T4: Optimal AAM-Networks

Location and traffic management of UAS landing sites

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Motivation

- The location of Advanced Air Mobility (AAM) aircraft landing sites influences the acceptance and efficiency of the AAM network but is subject to requirements from the integration of maintenance/charging stations.
- Efficient integration of UAS into urban environments requires coordination with airspace and traffic management systems.
- Restrictions for locating suitable landing sites: safety, noise reduction, urban planning, privacy, and flight operations.

Goal: Identification of multi-criterial optimal locations for UAS landing sites.

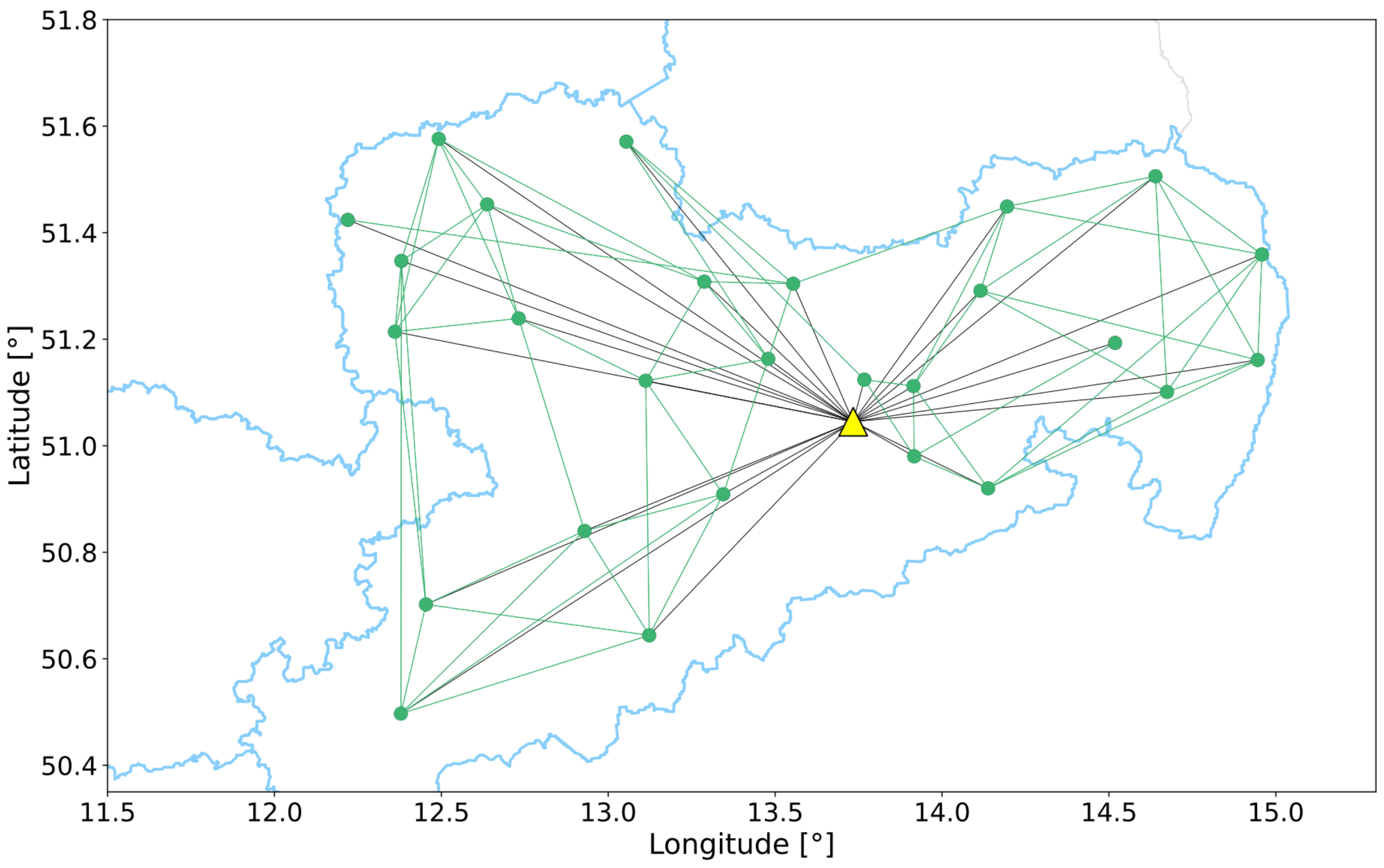

Figure 1: Example of the network topology of a Single-Hub AAM network with a hub in Dresden [1]

Methods

- Utilization of mathematical optimization methods for AAM network design (types: *Variable Routing Problem Time Windows, Resource Constrained Project Scheduling Problem, n-Hub Location Problem*).
- Robust fleet and rotation planning.
- Expansion to include subsequent AAM constraints after scaling up.

$$\min \sum_{i \in \mathcal{N}} \sum_{j \in \mathcal{N}} \frac{Q_{ij}}{S} \rho_{ij} C_{ij} \, 1.2 + \sum_{i \in \mathcal{N}} F_i y_i$$

$$+ \sum_{k \in \mathcal{N}} \sum_{i \in \mathcal{N}} \sum_{l \in \mathcal{N}} \sum_{j \in \mathcal{N}} \frac{Q_{ij}}{S} z_{kilj} (C_{ki} + \alpha C_{kl} + C_{lj})$$

Selected Constraints:

$$\sum_{i \in \mathcal{N}} y_i \leq P$$

$$\sum_{i \in \mathcal{F}} y_i = 0$$

$$\sum_{i \in \mathcal{N}} x_{ij} = 1 \qquad \forall j \in \mathcal{N}$$

$$x_{ij} \leq y_i \qquad \forall i,j \in \mathcal{N}$$

$$z_{kilj} \leq x_{lj} \qquad \forall i,j,k,l \in \mathcal{N}$$

$$z_{kilj} \leq x_{ki} \qquad \forall i,j,k,l \in \mathcal{N}$$

$$\rho_{ij} + z_{kilj} + 1 \geq x_{ki} + x_{lj} \qquad \forall i,j,k,l \in \mathcal{N}$$

$$\sum_{i \in \mathcal{N}} \rho_{ij} \leq \lambda (N - P) \qquad \forall i \in \mathcal{N}$$

Sets:

$\mathcal{N}$	set of all candidate nodes
$\mathcal{F}$	set of all nodes, which can not become a hub

Parameters:

D_{ij}	distance between nodes i and j
S	eVTOL seat capacity
P	number of available potential hubs
C_{ij}	operational flight cost between nodes i and j
F_i	fixed cost for node i to become a hub
R	maximum air taxi range
Q_{ij}	assumed passenger demand between nodes i and j
α	the cost reduction factor between two hubs
λ	level of point-to-point network
N	the total number of candidate nodes

Figure 2: Linear optimization model for AAM network design, Type Hub Location Problem [2]

Network member in:

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Results

- Multi-criterially optimized networks of hub-centric and point-to-point configurations for AAM operation.
- Network-specific traffic management considering regulatory frameworks.
- Demand-oriented sizing of AAM operations (fleet sizes and cycles in stochastic operational influences).

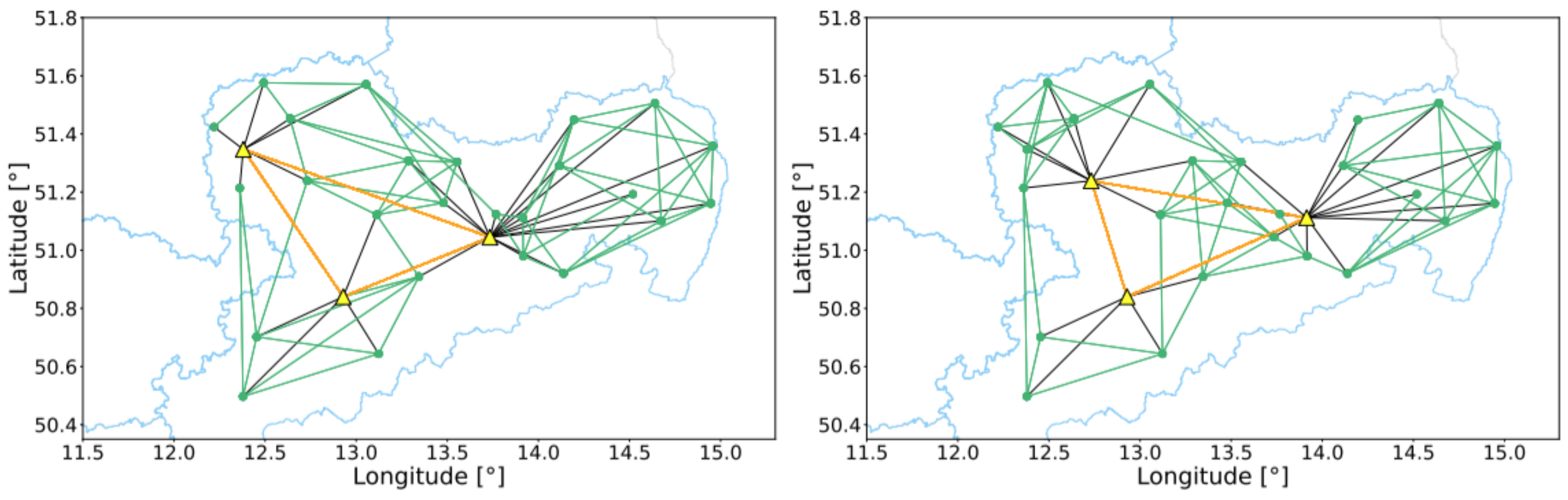

Figure 3: Network examples for future AAM scenarios in Saxony [2].

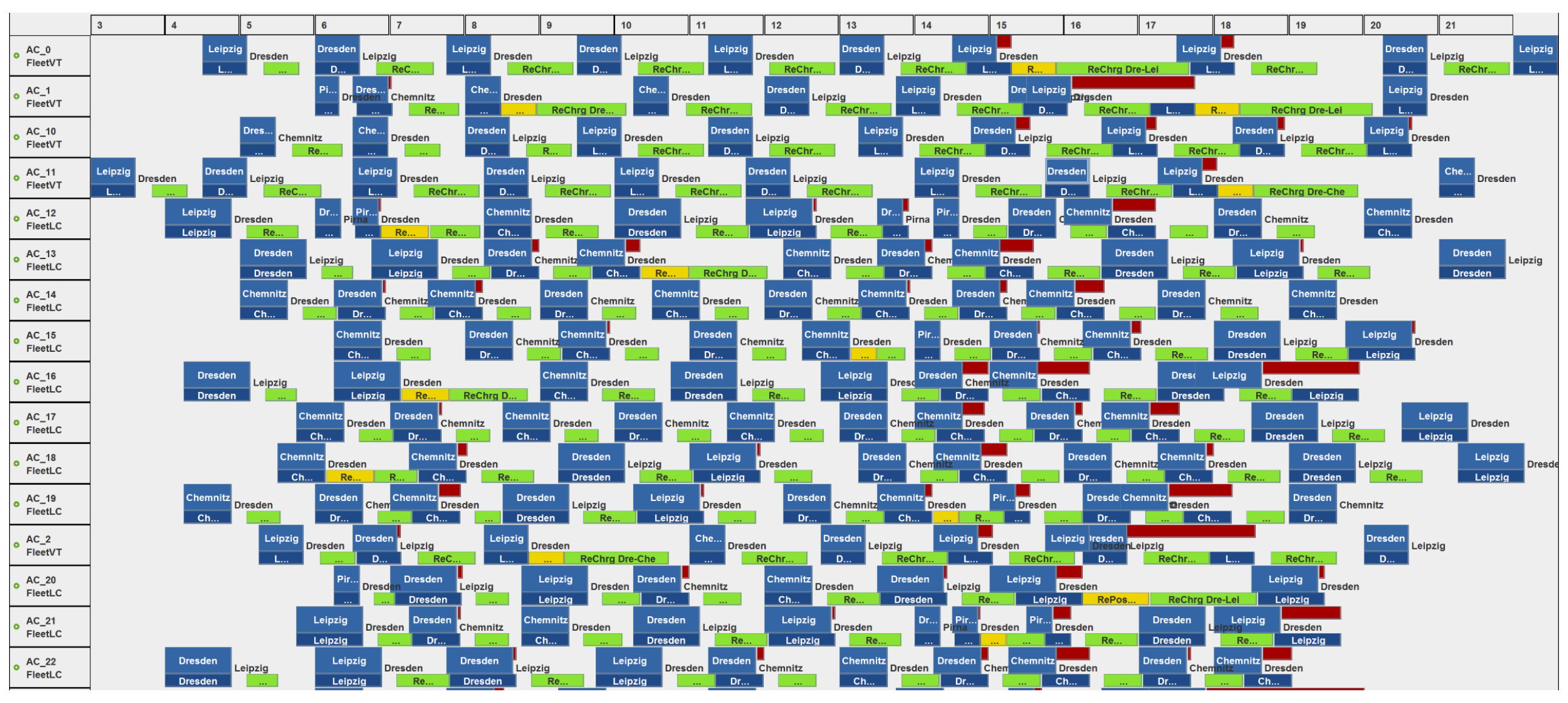

Figure 4: Aircraft schedule for AAM network (based on [3])

Networking in the RTG

- Close interconnection with T3 (safety-oriented design of AAM aircraft landing sites).
- Network design based on the results of analyzing various demand scenarios (T11).
- Examination and evaluation of various disruptions on flight operations and effects on landing site selection (T7, T8, T9).

Literatur:

[1] *R. Brühl, H. Fricke, N. Walla, C. Mutz, R. Erfurt und L. Tober et al., “SmartFly Final Report,” 2023, doi: 10.13140/RG.2.2.24570.98245*

[2] *R. Brühl, M. Lindner und H. Fricke, “Locating Air Taxi Infrastructure in regional Areas - The Saxony Use Case,” in Deutscher Luft- und Raumfahrtkongress DLRK 2022*

[3] *M. Lindner, Optimierung des Flugzeugeinsatzes nach Brennstoff-effizienz. Dissertation: Technische Universität Dresden, 2023*

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