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Automated Private 5G Network Planning for Professional Industries

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***Abstract*—Wireless 5G connectivity in private operation is rapidly evolving into a necessity component for business-critical services within professional industries, such as those related to manufacturing and logistics. The resulting large number of private 5G networks requires reliable methods for network planning and operation, for which current research is already presenting approaches for efficient AI-based automated network planning. However, there is often a significant gap between current research findings and their practical application in industry, resulting in insufficient delays for the utilization of research outcomes by industrial stakeholders. Hence, this paper introduces a solution that provides industry partners with free and open access to the latest research findings on automated network planning. As primary contribution, we present a web-based planning tool facilitating intuitive network planning within a few simple steps. As a result, radio environmental maps are generated using deep learning propagation modeling as well as AI-driven network planning outcomes are evaluated, balancing Quality of Service (QoS) levels against the requisite number of base stations.**

***Video Abstract*—Demonstration video is available online at https://tiny.cc/Private5GPlanner**

I. Introduction

Private 5G networks are becoming increasingly important and are being globally addressed in sub-6GHz and mmWave frequency ranges. Depending on requirements and technical possibilities, both private and public frequencies are used for network operation. On this basis, different operator models for Private (Non-Public) cellular networks address the main classes of fully private (isolated) and shared operation leveraging public infrastructure for resource-efficient and sustainable private network operation [1].

In this context, we present Artificial Intelligence (AI)-driven planning methods for private 5G networks in [2], which provides automated network planning for shared private networks within public macro networks. A detailed process architecture is visualized in Fig. 1. Automated network planning is carried out on the basis of the user input, which includes a polygon of interest, a priority area (if required) and a Quality of Service (QoS) requirement. Therefore, an environmental model of the scenario is required in order to identify potential Base Station (BS) locations and as a basis for an accurate channel estimation. The latter is performed using a deep learning-based propagation model, which not only processes numerical features but also implicitly extracts propagation characteristics from synthetic environmental images of the transmitter and receiver regions utilizing a Convolutional Neural Network (CNN). The channel predictions are further processed in the form of so-called Radio Environmental Maps (REMs) and provided to the actual network planning, which aims to determine the optimal number of BSs, their positions and configurations in order to fulfill the QoS requirements. To do so, the REMs are spatially clustered according to the k-means algorithm, allowing for a resource-efficient optimization of the BS combination by identifying the best BS in each cluster and merging the corresponding REMs to one composite one.

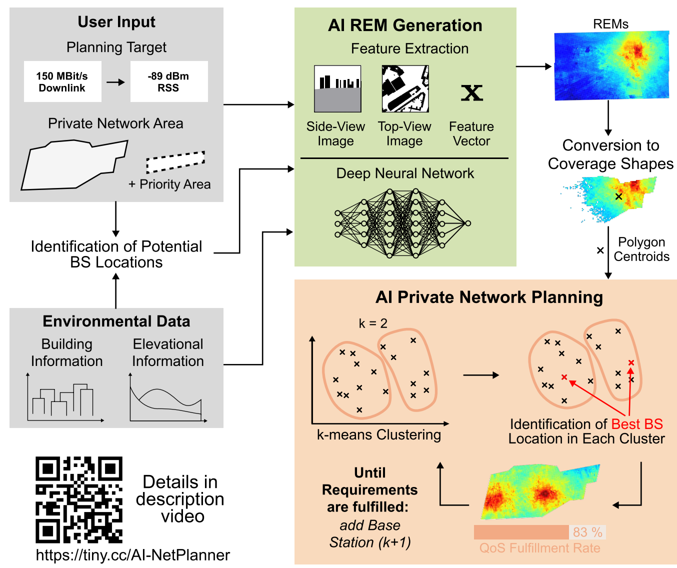
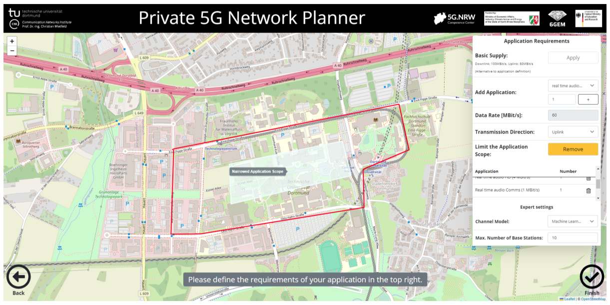


Fig. 1. Overview of AI-based private 5G network planning methodology.

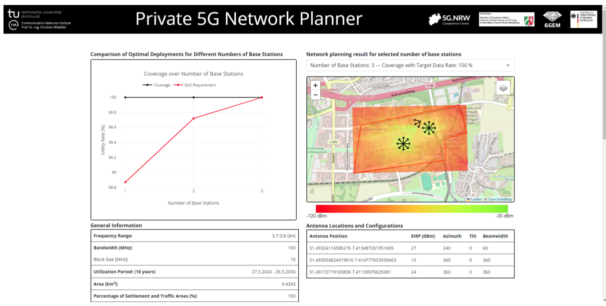
II. Open Use of AI-based Automated Private 5G Network Planning

In order to make the network planning described above accessible to others, we present an intuitive user-interface for easy and open operation in this contribution, which is visualized in Fig. 2. In the following, we present a catchy three-stage planning process.

Stage 1 and 2 - Definition of the private network area: The tooling initially starts with the user creating a polygon on a map that defines the private 5G network area. In a second stage, the user can either specify a bandwidth (exemplary up to 100 MHz are available in Germany in the frequency range from 3.7 to 3.8 GHz) and the corresponding block size or have the bandwidth determined automatically based on the later specified QoS requirements. In addition, the utilization period of the private network can be configured.



(a) Catchy three-stage planning process.



(b) Illustrative network planning result.

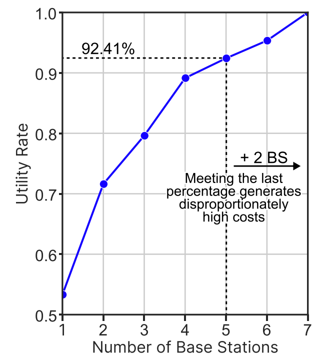
Fig. 2. Overview of presented private 5G network planning demonstrator.

Stage 3 - Specifying the application requirements: Following, the application requirements in terms of Data Rate (DR) can be specified either by choosing a basic supply or detailed specification of target application profiles. Moreover, it is possible to restrict the application scope by defining a priority area (see Fig. 2a). This can be highly relevant if particularly challenging application must be operated locally. In a further step, the maximum BS number and channel model utilized for REM generation can be selected in an expert setting section. It is possible to choose between well-known empirical models and the AI-based DRaGon [3] method.

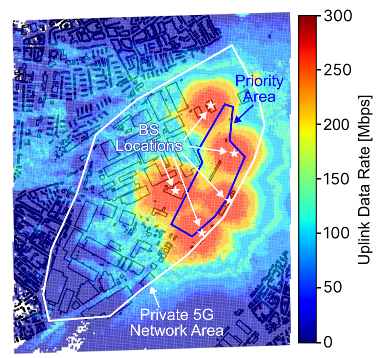
Based on these user inputs, the process chain (cf. Fig. 1), which was outlined in Sec. I and described in [2], is initiated. When searching for the optimal BS composition, various antenna configurations for each BS position are examined. This includes the consideration of different antenna types (omnidirectional vs. sector antennas with 60° beamwidth considering a diverse set of azimuth angles) and different transmit powers ranging from 0 to 40 dBm. The AI-generated REMs are further filtered for edge power violations, as there are common restrictions for private networks.

III. Planning Results Providing In-depth Deployment Details

Once the planning procedure is finished, the user can access the network planning results, see Fig. 2b. Composited REMs and the selected BS positions for increasing BS numbers are illustrated. Additionally, a plot is provided that shows the utility rate over the BS number. Fig. 3 depicts such an example network planning result of a professional industry scenario at the world's largest inner harbor in Duisburg, Germany. There, a priority area is defined within the private network area that comes with a total uplink requirement of 200 Mbit/s. It is of particular interest to professional industry users to trade off between the QoS fulfillment level and the costs associated with deploying more BSs. As can be seen in Fig. 3a, already over 90% of the area fulfills the QoS requirement when five BSs are deployed, whereas two more are needed to reach 100%. The corresponding composite DR REM for five BSs can be seen in Fig. 3b.



(a) Service level fulfillment for increasing BS number.



(b) Resulting uplink data rate REM for five BS.

Fig. 3. Planning progress of a professional industry scenario.

IV. Conclusion and Outlook

In this demo paper, we presented a web-based transfer solution with free and open access to the latest research findings on AI-enabled automated network planning leveraging deep-learning propagation modeling for private 5G networks. Network planning results are discussed on the basis of an industrial case study including a trade-off between QoS level and number of required BSs. In future, the private 5G network planning will be expanded by adding individual features, such as the limitation of potential antenna locations and the integration of mmWave frequencies. The improved efficiency of the planning process resulting from this will form the basis for a future 6G expansion, which will be realised initially by integrating a 6G multi-RAT architecture [4].

Acknowledgment

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