Cramér Rao Bound Analysis for Cooperative Positioning in Intelligent Transportation Systems

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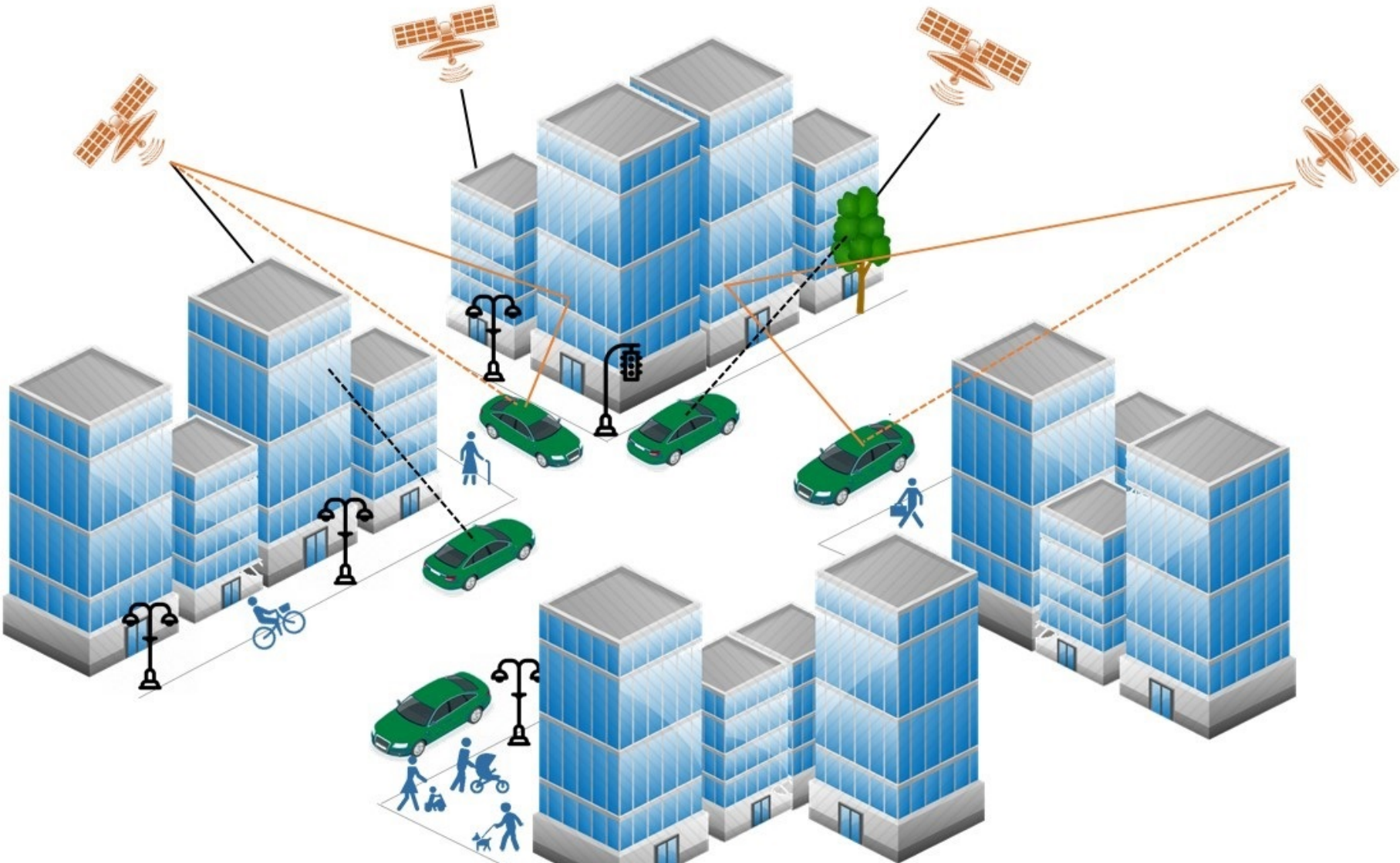
Introduction *(1)*

Urban environment = GNSS challenging environment

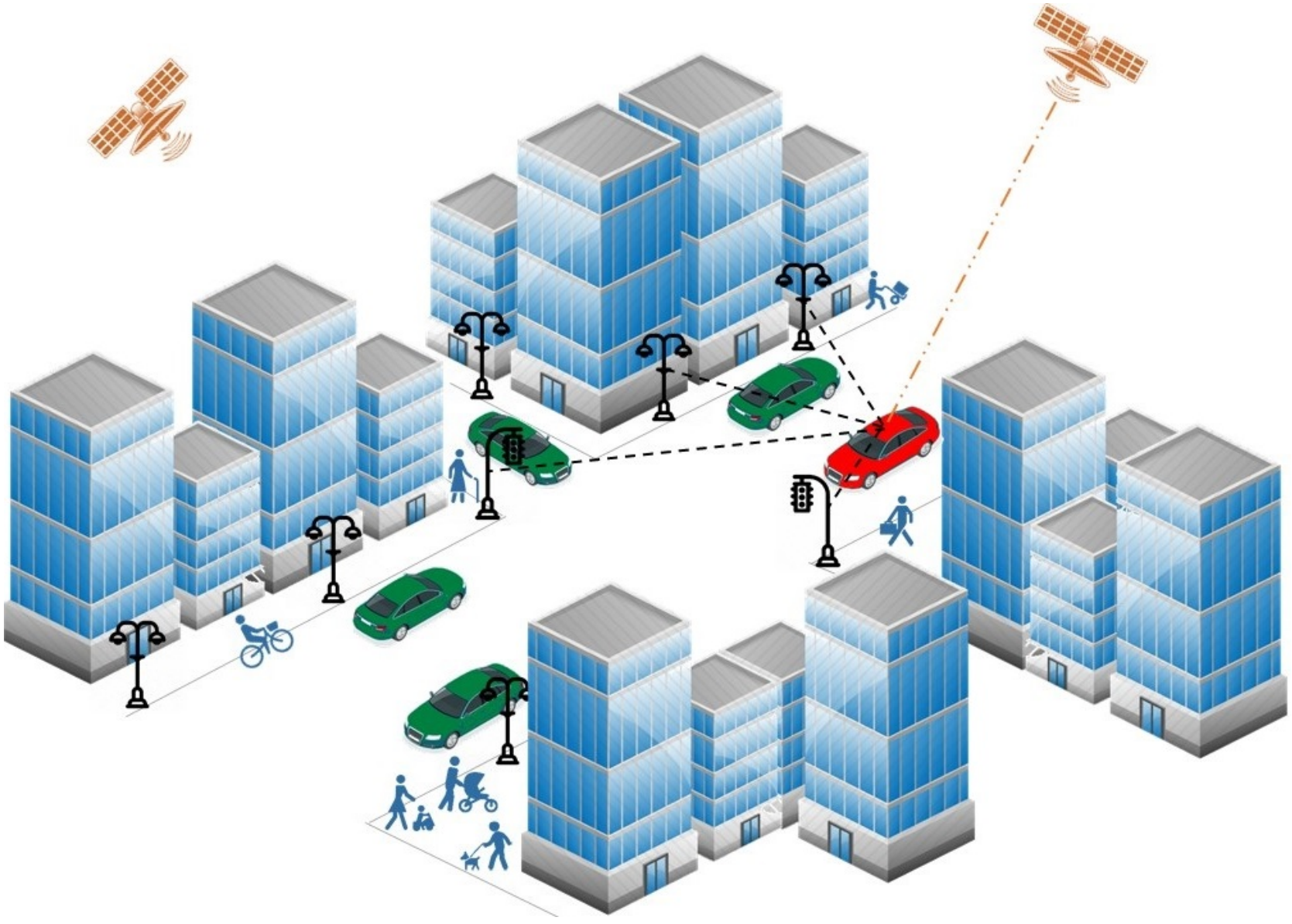


Introduction *(2)*

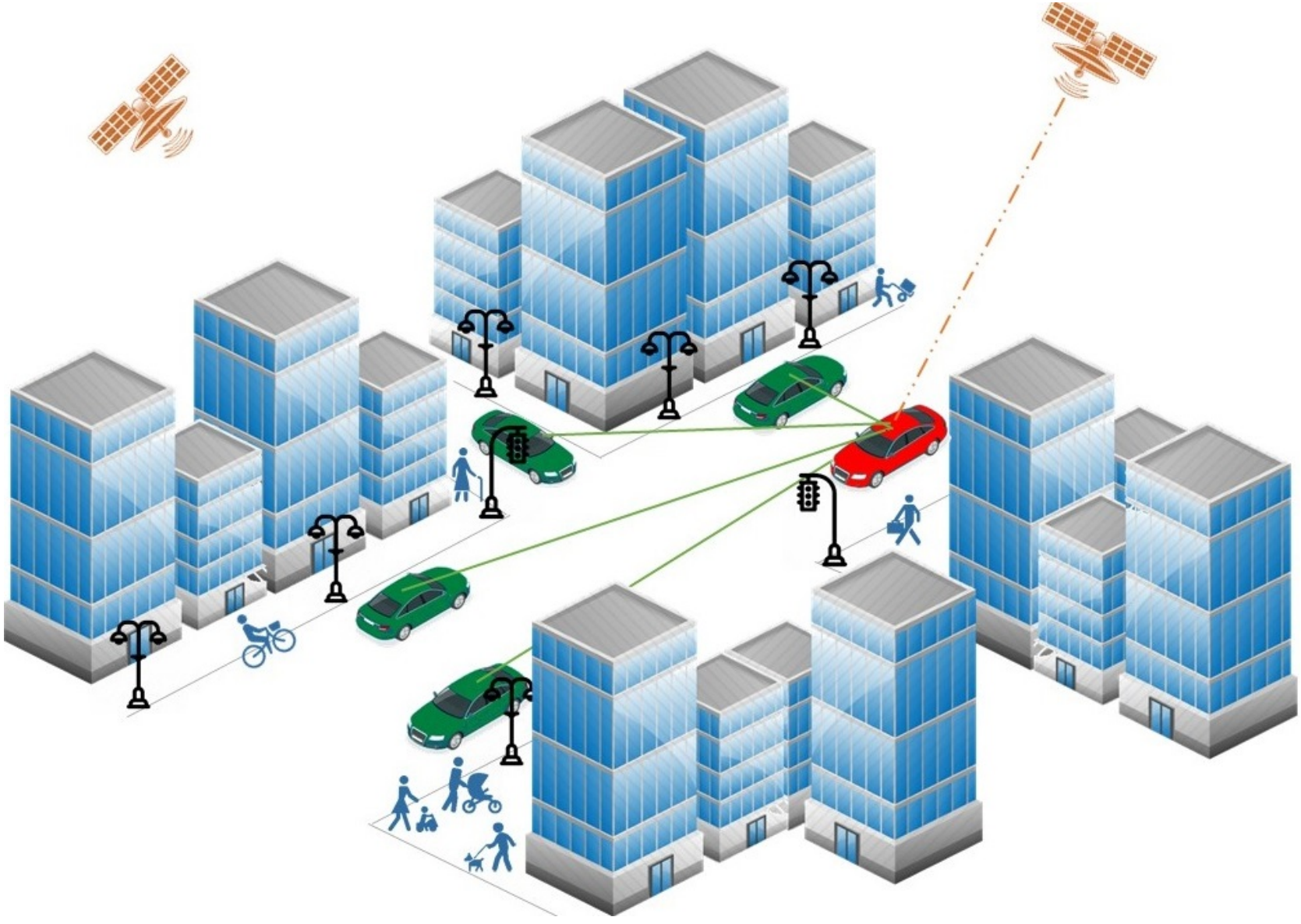
- Intelligent Transport Systems (ITS)
  - Rigid accuracy, integrity and availability requirements

  $\Rightarrow$ **Cooperative Positioning (CP)**
- **Aim** $\Rightarrow$ demonstrate benefits of CP in ad-hoc network of 4 vehicles and 15 infrastructure nodes
  - *Posterior Cramér Rao Bound*
    $\rightarrow$ theoretically best achievable performance

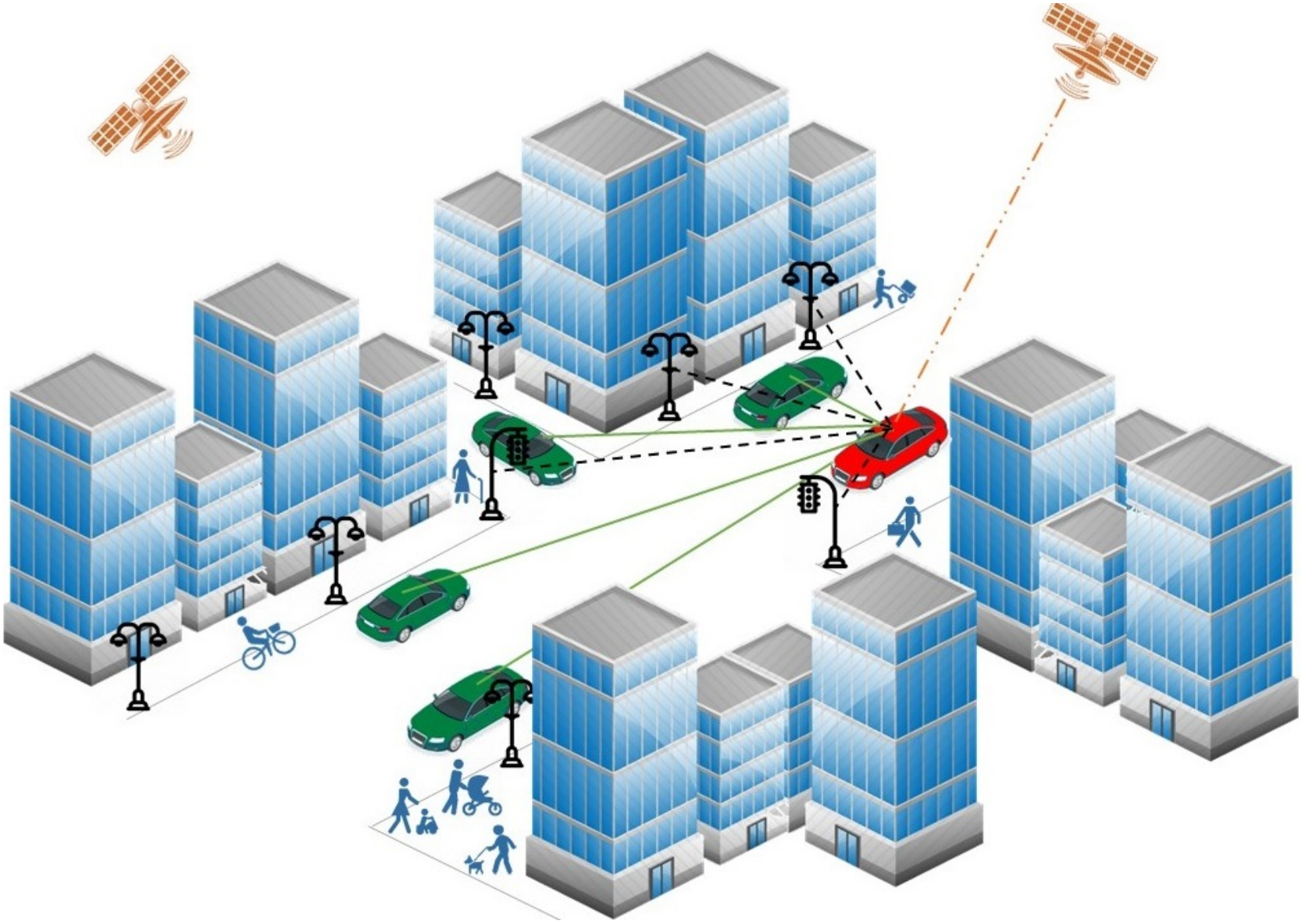
Vehicle-to-Infrastructure (V-2-I) cooperative positioning



Vehicle-to-Vehicle (V-2-V) cooperative positioning



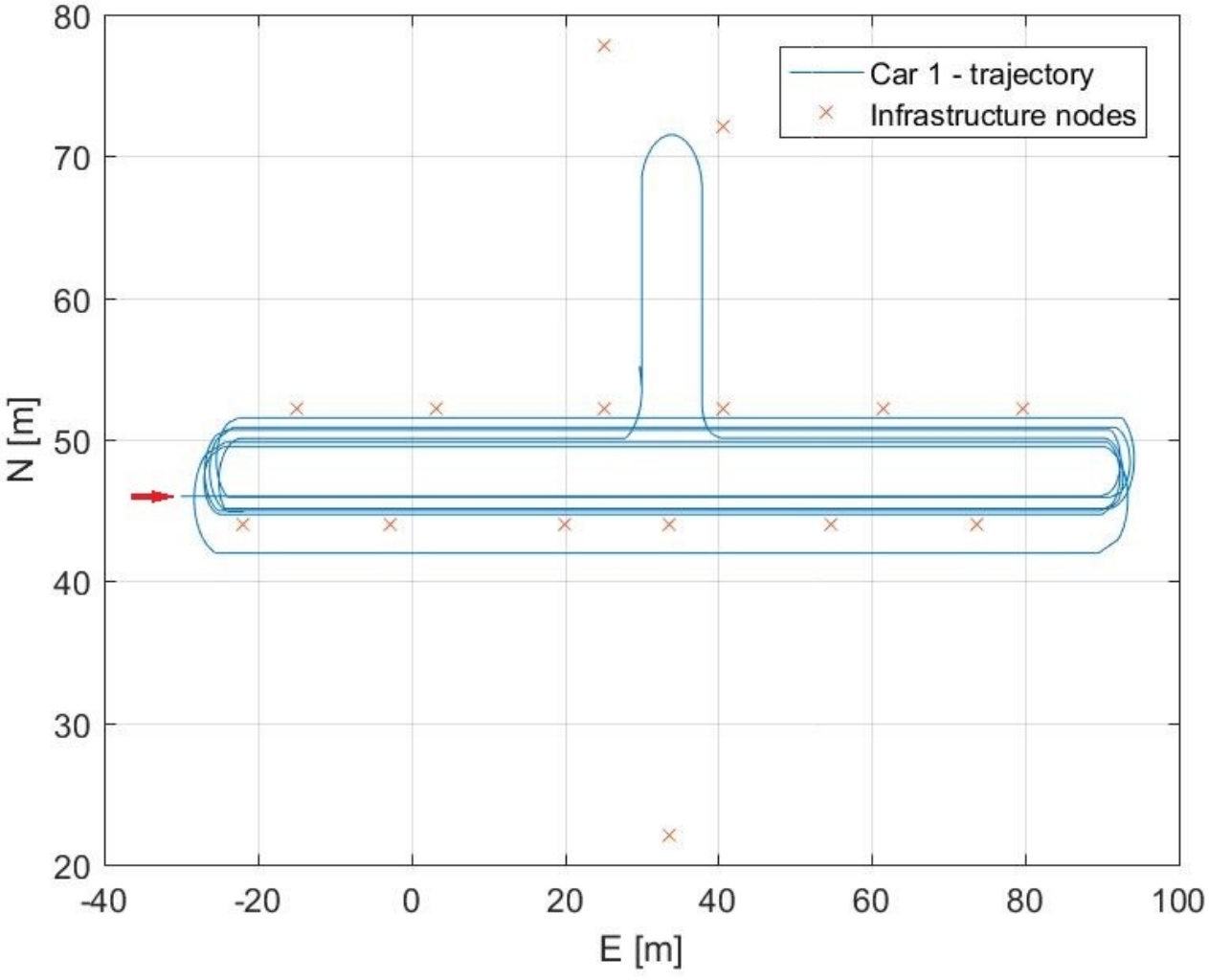
V-2-V + V-2-I cooperative positioning



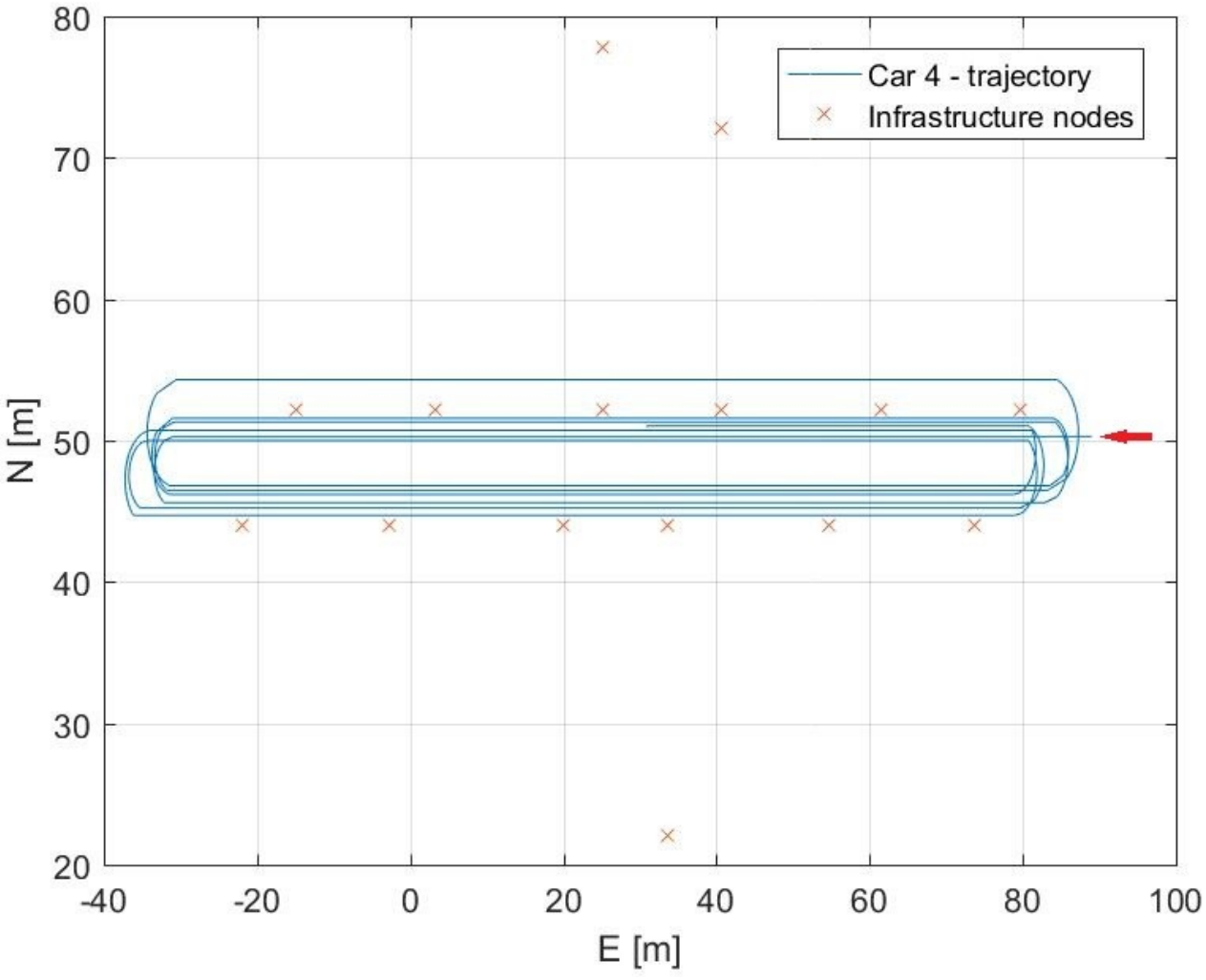
Centralised Cooperative Positioning Framework

- Extended Kalman Filter $\Rightarrow$ integration of GNSS and Ultra-WideBand
- Simulated ad-hoc network
  - 4 mobile nodes $\Rightarrow$ vehicles
  - 15 infrastructure nodes
- Available measurements
  - GPS determined positions for 3 vehicles
  - Relative ranges between all vehicles
  - Relative ranges between vehicle without GPS and infrastructure nodes

Simulated trajectory *(1)*

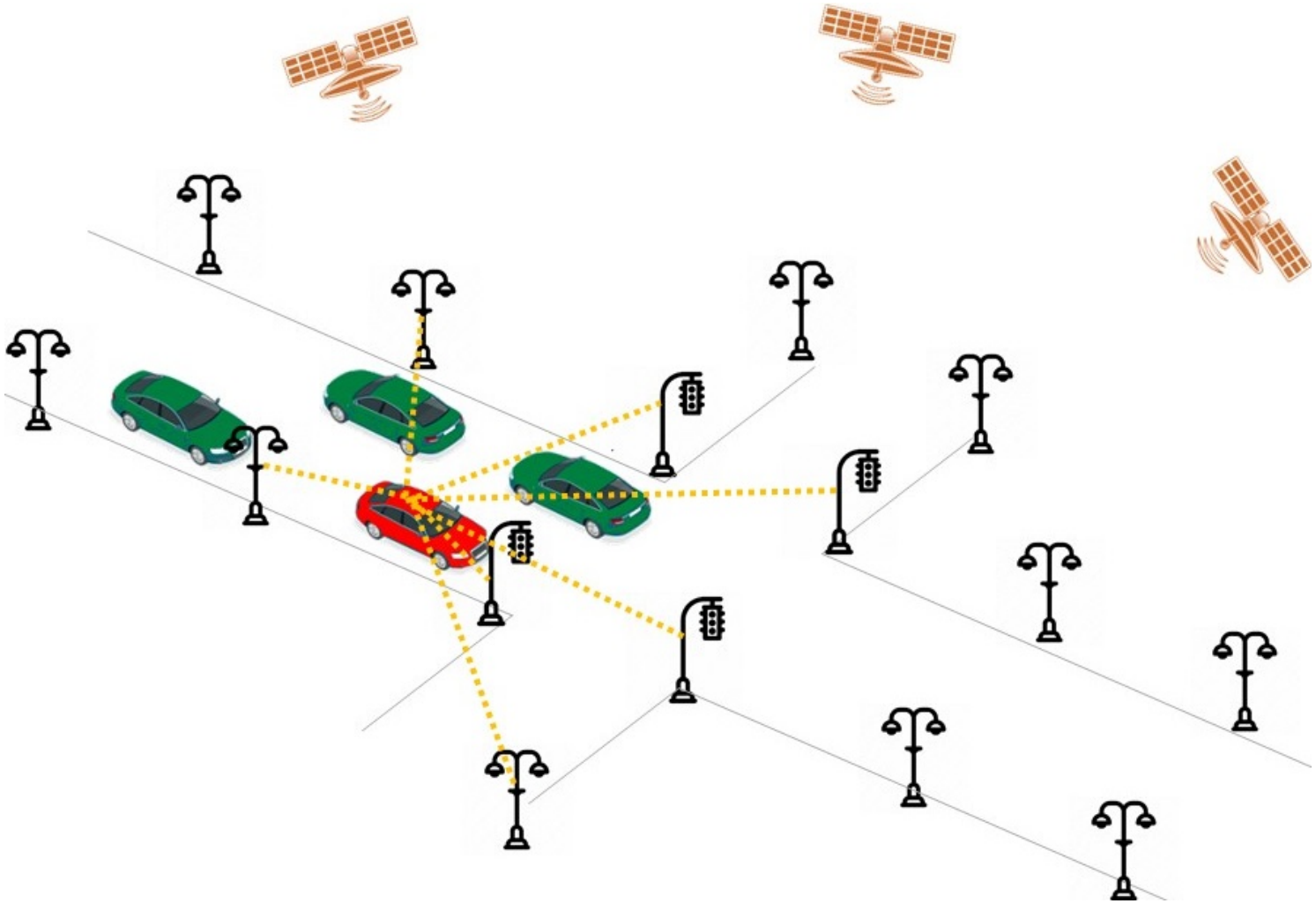


Simulated trajectory *(2)*



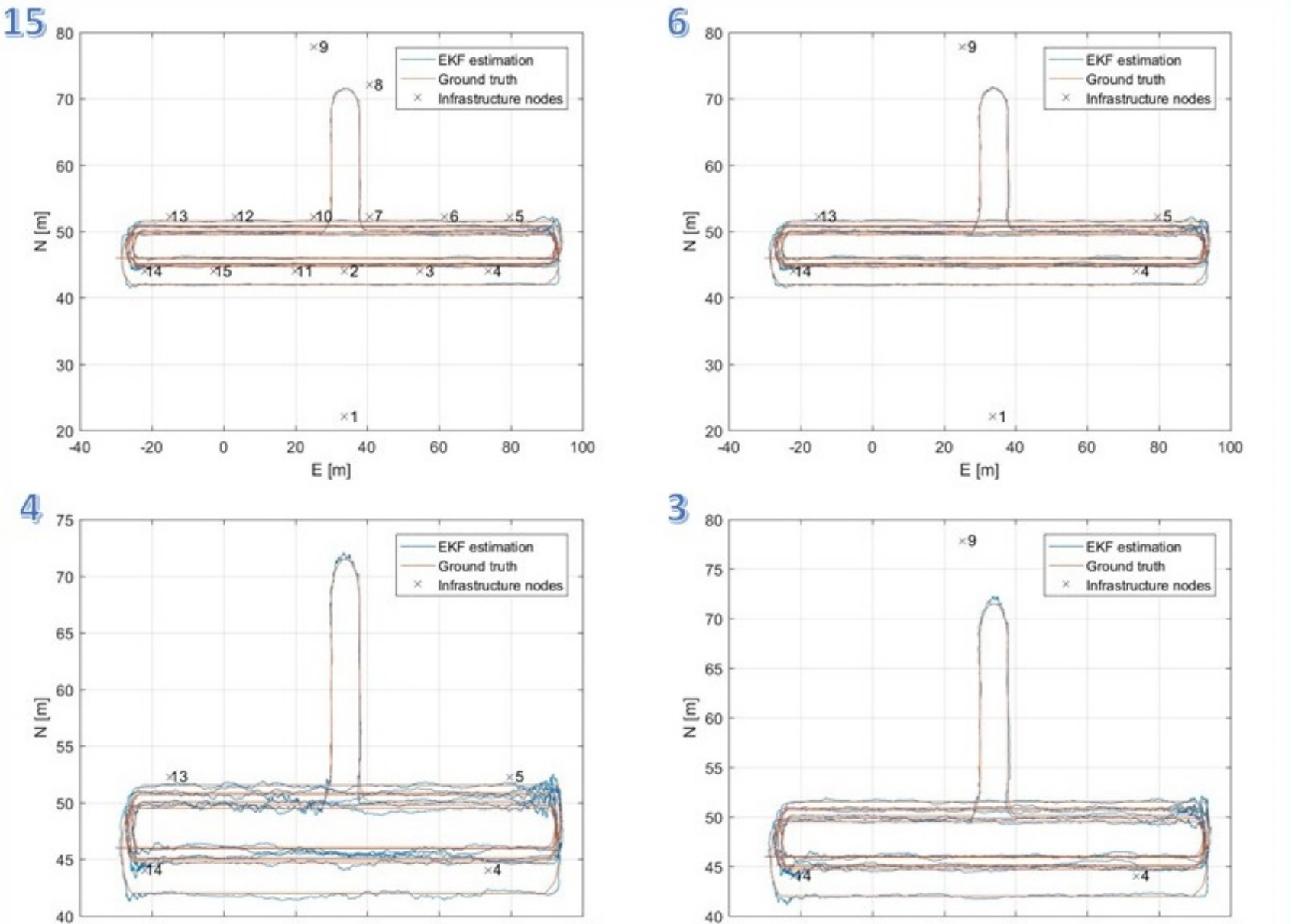
Results *(1)*

Vehicle-to-Infrastructure cooperative positioning



Results *(2)*

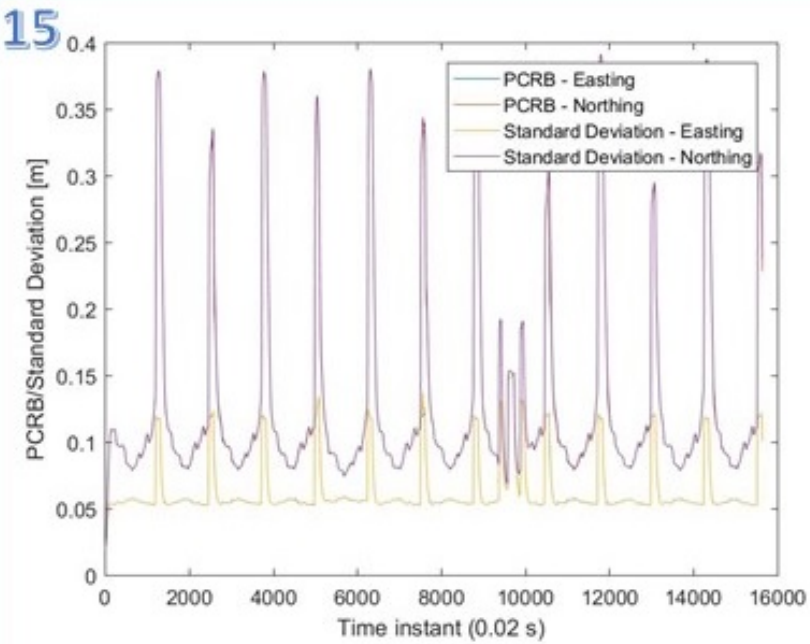
Vehicle-to-Infrastructure cooperative positioning



Results *(3)*

Vehicle-to-Infrastructure cooperative positioning

15



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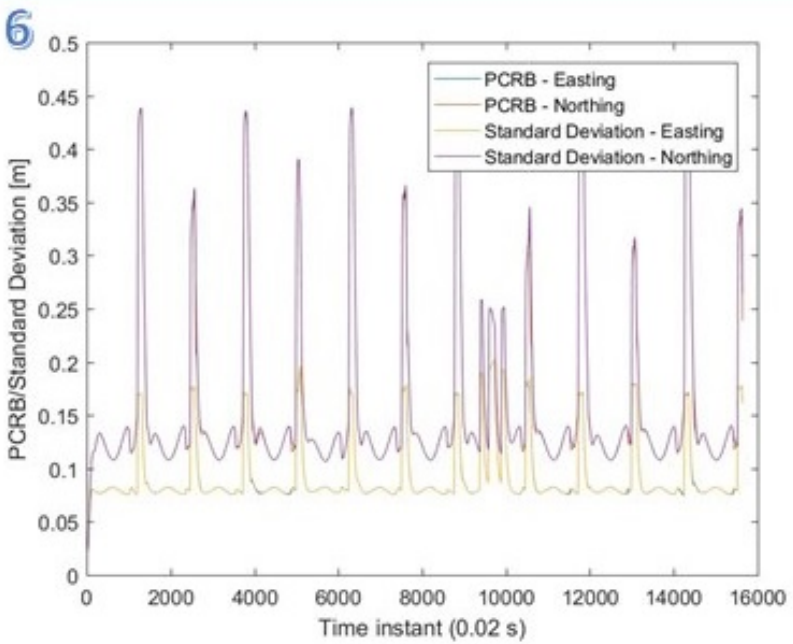

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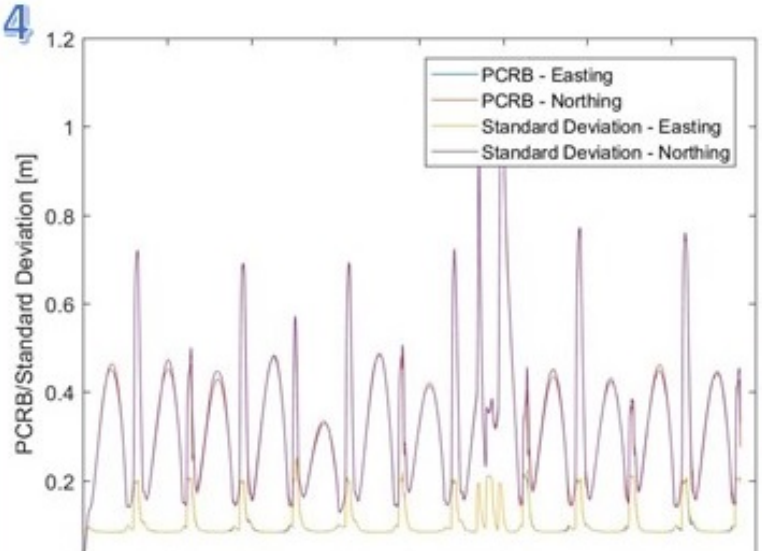

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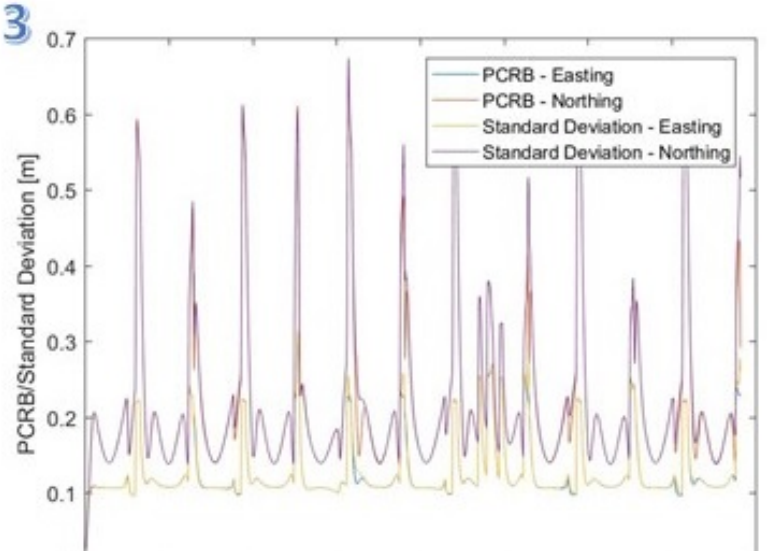
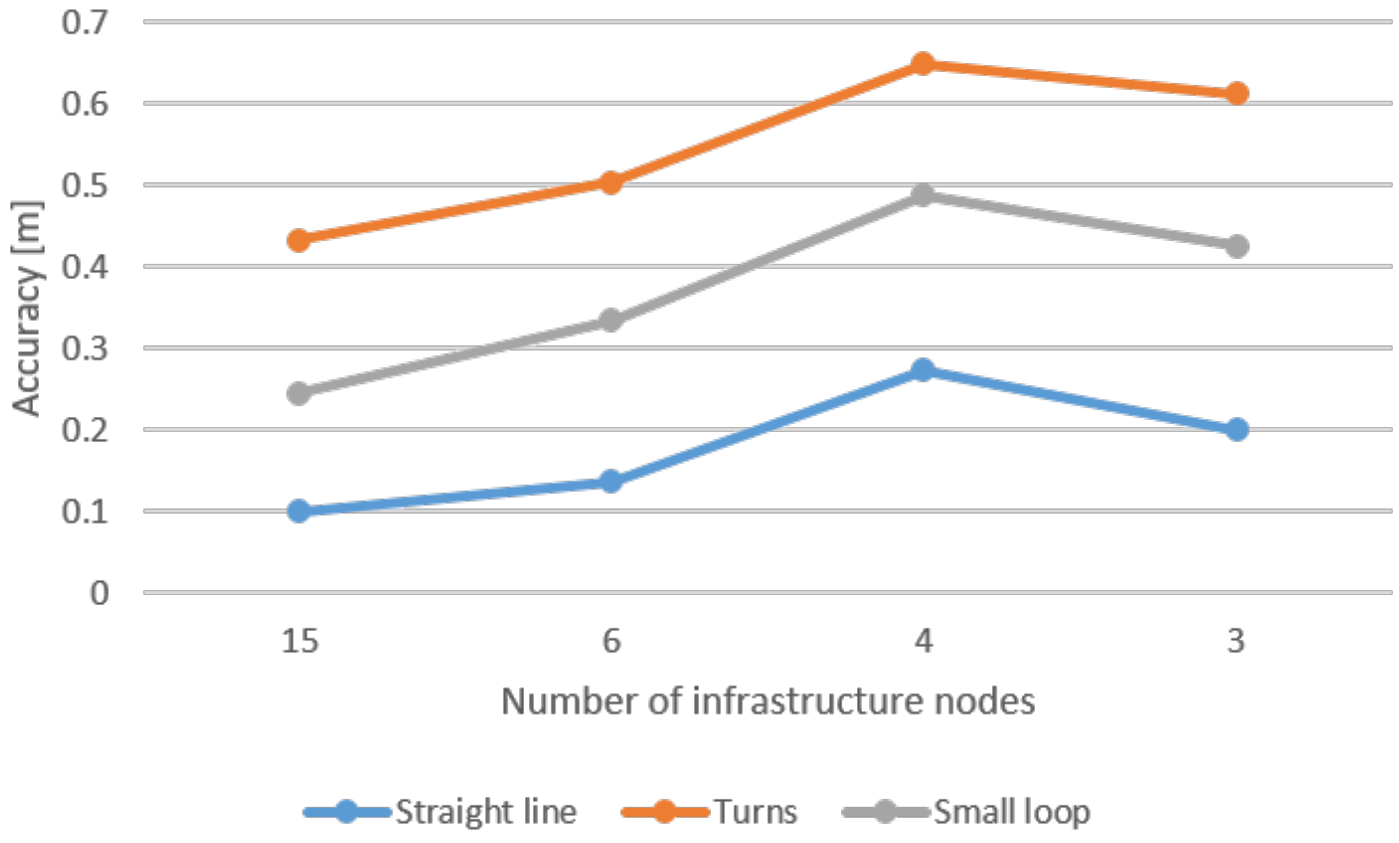


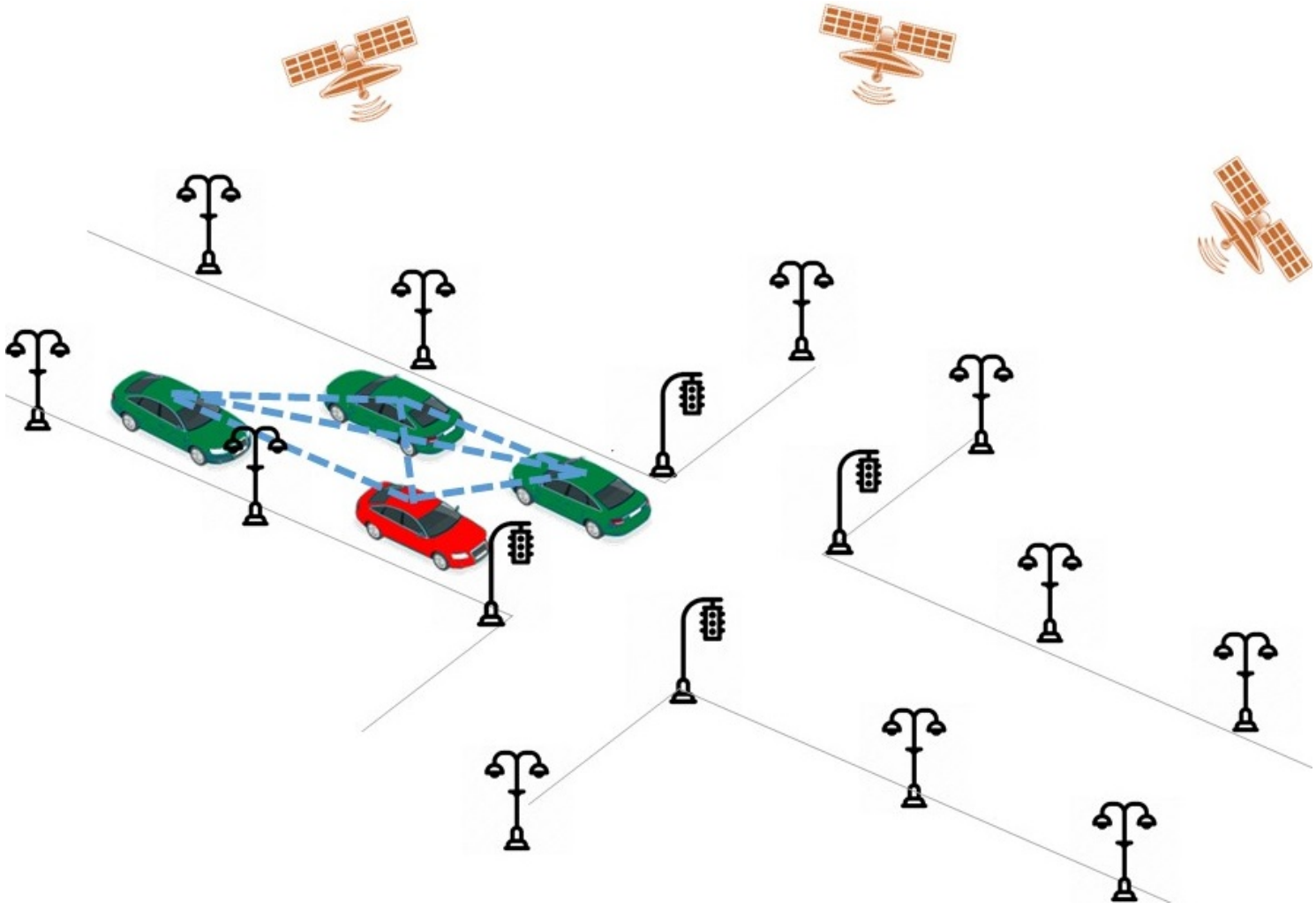
Results *(4)*

Vehicle-to-Infrastructure cooperative positioning



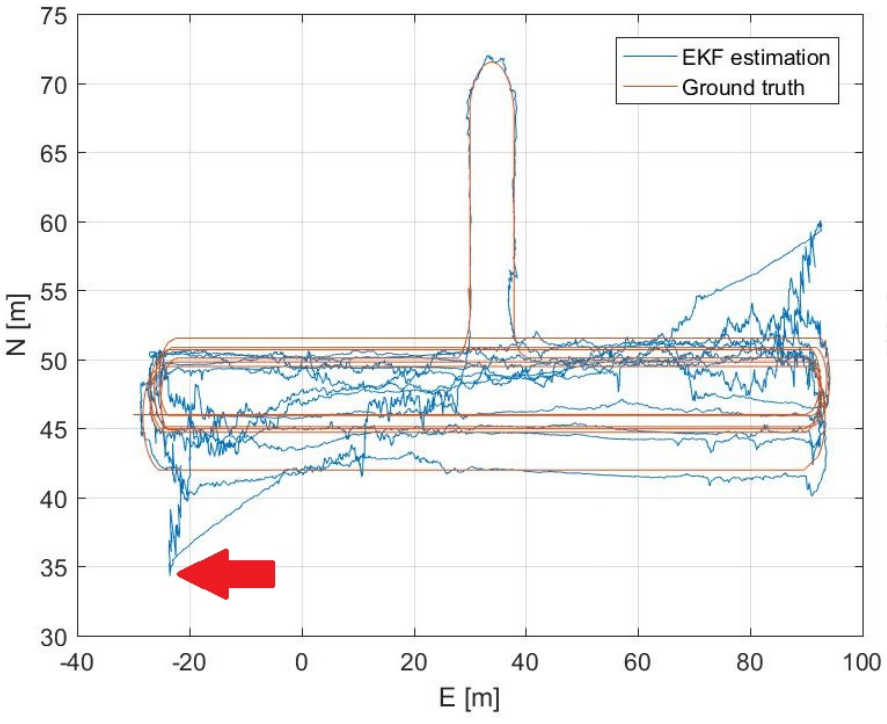
Results *(5)*

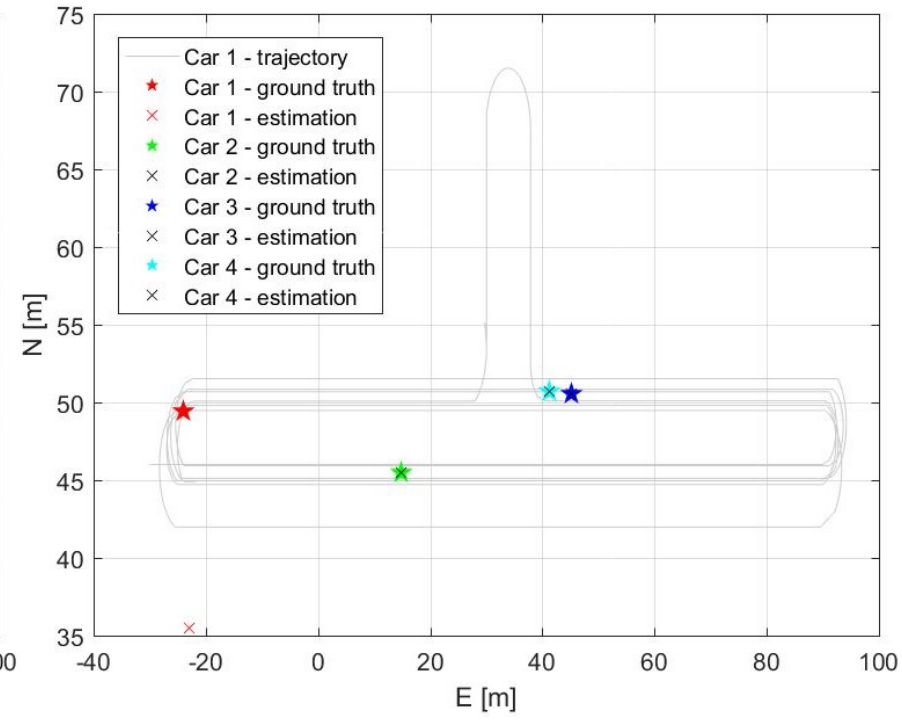
Vehicle-to-Vehicle cooperative positioning



Results *(6)*

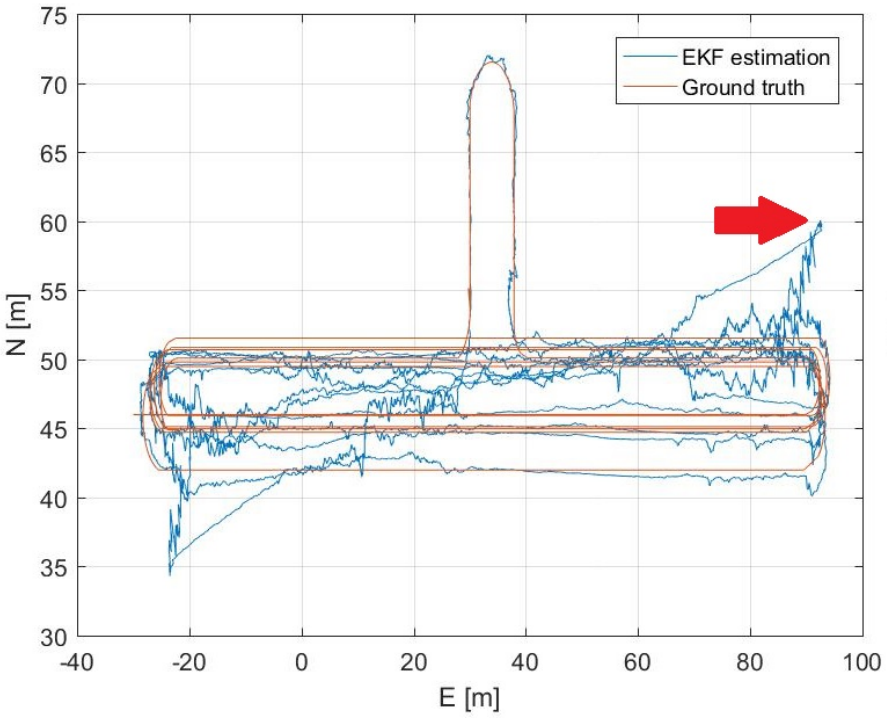
Vehicle-to-Vehicle cooperative positioning

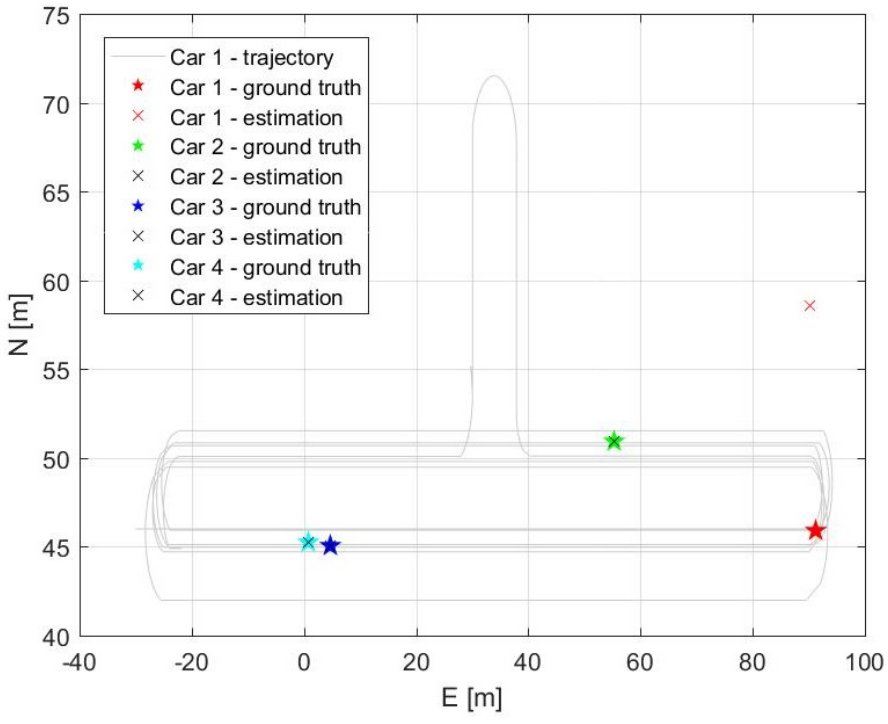




Results *(7)*

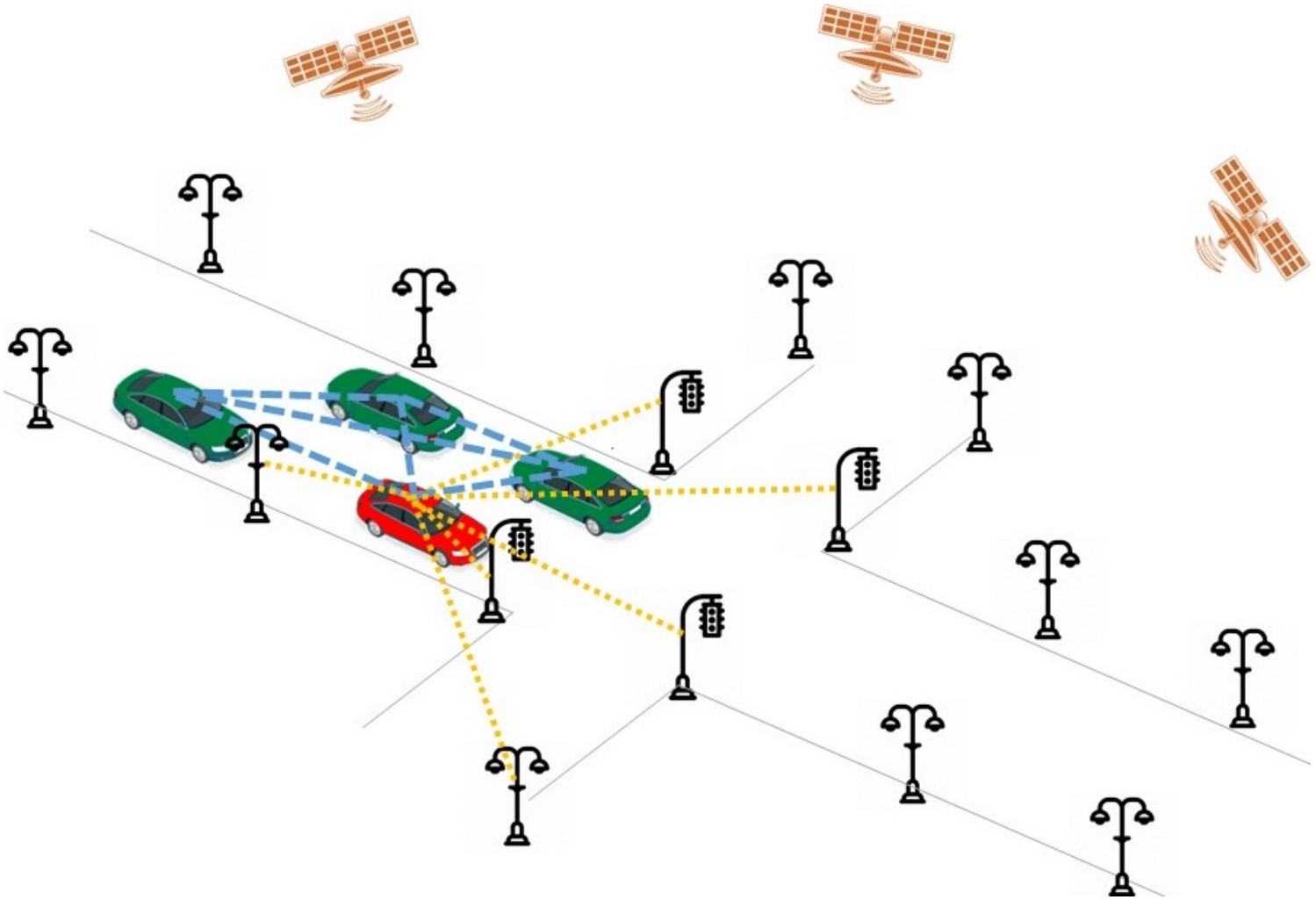
Vehicle-to-Vehicle cooperative positioning





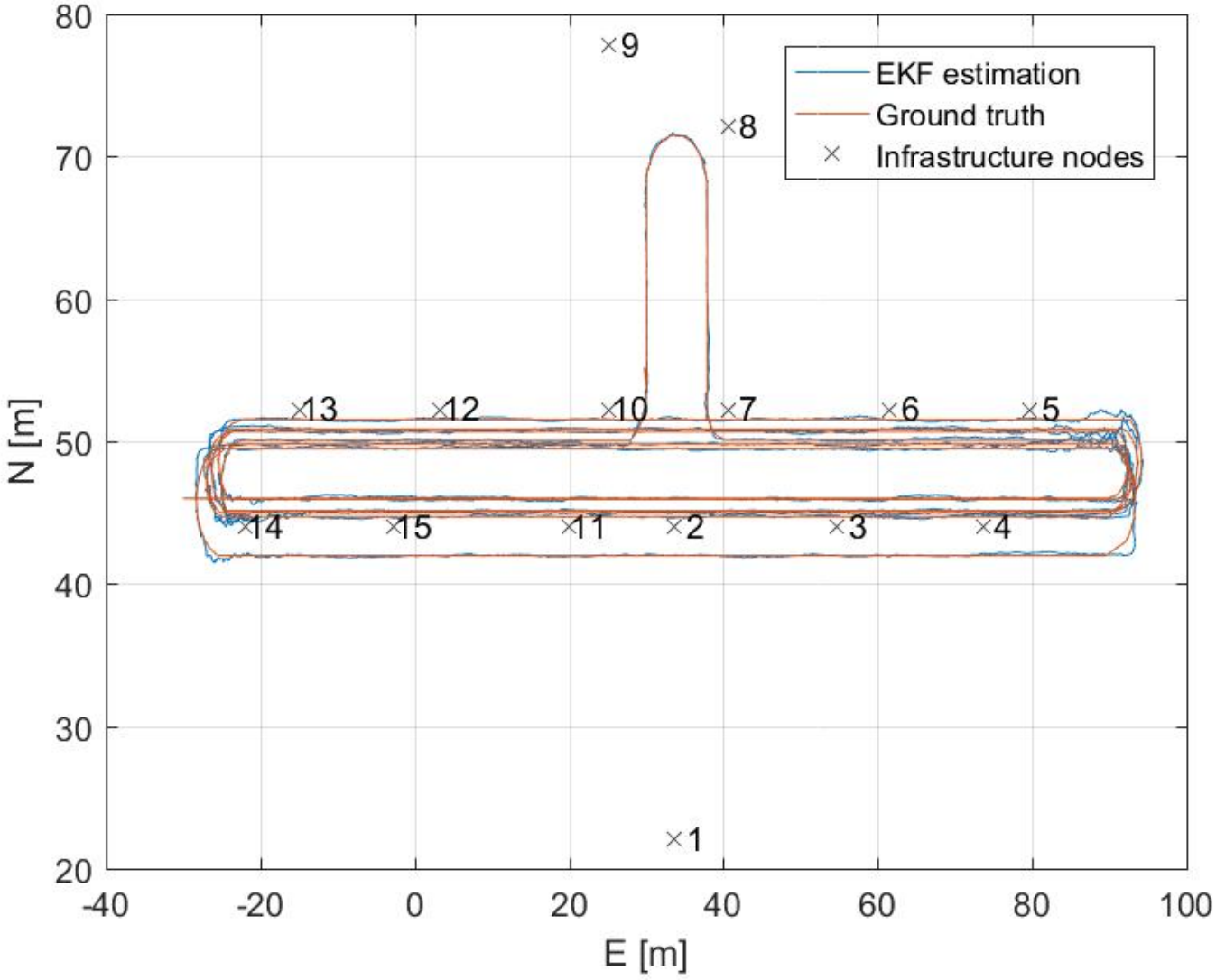
Results *(8)*

V-2-I + V-2-V cooperative positioning



Results *(9)*

V-2-I + V-2-V cooperative positioning



Conclusions and future work

- Theoretically best performance
  - In turns $\Rightarrow$ less than 40 cm
  - On straight parts $\Rightarrow$ $\sim$10 cm
- Promising start in developing a cooperative positioning system appropriate for ITS
- Fixed network of infrastructure nodes helps to constrain the accuracy of solution
- ITS = real-time application $\Rightarrow$ trustworthiness!
- In future:
  - Integrating existing solution with IMU
  - Modify EKF - GNSS pseudoranges
  - Experimental validation and evaluation based on collected data

Thank you!