DEMAND CAPACITY BALANCING AT VERTIPORTS FOR URBAN AIR MOBILITY

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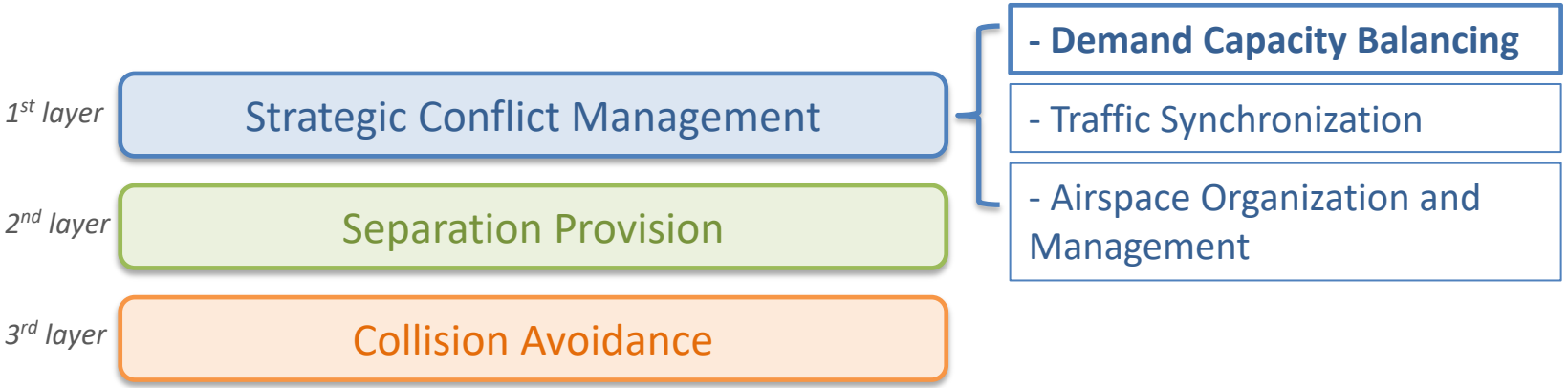


Demand Capacity Balancing at Vertiports for Urban Air Mobility

INTRODUCTION

Strategic Conflict Management for Urban Air Mobility

- Urban Air Mobility (UAM)
  - Enable highly automated, cooperative air transportation services in urban area
  - Require air traffic management to reduce conflict risks of UAM flights
- Strategic Conflict Management (SCM)
  - First layer of conflict management for safe flight operations
  - Aim to reduce the need for airborne separation provision



Demand Capacity Balancing at Vertiports

- Demand Capacity Balancing (DCB)
  - Strategically evaluate traffic demand and resource capacity and allow UAM operators to determine when, where, and how they operate flights
  - Can be applied whenever UAM demand exceeds airspace resource capacity, even for low operational tempo
- Vertiports
  - Facilities providing takeoff and landing areas and supporting other necessary services like maintenance and parking for UAM operations
  - May become a bottleneck of growing UAM traffic

➢ *DCB at vertiports can be an initial SCM approach for UAM operations*

Practical Considerations in UAM Operations

- Vertiport capacity
  - Dynamically changing vertiport capacity for a given demand
  - Adjustable capacity constraint parameters like slot size
- Multiple UAM operators
  - Different lead times for flight plan submission by service type
  - Different flight speeds, depending on UAM vehicle models
- Uncertainties in departure/arrival time
  - Departure time errors over the schedule
  - Inaccuracy in arrival time estimates due to uncertainties during flight

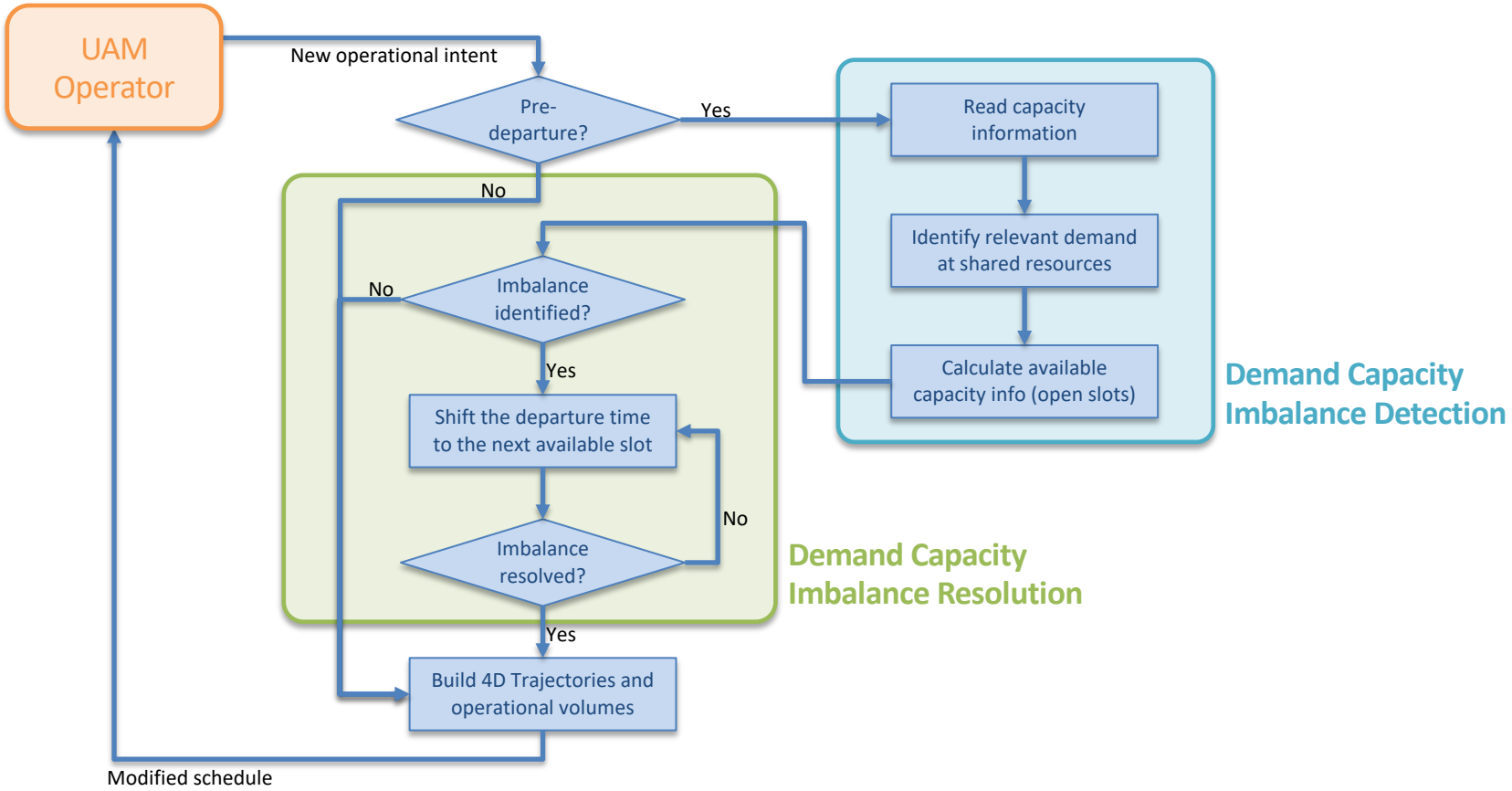
➢ *Practical issues in actual operations can affect scheduling performance*

Objectives

- Develop an algorithm for Demand Capacity Balancing (DCB) at Vertiports
- Evaluate the proposed DCB algorithm with traffic scenarios
  - Check if the DCB algorithm can work as initial strategic conflict management method
  - Investigate the impacts of various practical issues in UAM operations on flight scheduling performance
- Establish future research directions for UAM strategic conflict management from findings

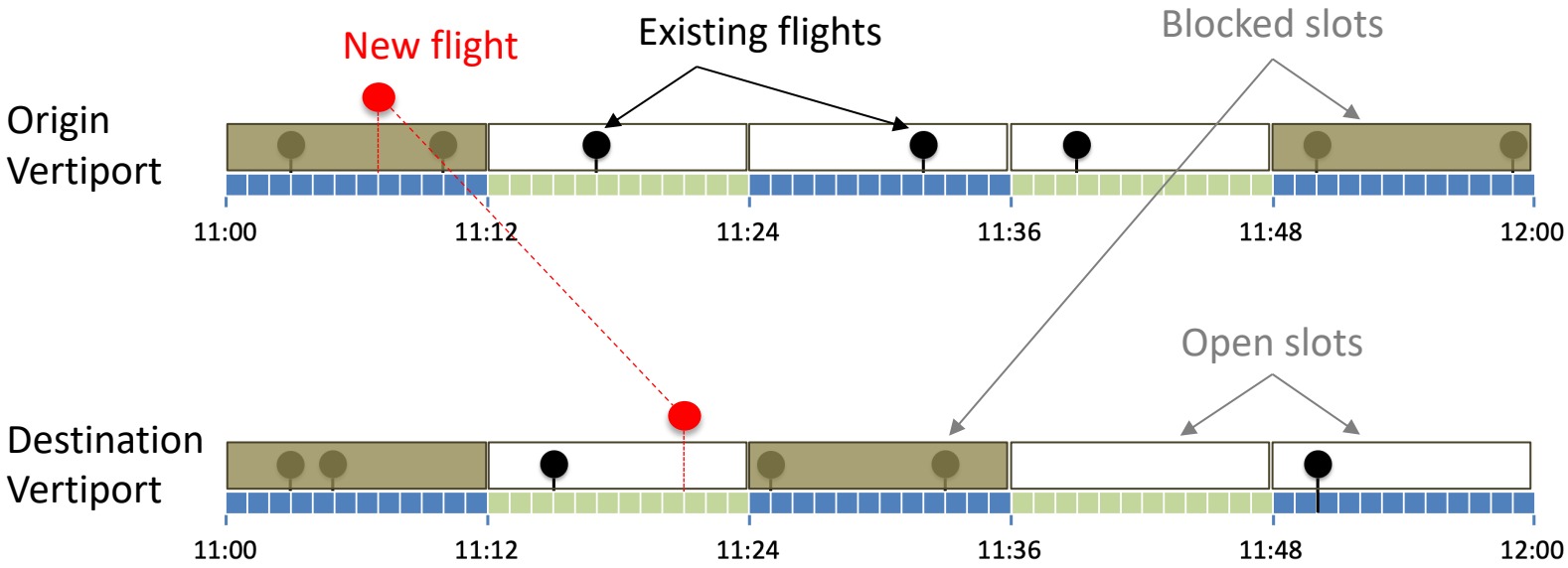
DCB ALGORITHM

Demand Capacity Balancing Algorithm



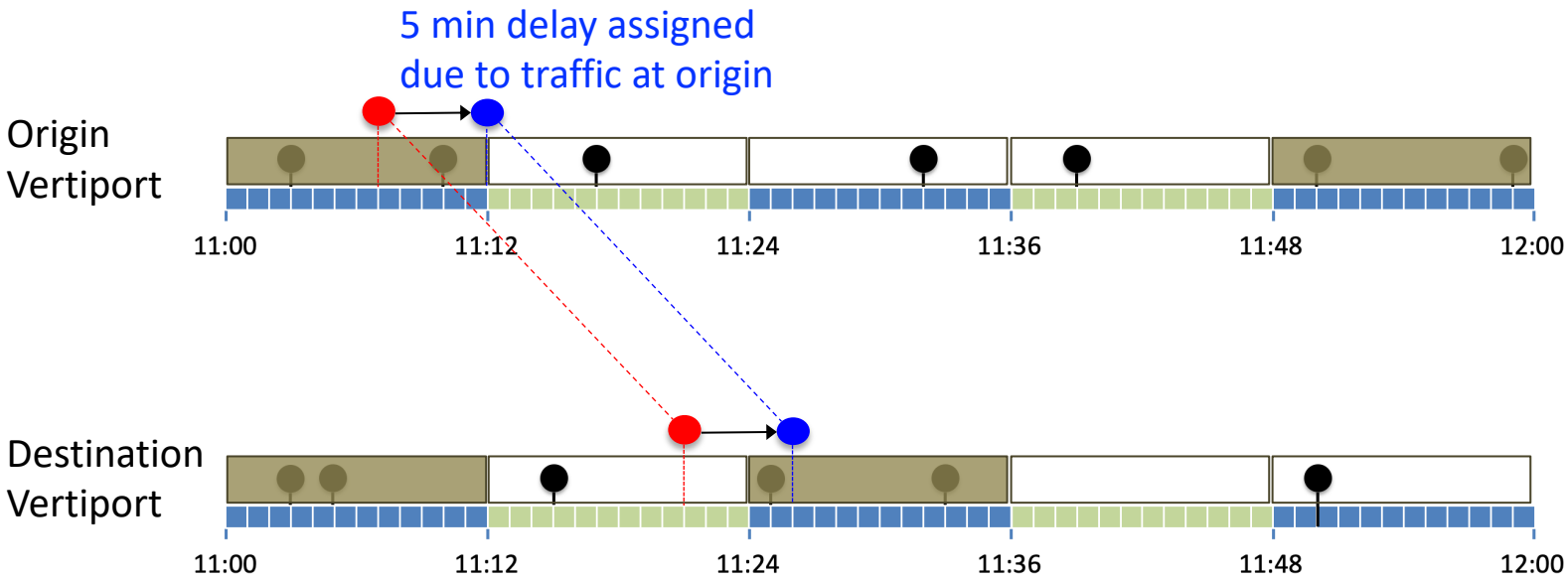
DCB Algorithm Use Case

- Assume two operations allowed in 12-min time slot as vertiport capacity
- Pre-departure delay only applied



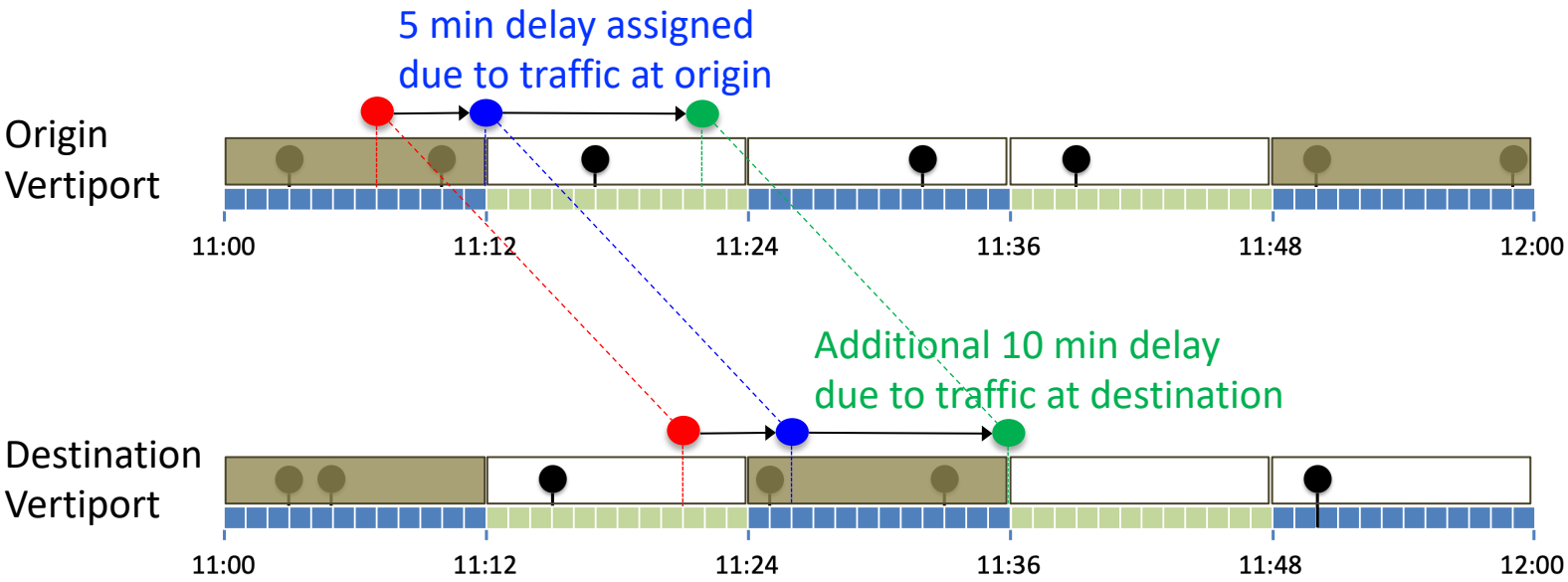
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DCB ALGORITHM EVALUATION

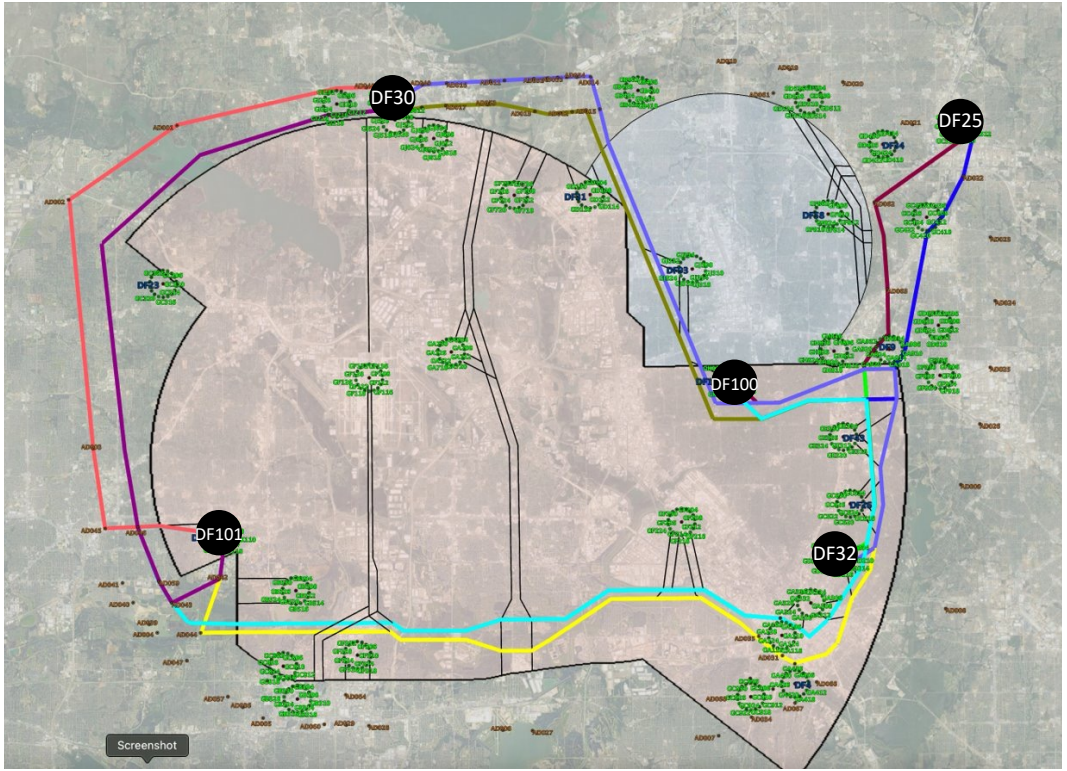
Experiment Setup

- Two UAM fleet operators
  - Balanced traffic share
  - Same UAM vehicle performance* (Baseline)
  - Same lead time for flight plan submission* (Baseline)
- Traffic scenario
  - Two-hour long scenario with one peak
  - Sixty flights evenly distributed to ten routes, corresponding to low traffic density
  - Departure times and routes randomly assigned to each flight
  - Estimated landing time based on the nominal flight time on each route
- Vertiport capacity
  - Four operations in a fixed 12min time bin for each vertiport* (Baseline)
  - Resultant demand-capacity ratio: 60%

* These assumptions will be explored later to address practical concerns in UAM operations

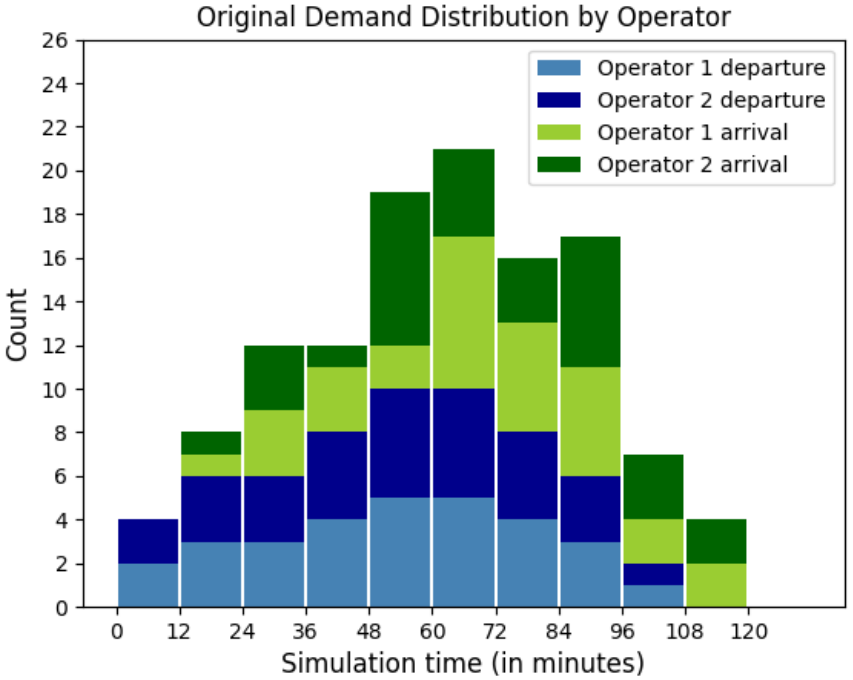
Airspace Route Structure

- Dallas/Fort Worth metropolitan area
  - Five vertiports (black disc): DF25, DF30, DF32, DF100, DF101
  - Ten routes to connect Origin-Destination pairs
  - All vertiports and routes shared



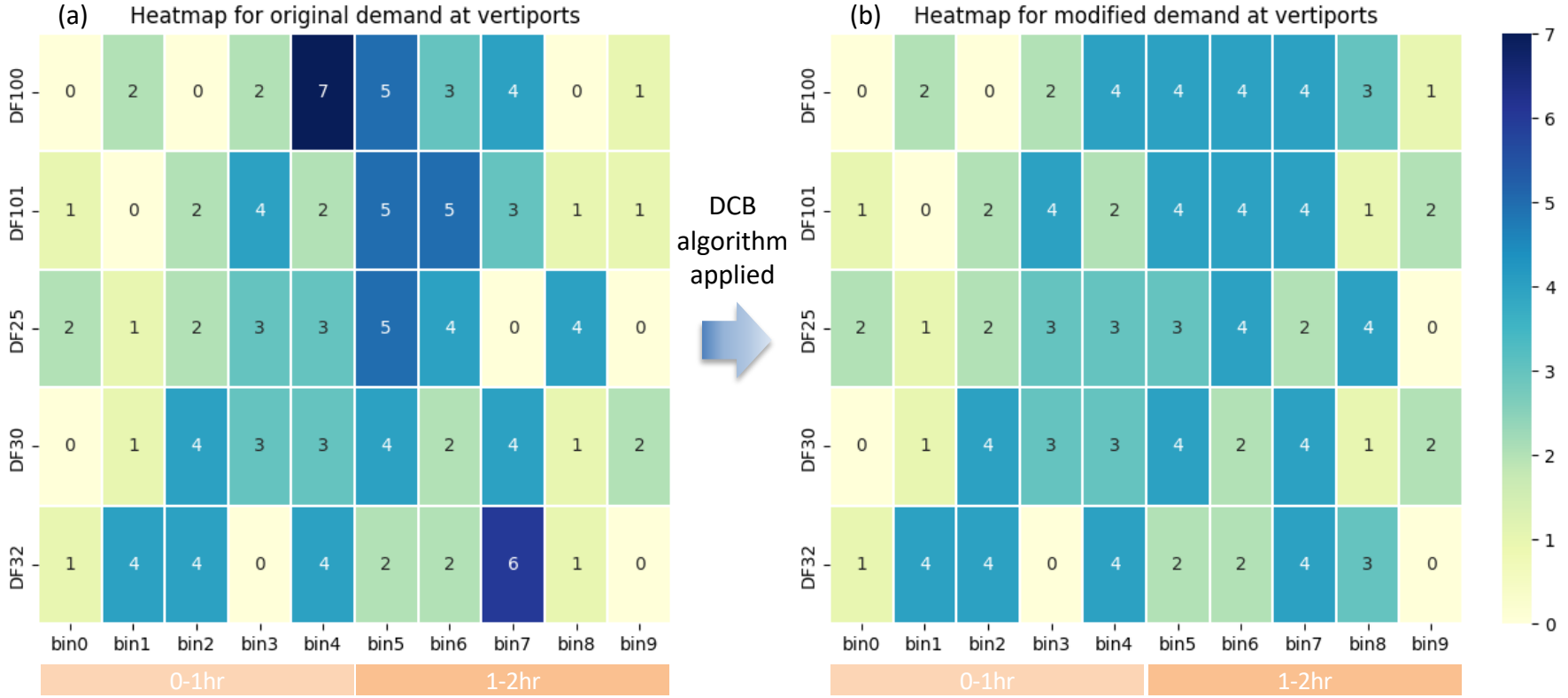
Traffic Scenario Example

- Total 60 flights over 2 hours
  - Operator 1 : Operator 2 = 30 : 30 flights (50% : 50%)
  - One peak in the middle of scenario
  - On average, 6 departures and 6 arrivals per hour at each vertiport
- Flight time dependent on routes
  - Range from 10.5min to 25.4min
  - Determine arrival demand profile

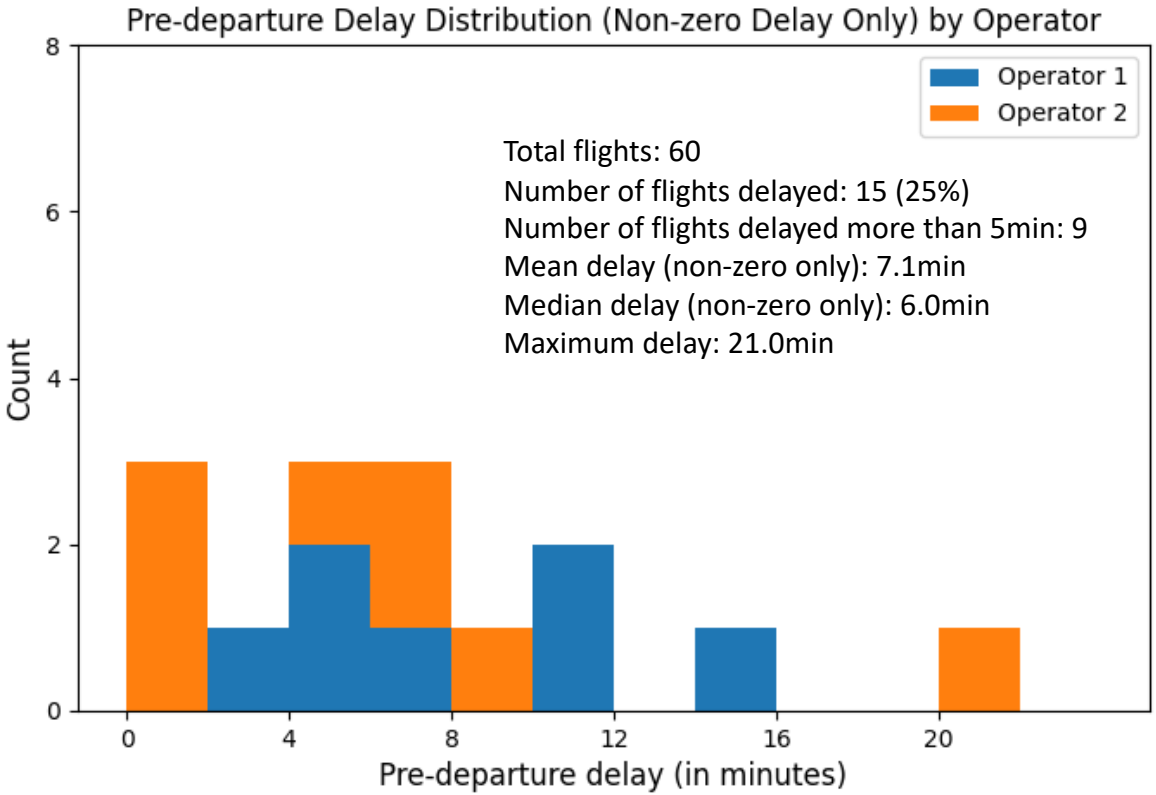


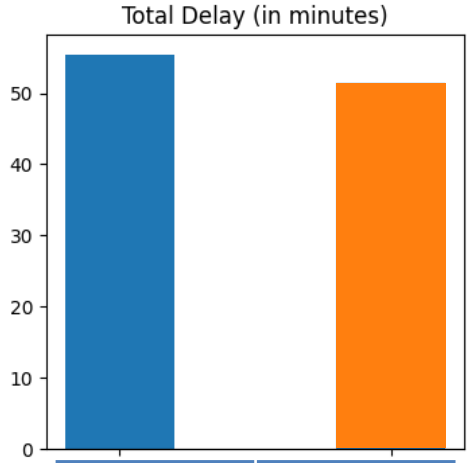
Heatmap Comparison before and after DCB

- Demand reduced to the vertiport capacity (4ops/12min) after DCB



Pre-departure Delay Assigned by DCB Algorithm





Operator 1	Operator 2
55.5 min	51.5 min

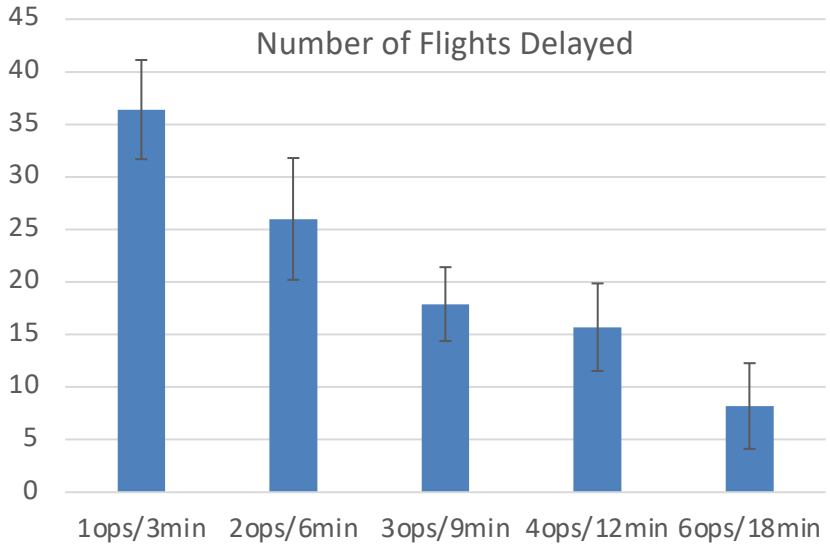
EXTENDED STUDIES FOR PRACTICAL CONSIDERATIONS

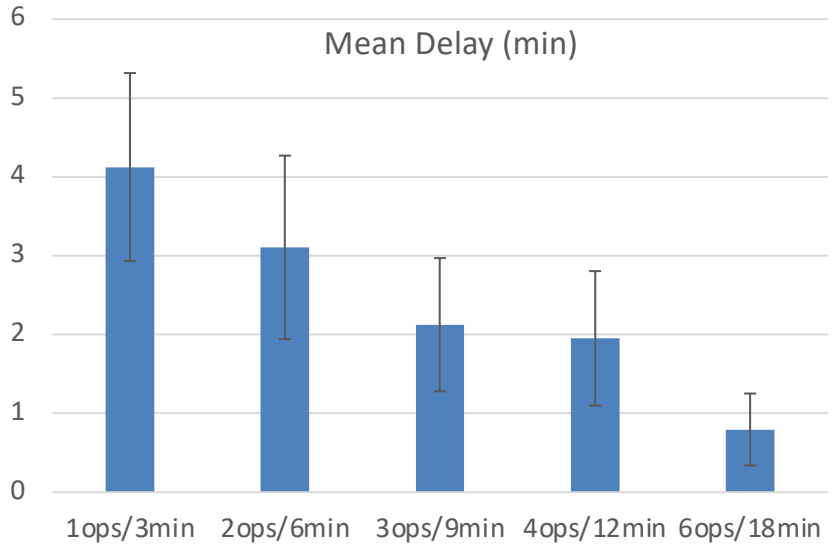
1. Effects of Time Bin Size in Capacity Constraint

- Motivation
  - As the baseline capacity constraint, 4ops/12min is used for each vertiport
  - Given the fixed vertiport capacity rate, other time bin sizes can be applied
- Objective: To see the impact of time bin size in capacity constraint on delay
- Variable
  - Time bin size used in vertiport capacity constraint (Baseline: 4ops/12min)
  - Range from 3min to 18min, while keeping the same capacity rate (1 ops every 3min)
- Simulated for 10 runs with random scenarios
- Measures, averaged from 10 runs
  - Number of delayed flights
  - Pre-departure delay

1. Effects of Time Bin Size in Capacity Constraint – Result

- Smaller capacity bin size can result in more delays with more delayed flights
- However, the large time bin size has a potential risk to increase the frequency of tactical separation provision in the air, as well as traffic concentration



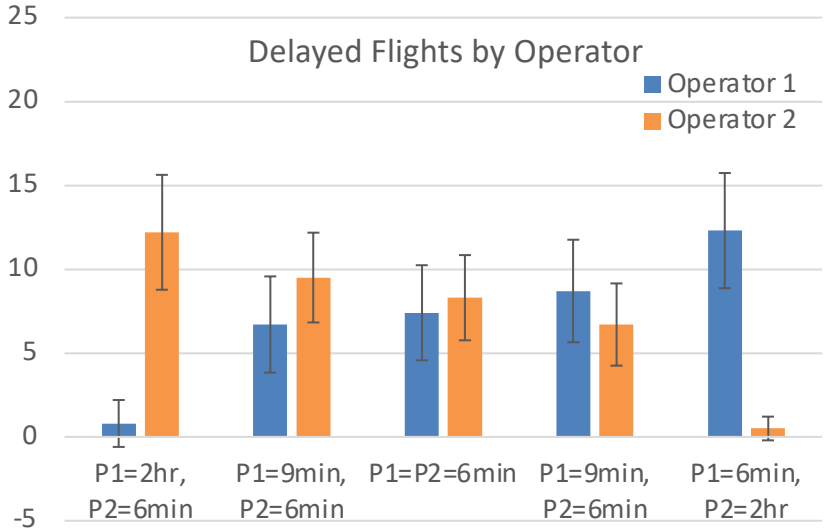


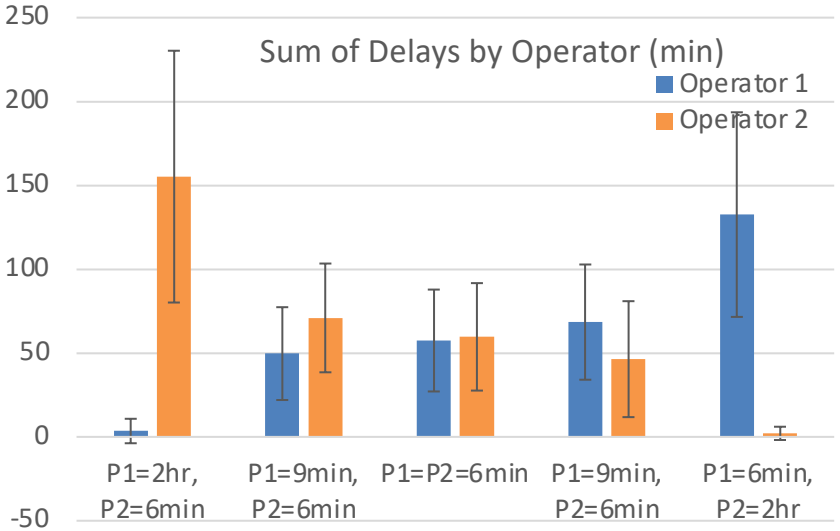
2. Effects of Lead Time Differences

- Motivation
  - Fleet operators may use different lead times for flight plan submission
  - Pre-scheduled shuttle service vs. on-demand service per customer's trip request
- Objective: To see the impact of lead time differences between operators
- Variable
  - Lead time between flight plan submission and desired departure time
  - Different lead times between operators (Baseline: same lead time of 6min)
- Simulated for 10 runs with random scenarios
- Measures, averaged from 10 runs
  - Number of delayed flights by operator
  - Total delay by operator

2. Effects of Lead Time Differences – Results

- Based on First-Request, First-Served discipline, earlier flight plan submissions take the available capacity slots in advance, leading to fewer delayed flights and lower delays
- Fairness issue between operators

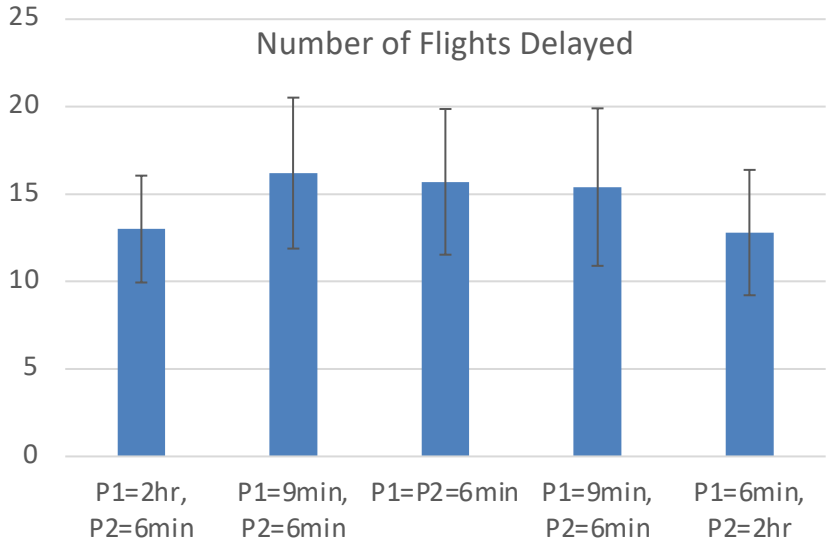


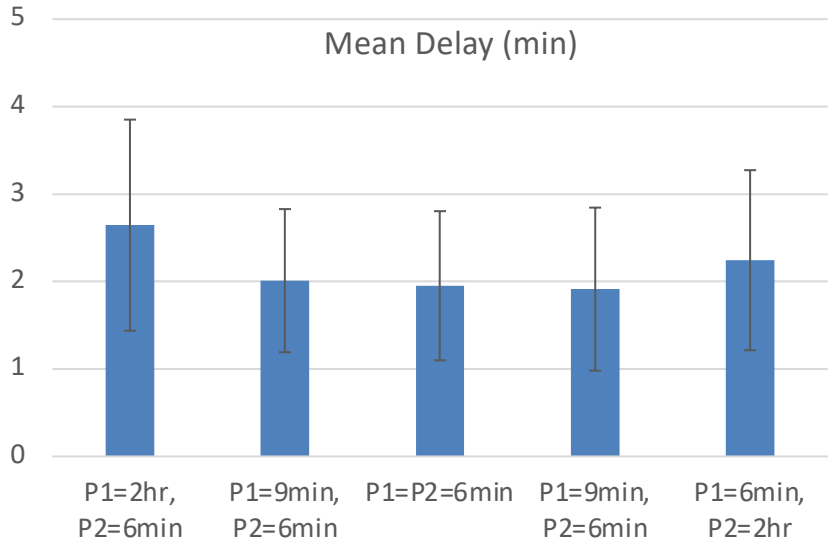


P1: Lead time of Operator 1; P2: Lead time of Operator 2

2. Effects of Lead Time Differences – Results

- Competitive vertiport slot assignment between operators may help reduce the delay in the whole system
- If one operator pre-occupies the vertiport slots, its flights are free from delay, but the other operator may get more delay penalty





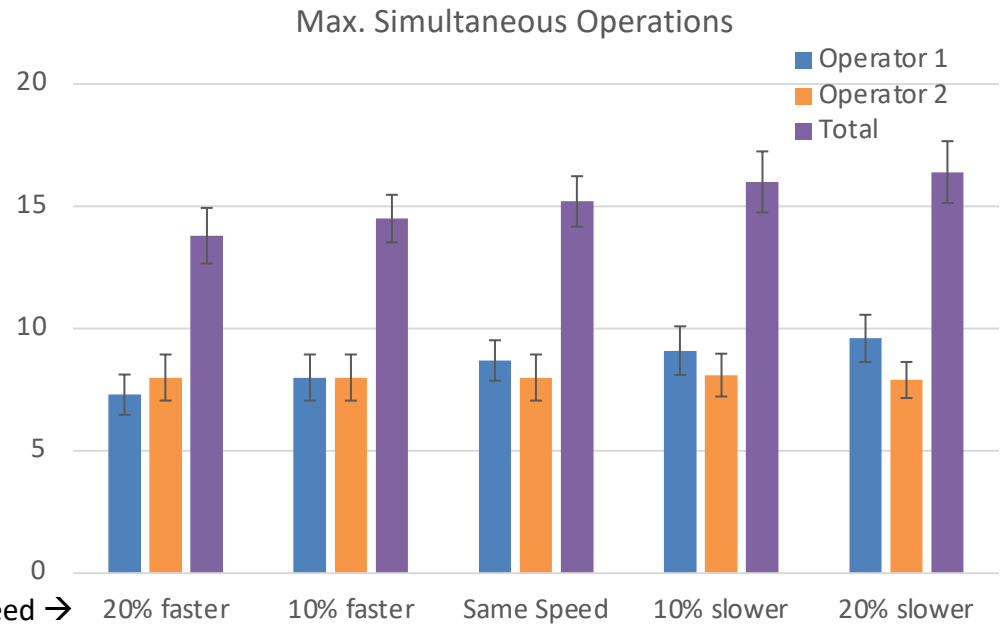
P1: Lead time of Operator 1; P2: Lead time of Operator 2

3. Effects of Flight Speed Differences

- Motivation
  - Expect to have various UAM vehicle models in airspace, with different flight performance
  - UAM vehicles can fly at different flight speeds, within the allowed speed range
- Objective
  - To see the impact of flight speed differences between operators
- Variable
  - Different nominal flight times for the same route between operators
  - Operator 1's flights are 10%/20% faster or slower (Baseline: same flight speed)
- Simulated for 10 runs with random scenarios
- Measures, averaged from 10 runs
  - Maximum number of simultaneous operations after DCB

3. Effects of Flight Speed Differences – Results

- The maximum number of simultaneous operations in post-DCB increases when Operator 1's flight speed gets slower
- Potential safety issue related to overtaking, when flying at different speeds



CONCLUSIONS

Summary

- Strategic conflict management for UAM operations
  - Demand Capacity Balancing (DCB) at vertiports only
  - DCB algorithm evaluated with traffic scenarios
- Impacts of various concerns encountered in actual UAM operations
  1. Time bin size for vertiport capacity constraint can affect pre-departure delay or separation provision frequency in the air
  2. Different lead times for flight plan submission can cause a fairness issue between operators
  3. Different flight speeds can affect arrival demand profile, as well as traffic density

Future Work

- Enhance strategic conflict management approaches
  - Demand Capacity Balancing (DCB) at vertiports and other airspace resources
  - Sequencing and Spacing at meter fixes
- Consider operational conditions in federated system
  - Fairness and prioritization issues for multiple operators
  - Scheduling disciplines that can handle higher priority flights
- Reflect more realistic constraints in DCB algorithm
  - Max. delay allowed, flight cancellation
  - Min. separation requirements, conformance with the schedule, vehicle performance
  - Resource availability (vehicles, pilots, ground crew, etc.)
  - Integration with other traffic

Thank You

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