RINGS: Resilient and Low-Latency Networks for Situation Awareness in the Factory of the Future

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Annual Report

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1 Blockage Intelligence for Beyond 5G Localization in IIOT

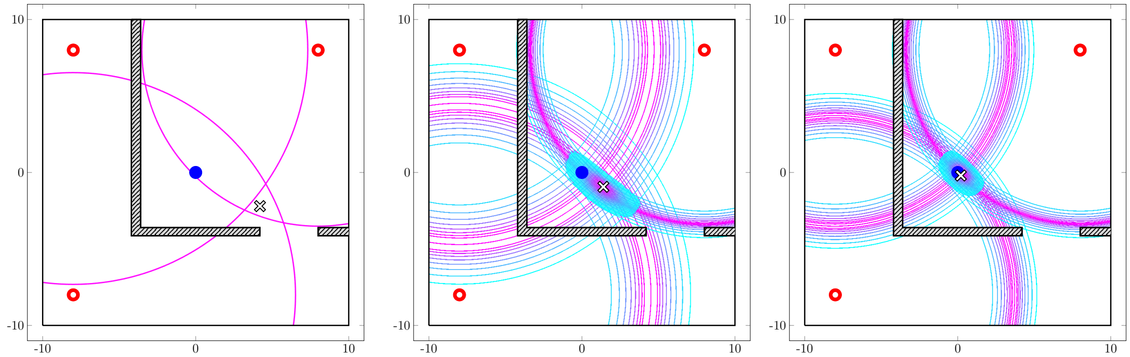
1.1 Technical Approaches

Location awareness is a key enabler for a myriad of applications in fifth generation (5G) and beyond wireless networks, including autonomy, smert environments, assets tracking, and Internet-of-Things (IoT). In particular, with the rapid transition towards Industry 4.0, the interest in accurate localization for Industrial IoT (IIoT) applications is increasing rapidly [1].

However, fulfilling the 3rd Generation Partnership Project (3GPP) localization requirements for IIoT applications is particularly challenging. Industrial sites are complex wireless environments, typically characterized by a large number of metallic surfaces and machines, which determine heavy multipath propagation and frequent non-line-of-sight (NLOS) conditions. This calls for the development of enhanced localization algorithms that provide accurate location information in impaired and highly cluttered wireless scenarios.

In this context, 3GPP study items for Release 18 are investigating the use of machine learning and artificial intelligence to improve sensing and communication capabilities of 5G networks. The support to machine learning solutions is fundamental to enable more effective algorithms for localization in 5G networks [2]. In particular, soft information (SI)-based localization can effectively leverage machine learning techniques to overcome the limitations of conventional localization algorithms. Specifically, SI-based localization makes use of probabilistic models to characterize the relationship among measurements, contextual information, and user equipment (UE) positions. To improve the localization performance of SI-based localization, NLOS identification techniques can be employed [3].

However, conventional NLOS identification techniques provide a binary information that is not able to represent the different propagation conditions that may generate NLOS conditions. Moreover, the prior geometrical or statistical characterization of the wireless environments typically required by such methods is not always available. Therefore, it is necessary to develop more effective NLOS identification



(a) Conventional localization **(b)** SI-based localization **(c)** SI-based localization with BI

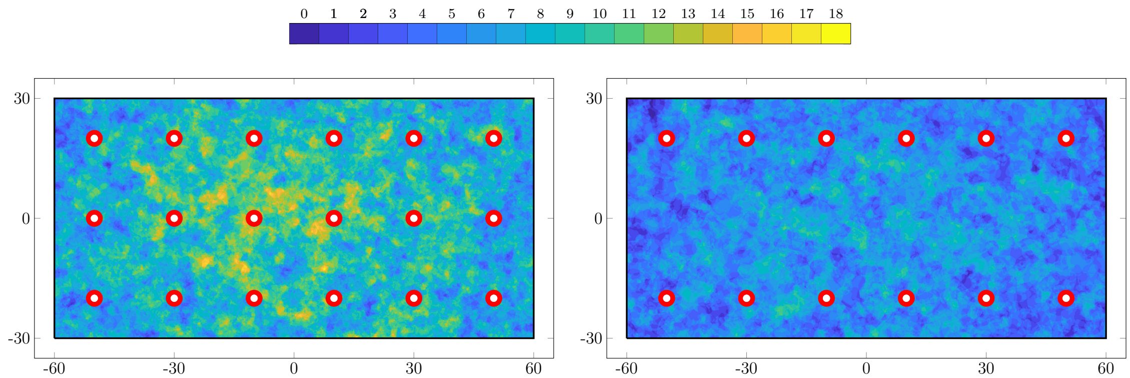
Figure 1: Pictorial view of single-value estimate (SVE)-based localization versus SI-based localization and SI-based localization with blockage intelligence (BI) considering time-of-arrival (TOA) measurements. A red annulus indicates a gNodeB (gNB), the blue circle indicates the real UE position and the cross indicates the estimated position. The coordinates on the axes are in meters.

techniques that are able to provide richer and more flexible positional information.

To overcome these limitations, we propose the concept of BI. The key idea of BI is to leverage the rich information encapsulated in 5G reference signals for localization to provide a probabilistic characterization of wireless propagation conditions. Accordingly, we advocate that the integration of BI in the SI framework is able to provide a new level of accuracy for localization in 5G and beyond complex industrial wireless environments. A pictorial view of the effect of the integration of BI in the SI-based localization algorithm and a comparison with conventional localization approaches are reported in Fig. 1.

1.2 Results

In this section, the results on the integration of BI in localization algorithms are reported. The results were obtained in full conformity with 3GPP technical specifications and reports. Specifically, the results were obtained in the 3GPP-standardized indoor factory (InF)-DH scenario in frequency range 1 (FR1) [4]. The 5G reference



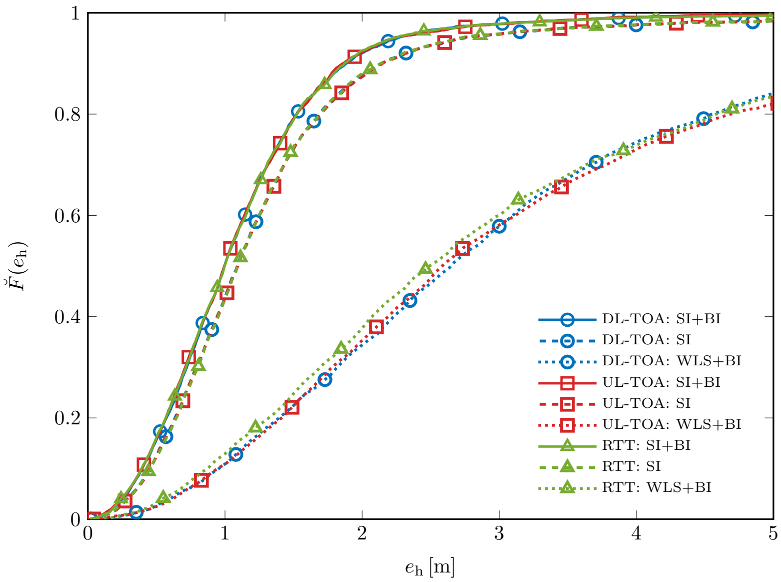
(a) InF-DH Case I

(b) InF-DH Case II

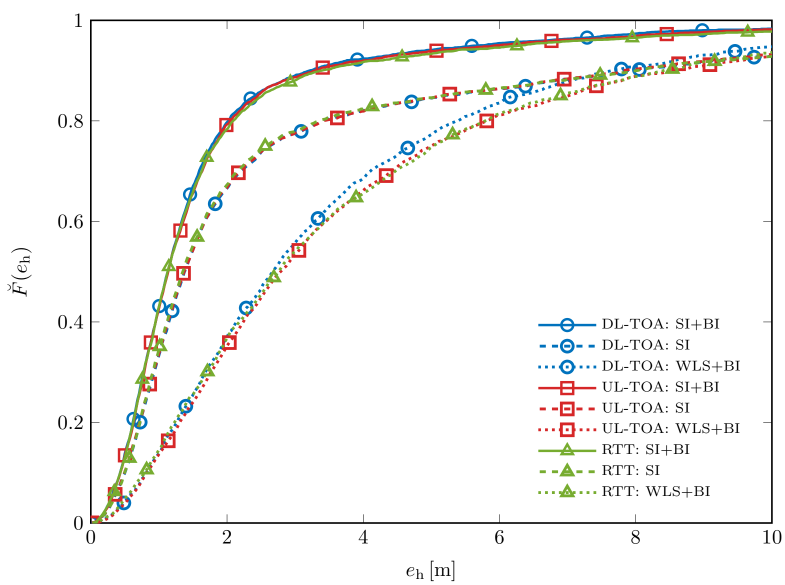
Figure 2: Examples of LOS maps for 3GPP (a) InF-DH Case I scenario, and (b) InF-DH Case II scenario. The colormap indicates the number of gNBs in line-of-sight (LOS) conditions for each position in the map. A red annulus indicates a gNB position. The coordinates on the axes are in meters.

signals (RSs) (i.e., the positioning reference signal (PRS) for downlink (DL) localization and the sounding reference signal (SRS) for uplink (UL) localization) were transmitted at 3.5 GHz with 100 MHz bandwidth. Results were obtained in terms of empirical cumulative distribution function (ECDF) $\breve{F}(e_{\mathrm{h}})$ of the horizontal localization error e_{h}, for two different case studies in the InF-DH scenario. Specifically, Case I consists of the baseline configuration in [4] with 18 gNBs (see Fig. 2a), while Case II considers a different deployment where only 12 gNBs of the original layout are available (see Fig. 2b). All the specifications for the simulations were set according to [5]. Results are reported for localization based on DL-TOA, UL-TOA, and round-trip time (RTT) measurements with (i) SI-based localization; (ii) SI-based localization with BI; and (iii) weighted least squares (WLS)-based localzization using BI to assign weights to the gNBs measurements

Fig. 3a shows the ECDF of the horizontal localization error for Case I. It can be observed that WLS-based localization with BI provides an accuracy of around 6 m at the 90th percentile for all the measurements considered. Moreover, it can be observed that SI-based localization, even without BI, outperforms WLS-based localization for all the configurations considered. The use of BI in SI-based localization enables



(a)



(b)

Figure 3: Localization performance in FR1. The performance is reported in terms of ECDF of the horizontal localization error for (a) InF-DH Case I; and (b) InF-DH Case II.

further improvement. In particular, at the 99th percentile, the localization error is reduced from around 7 m to less than 4 m for all the measurements considered. Note that very similar performance is obtained with localization based on DL-TOA and on UL-TOA despite the lowest transmitted power of SRS. Similar performance is also obtained considering localization based on RTT measurements.

Fig. 3b shows the ECDF of the horizontal localization for Case II. It can be observed that WLS-based localization with BI provides performance comparable to the ones obtained with SI-based localization at the percentiles over the 90th for all the measurements considered. However, if BI is integrated in SI, a significant performance gain of more than 4 m is noticeable for all the measurements considered, passing from around 8m to less than 3.5 m at the 90th percentile.

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