Fraunhofer Institute for Integrated Circuits (IIS)

Institute for Digital Communications (IDC)

User Documentation for SUDAS Simulation Test Bench

Fraunhofer-Institute for Integr. Circuits (IIS) Communications Systems Division Am Wolfsmantel 33 91058 Erlangen (Germany) `www.iis.fraunhofer.de`	F.-A.-University Erlangen-Nürnberg Institute for Digital Communications Prof. Dr. Robert Schober Wetterkreuz 15 91058 Erlangen (Germany) `www.idc.lnt.de`

SUDAS: `https://www.iis.fraunhofer.de/en/ff/kom/proj/sudas.html`

Summary

This document is a guide for the SUDAS simulation test bench. The software and hardware requirements, the instructions for execution, and the hints for extension of the test bench to a newer user cases are given in this document.

Terminology

AF	Amplify and Forward
BS	Base Station
LOS	Line Of Sight
QuaDRiGa	QUAsi Deterministic RadIo channel GenerAtor
SUDAS	Shared UE-side Distributed Antenna System
URU	UE-side Radio Unit
UE	User Equipment

1 Introduction and Overview

A user may need to take a number of necessary steps in order to run the simulation package. In this section, these steps as well as the channel models and optimization methods are briefly explained.

1.1 Primary Steps

1.1.1 Installation and System Requirements

The minimum system requirements in order to run this package are:

Requirement	Value
Minimal required MATLAB version	7.12 (R2011a)
Required toolboxes	none
Memory (RAM) requirement	1 GB
Operating System	Windows

Table 1: System requirements.

In order to use this package, a user needs to take the following steps:

1. Download the package from the SUDAS web page "`https://www.iis.fraunhofer.de/en/ff/kom/proj/sudas.html`".
2. Extract the ZIP-File containing the model files
3. Add the "Simulation_Bench_ddmmyyyy"-folder from the extracted archive to your MATLAB-path (user may download the latest version, ddmmyyyy represents the date of code update)
4. Command window >> run_simulation. User may need to wait for a few minutes to be able to observe the results.

1.1.2 Package Output

Figures 2 and 3 are outputs of the "run_simulation" command.

Figure 2 depicts the visualization of indoor environment. As can be seen, positions of UEs as well as URUs are shown in a 3D grid (The placement of URUs and UEs is configurable in the MATLAB code).

Figure 3 illustrates the average throughput of the whole system versus transmission power of BS for two optimization algorithms, namely, AF joint processing and AF independent processing. The cut-set bound is derived by assuming that the UEs' antennas are located in the place of URUs. Technical details of these algorithms can be found in [1, 2] and all the simulation parameters are configurable in the MATLAB code.

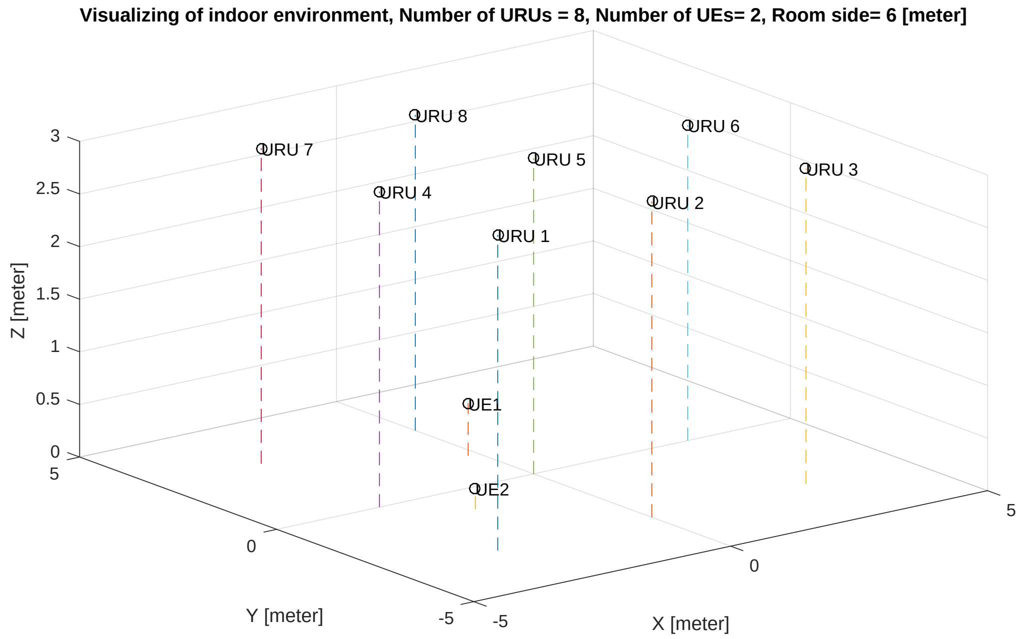

Figure 2: Visualizing the indoor environment

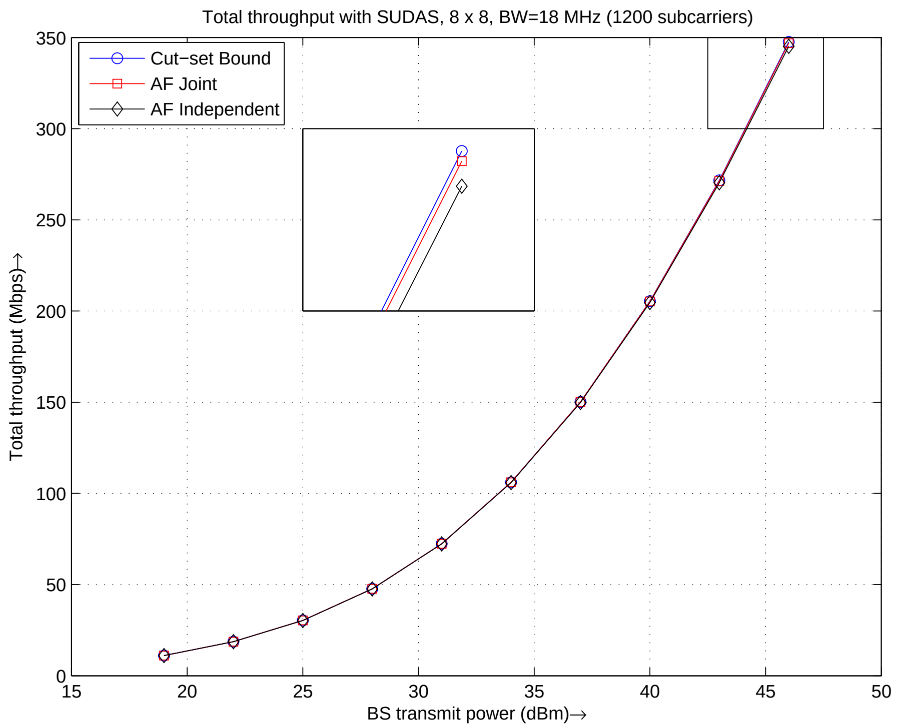

Figure 3: Performance of two optimization schemes. Number of transmit antennas = 8, number of URUs = 8, number of users = 1, BS-to-SUDAS distance = 100 [meter].

1.2 General remarks

This document gives a comprehensive overview of SUDAS system model and its implementation details. The model is developed based on [1, 3] and evolved during [2]. Figure 4 depicts the system model implemented in the simulation package. Figure 5 shows that the MATLAB implementation is split up to three main parts, namely, Outdoor-to-Indoor (O2I) channel, indoor channel, and optimization unit.

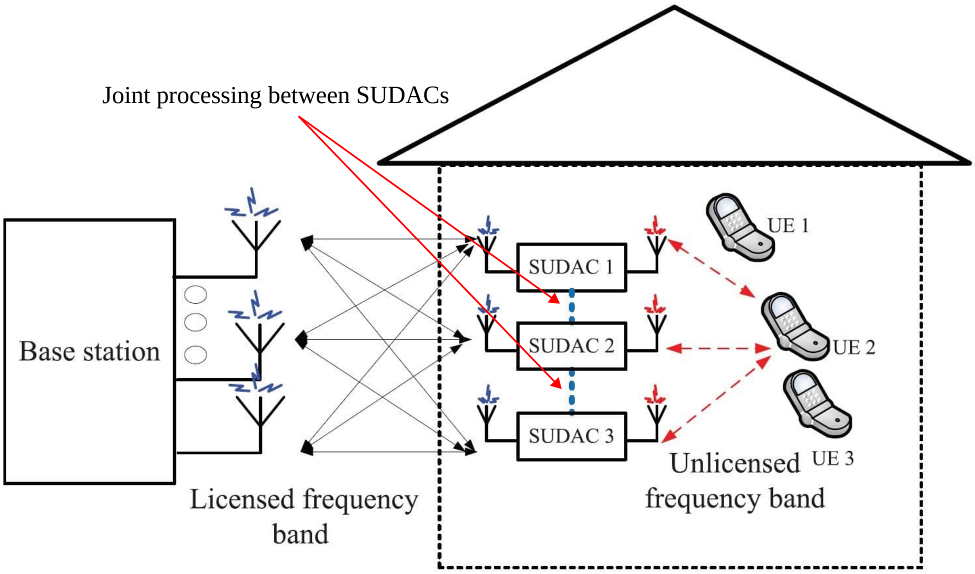

Figure 4: System model.

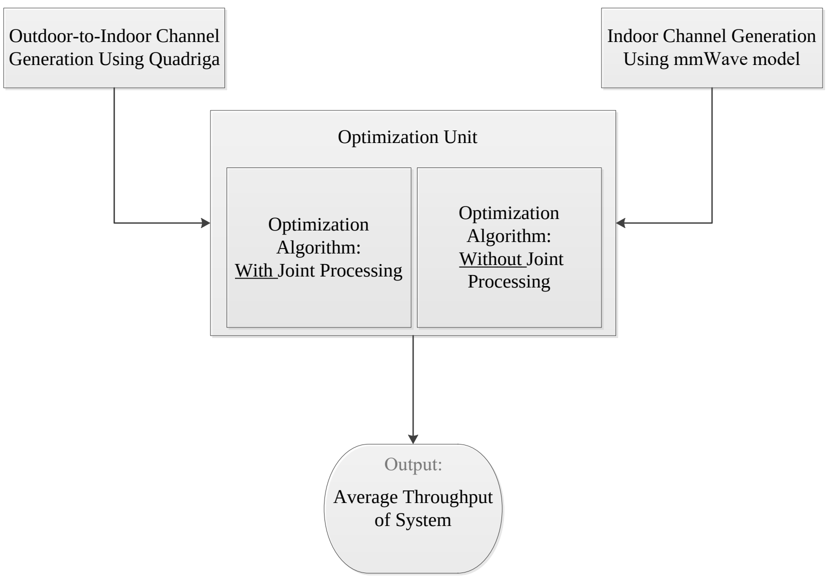

Figure 5: Structure of MATLAB implementation.

1.3 Quadriga Channel Model

1.3.1 General Properties

QuaDRiGa (QUAsi Deterministic RadIo channel GenerAtor) is developed by Fraunhofer Heinrich Herz Institute to enable the modeling of MIMO radio channels for specific network configurations, such as outdoor, indoor, outdoor-to-indoor, and satellite [4]. QuaDRiGa is a "statistical ray-tracing model" based on practical measurements in various propagation environments (e.g. urban, suburban, rural, and etc.). Statistics of Large Scale Parameters (LSPs) are describing the scenario (propagation environment) and are stored in configuration files which can be edited by user. Details may be found in [5, p. 47]. The latest version of this channel model can be downloaded from "`http://quadriga-channel-model.de/#Download`".

1.3.2 QuaDRiGa in SUDAS

Outdoor-to-indoor channel model in SUDAS system model is simulated using QuaDRiGa. The user needs to take the following steps in order to set up the desirable model (please note that the parameters are already set to the default values and the user may change them according to his desire)

- Setting the frequency properties (e.g. bandwidth)
- Setting the transmitter position (e.g. BS positions or transmit antenna positions)
- Setting the receiver position
- Defining the properties of transmit/receive antennas (e.g. type, gain)
- Setting the general scenario (propagation environment)

1.4 mmWave Channel Model

mmWave channel model is developed in [6] based on [7] in order to enable modeling of 60-GHz channel in specific indoor environments, such as conference room, living room, and cubicle office. Path loss, Line Of Sight (LOS) as well as low order reflected paths, and polarization characteristics are taken into account in this statistical model. Furthermore, the models allow employing different sort of antennas as well as beam forming techniques. The latest version of this channel model can be downloaded from "`https://mentor.ieee.org/802.11/dcn/09/11-09-0854-03-00ad-implementation-of-60ghz-wlan-channel-model.doc`".

1.5 Optimization Unit

Optimization unit allocates the available power, precoding matrices, and subcarriers at BS and URUs to the users such that the throughput of the system is maximized. Optimization unit in this simulation package consists of two main parts. One part is implementation of the [1, Algorithm 2] while another part implements [2, Algorithm 2]. The former is developed with the assumption of joint processing between URUs whereas in later this assumption is neglected and the URUs are to operate independently (they can only exchange control data).

2 Software Structure

2.1 overview

This simulation package is implemented in MATLAB. As can be seen in Figure 6, it is comprised of four main parts. “SUDAS_Layout” defines the network layout of simulation run. “channel_O2I” generates the outdoor-to-indoor channel based on Quadriga [4]. “channel_indoor_mmWave” generates indoor channel based on [7]. Lastly, “Optimization” is implementation of Algorithms in [1] and [2].

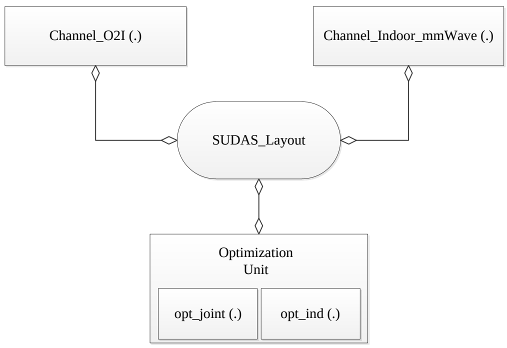

Figure 6: Software structure.

2.2 SUDAS_Layout

The following parameters may be configured in the “SUDAS_Layout.m”:

SUDAS_Layout.m		
Parameters		Default value
N	Number of transmit antennas at BS	8
M	Number of URUs	8
K	Number of Users	1
D	BS-to-URUs distance [meter]	100
a	Side of indoor room [meter]. a^2 is ceiling area	6

Table 2: Configurable parameters in SUDAS_Layout.m file

2.3 Outdoor-to-indoor channel

This function simulates outdoor-to-indoor channel using QuaDRiGa channel model. The function receives the required inputs from "SUDAS_Layout" and returns the outdoor-to-indoor channel coefficients. In the Table 3, the inputs and outputs of this function are explained. see [4] for more details about content of this function and the configuration. Furthermore, Table 4 describes the properties of function "LTEmode" whose outputs are used as inputs of the main function "channel_O2I".

hcoeff = **channel_O2I**(·)		
Description	This function generates the outdoor-to-indoor channel coefficients based on Quadriga [4].	
Input		Default value
BandWidth	The bandwidth in which system is operating [Hz].	18×10^6
no_subcarriers	Number of subcarriers	1200
CenterFrequency	The center frequency in which system is operating [Hz]	800×10^6
NoTx	Number of base stations.	1
BS_antenna_model	The antenna type used for antenna array at base station.	'omni'
no_TxArrayElements	Number of antenna elements in antenna array of base station.	8
no_URUs	Number of URUs.	8
room_side	side of the room (indoor environment) [meter].	6
BS_to_S_distance	Distance of BS to center of indoor environment [MHz]	800
GeneralScenario	The propagation environment of system model [4, p. 55].	C4 [5]
Output		
hcoeff	Outdoor-to-indoor channel coefficients for all subcarriers	

Table 3: Outdoor-to-indoor channel function (description, inputs, and outputs).

[BandWidth, no_subcarriers, fftLength] = **LTEmode** (·)		
Description	This function determines the LTE mode (each mode is referred to different bandwidth and number of subcarriers) in which system is operating.	
Input		Default value
mode	It can be a number between '1' to '7' which corresponds to different LTE modes.	2
Output		Default value
BandWidth	The system baseband bandwidth [Hz].	18×10^6
no_subcarriers	Number of subcarriers.	1200
fftLength	Length of fft.	2048

Table 4: The function which determines the parameters of the system.

2.4 Indoor channel

Function "channel_indoor_mmWave" simulates indoor 60 GHz channel for Conference room, living room, and Cubicle office based on [7]. The function receives the required inputs from "SUDAS_Layout" and returns the indoor channel coefficients. In the Table 5, the inputs and outputs of this function are explained. See [7] for more details about content of this function and configuration. Furthermore, Table 6 describes the properties of the function "'indoor_visualize' which is visualizing the indoor environment.

hcoeff_mmWave = **channel_Indoor_mmWave**(·)		
Description	This function generates the indoor channel coefficients based on [7].	
Input		Default value
IndoorScenario	The indoor propagation environment of system model. '1' = conference room, '2' = living room, '3' = cubicle.	1
no_subcarriers	Number of subcarriers.	1200
fftLength	Length of fft (in order to extract desired number of subcarriers)	2048
no_URUs	Number of URUs.	8
no_UE	Number of UEs in indoor environment.	1
RxTxDistance	Distance between each URU and each UE	–
mmw_Tx_antenna_gain_dB	transmit antenna gain of URUs [dB].	0
LOS	A vector which determines whether each of the URU-UE links are having line of sight or not ('1' = LOS, '0' = NLOS)	–
Output		
hcoeff_mmWave	Indoor channel coefficients for all subcarriers	

Table 5: Indoor channel function (description, inputs, and outputs).

indoor_visualize(·)		
Description	This function visualizes the indoor environment. Positions of URUs as well as UEs is shown in a figure as output	
Input		Default value
no_URUs	Number of URUs	8
RxTxDistance	Distance between each URU and each UE	-
BS_to_S_dist	Distance between BS and center of indoor environment [meter]	100

Table 6: Indoor environment visualizer.

2.5 Optimization

The optimization unit is developed based on [1] and [2]. Two functions, namely, "opt_joint" and "opt_ind" are implementing [1, Algorithm 2] and [2, Algorithm 2] respectively. The inputs and outputs of these function are explained in Table 7.

[.] = **opt_joint**(·) [.] = **opt_ind**(·)		
Description	This function optimizes the allocated powers to different antennas at BS and URUs. Two schemes are considered in these two functions, namely, joint processing and independent processing approach based on [2]	
Input		Default value
h_BS_S	BS-to-URUs channel matrix for all subcarriers	-
h_S_UE	Indoor channel matrix for all subcarriers	-
pt_max	Maximum available power at base station [dBm]	19 - 46
pt_URU_max_DLorUL	The maximum available power at the output of URUs [dBm]	23
no_subcarriers	Number of subcarriers	1200
no_URUs	Number of URUs	8
no_UE	Number of UEs	1
pt_UEk_max	Maximum available power of each UE (this is useful if the Uplink part of the function is activated) [dBm]	23
Output		
Y_P_BS_S	Allocated power to each antenna over each subcarrier at BS in downlink scenario	
Y_P_S_UE	Allocated power to each antenna over each subcarrier at URUs in downlink scenario	
Y_P_UE_S	Allocated power to each antenna over each subcarrier at UE in uplink scenario (if the uplink is activated)	
Y_P_S_BS	Allocated power to each antenna over each subcarrier at URUs in uplink scenario (if the uplink is activated)	
Y_s_DL	Allocated power to each antenna over each subcarrier at BS (if the uplink is activated)	
sumRate	Total throughput of the system	

Table 7: Optimization functions (description, inputs, and outputs).

References

[1] D. W. Kwan, M. Breiling, Ch. Rohde, F. Burkhardt, and R. Schober *Energy-Efficient 5G Outdoor-to-Indoor Communication: SUDAS Over Licensed and Unlicensed Spectrum,* IEEE Transactions on Wireless Communications, May 2016.

[2] M. Goodarzi, A. Krishnamoorthy, R. Schober *Resource Allocation in a Distributed Antenna System,* Master thesis at Friedrich Alexander University of Erlangen-Nuernberg, January 2017.

[3] M. Breiling, D. W. Kwan Ng, Ch. Rohde, F. Burkhardt, and R. Schober, *Resource Allocation for Outdoor-to-Indoor Multicarrier Transmission with Shared UE-side Distributed Antenna Systems,* 2015 IEEE 81st Vehicular Technology Conference (VTC Spring).

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Author:	Meysam Goodarzi (meysam.goodarzi@fau.de)
Contact:	Aravindh Krishnamoorthy(aravindh.krishnamoorthy@fau.de/@iis.fraunhofer.de)
	Marco Breiling (marco.breiling@iis.fraunhofer.de)