A Fault-Tolerant Distributed Air-to-Ground Communication Architecture for Urban Air Mobility

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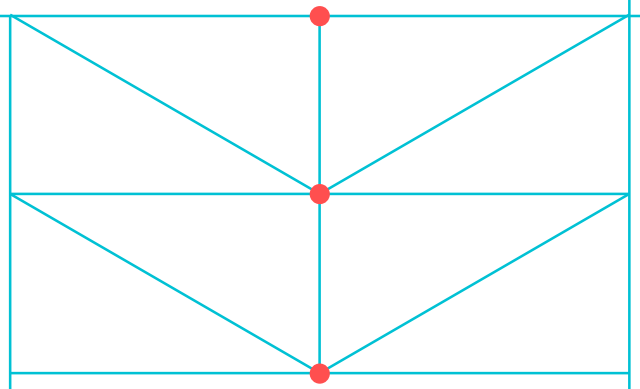

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Institut für Telematik

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ULTRAS

Gefördert durch: Bundesministerium für Wirtschaft und Energie aufgrund eines Beschlusses des Deutschen Bundestages

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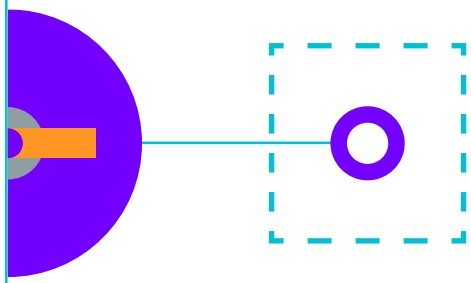
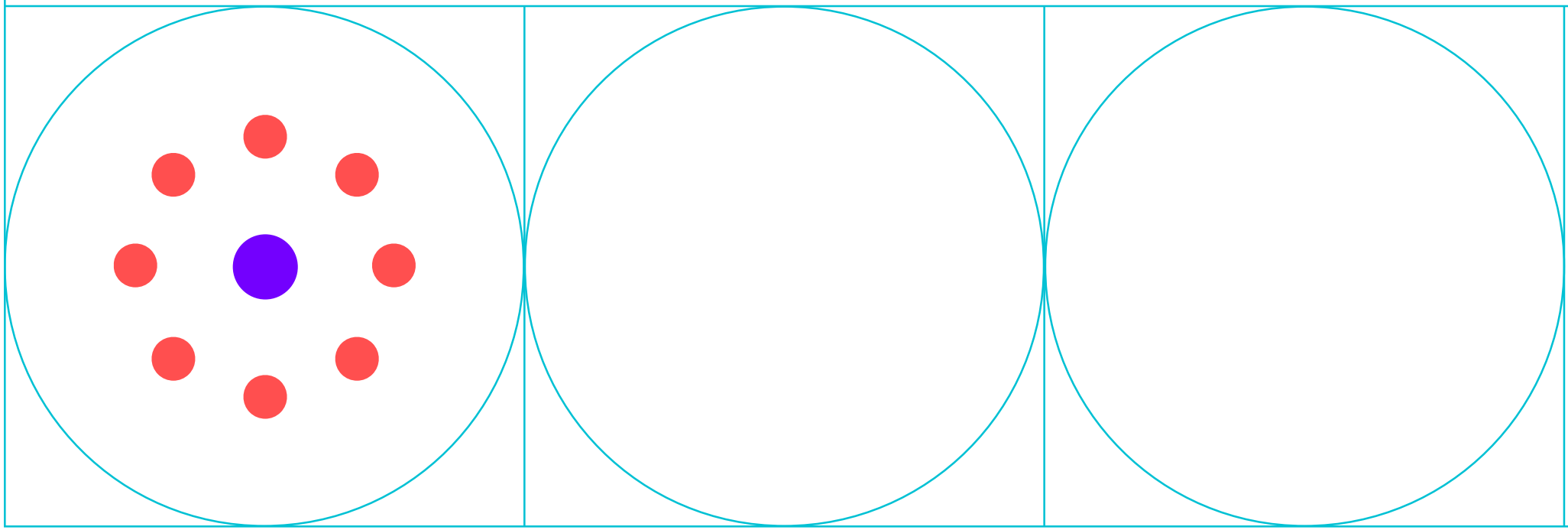


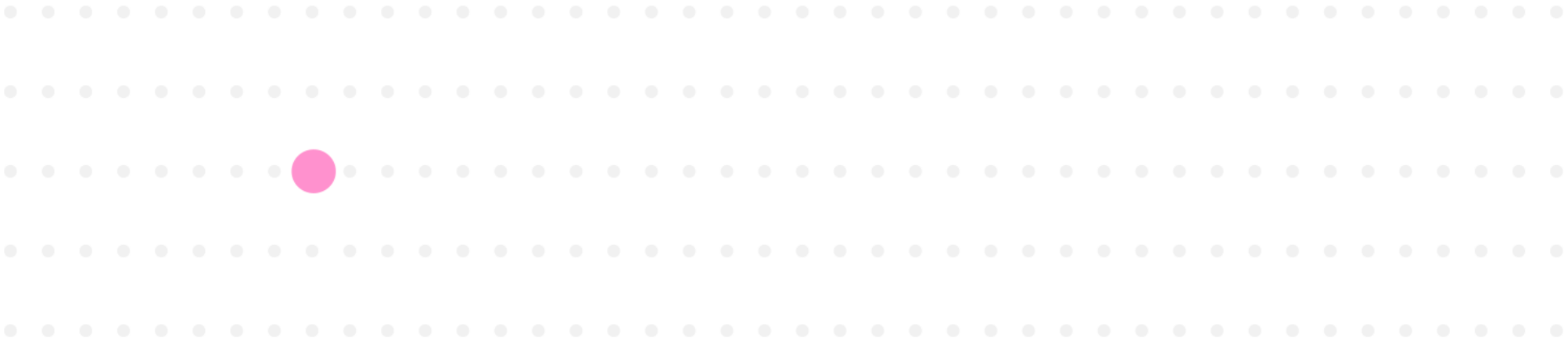
1. Background



Background

- Problem: Increasing demand for public transportation modes
- A possible attenuation: Urban air mobility (UAM)
- Challenge: Safe management of UAM traffic
- Solution: Unmanned Transport Management Concepts [4]
- Safety critical functions:
  - Exchange of sensor data
  - Flight information management
- Requirement: Fault-tolerant communication system

2. Objectives



Objectives

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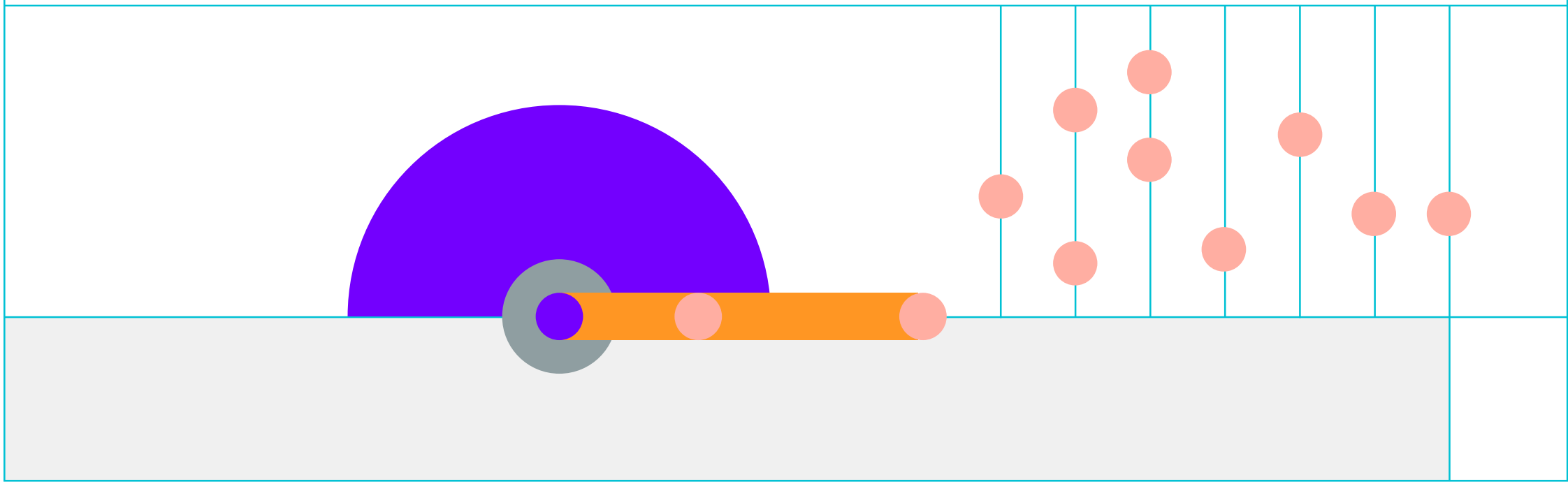
- Air-to-air communication
- Redundancy provision: Air-to-ground communication
- Proposal:
  - A distributed ground control station architecture
  - A concept for role-delegation between the ground stations

3. Concept



Concept | Single Ground Station

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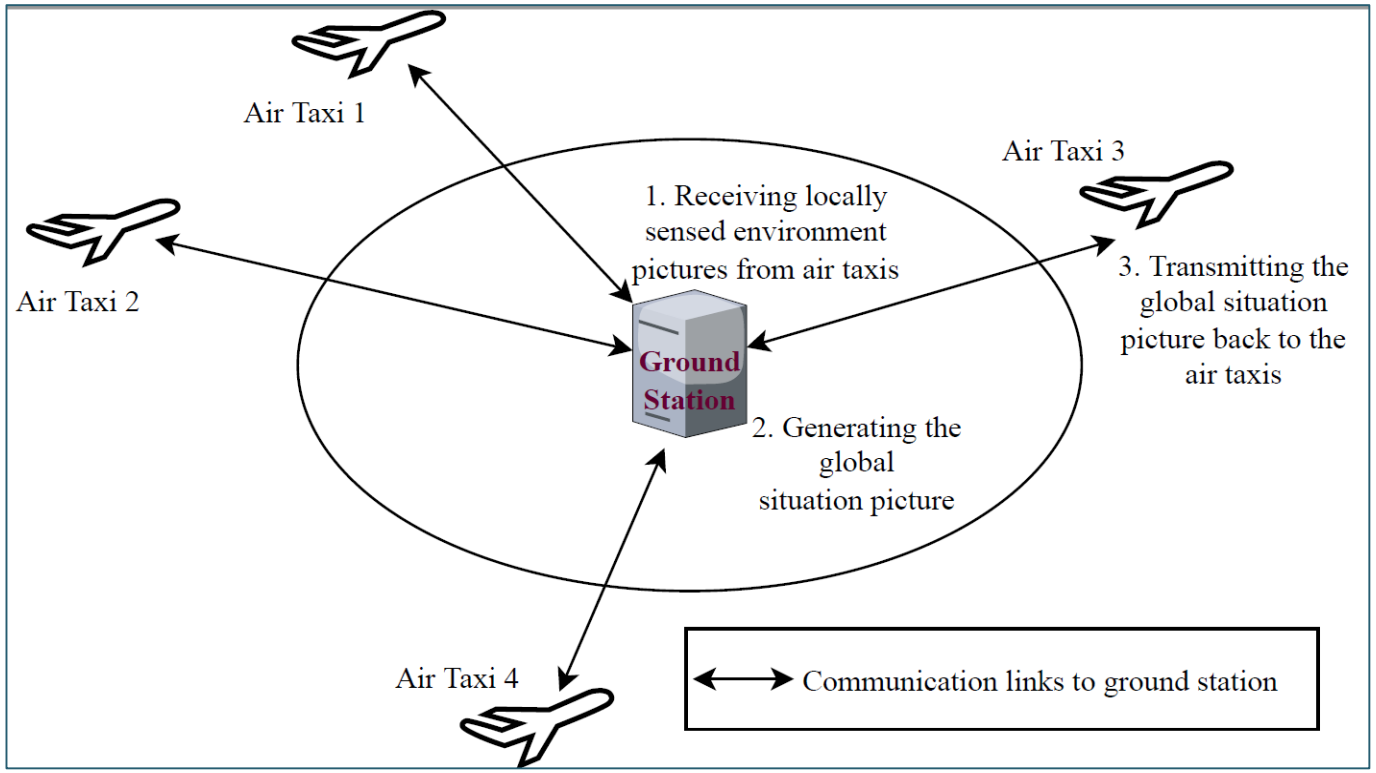
Option 1



Drawbacks :

- Unnecessary bandwidth usage
- High computational Complexity
- Single point failure

Concept | Replicated Ground Stations

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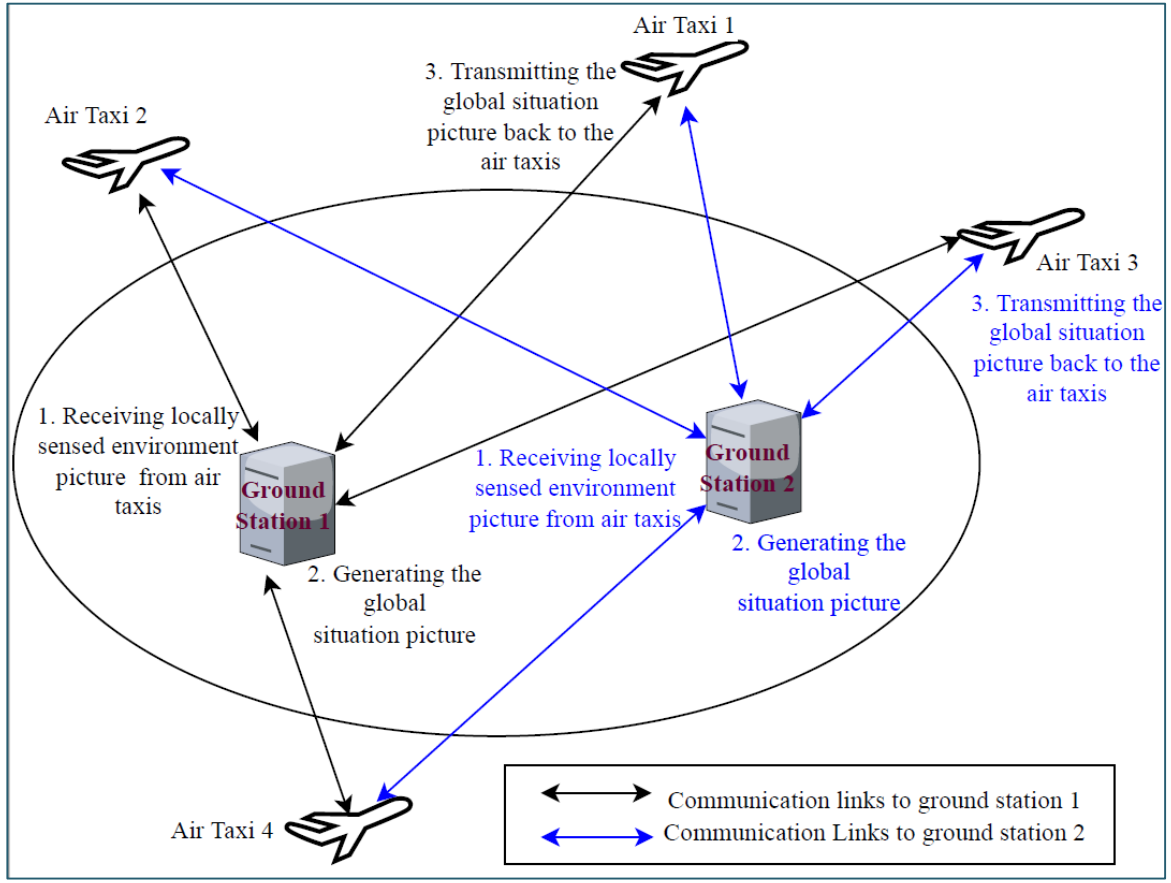
Option 2

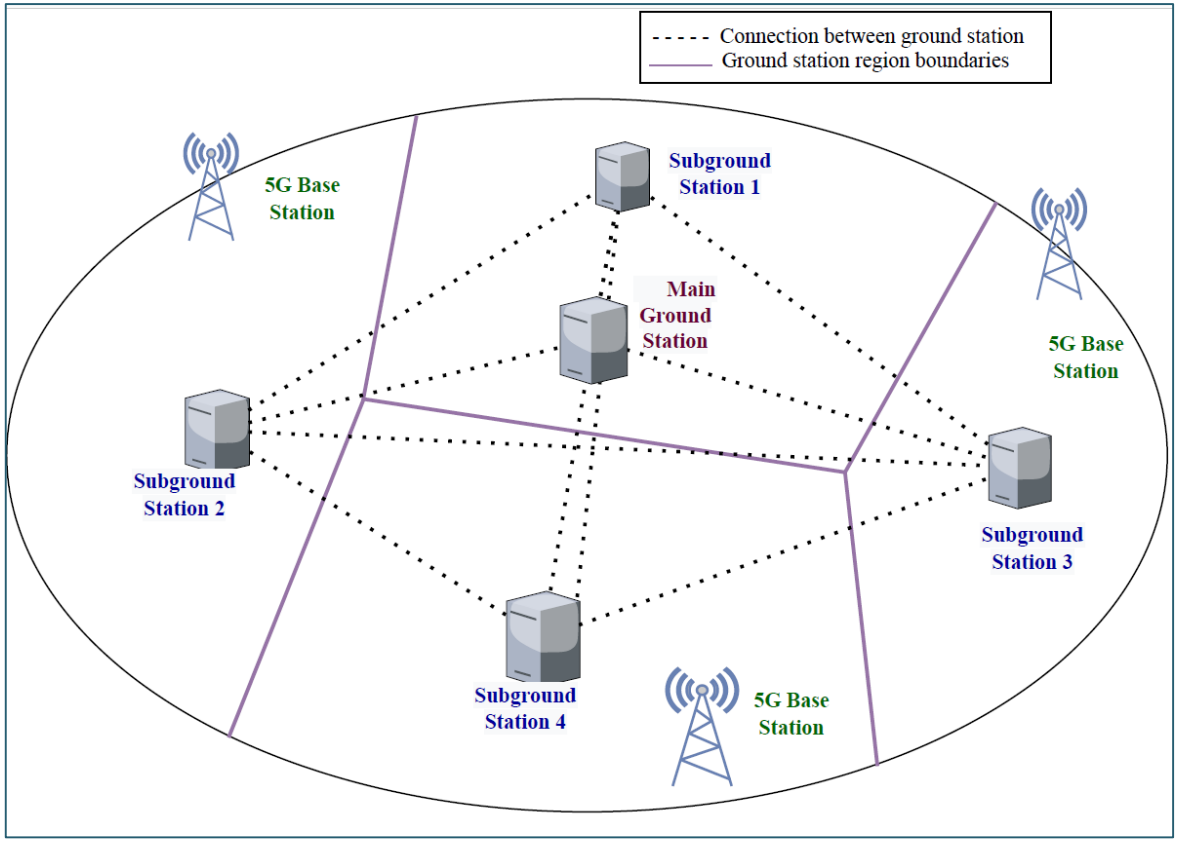


Drawbacks :

- Unnecessary bandwidth usage
- Huge message overhead

Concept | Proposed Architecture

- Main ground station: Global situation picture
- Sub ground station: Scope of responsibility
- Local situation picture: Local for each air taxi



Concept | Fault-Tolerant Capability

- Principle : Role delegation
- Three types of failures :
  - Failure in main ground station
  - Failure in sub ground station
  - Failure in both main ground station and sub ground stations simultaneously
- Heart beat protocol: Periodic signal indicating the current status of a node
- Sub ground station priority list : The order in which the role delegation proceeds

Concept | Role-Delegation Mechanism

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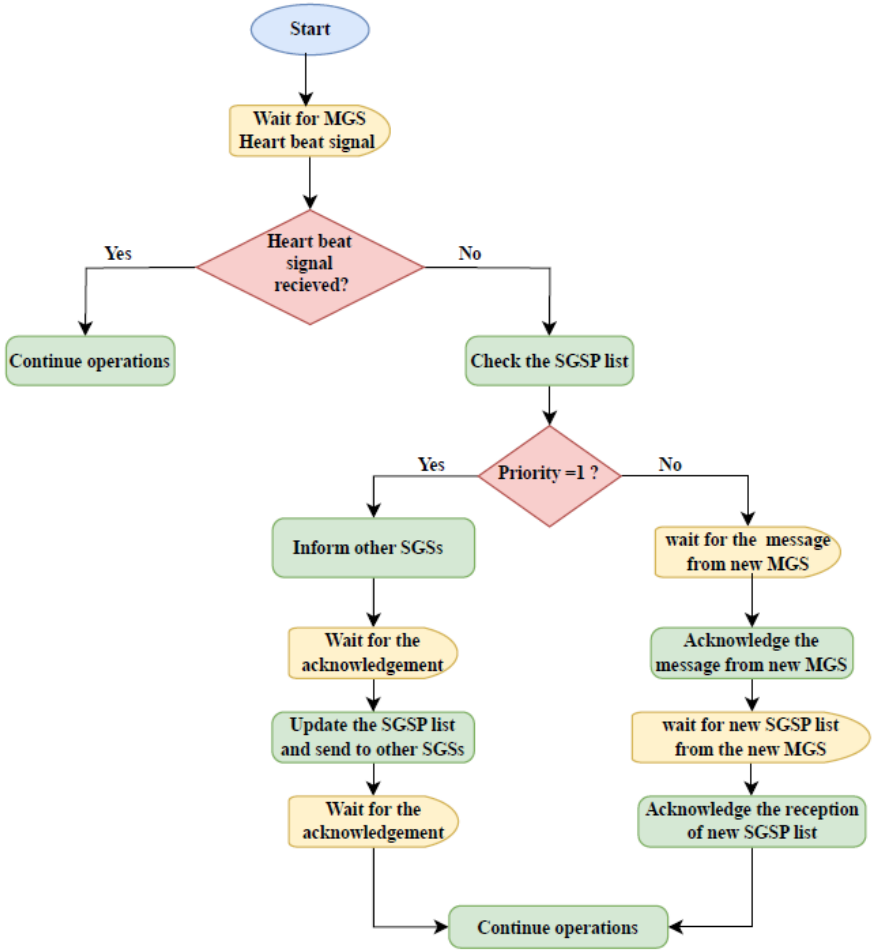
Failure of main ground station

MTTR = TUFR + TTRE

MTTR : Mean Time to Recover
TUFR : Time Until Failure Recognition
TTRE : Time to Recover



Concept | Role-Delegation Mechanism

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Failure of new main ground station in between the role delegation procedure

- Failure recognition: Not receiving the priority list
- Role delegation: Next in priority list

Failure of sub ground station

- Main ground station:
  - Failure announcement
  - Updating the sub ground station priority list

- MTTR = TTIF + TTU

MTTR : Mean Time to Recover
TTIF : Time to Identify Failure
TTU : Time to Update

Concept | Role-Delegation Mechanism

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Failure of main ground station sub ground stations simultaneously

- Detected by: Sub ground stations
- First address: Main ground station failure
- High MTTR
- Drawback in role delegation continuation : Rise in computational complexity
- Solution: Identifying the minimum number of active sub ground stations

Concept | Role-Delegation Mechanism

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Reinstating ground stations

- New update message broadcast
- Restoring a failed main ground station: Resets the system to default
- Reinstating of sub ground stations: Informed by the main ground station and the priority list is reset
- Air taxis: Set the sub ground station locations to default

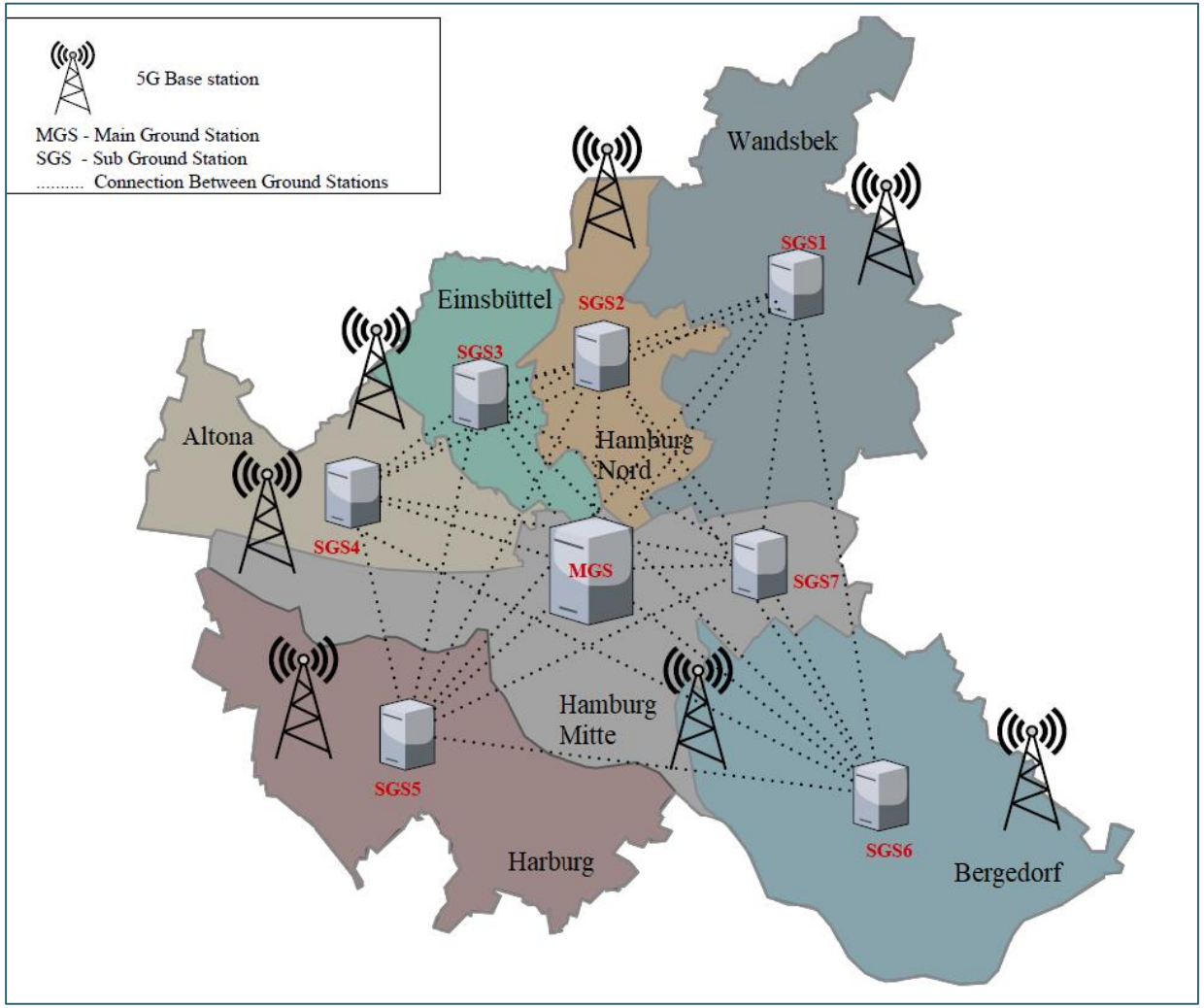
Concept | Use Case

Use case: Hamburg metropolitan region

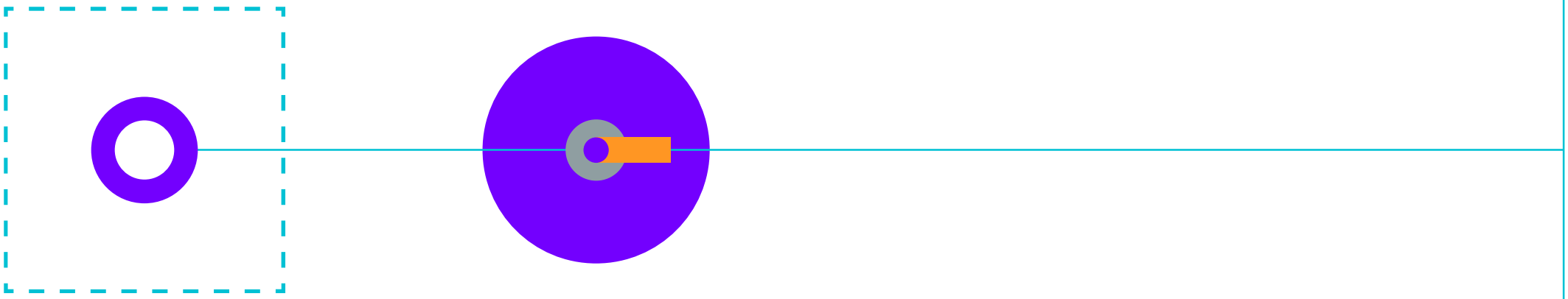
Simulator: OMNeT ++ [2]
ULTRAS tool chain [3]

Evaluation :

- Minimum number of required active sub ground stations
- Role delegation success rate
- Mean time to repair (MTTR)



4. Conclusion & Outlook



Conclusion & Outlook

Conclusion

- Fault-tolerant information management is a necessity
- Fault-tolerant concept :
  - Including Air-to-ground communication
  - A distributed ground network architecture
  - Concept of role delegation between ground stations

Outlook

- The concept to be validated with simulations
- Exploring methods to improve reliability and latency of communication links
- Assurance of fault-tolerance in sensor data collection phase

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Thank you for your attention

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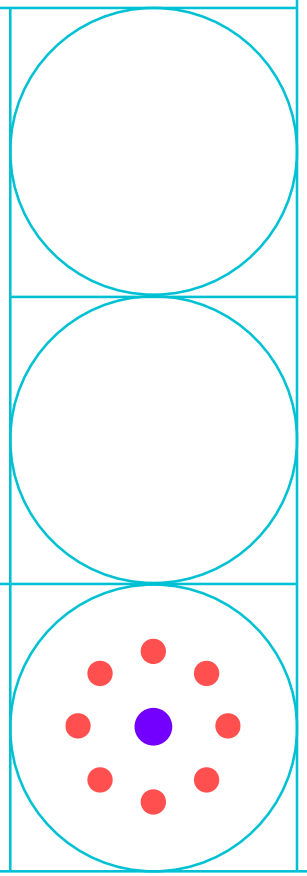

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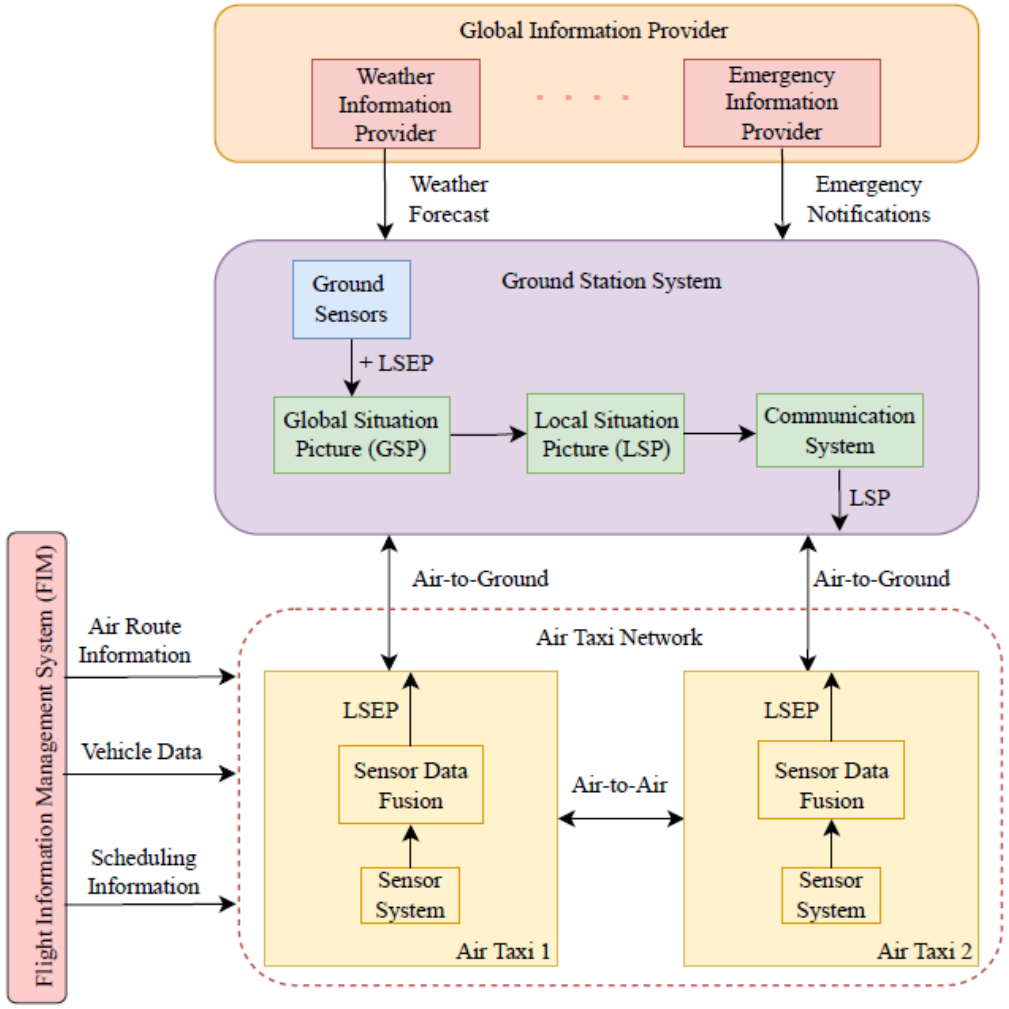
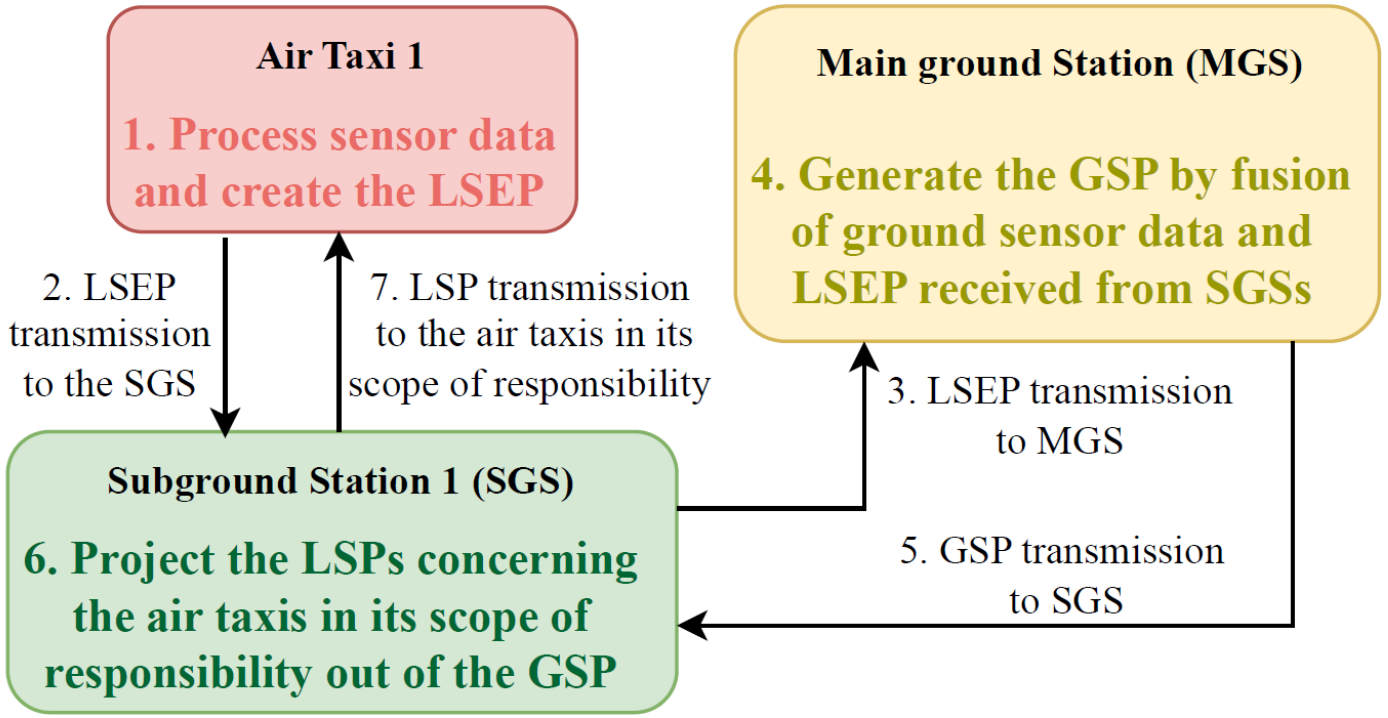
Concept | System Architecture



LSEP : Locally Sensed Environment Picture

Concept | Proposed Architecture

Methodology for air-to-ground communication implementation



- SGS : Sub Ground Station
- LSEP : Locally Sensed Environment Picture
- LSP : Local Situation Picture
- GSP : Global Situation Picture