Title

Vehicular navigation with cellular CDMA signals

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Vehicular Navigation with Cellular CDMA Signals

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Motivation

The global navigation satellite system (GNSS) is at the heart of autonomous vehicles navigation systems. However, GNSS signals are unreliable due to:

- Severe attenuation in deep urban canyons
- Intentional and/or unintentional jamming
- Spoofing!

Approach: Exploit SOPs

Ambient signals of opportunity (SOPs) may enhance and assist conventional navigation techniques.

Challenges

- **Unavailability of SOP models for navigation purposes**
- **Unavailability of receiver architectures for navigation observables extraction**
- Unavailability of most SOP emitters' states (position and clock)
- Substantially lower clock stability compared to GNSS satellite vehicles clocks

Cellular CDMA as SOP

- Uses code division multiple access (CDMA), which is good for ranging
- Abundant and free to use
- Higher received power and bandwidth than GNSS

CDMA Receiver Stages

A three-stage cellular CDMA software-defined radio (SDR) has been implemented in order to extract the "pseudorange", ρ, and the base transceiver station (BTS) information.

1-Acquisition Stage

Signals from different BTSs are identified and a coarse estimate of their corresponding code delay and Doppler frequency is obtained.

2-Tracking Stage

The code delay and Doppler frequency estimates are maintained and refined using tracking loops. The pseudorange is also calculated.

3-Decoding Stage

The message transmitted by the BTS is decoded and information that can be used for navigation is extracted.

Navigation Solution

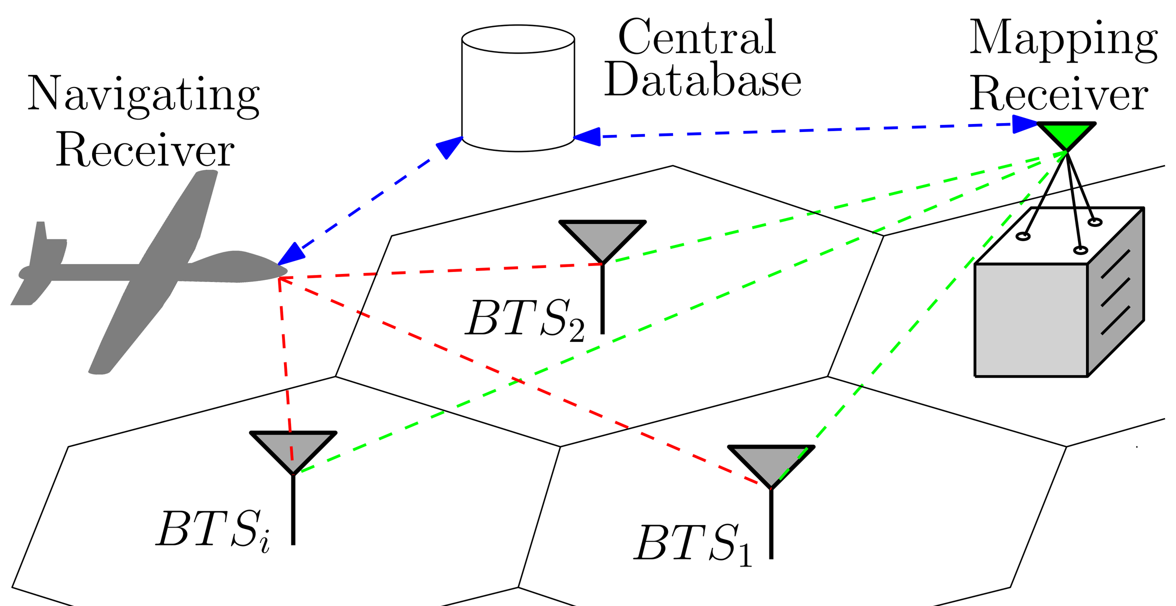
To estimate the position of the receiver and its clock bias, $\boldsymbol{r}_r$ and δt_r, respectively, a weighted least-squares (WLS) problem with pseudorange measurements from 4 or more BTSs is solved.

Pseudorange Model

Under measurement noise v, ρ is given by

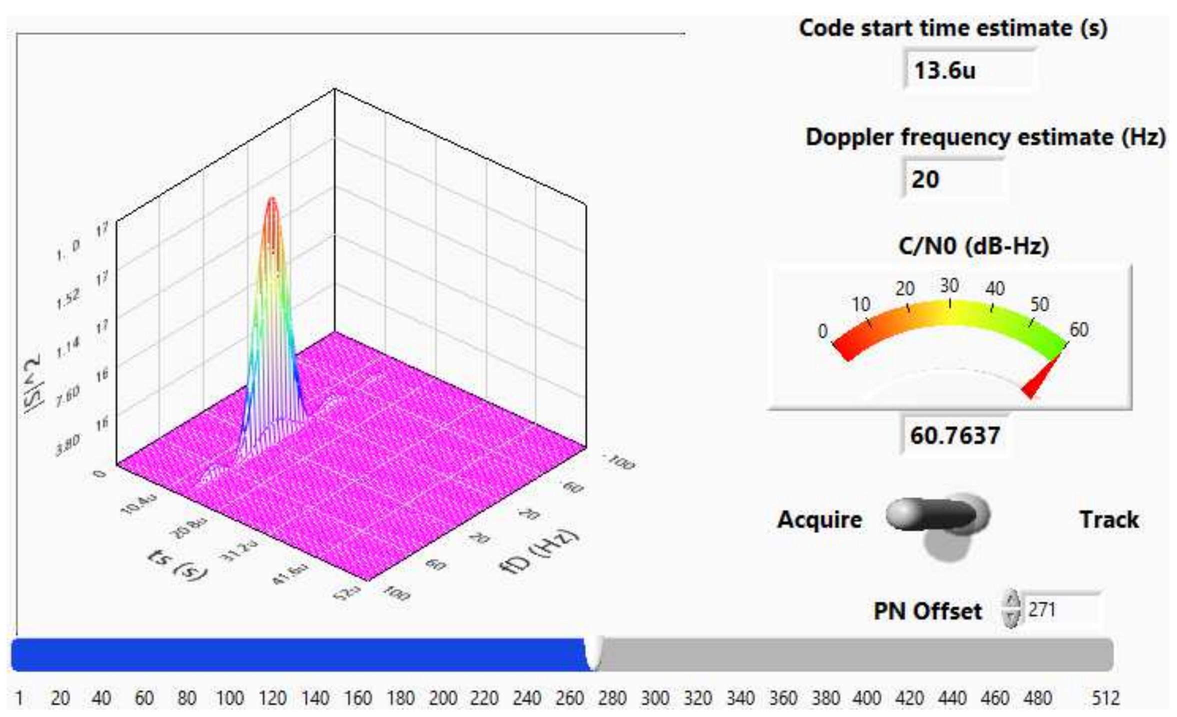
$$\rho = ||\boldsymbol{r}_r - \boldsymbol{r}_{BTS}||_2 + c \cdot (\delta t_r - \delta t_{BTS}) + v.$$

The position of the BTS, $\boldsymbol{r}_{BTS}$, and the pseudorange, ρ, are known. The clock bias of the BTS, δt_{BTS}, is also needed to solve for the receiver's state. It can be estimated either in a mapping/navigating receiver framework or in a simultaneous mapping and localization (SLAM) framework.

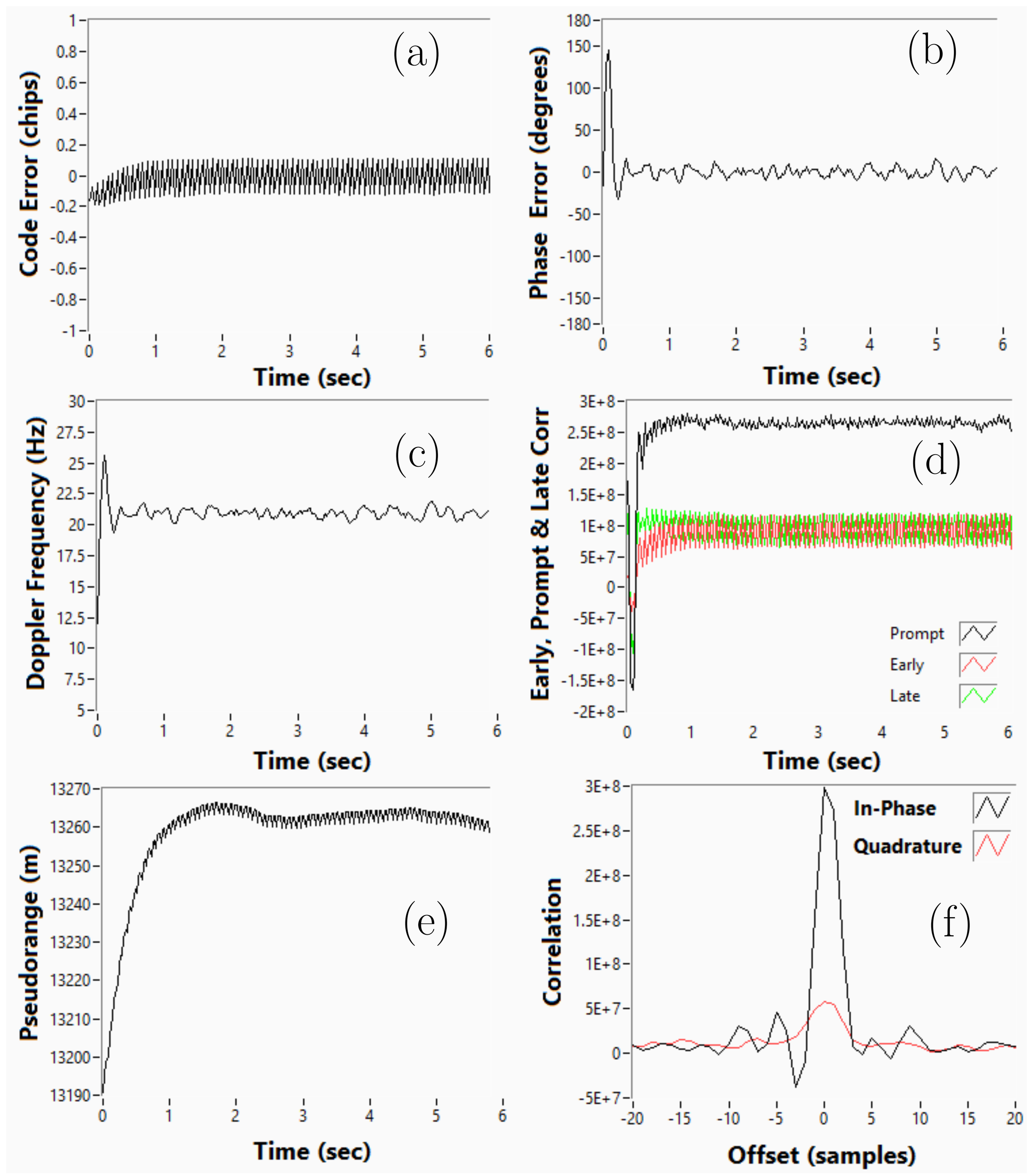


LabVIEW-Based CDMA SDR

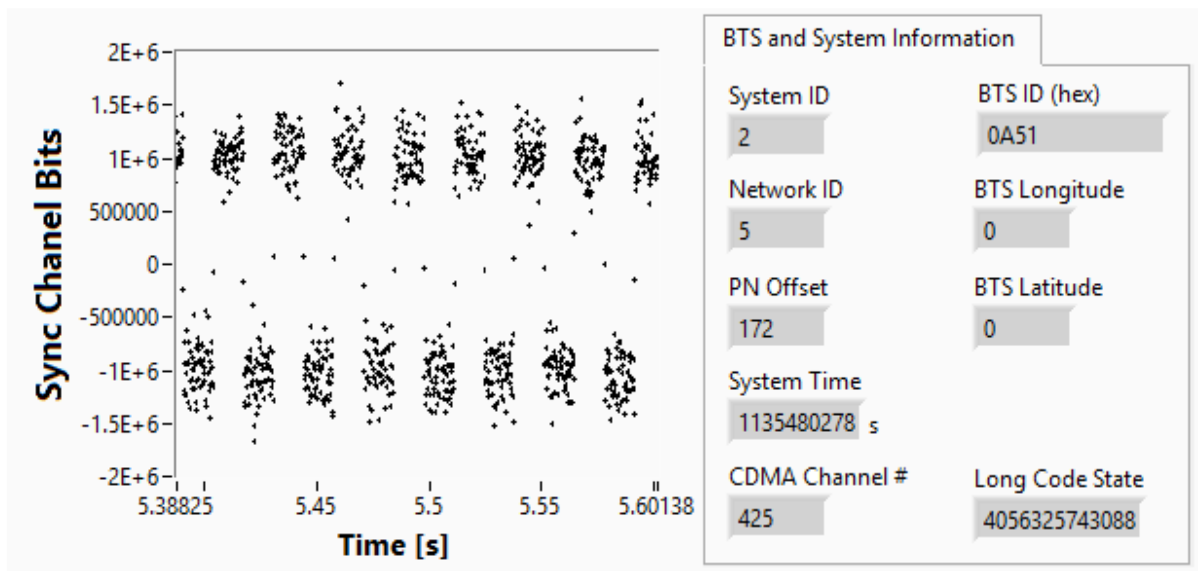
1-Acquisition



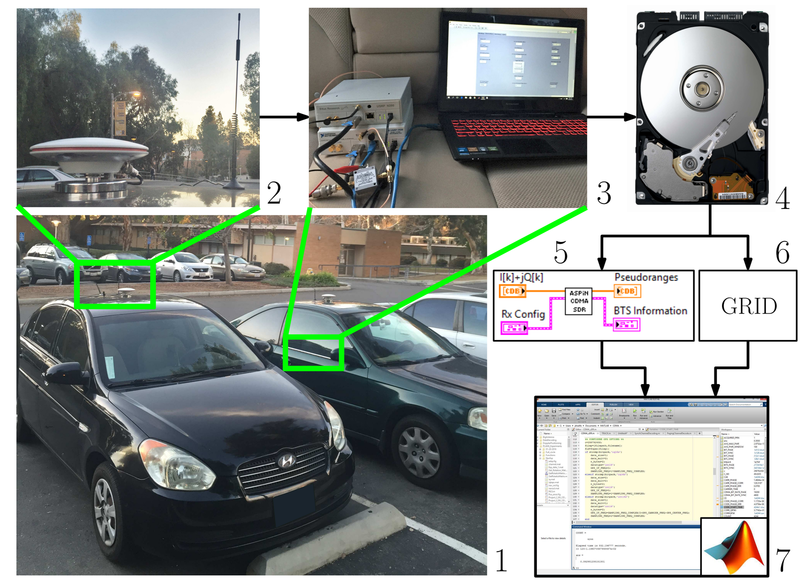
2-Tracking

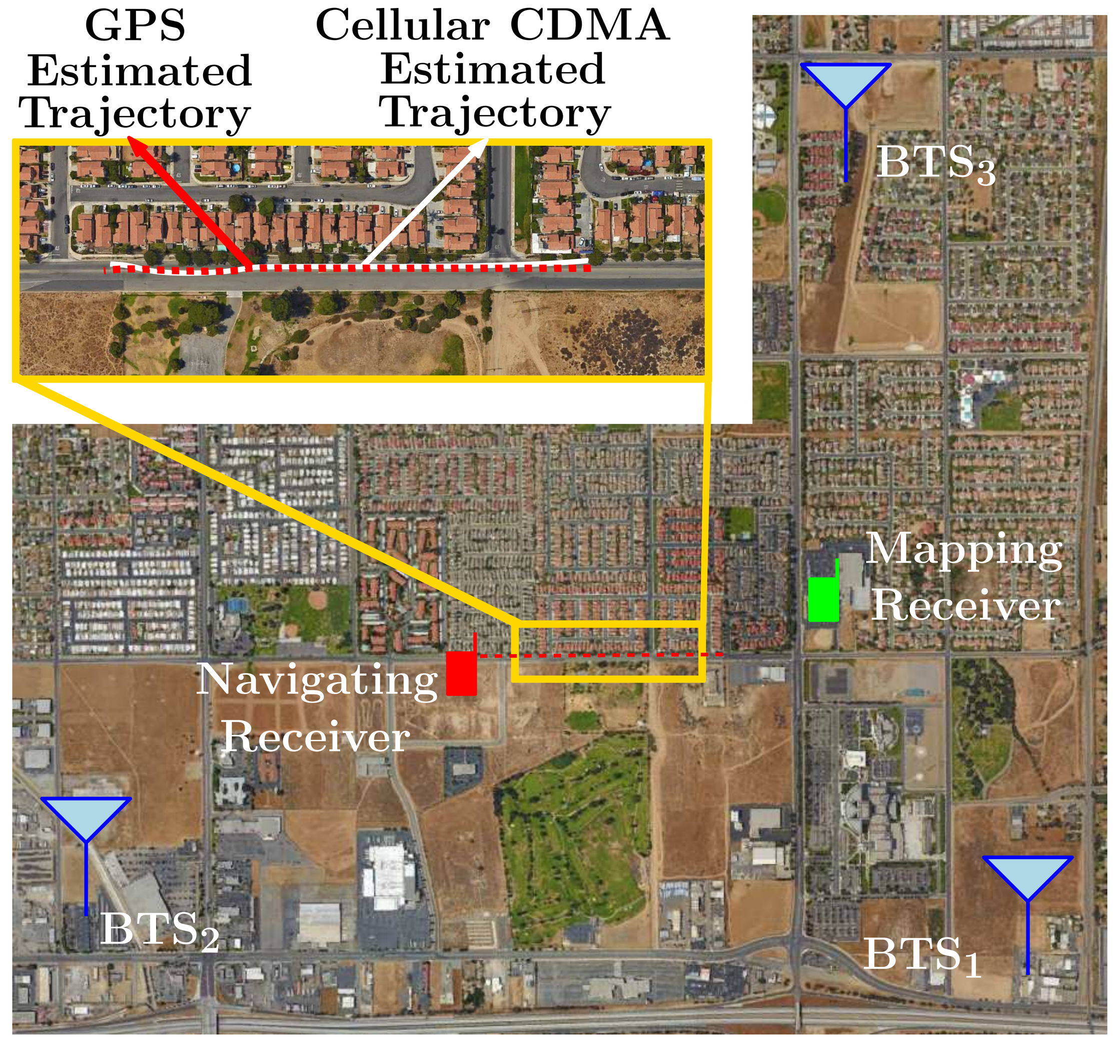


3-Decoding

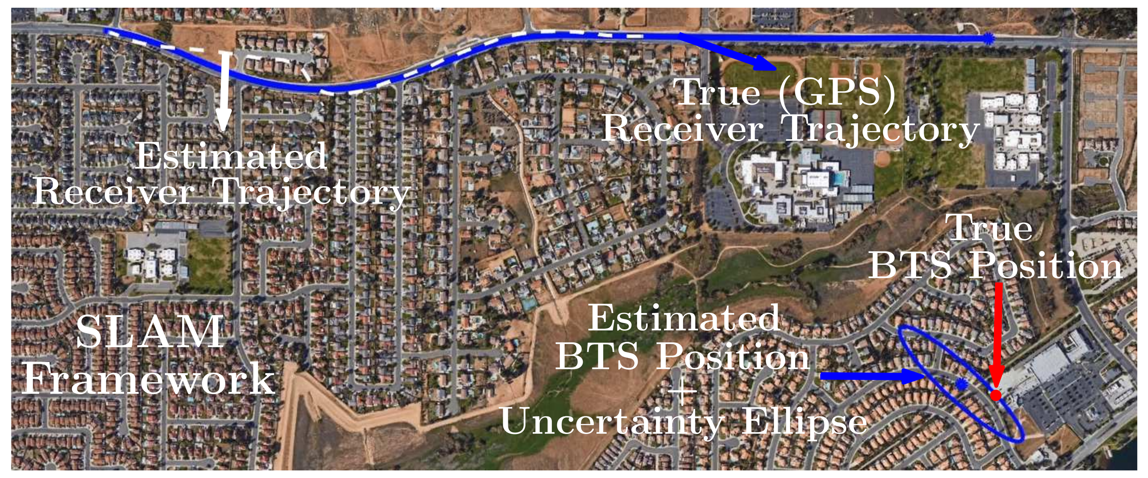


Experimental Demo





Mean Error: 5.51 m Standard Deviation: 4.01 m



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[2] J. Morales and Z. Kassas, "Optimal receiver placement for collaborative mapping of signals of opportunity," in *Proceedings of ION GNSS Conference*, September 2015, pp. 2362–2368.

[3] J. Khalife, K. Shamaei, and Z. Kassas, "A software-defined receiver architecture for cellular CDMA-based navigation," in *Proceedings of IEEE/ION Position, Location, Navigation Symposium*, April 2016.

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[1] K. Pesyna, Z. Kassas, J. Bhatti, and T. Humphreys, “Tightly-coupled opportunistic navigation for deep urban and indoor positioning,” in *Proceedings of ION GNSS Conference*, September 2011, pp. 3605–3617.

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