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Volume 06, Issue 01, Pages: 95-103

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Fingerprint based Localization for Massive MIMO-OFDM System with Deep Convolutional Neural Networks

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***Abstract*-**Fingerprint technique is a promising enabler formobile terminals (MTs) localization in richscattering environments,such as urban areas and indoor corridors. In this paper,we investigatefingerprint based location for massive multipleinputmultiple-output (MIMO) orthogonalfrequency-divisionmultiplexing (OFDM) systems with deep convolutional neuralnetworks(DCNNs). By taking full advantage of the high resolutionin the angle domain and the delay domain in massive MIMOOFDMsystems, we first propose an efficient angle-delay channelamplitude matrix (ADCAM) fingerprint extraction method. Thena DCNN enabled localization method is proposed, in whichthe modeling error for fingerprint similarity calculation can beovercome. Both DCNN classification and DCNN regression areconsidered. For practical implementation, a hierarchical DCNNarchitecture is proposed. The performance of the proposed DCNNlocalization method is evaluated via simulation performed in ageometry-based ray tracing signal propagation scene. Numericalresults demonstrate that DCNN performs well in achieving highlocalization accuracy as well as reducing storage overhead andcomputational complexity.

I. Introduction

As the explosive growth of location-based applications (LBAs) on intelligent mobile terminals (MTs) as well as vehicles, such as navigation, self-driving cars and the internet of vehicles (IOV), wireless localization for MTs has gained significant attention [1], [2]. Most of the localization requirements from the LBAs emerge in the urban environment where the widely used global positioning system (GPS) suffers an accuracy loss since the line-of-sight (LOS) propagation from satellites to MTs is continually blocked by tall buildings. To integrate the mobile localization requirements into the future 5G wireless communication systems, fingerprint based localization in wireless communication systems is drawing increasing interest for its wide applicability and high costefficiency without any hardware requirement on the MTs [3]– [15]. Fingerprint based localization exploits the fact that the wireless channels from MTs to base stations (BSs) or access points (APs) are uniquely determined by the scattering environments around the locations of MTs. Therefore, some unique characteristics from a wireless channel corresponding to each location, referred to as a fingerprint, can be extracted. Then the localization problem can be solved as a pattern recognition problem including fingerprint extraction, fingerprint matching and location estimation. Two major types of wireless channel characteristics are frequently used as the fingerprint in previous works: the receive signal strength indication (RSSI) and the multipath characteristics. Depending on multiple access points cooperation, the use of the RSSI fingerprint is limited in indoor scenarios with rich AP distribution, such as wireless sensor network (WSN) [3], [4] and WiFi network [5]. Furthermore, the RSSI fingerprint suffers from the fast fading fluctuation resulting from the multipath propagation. Instead of suffering from the multipath propagation, the multipath characteristics take full advantage of the statistics of the multipath wireless channels, including angle-of-arrival (AOA) [6], power delay profile (PDP) [7] and the combination of them [8], [9]. A single BS can extract rich details from the multipath wireless channels by exploiting antenna array signal processing. As a consequence, fewer BSs equipped with multiple antennas are enough to assure the accuracy. In recent years, massive multiple-input multiple-output (MIMO) orthogonal frequency-division multiplexing (OFDM) systems have become one of the promising technologies for the upcoming 5G wireless communications for their enormous potential in spectral efficiency and power efficiency with simple signal processing [16]–[20]. Benefiting from the largescale antenna array, the BSs are able to acquire high resolution of multipath characteristics in the angle domain, especially for OFDM signals. Thus it is well motivated to implement fingerprint wireless localization in massive MIMO-OFDM systems. Although massive MIMO-OFDM systems enable highresolution fingerprint extraction, the relatively high storage and matching overhead impose a heavy burden on the database. The pattern recognition problem then comes to a classical problem in artificial intelligence (AI): how to teach the computing units in the BSs to recognize the most similar fingerprints? An intuitive solution is to model the similarity by a set of mathematical rules, which we have already adopted in our previous work in [21].

However, any mathematical model for an unknown similarity function may introduce modeling error. To overcome this issue, we employ deep learning to let the BSs learn the knowledge on fingerprint similarity by themselves. Deep convolutional neural networks (DCNNs) are trained based on the labeled fingerprints in the database and a hierarchy of concepts for fingerprint clustering is built. Various neural networks have been applied to fingerprint based localization. For indoor localization, Wang et al. [10], [22] applied deep neural networks (DNNs) to channel state information (CSI) phase fingerprints extracted from WiFi signals. By transforming the CSI into the image form, DCNNs were exploited in [23] and [24] for reference points (RPs) matching. In the outdoor scenario, Vieira et al. [25] provided a DCNN based regression localization system with CSI fingerprints for massive MIMO systems within a relatively small coverage area. In a typical cellular massive MIMO-OFDM system covering a large area, the DCNNs tend to be corpulent and inefficient since the number of categories for DCNNs increase with the coverage area. One of the complications comes with the massive categories is that the discrimination of different categories becomes highly uneven. To adapt DCNN to practical large area localization while retaining the high separability of dense categories, we propose a handcrafted hierarchical DCNN architecture. Both DCNN classification and DCNN regression are considered and evaluated in this paper. We now summarize our major contributions in three aspects. 1) We propose an angle-delay channel amplitude matrix (ADCAM) fingerprint extraction method and a corresponding mathematical model of fingerprint similarity criterion. The ADCAM fingerprint has three major advantages. First, the ADCAM fingerprint can be extracted easily from the CSI known to the BSs through fast Fourier transform (FFT). Second, the ADCAM has rich multipath information with clear physical interpretation. As the channel amplitude associated with the specific angle of arrival (AOA) and time of arrival (TOA), the ADCAM is thus wide-sense stationary from offline phase to online phase. Third, the ADCAM is sparse along both dimensions, consequently, the multipath characteristics can be easily captured by the DCNN. 2) We propose a DCNN enabled localization method and a hierarchical DCNN implementation architecture for massive MIMO-OFDM systems. A typical structure of DCNN used for fingerprint clustering is first

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described, followed by a detailed introduction of the feature learning module (referred to as CALP1). Then we propose a classification-based localization method and a regressionbased localization method, respectively. Further, a hierarchical DCNN architecture is proposed for implementation. 3) We evaluate the performance of the proposed DCNN localization method via simulation performed in a geometry-based ray tracing signal propagation scene. Geographical correlation between fingerprints of two neighboring locations is considered and embodied in the CSI generating process. The rest of the paper is organized as follows. In Section II, the localization system architecture as well as the ADCAM fingerprint extraction method are presented. We also propose a corresponding mathematical model of fingerprint similarity criterion. In Section III, we propose a DCNN enabled localization method and a hierarchical DCNN implementation architecture. Both DCNN classification and DCNN regression are considered. In Section IV, we evaluate the performance of the proposed DCNN localization method via simulation performed in a geometry-based ray tracing signal propagation scene, and numerical results are provided to demonstrate the performance of the proposed localization method.

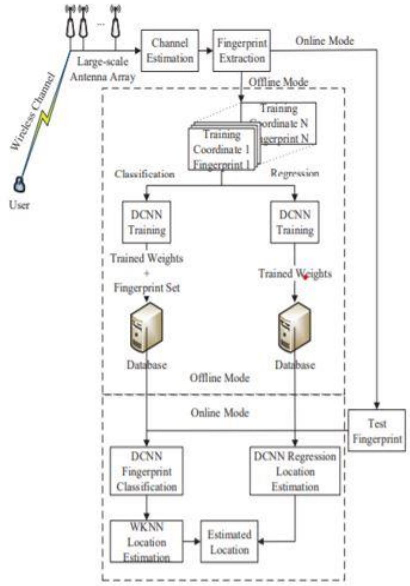

Fig 1: general system model of the fingerprint wireless localization method.

II. Existing Work or Literature Survey

Beixiong Zheng et al."Multiple-Input Multiple-Output OFDM with Index Modulation: Low-Complexity Detector Design", in this paper proposed two low-complexity detectors derived from the SMC theory for the MIMO-OFDMIM system. The first proposed subblock-wise detector draws samples at the subblock level, exhibiting near-optimal performance for the MIMO-OFDMIM system. The second proposed subcarrier-wise detector draws samples at the subcarrier level,

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exhibiting substantially reduced complexity with a marginal performance loss. An effective legality examination method has been also developed to couple with the subcarrier wise detector. Computer simulation and numerical results have validated the outstanding performance and the low complexity of both proposed detectors.

Ertugrul Basar et al."Multiple-Input Multiple-Output OFDM with Index Modulation", A novel scheme called MIMOOFDM with index modulation has been proposed as an alternative multicarrier transmission technique for 5G networks. It has been shown via extensive computer simulations that the proposed scheme can provide significant BER performance improvements over classical MIMO-OFDM for several different configurations. The following points remain unsolved in this study:

i) performance analysis,
ii) the selection of optimal N and K values,
iii) diversity techniques for MIMO-OFDM-IM, and

iv) Implementation scenarios for high mobility. Ertugrul Basar et al. "On Multiple-Input Multiple-Output OFDM with Index Modulation for Next Generation Wireless Networks", In this study, the recently proposed MIMO-OFDM-IM scheme has been investigated for next generation 5G wireless networks. For the MIMO-OFDM-IM scheme, new detector types such as ML, near-ML, simple MMSE, MMSE-LLR-OSIC detectors have been proposed and their ABEP have been theoretically examined. It has been shown via extensive computer simulations that MIMO-OFDM-IM scheme provides an interesting trade-off between complexity, spectral efficiency and error performance compared to classical MIMO-OFDM scheme and it can be considered as a possible candidate for 5G wireless networks. The main features of MIMO-OFDM-IM can be summarized as follows:

i) better BER performance,
ii) flexible system design with variable number of active OFDM subcarriers and
iii) Better compatibility to higher MIMO setups. However, interesting topics such as

diversity methods, generalized OFDM-IM cases, high mobility implementation and transmit antenna indices selection still remain to be investigated for the MIMO-OFDM-IM scheme.

Ertugrul Bas¸ et al. “Performance of Multiple-Input Multiple-Output OFDM with Index Modulation”, In this paper, proposed ML and near-ML detectors for the recently introduced MIMO-OFDM-IM scheme to improve its error performance compared to MMSE based detection. The ABEP upper bound of the MIMO-OFDM-IM scheme with ML detection has been derived and it has been shown that the derived theoretical upper bound can be used as an efficient tool to predict the BER performance of the MIMO-OFDMIM scheme. It has been shown via computer simulations that MIMO-FDM-IM scheme can provide significant improvements in BER performance over classical MIMO-OFDM using different type of detectors and MIMO configurations.

Beixiong Zheng et al. “Low-Complexity ML Detector and Performance Analysis for OFDM With In-Phase/Quadrature Index Modulation”, In this letter, we've planned a low-complexity detector supported the milliliter criterion, that dispenses with a priori data of the noise variance and also the potential realizations of the active subcarrier indices. supported the framework of OFDM-I/Q-IM using the planned milliliter detector, the straight line ABEP and also the actual coding gain achieved by OFDMI/Q-IM are derived, that absolutely matches the simulation results. Moreover, the exact coding gain including the spectral efficiency price has provided a clear plan of a basic trade-off between the system performance and also the spectral efficiency of OFDM-I/Q-IM by the adjustment of the quantity of active subcarriers.

Sheng Wu et al.“Low-Complexity Iterative Detection for Large-Scale Multiuser MIMO-OFDM Systems Using Approximate Message Passing”, For the detection of large-scale multiuser MIMO-OFDM systems, we have proposed a range

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of low-complexity approximate message passing algorithms that can offer desirable tradeoff between performance and complexity. It is verified through extensive simulations that our proposed approximate message passing algorithms can achieve near optimal performance with low complexity. Compared with existing turbo detection algorithms, the proposed schemes can achieve or even outperform the performance of some complex algorithms, such as the iterative decoding based on STS-SD and MMSESIC. In addition, the number of iterations required to achieve near-optimal performance is small and does not increase with the system dimension.

III. WRITE DOWN YOUR STUDIES AND FINDINGS(PROPOSED WORK)

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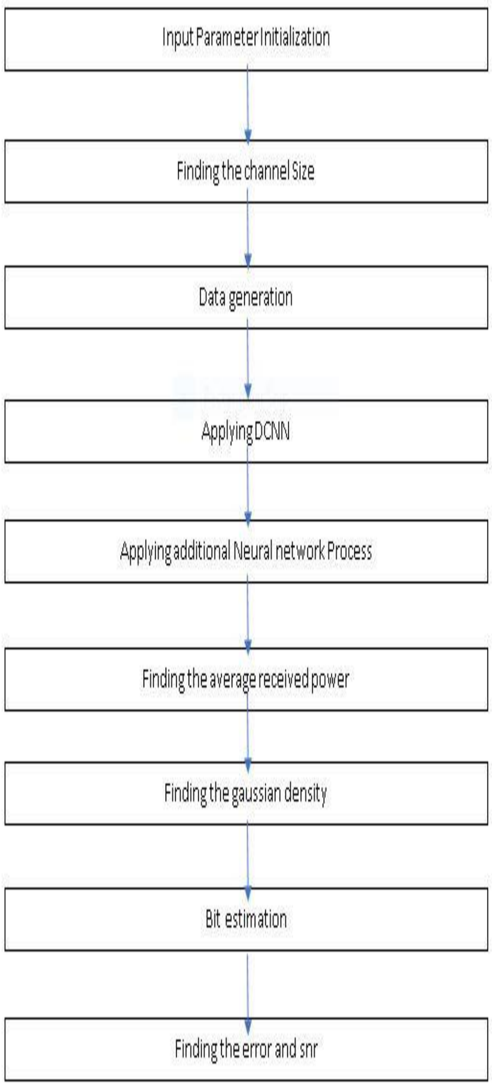
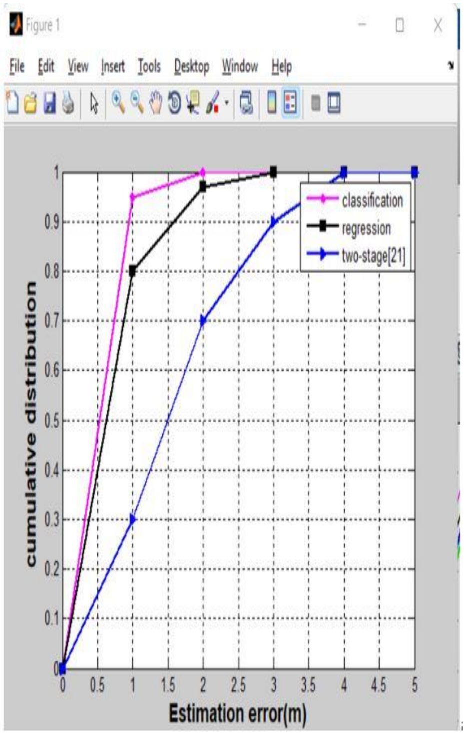


IV. RESULTS AND DISCUSSION(IF ANY)

In this section, we evaluate the performance of the proposed DCNN localization method via simulation performed in a geometry-based ray tracing signal propagation scene. First, we introduce the implementation of the simulation setup. After that, we deep dive into the DCNN localization method to evaluate the performance from multiple perspectives, including localization accuracy, time complexity, storage overhead and so on.



V. CONCLUSION

In this project, we have investigated fingerprint based location for massive MIMO-OFDM systems with DCNNs. By taking full advantage of the high resolution in the angle domain and the delay domain in massive MIMO-OFDM systems, we have first proposed an efficient ADCAM fingerprint extraction method. Then a DCNN enabled localization method has been proposed, in which the modeling error for fingerprint similarity calculation can be overcome. Both DCNN classification and DCNN regression have been considered. Further, we have first proposed a hierarchical DCNN architecture for practical implementation. The performance of the proposed DCNN localization method has been evaluated via simulation performed in a geometry-based ray tracing signal propagation scene. Numerical results demonstrate that DCNN performs well in achieving high localization accuracy as well as reducing storage overhead and computational complexity.

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