Synopsis Seminar

Seminar Title	: Deep Learning Aided Channel Feedback and Estimation in Massive MIMO Systems
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Venue	: ECE Seminar Room-EC303
Date and Time	: 16 Jun 2025 (4 P M)

Abstract

: The fifth-generation (5G) wireless access technology, known as New Radio (NR), aims to cater to diverse applications and usage scenarios, ranging from Enhanced Mobile Broadband (eMBB) and Ultra-Reliable and Low-Latency Communication(uRLLC) to Massive Machine Type Communication (mMTC). Massive multiple-input multiple-output (M-MIMO), where the base station (BS) employs a large number of antennas, is the prime technology of fifth-generation (5G) communication systems to satisfy these usage scenarios. M-MIMO antenna systems enable BS to operate with significant improvement in radiated energy and spectral efficiency by utilising less complex and simpler linear processing techniques. The enhancement in spectral efficiency is achieved by serving multiple terminals simultaneously within the same time-frequency resource using spatial multiplexing, while the improvement in energy efficiency results from the array gain provided by the large number of antennas at the BS. Most of the practical systems operate using frequency division duplexing (FDD), and FDD systems lack the principle of channel reciprocity as the transmission of downlink and uplink operates on distinct frequency bands. The potential advantage of M-MIMO systems to achieve antenna diversity and spectral efficiency depends on the availability of precise downlink channel state information (CSI) at the BS. However, despite its promising outcomes, M-MIMO systems operating in FDD mode experience challenges. In such cases, the downlink CSI, estimated at the user equipment (UE) using pilot signals, needs to be fed back to the BS through the uplink control channel. This CSI transmission to the BS increases the feedback overhead, consuming a significant amount of the limited available uplink bandwidth resources. The CSI must be feedback with manageable overhead and sufficient accuracy to meet system requirements. Therefore, it necessitates the development of effective feedback compression and reconstruction algorithms. The 3rd Generation Partnership Project (3GPP) Release 18 aims to explore the advantages of integrating Artificial Intelligence (AI) into the air interface, where AI-enabled CSI feedback enhancement is considered as one of the representative use cases. This report focuses on the design of novel deep learning (DL) based feedback architectures that offer acceptable accuracy on the standardised channel model while maintaining their complexity, suitable for deployment in practical environments. Further, the complete process of downlink CSI acquisition in the M-MIMO FDD systems includes the transmission of the pilot, channel estimation, and feedback. The realisation of joint estimation and feedback is challenging because the optimal performance of one step does not guarantee the optimal performance of the total system. Therefore, the analysis by introducing channel estimation errors in the feedback system is a prerequisite, considering the conditions for real-time scenarios. In addition, with the advent of the sixth-generation (6G) communication, orthogonal time frequency space (OTFS) is used as the modulation technique that aims to assist reliable communications in high-speed applications. The challenge lies in providing precise CSI to the BS in such high-mobility conditions. Therefore, the study of the performance in these scenarios is also necessary. The first contribution of the report designs novel DL-based networks, InceptCodeNet and VAECNN-Net, that show superior CSI compression and reconstruction performance in the widely used COST 2100 channel model. The COST 2100 channel is not adopted in 5G NR therefore, motivated by this issue, a dataset is generated considering the new radio clustered delay line (nrCDL) channel that conforms to the current standards and specifications of 3GPP and the channel model adopted in 5 G. The second and third contributions of this report propose DeConvD-CRNet and DSCNN-AttNet and analyse the performance of the proposed networks using the generated set of synthetic dataset. The proposed frameworks are observed to be competitive with the baseline networks in terms of normalised mean square error (NMSE) and cosine similarity (&rho) as the performance criterion. Further, in the fourth contribution, a joint estimation and feedback network, SqAttDeConvD-CRNet is proposed by incorporating estimation errors into the feedback process to validate the applicability of the network in practical conditions. The network is investigated in the nrCDL channel, and the performance analysis is carried out for the whole architecture as well as the estimator, SqAttNet, and the feedback network DeConvD-CRNet separately. Later, to address the issue of the feedback system in a high-speed environment, the fifth contribution of this report proposes a novel network based on long short-term memory(LSTM) for the CSI feedback analysis. The applicability of the network is analysed for 6 G, where OTFS is used
as the modulation technique. Overall, this report proposes novel DL assisted frameworks that meet the requirements of future generation networks.