IJARCCE

ISSN (Online) 2278-1021
ISSN (Print) 2319 5940

International Journal of Advanced Research in Computer and Communication Engineering
ISO 3297:2007 Certified
Vol. 5, Issue 9, September 2016

Energy Efficiency Analysis for MIMO Communication Systems

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Abstract: The paper presents to optimize the energy efficiency in the MIMO system. The Energy Efficiency and the power consumption are the two important factors for the wireless communication systems. Recently the dramatic growth in high-rate multimedia data traffic driven by usage of wireless devices has been straining the capacity of today's networks and has caused a large amount of energy consumption. In the past decade, suboptimal algorithm is implemented, which requires more energy and power allocation for the transmission of data in distributed antenna system. Therefore the developed optimal resources allocation algorithm in the MIMO systems optimizes the energy efficiency in the uplink and downlink transmission of data with the increase of mobile stations. The energy-efficient system design has recently drawn much attention in both academic and industrial worlds, and is becoming the mainstream for the next generation of wireless communications. The demonstrated optimal resource allocation algorithm requires less transmission power, less complexity and more energy efficient.

Keywords: Distributed antenna systems (DASs), energy efficiency (EE), fractional programming, proportional fairness, resource allocation, spectral efficiency (SE) Multiple Input and Multiple Output (MIMO) systems.

I. INTRODUCTION

With increasing demands for the minimize energy efficient systems fall short in terms of the capacity and reliability performance. Among various techniques, the diversity is one of promising techniques for enhancement of system performance in the aspects of system capacity and reliability for 5G wireless communication systems. Especially, the spatial diversity (SD) and the multi user diversity (MUD) have been widely investigated rather than the time diversity or the frequency diversity in multiple-input multiple-output (MIMO) systems and the related works are given as follows:

Chunlong He and Geoffrey et al. in [1] presented the resources allocation to orthogonal frequency-division multiplexing (OFDM) distributed antenna system for energy efficiency calculation by using the sub optimal algorithm and uses the overall transmission power in the distributed antenna system. The proposed multiple-input–multiple-output (MIMO) system energy efficiency calculations are based on more number of antennas for the transmission.

The distributed antenna system and microcellular system performances have been studied in H.-L. Zhu, [2]. H.-L. Zhu, S. Karachontzitis, and D. Toumpakaris in [3] studied Low-complexity resource allocation and its application to distributed antenna systems is to present low-complexity resource allocation approaches that rely on chunks of subcarriers for downlink distributed antenna systems. H. Kim, S.-R. Lee, K.-J. Lee, and I. Lee, in [4] Transmission schemes based on sum rate analysis in distributed antenna systems single cell multi-user downlink distributed antenna systems (DAS) where antenna ports are geographically separated in a cell Based on the ergodic sum rate expressions, the method chooses the best mode maximizing the ergodic sum rate among mode candidates. X.-H. You, D.-M.Wang, P.-C. Zhu, and B. Sheng, in [5] studied the cell edge effects of traditional cellular systems and distributed cellular systems are evaluated and compared in environments with or without inter-cell interference (ICI).

Z.-K. Shen, J. Andrews, and B. Evans, in [6] explained the adaptive resource allocation in multiuser OFDM systems with proportional rate constraints in multiuser orthogonal frequency division multiplexing (MU-OFDM) systems. The sum capacity of MU-OFDM is maximized when each sub-channel is assigned to the user with the best channel-to- noise ratio for that sub-channel, with power subsequently distributed by water-filling.

Energy efficiency, high data rates, and security are the main driving forces for the evolution of wireless communication systems. Traditionally, these requirements have been fulfilled by increasing both the transmit power and the bandwidth. However, nowadays the radio spectrum available for wireless services is extremely scarce and universal frequency reuse is a new trend to accommodate the increasing number of users.
In other words, increasing the transmission bandwidth will not always be an option in the future. On the other hand, power consumption in cellular networks is not only a financial burden to the service providers, but also one of the main sources of greenhouse gas emission.

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II. MIMO MODEL

We focus on a multi-user communication model and consider a multi-to-multi link where the transmitter is equipped with n antennas and the receiver employs n antennas (see Figure 1).

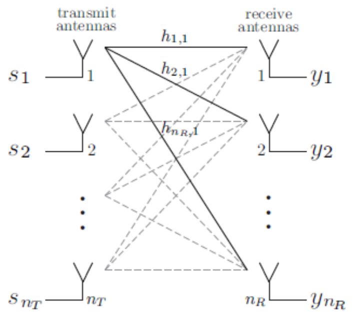

Fig.1 A MIMO channel with n transmit and n receive antennas.

Next to the single user assumption in the depiction as multi-to-multi link, we suppose that no inter symbol interference (ISI) occurs in OFDM system. This implies that the bandwidth of the transmitted signal is very small and can be assumed high frequency (narrowband assumption), so that each signal path can be represented by a complex-valued gain factor. For practical purposes, it is common to OFDM model the channel as frequency at whenever the bandwidth of the system is smaller than the inverse of the delay spread of the channel; hence a wideband system operating where the delay spread is fairly small may sometimes be considered as frequency. If the channel is frequency selective method, one could use an MIMO system, to turn the MIMO channel into a set of parallel frequency at MIMO channels, of which each obeys our stated assumptions.

Now let $h_{i,j}$ be the complex-valued path gain from transmit antenna j to receive antenna I (the fading coefficient). If at a certain time instant the complex-valued signals fs1…fsn, are transmitted via the n_T antennas, respectively, the received signal at antenna i can be expressed as

$$y_i = \sum_{j=1}^{n_T} h_{i,j}\, s_j + n_i \qquad (1)$$

or equivalently,

$$Y = HS + N \qquad (1.1)$$

III. CAPACITY IN MIMO CHANNELS

The capacity of a MIMO channel in the case that the channel matrix H is deterministic. The capacity of the MIMO channel is defined as

$$C = \max i(s;y) \qquad (3)$$

Where

$$I(s; y) = H(y) - H(yjs) \qquad (3.1)$$

Where H(¢) denotes the entropy, y denotes as linear MIMO transmission model, we can use the identity H(yjs) = H(njs) Since according to our premises, the noise n and the transmit vector s are statistically independent, we can further write H(yjs) = H(n).
By our assumptions about the noise term n, the entropy H(n) can be evaluated as

$$H(n) = \ln\det(\Pi e C n) = \ln\det(\Pi e I) \qquad (4)$$

Thus, the maximization of the mutual information I(s; y) reduces to a maximization of H(y). To derive an expression for the entropy of y, worst investigate its covariance matrix.
For a fading channel, the channel matrix H is a random quantity and hence the related channel capacity C(H) is also a random variable. So, the ergodic channel capacity as in MIMO system is given by

$$C_E = E\left\{\max \log\det(I + \frac{\rho}{n_T} H\, C_S\, H^H\right\} \qquad (5)$$

After having identified the channel capacity in a MIMO system, it remains to evaluate the optimal input power distribution, or covariance matrix Cs that minimize the capacity. The maximization depends on an important condition, we have not taken into account yet. Before being able to compute the maximization, we have to clarify if the transmitter, the receiver, or both have perfect knowledge of the channel state information (CSI).
This is equivalent to the constraint that the channel matrix H is perfectly in fading channel of both sides of the communication system. If the channel H is known to the transmitter, the transmit correlation matrix Cs can be chosen to finite the channel capacity for a given realization of the channel.

IV. ENERGY EFFICIENT AND POWER CONSTRAIN IN MIMO SYTEM

The energy efficiency is given by the data rate to the total power consumption. The total average power consumption of a MIMO signal is divided into the power consumption of the transmitter and the power consumption of the receiver. The power consumed by the MIMO system is given by

$$P_{out} = E_b\, R_b \times \frac{(4\pi d)^2}{G_t G_r \lambda^2}\, M_l\, N_f \qquad (6)$$

Where E_b is the required energy per bit at the receiver for a given BER requirement, R_b is the bit rate, d is the transmission distance, Gt is the transmitter antenna gain, Gr is the receiver antenna gain, λ is the carrier wavelength, Pc is circuit power consumption, M is the link margin and Nf is the receiver noise figure

DOI 10.17148/IJARCCE.2016.5910

IJARCCE

ISSN (Online) 2278-1021
ISSN (Print) 2319 5940

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The total energy consumption per bit for a fixed rate system is given by

$$E_{bt} = \frac{P_{PA} + P_c}{R_b} \quad (7)$$

In addition to the path loss, the signal is further attenuated by a scalar fading channel matrix, channel matrix H which is modeled such that each entry is a zero-mean circularly symmetric random values with unit variance.
The Energy Efficiency of an MIMO system is defined as the ratio of the overall data rate or SE over the total power consumption (in bits/J/Hz), i.e.,

$$EE = \frac{R}{P_{Total} = \frac{P_t}{\tau} + P_c + MP_o} \quad (8)$$

Where R is the overall data rate or the SE,τ is the drain efficiency of the radio-frequency power amplifier, Pc is the constant circuit power consumption by RAUs, Pt is the transmit power, and Po is the dissipated power by the fiber-optic transmission
A MIMO link consists of a transmitter and a receiver. Therefore, the power consumption of a MIMO linkP_{MIMO} includes the power consumption of the transmitter$P_{transmit}$ and that of the receiver $P_{receive}$.

$$P_{MIMO} = P_{transmit} + P_{receive} \quad (9)$$

One can divide $P_{transmit}$ in to the power consumed by all the power amplifiersP_{PA}, and that by all the other transmit circuit blocks$P_{circuit}$, i.e.

$$P_{transmit} = P_{PA} + P_{circuit} \quad (10)$$

V. PROPOSED ALGORITHM

Optimal resource allocation algorithm is implemented by considering the hardware impairments in the data transmission. Because of the impairments the interference is to be occurred in the system. The Energy Efficiency and the transmission power are to be observed in accordance with the user antennas in the optimal resource allocation algorithm.

The procedural steps for the calculation of Energy Efficiency and transmission power by using optimal resource allocation algorithm is
Step (1) Simulation parameters are defined
Step (2) Range of number of BS antennas.
Step (3) Define the normalized channel covariance matrix R as an identity matrix
Step (4) Define the range of level of hardware impairments at the transmitter and receiver.
Step (5) Portion of all symbols used for either DL or UL data transmission
Step (6) Range of SNRs in simulation
Step (7) Number realizations in Monte Carlo simulations
Step (8) Generate channel realizations
Step (9) Generate distortion noise at UE
Step (10) Initialize the matrices for asymptotic capacity limits
Step (11) Go through all level of impairments values
Step (12) Extract current level of impairments at BS and UE
Step (13) Compute matrix in the LMMSE estimator
Step (14) Compute the lower capacity limit
Step (15) Compute received signal
Step (16) Compute the beam forming vector
Step (17) Compute the un-normalized beam forming vector in the upper bound

The procedural steps for the calculation of Relative channel gain by considering the uplink spectral efficiency in the MIMO communication system.
Step (1) Number of BS antennas are defined
Step (2) Define the normalized channel covariance matrix R as an identity matrix
Step (3) Number of co-users that interfere during data transmission
Step (4) Number of co-users that interfere during pilot transmission
Step (5) Define the range of level of hardware impairments at the BS and UE. The values are the same for BS and UE, but can be different
Step (6) Portion of all symbols used for either DL or UL data transmission.
Step (7) Range of how much weaker the interfering signals are as compared to the useful signal (on average).
Step (8) Initialize Monte Carlo simulations
Step (9) Compute matrix A in the LMMSE estimator by extending them to also take interference into account
Step (10) Compute received signal, channel estimates, beam forming vector
Step (11) Compute a realization of the first and second moments of the inner product between
Step (12) beam forming and channel
Step (13) The element wise product between channel and beam forming vectors (and sum over these elements) appear in the distortion noise term.
Step (14) Compute the interference power during data transmission, when there is only pilot contamination or also regular interference
Step (15) Compute averages and variances by the Monte Carlo simulation
Step (16) Finalize the Monte Carlo simulations by computing the achievable uplink spectral efficiency

VI. EXPERIMENTAL RESLTS

The simulation results have shown that the energy efficiency is increased with the increase of antennas in the MIMO communication systems by considering impairments. The transmission power is decreasedin accordance with the base stations is verified and the spectral efficiency or the data rate efficiency related to channel gain is simulated by using the optimal resource allocation algorithm.

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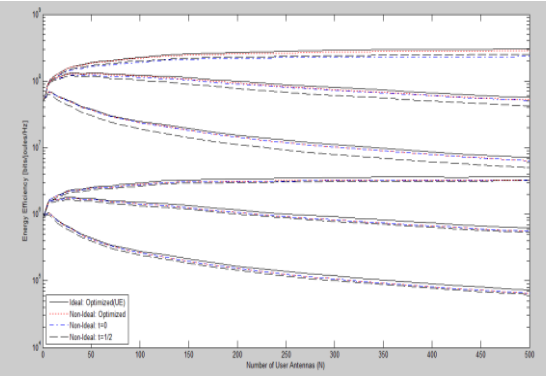

Fig.2 Number of user antennas versus Energy Efficiency for MIMO systems

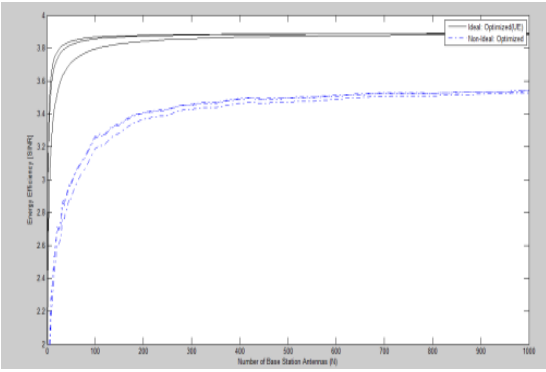

Fig3: Number of Base station Antennas versus Energy Efficiency for MIMO systems

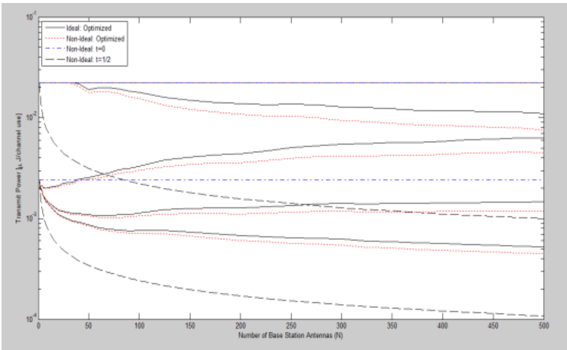

Fig4 Number of Base station Antennas versus Transmit power in MIMO systems

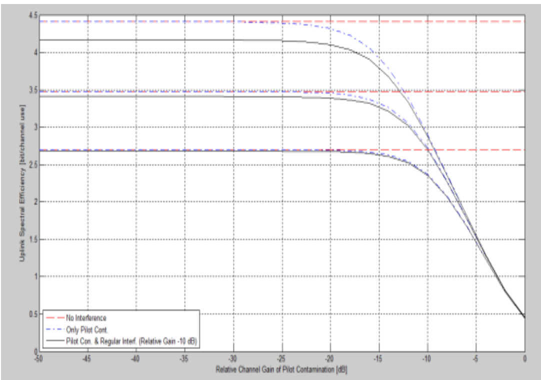

Fig5 Relative channel gain Versus Spectral Efficiency for MIMO systems

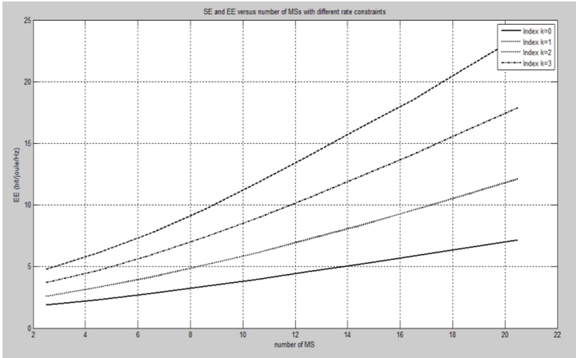

Fig.6 Energy efficiency changes with different rate Constraint in mobile stations using sub optimal algorithm

Table.1 Energy Efficiency comparison of the optimal resource allocation algorithm and suboptimal algorithm

Suboptimal Resource algorithm in Distributed antenna system		Optimal Resource allocation algorithm Energy Efficiency in MIMO system	
Mobile stations	Energy Efficiency (bits/joule /Hz)	Mobile stations	Energy Efficiency(bits /joule /Hz)
4	2.5	200	3.8 (optimal value)
10	2.7	400	3.8
14	3	600	3.8
18	6.5	800	3.8
20	7	1000	3.8

The optimal resource allocation algorithm for the MIMO systems gives the optimized value with the increase of the mobile user antennas. The comparison of the two algorithms is done from the figure 3 and figure 6. From the table 7.9 it is observed that the distributed antenna system with suboptimal is limited to the less number of mobile stations. While 20 mobile stations require 7 joules of energy is for the transmission of data bits in the distributed antenna system and in MIMO system for the transmission of data bits between 200 mobile stations required only 3.8 joules only. The decrease of transmission power is observed in fig.4 for proposed algorithm.

VII. CONCLUSION

The optimal resource allocation algorithm converges to the optimal solution for the transmission of data in the Multiple Input Multiple Output systems. The suboptimal algorithm implemented in the downlink multiuser distributed antenna system requires more transmission power for the transmission of data. Simulation results have shown that the optimal resource algorithm decreases the transmission power and optimizes the Energy Efficiency with the increase of the mobile stations in the MIMO communication systems.

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BIOGRAPHIES

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