Positioning in NB-IoT Systems Based on TDOA Measurements

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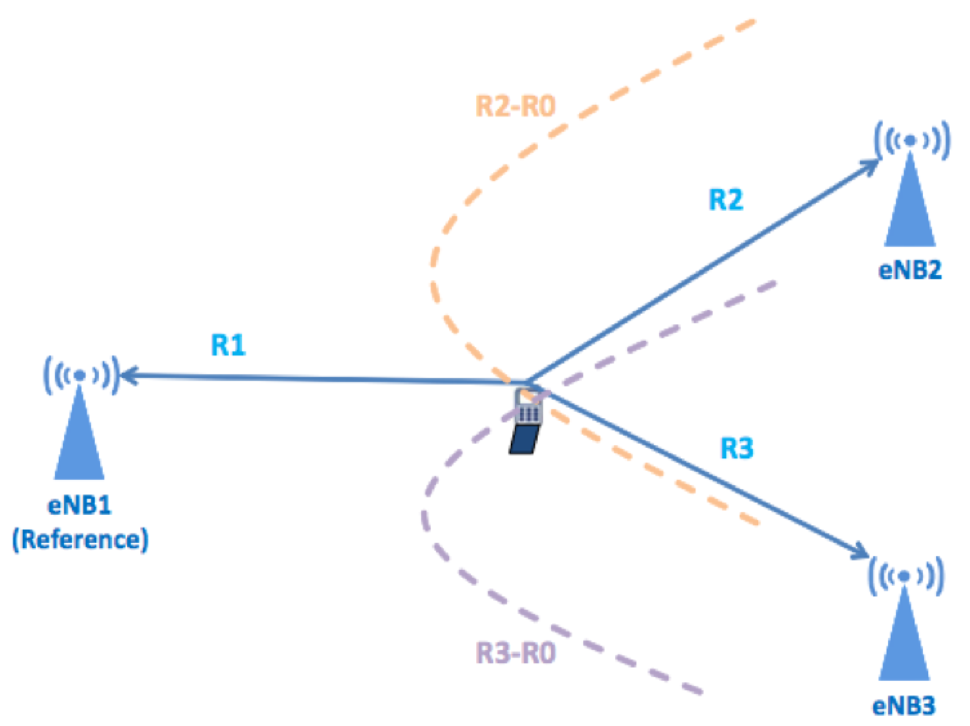
Contribution

The potential of device tracking in narrowband internet of things (NB-IoT) systems using observed time difference of arrival (OTDOA) measurements is evaluated. The reference signals for the timing measurement estimates are assumed to be reported from the user equipment (UE) to the location center periodically or on an on-demand basis. Wireless channels are modeled considering multipath fading propagation conditions. Extended Pedestrian A (EPA) and Extended Typical Urban (ETU) delay profiles corresponding to low and high delay spread environments, respectively, are simulated for this purpose.

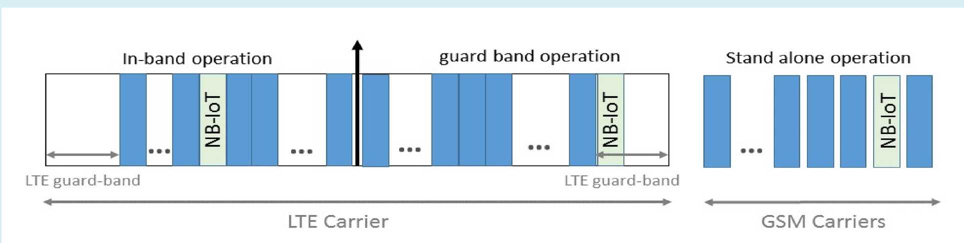
Background

Long term evolution (LTE) Release 14 enhancements: OTDOA positioning support based on reference signal time difference (RSTD).

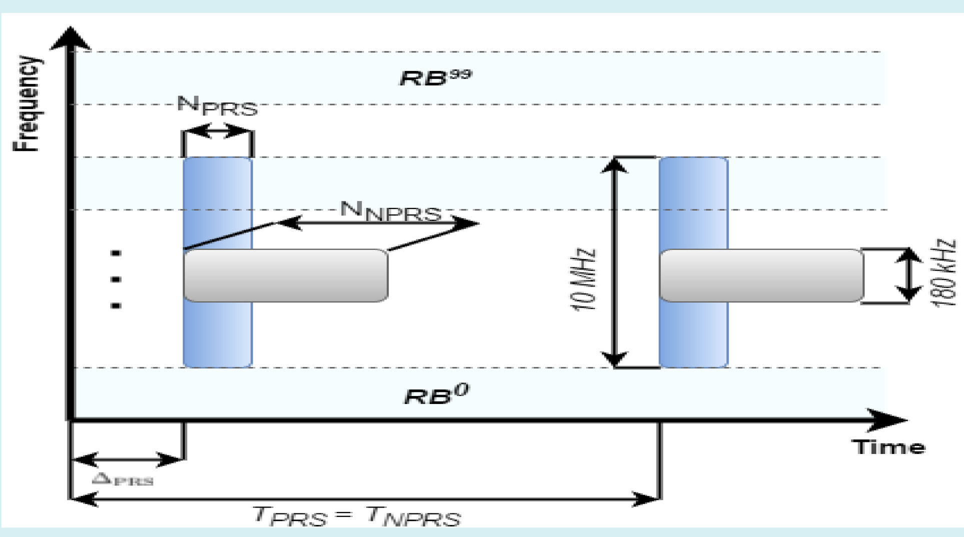


NB-IoT

- Design specifications: low device complexity, low power consumption, cheap devices.
- Deployment: three different alternatives



- Positioning reference signal



- Comparison with legacy LTE

System	N_{PRS}	T_{PRS} [ms]
LTE	1, 2, 4, 6	160, 320, 640, 1280
NB-IoT	10, 20, 40, 80, 160, 320, 640, 1280	160, 320, 640, 1280

Estimation

Estimating Propagation Delay

Channel model with L multipath taps is given by

$$h(t) = \sum_{l=0}^{L-1} \alpha_l \delta(t - \tau_l), \tag{1}$$

where α_l is the amplitude and τ_l is the time delay of the l-th tap. The received sequence becomes

$$y[i] = h[i] \star x[i] + w[i], \tag{2}$$

$$R(\tau) = \sum_{i=0}^{N_w-1} y[i]x^*[i-\tau], \tag{3}$$

where N_w is the search window for positioning and $(\cdot)^*$ denotes the complex conjugate. The first tap is detected with the predetermined threshold value ζ.

$$R_{\text{ave}}(\tau) = \frac{1}{|S|}\sum_{s\in S}|R_s(\tau)|, \tag{4}$$

$$\hat{\tau} = \arg\min_{\tau} \left\{ \frac{R_{\text{ave}}(\tau)}{\max\{R_{\text{ave}}\}} \geq \zeta \right\}. \tag{5}$$

State-Space Model

Measurements collected from eNBs with known locations $\boldsymbol{\ell}^i, \boldsymbol{\ell}^j$

$$\mathbf{x}_k = \boldsymbol{F}\boldsymbol{x}_{k-1} + \boldsymbol{\omega}_k \tag{6a}$$

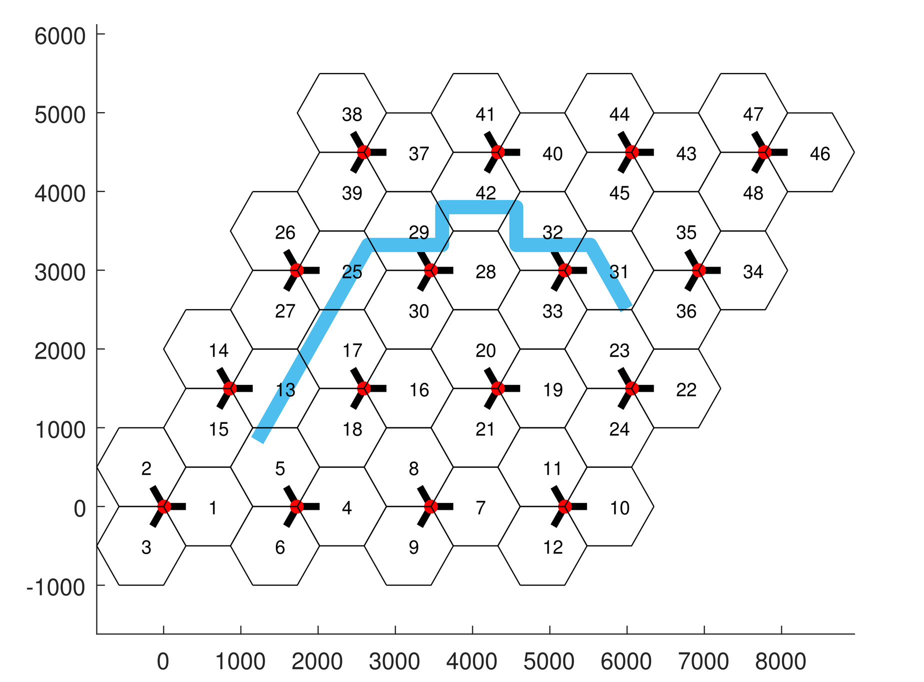
$$\mathbf{y}_k = \mathbf{h}(\boldsymbol{x}_k) + \boldsymbol{e}_k, \tag{6b}$$

$$h(\boldsymbol{x}_k) = \|\boldsymbol{x}_k - \boldsymbol{\ell}^i\| - \|\boldsymbol{x}_k - \boldsymbol{\ell}^j\|, \tag{6c}$$

$$\boldsymbol{e}_k \sim \mathcal{N}(\mathbf{0}, \boldsymbol{R}_k), \boldsymbol{\omega}_k \sim \mathcal{N}(\mathbf{0}, \boldsymbol{Q}_k). \tag{6d}$$

Simulation study

	Deployed NB-IoT
System carrier bandwidth	20MHz
NB-IoT configuration	In-band
NB-IoT carrier bandwidth	180KHz
Number of consecutive NPRS	40
NPRS period	160ms

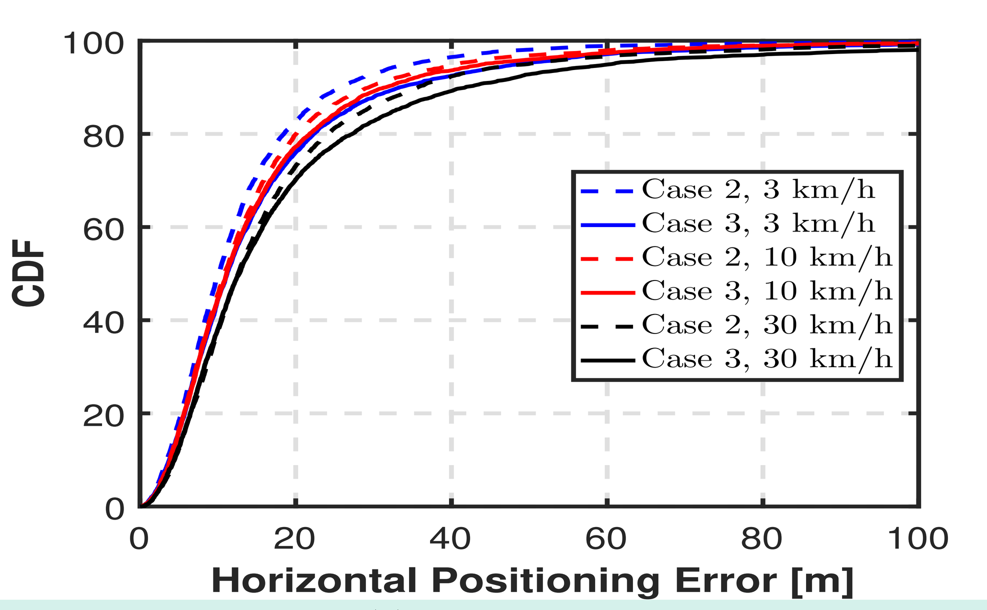


RSTD reporting schemes

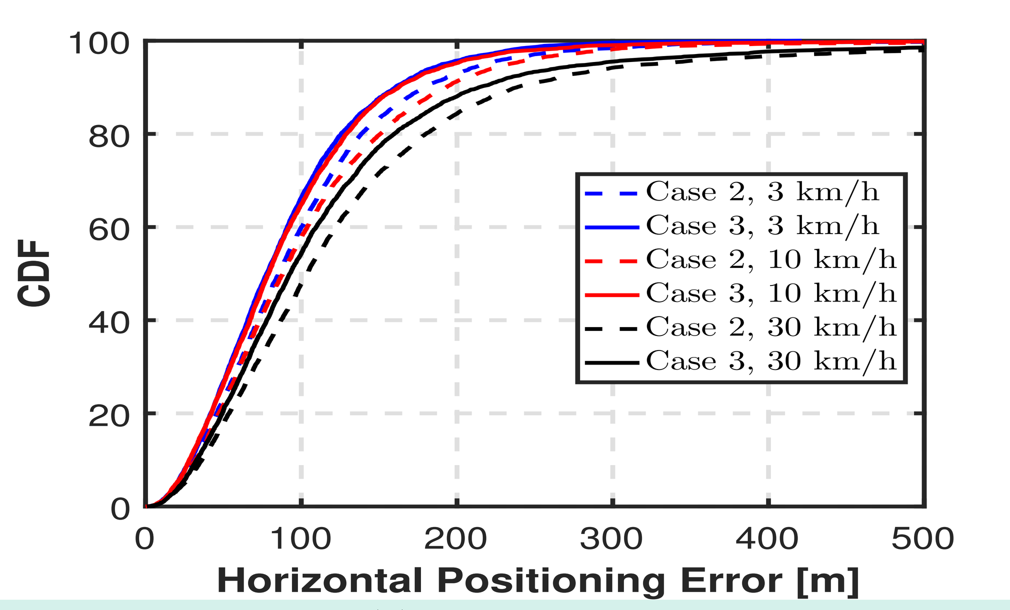
- **Case 1:** Two reports every two seconds.
- **Case 2:** Three reports every three seconds.
- **Case 3:** Five reports every four seconds.
- **Case 4:** The UE increases the accuracy by forming more RSTD reports if SNR values of available cells are above a certain threshold. However, it cannot exceed 85 reports per minute.
- **Case 5:** Varying number of reports every four seconds. The UE has a maximum budget 45 reports per minute and depending on the SNR values, reports less or more cells to optimize resource consumption.

Performance Evaluation

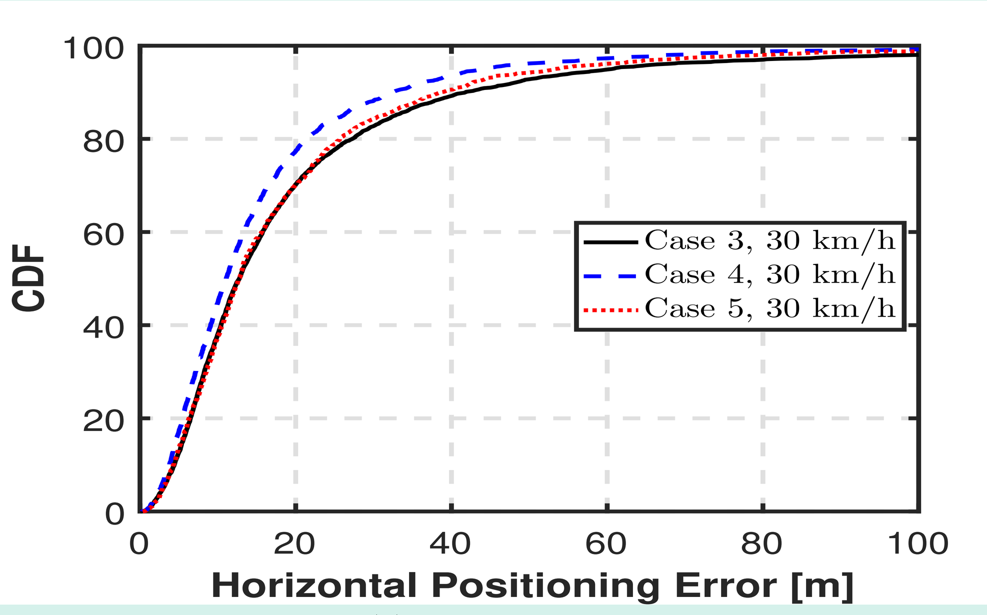
The results indicate that, using an on-demand reporting scheme, a decent position accuracy can be achieved despite the narrow bandwidth of the channel.



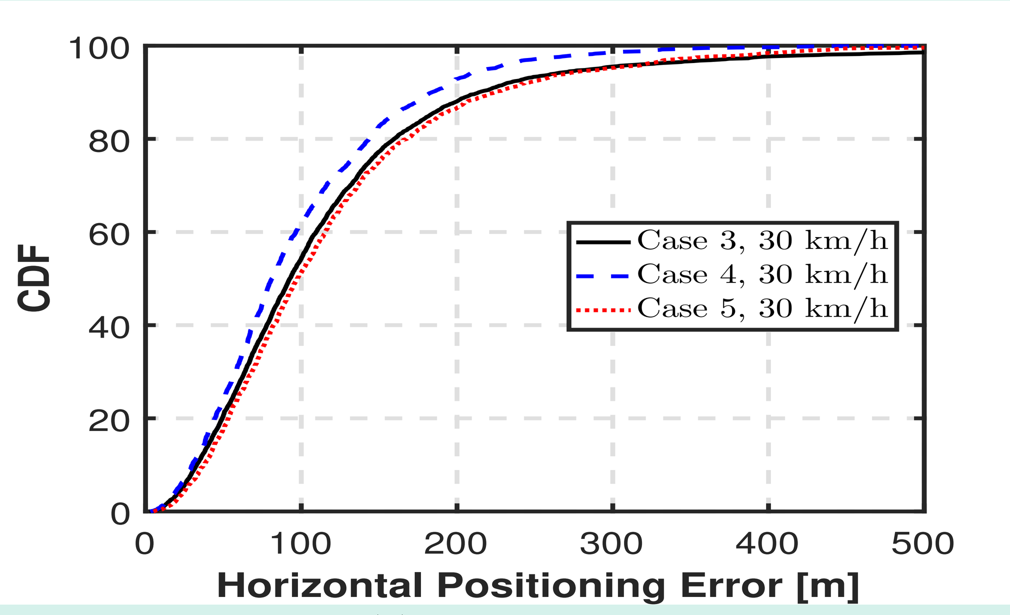
(a) Channel: EPA



(b) Channel: ETU



(c) Channel: EPA



(d) Channel: ETU

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