Title

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Ultimate Navigation Chip: Synthetic Aperture Navigation with Cellular Signals and IMU

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Motivation

- Americans spend, on average, 90% of their time indoors
- No single infrastructure-free technology exists today that provides submeter-level or meter-level localization indoors

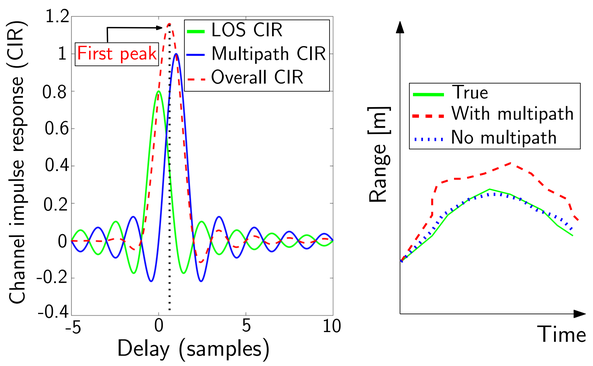
Our Approach

Exploit cellular long-term-evolution (LTE) signals of opportunity due to their inherent desirable characteristics:

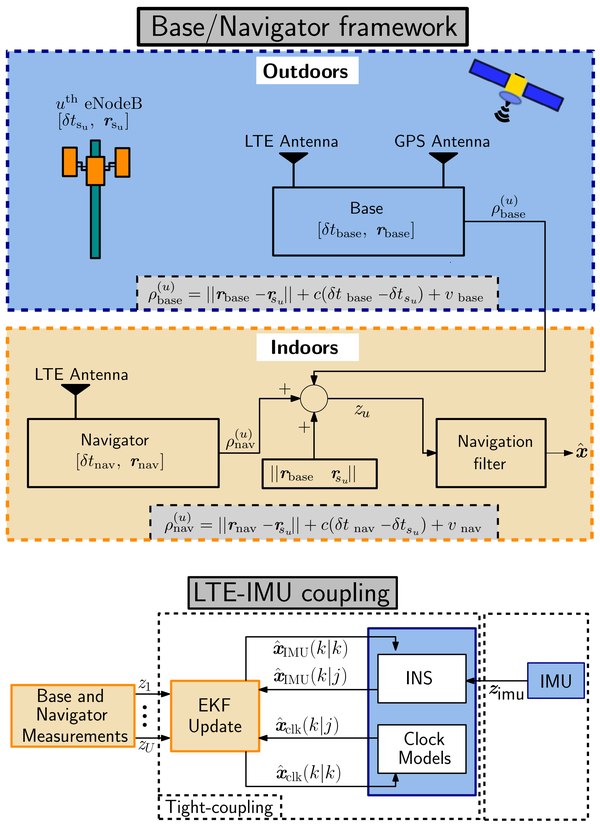
- **High received carrier-to-noise-ratio**: $C/N_0 \approx$ 55-80 dB-Hz in different indoor environments
- **Free to use**: exploit LTE reference signals (dataless) without being a subscriber
- **Abundant**: dozens of nearby eNodeBs corresponding to different providers are available
- **High bandwidth**: up to 20 MHz and even higher with LTE-Advanced (up to 100 MHz)
- **Favorable geometry**: geometrically diverse by construction to provide maximum communication coverage

Challenges

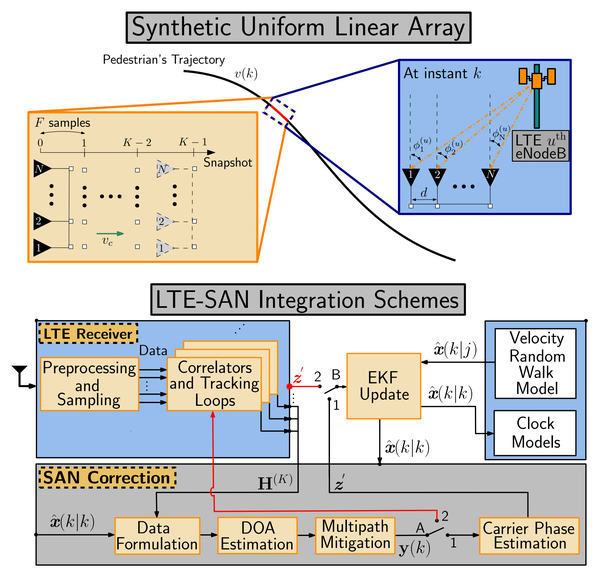
- Unknown eNodeBs' states (position, clock bias, and clock drift)
- LTE eNodeBs' clocks are less stable than GNSS clocks and not perfectly synchronized
- Short-delay multipath



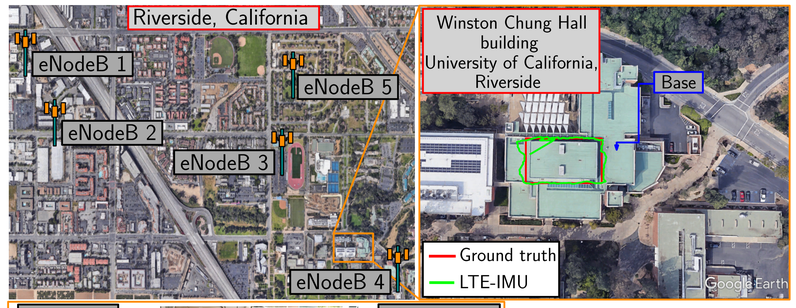
Framework 1: LTE-IMU

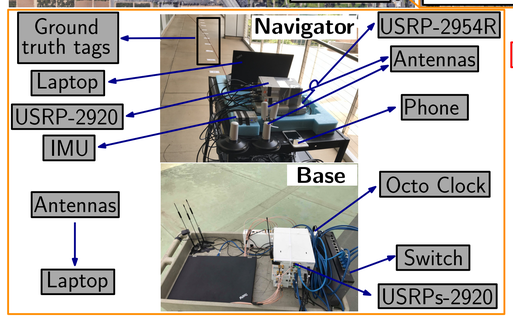


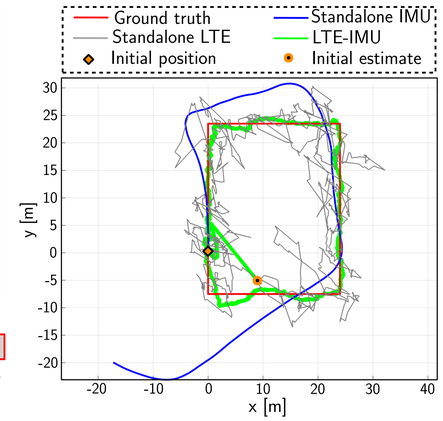
Framework 2: LTE-SAN



Experiment 1: LTE-IMU





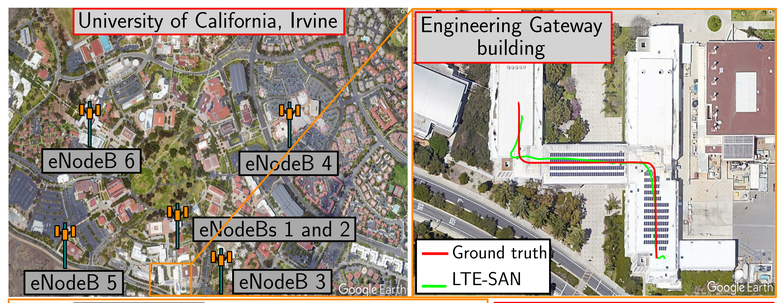


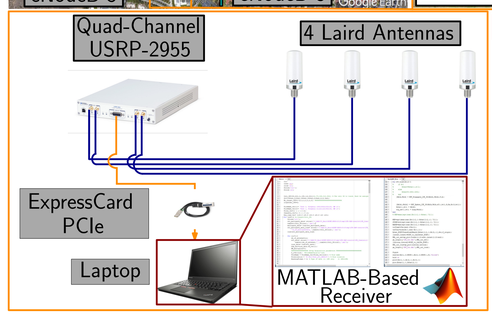
LTE eNodeBs' Characteristics

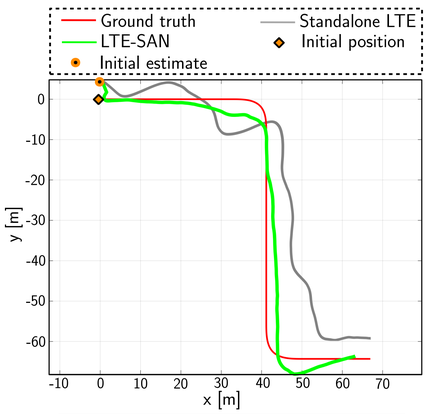
eNodeB	Cellular provider	Bandwidth [MHz]
1	AT&T	10
2	T-Mobile	20
3	AT&T	20
4	T-Mobile	20
5	Verizon	10

Performance Measure [m]	Standalone IMU	Standalone LTE	LTE-IMU
RMSE	9.48	5.09	2.92
Standard deviation	10.36	5.66	2.74
Maximum error	22.53	14.24	5.60

Experiment 2: LTE-SAN







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4	AT&T	20
5	T-Mobile	20
6	AT&T	20

Performance Measure [m]	Standalone LTE	LTE-SAN
RMSE	7.19	3.93
Standard deviation	3.32	1.65
Maximum error	12.89	5.63

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