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Automatic Planning of NLOS Backhaul Links at 300 GHz arranged in Star Topology

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Abstract

In 5G and Beyond networks the ultra-densification of networks will require ultra-high backhaul capacities for a very large number of base station locations, especially in urban areas. Since fibre connections will not be available everywhere, the use of spectrum at 300 GHz and beyond might enable the complementary use of wireless backhaul solutions to nearby fibre connected hubs. In some cases a line-of-sight connection is not available and the backhaul connection might be realized using one refection. In this paper a planning algorithm is presented, which automatically identifies possible wireless links taking into account none-line-of-sight connections in backhaul networks arranged in star topology.

1 Introduction

The introduction of fifth generation (5G) and Beyond networks implies a tremendous growth in connectivity and data traffic density/volume as well as the required ultra-densification especially in urban areas. Traffic densities of several Tbps/km^2 are already predicted for foreseeable 5G networks in the near future [1]. The Ericsson Technology Review Report [2] mentions, that "by 2021, 65 % of the world's cell site (excluding those in north-east Asia) will be connected using microwave backhaul technology". The same report expresses the expectation that in 2025 to 2030 a large-scale deployment of wireless backhaul links beyond 100 GHz solutions is foreseen and mentions 252-325 GHz as a possible candidate band. These wireless backhaul links are attractive to backhaul sites, where fibre links are not available or too costly.

The EU-Japan Horizon 2020 project ThoR [3] is working towards a hardware demonstrator of 300 GHz wireless backhaul links [4], which is compliant with IEEE Std. 802.15.3d-2017 [5]. ThoR is also working on software simulation and automatic planning of wireless backhaul links [6,7] and has defined realistic scenarios in cities in Germany and Japan [8]. The ThoR planning approach makes the assumption, that a limited number of base stations exist, which have a fibre connection and the remaining base stations can be connected to the fibre-connected base stations with one hop. Algorithms, that automatically identify and maximize the number wireless connected base stations have been already developed in ThoR [9,10,11] applying both ring and star topologies. However, these approaches take into account only possible line-of-sight (LOS) links. Especially an ultra-densified network in dense urban areas many base stations will be deployed at lamp-post heights, where no LOS connection exist to any fibre-connected base station. In these cases a one-hop connection via one reflection might exist as depicted in Figure 1.

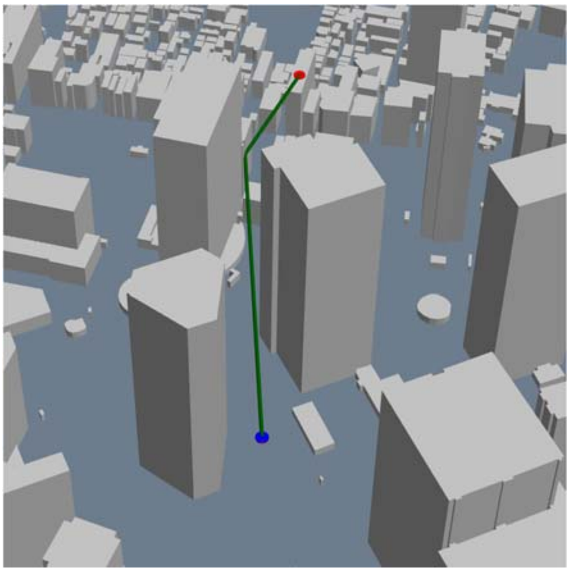

Figure 1. Wireless connection of a base station at lamp-post hight (blue dot) to a fibre-connected base station at roof-top level (red dot) exploiting one reflection

In this contribution the planning algorithm for backhaul networks arranged in star topology described in [9] has been extended by taking into account possible once-reflected rays in none-line-of-sight (NLOS) conditions.

The remaining part of the paper is structured as follows. Chapter 2 introduces the algorithmic approach. Results are presented in chapter 3. Chapter 4 contains conclusions and an outlook.

2 Algorithmic Approach for Planning of NLOS Links

To facilitate planning of NLOS wireless backhaul links, a new algorithm has been developed extending the algorithm introduced in [9], which automatically derived wireless connections linked to a fibre connected base station assuming LOS. Furthermore the wireless links are arranged in a star topology with fibre connected base stations in the centre of each hub. The extension of the algorithm from [9] consists of a new element to identify multi-paths allowing a connection via one reflection. A simplified simulation flow is shown in Figure 2 and the following steps are performed in order to identify possible links:

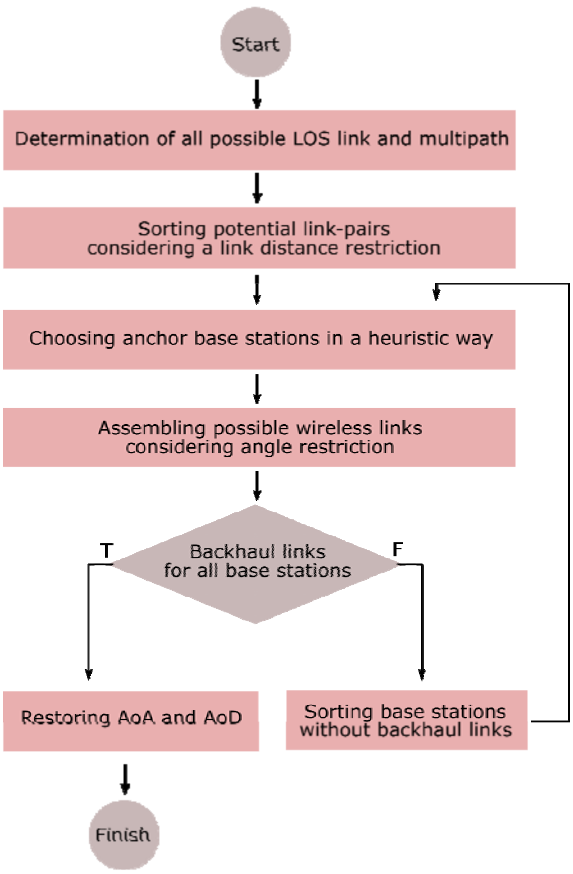

Figure 2. A simplified diagram of the simulation flow

1. All possible LOS links and multipath signals taking into account single reflections are determined for all pairs of base stations.
2. The potential link-pairs considering a link distance restriction are identified.
3. The base stations, which require a fibre backhaul connection and can be potentially served as anchor cell sites are determined. The determination of such anchor base stations is done in a heuristic way based on the potential link-pairs obtained in the previous step. For this, the base stations are determined sequentially as anchor base stations, which have the most number of link-pairs first.
4. With the shortest wireless link to a fibre connected hub is assigned consecutively taking into account a so-called safety angle margin. Here, the safety angle margin refers to the angle between two wireless backhaul links, which might interfere. This restriction prevents the high interference signal of wireless links beforehand. In this step LOS link has always priority. This means that the NLOS link is considered only when LOS connection is not feasible. The assignment of wireless links is conducted by examining all discovered multi-paths form step 1.
5. Due to the angle restriction, the backhaul connections of some of cell sites are possibly fed neither by fibre nor wireless. Using these remaining base stations, the algorithm iterates the third and fourth step until every gets a backhaul connection.
6. The algorithm completes the simulation by restoring the angle-of-arriaval (AoA) and angle-of-departure (AoD) of each determined THz link.

3 Results

The algorithm has been applied to the Hanover scenario defined in [8]. A maximum link distance of 400 m, a safety angle margin of 4°, transmit power of 0 dBm and antenna gains of 50 dBi both on Tx and Rx have been applied. It is further assumed that 3 base stations, totally 7 sectored antennas, have a priori fibre connections.

Table 1: Comparison of the number of automatically planned backhaul links

Number of backhaul links	Wireless Link Types	
	LOS (based on [9])	**LOS +NLOS** (extension of [9])
Wireless @ 300 GHz	208	219
Fibre	92	81

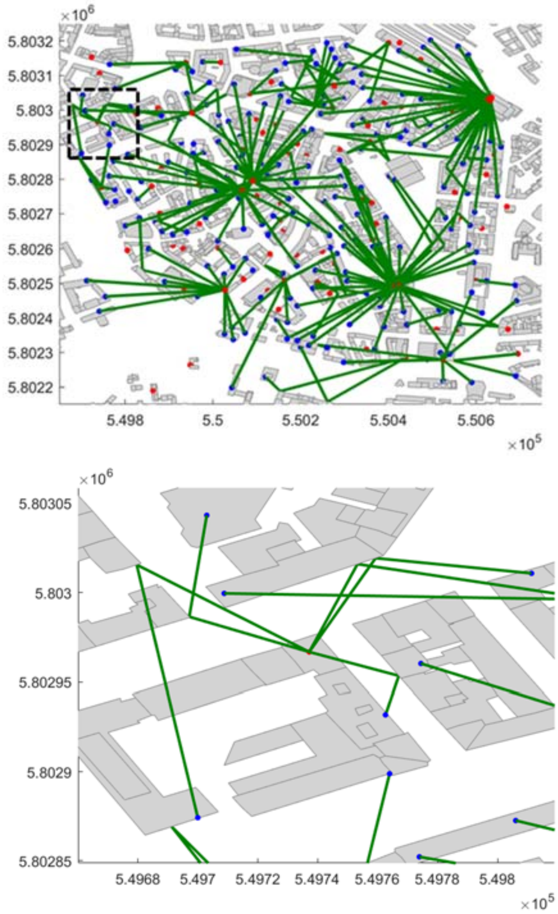

Figure 3. Automatically planned backhaul network in the Hanover sceanrio; complete network (top) and zoom into the dotted black square (bottom). Blue (red) dots represenst base stations without (with) fibre connections.

The results are summarized in Table 1, which includes also a comparison with the solution achieved by taking into account LOS connections only. For both algorithms, the optimization criteria is cost reduction. Thus, the algorithms try to reduce as many fibre backhaul connection as possible since the costs of fibre links are assumed to be higher compared to the wireless links. By introducing NLOS connections the number of base stations requiring a fibre connection is reduced by ~12%. The visualization of the planned network is depicted in Figure 3. The zoom into left upper corner of the complete network shows examples of 4 planned NLOS connections. In order to evaluate, whether the automatically planned network satisfies the quality requirements the cumulative distribution (CDF) of the signal-to-interference –and noise ratio is plotted in Figure 4. A bandwidth of 5 GHz and the clear weather condition (7.5 g/m^3 of water vapour density, 17° of temperature and 1013.25 hPa of air pressure) have been assumed in this evaluation. As can be seen in Figure 4, an SINR of 22 dB is exceeded in 211 of 219 wireless links, around 96.5%, respectively. This SINR corresponds to the minimum required value for 64 QAM with 14/15 FEC to achieve a data rate of at least 100 Gbit/s.

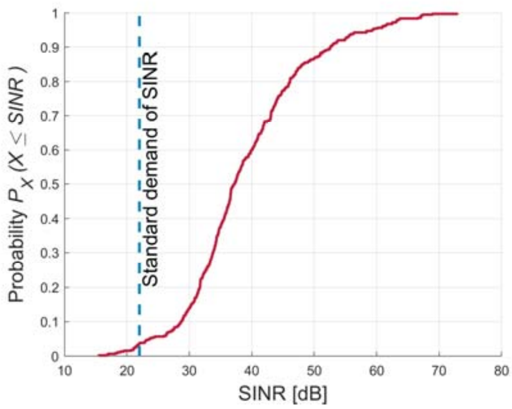

Figure 4. CDF of SINR of the complete automatically planned network (blue dashed line corresponds to the minimum required SINR)

4 Conclusion and Outlook

A planning algorithm has been presented, which automatically identifies possible wireless links taking into account 300 GHz wireless none-line-of-sight connections a backhaul networks. The wireless connections are arranged in star topology with the fibre connection hub in the center. By allowing also NLOS connections a reduction of 12.7% of required fibre-connected base stations. As a next step this algorithm will be extended also for backhaul networks arranged in a ring topology, which will add additional redundancy and increase the reliability of the network.

Acknowledgement

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