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Antenna selection and transmission power for energy efficiency in downlink massive MIMO systems

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Abstract: Massive multiinput-multioutput (M-MIMO) systems are crucial for maximizing energy efficiency (EE) in fifth-generation (5G) wireless networks. A M-MIMO system's achievable high data rate is highly related to the number of antennas, but increasing the number of antennas the system raises energy consumption. In this paper, we derive ergodic EE based on the optimal transmit power and joint optimization antenna selection (AS) with impact pilot reuse sequences (PRSs). We apply Newton's method and the Lagrange multiplier to derive jointly optimized AS and optimal transmission power under the effect of PRSs. The proposed algorithm prevents repeated searching for joint optimal AS and optimal transmission power to reduce the complexity caused by an increasing number of antennas. From the simulation results, we conclude that EE could be maximized by employing the minimal PRSs and transmission power that are greater than the circuit's power consumption. The proposed algorithm offers maximum EE by repeating a minimizing pilot signal until the optimal AS and transmission power are achieved.

Key words: Massive multiinput-multioutput, energy efficiency, fifth-generation, quality of service

1. Introduction

Massive multiinput-multioutput systems are an exciting area of study and an important technology for fifth-generation (5G) wireless networks that support high-data-rate traffic. Improving energy efficiency (EE) in a massive multiinput-multioutput (M-MIMO) system depends on reducing transmission power per active user (UE) and per antenna. However, energy cost is problematic; addressing this requires improving wireless networks to handle the increasing demand for EE. An increase in the number of antenna arrays at a base station (BS) results in greater power consumption due to a higher number of radio frequency (RF) chains and intercell interference for channels. Besides, greater numbers of RF chains in both BS and UE consume more power due to processing activities in the digital-to-analog converter, power amplifier, multiplexer, and filter. Moreover, all antennas at the BS need to connect to the RF chains. It has been reported that BSs are responsible for 80% of the energy consumed in cellular networks, which cannot be neglected and has become a technical challenge [1]. Most EE techniques focus on reducing the transmission power in large-scale MIMO systems when the transmission power is high. Furthermore, regarding energy resources in cellular networks, power allocation algorithms require minimizing power consumption and maximizing the achievable data rate [2,3]. Previous

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studies in [4,5] focused on the selection of an optimal number of RF chains to reduce the circuit consumption power at the BS. In addition, the authors in [6] reviewed the effects of pilot contamination (PC) on EE and proposed improving EE for single cells in an M-MIMO system by making downlink (DL) and uplink dependent on a new, realistic power consumption model for transmission power, active users, and AS. Similarly, [7] proposed that channel capacity could be maximized depending on the AS and limited power consumption. The authors in [8] studied the number of antennas per UE that managed to achieve the optimal EE performance by considering consumption circuit power in the DL. The key requirement for maximizing EE is computing the transmission power algorithm, optimal AS, and affected pilot sequences. The number of selected antennas is very important, because when the RF chains are connected with the selected antennas, those antennas consume more power and impact EE. In this study, we derived an ergodic EE based on optimized AS and optimal transmission power with the impact of pilot interference by applying Newton's method and the Lagrange multiplier. This enabled us to reuse pilot sequences, minimize the total transmit power based on the proportional number of AS, and reduce the number of RF chains at the receiver by allocating every RF chain to one of the massive receiver antennas.

2. System model

The downlink signal of the multiuser-MIMO system included the BS, which contained many antenna arrays, L, and received data from many random UEs, K. The achievable DR for every UE was limited due to interference and noise between users. The received signal vector for the UEs is given by:

$$\gamma_k = \sqrt{\Gamma_k \alpha}\, h \,\pounds\, \hat{W}\, x + n, \tag{1}$$

where γ_k represents k received antennas, α is the average transmission power, and Γ_k represents the pilot sequences for all users, which are higher than the data signal power to enhance channel estimation. Moreover, each user transmits pilot sequences synchronously to each cell from the beginning coherence channel; the vector pilot becomes $\Gamma_k \Gamma_k^H = 1$ and $\Gamma_i \Gamma_j^H = 0$, $\forall i \neq j$. We assumed that the BS was working with perfect channel state information (CSI) and the feedback channel is assumed to be error-free and zero-delay, which represents the ideal case, where h is $K \times L$ independent and identically distributed (i.i.d.) for the Rayleigh fading channel matrix and the CSI with zero delay is optimal transmission in that it achieves the same minimum mean square error (MMSE) for channel estimation [9]. From Eq. (1), x is the L transmission antenna signal vector, $\hat{W}$ is the $L \times K$ precoding matrix to mitigate interference, $\pounds$ is the transmission power normalized and represented as $\pounds = \sqrt{L}/K$, and n is the noise vector associated with the selected receiver antenna. The DL transmission that each UE receives from all BSs, which achieves a DR at the receiver when $L \geq K+1$ and contains the desired signal, interference, can be written as:

$$\gamma_k = \underbrace{\sqrt{\Gamma_k \frac{\alpha L}{K}} h_k \hat{W}_k x_k}_{desired\ signal} + \underbrace{\sqrt{\Gamma_k \frac{\alpha L}{K}} \sum\nolimits_{l \neq k}^{K} h_k \hat{W}_l x_l}_{interference} + \underbrace{n_k}_{noise} \tag{2}$$

The M-MIMO system sends power to every UE, taking into account that in the DL, the transmit PRS delivered from BS to K should be allocated to reduce interference [10–13]. The received signal-to-interference-noise ratio

(SINR) in terms of UE is:

$$\varsigma_K = \frac{\Gamma_k \frac{\alpha L}{K} \left| h_k \hat{W}_k \right|^2}{\underbrace{\Gamma_k \frac{\alpha L}{K} \left| \sum_{l \neq k}^{K} h_k \hat{W}_l \right|^2} + \mathcal{N}}, \tag{3}$$

where $\mathcal{N}$ is the noise power; the high data rate (DR) for the users depends on the number of available PRSs, due to the limited coherence channel interval, which can be expressed as

$$R_k\left(\Gamma_k\right) = \sum_{k=1}^{K} E\left[\log_2\left(1 + \frac{\Gamma_k \frac{\alpha L}{K} \left| h_k \hat{W}_k \right|^2}{\underbrace{\Gamma_k \frac{\alpha L}{K} \left| \sum_{l \neq k}^{K} h_k \hat{W}_l \right|^2} + \mathcal{N}}\right)\right] \tag{4}$$

According to the number of UEs, K, and the number of selected antennas, every UE has a transmission data rate of:

$$R\left(\Gamma_k\right) = K \log_2\left(1 + \frac{\Gamma_k \, \alpha \, L}{\left(I + \mathcal{N}\right) K}\right). \tag{5}$$

An approximation of the achievable DR in a M-MIMO system, considering the number of transmission antennas, L, and the number of UEs, K, can be expressed as:

$$R_{tot}^{approx}\left(\Gamma_k\right) \approx K\beta \log_2\left(1 + \frac{\Gamma_k \, \alpha \, L}{\left(I + \mathcal{N}\right) K}\right), \tag{6}$$

where β represents the bandwidth of the baseband signal and $I = \Gamma_k \frac{\alpha L}{K} \left| \sum_{l \neq k}^{K} h_k \hat{W}_l \right|^2$ reflects the accuracy of the interuser interference for the estimation channel.

2.1. Energy efficiency

Some losses occur in the EE when transmitting a large number of PRSs using maximum transmit power, which eventually affects the achievable high DR with a large number of antennas L. We used the new model to improve EE by reducing the consumption power; this slightly affected the data rate. For an arbitrary signal-to-noise ratio (SNR) value, EE can be expressed as a concave function depending on $R\left(\Gamma_k\right)$ with Q_{tot}, which can be written as:

$$\varepsilon = \frac{R_{tot}^{approx}\left(\Gamma_k\right)}{Q_{tot}} = \frac{K\beta \log_2\left(1 + \frac{\Gamma_k \, \alpha \, L}{(I+\mathcal{N})K}\right)}{Q_{tot}}. \tag{7}$$

First, we analyzed the effect of increasing L on EE, and then we solved the reduced consumption power algorithm for EE in DL. Evaluating EE required determining the total transmission power using the following equation:

$$Q_{tot} = L Q_c + Q_{PA}, \tag{8}$$

where Q_{PA} represents the DL total power consumed by the power amplifier for pilot sequences and data transmission and Q_c represents dynamic power consumption proportional to the number of transmission antennas and the circuit power of the RF chains. Circuit power consumption increases proportional to the number of antennas, L. From the practical view of power consumption, we could not ignore the circuit power consumption when increasing the number of antennas. In addition, circuit power consumption, Q_c, represents baseband processing power, Q_{BB}, due to conversion from analog to digital or digital to analog (ADC/DAC); Q_{RF} is the power consumption of each antenna in the RF chains due to the noise amplifier, where $Q_c = Q_{BB} + Q_{RF}$. Reducing the number of RF chains for EE requires that the number of antennas available for selection be less than the total number of available antennas. The total power consumed by the power amplifier, related to transmission power, α, according to [14,15], exploited the AS for each subcarrier, which caused imbalance across the transmit antenna, as given by:

$$Q_{PA} = \frac{\nu \ \alpha \Gamma_k}{\vartheta}. \tag{9}$$

The peak-to-average power ratio (PAPR), according to [16], is given as:

$$\nu = 3 \times \left[\frac{L - 2\left(L\right)^{1/2} + 1}{L - 1} \right]. \tag{10}$$

The efficiency of high-power amplifiers (HPAs), ϑ, is given as:

$$\vartheta = \frac{\Gamma_k \, \alpha}{Q_{in}}, \tag{11}$$

where Q_{in} is the supply power. We considered that the pilot sequences could efficiently mitigate pilots at an increased number of antennas, L. The power consumed for a number of RF chains at the BSs can be expressed as:

$$Q_{tot} = LQ_c + \nu \, \Gamma_k \frac{\alpha}{\vartheta}. \tag{12}$$

The EE can be expressed as:

$$\varepsilon = \frac{R_{tot}^{approx}\left(\Gamma_k\right)}{Q_{tot}} = \frac{K \beta \log_2 \left(1 + \frac{\Gamma_k \, \alpha \, L}{(I + N)K}\right)}{L \, Q_c + \nu \, \Gamma_k \frac{\alpha}{\vartheta}}. \tag{13}$$

In this paper, we considered that PC affected channel estimation in the EE. Consequently, we maximized EE using optimization methods for proposed joint AS and optimal transmission. The subsequent sections provide detailed explanations.

2.2. Proposed joint antenna selection scheme

In this subsection, we discuss the proposed use of AS to reduce the number of RF chains to L.

In a high-SNR regime: High SNR is necessary in the case $L \leq M$ to maintain the degrees of freedom of the channel $m = rank\left(h\right) = \min\left[L_{\max}, M\right]$ and prevent excessive rate loss. Suppose we select $K \leq L \leq \min\left[L_{\max}, M\right]$ out of M transmit antennas from the simple approximation for $\left(1 + \frac{\Gamma_k \, \alpha \, L}{(I +, N)K}\right)$. In this case, the number of selected antennas would be incapable of reducing the total power consumption. Therefore, to reduce the transmission power, we used the AS optimization problem in Eq. (13).

In the low-SNR regime: Suppose we select L transmit antennas with equal power allocation. The channel associated with the largest eigenvalue of h_k, the capacity for channel increase, is very large at low SNRs, while for high SNRs, it tends to a fixed value from a simple approximation of $\left(1+\frac{\Gamma_k\,\alpha\,L}{(I+\mathcal{N})K}\right)$. In different AS, the data rates also tend to have improved EE. In the low-SNR regime (low power budget), the input power is allocated to the interface that has a better channel condition, so power loading can improve EE. Also, its effectiveness depends on the particular AS scheme $L \ll M$. The closed form for EE per AS in the high-SNR regime can be described as:

$$\max_{L} \frac{K\beta\log_2\left(1+\frac{\Gamma_k\,\alpha\,L}{(I+\mathcal{N})K}\right)}{LQ_c+\nu\,\Gamma_k\frac{\alpha}{\vartheta}}. \tag{14}$$

From Eq. (14), if the number of antennas is fixed, the EE can be maximized for any transmit power α because the nominator of transmitting power α and pilot reuse Γ_k are proportional to EE.

$$st. \quad K \leq L \leq \min\left[L_{\max},\, M\right], \tag{15}$$

$$L\,Q_c+\nu\,\Gamma_k\frac{\alpha}{\vartheta} \leq Q_{\max}, \tag{16}$$

where $Q_{\max}$ is the maximum power constraint, M is the available number of antennas, and $L_{\max} = \left(Q_{\max}-\nu\,\Gamma_k\frac{\alpha}{\vartheta}\right)/Q_c$ for data power and nonnegative pilot sequences. To reduce energy consumption, we used the AS algorithm, which selected a subset of the number of transmitted antennas more than the number of RF chains under transmit power constraints and pilot sequences reuse. We also assumed that maximal EE could be achieved with the number of antennas L per BS optimized with respect to the available transmission power. A general nonlinear fractional program can be formulated as:

$$\max_{L\epsilon\tau} \bar{\varepsilon}\left(L\right) = \frac{\Delta_1\left(L\right)}{\Delta_2\left(L\right)}, \tag{17}$$

where $\tau \subseteq \psi$, Δ_1, $\Delta_2 : \tau \rightarrow \psi$ and $\Delta_2\left(L\right) >$; the problem in Eq. (17) is called a concave-convex fractional program if Δ_1 is concave, Δ_2 is convex, and τ is a convex set. This kind of fractional program can be transformed to an equivalent convex program, with ψ as the antenna set of the cell. In terms of the fractional program in Eq. (17), in accordance [17], the EE constraint can be arranged as follows:

$$\max_{L\epsilon\tau,\ \varepsilon\in\psi} \bar{\varepsilon}$$

$$s.t \qquad \frac{\Delta_1\left(L\right)}{\Delta_2\left(L\right)} - \bar{\varepsilon} \geq 0. \tag{18}$$

From Eq. (18), we can obtain the following:

$$\Delta_1\left(L\right) - \bar{\varepsilon}\Delta_2\left(L\right) \geq 0. \tag{19}$$

Depending on Eq. (19) and using Newton's method, we can rewrite Eq. (17) in terms of the fractional program as:

$$\xi\left(\bar{\varepsilon}\right) = \max_{L} \Delta_1\left(L\right) - \bar{\varepsilon}\,\Delta_2\left(L\right) = 0, \tag{20}$$

where Δ_1 is concave and Δ_2 is convex, and $\Delta_1(L) - \bar{\varepsilon}\Delta_2(L)$ is concave with a fixed value of $\bar{\varepsilon}$. Let $\bar{\varepsilon}$ be the optimum value of the objective function in Eq. (17). According to Eq. (13), the problem for joint AS can be expressed as:

$$L^* = \arg\max_{L} \frac{K\beta \log_2\left(1 + \frac{\Gamma_k\, \alpha\, L}{(I+\mathcal{N})K}\right)}{LQ_c + \nu\, \Gamma_k \frac{\alpha}{\vartheta}}. \tag{21}$$

The optimal AS that corresponds to maximal EE by updating the iteration for all users to find the root of $\xi(\varepsilon_n)$ can be found using Newton's method, as

$$\varepsilon_{n+1} = \bar{\varepsilon}_n - \frac{\xi(\varepsilon_n)}{\xi'(\varepsilon_n)} = \frac{\Delta_1(L^*)}{\Delta_2(L^*)}, \tag{22}$$

where L^* represents the optimal value for $\xi(\varepsilon_n)$; it can be proposed that the function is represented as $\Delta_1(L^*) = K\beta \log_2\left(1 + \frac{\Gamma_k\, \alpha\, L}{(I+\mathcal{N})K}\right)$ and as $\Delta_2(L^*) = LQ_c + \nu\, \Gamma_k \frac{\alpha}{\vartheta}$, so the optimal number of antennas was selected from the best available antennas. From Eq. (21), the number of antennas is inversely proportional to Q_c at a large number of antennas, which consumes more power in the denominator and creates interference for a large number of PRSs. The initial point of EE was calculated using an ε_0 that fulfilled $\xi(\varepsilon\ ) \geq 0$. It was made optimal for $\xi(\varepsilon_n)$ using the L^* equation:

$$L^* = \left[\frac{\beta}{Q_c\, \varepsilon_n \ln 2} - \frac{(I+\mathcal{N})}{\Gamma_k\, \alpha}\right] K. \tag{23}$$

We chose the optimal transmit AS based on Newton's method, as in Eqs. (22) and (20), where $\bar{\varepsilon}_n$ was strictly increasing and accordingly became convex. Achieving maximal EE requires minimizing the number of PRSs when Γ_k is smaller than the optimal number of available antennas, where every antenna L must transmit its pilot sequences using maximum transmit power α. In Eq. (21), we prove that the near-optimal AS L^* is proportional to the distributed number of users K and increases monotonically as SNR increases.

Proposed Algorithm I. Joint antenna selection algorithm.

$\varepsilon_n \leftarrow 0,\ L \leftarrow 0,\ n \leftarrow 1$
for $n = 1$ to M do
  Solve the optimization problem in Eq. (21) for a given L and obtain the optimal L^*
  Compute the optimal AS by using Newton's method according to Eq. (22)
  Find the optimal number of antenna selection L^* according to Eq. (23)
  Update the iteration $\varepsilon_{n+1} = \varepsilon_n - \xi(\varepsilon_n)/\xi'(\varepsilon_n)$
  Calculate the EE based on the first derivative for antenna selection, **if** $p'(L)$ is positive in Eq. (24)
end for
Compare all values of EE and choose the received optimal AS that maximizes EE.

The effect of the number of antennas selection on EE can be found using Eq. (14) based on the first derivative, considering the number of selected antennas, L, and ignoring the denominator. The numerator is given as:

$$p^{'}(L)=\left(\frac{\beta\,\Gamma_k\alpha}{(I+\mathcal{N})}\right)\left[LQ_c+\nu\Gamma_k\frac{\alpha}{\vartheta}\right]-\left[\left(1+\frac{\Gamma_k\alpha\,L}{(I+\mathcal{N})\,K}\right)\ln 2\right]\left[K\beta\log_2\left(1+\frac{\Gamma_k\alpha\,L}{(I+\mathcal{N})\,K}\right)Q_c\right]. \tag{24}$$

From Eq. (24), the first term is written as:

$$p^{'}(L)=\left(\frac{\beta\,\Gamma_k\,\alpha\,LQ_c}{(I+\mathcal{N})}+\nu\,\Gamma_k\frac{\beta\alpha^2}{(I+\mathcal{N})\,\vartheta}\right). \tag{25}$$

From Eq. (25), the EE was found to be positive and to increase monotonically with increments in the number of selected antennas.

2.3. Proposed transmission power algorithm for energy efficiency

In this subsection, calculating EE requires computing the power consumption of wireless cellular networks. To solve this problem, we used an optimal transmission-power scheme for UEs by accounting for the effect of PRSs. Maximum EE was achieved by applying the constraint data rate and transmission power under the impact of PRSs. The optimization problem of transmission power can be described as:

$$\max_{\alpha}=\varepsilon\quad st.\;\;\Gamma_k\alpha\geq 0, \tag{26}$$

$$\varepsilon^{*}=\frac{r_{tot}\,(\alpha)}{Q_{tot}}\frac{R^{*}_{tot}\,(\Gamma_k)}{L\,Q_c+\,\nu\,\Gamma_k\frac{\alpha^{*}}{\vartheta}}, \tag{27}$$

$$st\;\;\mathbb{C}_1:\quad R\geq R_{\min}, \tag{28}$$

$$\mathbb{C}_2:\,\Gamma_k\,\alpha\;\leq\vartheta\,Q_{\max}, \tag{29}$$

where ε^{*} represents maximum EE at optimal transmission power α^{*}. From [18,19], the objective function was equivalent to $r_{tot}\,(\alpha)-\bar{\varepsilon}\left(LQ_c+\nu\,\Gamma_k\frac{\alpha}{\vartheta}\right)$ and the properties of the objective function for fractional programming were used to obtain the optimal value of α^{*}. EE was maximized using Eq. (29); the problem can be expressed as:

$$\max_{\alpha}\,r_{tot}\,(\alpha)-\bar{\varepsilon}\left(LQ_c+\nu\,\Gamma_k\frac{\alpha}{\vartheta}\right), \tag{30}$$

$$st\;\;\mathbb{C}_1\;\;:\;\;R\,(\Gamma_k)\geq R_{\min}, \tag{31}$$

$$\mathbb{C}_2\;\;:\;\;\Gamma_k\alpha\;\leq\;\vartheta\;Q_{\max}, \tag{32}$$

where $\bar{\varepsilon}$ represents the updated EE and R_{min} is the minimum data rate requirement for users. If α satisfies the constraint condition $\Gamma_k\alpha\leq\vartheta\;Q_{\max}$, then EE is actually quasi-concave. The updated value of EE, $\bar{\varepsilon}=\max_{\alpha}\frac{r_{tot}(\alpha)}{L\,Q_c+\,\nu\,\Gamma_k\frac{\alpha}{\vartheta}}$, was obtained by updating transmit power α until the convergence condition was achieved. Eq. (31) shows that $\frac{\partial^2 r_{tot}}{\partial^2_{\alpha}}<0$; the problem formulated in Eq. (30) became a convex optimization of transmission power to all users. Furthermore, the effected EE was due to a high pilot, which requires the optimization of PRS in the high-SNR regime. The Lagrange multipliers $\lambda_1>0$ and $\lambda_2>0$ correspond to the constraints of the DR with impact interference for PRS and transmission power [20], which can be seen in Eqs. (31) and (32). We solved the optimization problem using the following Lagrange multiplier:

$$L(\alpha,\,\lambda_1,\,\lambda_2)=\frac{K\beta log_2\left(1+\frac{\Gamma_k\,\alpha\,L}{(I+\mathcal{N})K}\right)}{\partial\alpha}-\left(\bar{\varepsilon}\left(LQ_c+\nu\,\Gamma_k\frac{\alpha}{\vartheta}\right)\right)+\lambda_1\left(R\left(\Gamma_k\right)-R_{min}\right)-\lambda_2\left(\Gamma_k\frac{\alpha}{\vartheta}-Q_{\max}\right). \tag{33}$$

The transmission power constraint was $\alpha \leq \vartheta\, Q_{\max}/\Gamma_k$. The reduced pilot sequence optimizes the power allocation for the number of activated L and data rate constraint $R\left(\Gamma_k\right)\geq R_{min}$, while the dual optimization problem can be written as:

$$\min_{\lambda_1,\lambda_2}\max_{\alpha} L(\alpha,\,\lambda_1,\,\lambda_2). \tag{34}$$

Moreover, the Karush–Kuhn–Tucker conditions were used to obtain the optimal value of transmission power α, which met the following conditions:

$$\frac{\partial L(\alpha\,,\,\lambda_1,\,\lambda_2)}{\partial\alpha}=\frac{\partial r_{tot}(\alpha)}{\partial\alpha}+\lambda_1\frac{\partial r}{\partial\alpha}-\nu\,\Gamma_k\frac{\bar{\varepsilon}}{\vartheta}-\frac{\lambda_2}{\vartheta}\geq 0. \tag{35}$$

From the Lagrange dual problem, the transmission power was optimized for a fixed set of Lagrange multipliers and the optimal transmission power, using λ_1 and λ_2, was obtained using:

$$\alpha^*=\left[\left(\frac{\vartheta\,(\beta+\,\lambda_1)}{(\nu\,\varepsilon\,+\,\lambda_2)\ln 2}-\frac{(I+\mathcal{N})}{\Gamma_k\,L}\right)K\right]^{\blacksquare}. \tag{36}$$

In Eq. (36), the optimal transmitted power is inversely proportional under the effect of large PRS to serve greater numbers of users, while the number of transmit antennas L is fixed and the EE converges to a maximum.

Proposed Algorithm II. Transmission power algorithm.

Step 1: Input : set of $\vartheta,\beta,\varepsilon^*,\,\lambda_1,\,\lambda_2\Gamma_k$ and L
Step 2: Output: α^*
Step 3: **if** $\lambda_2 =$ and $\lambda_1=\frac{\beta\,K}{\nu\,\bar{\varepsilon}\ln 2}+\vartheta K\geq\frac{\beta\,K}{\nu\bar{\varepsilon}\ln 2}$
Step 4: $\alpha^*{=}\,0$
Step 5: **Else if** $\lambda_2>0$ and $\lambda_1=\frac{\beta K}{(\nu\bar{\varepsilon}+\lambda_2)\ln 2}$
Step 6: Update λ_1 and λ_2 according to Eqs. (37) and (38)
Step 7: Comparison If $r_{tot}(\alpha)-\bar{\varepsilon}\left(LQ_c+\nu\,\Gamma_k\frac{\alpha}{\vartheta}\right)>ϟ$
Step 8: Then set $\alpha^*=\left[\left(\frac{\vartheta(\beta+\lambda_1)}{(\nu\bar{\varepsilon}+\lambda_2)\ln 2}-\frac{(I+\mathcal{N})}{\Gamma_k\,L}\right)K\right]^{\blacksquare}$
Step 9: Check the convergence $=$ false
Step 10: **end if**
Step 11: until Convergence $ϟ<0.01$ go to Step 6

The EE first increased then decreased due to increases in circuit power consumed for every L and the impacted interference for pilot sequences when the transmitted power was increased. $[\varphi]^{\blacksquare}=\max\{0,\varphi\}$ and the optimal transmission power α^* were derived using the Lagrange multiplier. Consequently, the Lagrange multiplier was updated using the gradient method:

$$\lambda_1(\delta + 1) = [\lambda_1(\delta) - \sigma(R - R_{min})]^{\blacksquare}, \tag{37}$$

$$\lambda_2(\delta + 1) = \left[\lambda_2(\delta) - \theta\left(Q_{\max} - \Gamma_k \frac{\alpha}{\vartheta}\right)\right]^{\blacksquare}, \tag{38}$$

where σ and θ are step sizes and δ is the iteration index.

3. Numerical results

The proposed algorithm was tested via MATLAB simulation. This section presents the numerical results from Monte Carlo simulations. Figure 1 shows the EE against the number of transmit antennas for SNR values, where SINR affected every antenna at $K < L$. Increasing the number of antennas led to a linear increase in dynamic power due to the large number of PRSs among different cells. This problem for PRSs required a finite number of PRSs due to limited channel coherence and increases in transmission power and the distributed users inside the cells, which depended on transmission power and PRS power where EE was affected by the use of maximized PRS with high SINR. The convergence of the proposed EE algorithm reduced the complexity of the channel matrix with an increased number of transmission antennas and a large number of UEs because EE was related only to the number of users, K, and AS, L, with minimal PRS. Therefore, the optimal number of transmission antennas existed when transmission power was adequate. In addition, when the number of users was $\Gamma_k = K = 16$, EE was greater than when $\Gamma_k = K = 8$ and $\Gamma_k = K = 4$.

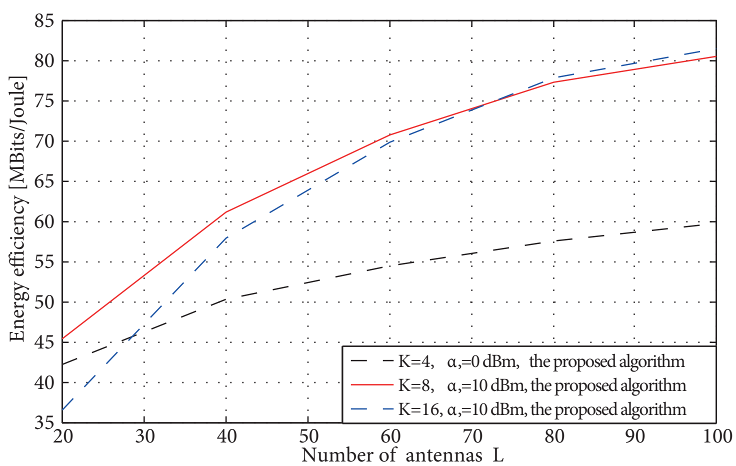

Figure 1. Performance of the proposed algorithm with number of antennas under the effect of pilot sequences at SNR = 5 dB.

Figure 2 shows that the proposed algorithm performed better depending on the iteration of a high pilot of SINR for users, K, which reflects the effect of PC and generalizes the pilot interference with transmit power. When transmission power was low, $\propto$=10 dB, and when $\Gamma_k = K = 12$, the proposed algorithm provided smaller EE compared to when transmission power was $\propto$=10 dB and the number of users $\Gamma_k = K = 20$. Consequently, a transmission antenna, L, with fixed transmission power, $\propto$, could improve EE. Therefore, as illustrated in Figure 2, the EE of UEs and the performance of the proposed algorithm depend on the number of users and circuit power consumption. The performance of the proposed method shows that EE is an increasing function of the number of selected antennas, L, if the transmit power is sufficiently larger than the circuit power consumption; then the optimal value of L^* can be M. Maximum EE is increased because the proposed algorithm enables the choosing of maximum power in relation to optimal AS and is capable of working at high SINRs, such as when SNR = 10 dB. Hence, in a high-SNR regime with spatial correlation, the proposed algorithm is not suitable for antenna selection.

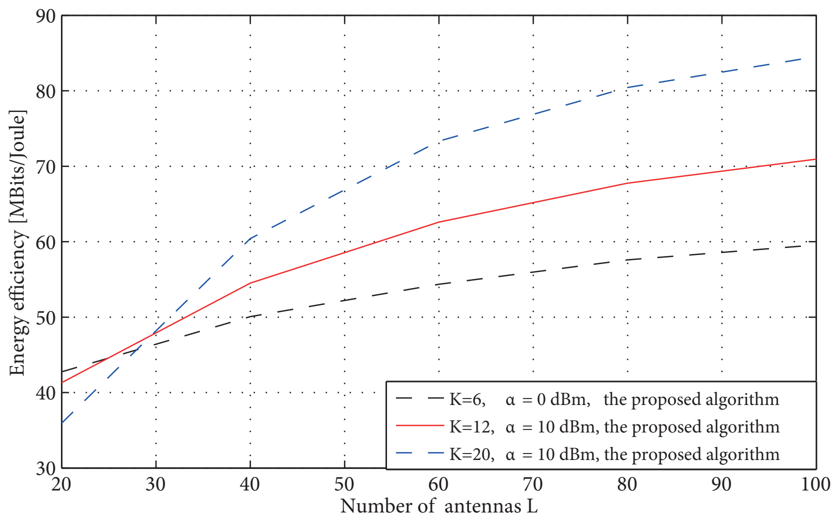

Figure 2. Performance of the proposed algorithm with number of antennas under the effect of pilot sequences at SNR = 10 dB.

The effect of transmission power with an increased number of antennas made EE move toward zero due to circuit power consumption and the increased number of pilot sequences, as shown in Figure 3. However, when the transmission PRS was reasonable with the available antennas, the circuit power consumption was less than the transmission power, which improved EE. In addition, Figure 3 shows that the EE approached constancy when the transmit power dropped to small values. The proposed algorithm for optimal transmission power was used to compare conditions with more antennas, which caused interference for the pilot sequence and improved maximum EE. Alternatively, if the transmission power is greater than the circuit power consumption in the extra antennas, EE is improved. Consequently, when the consumption circuit power was comparable to the transmit power, more antennas must have been used, which finally decreased EE.

Figure 4 shows that maximal EE was achieved with repeated reductions of PRSs at increasing transmission power. In addition, when the transmission power was higher than the circuit power consumption, EE was completely quasi-concave with transmit power. Furthermore, after obtaining a high maximum value, EE began to decrease due to an increase in transmission power and the different numbers of users inside the cells. However, EE still increased with the total transmit power. This shows that maximum EE could be achieved with the desired maximum transmit power threshold with minimized PRS (where the achievable EE became lower when the pilot sequences increased). Alternatively, when the transmission power increased slowly, the total circuit power consumption increased, which decreased EE, as shown in Figure 4. All EE curves were nonlinear to the transmit power, which required us to choose the optimal transmit power according to equation (36).

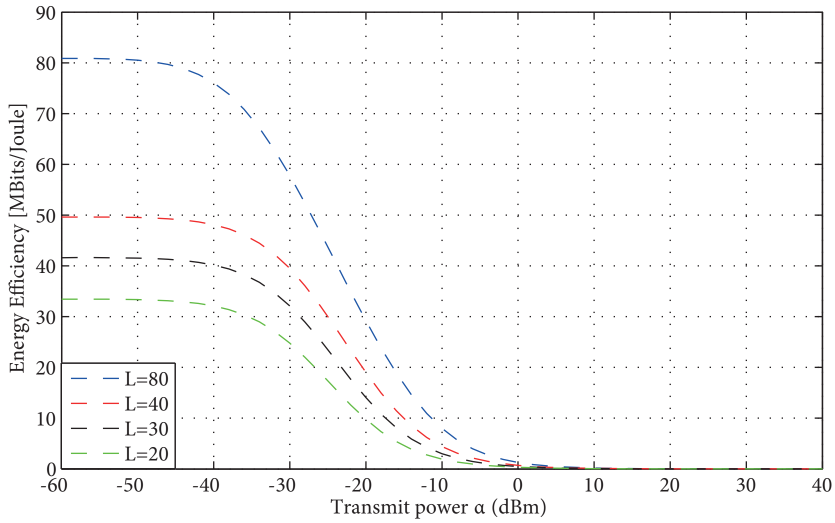

Figure 3. Effect of the proposed algorithm with transmission power.

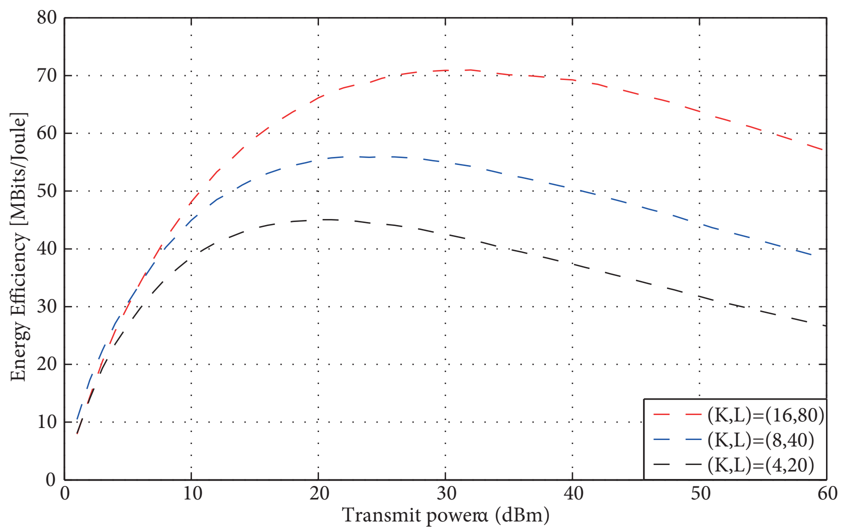

Figure 4. Performance of the proposed algorithm with transmission power under the effect of pilot sequences.

4. Conclusion

In this paper, we studied the joint optimal AS and optimal transmission power of UEs under the effect of PRSs. We formulated the problem of transmission power and AS under effect pilot sequences by applying Newton's method and Lagrange multipliers to reduce the complexity of the iteration for AS and transmission power. The numerical results show that the pilot interference and the number of activated transmit antennas selection played an essential role in maximizing EE. The results also show that the proposed algorithm achieved maximal EE by optimizing the PRSs to available (optimal) transmission power with more antennas. In addition, AS could be an ideal choice for reducing power for RF chain constraints, which increased maximum EE.

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