LoRaPlan: A Software to Evaluate Gateway Placement in LoRaWAN

Frank Loh, Noah Mehling, Florian Metzger, Tobias Hoßfeld
University of Würzburg, Institute of Computer Science, Würzburg, Germany
{firstname.lastname}@informatik.uni-wuerzburg.de
David Hock
Infosim GmbH & Co. KG, Würzburg, Germany
{hock}@infosim.net

Abstract—**Long Range Wide Area Network (LoRaWAN) is one of the fastest growing Internet of Things (IoT) access network solutions. One major challenge in current LoRaWAN planning is message collision due to the random channel access. To study the collision behavior in LoRaWAN, we present LoRaPlan in this demonstration. LoRaPlan is a software to evaluate gateway placement decisions by studying the collision probability. Therefore, sensor and gateway locations can be imported to create a LoRaWAN. Furthermore, existing networks can be extended by additional gateways. Based on this setup, network coverage, network quality with regard to the number of sensors a single gateway has to manage, and also transmission quality and collision probabilities can be studied.**

In this demonstration, first the process of network creation with gateway and sensor import and additional manual gateway placement in LoRaPlan is presented. Different adjustable parameters are shown and the influence on network coverage and collision probability is discussed. At the end of this demonstration, it is possible for the audience to place their own gateways and evaluate own placements by means of collision probability and the coverage.

Index Terms—**Network planning, IoT, LoRa**

I. INTRODUCTION AND PROBLEM FORMULATION

Long Range Wide Area Networks (LoRaWANs) have proven as important access technology for Smart City IoT deployments [1]. But especially with the random channel access nature in these networks, dealing with message collisions and packet loss is a crucial challenge.

From a LoRaWAN service provider's point of view, network planning and especially reasonable gateway placement is essential for high transmission quality. However, nowadays besides analyzing coverage and gateway capacity, two contrary approaches in LoRaWAN planning are discussed: 1) infrastructure cost minimization or 2) message collision and thus loss probability reduction. There, the goal is to find a good trade-off between high cost for gateway acquisition and deployment and a satisfiable network quality for the devices. But so far, in literature mainly the infrastructure cost is taken into consideration by minimizing the number of required gateways for a network [2], [3].

With the increasing number of application areas for LoRaWAN, a sole consideration of only infrastructure cost is not possible anymore. Intelligent network planning and gateway placement is required to compare pros and cons for different locations. For that reason, this demonstration presents LoRaPlan, an easy-to-use LoRaWAN network planning software to evaluate gateway placement decisions by means of coverage but also collision probability. With the software, it is possible to import sensor and gateway locations with latitude and longitude coordinate and visualize gateway placement and network coverage. Additional information is available like the number of connected sensors per gateway, expected connection quality, or expected packet collision information for predefined transmission rates for the sensors. Furthermore, the LoRaPlan software can be used as basis for additional optimization or initial evaluation of placement heuristics since the created placement can be exported as JSON file. In this demonstration, it is possible for the audience to place their own gateways and see the influence on coverage and collision probability based on th eir selected placement decisions. This shows the importance of intelligent network planning in LoRaWAN with focus on network quality by collision probability and loss reduction, and not only on cost.

From a technical point of view, several influencing parameters are essential in LoRaWAN planning, highlighted and presented in this demonstration. For each sensor, the data transmission rate, the payload of the transmitted data, and the distance to the next gateway is important to select relevant transmission parameters in LoRa and calculate collision probability. Especially for the transmission distance, several path loss models are introduced in the software and can be tested during the demonstration. Furthermore, it is possible to add topography information influencing the transmission behavior from sensor to gateway by additional attenuation.

In the following, a short technical background of relevant LoRa-related terms and important parameters the software uses is given and the demonstration scenario is introduced.

II. IMPLEMENTATION DETAILS AND SOFTWARE COMPONENTS

The LoRaPlan software presented in this demonstration is a Python implementation to study and evaluate gateway placements for LoRaWAN. The visualization is based on the tkinter
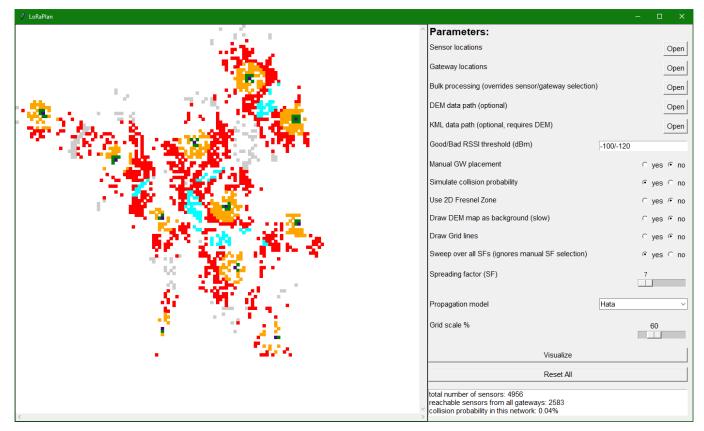
Figure 1: Screenshot of the LoRaPlan software with example placement and gateway coverage (purple: gateway, green: good coverage, yellow: covered with medium quality, red: covered with bad quality, light blue: covered by multiple gateways, grey: no coverage). In this example setup, 2290 of all 4760 sensors are covered and a calculated collision probability of 0.04 % is achieved.

package. For data import and processing, the Python pandas and Python numpy libraries are used. The complete software with a documentation is available on Github [4]. LoRaPlan contains two graphical user interface (GUI) components according to Figure 1, the panel at the right side to upload data, define individual settings, and specify parameters and the visualization area on the left, where the created placement is shown. In the following, relevant software components and adjustable parameters are explained briefly and the placement creation process of the software is introduced afterwards.

Sensor Location Upload: The first step to create a LoRaWAN with LoRaPlan is the sensor location upload. Therefore, the sensors are imported from a csv file with latitude, longitude, and the number of sensors at this specific location. Furthermore, additional optional parameters can be added to the csv file like sensor height, payload size, transmission rate, and specific transmission start times for a more detailed investigation. However, these values are not integrated in the collision calculation yet and a sensor height of 1 m is used.

Gateway Placement: Next, the gateways are selected and placed. The gateways can be added from a csv file or by manual placement in the software. Each gateway has a specific ID, a latitude and longitude value, a height in meters for the

transmission distance calculation, and an environment that is required for the path loss model.

Topography and Existing Urban Development Import: For a more accurate network simulation, especially in geographically exposed positions, it is possible to import existing development information for urban areas and topography information. The topography data import is based on the digital elevation model (DEM) as Shuttle Radar Topography Mission (SRTM) data while the urban development is based on keyhole markup language (KML) files.

Path Loss: When sensors and gateways are placed, the path loss is an important metric to receive the possible transmission distance for each device. There are five path loss models available with LoRaPlan: free space path loss [5], Hata [6], Lee [7], Cost 231 [5], and Ericsson [5].

Additional Adjustable Parameters: Furthermore, several additional optional parameters and settings like the usage of a 2D fresnel zone for transmission calculation or the drawing of additional grids for better visualization can be chosen for calculation. The spreading factor for transmission can be selected manually or it is chosen automatically by the software. The automatic spreading factor selection uses the lowest possible spreading factor, where a sensor is still able, if possible, to transmit to at least one gateway. At the end of

the parameter setting process, it must be decided whether the estimated message collision probability is to be simulated.

Collision Probability Calculation: The optional collision calculation of the software is based on three steps: First, important parameters for the sensors must be specified. Therefore, the transmitted payload for each sensor is currently set to 8 B and the transmission rate to one message per hour for simplicity and demonstration purpose. All other LoRa message related parameters according to, e.g., [8] are set to the default values. Second, the time on air for each LoRa message is calculated according to [8] and for each LoRa message, a random time for transmission start is calculated with a uniform random distribution between 0 s and 3600 s to simulate one hour. This start time, however, is also an open parameter to be uploaded for each sensor.

Two LoRa messages can only collide if the interval between their transmission start and transmission end time overlaps. If then, the transmission radius of the sensors overlap in a way that either the gateway they transmit to, or the direct line of sight between the sensor and the gateway is in the transmission radius of both sensors, the messages collide. Note that currently only one LoRa channel is simulated for collision probability calculation. At the end, the collision probability in the network is calculated by dividing all achieved collisions through all sent messages.

III. Network Creation and Visualization

This section describes the network creation with the presented software and highlights details about the visualization.

Coverage Calculation: The coverage calculation process of the software is as follows: For each gateway all sensors in range are determined based on the path loss models and the used spreading factor (SF). Together with possible topography information and path loss limitations, the SF is the main influencing parameter for the transmission distance in LoRa. Other factors like transmission power are not varied in this software so far. For each sensor, the distance to the closest gateway is logged in this step. Furthermore, the coverage of the same sensor by multiple gateways is logged. For later visualization, the expected transmission quality is also logged. With an expected received signal strength (RSSI) of above -100 dBm, high quality is expected, for -100 dBm to -120 dBm it is medium quality, for an RSSI below -120 dBm low quality is received. However, these parameters are adjustable in the GUI. Currently, the sensor is expected to be out of range with RSSI values below -131 dBm for SF 7, below -134 dBm for SF 8, below -137 dBm for SF 9, below -140 dBm for SF 10, below -141 dBm for SF 11, and below -144 dBm for SF 12 according to [9]. However, these values are variable and dependent on the sensitivity of the LoRa transceiver.

Visualization: The current placement can be visualized when the sensor and gateway import is finished, the path loss is selected, and additional parameters are chosen. An example visualization for the city of Würzburg in Germany is presented at the left side of Figure 1. The LoRaPlan software colors the sensors and gateways according to the expected RSSI with the gateways colored and highlighted in purple. In addition to the visualization on the presented map, information like number of connected sensors, number of sensors per gateway, and collision probability in the network are available on the bottom right of the software GUI for the complete network and for each individual gateway by clicking on them.

IV. Demonstration Scenario

The demonstration scenario for LoRaPlan is as follows: In a first step, potential sensor and gateway locations from the city of Würzburg are imported and visualized to show the audience the software usage. Afterwards, the influence of different path loss models on the coverage of the gateways is visualized.

In a next step, the influence of the spreading factor parameter on the potential data transmission distance is shown with different pre-settings. With the functionality of selecting the best spreading factor for each sensor, the optimal parameter settings for all sensors are set and visualized.

In a third step, the collision probability calculation is presented to evaluate different gateway placements on the same network and show the audience another influencing factor of a good placement. There, especially the methodology and importance of a collision probability calculation study is highlighted with regard to future LoRaWAN network planning. This is shown by different network scenarios with different number of expected devices in future smart city networks.

In a last demonstration step, it is possible for the audience to place their own gateways in a predefined sensor network. There, the goal is to cover the complete network with a set number of gateways and minimize the collision probability within the network. The results can be compared to other placements from the audience or placements from the authors.

References

[1] P. J. Basford, F. M. Bulot, M. Apetroaie-Cristea, S. J. Cox, and S. J. Ossont, "LoRaWAN for Smart City IoT Deployments: A Long Term Evaluation," *Sensors*, 2020.

[2] N. Matni, J. Moraes, H. Oliveira, D. Rosário, and E. Cerqueira, "LoRaWAN Gateway Placement Model for Dynamic Internet of Things Scenarios," *Sensors*, 2020.

[3] S. Mnguni, A. M. Abu-Mahfouz, P. Mudali, and M. O. Adigun, "A Review of Gateway Placement Algorithms on Internet of Things," in *International Conference on Advances in Big Data, Computing and Data Communication Systems (icABCD)*. IEEE, 2019.

[4] F. Loh and N. Mehling, "LoRaPlan: A Software to Evaluate Gateway Placement in LoRaWAN," 2021. [Online]. Available: https://github.com/lsinfo3/loraplan/

[5] Y. A. Alqudah, B. Sababha, A. Elnashar, and S. H. Sababha, "On the Validation of Path Loss Models Based on Field Measurements Using 800 MHz LTE Network," in *Annual IEEE Systems Conference*, 2016.

[6] B. Reynders and S. Pollin, "Chirp Spread Spectrum as a Modulation Technique for Long Range Communication," in *Symposium on Communications and Vehicular Technologies (SCVT)*. IEEE, 2016.

[7] D. Dobrilović, M. Malić, D. Malić, and S. Sladojević, "Analyses and Optimization of Lee Propagation Model for LoRa 868 MHz Network Deployments in Urban Areas," *Journal of Engineering Management and Competitiveness (JEMC)*, 2017.

[8] D. Bankov, E. Khorov, and A. Lyakhov, "On the Limits of LoRaWAN Channel Access," in *International Conference on Engineering and Telecommunication (EnT)*. IEEE, 2016.

[9] Semtech. (2021) Wireless and Sensing Products: SX1276/77/78/79 Datasheet. [Online]. Available: https://semtech.my.salesforce.com/sfc/p/#E0000000JelG/a/2R0000001Rbr/6EfVZUorrpoKFfvaF_Fkpgp5kzjiNyiAbqcpqh9qSjE