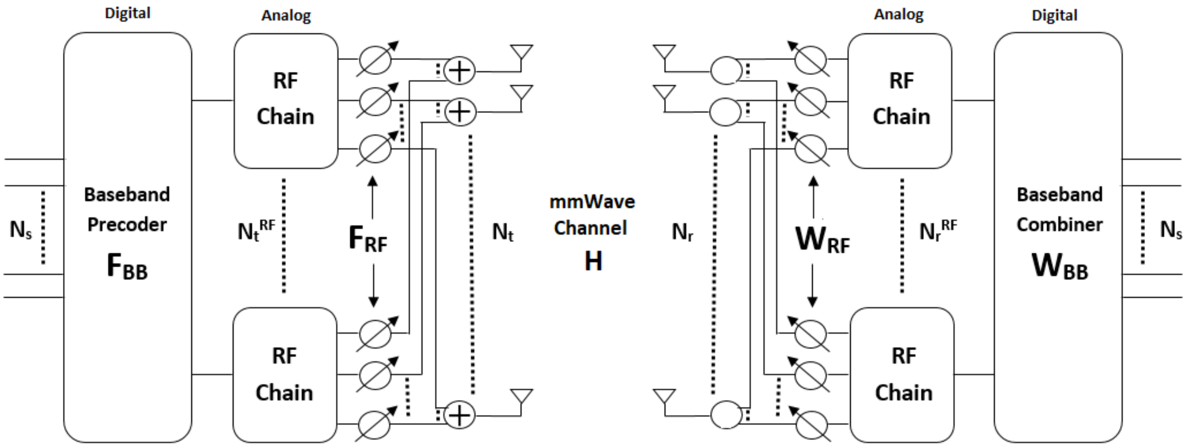

Fig. 1. Millimeter Wave Hybrid Beamforming System

to select subsets of antennas. Alternatively, to reduce the complexity, reduction of ADCs resolution to 1 to 3 bit/s leads to significant saving in power consumption.

III. SYSTEM MODEL

We assume a multi-user MIMO uplink scenario in which the base station (BS) is equipped with $\mathrm{N_r}$ antennas serving K users with a single antenna each. The number antennas at BS is assumed to be much larger than the number of users ($\mathrm{N_r} \gg \mathrm{K}$). Once BS receives the pilot signals from user, it selects N antennas and activates them for beamforming. The active antennas are connected to RF chains comprising ADCs. The baseband pilot signal $\boldsymbol{r} \in \mathbb{C}^{\mathrm{N_r}}$ received through a narrowband channel can be represented as

$$\boldsymbol{r} = \sqrt{\rho}\boldsymbol{Hs} + \boldsymbol{n} \tag{1}$$

Where ρ denotes the transmit power, $\boldsymbol{H}$ represents mmWave channel matrix, $\boldsymbol{s}$ is the pilot symbol vector and $\boldsymbol{n}$ being the additive white Gaussian noise (AWGN) vector. Here, $\boldsymbol{s}$ and $\boldsymbol{n}$ assumed to have zero mean and unit variance. Number of columns in $\boldsymbol{H}$ represents the number of users. Each column representing the channel vector corresponding to the respective user. The channel vector corresponding to user k is written as

$$\boldsymbol{h_k} = \sqrt{\gamma_k}\boldsymbol{g_k} \tag{2}$$

Here, γ_k is the large scale fading gain which includes geometric attenuation and shadowing effect, $\boldsymbol{g_k}$ denotes the small scaling gain vector for user k. The BS assumed to be having the knowledge of the channel $\boldsymbol{H}$. The BS selects N antennas and connects them to N RF chains. The analog signal in (1) received through the N selected antennas would become

$$\boldsymbol{r_{\mathcal{K}}} = \sqrt{\rho}\boldsymbol{H_{\mathcal{K}}s} + \boldsymbol{n_{\mathcal{K}}} \tag{3}$$

Where $\boldsymbol{\mathcal{K}}$ denotes the index vector of selected antennas with cardinality of $|\boldsymbol{\mathcal{K}}| = \mathrm{N}$, $\boldsymbol{r_{\mathcal{K}}} \in \mathbb{C}^{\mathrm{N}}$.

A. Power reduction Models

Massive MIMO systems can simultaneously serve tens of users, very large antenna arrays can substantially reduce intra-cell interference with simple signal processing and effect of small-scale fading can be averaged out by channel hardening. As the number of antennas grows large at BS, the channel vectors between the users and the BS become pairwise orthogonal. Furthermore, massive MIMO enable devices to reduce their transmit power helping them drain their batteries slower, thus prolonging the device lifetime.

Considering user 1 as the desired user without loss of generality, the received signal can be expressed in terms of desired signal and interference components as

$$\boldsymbol{r_1} = \sqrt{\rho\gamma_1}\boldsymbol{g_1 s_1} + \sqrt{\rho}\textstyle\sum_{i=2}^{\mathrm{K}}\sqrt{\gamma_i}\,\boldsymbol{g_i s_i} + \boldsymbol{n} \tag{4}$$

the matched filter receiver or maximal ratio combiner(MRC) for user 1 is given as

$$\boldsymbol{r_1} = \sqrt{\rho\gamma_1}\|\boldsymbol{g_1}\|\boldsymbol{s_1} + \sqrt{\rho}\textstyle\sum_{i=2}^{\mathrm{K}}\sqrt{\gamma_i}\,\frac{\boldsymbol{g_1}^{\mathrm{H}}}{\|\boldsymbol{g_1}\|}\boldsymbol{g_i s_i} + \frac{\boldsymbol{g_1}^{\mathrm{H}}}{\|\boldsymbol{g_1}\|}\boldsymbol{n} \tag{5}$$

and the signal to noise interference ratio (SINR) is given as,

$$SINR = \frac{\rho\|g_1\|^2}{\rho\sum_{i=2}^{\mathrm{K}} E\left\{\left|\frac{g_1^{\mathrm{H}}}{\|g_1\|}g_i\right|^2\right\} + E\left\{\left|\frac{g_1^{\mathrm{H}}}{\|g_1\|}n\right|^2\right\}} \tag{6}$$

Recalling that the noise samples are distributed as $\mathcal{CN}\ (0{,}1)$ and it follows that $E\left\{\left|\frac{\boldsymbol{g_1}^{\mathrm{H}}}{\|\boldsymbol{g_1}\|}\boldsymbol{n}\right|^2\right\}$ =1. Further, coefficients of $\boldsymbol{g_i}$ are distributed as $\mathcal{CN}\ (0, \gamma_i)$, hence it follows $E\left\{\left|\frac{\boldsymbol{g_1}^{\mathrm{H}}}{\|\boldsymbol{g_1}\|}\boldsymbol{g_i}\right|^2\right\} = \gamma_i$.

Therefore, SINR can be further simplified as

$$SINR = \frac{\rho\|\boldsymbol{g_1}\|^2}{\rho\sum_{i=2}^{\mathrm{K}}\gamma_i + 1} \tag{7}$$

Considering the power of each user is scaling inversely as the number of antennas at the BS $(\frac{E_u}{N_r})$, the SINR scales as

$$SINR = \frac{E_u\frac{\|\boldsymbol{g_1}\|^2}{\mathrm{N_r}}}{E_u\left(\frac{1}{\mathrm{N_r}}\sum_{i=2}^{\mathrm{K}}\gamma_i\right) + 1} = E_u\gamma_1 \tag{8}$$

And the rate scales as

$$log_2(1 + SINR) = log_2(1 + E_u\gamma_1) \tag{9}$$

Thus, we can maintain constant rate even with power scaling as $\frac{1}{\mathrm{N_r}}$, thus the power of each user can reduce inversely proportional to the number of antennas $\mathrm{N_r}$. Similarly, if the channel is not known at the BS and the channel undergoes uncertainties, then the power of each user can be reduced by the factor of $\frac{1}{\sqrt{\mathrm{N_r}}}$.

Another way to reduce the power consumption in massive MIMO systems is by using low-resolution ADCs. After the antenna selection, real and imaginary components of the received signal $\boldsymbol{r}_{\mathcal{K}_i}$ are quantized at the ADC pairs for analytical tractability. The Quantized signal can be represented as

$$\boldsymbol{y} = Q(R_e\{\boldsymbol{r}_{\mathcal{K}}\}) + jQ(I_m\{\boldsymbol{r}_{\mathcal{K}}\})$$

$$= \alpha\sqrt{\rho}\boldsymbol{H}_{\mathcal{K}}\boldsymbol{s} + \alpha\boldsymbol{n}_{\mathcal{K}} + \boldsymbol{q} \qquad (10)$$

Where, Q denotes the element wise quantization function, $\alpha = 1 - \beta$ is the quantization gain and β being the normalized mean square quantization error given as $\beta = \frac{E\left\{\left|y_i - y_{q_i}\right|^2\right\}}{E\{\|\boldsymbol{y}_i\|^2\}}$.

q represents additive quantization noise vector that follows as the complex Gaussian distribution with $\mathcal{CN}\,(0, \boldsymbol{R}_{qq})$. The covariance matrix $\boldsymbol{R}_{qq}$ is written as

$$\boldsymbol{R}_{qq} = \alpha(1-\alpha)\; diag\{\rho\boldsymbol{H}_{\mathcal{K}}{\boldsymbol{H}_{\mathcal{K}}}^{H} + \boldsymbol{I}\} \qquad (11)$$

IV. PROPOSED SCHEME FOR ANTENNA SELECTION

In this section we propose an antenna selection algorithm and also a sophisticated method to determine the optimal number of antennas to be selected is presented. We consider a capacity maximization problem and draw a solution that enhances the capacity for the channel matrix. We formulate the antenna selection problem as to first determine the optimal number of antennas to be selected that maximizes the capacity and then antenna selection vector describing the indices of N antennas selected out of $\mathrm{N_r}$. We employ the generalized spatial modulation (GSM) scheme to determine the optimal number of antennas. The net achievable rate in GSM is given as in (12)

$$\mathrm{R} = \left[\log_2\left(\binom{\mathrm{N_r}}{\mathrm{X}}\right) + \mathrm{X}\log_2\mathrm{M}\right] \qquad (12)$$

Where M is the M-ary modulation bits. The number of antennas to be selected is found as the value of X for which the achievable rate described in (12) is maximum.

$$\mathrm{N} = \underset{\mathrm{X}\subset\{1\ldots\ldots\mathrm{N_r}\}}{\operatorname{argmax}}\,(\mathrm{R}) \qquad (13)$$

Here, we propose a novel antenna selection scheme based on the capacity maximization approach presented in [17]. The capacity for the channel matrix $\boldsymbol{H}_{\mathcal{K}}$ is written as

$$C(\boldsymbol{H}_{\mathcal{K}}) = \log_2\left|\boldsymbol{I} + \rho\alpha{\boldsymbol{D}_{\mathcal{K}}}^{-1}\boldsymbol{H}_{\mathcal{K}}{\boldsymbol{H}_{\mathcal{K}}}^{\mathrm{H}}\right| \qquad (14)$$

where, $\boldsymbol{D}_{\mathcal{K}}$ is the diagonal matrix with $1 + \rho(1-\alpha)\left\|f_{\mathcal{K}_i}\right\|^2$ for $i = 1 \ldots\ldots\ldots N$ at its diagonal entries. Equation (14) can be decomposed and the capacity for every selected can be computed as

$$C(\boldsymbol{H}_{\boldsymbol{n+1}}) = C(\boldsymbol{H}_{\boldsymbol{n}}) + \log_2\left(1 + \frac{\rho\alpha}{d_{\mathcal{K}(n+1)}}c_{\mathcal{K}(n+1)}, n\right) \quad (15)$$

Where

$$c_{\mathcal{K}(n+1),n} = f^{H}_{\mathcal{K}(n+1)}\left(1 + \rho\alpha{\boldsymbol{H}_{\boldsymbol{n}}}^{\mathrm{H}}{\boldsymbol{D}_{\boldsymbol{n}}}^{-1}\boldsymbol{H}_{\boldsymbol{n}}\right)^{-1} f_{\mathcal{K}(n+1)}$$

$\boldsymbol{f}^{\mathrm{H}}_{\boldsymbol{\mathcal{K}(n+1)}}$ denotes the $(n+1)^{th}$ selected row of $\boldsymbol{H}$.

To maximize $C(\boldsymbol{H}_{\boldsymbol{n+1}})$, any antenna j among N (number of antennas to be selected) out of $\mathrm{N_r}$ is selected such that it maximizes $c_{j,n}$. Accordingly the antenna selection algorithm is illustrated as

Algorithm: Capacity based Quantization aware antenna selection (QAS)

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1. Initialize $\mathcal{T} = \{1 \ldots\ldots\ldots \mathrm{N_r}\}$ and $\mathrm{Q} = I$.
2. Compute number of antennas $(\mathrm{X} = \mathrm{N})$ to be selected.
    a. Initialize antenna gain and compute penalty:
    b. $c_j = \|f_j\|^2$ and $d_j = 1 + \rho(1-\alpha)\|\boldsymbol{f}_{\boldsymbol{\mathcal{K}_i}}\|^2$
       for $j \in \mathcal{T}$.
3. Select antenna j such that $j = \underset{c_{j,n}}{\operatorname{argmax}}\, C(\boldsymbol{H}_{\boldsymbol{n+1}})$.
    a. Update the candidate set: $\mathcal{T} = \mathcal{T}\setminus\{j\}$.
4. Go to step 3 and repeat until N antennas are selected.
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V. RESULTS AND DISCUSSION

Figure 2 depicts the performance of power scaling analysis for massive MIMO receivers presented in this work. With perfect CSI while 10 users being served simultaneously in the uplink assuming pilot transmit power 10dB each, a constant rate can be maintained even when the transmit power is scaled as $\frac{1}{\mathrm{N_r}}$. Hence, the power of each user can decrease inversely proportional to the number of antennas at the BS. Furthermore, the power of the desired signal rises $\mathrm{N_r}$ times the multi-user interference added with noise, and as $\mathrm{N_r}$ becomes very large the channel vectors of the users become pairwise orthogonal and this completely defeats the multi-user interference using the simple low complexity matched filter. It is noticed that the power scaling in imperfect CSI cannot be $\frac{1}{\mathrm{N_r}}$ because of the transmit power decreases and CSI estimation error increases as $\frac{\mathrm{N_r}}{\rho\text{*number of users}}$, thus it is further examined and noted as the consistency in sum-rate can be achieved if the power scaling is done as $\frac{1}{\sqrt{\mathrm{N_r}}}$ as depicted in Fig.3.

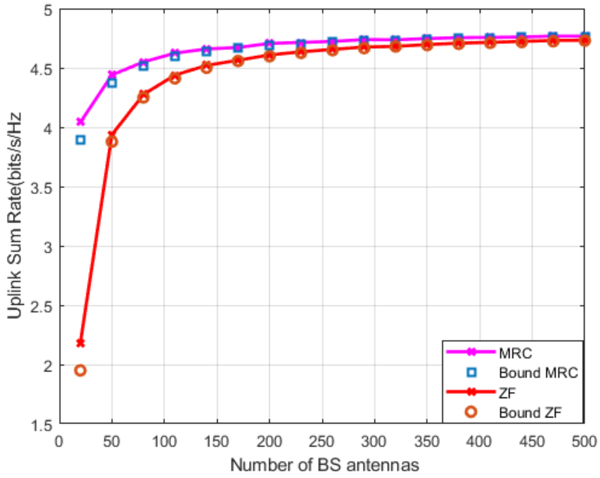

Fig. 2. Power scaling in massive MIMO with perfect CSI

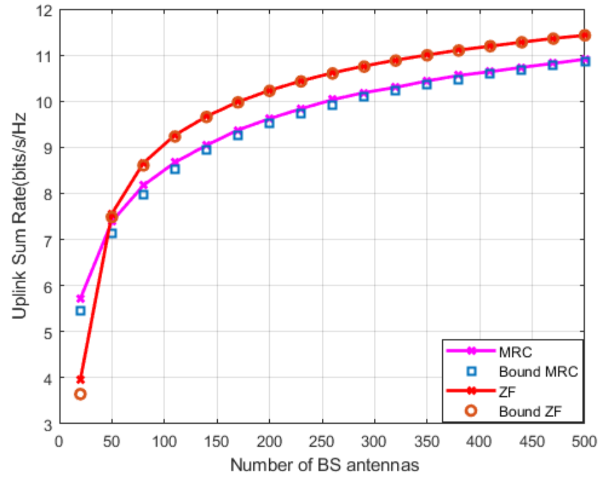

Fig. 3. Power scaling in massive MIMO with imperfect CSI

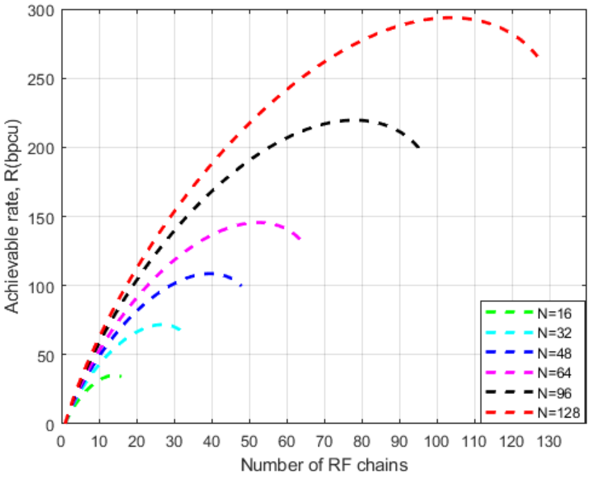

Fig. 4. Achievable rate versus number of RF chains in GSM

The achievable rate versus the number of RF chains for a given N_r shows very interesting behavior in Fig.4. For a given N_r, there is an optimum number of RF chains that maximizes the achievable rate R as depicted in Table I. It is interesting to see that the maximum R does not necessarily occur at Number of RF chains= N_r but at some Number of RF chains< N_r.

TABLE I
OPTIMUM NUMBER OF RF CHAINS TO BE USED

Number of Antennas (N_r)	Optimum Number of RF chains
16	14
32	27
48	40
64	52
96	78
128	104
256	206

In Fig.5, the investigation on capacity versus SNR is presented for a mmWave system model equipped with 32 antennas at BS and 8 RF chains, a mmWave sparse channel having the sparsity level of 8 and with 6 data streams being simultaneously transmitted. It is noticed that HBF scheme outperforms the conventional MIMO adopting digital beamforming.

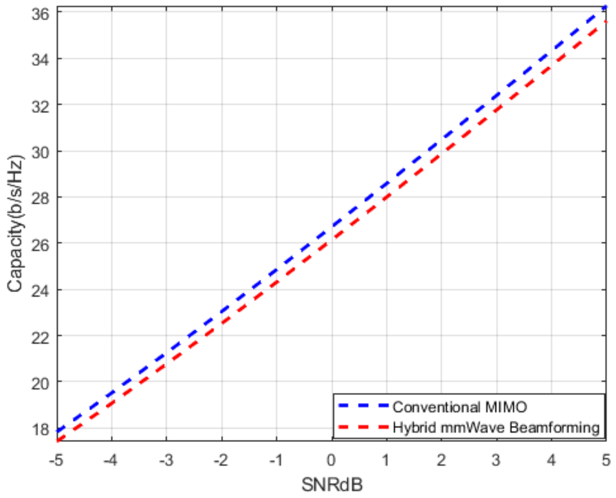

Fig. 5. Performance of HBF for reduced number of RF chains

Figure 6 describes the evaluation of the proposed QAS algorithm as compared to the conventional antenna selection algorithm in [30]. It presents a similar performance to the optimal selection case under a precise quantization assumption. We also cover a random selection case for a reference. The Rayleigh channel with a zero mean and unit variance is considered, the log-distance path loss model in [30] is being adopted, 8 users are assumed to be randomly distributed over a single cell with minimum and maximum distance between BS and users being 20 meters and 100 meters respectively. The carrier frequency of 28 GHz and a bandwidth of 200 MHz is assumed. 256 antennas at BS, 52 RF chains and ADCs with 3 quantization bits are used in the simulation. It is observed that the capacity achieved by the proposed method is better than the conventional antenna selection and random antenna selection methods.

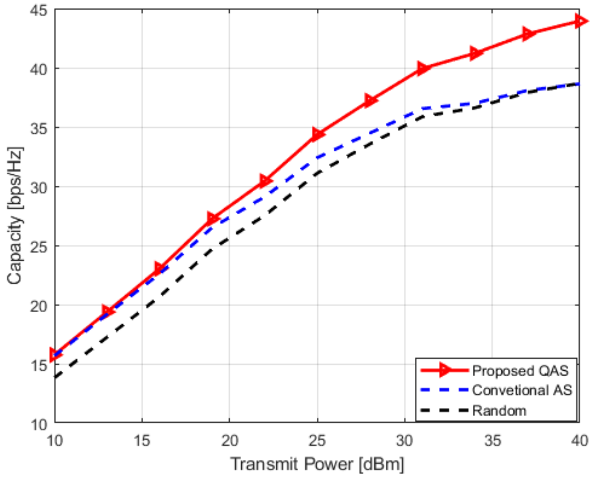

Fig. 6. System capacity for different transmit power

Figure 7 presents the performance of the proposed antenna selection algorithm with respect to the symbol error rate (SER) against the transmitted power. It is noticed that the SER for the proposed method is significantly reduced as compared to the conventional algorithm. The proposed QAS algorithm outperforms the conventional antenna selection algorithm.

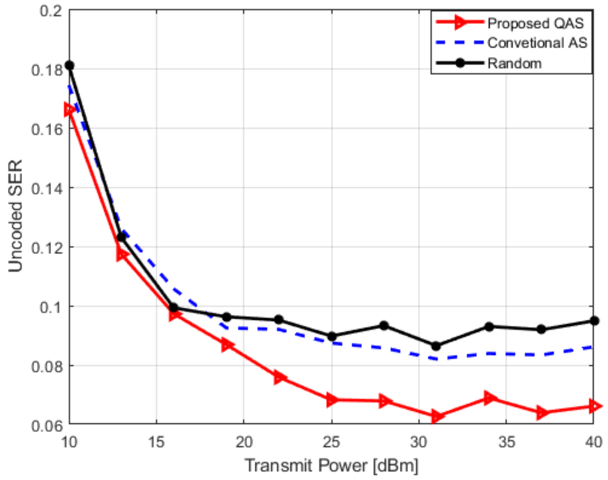

Fig. 7. SER performance of proposed QAS algorithm

VI. CONCLUSION

Advanced antenna systems will enable the 5G implementation. The component engineering behind 5G implementation is focusing on massive MIMO systems and can only be implemented with smart and reconfigurable antennas. With such massive number of antenna elements and RF chains at the receiver, power consumption and hardware complexity pose a challenge to design engineers.

This work reduces the power and hardware complexity by swiftly migrating to Hybrid beamforming techniques. Hybrid beamforming is a compromise between analog and digital beamforming with few RF chains which will optimally exploit the full potential of massive MIMO systems. Here a quantization aware algorithm has been proposed to further reduce the power consumption. The results are not only encouraging but outperforms the conventional techniques. The algorithm also executes additional functionality of antenna selection with appropriate antenna elements. This work has reduced the demand for power and hardware which is good for both service providers and environment. Further AI and ML techniques can be applied to reduce the number of antennas selected without any compromise on the reception.

REFERENCES

[1] Ngo, Hien Quoc, Erik G. Larsson, and Thomas L. Marzetta. "Energy and spectral efficiency of very large multiuser MIMO systems." *IEEE Transactions on Communications* 61.4 (2013): 1436-1449.

[2] Hoydis, Jakob, Stephan Ten Brink, and Mérouane Debbah. "Massive MIMO in the UL/DL of cellular networks: How many antennas do we need?." (2013).

[3] Larsson, Erik G., et al. "Massive MIMO for next generation wireless systems." *IEEE communications magazine* 52.2 (2014): 186-195.

[4] Roh, Wonil, et al. "Millimeter-wave beamforming as an enabling technology for 5G cellular communications: Theoretical feasibility and prototype results." *IEEE communications magazine* 52.2 (2014): 106-113.

[5] Wang, Cheng-Xiang, et al. "Cellular architecture and key technologies for 5G wireless communication networks." *IEEE communications magazine* 52.2 (2014): 122-130.

[6] Kutty, Shajahan, and Debarati Sen. "Beamforming for millimeter wave communications: An inclusive survey." *IEEE Communications Surveys & Tutorials* 18.2 (2015): 949-973.

[7] Lu, Lu, et al. "An overview of massive MIMO: Benefits and challenges." *IEEE journal of selected topics in signal processing* 8.5 (2014): 742-758.

[8] Zhang, Qi, et al. "Power scaling of uplink massive MIMO systems with arbitrary-rank channel means." *IEEE Journal of Selected Topics in Signal Processing* 8.5 (2014): 966-981.

[9] Zhu, Jun, and Wei Xu. "Securing massive MIMO via power scaling." *IEEE Communications Letters* 20.5 (2016): 1014-1017.

[10] Liu, Wenjia, Shengqian Han, and Chenyang Yang. "Energy efficiency scaling law of massive MIMO systems." *IEEE Transactions on Communications* 65.1 (2016): 107-121.

[11] Xu, Wei, et al. "Spectral and energy efficiency of multi-pair massive MIMO relay network with hybrid processing." *IEEE Transactions on Communications* 65.9 (2017): 3794-3809.

[12] Jin, Si-Nian, Dian-Wu Yue, and Ha H. Nguyen. "Power scaling laws of massive MIMO full-duplex relaying with hardware impairments." *IEEE Access* 6 (2018): 40860-40882.

[13] Mezghani, Amine, and Josef A. Nossek. "On ultra-wideband MIMO systems with 1-bit quantized outputs: Performance analysis and input optimization." *2007 IEEE International Symposium on Information Theory*. IEEE, 2007.

[14] Mo, Jianhua, and Robert W. Heath. "Capacity analysis of one-bit quantized MIMO systems with transmitter channel state information." *IEEE transactions on signal processing* 63.20 (2015): 5498-5512.

[15] Rusu, Cristian, Nuria González-Prelcic, and Robert W. Heath. "Low resolution adaptive compressed sensing for mmWave MIMO receivers." *2015 49th Asilomar Conference on Signals, Systems and Computers*. IEEE, 2015.

[16] Choi, Junil, Jianhua Mo, and Robert W. Heath. "Near maximum-likelihood detector and channel estimator for uplink multiuser massive MIMO systems with one-bit ADCs." *IEEE Transactions on Communications* 64.5 (2016): 2005-2018.

[17] Choi, Jinseok, Brian L. Evans, and Alan Gatherer. "ADC bit allocation under a power constraint for mmWave massive MIMO communication receivers." *2017 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP)*. IEEE, 2017.

[18] Mo, Jianhua, et al. "Hybrid architectures with few-bit ADC receivers: Achievable rates and energy-rate tradeoffs." *IEEE Transactions on Wireless Communications* 16.4 (2017): 2274-2287.

[19] Choi, Jinseok, Brian L. Evans, and Alan Gatherer. "Resolution-adaptive hybrid MIMO architectures for millimeter wave communications." *IEEE Transactions on Signal Processing* 65.23 (2017): 6201-6216.

[20] Méndez-Rial, Roi, et al. "Hybrid MIMO architectures for millimeter wave communications: Phase shifters or switches?." *IEEE Access* 4 (2016): 247-267.

[21] Gao, Xiang, et al. "Massive MIMO in real propagation environments: Do all antennas contribute equally?." *IEEE Transactions on Communications* 63.11 (2015): 3917-3928.

[22] Gharavi-Alkhansari, Mohammad, and Alex B. Gershman. "Fast antenna subset selection in MIMO systems." *IEEE transactions on signal processing* 52.2 (2004): 339-347.

[23] Gorokhov, Alexei, Dhananjay Gore, and Arogyaswami Paulraj. "Receive antenna selection for MIMO flat-fading channels: theory and algorithms." *IEEE Transactions on Information Theory* 49.10 (2003): 2687-2696.

[24] Sadek, Mirette, Alireza Tarighat, and Ali H. Sayed. "Active antenna selection in multiuser MIMO communications." *IEEE Transactions on Signal Processing* 55.4 (2007): 1498-1510.

[25] Yang, Nan, et al. "Safeguarding 5G wireless communication networks using physical layer security." IEEE Communications Magazine 53.4 (2015): 20-27.

[26] Heath, Robert W., et al. "An overview of signal processing techniques for millimeter wave MIMO systems." IEEE journal of selected topics in signal processing 10.3 (2016): 436-453.

[27] Wei, Lili, et al. "Key elements to enable millimeter wave communications for 5G wireless systems." IEEE Wireless Communications 21.6 (2014): 136-143.

[28] Boccardi, Federico, et al. "Five disruptive technology directions for 5G." IEEE communications magazine 52.2 (2014): 74-80.

[29] Alkhateeb, Ahmed, et al. "MIMO precoding and combining solutions for millimeter-wave systems." IEEE Communications Magazine 52.12 (2014): 122-131.

[30] Erceg, Vinko, et al. "An empirically based path loss model for wireless channels in suburban environments." *IEEE Journal on selected areas in communications* 17.7 (1999): 1205-1211.