Racing with 5G speeds: Ad-hoc & Nomadic 5G-Campus networks for temporary operation

Zukunft der Netze / Future of Networking 2021

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&

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Online-Conference, 16.09.2021

Plan & Play
Zuverlässige ad-hoc 5G-Campusnetze für den temporären Einsatz

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Outline

- **Emerging opportunities for private 5G networks**
  - 5G Campus Network Planner of the Competence Center 5G.NRW
  - Plan & Play: From Stationary to **Temporary Deployments**
- **Private 5G network perspective of the event industry (PLAY)**
  - Reference scenarios and application requirements for the Plan & Play project
- **Automated Network Planning for Temporary 5G Deployments (PLAN)**
  - Overview of the Automated Network Planning
  - Example event-based scenario in Monaco City
  - Coverage planning results for the Monaco scenario
- **Racing with 5G Speeds: SDR/SDN research platform (PLAY)**
- **Summary and Outlook**

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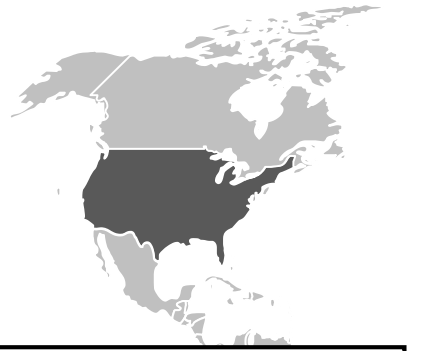
Background: Emerging opportunities for private 5G networks

Global snapshot of 5G spectrum opportunities for private use *



Germany

Local licenses, assignment complete
- **3.7 – 3.8 GHz (Q4/2019)**
- **24.25 – 27.5 GHz (Q1/2021)**

Already > 150 local frequency assignments (as of 08/2021)

Support of licensing by open "Campus Network Planer"

5G.NRW Competence Center

U.K.

Local licenses, applications open
- 3.8 – 4.2 GHz (Q4/2019)
- 24.25 – 26.5 GHz (Q4/2019)

USA

CBRS exclusive and shared licenses
- 3.5 GHz

Shared spectrum/local licenses (under evaluation)
- 37 – 37.6 GHz

Netherlands

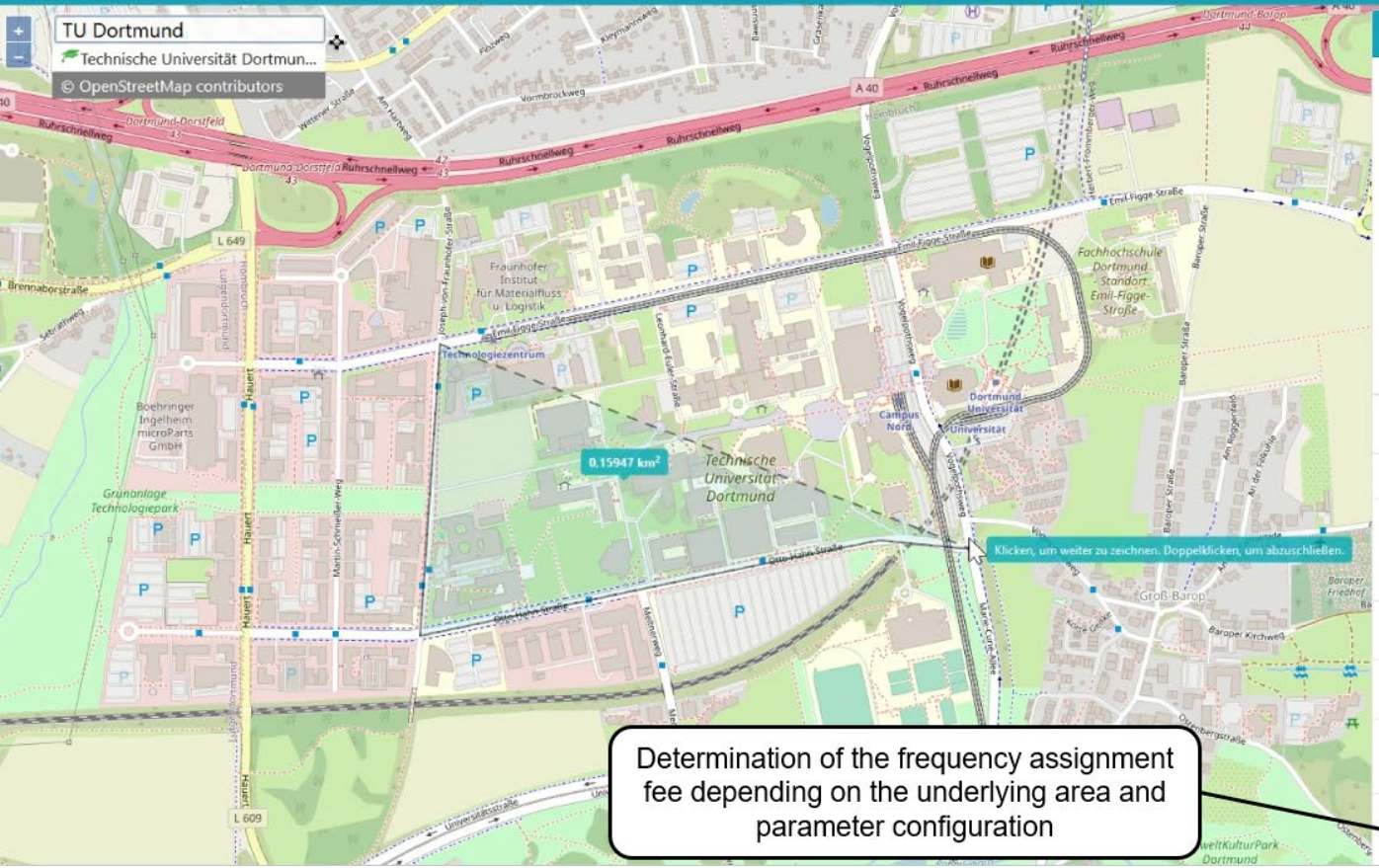
Local industrial use
- 3.5 GHz
- 3.7 – 3.8 GHz (in consultations)

Licensed shared access (online booking)
- 2.3 – 2.4 GHz

....

** Qualcomm, Global update on spectrum for 4G & 5G, Dec. 2020. Online: https://www.qualcomm.com/media/documents/files/spectrum-for-4g-and-5g.pdf (illustrative excerpt only)*

5G Campusnetzplaner



Determination of the frequency assignment fee depending on the underlying area and parameter configuration

Konfiguration Ihres 5G-Campusnetzes

In nur wenigen Schritten zur Planungshilfe für Ihr lokales 5G-Netz:

Schritt 1: Wählen Sie mit der Maus die Grenzen Ihres Wunschgebiets in der Karte. Die **Suchfunktion oben links** hilft Ihnen bei der einfachen Standortfindung.
Schritt 2: Konfigurieren Sie Frequenzbereich, Bandbreite, Laufzeit und Flächenanteile.
Schritt 3: Die Zuteilungsgebühr berechnet sich automatisch nach der BNetzA-Gebührenformel für lokales Breitband des jeweiligen Frequenzbereichs.

Gebiet zurücksetzen

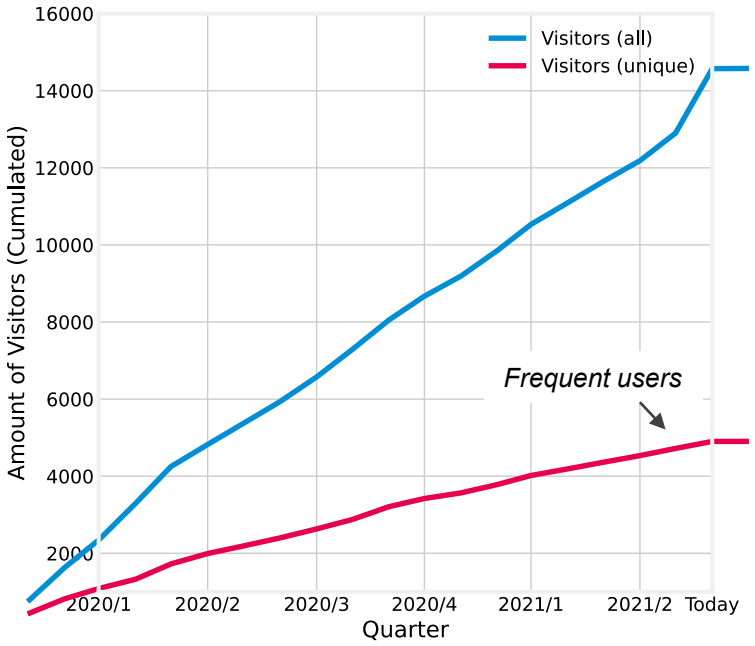
☐ Veröffentlichte Zuteilungsinhaber anzeigen*

Frequenzbereich:	3,7-3,8 GHz
Fläche [km²]:	0.15947
Bandbreite [MHz]:	100
Blockgröße [MHz] (als Schrittweite der Bandbreite):	10
Laufzeit [Jahre]:	10
Anteil Siedlungs- und Verkehrsfläche [%]:	100
Anteil Andere Flächen [%]:	0

Ihre Zuteilungsgebühr**:

5G Campus Network Planner: 5000+ users since 2019

Number of cumulative visitors since the release of the 5G Campus Network Planner to date

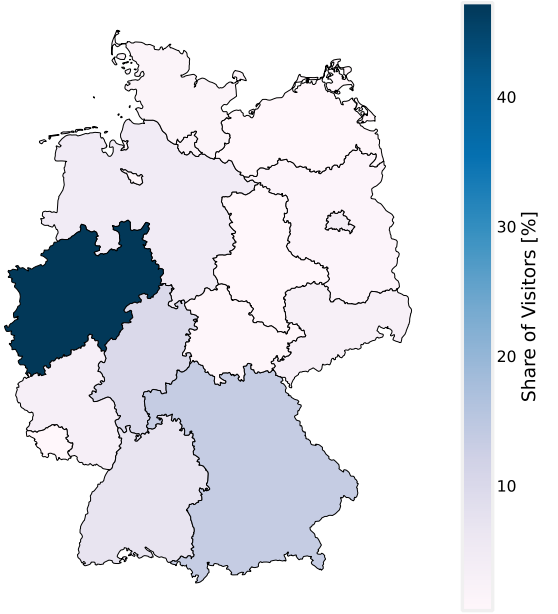


General visitor statistics (nationwide)

Visitors total	14577
Visitors unique*	5058

*Number of different IP addresses, TUDo excluded (Status: 01.09.2021)

1.	NRW	47,3%
2.	Bavaria	13,6%
3.	Hesse	9,9%
4.	Baden-Wuerttemberg	7,1%
5.	Lower Saxony	4,7%



Potential confirmed: 5G campus network planner with very strong response **reinforces interest/need for use of private 5G solutions**

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Plan & Play: from stationary to temporary deployments

PLAN: Development of AI-based automated network planning

5G Campus Network Planner (based on OpenStreetMap)

5G.NRW Competence Center

OpenGeoData.NRW / Open.NRW

3D building models (LoD1 and LoD2) | Height models | More geo-based open map models

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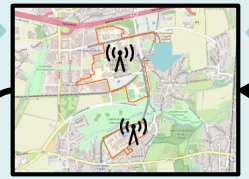

KPIs

Regulatory conditions, interference from neighboring cells, frequency band, …

Application requirements Coverage, data rate, capacity, …

Functional requirements (e.g. Duplexing config, C-V2X)

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PLAY: Upgrading 5G solutions for temporary deployment

Major Events (e.g. formula 1 racing)

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Intralogistics

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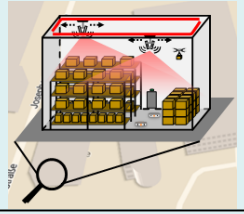

Agriculture | **Fun Fairs** | **Construction** | **Trade Fairs** | …

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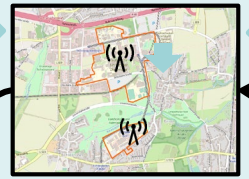

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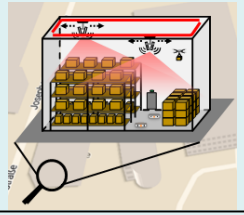

Agriculture | **Fun Fairs** | **Construction** | **Trade Fairs** | …

Plan & Play Scenarios

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Reference Scenarios - Overview

Live Sports Event:

- Size: small
- Propagation: indoor
- No. users: low
- Mobility: moderate
- Position: distributed
- Uptime: moderate
- Form factor: small & light weight

Westfalenstadion

Live Motorsport Event:

- Size: moderate
- Propagation: outdoor
- No. users: high
- Mobility: high
- Position: deterministic
- Uptime: low
- Form factor: large

Nürburgring

Live Music Event:

- Size: large
- Propagation: outdoor
- No. users: moderate
- Mobility: low
- Position: clustered
- Uptime: long
- Form factor: moderate

Wacken

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Reference Scenarios - Application Requirements

Low Latency Audio:

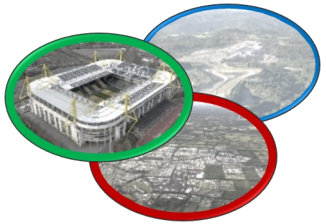
- Data flow: stream
- Direction: bidirectional
- Data rate: 32 – 2400 kbps
- Interval: 10 ms
- Latency: 30ms (round trip)
- Current Standard: DECT/TETRA

Low Latency Video:

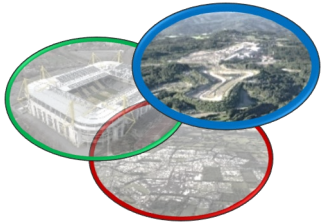
- Data flow: stream
- Direction: uplink
- Data rate: 10 – 80 Mbps
- Interval: 20 ms
- Latency: 50 ms
- Current Standard: proprietary

Supplementary Data:

- Dataflow: polling/burst
- Direction: uni- and bidirectional
- Data rate: 30k – 10Mbps
- Interval: 20 ms – 1 s
- Latency: 50 – 500 ms



- Intercom
- HD Audio



- HD Video
- UHD Video
- 360° Video

- Telemetry (vehicle)
- Remote-Control
- AR/VR
- Positioning data
- Cashless Payment

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1

Simulation (e.g. Raytracing)

KPIs

Regulatory conditions, interference from neighboring cells, frequency band, …

Application requirements Coverage, data rate, capacity, …

Functional requirements (e.g. Duplexing config, C-V2X)

Network Planning Result

4

5

Evaluation

Transformation of results space

2

3

Set or modify base stations

6

Machine Learning Models

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PLAY: Upgrading 5G solutions for temporary deployment

Major Events (e.g. formula 1 racing)

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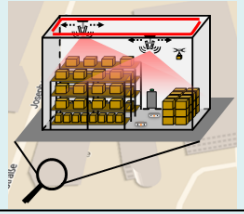

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Example Use Case Monaco: 5G City vs. Event networks

Inputs

Site boundary polygon

-90 dBm

Target (mean) power and coverage [dBm]

Download environment data

OpenStreetMap

Download building data and convert to Raytracing environment

Varying spatial priorities within a private 5G network in Monaco

Temp. Event Sailing Regatta

Temp. Event Formula 1 Racing

Temp. Event Royal Event

C. Bektas, S. Böcker, B. Sliwa, C. Wietfeld, "Rapid Network Planning of Temporary Private 5G Networks with Unsupervised Machine Learning", In 2021 IEEE 94th Vehicular Technology Conference (VTC-Fall), Virtual Event, September 2021. (accepted for presentation).

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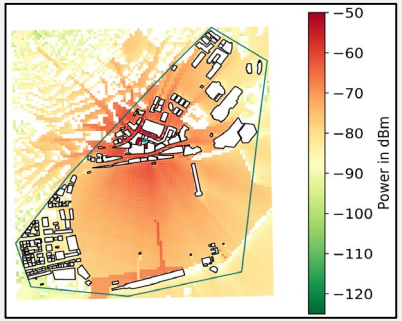
Creation of data base for unsupervised learning

Identify antenna positions

Use building centroids of buildings with preconfigured min. height (here: 5 m)

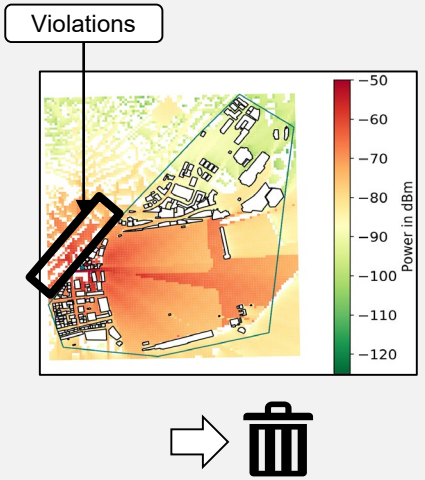
Simulate and convert Radio Environmental Maps REMs

Use Raytracing application to generate REMs for all antenna positions with different EIRP and convert to internal scenario model



Check regulatory rules

Filter all results violating the boundary power restriction imposed by the regulator (here: -80 dBm)



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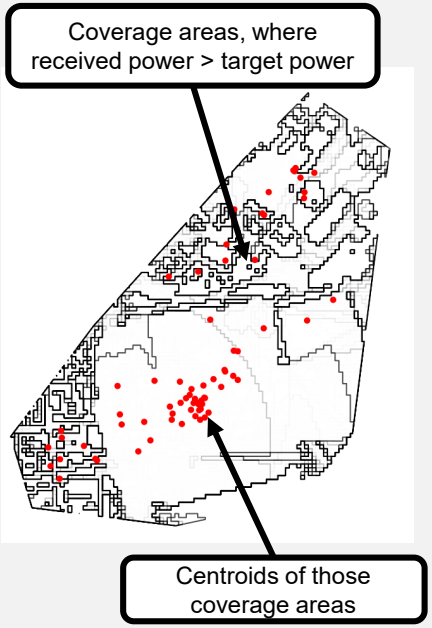
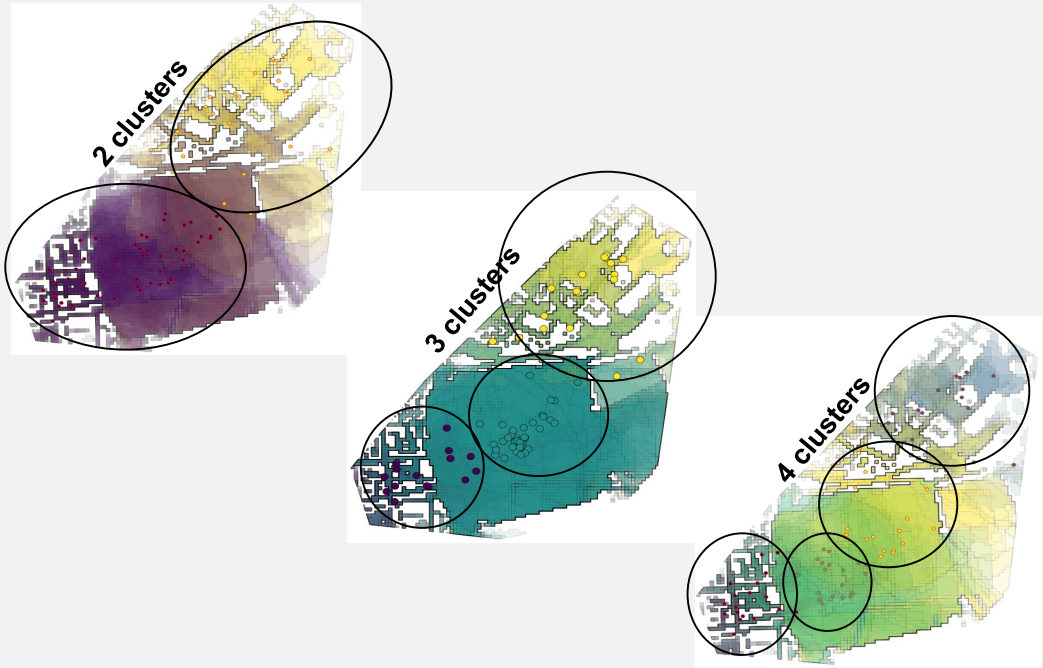
Clustering Analysis helps to boil down the solution space

Derive valid solution space: Match base station locations with coverage areas



Clustering of coverage area centroids and base station location selection

Cluster centroids based on Unsupervised Learning and choose base station per cluster corresponding to highest sum coverage



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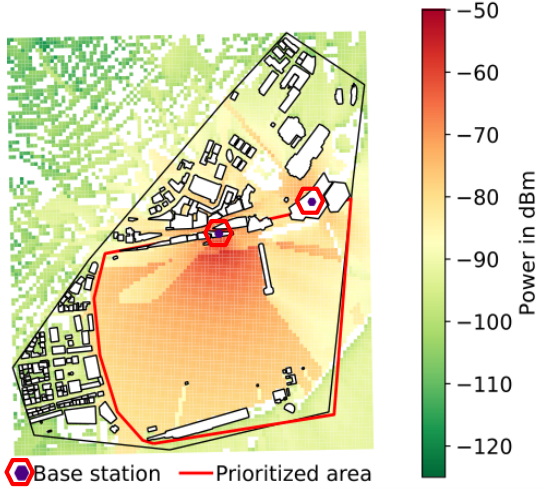
Different use cases lead to scenario-specific network deployments

Example Network Planning Results for Monaco Scenario

Temporary Event

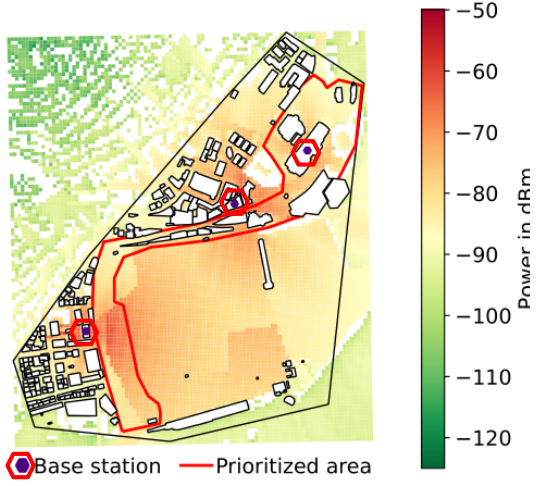
Sailing Regatta



Sailing - Base stations: 2, Coverage: 94.74 %

Temporary Event

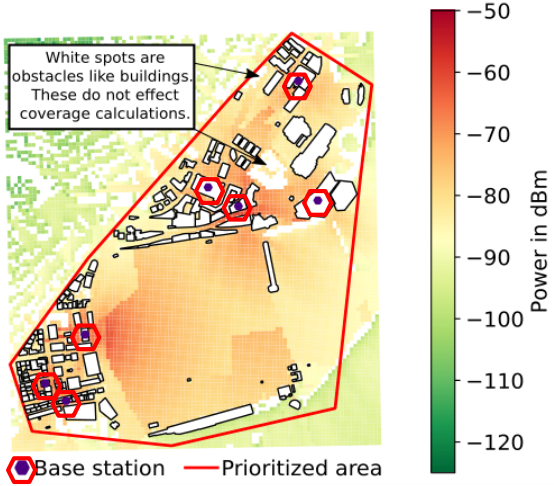
Formula 1 Racing



Formula 1 - Base stations: 3, Coverage: 97.59 %

Overall Private 5G Network

Royal Event



City - Base stations: 7, Coverage: 94.99 %

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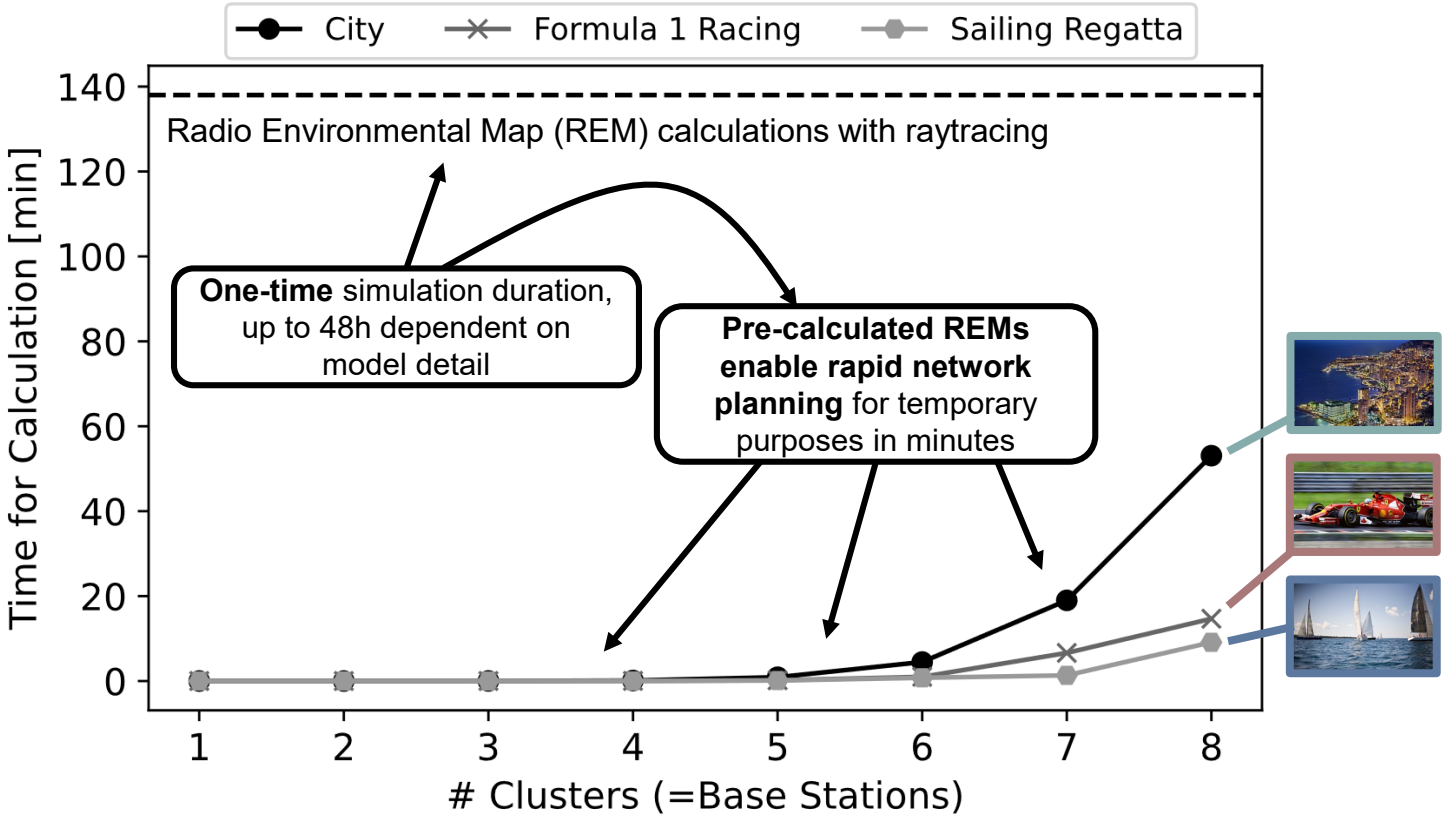
Fast network planning enables „playing around“ with requirements



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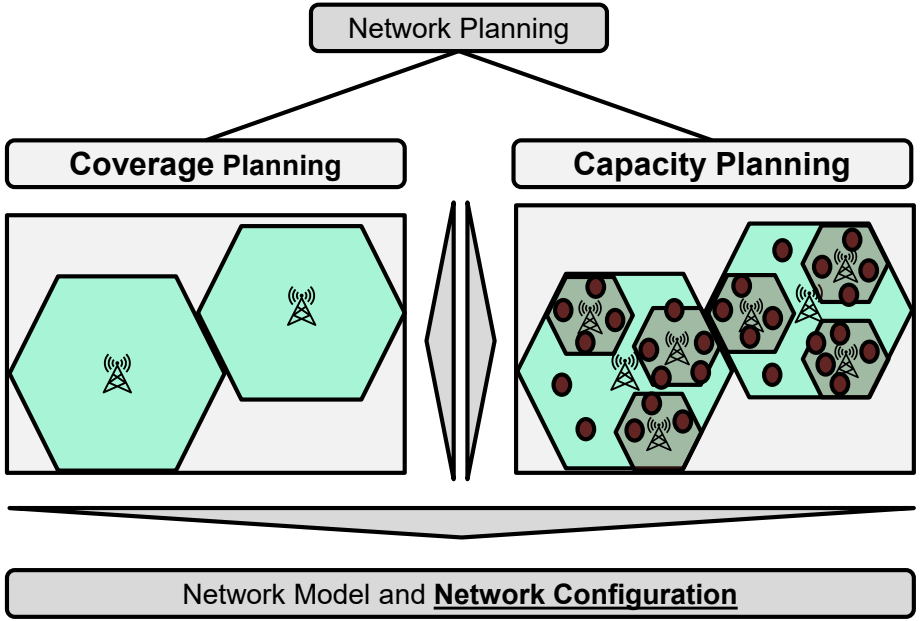
But there is more to address than coverage planning….

- **Capacity planning:**
  - Bandwidth
  - Duplexing configuration
  - Network slicing
  - …..

- Need for **in-depth access to system platform for automatic configuration** → Software-defined Radio / Networking

- Video: Illustration of **Plan & Play scaled research platform**



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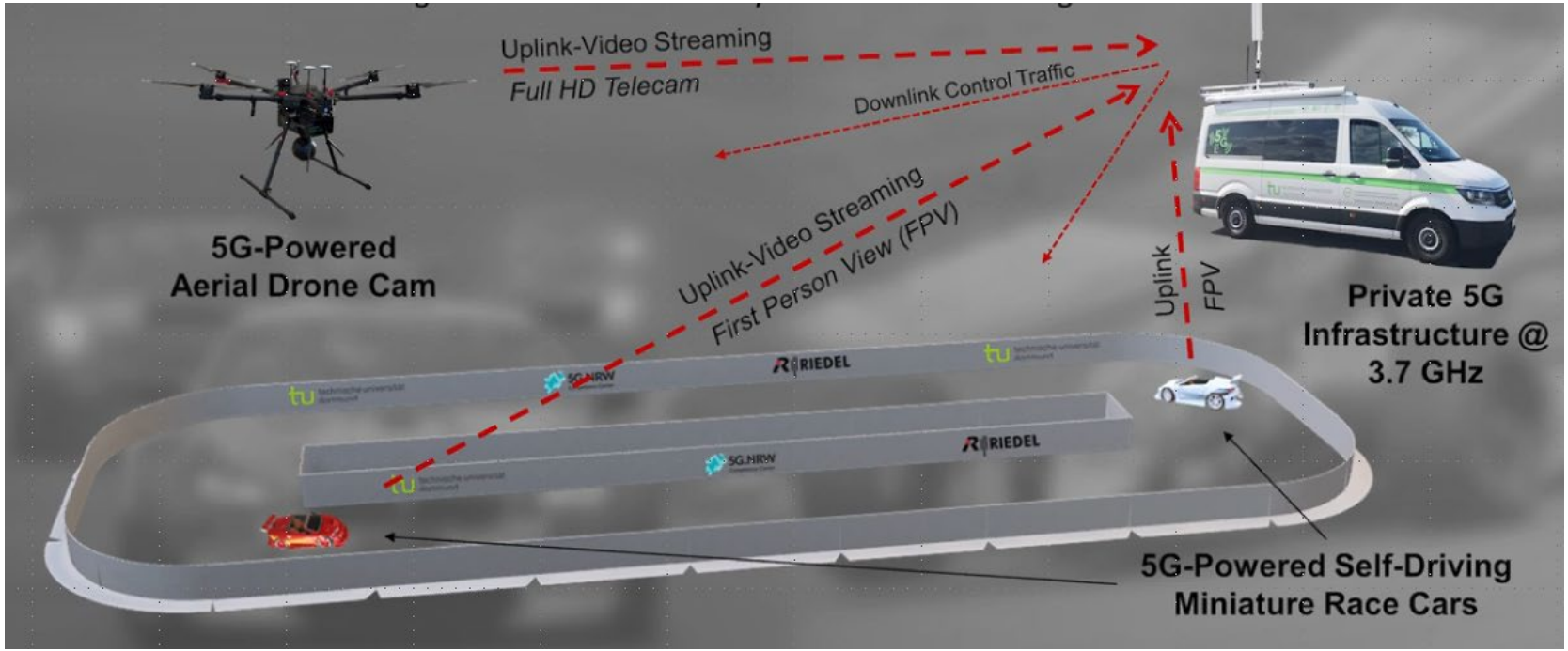
SNR/SDN research platform for ad-hoc network deployment



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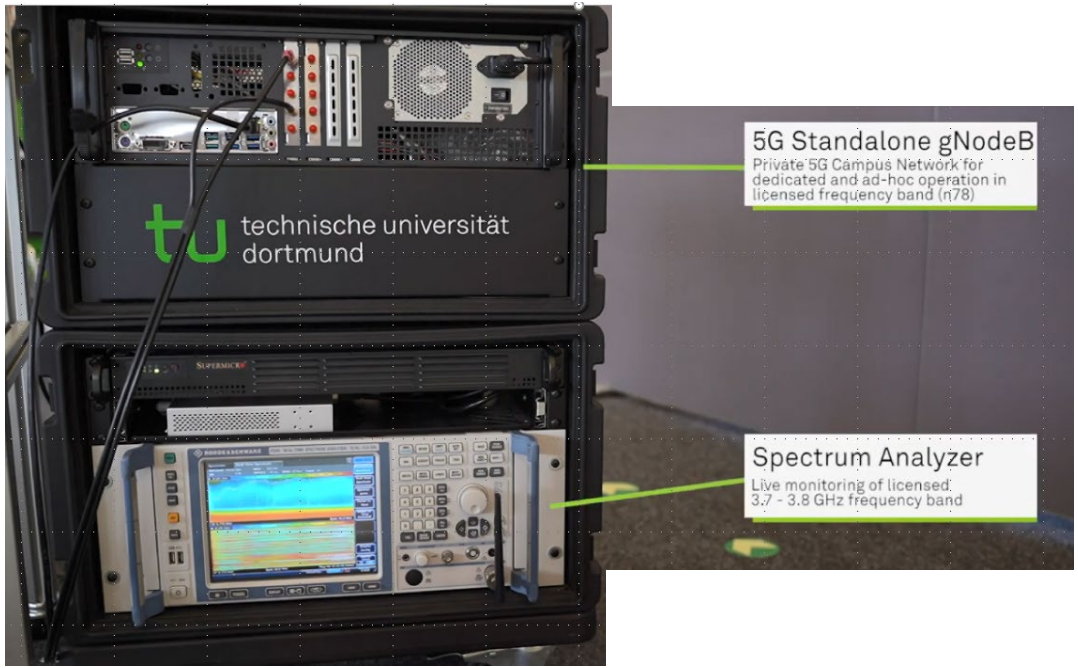

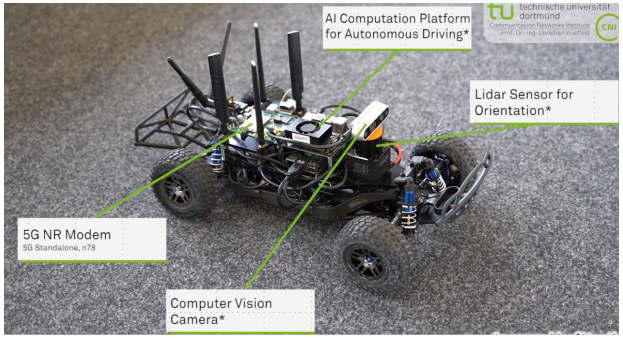

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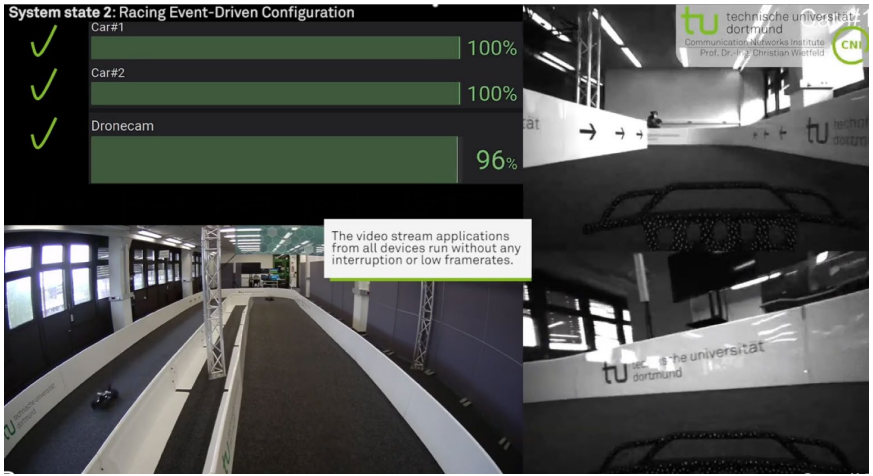
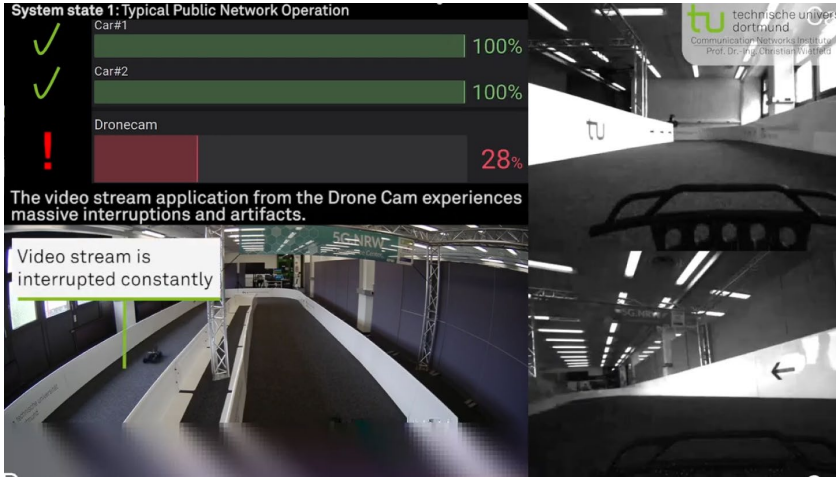
Demonstrator: Racing at 5G Speeds





Summary and Outlook

Summary

- Temporary and Nomadic Ad-Hoc **Campus Networks** become **increasingly important and popular**
- **Plan & Play Project** aims to by provide an **Open and Automated Network Planning and Configuration**
- **Validation and implementation for realistic and detailed reference scenarios**

Outlook

- **Capacity Planning** including **Automated Configuration** of the 5G Infrastructure
- **Latency reduction** for Ultra-Reliable Low-Latency Communication
  - Direct Communication via **Cellular Vehicular-to-Everything (C-V2X) Sidelink**
  - Incorporation of **Network Slicing Planning → uRLLC Slices**
- **Automated licensing** based on standardized interfaces to regulator “Bundesnetzagentur”
- Alternatives to raytracing: **Deep Learning-Based Radio Propagation Modeling and Prediction Using Geographical Data**

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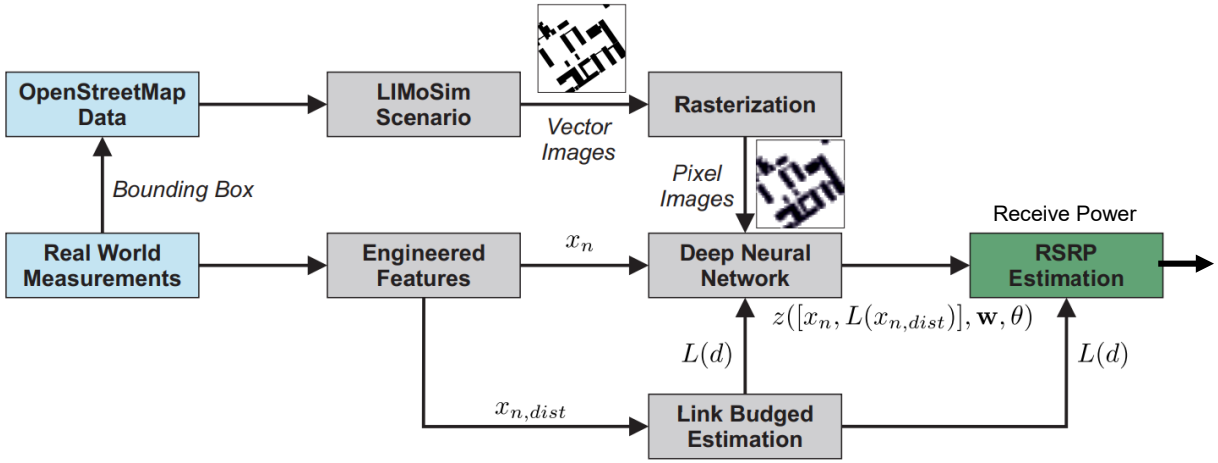
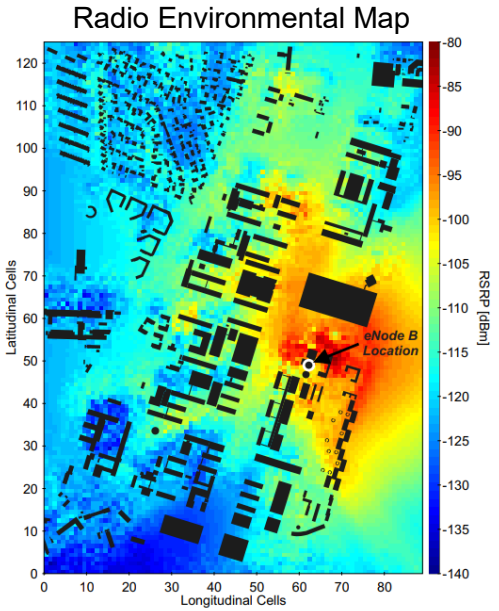
Alternatives to raytracing

Derive Radio Environmental Maps (REM) directly from geo data by leveraging deep learning





J. Thrane, B. Sliwa, C. Wietfeld, H. Christiansen, "Deep Learning-based Signal Strength Prediction Using Geographical Images and Expert Knowledge", In 2020 IEEE Global Communications Conference (GLOBECOM), Taipei, Taiwan, December 2020.

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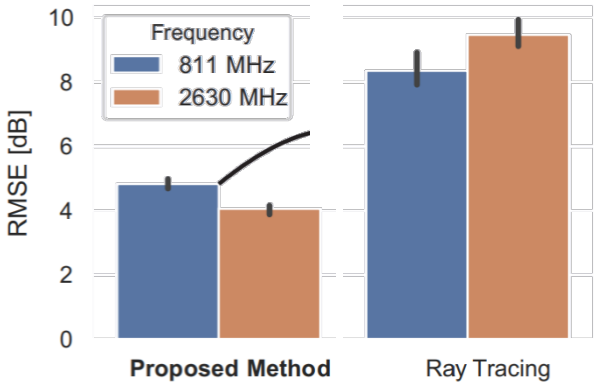
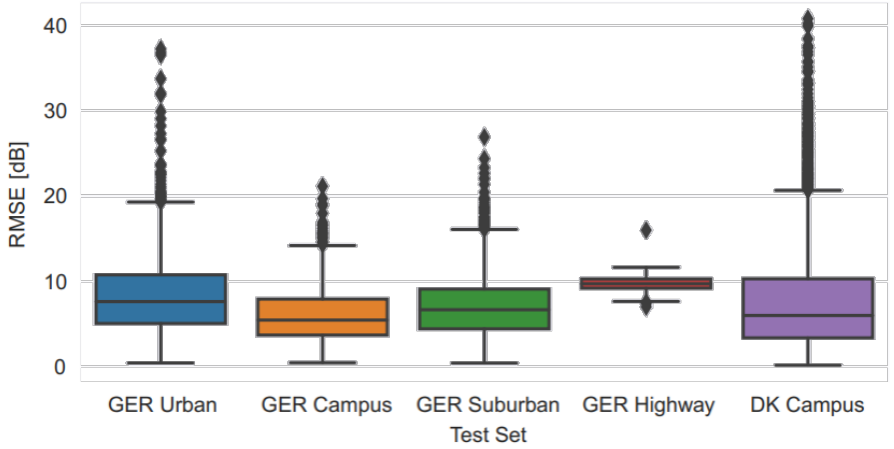
Promising first results for raytracing alternative…

It works - *even better than raytracing*

Lower errors compared with raytracing



Works across different environments



→ More results to be published in 2022

J. Thrane, B. Sliwa, C. Wietfeld, H. Christiansen, "Deep Learning-based Signal Strength Prediction Using Geographical Images and Expert Knowledge", In 2020 IEEE Global Communications Conference (GLOBECOM), Taipei, Taiwan, December 2020.

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Thank you for your attention!

Contact Information:

Plan & Play
Zuverlässige ad-hoc 5G-Campusnetze
für den temporären Einsatz

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