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10a.002.TAU_WP7 – Learning-aided Mobile THz Communications

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Project 10a.002.TAU_WP7 – Learning-aided Mobile THz Communications

Contents

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Executive Summary/Abstract

The terahertz (THz, 0.3-3 THz) band offering tens of gigahertz of consecutive bandwidth is nowadays considered as a major candidate for new radio access technology for 6G cellular systems. By utilizing this bandwidth one may not only provide extreme data rates but enable principally new applications such as holographic telepresence and virtual reality. The sub-millimeter wavelength promises ultra large antenna arrays capable of creating extremely directional steerable antenna radiation patterns with the beamwidth of just a few degrees or even less. This feature is vital for THz communications not only allowing to overcome severe path loss at these frequencies but ensuring almost interference free environment. In this project, we plan to develop Machine Learning (ML) -aided ray-tracing simulation methodology capable of representing dynamically changing propagation conditions in real-time for extension of propagation models obtained for specific environments to other typical deployment options.

Goals and Objectives

This work package has two objectives:

- First, we will develop 3D cluster-based stochastic propagation models for precise link- and system-level analysis of communications algorithms.
- Then, we will develop of ML-based ray-tracing simulator capable of representing dynamically changing propagation conditions in real-time.

Differences from Current State of Art

There is a number of works aimed at optimizing and accelerating the wireless ray tracing procedure, for example, a visibility graph based method [1, 2]. This method involves dividing the field of view of the transmitter into zones, taking into account line of sight, reflections and diffraction, compiling a visibility graph based on them and searching for zones in which the transmitter is located. The authors in [3] proposed to use Fermat's least principle to convert data from 2D to 3D. In addition to this, the optimal number of reflections that should be taken into account in the simulation was investigated. To simplify ray tracing, a novel method was proposed in [4] for dividing the space into smaller ones to distribute objects over them. In ray tracing, only the areas in which propagation occurs are considered. The authors in [5] proposed to remove from the database, which contain a lot of data on the propagation of radio waves, as well as a geometric method based on smoothing irregularities in buildings with a complex shape. In [6], rays that have undergone the same interaction with surrounding objects are proposed to be combined into single "entities" to reduce the number of rays and, as a result, accelerate ray tracing. The authors in [7] presented a method for compiling a visibility table, in which all reflections are calculated in advance, for subsequent use in modeling. In [8], using machine learning methods, the influence of objects such as buildings, distance, as well as smaller objects on the result of modeling using ray tracing was plotted. Thus, the authors of previous studies used mostly deterministic methods to accelerate ray tracing, with the exception of the latest work, where the authors used machine learning to explore the degree to which external factors influence the result. However, no one has used neural networks to speed up the ray tracing method, so using them to increase the performance of ray tracing in modeling radio channels is relevant.

Methods and Datasets

In this project, to analyze environments that substantially differ from the measured ones, we explored the option of complementing ray-tracing simulations with supervised ML--based algorithms. Particularly, we first constructed geometric and physical models of the measured environment in a manner consistent with the conventional 3D engines, including faces, vertices, bounding boxes, etc., using the data from Open Street Map project, our minor measurement campaign providing reflection/diffraction specifics of surfaces and Kirchhoff's diffraction theory. For radio wave propagation and data acquisition we used Communication toolbox module of Matlab software. Based on the collected data using a neural network, it will be possible to calculate the distance through which it will be necessary to launch new rays, rather than launching them at every step, which will reduce the computational complexity of ray tracing.

To obtain the results, convolutional neural networks (convolutional NN) and LSTM (Long short-term memory) networks are used, since these neural networks are able to take into account memory over time. The following input data are required to parametrize a neural network:

- Number of reflections - the number of reflections of each beam on the way from the transmitter to the receiver
- Number of diffractions - the number of diffractions of each beam on the way from the transmitter to the receiver
- Received power – received power to the receivers in total from all beams
- Path loss - energy loss during the propagation of each beam on the way from the transmitter to the receiver
- Distance - the distance that the beam traveled before reaching the receiver
- Angle of departure – beam deflection angle when launched from the transmitter.
- Angle of arrival – beam arrival angle at the receiver

Based on the received data, the neural networks calculate the sector into which beams must be sent to achieve the required power data at the receiver.

Functionality of Innovation(s)

The solution developed in this project can introduce ML-based ray-tracing simulation methodology capable of representing dynamically changing propagation conditions in real-time for extension of propagation models obtained for specific environments to other typical deployment options.

Conclusions and Recommendations

The proposed solution provides the algorithms that can be used in many industries where THz communications will be applied. It will help to speed-up ray-tracing simulation software allowing faster network planning for different applications.

Impact and Uses/Benefits

The developed algorithms and their implementation in ray-tracing simulation software will be especially beneficial for YL-Verkot Oy since it can be used to adequately simulate THz channels, where YL-Verkot Oy accumulates industrial expertise.

Publications

Y Koucheryavy et al. A Tutorial on Mathematical Modeling of 5G/6G Millimeter Wave and Terahertz Cellular Systems, IEEE Communications Surveys & Tutorials, vol. 24, issue 2, 2022, pp. 1072 – 1116.

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Appendix