A study on the Influence of 5G Network Planning on Communication in Urban Air Mobility

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Institut für Telematik

Shashini Thamarasie Wanniarachchi, Volker Turau

Presented by: Shashini Thamarasie Wanniarachchi

ULTRAS

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aufgrund eines Beschlusses des Deutschen Bundestages

Contents:

1. Background

Background

- A growing interest on autonomous aerial vehicles for passenger transportation
- Key priority: Safe navigation
- Requirement: Reliable and efficient information exchange
- Promising and cost effective technology: 5G and beyond
- Challenge: Balance between costs and metrics
  - Coverage and connectivity
  - Message delay
  - Reliability

2. Objectives

Objectives

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- Focus: Air-to-ground communication
- Particular aspect: Base station network
- Explore factors affecting a cost-effective base station (gNodeB) network
- Investigate system parameters for different types of data transmissions
- Performance evaluation

3. Methodology

Methodology

- Use case: Hamburg City

- Simulation framework :
  - OMNeT ++ (version 6.0) [1]
  - Simu5g (version 1.2.1) [2]

- Flight trajectories: ULTRAS tool chain [3]

- Two aspects:
  - Channel Model
  - Implementation

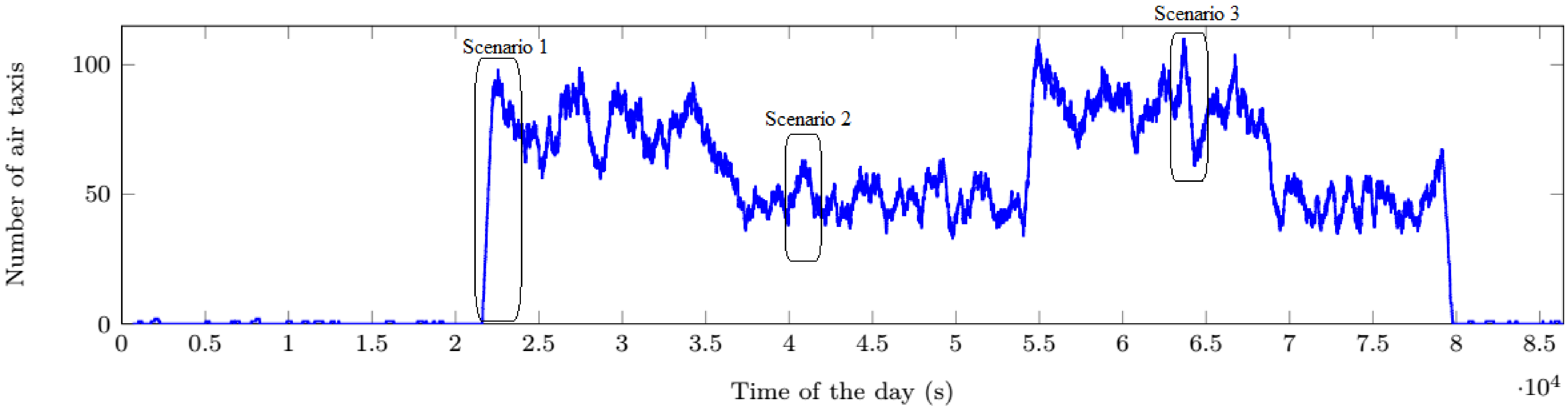
Methodology | Channel Model

- Height of the user equipment affects the path loss model
- Propagation model : Urban macro cell
- Path loss models adopted from:
  - 3GPP standards (TR36.777 [4] and TR38901 [5])
  - Path loss characteristics for UAV-to-ground wireless channels by G. E. Athanasiadou and G. V. Tsoulos [6]
- Other considerations:
  - Shadowing
  - Rayleigh fading

Methodology | Implementation

Scenario Definition

- Simulation time: 24 hours
- Duration of each scenario: 2000 s



Methodology | Implementation

Experiments

- Message size: 40 Bytes
- Message type: Coordinates

Experiment	Scenario	Description
Number of Base Stations	2	Simulating different number of base stations
Base Station Placement	All three	Studying two base station placement techniques (map based and grid)
Network Planning	All three	Examining the number of messages received at each base station
Load Sharing	3	Investigating the effect of sharing the load by replacing one base station by two
Use Cases	2	Performance evaluation under use cases

Methodology | Implementation

Calculation of Number of Base Stations

- Link budget calculations (3GPP TR38901 [5])
- Network area: 42 x 40 km^2
- Calculated number of base stations: 47
- Test Instances:
  - 30
  - 40
  - 50

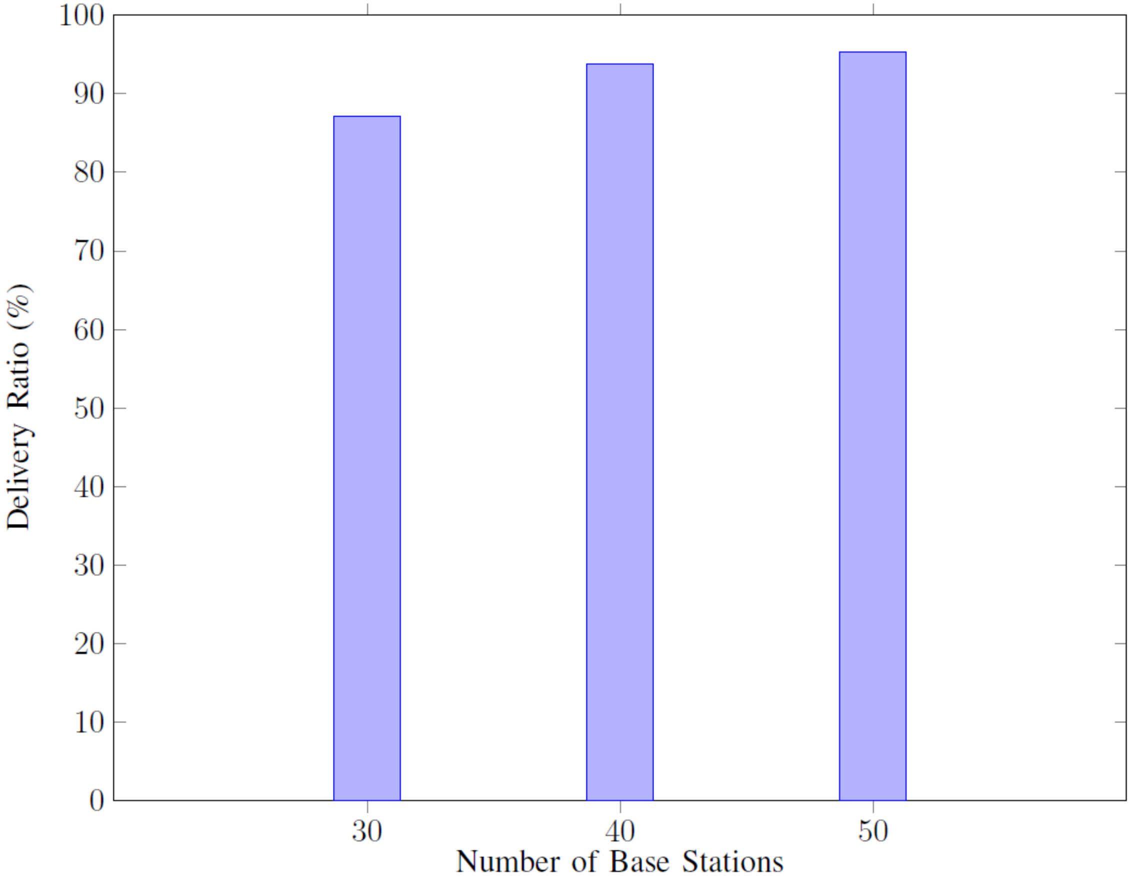
Performance Evaluation Criteria

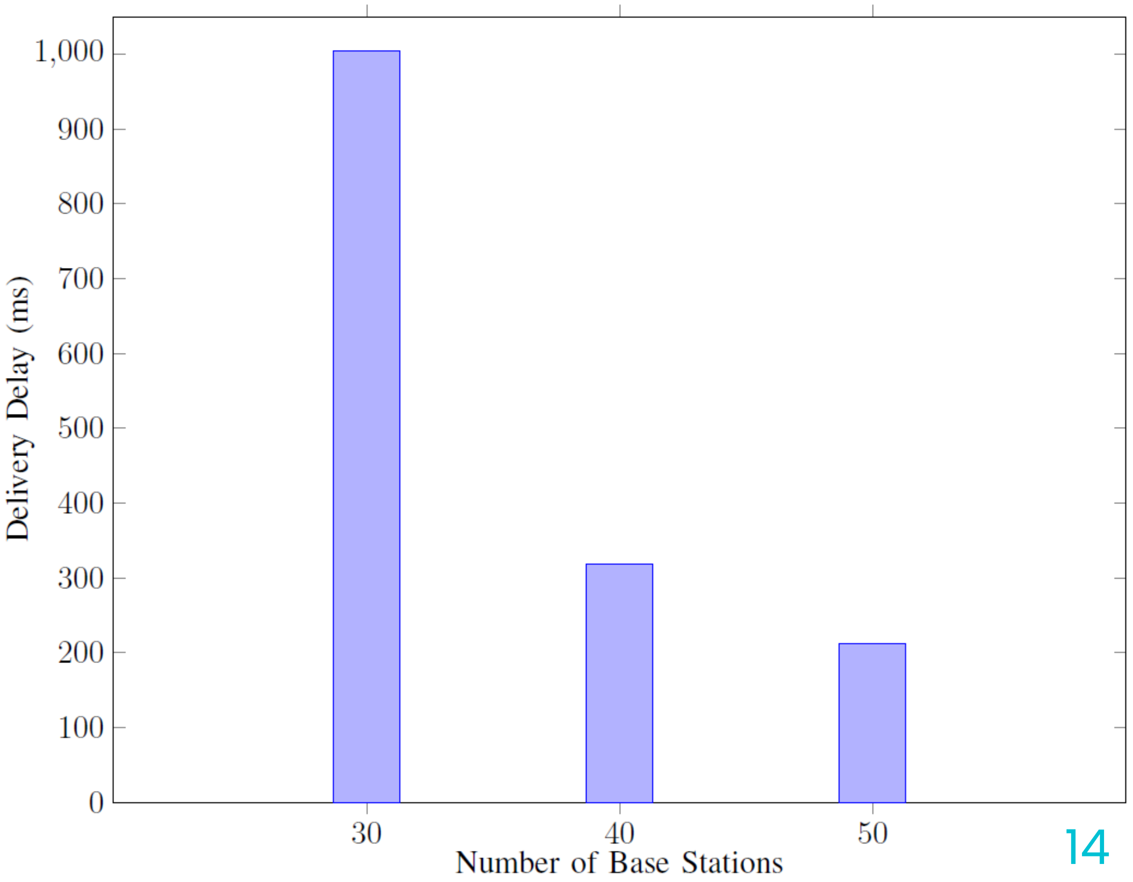
- Delivery ratio
- Delivery delay

4. Results

Results

Number of Base Stations





Results

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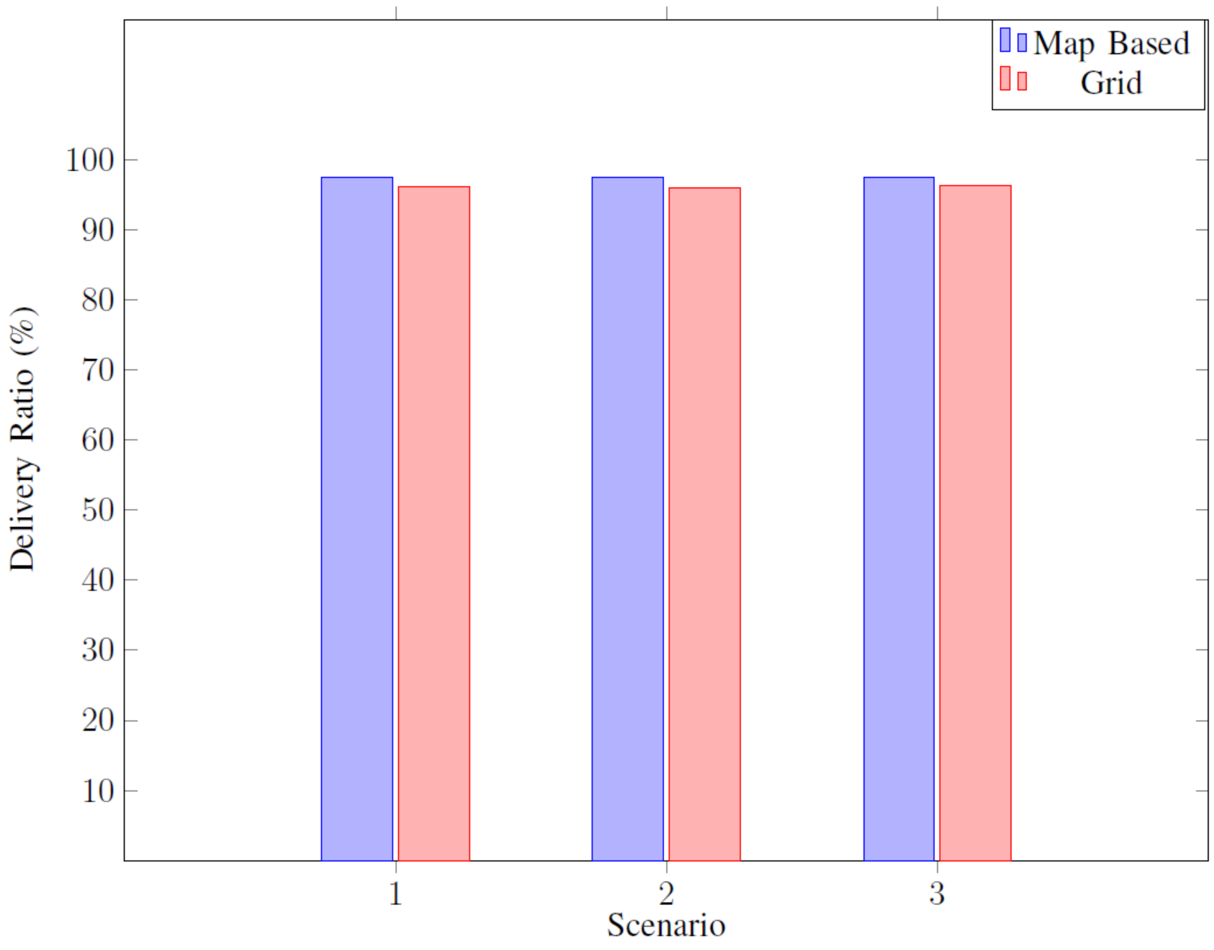
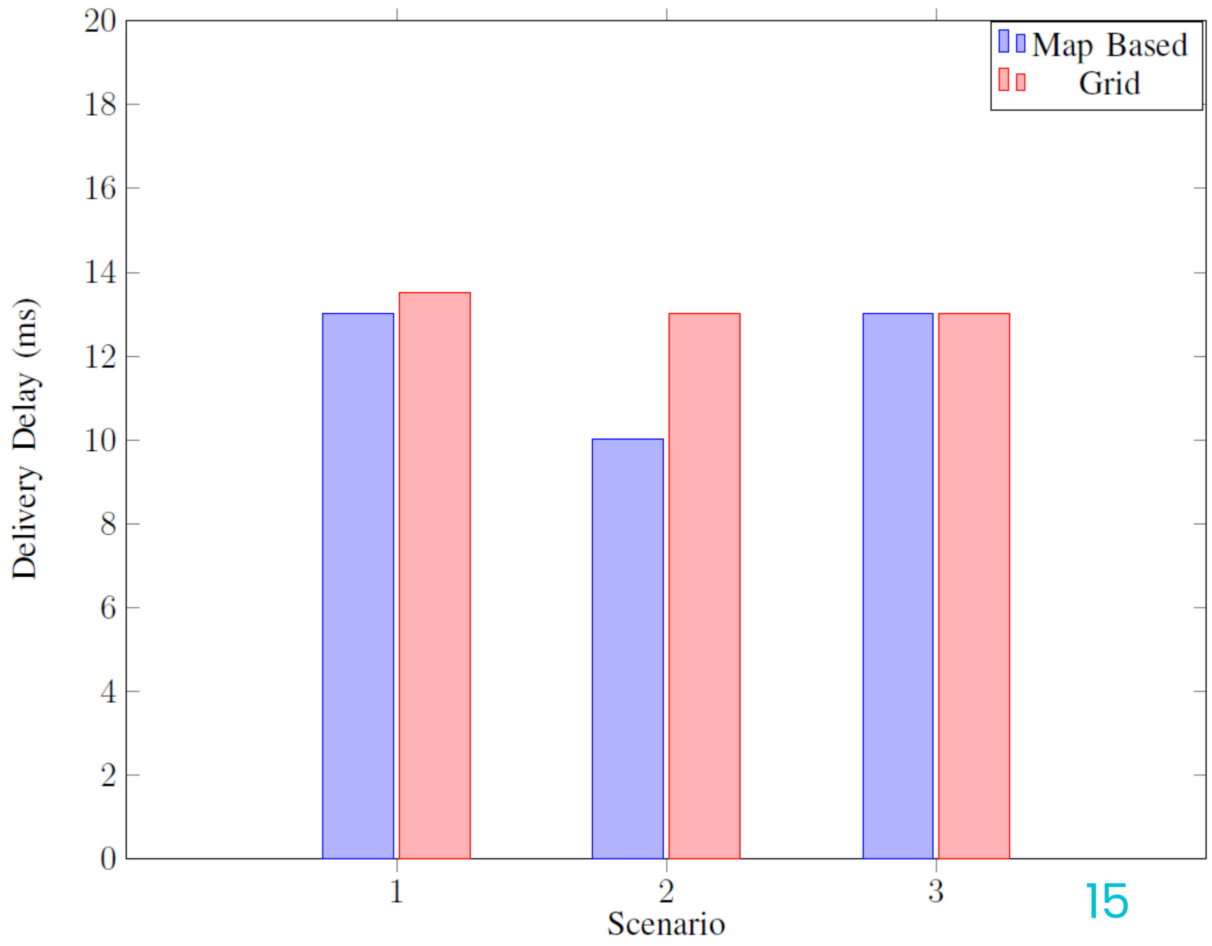
Base Station Placement





Results

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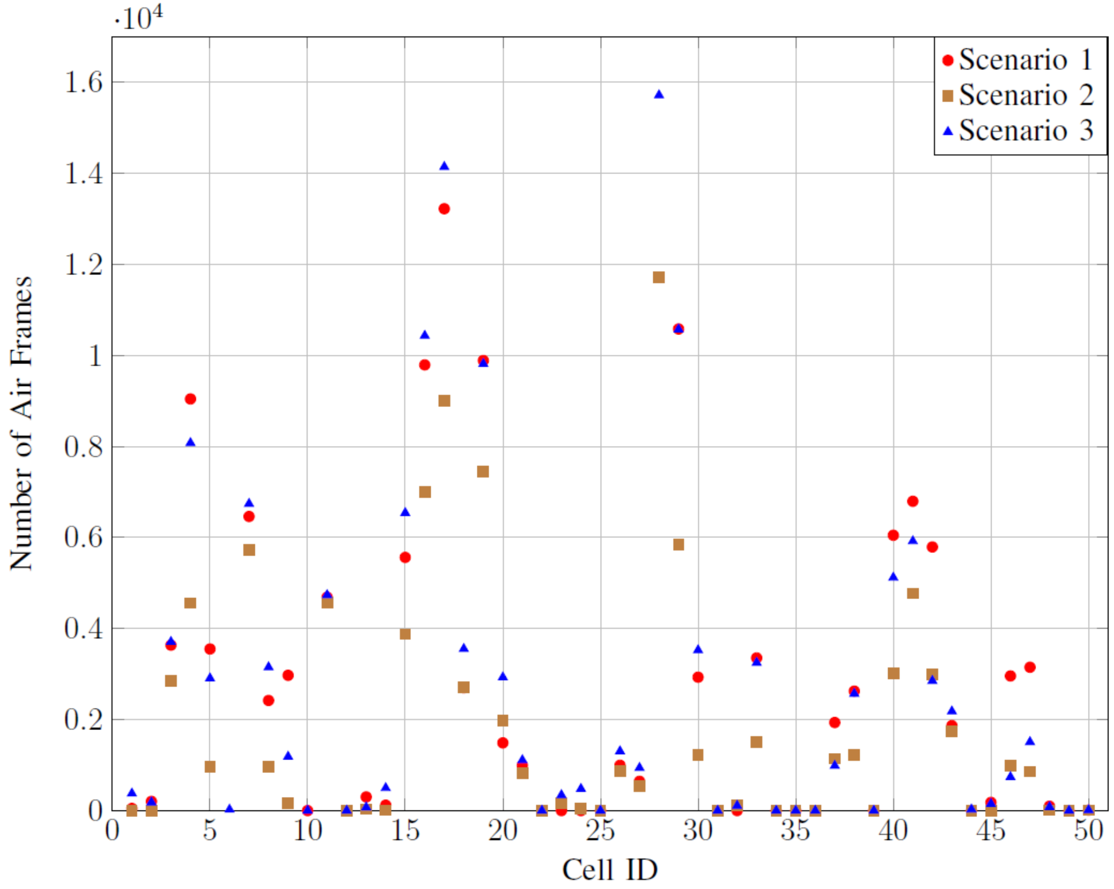
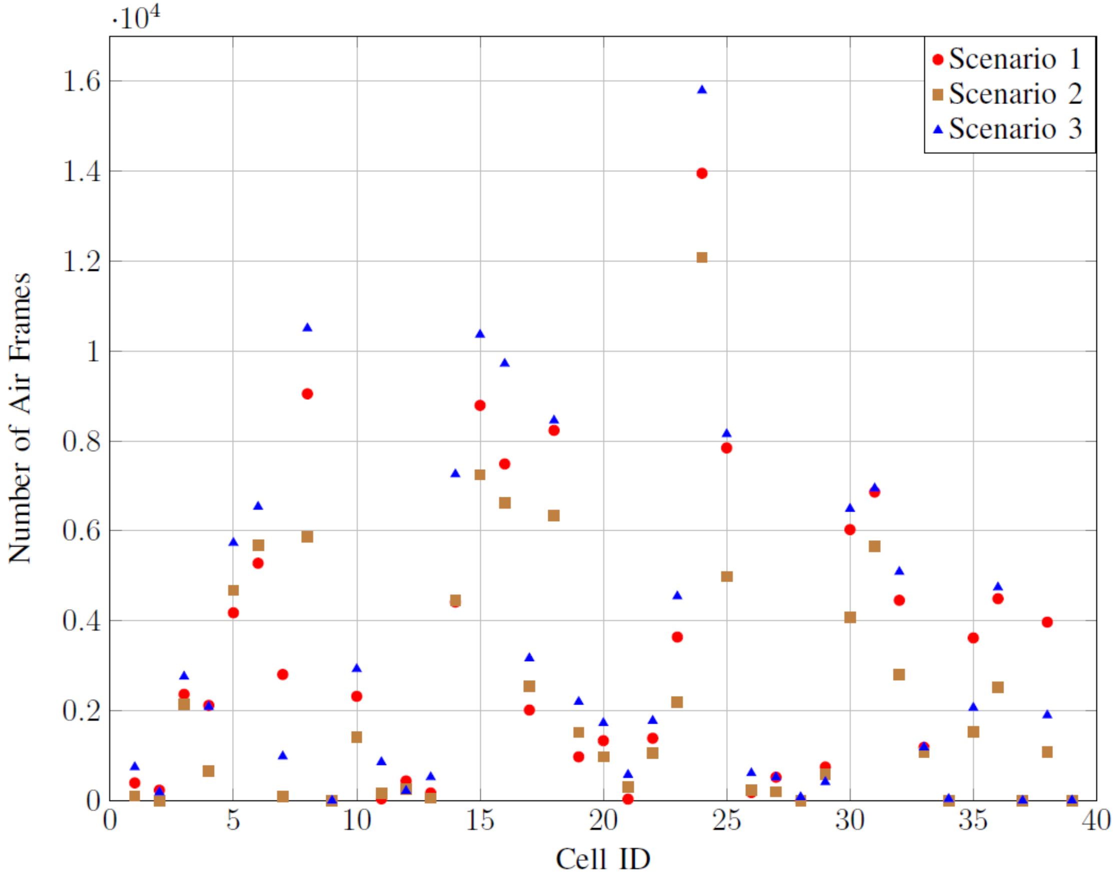
Network Planning



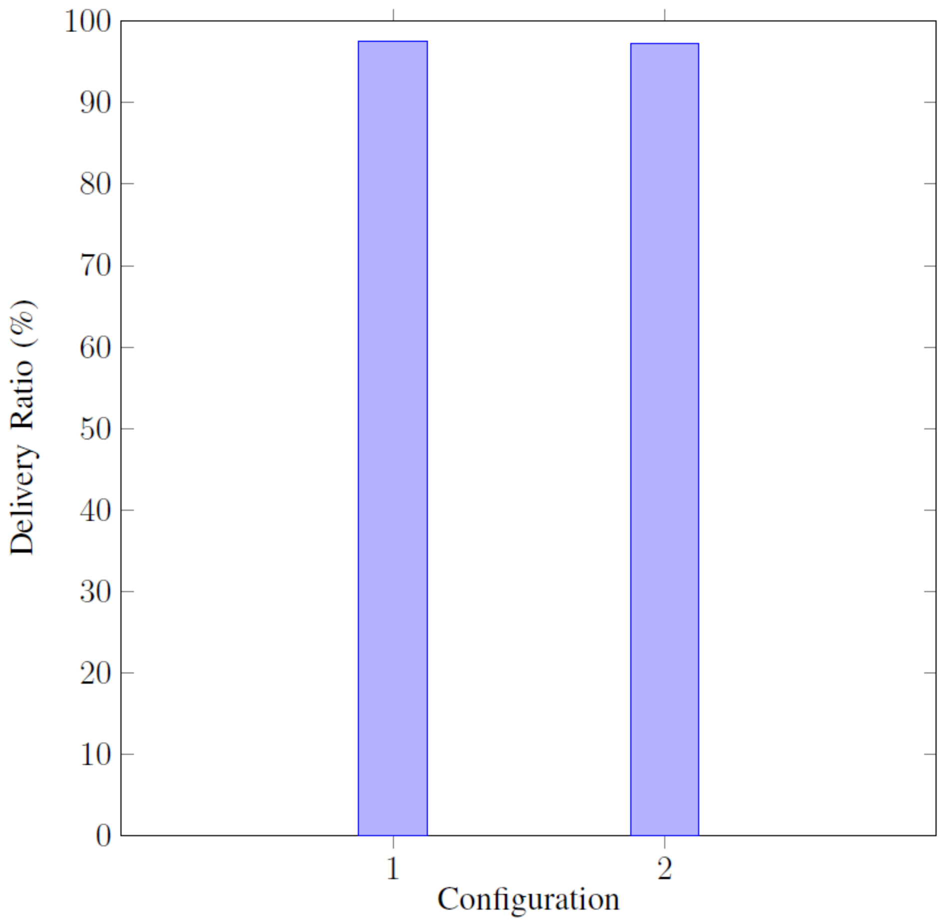
Case of 50 Base Stations

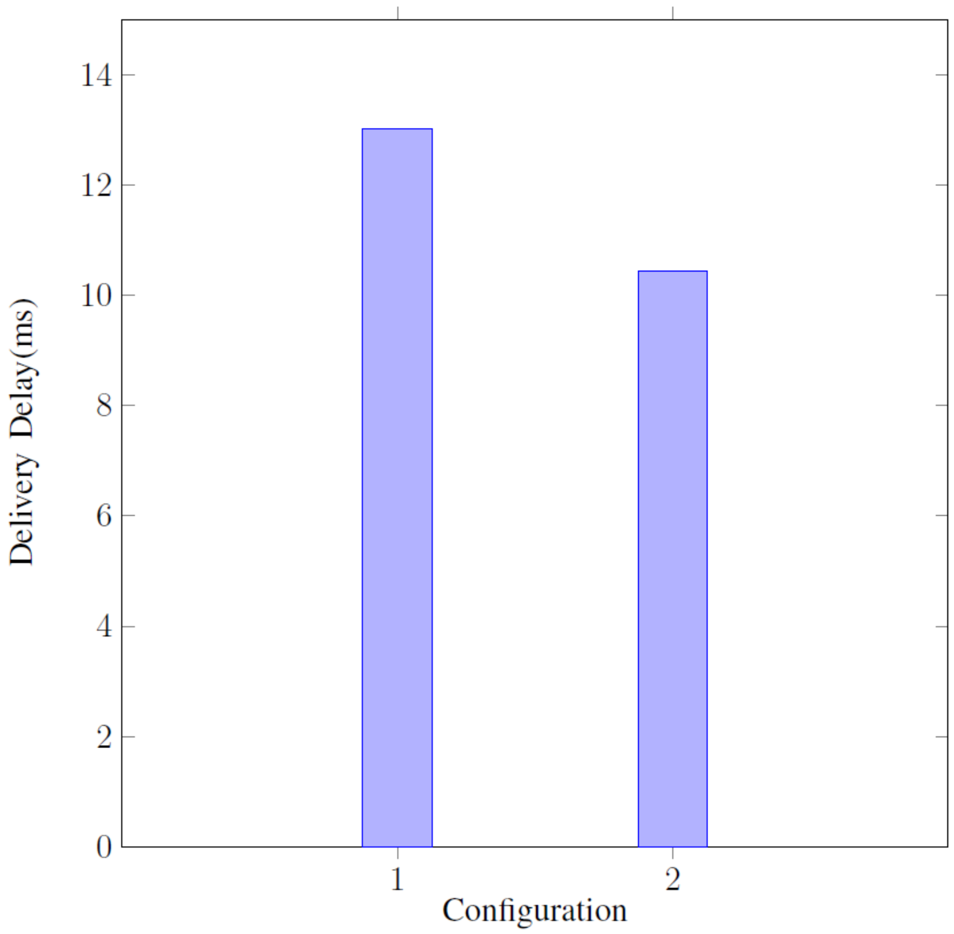


Case of 39 Base Stations

Results

Load Sharing





Configurations:

1 : Before load sharing

2 : After load sharing

Results

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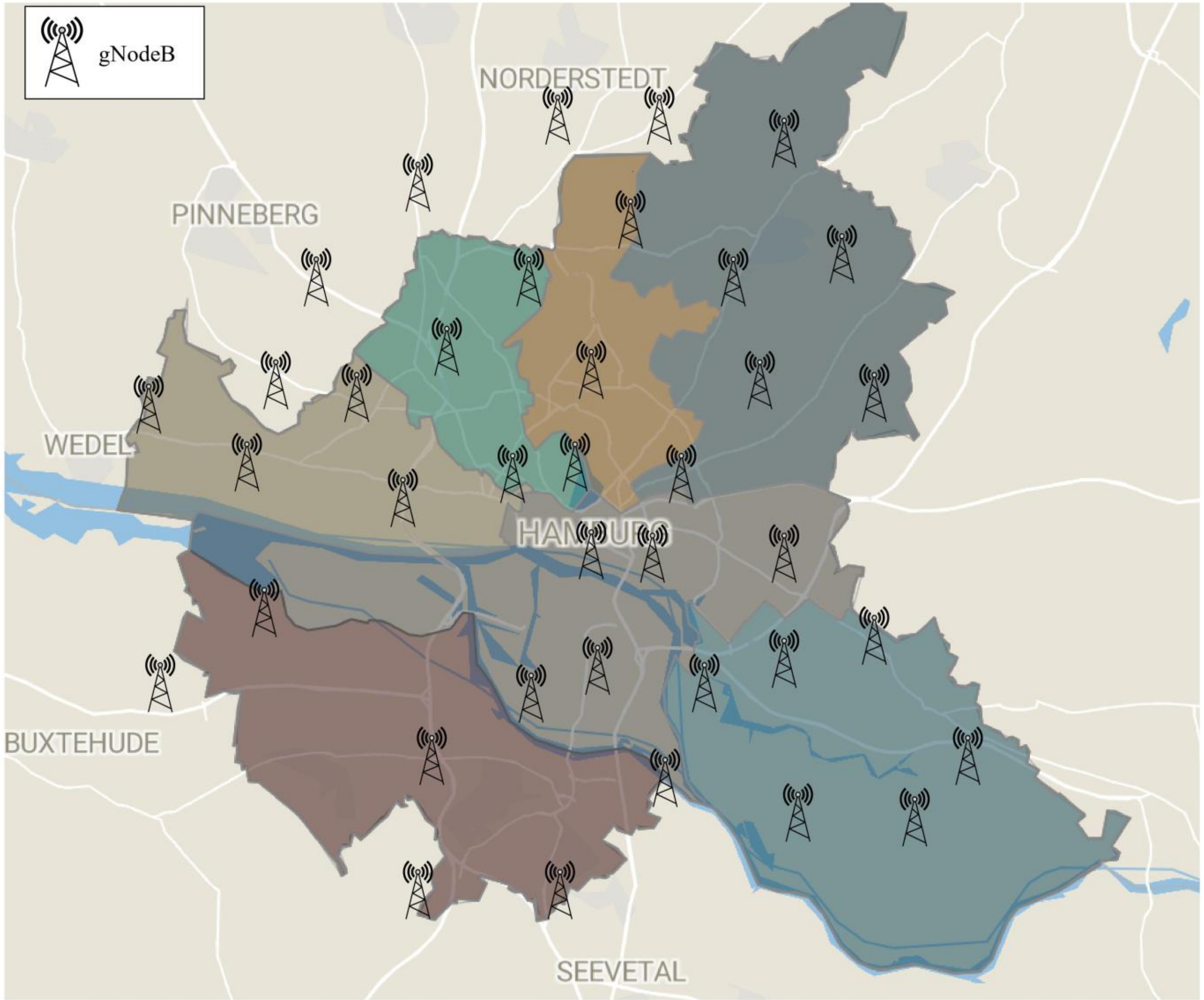
Finalized Base Station Network

Number of Base Stations: 38

Delivery Ratio : 97%

Delivery Delay: 10 ms



Results

Use Cases

Use Case	Data Type	Bandwidth (MHz)	Period (s)
1	Coordinates	5	2
2	Coordinates	20	2
3	Image	20	Uniform(2,5)
4	Image	50	Uniform(2,5)
5	Video	100	Uniform(2,5)
6	Video	100	Uniform(15,18)

Results

Use Cases

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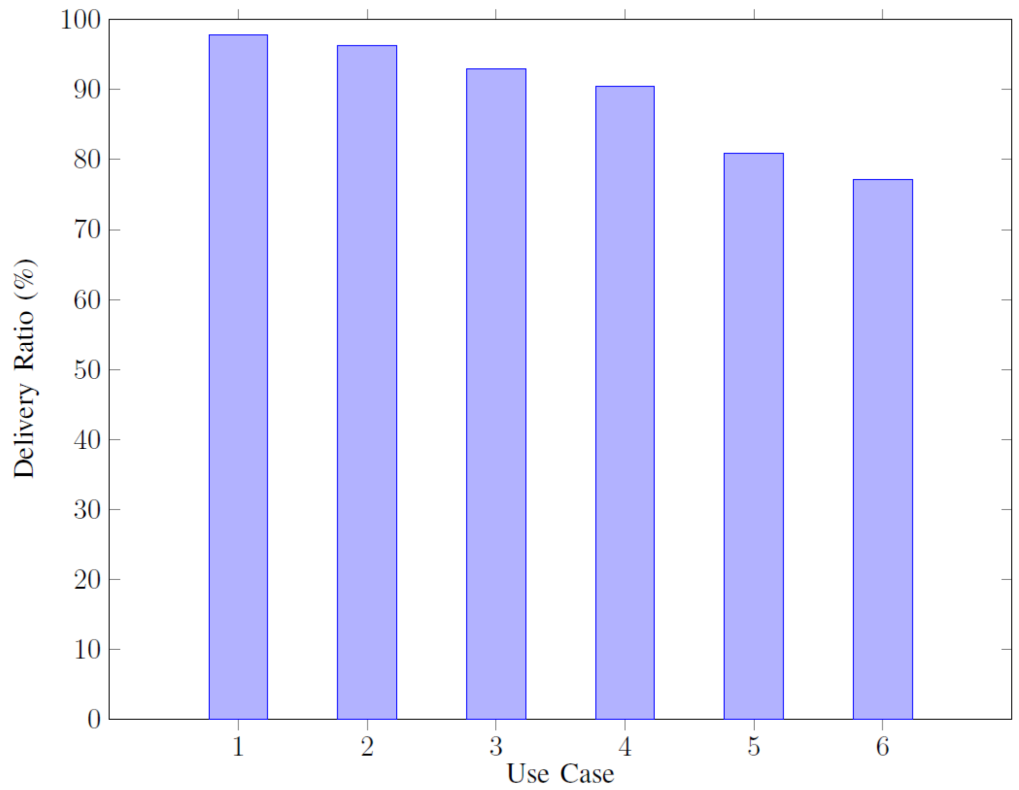

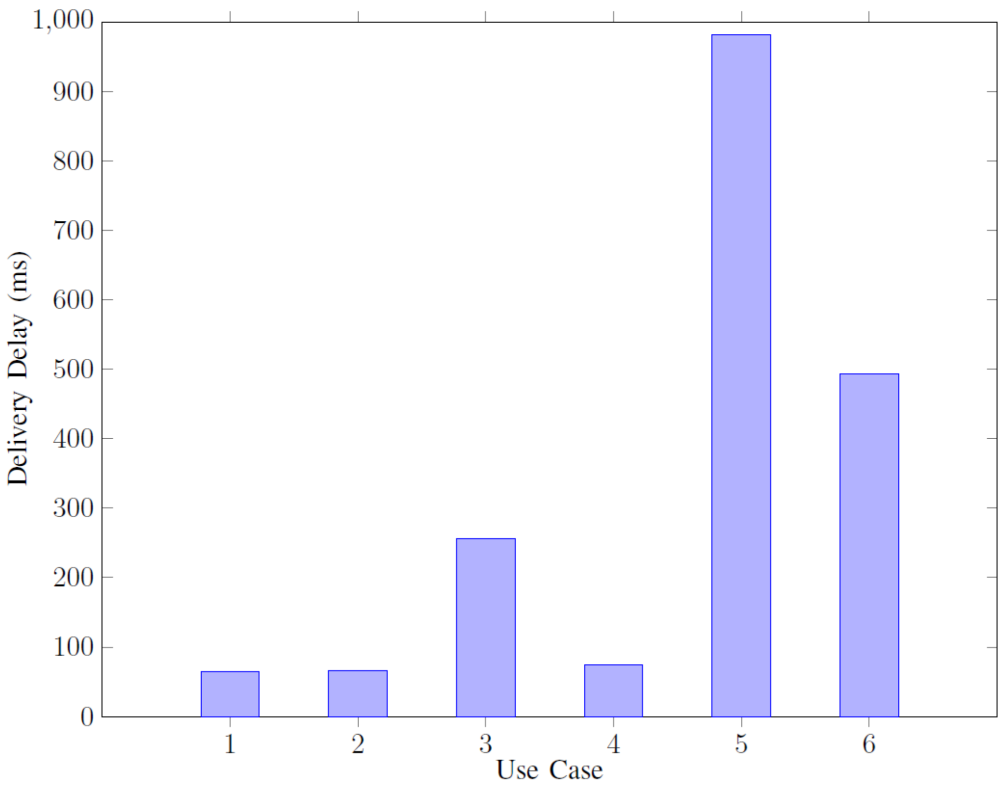

File Sizes :
Coordinates : 40 B
Images : 130 – 150 KB
Video : 1 – 2 MB

5. Conclusion & Outlook

Conclusion & Outlook

Conclusion

- Base Station placement: Geographical conditions and actual demand
- Channel model to suit the application
- Reduction of delivery delay:
  - Increasing the bandwidth or the period
  - Load Sharing
- Presented Base Station network: Usable for real UAM implementation in Hamburg

Outlook

- Investigate the effect of shared network
- Applying data retransmission techniques
- Explore extreme cases of spontaneous air taxi movements
- Fine tune the system to avoid video data losses

References

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Thank you for your attention

Shashini Thamarasie wanniarachchi
Institut für Telematik,
Hamburg University of Technology,
Hamburg, Germany
https://www.ti5.tuhh.de/

tuhh.de

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Technische Universität Hamburg

Link Budget Calculations

3GPP TR38901 [2]

$$PL_{NLOS}(d_{3D}) = 13.54 + 39.08\ log_{10}(d_{3D}) + 20\ log_{10}\ (fc) - 0.6\ (h_{UT} - 1.5)$$

$$Cell\ Radius = sqrt[d^2{}_{3D} - (hBS - hUT)]$$

$$Number\ of\ Base\ Stations = \frac{Network\ Area}{(2\ X\ Cell\ Radis)^2}$$

PL_{NLOS} = *Non line of sight path loss* d_{3D} = *3-dimensional Distance* fc = *Carrier frequency* h_{UT} = *User equipment height* h_{BS} = *Base station height*