Expectation-Maximization for Scheduling Problems in Satellite Communication

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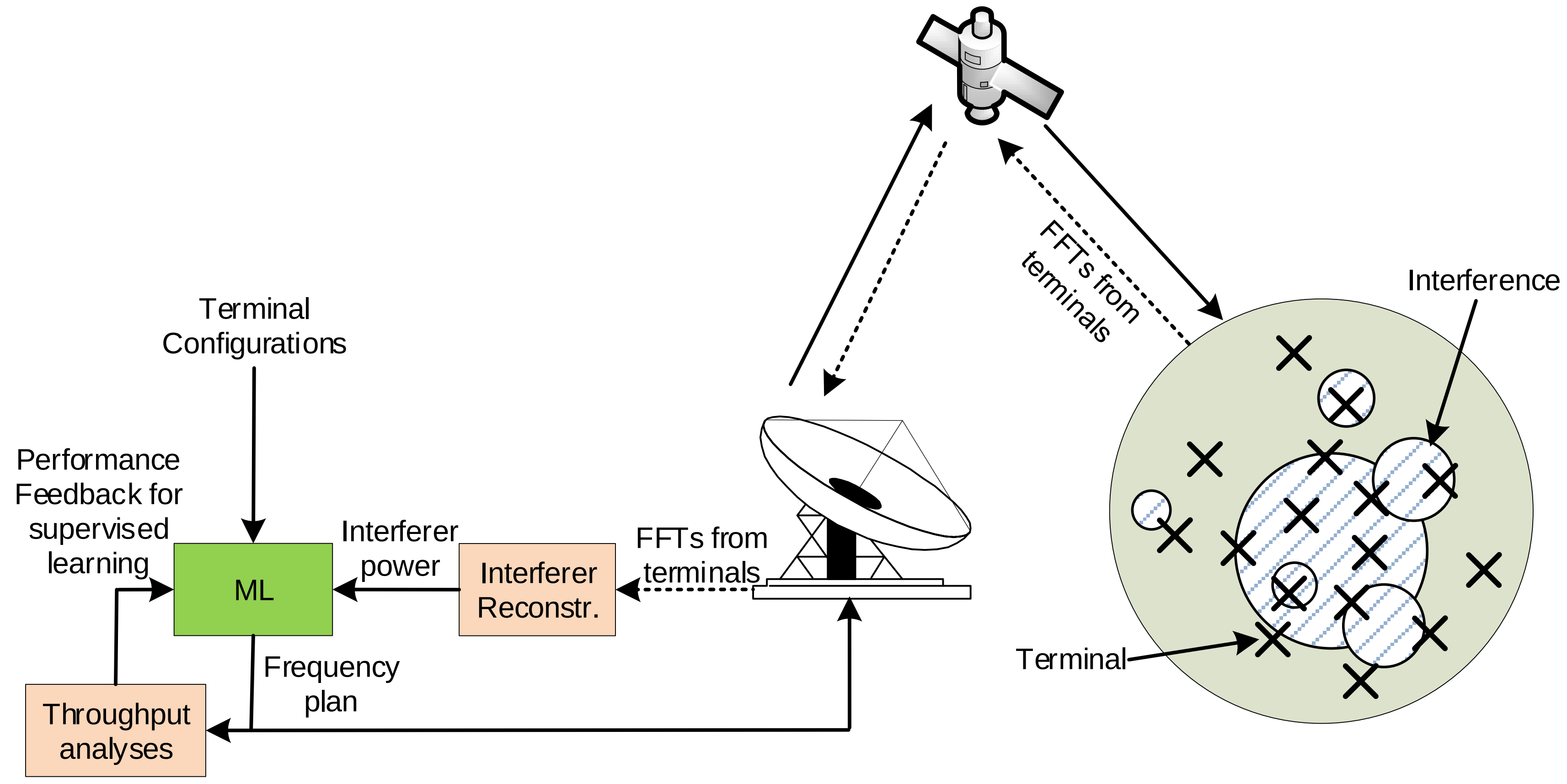
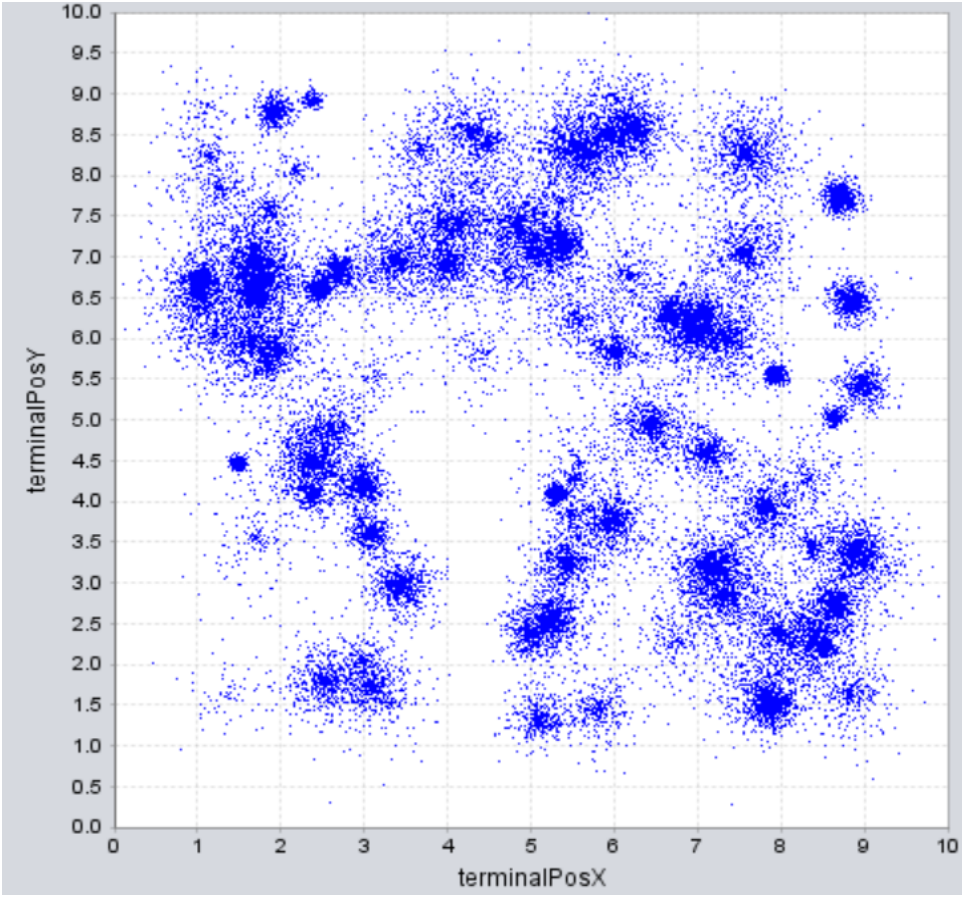
Overview

- Satellite Communications involves a number of scheduling/resource allocation problems
  - Ka-band frequency plan optimization
  - dynamic configuration of an active antenna array satellite
- Typically unsupervised, no ground truth optimal solution
- Expectation-Maximisation (EM) well suited
  - terminals $T = \{t_0,\ldots,t_n\}$ with labels $Z=\{z_0,\ldots,z_n\}$
  - parameters θ of model (specific to problem)

Use Case: Ka-band Frequency Plan Optimization and Interference Mitigation

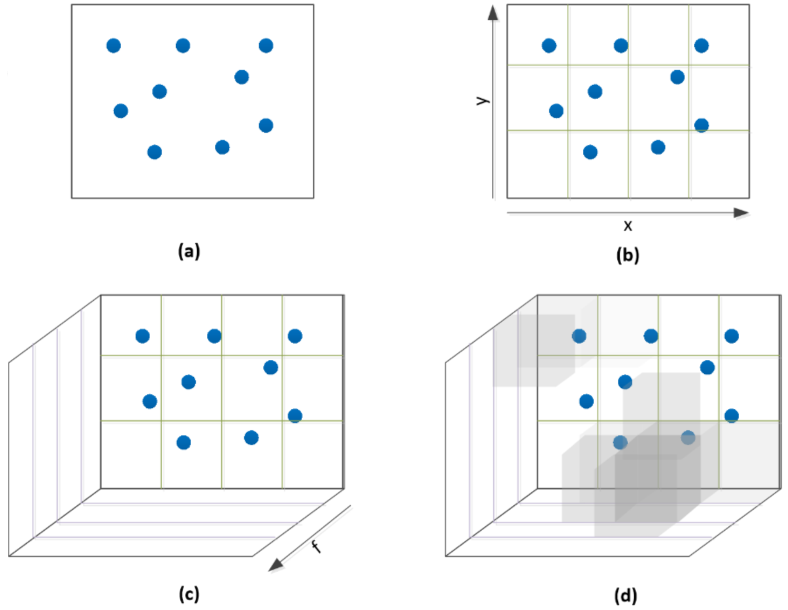


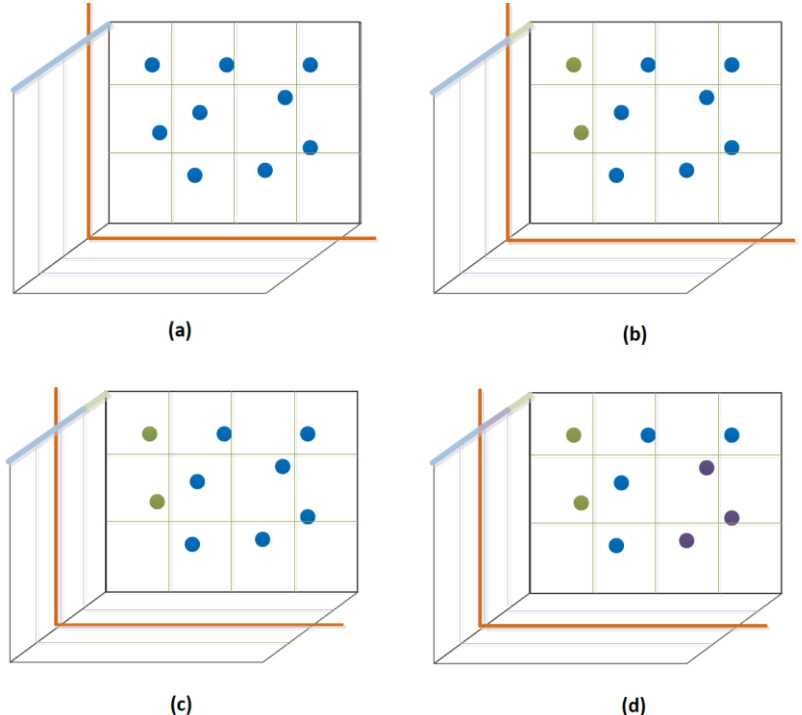
considering single spot beam



Ka-band Frequency Plan Optimization and Interference Mitigation

- Expectation: carrier assignment
  - assign terminals, given position and subdivision of subbands
  - fulfilment of bandwidth requests vs. interference costs
- Maximisation: subdivision
  - initially subdivide to minimum number carriers
  - choose whether to split subbands
  - determine where to split at lowest cost
- Terminate if no improvement over *r* iterations

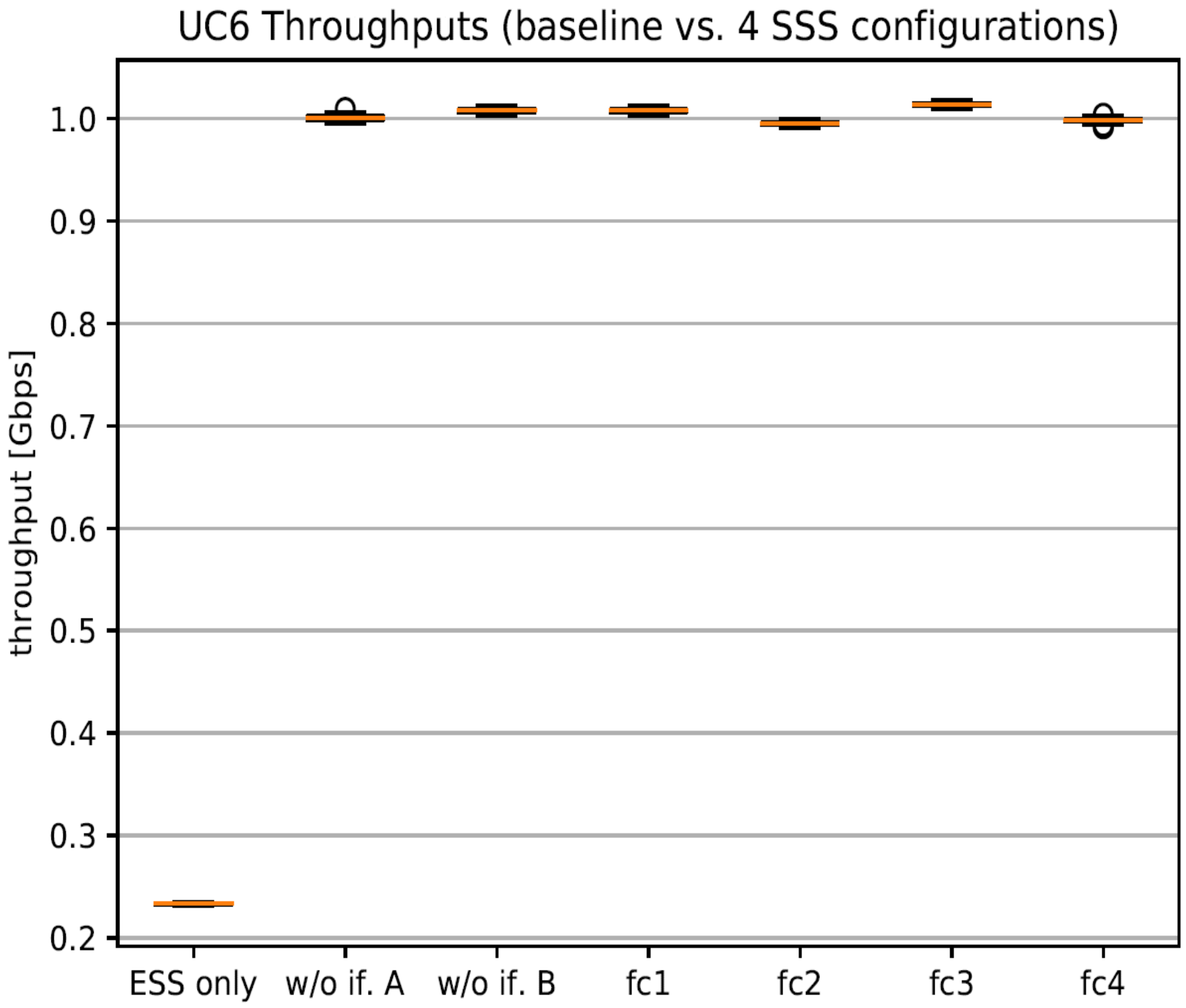


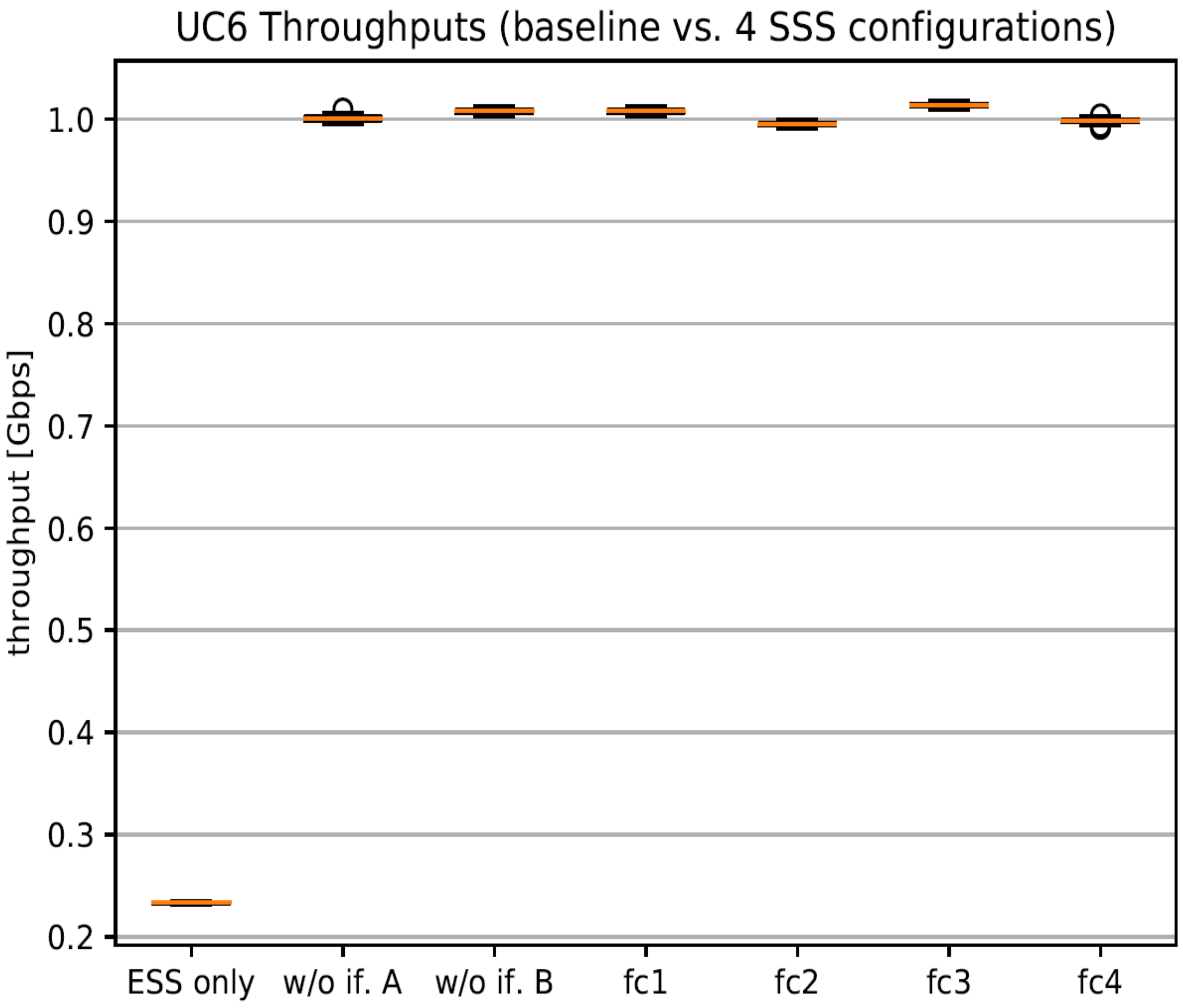


Experimental results

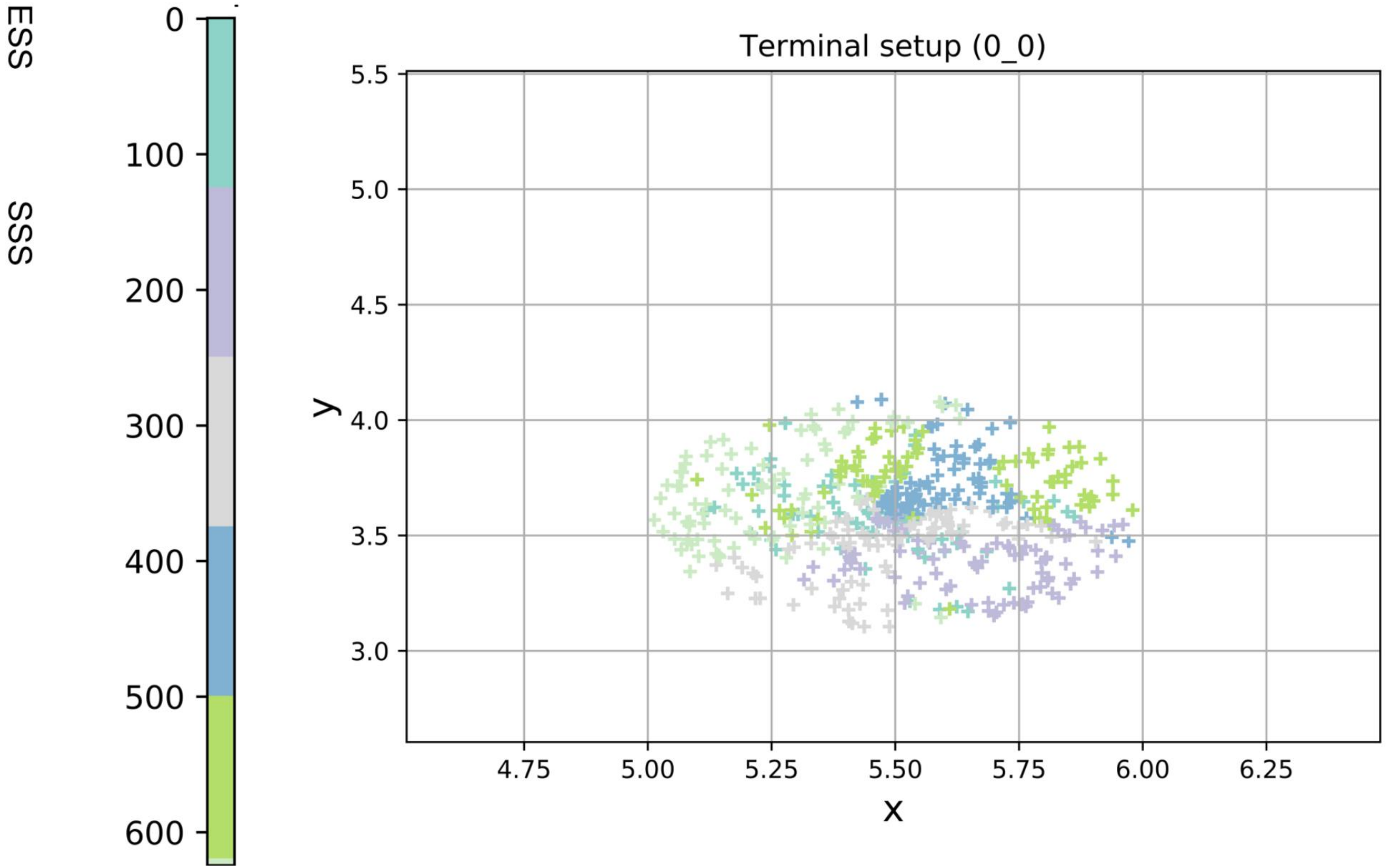
- Frequency reuse 4
  - upper/lower half of available band, 2 polarisations -> test 4 possible frequency configurations (as interferers may have different impact, fc1-fc4)
- Baselines:
  - ESS only: using only the exclusive band without interferers (lower bound)
  - w/o interferers A: minimum number of carriers in shared band (SSS), distributing the available bandwidth and terminals equally (assuming no interferers)
  - w/o interferers B: best carrier configuration found using the proposed method (assuming no interferers)

Experimental results
(2 datasets, differing by interferer power)



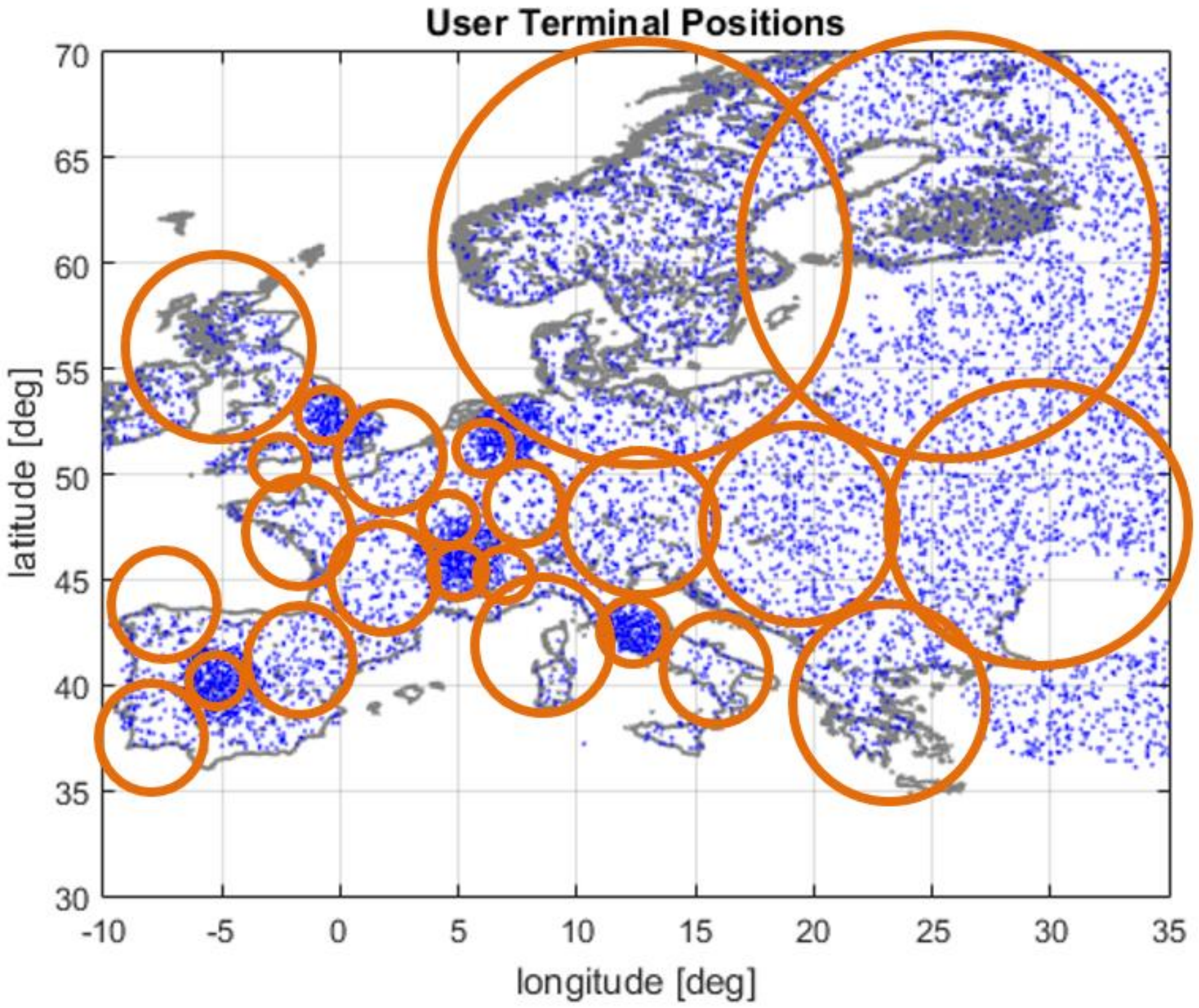


Experimental results



Use case: Dynamic configuration of an active antenna array satellite

- Non-uniform distribution of terminals/traffic demands
- Dynamic setup
- Size and position of spot beams are flexible
- Find optimal beam setup
  - clusters represent circular beams (fixed set of radii)
  - frequency reuse 4 => 4 independent sets of clusters

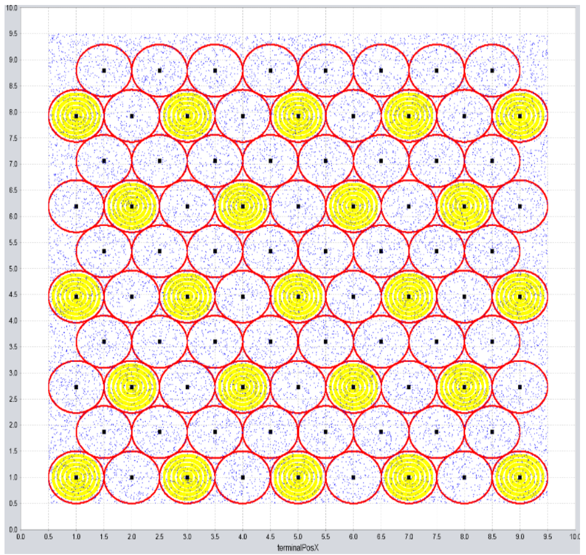


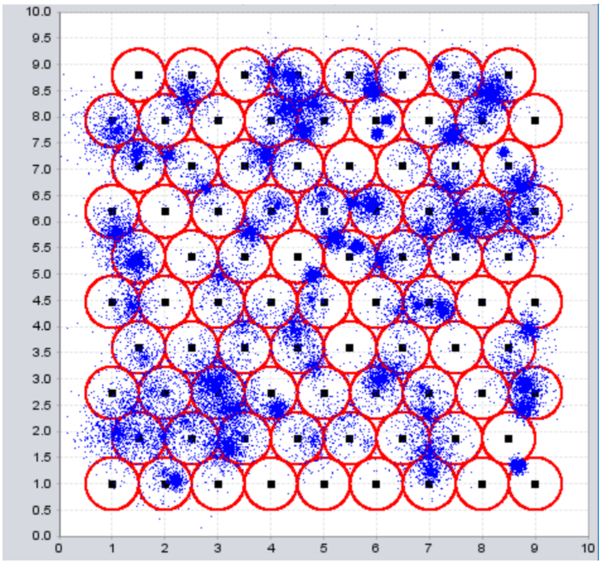
Dynamic configuration of an active antenna array satellite

- Initialisation: density based sampling + non-maxima suppression
- Expectation: assign terminals to beams
  - choose beam with closest centre
  - constraint: if previous fulfilment data is known, do not assign terminals with low fulfilment if mean bandwidth demand of beam is already used
- Maximisation: update beams
  - update centre (centre of mass of terminals)
  - update size based on demand, coverage, overlap (remove if overlap exceeds threshold)
  - add beams (density based sampling, erasing served areas from density map)

Experimental Results

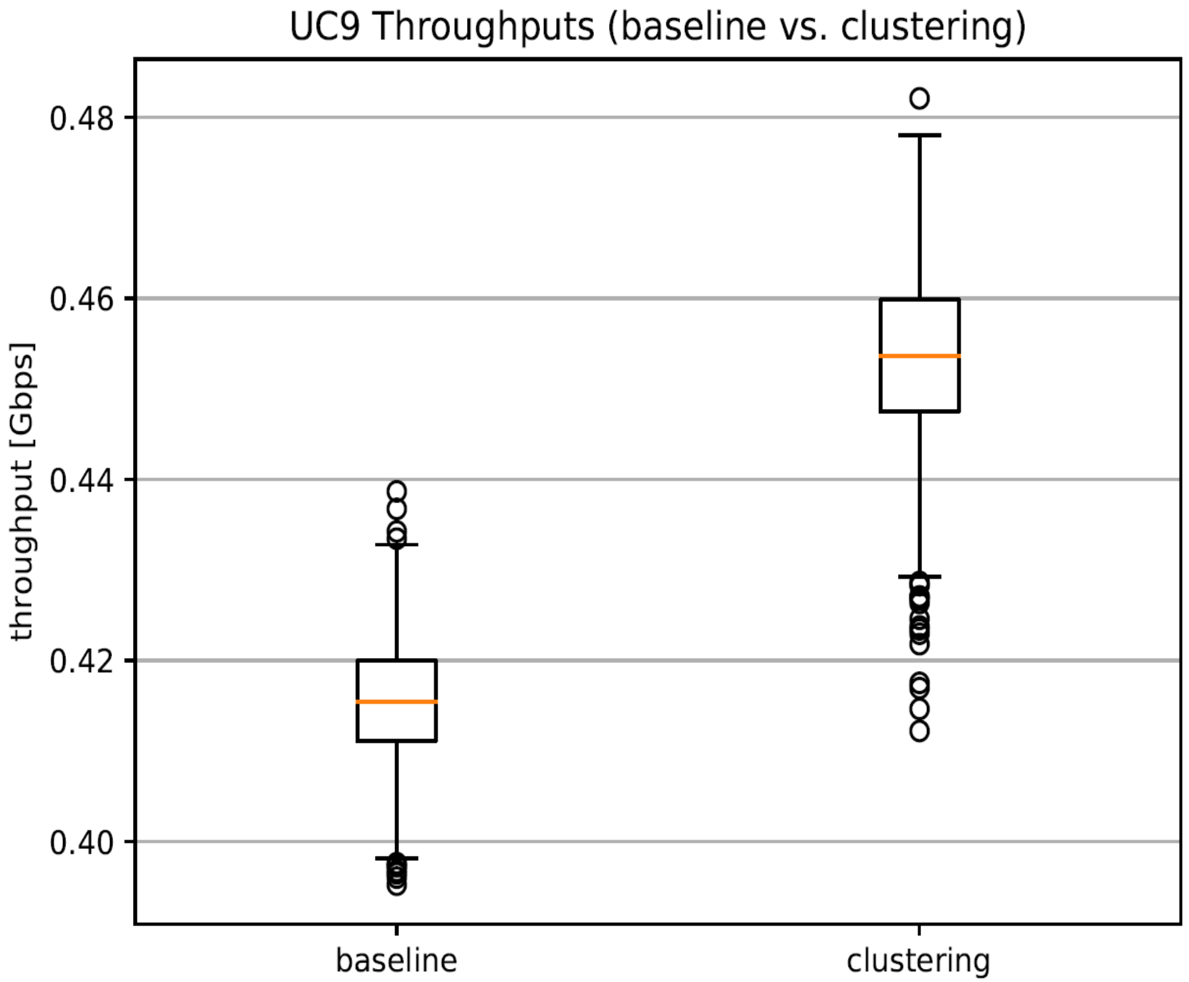
- Iterative application: update from previous configuration (position and bandwidth demand of terminals may have changed)
  - independent: treat each configuration independently, optionally with retrying 5 times from best solution encountered
  - incremental: independent for first configuration, then update from previous
- Baseline
  - regular beam setup (lower bound)
  - “benign” equally distributed terminal configuration reaches 0.5 Gbps for such a configuration (upper bound)

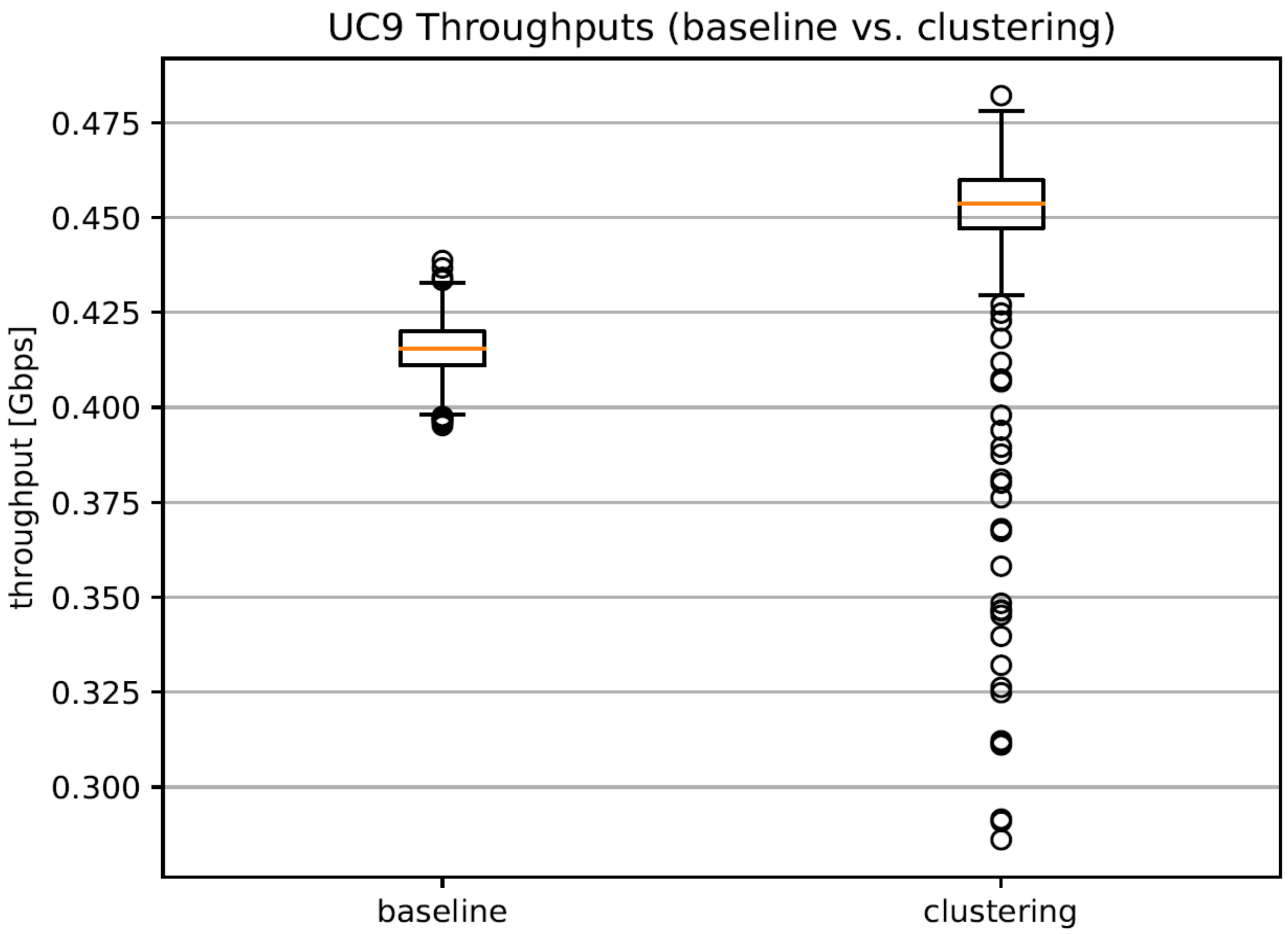


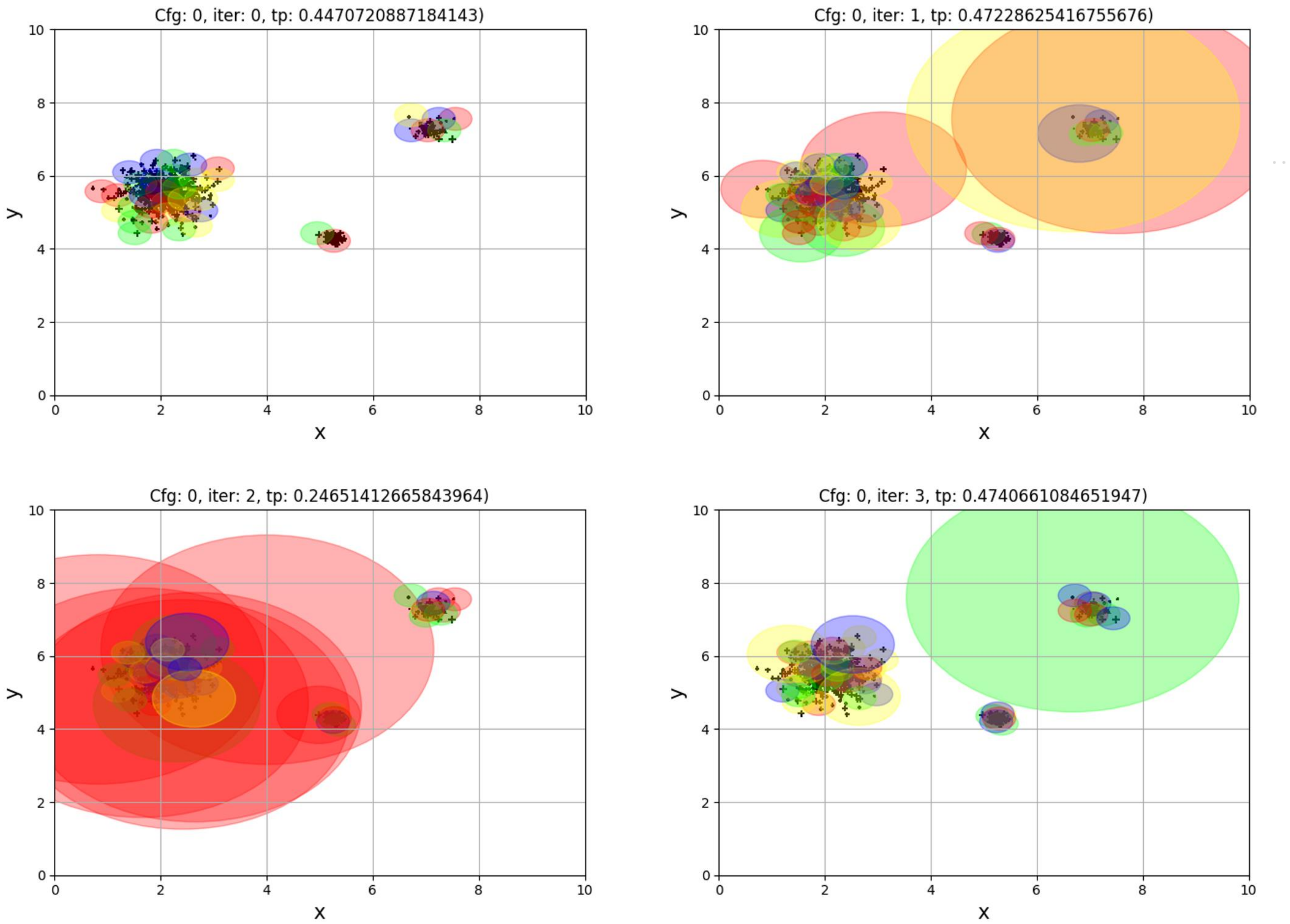


Experimental Results

- independent (left), incremental (right)







Cfg: 0, iter: 0, tp: 0.4470720887184143)
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x
y
0
2
4
6
8
10

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