Wireless Information and Energy Transfer for Outdoor to Indoor Multicarrier SUDAS

Syed Adil Abbas Kazmi
Department of Electrical and Electronics Engineering
Koc University Istanbul, Turkey
skazmi14@ku.edu.tr

Sinem Coleri Ergen
Department of Electrical and Electronics Engineering
Koc University Istanbul, Turkey
sergen@ku.edu.tr

***Abstract*—~~In this paper,~~ we study the resource allocation in an amplify and forward (AF) relay assisted orthogonal frequency division multiple access (OFDMA) system employing a shared user equipment (UE)-side distributed antenna (SUDAS). ~~It~~ simultaneously utilizes ~~both~~ unlicensed (in the UE to AF relay link) and licensed frequency bands (AF relay to BS link), hence exploiting the advantages of both MIMO over licensed band with its favorable propagation conditions and mmW band with larger bandwidths, to improve achievable rate of the future 5G communication systems. The users in the system have no energy of their own, so for transmitting information to the base station in the uplink, they first need to harvest energy from the SUDACs (shared UE-side distributed antenna components) in the downlink. For this purpose, we present a time switching based MIMO-OFDMA (TS) protocol. To explore the system performance limits, we formulate a non-convex optimization problem to maximize the end-to-end achievable information rate of the system. Due to the non-convexity of the problem, we propose a polynomial time algorithm based on the separation of energy harvesting and information transmission problems and optimization of the interactive time variable. Simulation results illustrate that the proposed system achieves a significant performance gain over the conventional systems exploiting only licensed bands. Moreover, the effect of the number of SUDACs (relays) and number of subcarriers on the system performance are also investigated.**

I. Introduction

We present a SUDAS uplink communication system ~~in this paper which resembles~~ a wireless relay assisted MIMO system ~~and utilizes~~ both licensed and unlicensed frequency bands. SUDAS is a system ~~which~~ translates spatial multiplexing in the mobile band into frequency multiplexing in the mm-wave band. In [1], an efficient resource allocation algorithm design to maximize the end-to-end system throughput for downlink multicarrier transmission with SUDAS is presented. However, considering the mobile networks, ~~in which the nodes having a~~ limited lifetime, have garnered a great interest on an efficient use of energy in wireless networks. Thus, for that purpose, we consider that the users in the system have no energy of their own, and for transmitting the information to the BS, they first harvest energy from the SUDACs available in the downlink. For energy harvesting (EH), we assume that the time switching (TS) based protocol is used. In [2], the authors studied the wireless energy and information transfer for two hop MIMO-OFDM relay networks for a single user, but they considered the relay to be energy harvesting component. On the contrary, we have multiple users in our system and they are the energy harvesting components. In [3], the authors presented a SUDAS system and their objective was to maximize the energy efficiency of the system but there were no energy harvesting components. The contribution of our work is summarized as follows:

We propose a SUDAS communication system which utilizes both licensed and unlicensed frequency bands to increase the information rate of the system. To explore the system performance, we formulate a non convex optimization problem to maximize the end-to-end achievable rate. Due to non convexity of the problem, we divide the main problem into two sub problems ~~namely~~ EH problem and information transmission problem and present an algorithm to solve it optimally.

II. System Model

We consider an OFDMA uplink communication system that consists of K UEs, M SUDACs and a BS. We assume that the users have no power of their own, so for communication to the BS, they need to harvest energy from the SUDACs available in the downlink. The UEs transmit the information to SUDACs in the unlicensed band and every SUDAC transmits to the BS in the licensed band. Simultaneous transmission and reception is possible at SUDACs since the two signals are separated in frequency.

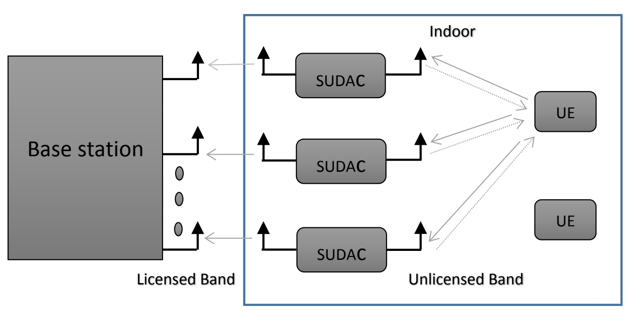

Figure 1. SUDAS communication system

The framework of time switching based (TS) protocol is presented in ~~figure~~ 2 ~~where the~~ time period T is divided into two phases. The first phase is of duration αT. This phase is used to transfer energy to UEs from the SUDACs available and $\alpha \in [0, 1]$ is the time switching factor. The second phase is of $(1 - \alpha)T$ duration and ~~it is~~ used to transfer information from the UEs to SUDACs and from SUDACs to BS. For simplicity, we normalize the time period T to be 1.

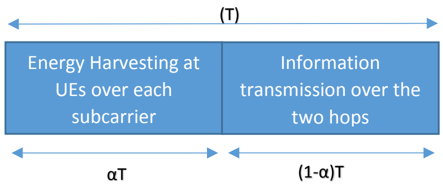

Figure 2. Framework of TS protocol

III. Optimization problem formulation

The optimization problem for the SUDAS assisted MIMO-OFDMA system can be expressed as:

$$\max_{\alpha, m_n^k, P_{1,n,j}^k, P_{2,n,j}^k} \quad \sum_{k=1}^{K} \sum_{n=1}^{n_F} (1-\alpha) m_n^k R_n^k$$

$$s.t$$

$$\sum_{j=1}^{N_s} m_n^k P_{1,n,j}^k \le \frac{E_{harv,n}^k}{1-\alpha}; \forall k, \forall n \qquad (1a)$$

$$\sum_{k=1}^{K} \sum_{n=1}^{n_F} \sum_{j=1}^{N_s} m_n^k P_{2,n,j}^k \le M P_R \qquad (1b)$$

$$\sum_{k=1}^{K} m_n^k \le 1; \quad \forall n \qquad (1c)$$

$$m_n^k \epsilon [0, 1]; \quad \forall k, \forall n \qquad (1d)$$

$$P_{1,n,j}^k \ge 0 \qquad (1e)$$

$$P_{2,n,j}^k \ge 0 \qquad (1f)$$

$$0 \le \alpha \le 1 \qquad (1g)$$

where the objective is to maximize the end-to-end achievable information rate. m_n^k, $P_{1,n,j}^k$, $P_{2,n,j}^k$ and α are the decision variables. m_n^k is the subcarrier allocation variable whose value is 1 when subcarrier n is assigned to user k and 0 otherwise. Moreover, constraints (1a) and (1b) represent the transmit power constraints of the energy harvesting users and the SUDACs. Constraints (1c) and (1d) ~~are imposed to~~ ensure that each subcarrier serves at most one user, while constraint (1g) shows that the fraction of time in which the users harvest energy is between 0 and 1. It can be observed that the above problem is a mixed integer non linear programming problem (MINLP). Therefore, it is very difficult to solve.

IV. Numerical Results and Discussions

The goal of this section is to evaluate the increase in achievable information rate of the proposed EH multicarrier SUDAS system based on simulations.

A. Performance vs Power Harvested (Pmax)

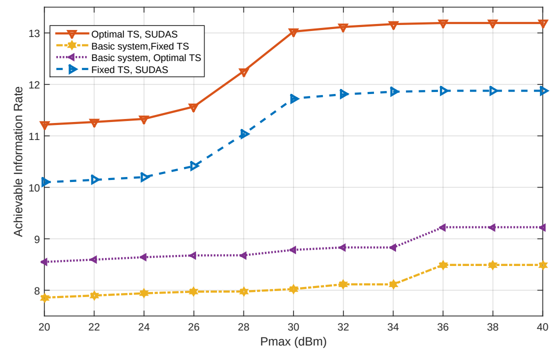

Figure 3. Pmax versus Achievable information rate of the system

B. Performance vs Number of Subcarriers

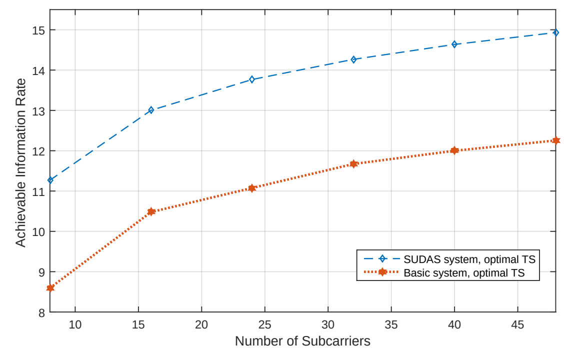

Figure 4. Number of subcarriers vs achievable information rate of the system

C. Number of SUDACs vs α

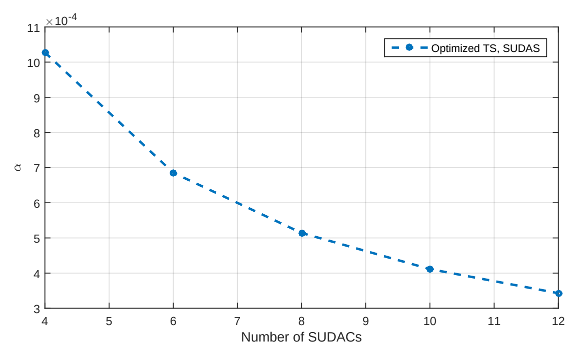

Figure 5. Number of SUDACs vs α

V. Conclusion

In this paper, we studied the wireless energy and information transfer in SUDAS assisted multicarrier transmission system. SUDAS is a system which utilizes both licensed and unlicensed bands. ~~For EH, we present the time switching~~

based (TS) protocol. To investigate the system performance, we formulated a non convex optimization problem with the objective of maximizing the achievable rate of the system. For the solution of the problem, we divided the main problem into two sub problems namely EH and information transmission problem. The simulation results suggested that the SUDAS system outperforms the basic system which utilizes only licensed band. We observe that the increase in the number of SUDACs and subcarriers results in higher achievable information rate of the system.

References

[1] Marco Breiling, Derrick Wing Kwan Ng, Christian Rohde, Frank Burkhardt, and Robert Schober, Resource Allocation for Outdoor to Indoor Multicarrier Transmission with Shared UE-side Distributed Antenna Systems, IEEE Vehicular Technology Conference, May 2015.

[2] Ke Xiong, Pingyi Fan, Chuang Zhang, and Khaled Ben Letaief, Wireless Information and Energy Transfer for Two-Hop Non-Regenerative MIMO-OFDM Relay Networks, IEEE Journal on selected areas in Communications, VOL. 33, NO. 8, August 2015.

[3] Derrick Wing Kwan Ng, Marco Breiling, Member, Christian Rohde, Frank Burkhardt, and Robert Schober, Energy-Efficient 5G Outdoor-to-Indoor Communication: SUDAS Over Licensed and Unlicensed Spectrum, IEEE Transaction on Wireless Communications, Vol. 15, No. 5, May 2016.