



DRONE ENABLE

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Urban Performance-Based Navigation

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Air Traffic Management
Research Institute



UTM Implementation & Challenges

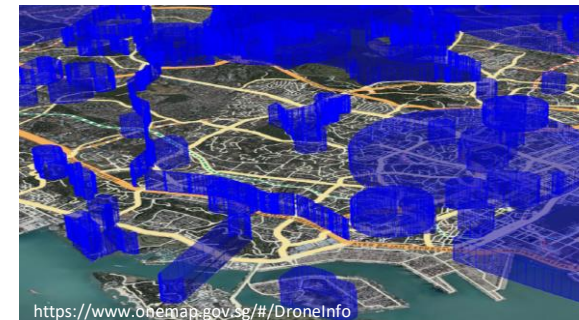
- Initial UTM operations are observed
- Fundamental UTM services have been deployed
- Under-standardized systems including communication, navigation and surveillance (CNS) systems remain a challenge



Meituan delivery drone



Amazon delivery drone



Interactive NFZ guidance



Standalone drone tracker

Availability of Singapore airspace

Motivation of This Study

- Under-standardized UAS and UTM systems and CNS systems increase the difficulty in procedure design and operation management
- Performance-Based Navigation (PBN) concept in air traffic management provides an opportunity
- In addition to CNS system specifications, the urban environment affects the performance of the infrastructure
- A new development is needed to address CNS variation issue in urban airspace

Urban Performance-Based Navigation (uPBN): An Airspace-Resource-Centric (ARC) Approach

- The ARC concept serves for 4D management of airspace resources in a quantitative manner

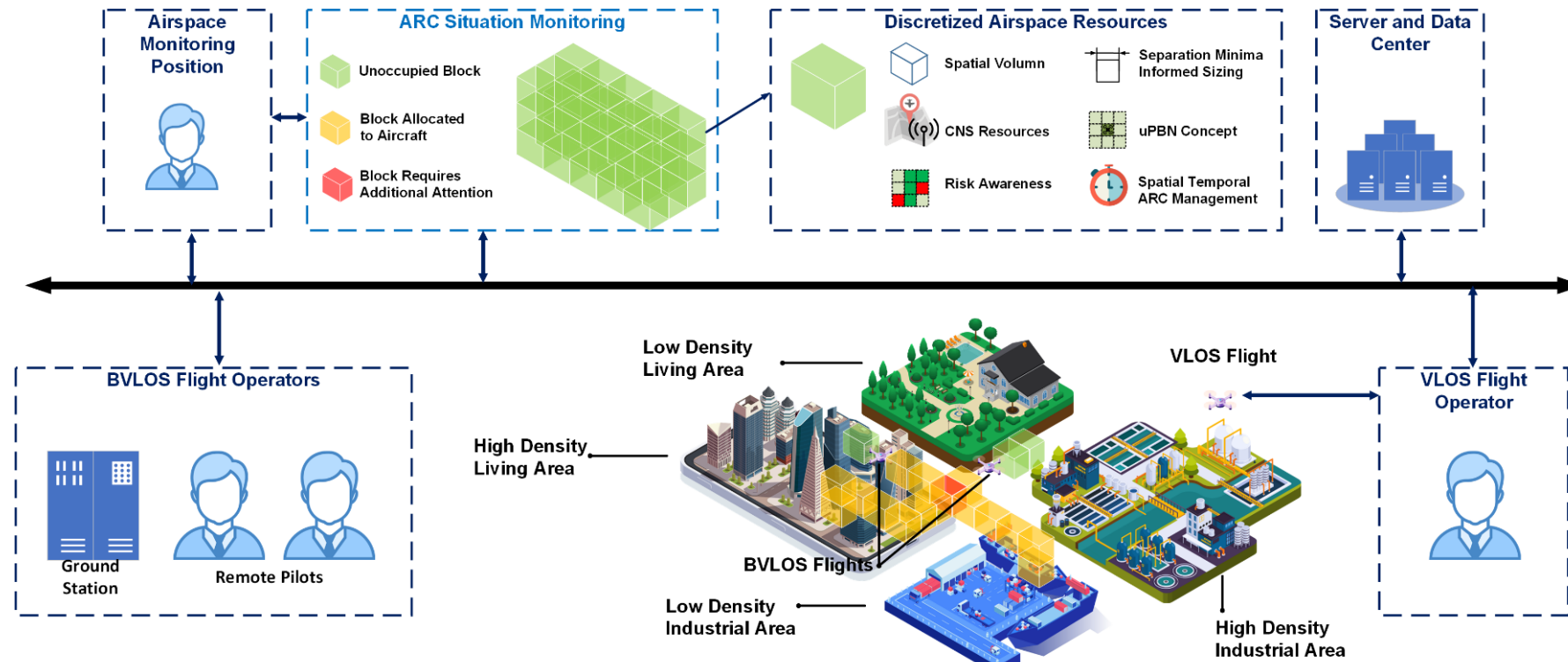
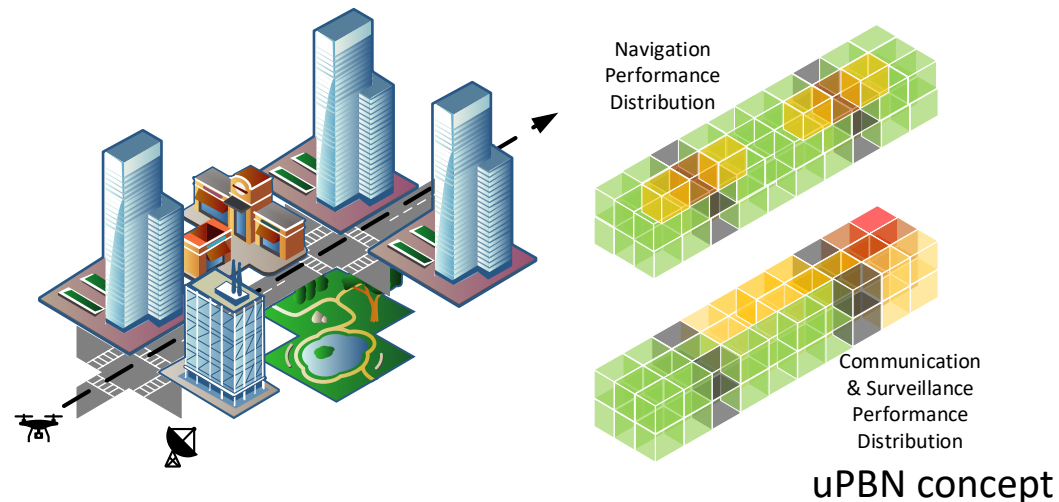


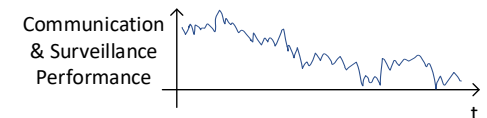
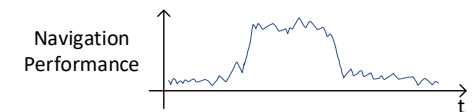
Illustration of AirMatrix ARC concept

Urban Performance-Based Navigation (uPBN): An Airspace-Resource-Centric (ARC) Approach

- uPBN is an extension of ARC concept in CNS resources
- In addition to CNS specifications, the urban environment is accounted for in the performance estimation
- Geographical distribution of CNS performances supports decision-making, e.g., flight approval or operational intent volume (OIV) generation

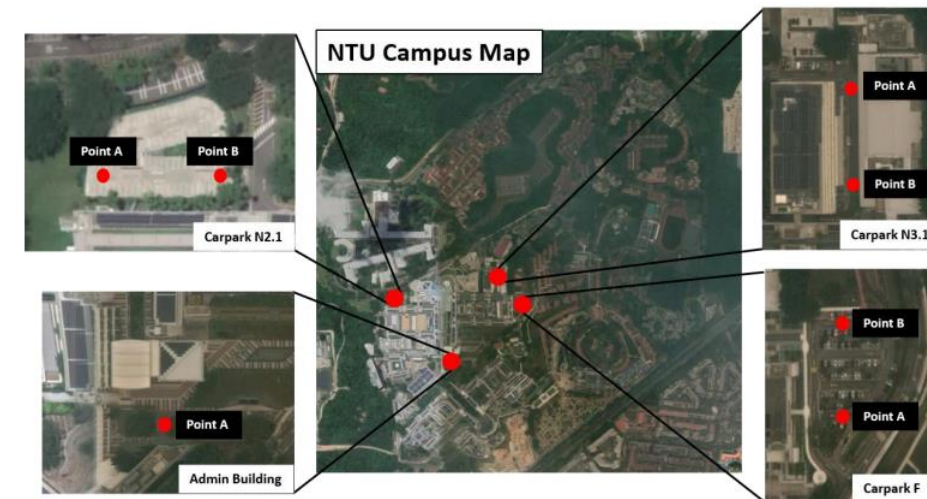
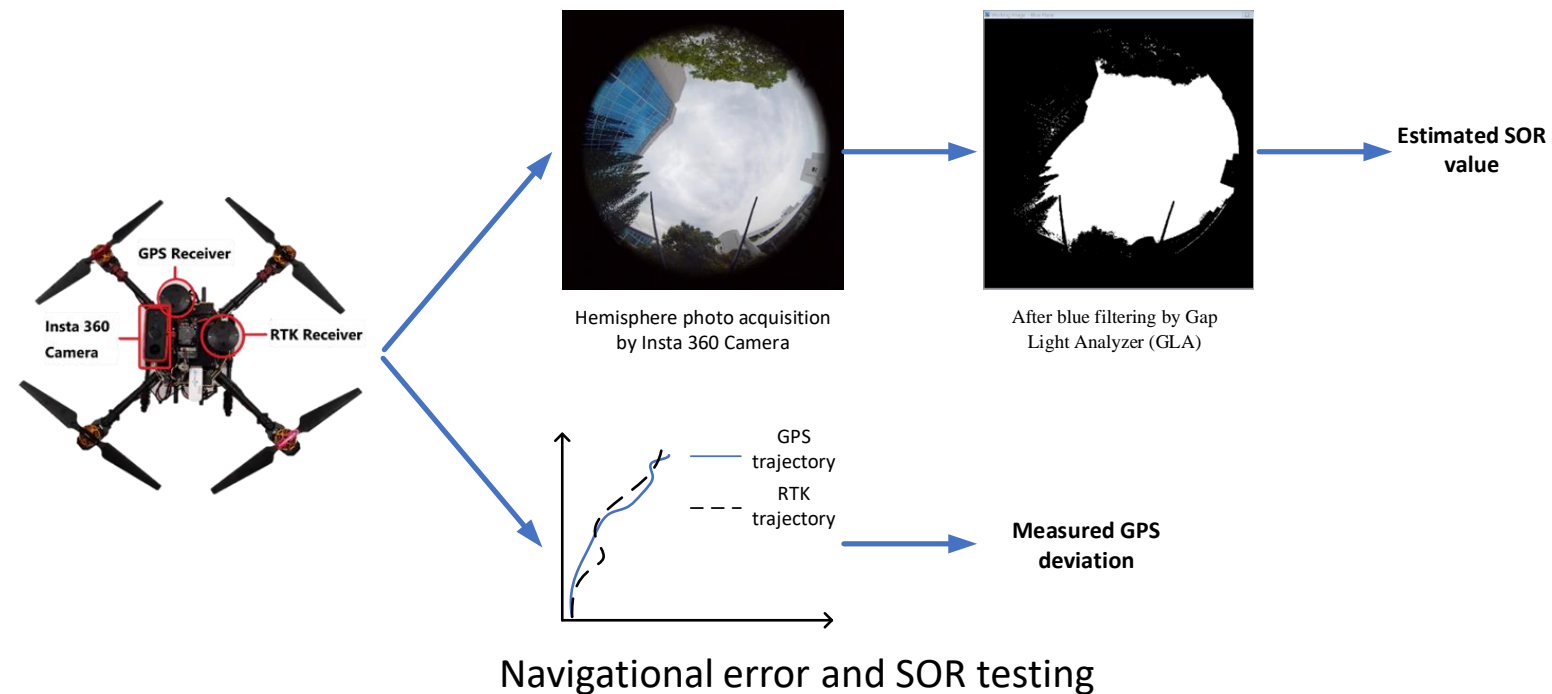


CNS Performance Estimation



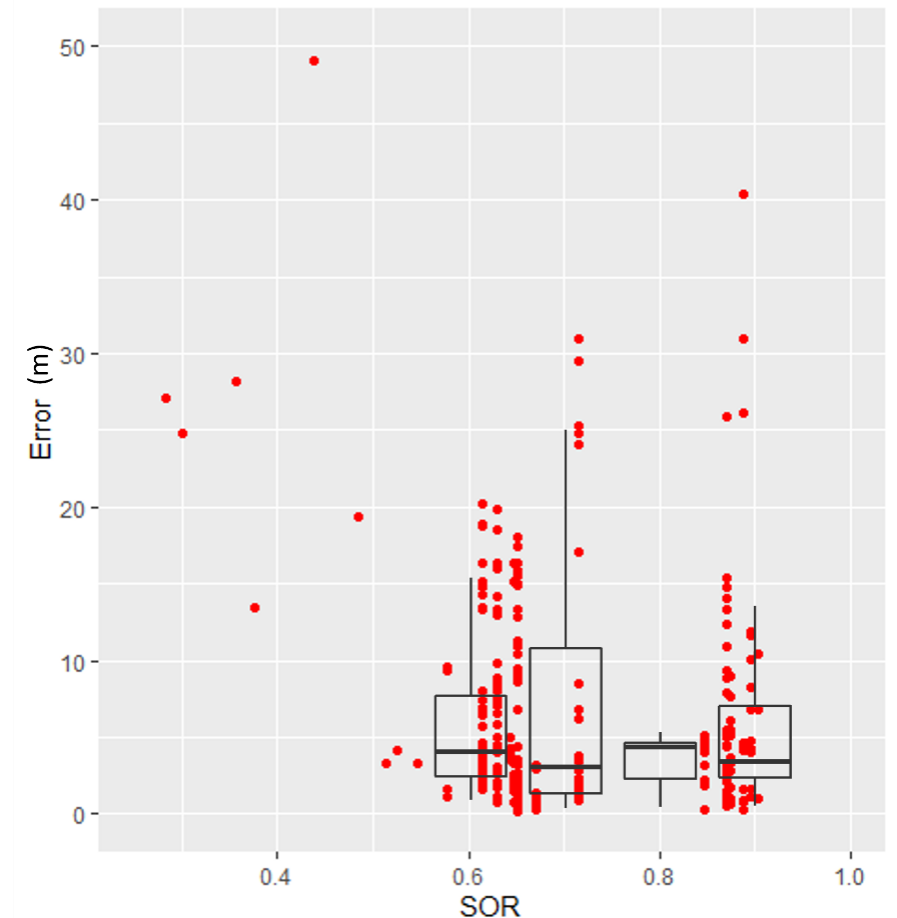
Navigation Performance Estimation: Sky-Openness-Ratio (SOR) Based Experimental Method

- SOR is an easy-to-implement representation of the blockage environment
- Experiment was performed to measure SOR and GPS error



Navigation Performance Estimation: Relationship between SOR and navigational error

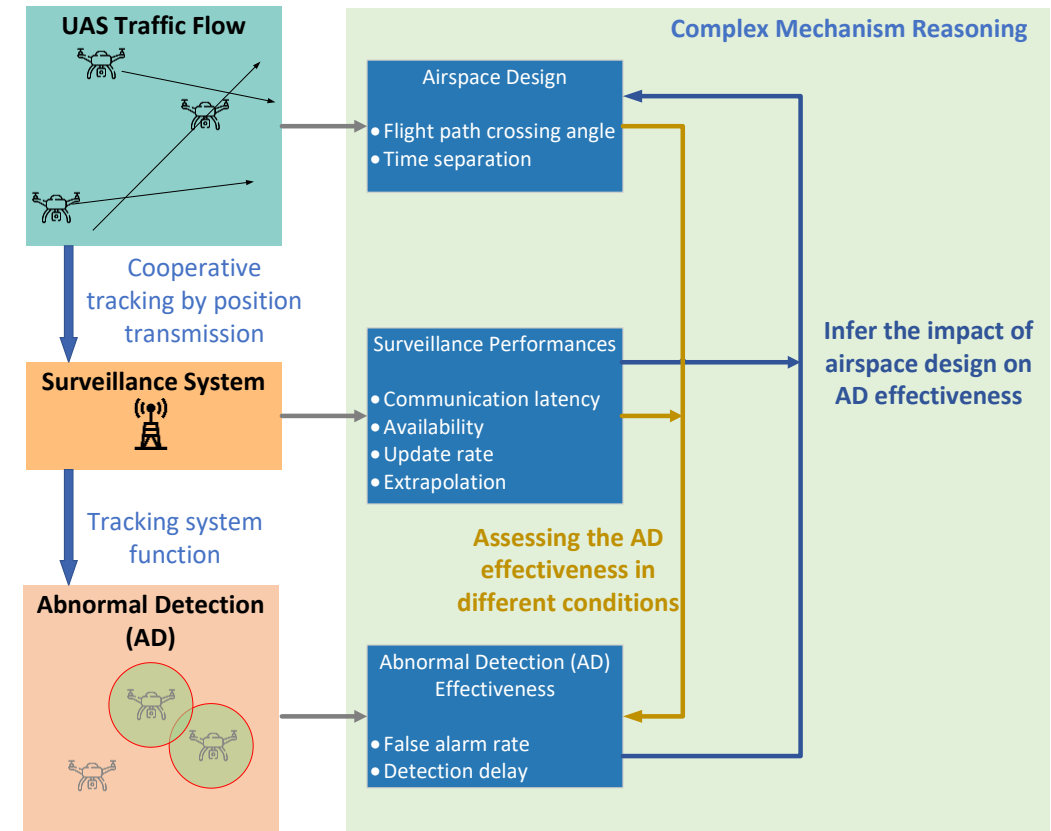
- Experiment results
 - $SOR > 55\%$, positional error is not significantly subject to SOR changes
 - $SOR < 55\%$, positional error increases significantly
- Ground-based augmenting system may be required for navigating UAS in low SOR airspace



Navigational error under different SOR values

Communication & Tracking Performances: Safety-Driven Performance Evaluation

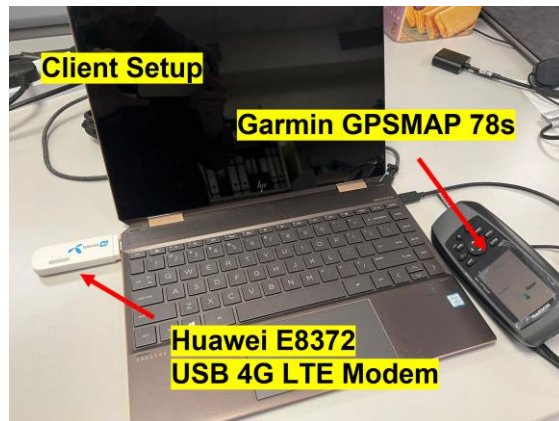
- Cooperative tracking affected by communication technology
- Tracking performance is evaluated by the higher-level functions, like abnormal detection
 - Conflict detection
 - Conformance monitoring
- The impact of tracking performances on abnormal detection is stochastic



Reasoning of the relationships among traffic flow patterns, tracking performance and abnormal detection performance

Communication & Tracking Performances: A Monte Carlo Simulation Approach

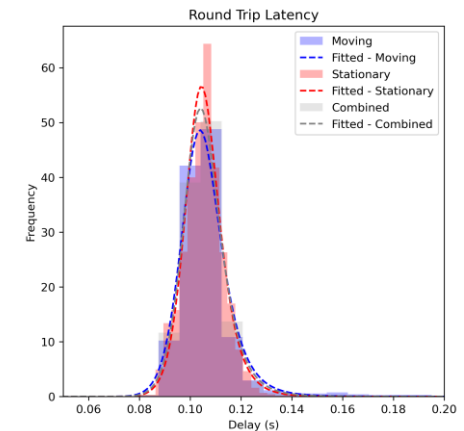
- A framework is developed using Monte Carlo simulation to solve the probabilistic reasoning problem
- Using data to ensure the reliability of simulation settings
 - Probability distribution of navigational error
 - Probability distribution communication latency



Settings of com-latency experiment



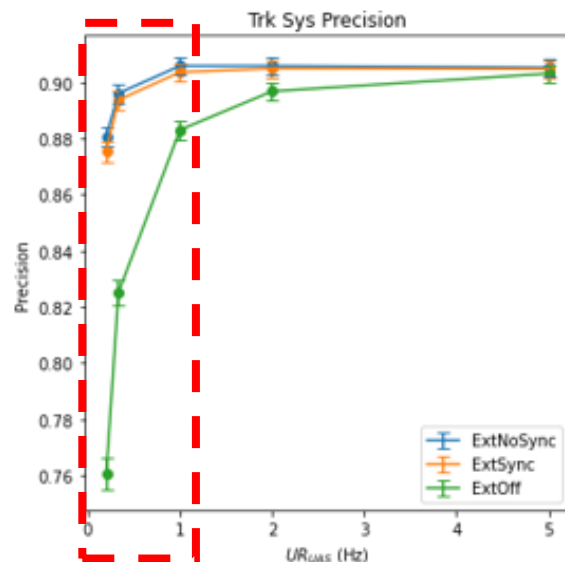
Com-latency test track



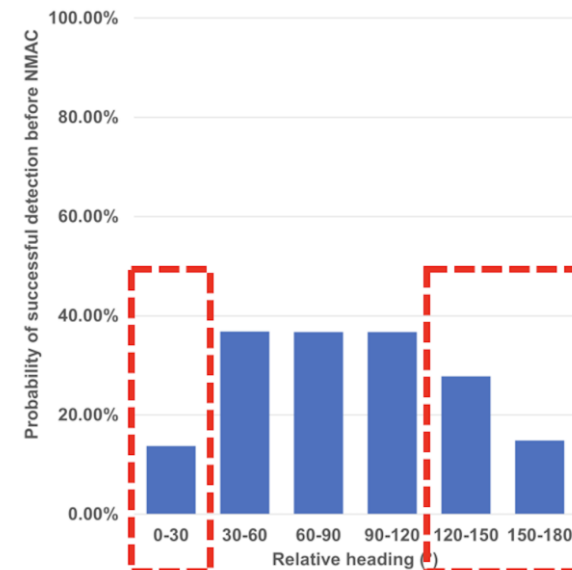
Prob. Distribution function fitting:
Fisk distribution

Communication & Tracking Performances: Results of Sensitivity Analysis

- Sensitivity analysis with a one-factor-at-a-time method
- The result implies:
 - Impact of tracking performance on detection effectiveness
 - Relationship between traffic flow and detection effectiveness



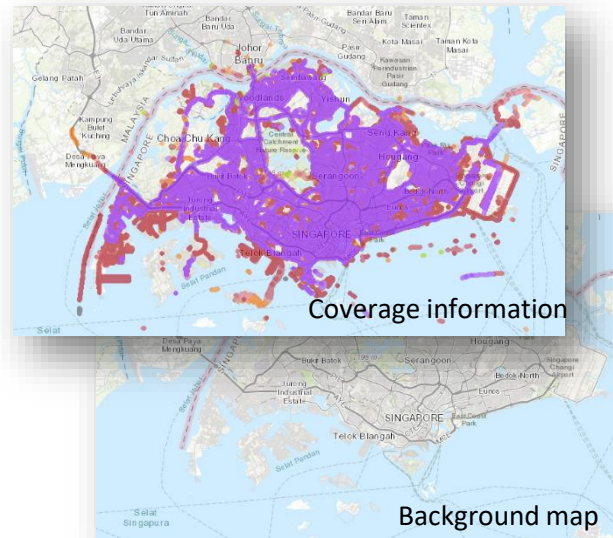
Update rate v.s. precision of detection



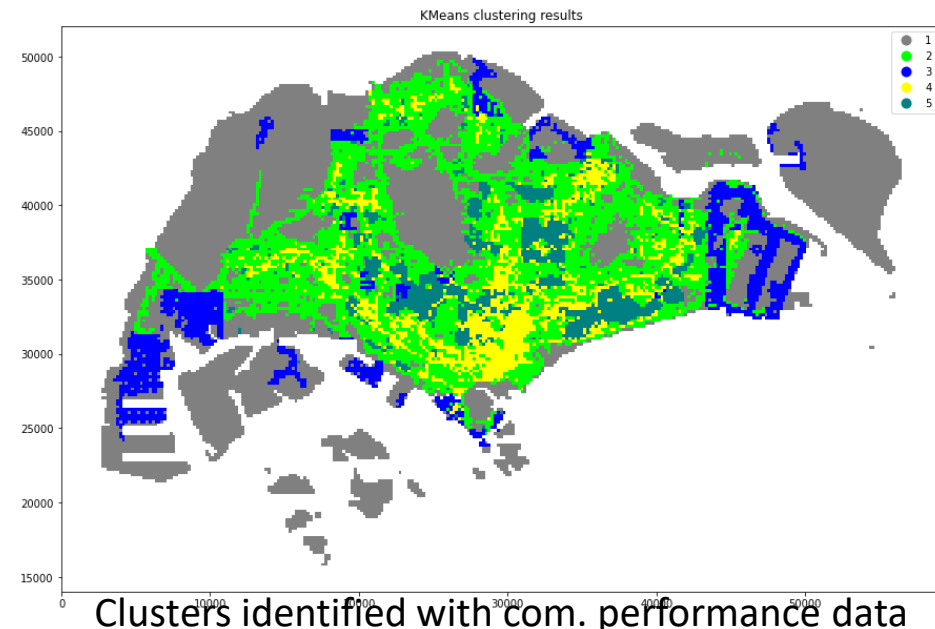
Relative heading v.s. prob. successful detection

Communication & Tracking Performances: Next Steps

- Cellular communication performance extraction and clustering analysis on its geographical distribution
- Geographical distribution of tracking performance that supports pre-flight authorization of operational intent volume



Information extraction from open-source



Clusters identified with com. performance data

Conclusion

- We proposed the uPBN concept addressing the CNS performance variation problem in urban airspace
- Estimation of CNS performances in the urban environment
 - SOR-based analysis on navigational error in urban airspace
 - Assessment of tracking and communication performance, which affect the effectiveness of abnormal direction
- The expected outcome provides references for flight approval and OIV generation

Thank You!

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