Link-Level and System-Level Simulation of 300 GHz wireless Backhaul Links

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Abstract – One of the goal of the EU-Japan joint project ThoR is to demonstrate the feasibility of the IEEE Standard 802.15.3d-2017 for backhaul/fronthaul links. This will be done in a realistic deployment scenario using both system-level and link-level simulations integrated in the same tool. Based on the system-level simulations, a wireless backhaul network for a given ultra-dense mobile network is automatically planned and analyzed. Exemplary links are then simulated using the link-level simulations. Preliminary results of both simulations are presented from a scenario in Hanover, Germany and showing the achievability of >100 Gbit/s data rate fully considering the current IEEE Std 802.15.3d-2017.

Keywords — THz communication, wireless backhaul, wireless backbone, link level simulation, system level simulation.

I. INTRODUCTION

Towards to 5G and beyond 5G mobile communication systems, the increasing number of end user devices and the growing demand of high data rate is foreseen [1]. Furthermore, the data consumption patterns are shifting to the volume critical applications such as VoD (video-on-demand) streaming services and immersive media applications (VR and AR) [1]. In order to support these trends, a massive implementation of new mobile cell sites seems to be required. In fact, the connection from the new cell sites into the backbone network, so called backhaul link with aggregated data rates of beyond 100 Gbit/s should be guaranteed. Here, the wireless link operating at 300 GHz is a promising alternative to substitute the conventional cable backhaul connection. Based on IEEE Std 802.15.3d-2017 [2], >100 Gbit/s data rate is achievable and the EU-Japan project ThoR will show the feasibility of this standard by means of the system-level and the link-level simulation. Through the system-level simulation, the planning methods and guidelines are deducted using cell coverage probability and SINR, while the study on scalability and capability of IEEE Standard 802.15.3d is investigated in the link-level simulation. In this paper, the preliminary result of system-level as well as link-level simulations will be shown using the wireless based backbone network under highly densified cell environment.

II. System Level Simulation

As a part of ThoR, various scenarios have been designed for simulating the THz communication application case of wireless backhaul links [3]. Using Hanover scenario from

[3], the wireless backhaul links have been tested using the automatic planning algorithm for 300 GHz backhaul links [4]. The algorithm automatically finds the possible wireless backhaul cell sites given the conventional fibre required cell sites with heuristic means.

Fig. 1. Automatic planned backhaul network in Hanover.

In Fig. 1, the automatic planned backhaul network in Hanover using a star topology is shown. Here, the red points indicate anchor cell sites with a fibre backhaul, while the blue points represent cell sites with a wireless 300 GHz backhaul. The connections between wireless backhauled base stations and anchor base stations are displayed by green lines. Herein only around 29 % of newly deployed cell sites require a fibre backhaul connection.

Fig. 2. SINR of the automatic planned wireless backhaul network using various weather conditions.

In Fig. 2, SINR values of the planned backhaul network have been investigated under various weather conditions. SINR values always exceed the demand of 22 dB which

enables the use of the highest modulation and coding scheme defined in [2] even using 50 GHz bandwidth at high rain rates.

III. Link Level Simulation

The link-level simulator performs Monte-Carlo-Simulations to compute statistics and various key performance indicators (KPIs) for a single transmission link. These include but are not limited to bit error rate (BER), data rate and error vector magnitude (EVM). The link-level simulator incorporates modulation and coding schemes defined by [2] as well as hardware impairments such as phase noise, IQ-imbalance and hardware specific transfer functions. One of the ultimate goal of the simulator development in ThoR is to combine both, the system-level and the link-level simulator, in order to provide more accurate estimation of a link's performance by including effects of hardware and specific modulation and coding schemes. To trigger and execute a link-level simulation, a link between two base stations from the system-level simulation in Fig.1 has been chosen. The ray-tracing result of a chosen link is shown on the left hand side of Fig.3 while on the right hand side, the impulse response of the ray-tracing results is visualized.

Fig. 3. Ray-tracing results of the system-level simulation (left) and the impulse response (right).

In this way, a seamless integration allows for the close investigation of single links and their performance. From the system-level configuration, a set of configuration parameters is derived that includes hardware components, settings and specific channel characteristics.

Fig. 4. Link-level simulation results using hardware impairments.

In Fig.4, one of the results from the link-level simulation is shown. The impulse response is determined with ray-

tracing and the performance of a link using various modulation and coding schemes is analyzed. Here, a 16-QAM modulation is simulated and the AWGN is adapted to the selected SINR. The simulation also considers the phase noise of the photonic oscillator and the transfer function of the power amplifier developed in ThoR [5, 6].

The link-level simulator implements features to create automated parameter sweeps to check various combinations of configuration settings. It can also put out intermediate values while continuing the computation of more accurate results. These features offer the possibility of real-time output and analysis of different configuration settings to compare them within the simulation.

IV. CONCLUSION

In this paper, both system-level and the link-level simulation results from the ThoR simulator are shown considering 300 GHz wireless backhaul links. The system-level simulation has shown that every link of the planned backhaul network using the automatic planning algorithm can be supported even the highest modulation and coding scheme defined in [2] regardless of given weather conditions. Based on this studies, the planning methods and guidelines of the backhaul network will be driven. Links from the planned backhaul network have been chosen for running the link-level simulation. This will enable to investigate the scalability of the ThoR project to full IEEE 802.15.3d capabilities. This also figures out the best suitable modulation and coding scheme to achieve a certain data rate considering the impact of hardware impairments. Further work will deal with a closer integration and coupling of the system-level and the link-level simulator. In this way, the reciprocal influence by simulations can be considered.

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