



Prototyping a Low-cost Roadside Device System for Cooperative Automated Driving

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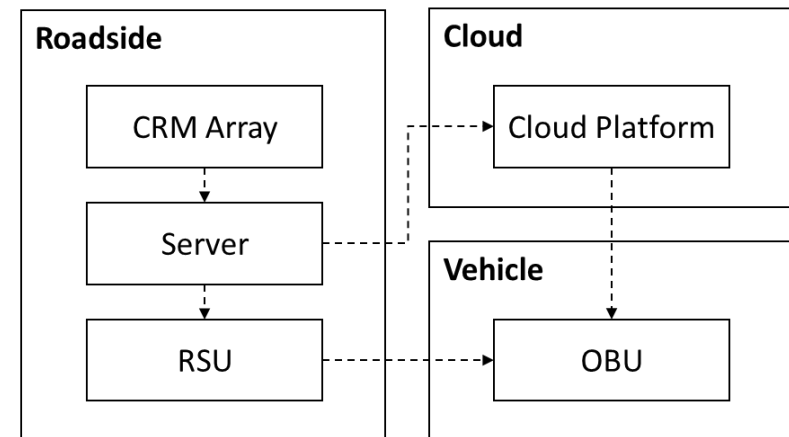
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CCAT 2024 Research Project

Background

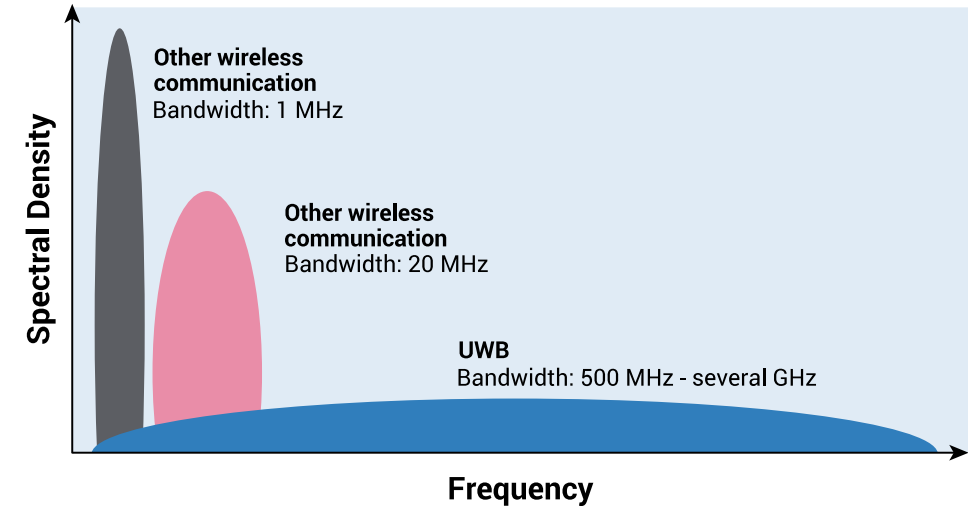
- Cooperative driving automation (CDA) with intelligent road infrastructure to address difficult scenarios
- Gateway solutions to Infrastructure-based (IB) CDA
 - Cost, right-of-way, use cases, etc.
- Connected Reference Marker (CRM) System
 - Vehicle ranging and localization
 - Roadway geometry
 - Low cost roadside devices
 - Versatile system configurations



CRM System Architecture

One CRM Ranging Solution

- Ultra-Wideband (UWB)
 - A pulse radio technology: short range, high bandwidth/short pulses
 - Precise ranging, secure data communication
 - Low energy consumption
 - Hands-free access control, location-based services, device-to-device services: smartphone car access, contactless payment, AirTag, etc.



UWB Spectrum Comparison



SAMSUNG

UWB Industry Ecosystem

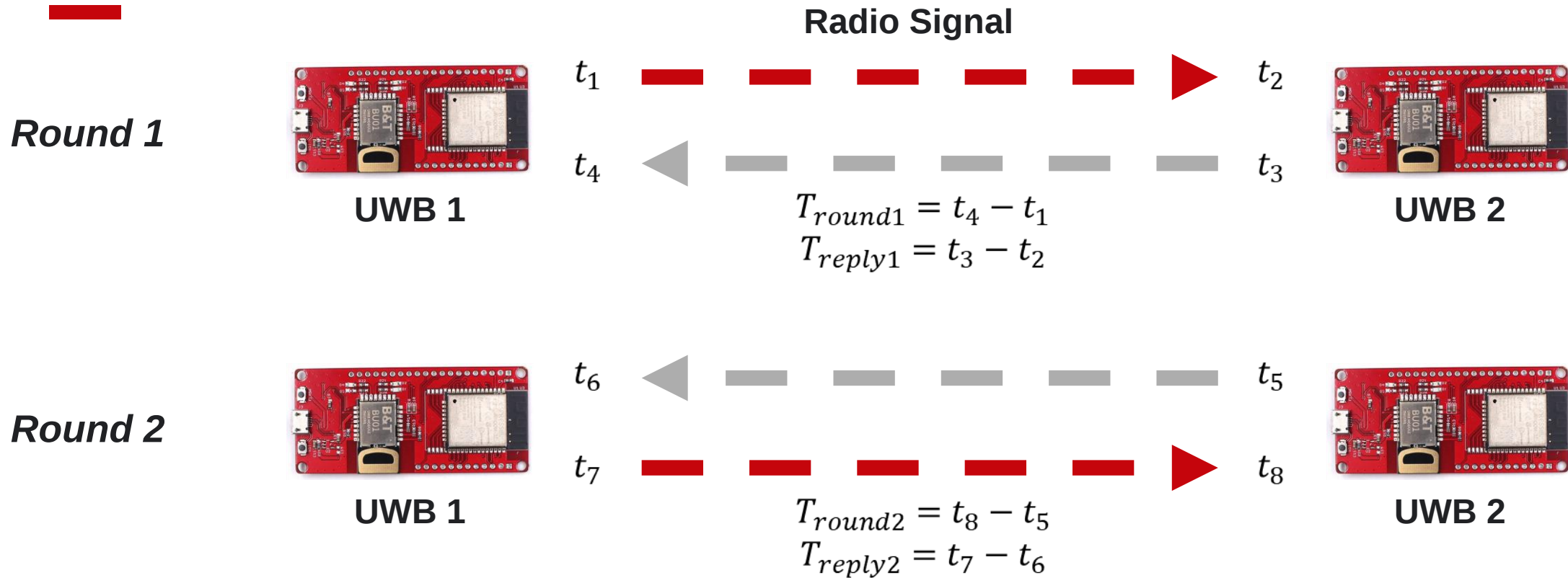
UWB Ranging

- Basic components
 - Anchor: Fixed unit – measures location of mobile units
 - Tag: mobile unit – in motion
 - Location engine/server
- Time of Flight (ToF) measurement based
- Various algorithms of measurement
 - Two-way ranging, time difference of arrival
 - Angle of arrival, phase difference of arrival



UWB Hardware Device

Double-sided Two-way Ranging



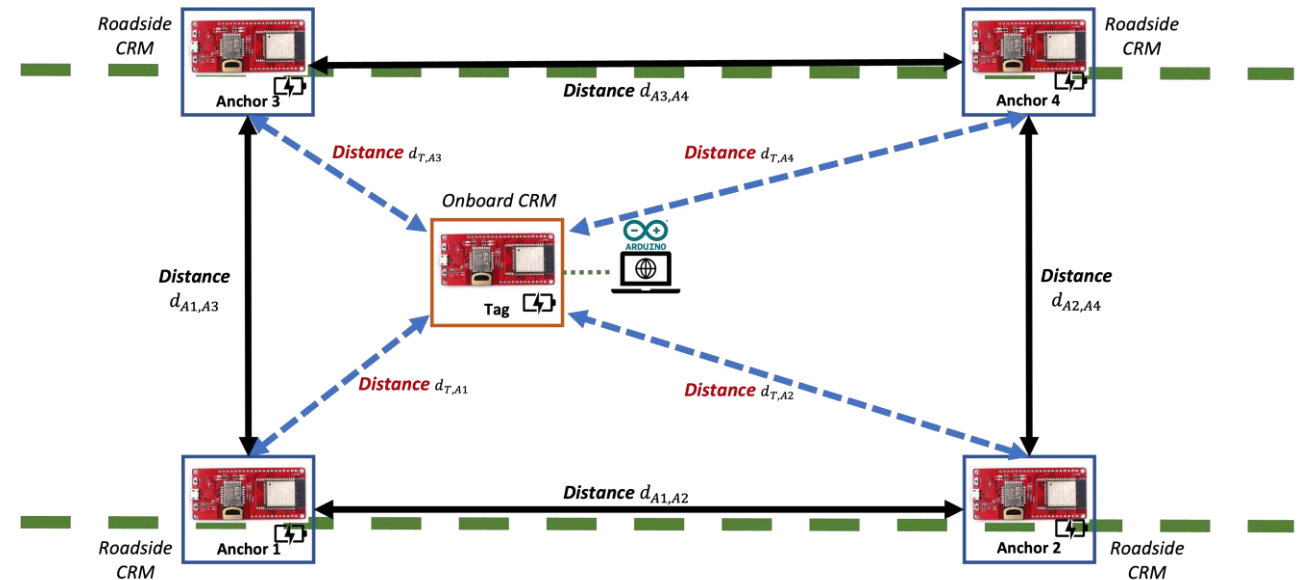
UWB two-way ranging process used by the CRM distance-measurement module

$$\hat{T} = \frac{T_{round1} \times T_{round2} - T_{reply1} \times T_{reply2}}{T_{round1} + T_{round2} + T_{reply1} + T_{reply2}}$$

$$Distance = speed\ of\ light \times \hat{T}$$

Experiment Settings

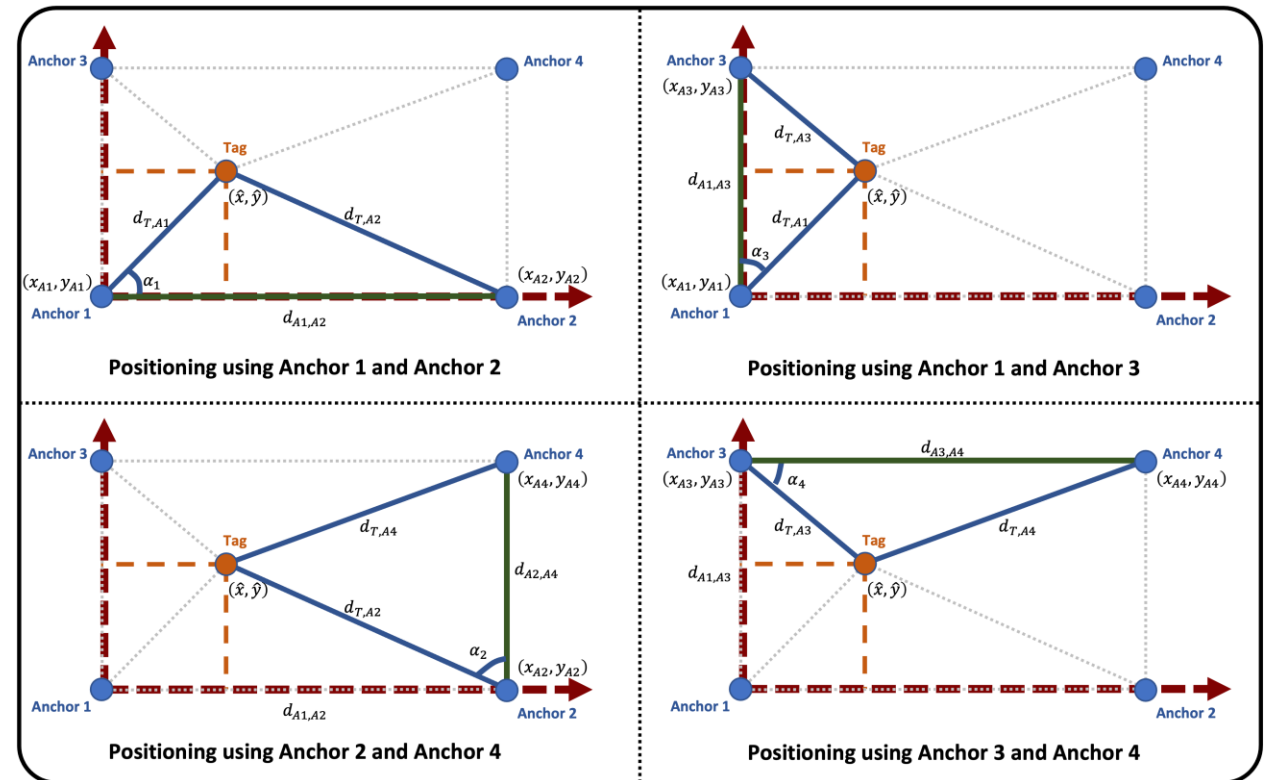
- One Tag with one anchor
 - Distance accuracy, data rate, range, connection reliability, multi-path effect
- Multi-Tag with multi anchors
 - Lower data rate per anchor
- One Tag with multi-anchors
 - Location calculation



Four-anchor CRM/Tag architecture for advanced triangular positioning

Location Calculation

- Triangulation using a pair of anchors
- Averaging the results based on different pairs of anchors

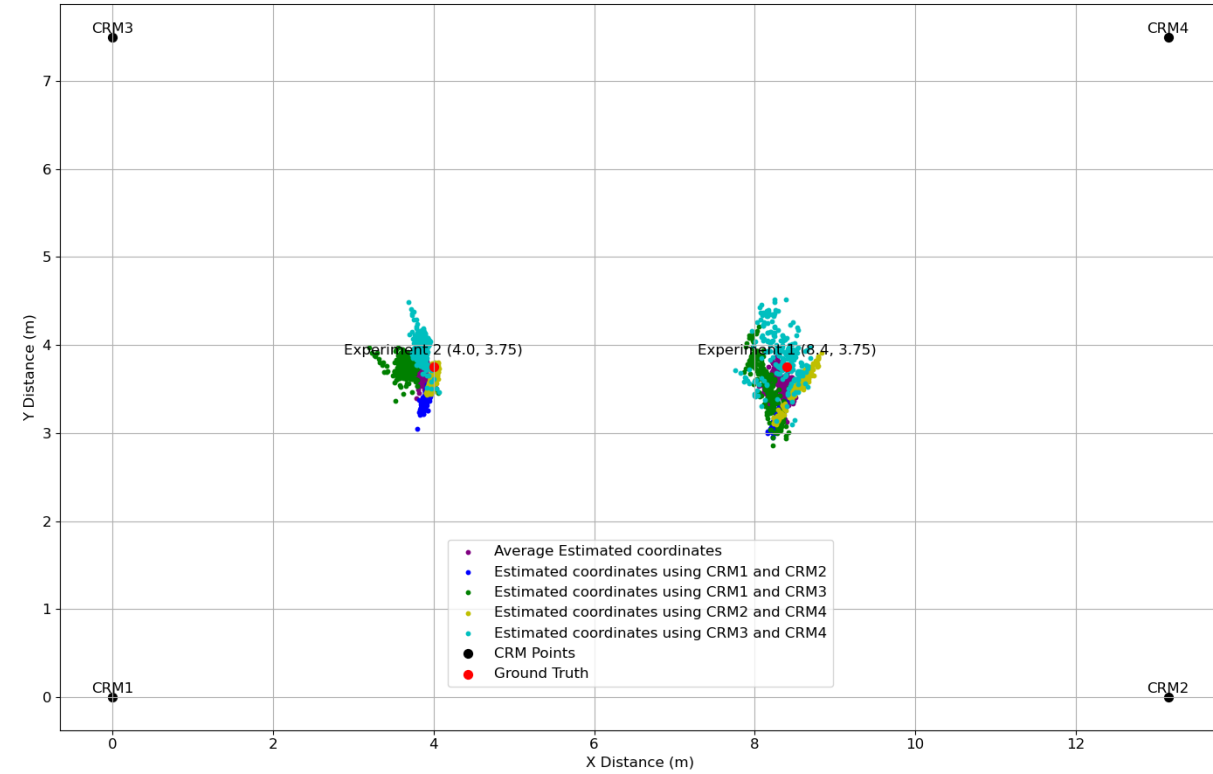


Four-anchor triangular positioning geometry and coordinate averaging

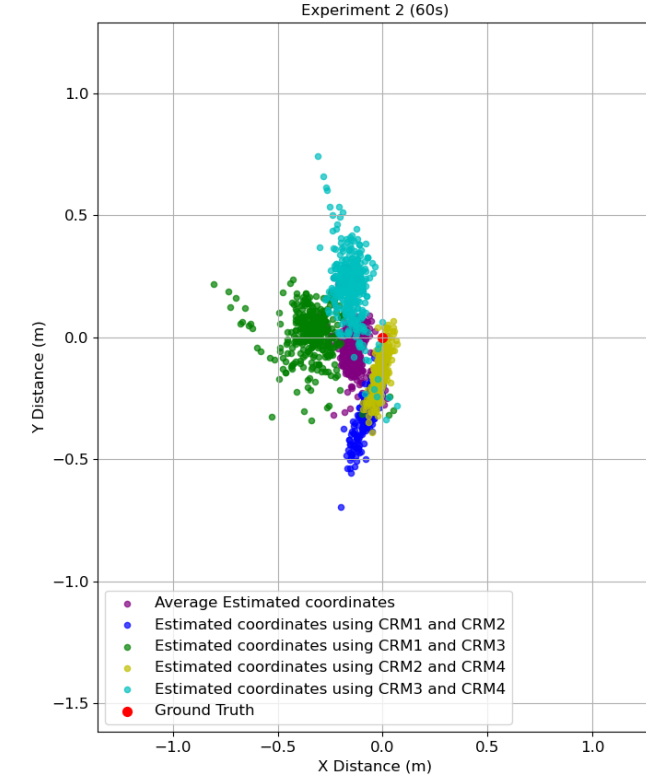
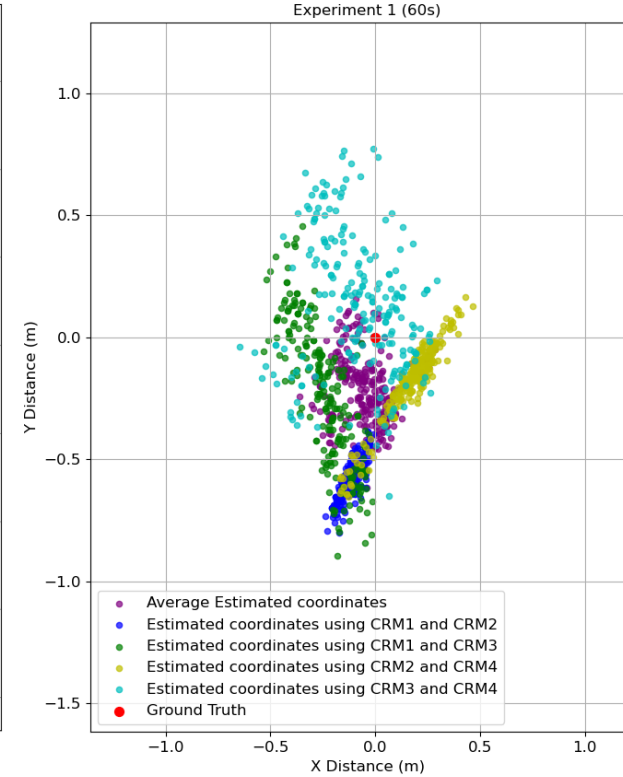
Static Scenario



Visualization of Estimated Coordinates and Clusters



Visualization of Estimated Coordinates and Clusters

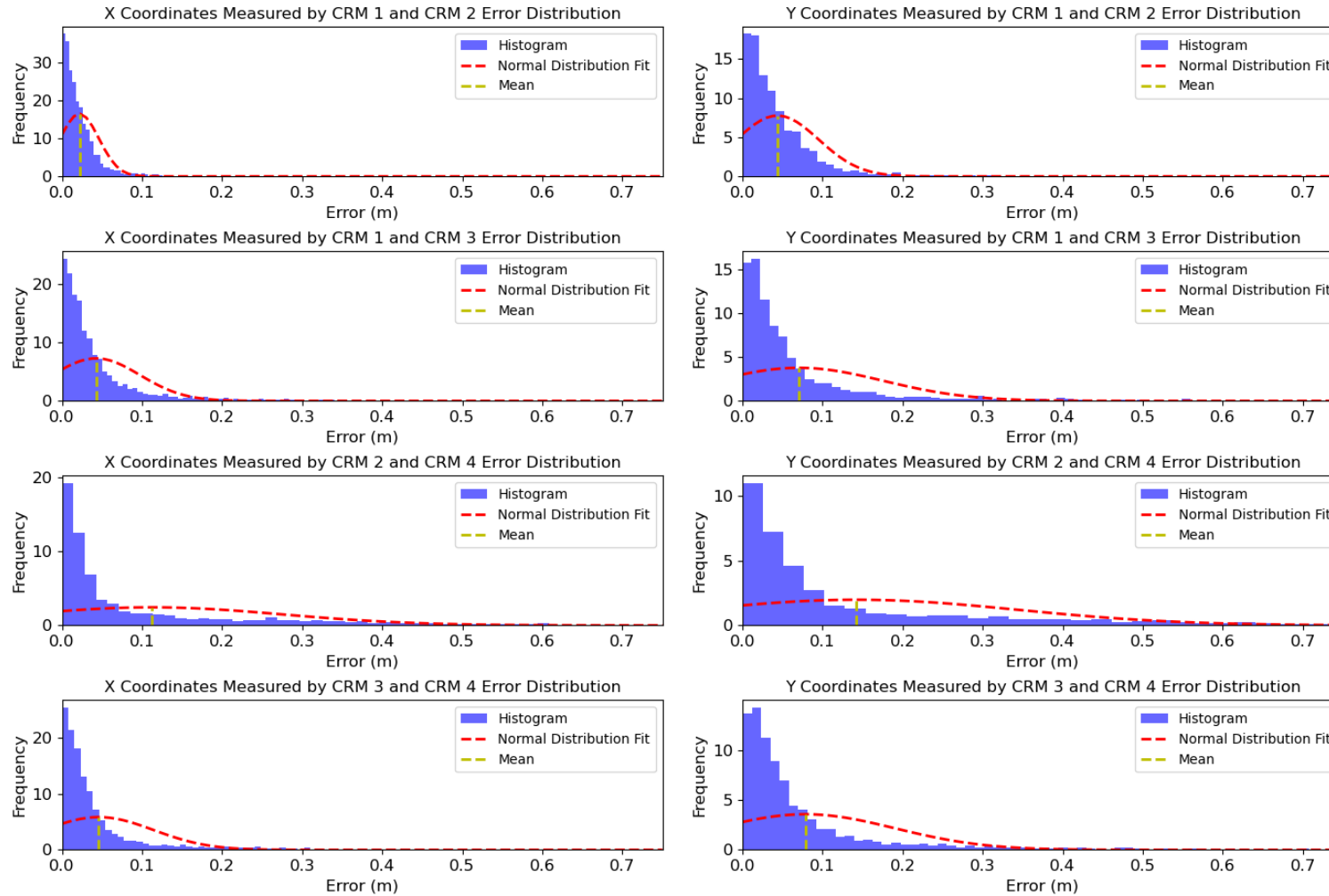


Static-scenario two-dimensional positioning clusters and ground-truth comparison.

Static Scenario – Error Distribution

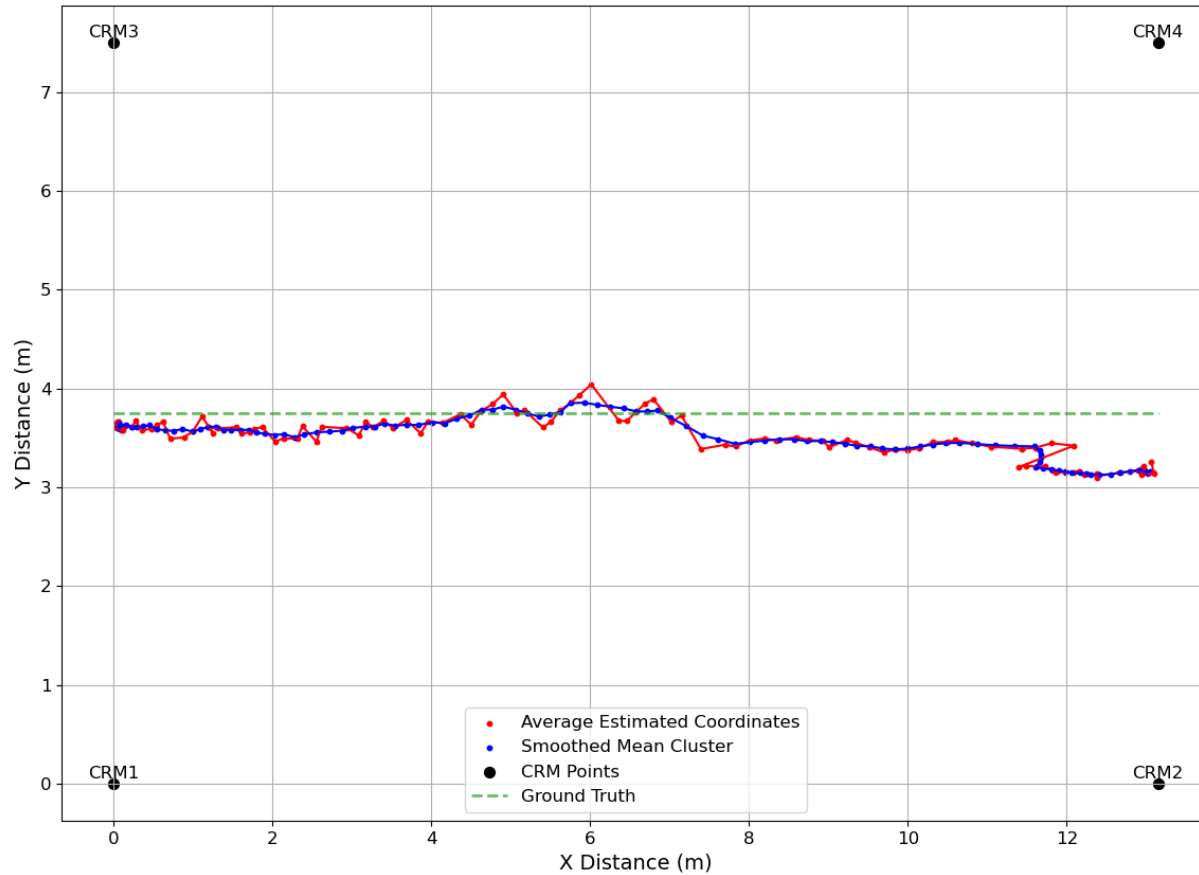


Error Distribution of CRM Combinations in Static Scenario

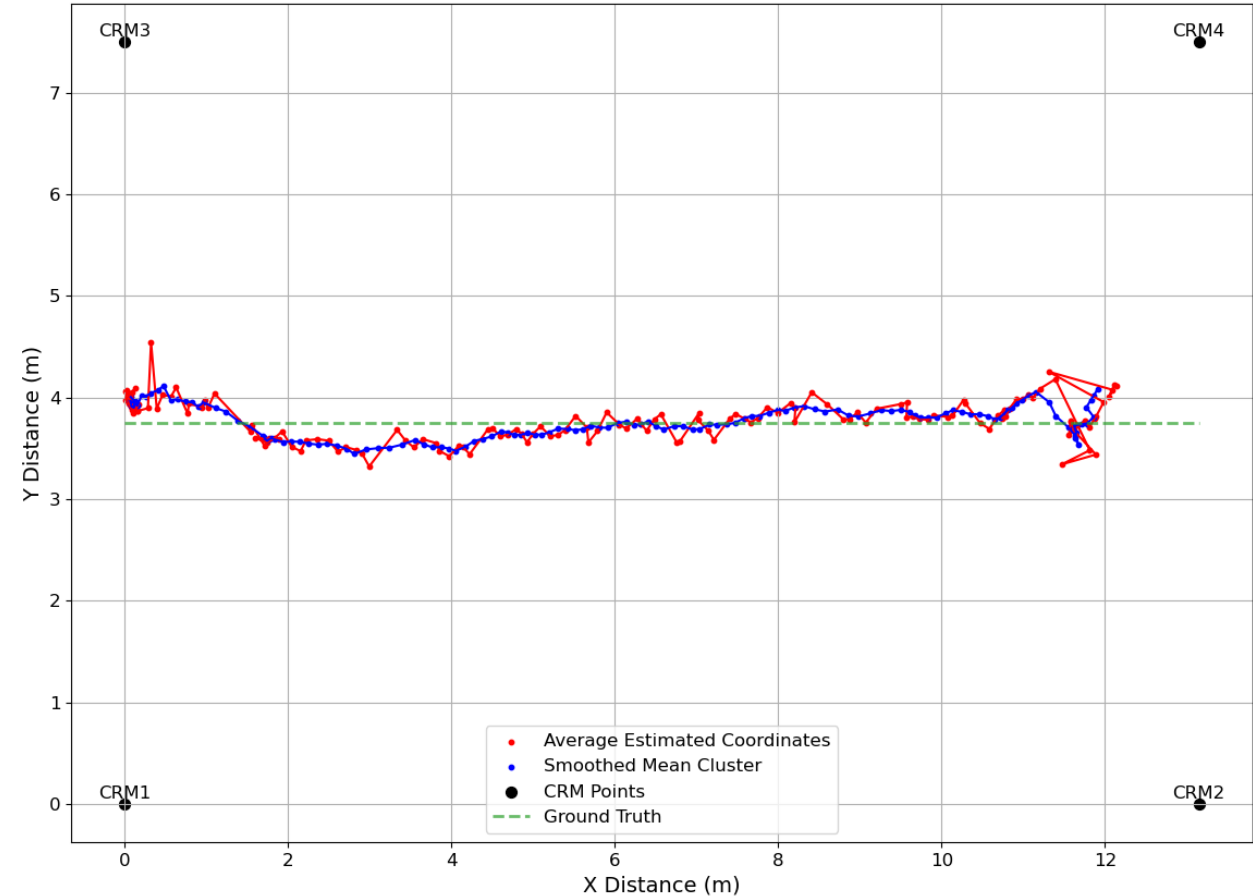


Error distribution of CRM combinations in the static scenario.

Dynamic Scenario – Trajectory



Estimated moving trace in Dynamic Experiment 1

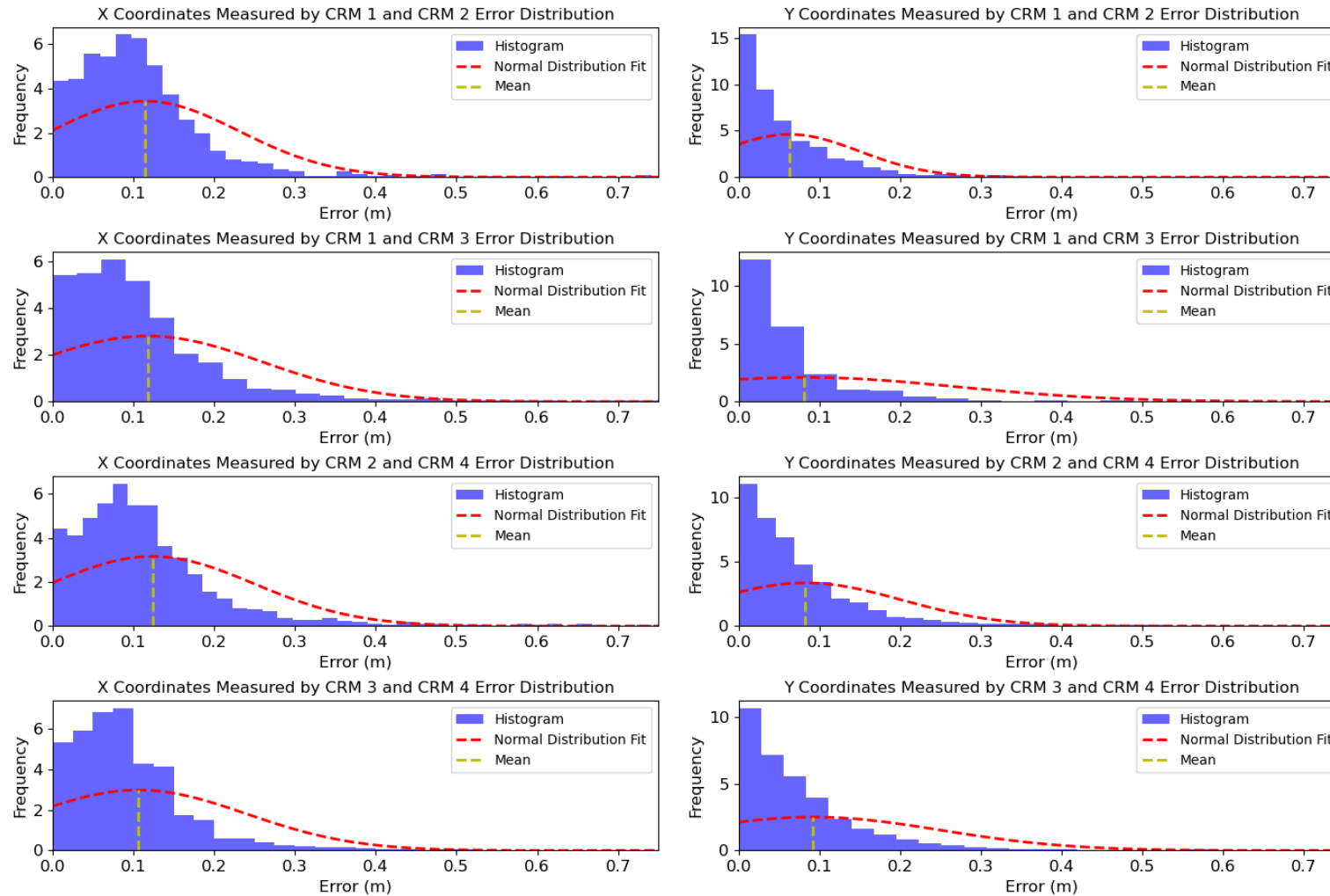


Estimated moving trace in Dynamic Experiment 2

Dynamic Scenario – Error Distribution



Error Distribution of CRM Combinations in Dynamic Scenario



Error distribution of CRM combinations in the Dynamic scenario.

Preliminary Findings

- High ranging accuracy, reliability, and data frequency
 - Less susceptible to environmental factors
 - Occasional outliers, missing signal block, reflection, and losses
 - Relative short detection range without additional antennas
 - Lower detection frequency for longer distance
- Good system scalability
 - Multi-tag with multi-anchor
- Low energy consumption
 - Even lower when paired with Bluetooth® LE

Next Steps

- Localization/trajectory estimation algorithm
 - Various configurations: Anchor/Tag, moving speed, etc.
 - Sophisticated trajectory estimation algorithms
- Work zone boundary mapping
 - Anchor placement method
 - Procedures and algorithms
- Real-time work zone data feed
 - Follow work zone data exchange (WZDx)/connected work zone (CWZ) specification
 - Use the CRM system as a data source

Project Team

- Co-PIs:



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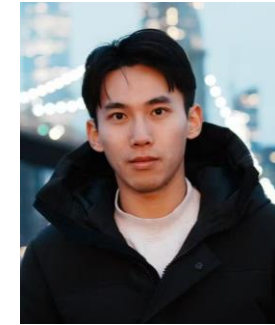


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Thank You!

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