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TECHNISCHE UNIVERSITÄT KAISERSLAUTERN

Dynamic Live Wireless Communication Monitoring for Jamming and Interference Detection in Industry 4.0

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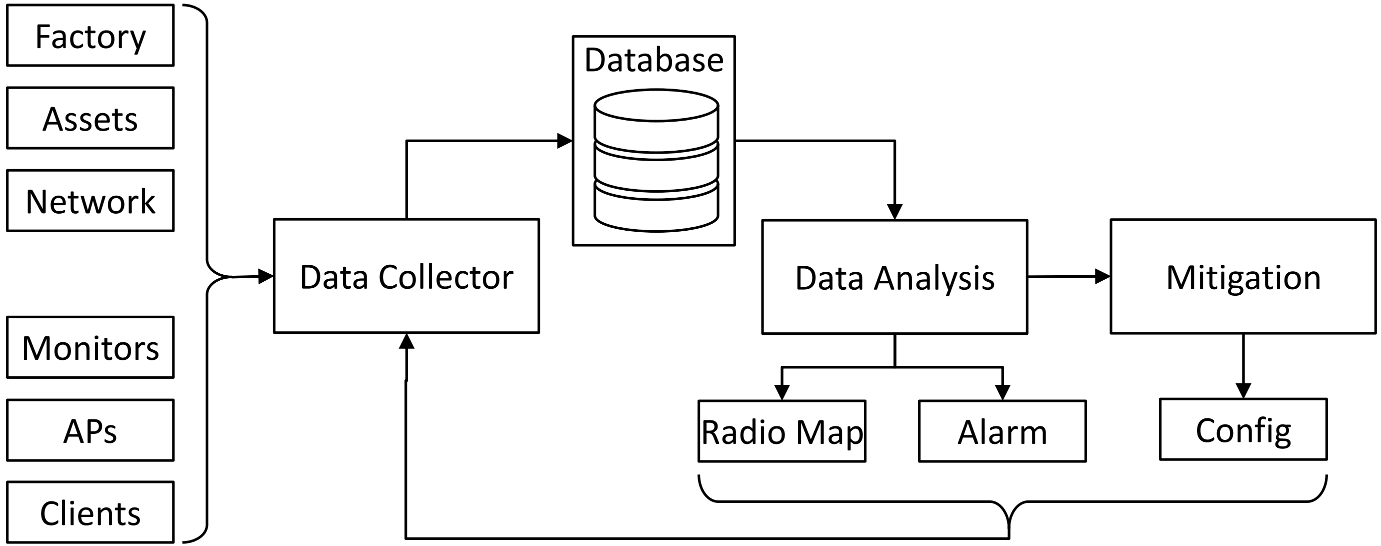
Introduction

- Wireless monitoring system for jamming and interference detection in industrial environments
- Simulation of the wireless propagation based on environment information of the factory map including static and moving assets
- Live monitoring of the real status of the wireless communication by network participants and dedicated monitoring devices
- Comparison of the real with the simulated status and correction of the simulation model
- Detection of external influences based on the corrected model and live measurements

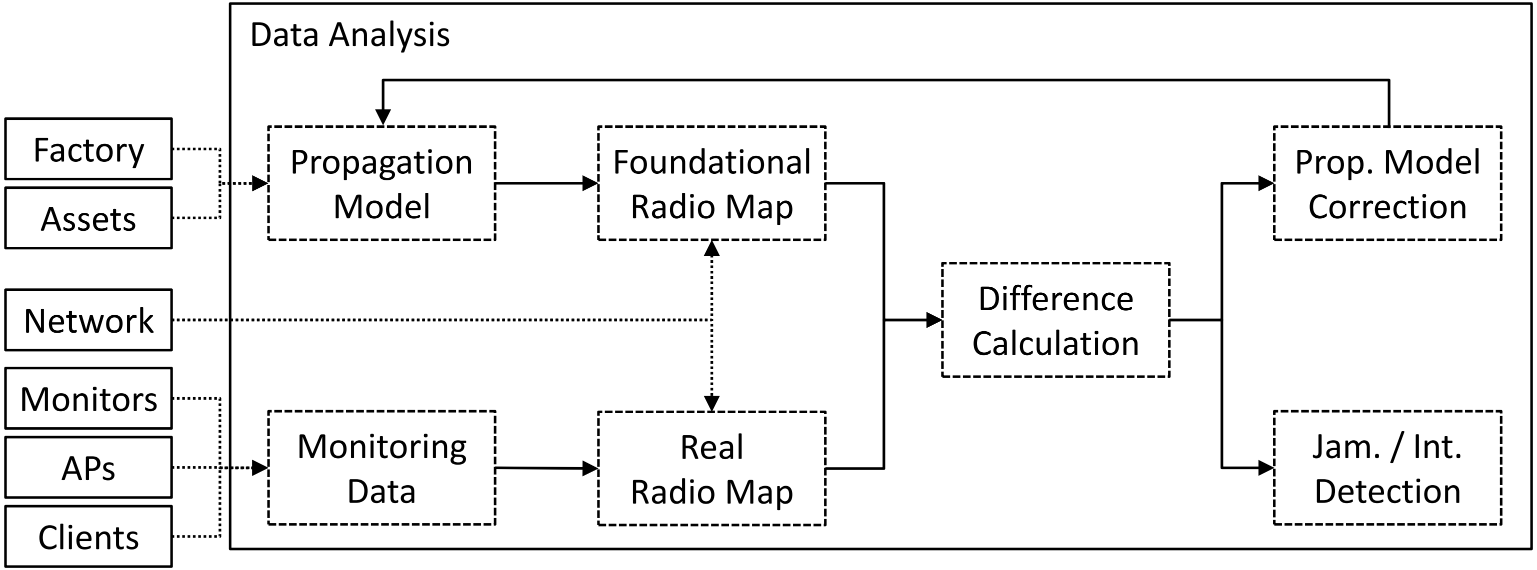
Motivation

- Wireless communication as a key enabler of Industry 4.0
- Strong desire for high reliability, especially for processes like motion control and machine-to-machine interaction
- More and more mobile devices in the factory like AGVs and connected workers
- Communication susceptible to external influences by other networks, radiating machines, moving objects and malicious jammers
- Need for communication monitoring, prediction and autonomous mitigation

System Design

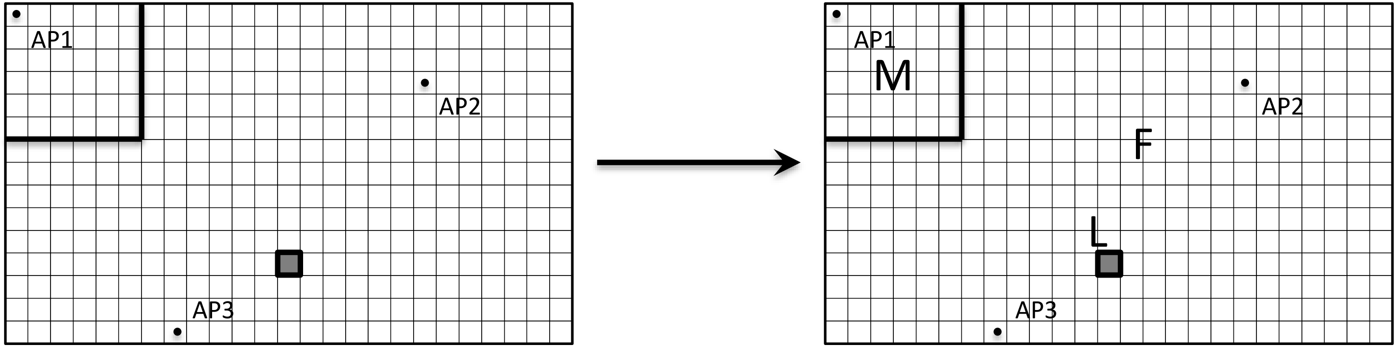


Data Analysis



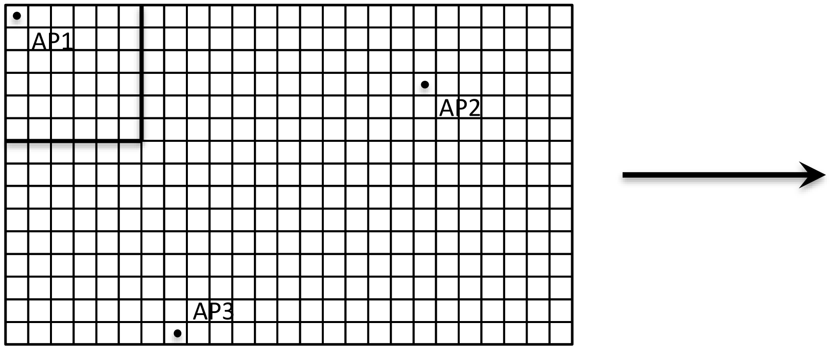
Data Analysis

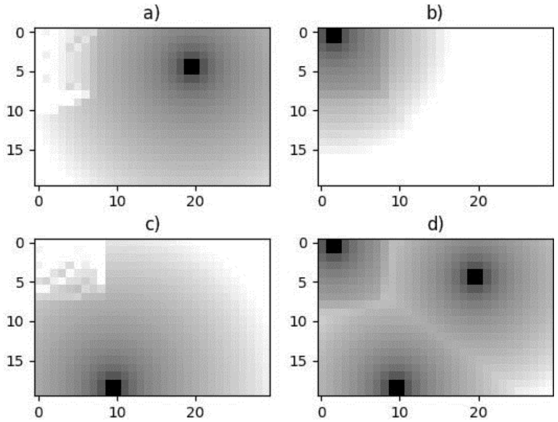
- **Propagation Model**
  - Model in 3D where for each cube different propagation models can be chosen (i.e. Free space – F, Multi-Wall – M; Log-Distance – L)
  - Takes the factory's environment and floor plan information to estimate a propagation model or propagation parameters, i.e., for ray-tracing
  - Dynamic model by using input of an asset tracker (boxes, fork lifts, …) to calculate live model changes



Data Analysis

- **Foundational Radio Map**
  - Simulates the RSS for every network participant at every place in the factory
  - Based on location and configuration of each communication device
  - Uses the previously introduced propagation model
  - Updated each time the model, locations or configurations change





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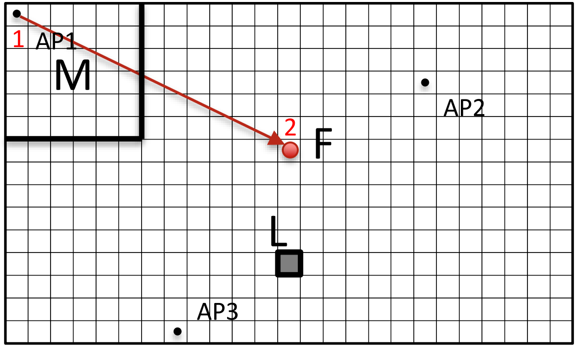
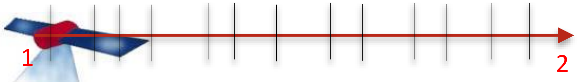
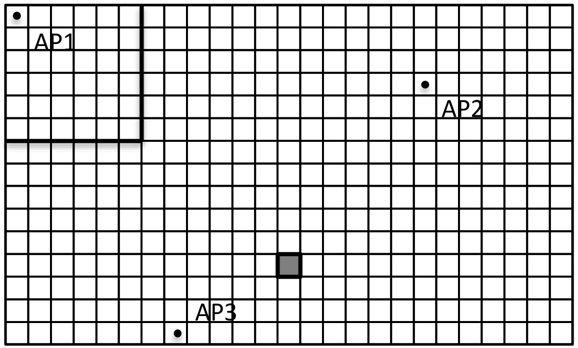


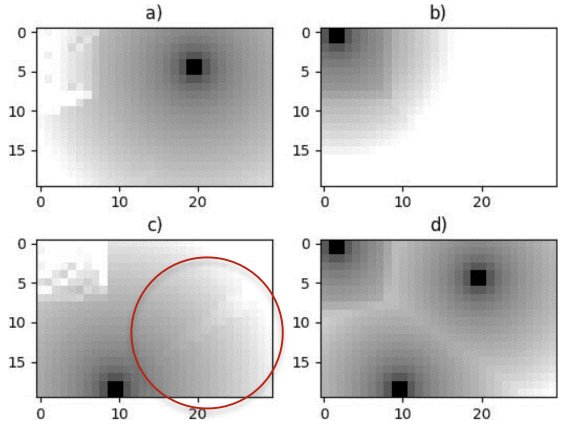


- **Foundational Radio Map – Calculation**
    1) Find the propagation path from the AP to the grid point (center of the cube)
    2) Determine the distances the signal propagates in each cube by intersecting the path with virtual planes representing the cube's faces
    3) Use the RSS at the start of the path and calculate the RSS at the piercing point on the nearest plane with respect to the propagation model for that particular cube
    4) Use the piercing point as new start and calculate the RSS for the next point
    5) Repeat 4) until the end of the path is reached and the final RSS is the value of the grid point
    6) Use the process for each grid point

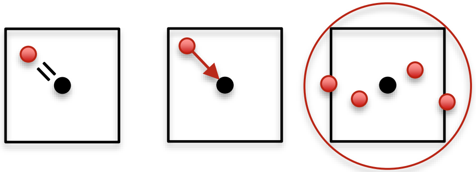
Data Analysis

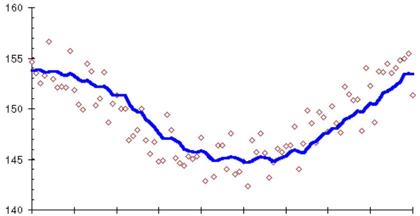
- **Real Radio Map**
  - Generated from measured values from network or monitoring devices
  - Dynamic model due to constant live monitoring and updating
  - Missing values are obtained by interpolation or calculation with respect to the estimated propagation model

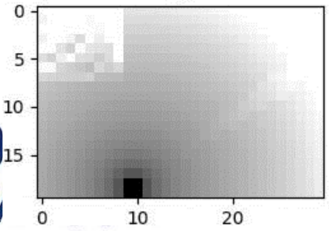




Data Analysis



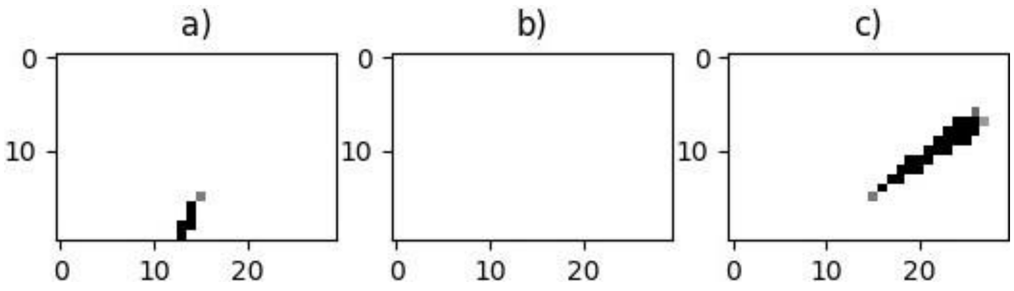




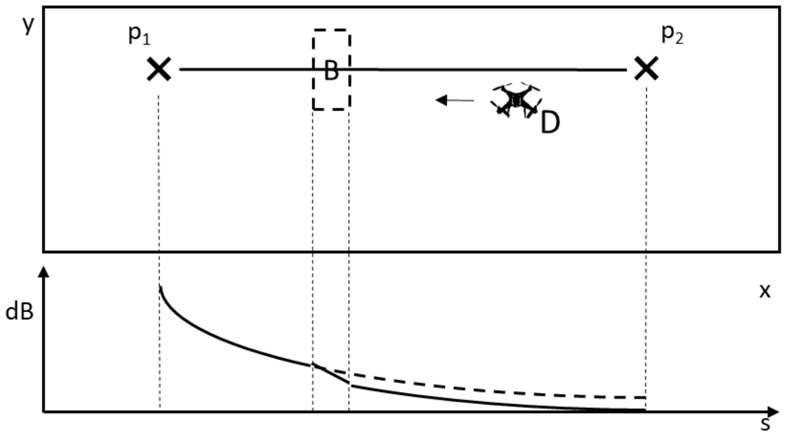
- **Real Radio Map Calculation**
  1) Determine the location accuracy of the data source and apply a model
     a) Static or slow moving device (high accuracy) and high resolution:
        -> Directly map the data to the grid point
     b) Static or slow moving device and small resolution:
        -> Apply the path loss/gain of the distance between location and grid point with respect to the propagation model of the cube
     c) Moving devices or inaccurate location:
        -> Calculate the mean of all data points within a sphere around the grid point
  2) Use a filter like moving average to smooth the RSS value over some time
  3) Interpolate over all points of the grid with a smaller weight for untrustworthy support points as from c)

Data Analysis

- **Difference Calculation (Error Map)**
  - Shows the difference between the foundational and real radio map
  - Differences are evaluated for each network device itself and in combination
  - Assuming there is currently no external influence results are areas of false propagation model estimations
  - In its simplest form, areas are cones where the aperture point away from the considered AP



Data Analysis



- **Propagation Model Correction**
  - Differences with the shape of a cone can arise due to something blocking the signal (i.e. a box)
  - The cone's apex is on that grid point where the signal hits the box as the propagation model and therefore the RSS doesn't match
  - The value of the RSS drop is used to estimate the propagation model correction by calculating the models parameters in reverse
  - The cause can be determined by known patterns or Active Probing using, e.g., a drone with visual identification and a monitoring device
  - A closed-loop process with measuring and correcting leads to a stable representation of the real RSS

Data Analysis

- **Jamming / Interference Detection**
  - Assuming the model is stable and correct, the RSS difference can be used to detect and locate jamming devices and interference sources
  - By comparing the measured and the theoretically RSS-based network performance, external influence can be detected
  - Differences that can not be explained by the model are most likely caused by those external influences and can be further analyzed with additional data like packet flows, spectral patterns or rate statistics
  - Due to the effect of the influences even the type of jammer/interferer my be classified

Conclusion

- Fusion of Industry 4.0 information leads to a live representation of radio propagation models in 3D
- Monitoring is used to correct the models as well as detect external influences like jamming or interferences
- Value-add for high reliable industrial communication
- Additional benefits like support of coverage planning or analysis and improve localization based on radio propagation
- Further research needed for jammer classification and mitigation strategies