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Energy-Efficient Resource Allocation In Secure OFDMA Communication Systems

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Abstract— Orthogonal frequency division multiple access (OFDMA) is a multiple access technique in which the base stations allow multiple users to transmit simultaneously on different number of subcarriers during the same symbol period. Due to the broadcast nature of the radio propagation, the wireless data transmission can be highly vulnerable to eavesdropping attacks. To this end, physical-layer security mechanism is a promising technique to protect the wireless communications against eavesdropping attacks. A key issue in OFDMA is the allocation of the OFDM subcarriers and power among users sharing the channel. In this paper, the resource allocation mechanism for energy-efficient communication in secure orthogonal frequency-division multiple-access downlink network is proposed. The power, subcarrier allocation policies and secrecy data rate are optimized for maximization of the energy efficiency of secure data communication (bit/joule securely delivered to the users).

Keywords—Artificial noise generation scheme, energy efficiency, multiple-input–multiple-output(MIMO)

I. INTRODUCTION

Orthogonal Frequency-Division Multiple Access (OFDMA) is a multi-user version of the orthogonal frequency-division multiplexing (OFDM) digital modulation scheme. Multiple access is in OFDMA is achieved by assigning subsets of subcarriers to individual users. This allows simultaneous low data rate transmission from several users. OFDMA is a promising candidate for high-speed wireless communication networks such as, worldwide interoperability for microwave access and advanced IEEE 802.16, Third- Generation Partnership Project (3GPP), Long-Term Evolution(LTE).It provides robustness against multipath fading and also flexibility in resource allocation[1]. OFDMA enables efficient transmission of a wide variety of data traffic by optimizing of the power, subcarrier allocation among different users.

The increasing interest in multimedia communication services has led to a tremendous demand for high-data rate communications. This demand has leads to rapidly increasing energy consumption. As a result, propose an energy efficient system in which energy efficiency (bits per joule) is used as the performance metric have received much attention in industry[3]-[7] .On the other hand security of information transmission via wireless networks remains a challenging issue. The application of physical layer security [2] schemes makes it more difficult for attackers to decipher transmitted information..The PHY layer security by Wyner[8] showed that in a wiretap channel in which a source and a destination can exchange secure messages if the desired receiver have better channel conditions than the passive eavesdroppers. The channel state information(CSI) of the eavesdroppers, which is assumed to be known at the base station (BS). In other words, a secure communication can always be guaranteed by carefully adapting the transmit power. The eavesdroppers are usually passive and silent to hide their existence [9]. Thus, the channel state information (CSI) of the eavesdroppers cannot be obtained from the eavesdroppers or it can be measured at the BS based on handshaking signals. In order to overcome this problem, multiple antennas and artificial noise generation scheme have been proposed for security provision.

Motivated by the above observations, propose the resource allocation problem for energy-efficient communication in secure OFDMA downlink systems with artificial noise generation . By using iterative resource algorithm the closed-form power, secrecy data rate, and subcarrier allocation policies for maximizing the energy efficiency are obtained.

II. ORTHOGONAL FREQUENCY DIVISION MULTIPLE ACCESS DOWNLINK NETWORK

2.1. Notations

A complex Gaussian random variable with mean μ and variance $\sigma 2$ is denoted by $CN(\mu, \sigma 2)$, and ~ means "distributed as." $[x]+ = \max\{0, x\}$. $EX\{\cdot\}$ denotes statistical expectation with respect to (w.r.t.) random variable X. $CN\times M$ is the space of all $N \times M$ matrices with complex entries $[\cdot]\dagger$ represents the conjugate transpose operation. $1(\cdot)$ denotes an indicator function that is 1 when the event is true and 0 otherwise.

2.2. Channel model

Consider an OFDMA downlink network that consists of a base station (BS) with NT antennas and an eavesdropper with NE antennas, and there are K mobile users equipped with a single antenna shown in (Fig.1).We assume that number of transmit antennas in the base station must be greater than that of eavesdropper ie NT > NE to enable secure communication. The eavesdropper which is passive and its goal is to decode the information transmitted by the BS without causing any interference to the communication channels.

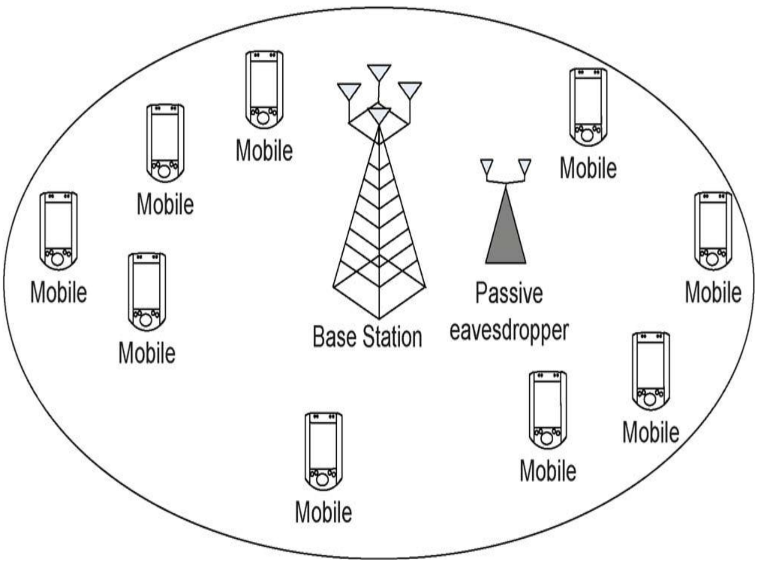


Figure. 1. OFDMA downlink network. There are one BS with NT = 4 antennas, K = 9 desired users with a single antenna, and one eavesdropper with NE = 2 antennas

The impulse responses of channels are assumed to be time invariant (slow fading). Consider an OFDMA system with nF subcarriers[10]. The received symbols at user k yk[i] and the eavesdropper yE[i] on subcarrier i €{1, . . . , nF } are respectively, given by

$$yk[i] = xk[i]Hk[i] + n[i]$$

$$yE[i] = xk[i]G[i] + e[i] \quad (1)$$

Where xk[i] denotes the transmitted symbol vector and hk[i] is the channel vector between the BS and user k on subcarrier i, and G[i] is the channel matrix between the BS and the eavesdropper on subcarrier i. Both hk[i] and G[i] include the effects of path loss and also multipath fading. n[i] is the additive white Gaussian noise (AWGN) in subcarrier i at user k with distribution N(0,N0),where N0 is the noise power spectral density. e[i] which is the AWGN vector in subcarrier i at the eavesdropper.

The CSI (path loss information and multipath fading) of the desired users which is perfectly known at the BS due the accurate channel measurements. On the other hand, the BS knows only the number of antennas NE employed by the eavesdropper and the associated channel distribution .Since the CSI of the eavesdropper is unavailable at the BS. In order to secure the desired wireless communication, an artificial noise signal is generated at the base station (BS) to degrade the channels between the BS and the eavesdropper [11][12].

2.3. Artificial noise scheme

The BS chooses transmitted symbol vecor xk[i] as a linear combination of information bearing signal uk[i] and the artificial noise signal vk[i] shown below

$$xk[i] = bk[i]uk[i] + Vk[i]vk[i] \quad (2)$$

Where bk[i] is a beam forming vector. Since hk[i] is known at the BS, ,we define an orthogonal basis Vk[i] for the nullspace of hk[i] such that hk[i]Vk[i]vk[i] = 0 and V†k[i]Vk[i] =I, where I is a (NT − 1) × (NT − 1) identity matrix. In other words, the artificial noise does not interfere with the desired users.

$$yk[i] = bk[i]uk[i] + e[i]]$$

$$yE[i] = G[i]bk[i]uk[i] + G[i]Vk[i]vk[i] + e[i] \quad (3)$$

Where bk[i] is a beam forming vector. Since hk[i] is known at the BS, ,we define an orthogonal basis Vk[i] for the null space of hk[i] such that hk[i]Vk[i]vk[i] = 0 and V†k[i]Vk[i] =I, where I is a (NT − 1) × (NT − 1) identity matrix. In other words, the artificial noise does not interfere with the desired users

III. RESOURCE ALLOCATION AND SCHEDULING

3.1.Channel capacity,Secracy outage,Energy efficiency

The maximum secrecy capacity on subcarrier i is given by the difference between the BS-to-user *k* channel capacity and the BS-to-eavesdropper channel capacity[13][14] which is

$$\mathrm{Csec,k[i]} = (\mathrm{Ck[i]} - \mathrm{CE[i]})\,\mathbf{1}\,(\mathrm{Ck[i]} > CE[\mathrm{i}]) \quad (4)$$

where ck[i] is the bs to user k channel capacity and ce[i] is the bs to eavesdropper capacity.
The average secrecy outage capacity is defined as the total average number of bits/s securely delivered to the K mobile users (averaged over multiple scheduling slots) .

The energy efficiency of the secure system is defined as the total average number of bits securely delivered bits/joule .

3.2. Resource allocation algorithms

The block diagram for the downlink of a typical OFDMA system is shown in Figure.2. At the base station transmitter, the bits for each of the different K users are allocated to the N subcarriers, and user k (1 · k · K) is assigned a power pkn. It is assumed that subcarriers are not shared by different users. Each of the user's bits are then modulated into N M-level QAM symbols, which are subsequently combined using the IFFT into an OFDMA symbol. This is then transmitted through a slowly time-varying, frequency-selective Rayleigh channel with a bandwidth B. The subcarrier allocation is made known to all the users through a control channel beforehand; therefore, each user needs only to decode the bits on their respective assigned subcarriers. The slowly time-varying assumption is crucial since it is also assumed that each user is able to estimate the channel perfectly and these estimates are made known to the transmitter via a dedicated feedback channel. These channel estimates are then used as input to the resource allocation algorithms.

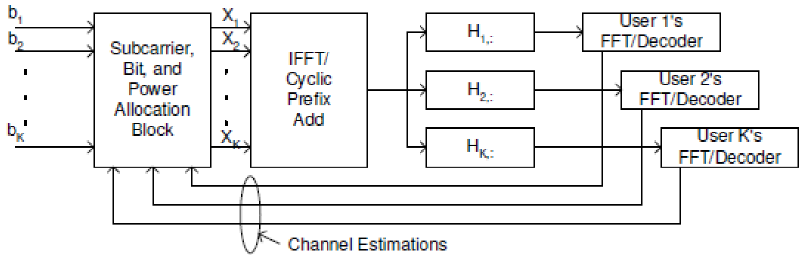


Figure.2. OFDMA model

In root finding resource allocation, the number of subcarriers and amount of power for each user is determined and subsequently a subcarrier assignment step, wherein each user is assigned their corresponding subcarriers. The subcarrier allocation was determined by allowing each user to take turns choosing the best subcarrier for him. In each turn, the user with the least proportional capacity gets the priority to choose his best subcarrier.

Linear resource algorithm exploit the nature of the problem and signicant complexity reduction benefits while maintaining reasonable performance. The proposed steps are as follows :

Step 1: Determine the number of subcarriers Nk to be initially assigned to each user; Determine Nk to satisfy Nk= [Qk N] This may lead to N* = N- Σ Nk unallocated subcarriers.

Step 2 : Assign the subcarriers to each user in a way that ensures rough proportionality;

- The 1st step of the algorithm initializes all the variables. Rk keeps track of the capacity for each user and N is the set of yet unallocated subcarriers.
- The second step assigns to each user the unallocated subcarrier that has the maximum gain for that user.
- The third step proceeds to assign subcarriers to each user according to the greedy policy that the user that needs a subcarrier most in each iteration gets to choose the best subcarrier for it .
- The fourth step assigns the remaining N¤ subcarriers to the best users for them, wherein each user can get at most one unassigned subcarrier.

Step 3: Assign the total power Pk for user k to maximize the capacity while enforcing the proportionality.

Step 4 : Assign the powers pkn for each user's subcarriers subject to his total power constraint Pk.

The proposed method waives the restriction of high sub channel SNR, has significantly lower complexity, and in simulation, yields higher user data rates[15].

IV. SIMULATION RESULTS

This section describes the simulation results for the proposed system

4.1.Energy Efficiency Versus Number of Users

Figure.3 depicts the energy efficiency versus the number of users. It can be observed that both the energy efficiency grow with the number of users. Moreover, when the number of users is large, the energy efficiency eventually approaches a constant that is similar to the case of high transmit power.

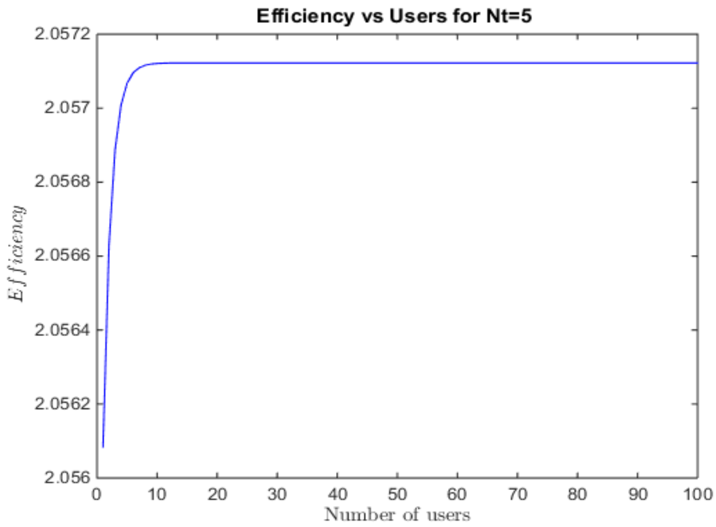
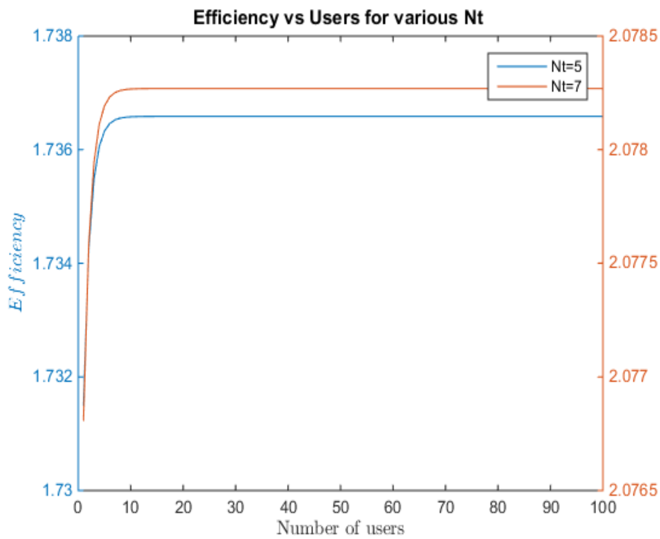


Figure. 3. Energy efficiency (bits per joule) versus the number of users Nt=5

The variation of energy efficiency for different no of transmit antennas is depicted in fig.4.As the no of transmit antennas increses the energy efficiency also increases.



Figre. 4. Energy efficiency (bits per joule) versus the number of users for various transmit antennas

4.2.Average secrecy outage capacity Versus Number of Users

Figure.5 depicts the Average secrecy capacity versus the number of users. It can be observed that Average secrecy outage capacity grow with the number of users. Moreover, when the number of users is large, the secrecy capacity eventually approaches a constant that is similar to the case of high transmit power.

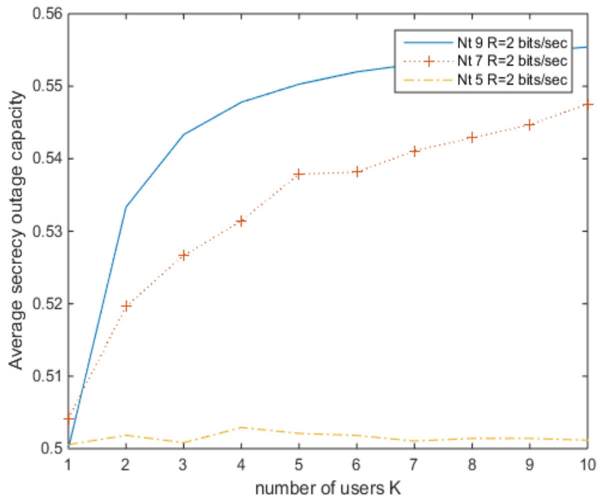


Figure 5. The Average secrecy capacity versus the number of users

4.3.Average secrecy outage capacity versus transmit power

Figure.6 depicts the Average secrecy capacity versus the transmit. power. The average secrecy outage capacity approaches a constant in the high transmit power.

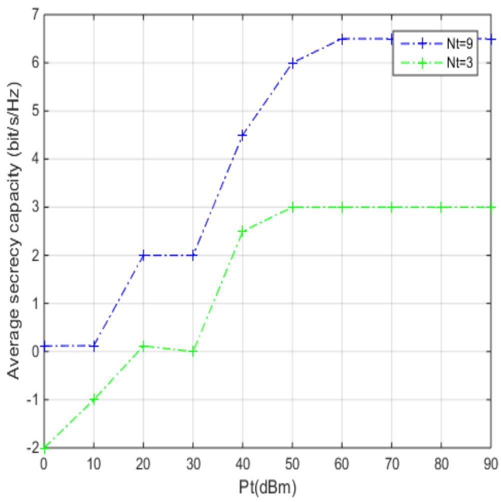


Figure 6. The average secrecy capacity versus the transmit power

4.4. Performance comparison of linear Vs root finding algorithm

The linear method has a consistently higher total capacity than the root finding method for all the numbers of users. The capacities increase as the number of users increases.

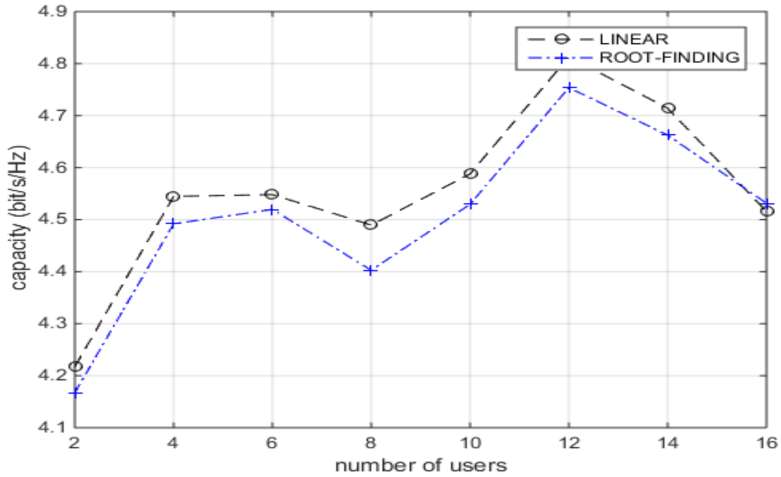


Figure.7. Capacity vs no of user

V. CONCLUSION

The resource allocation for energy efficient secure communication in an orthogonal frequency-division multiple-access (OFDMA) downlink network is designed. An efficient resource allocation algorithm with closed-form power, secrecy data rate, and subcarrier allocation was derived. Comparison of two resource allocation algorithms are executed and linear method have less computational complexity, and yet achieving higher total capacities, while being applicable to more general class of systems.

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