Ph.D. in Information Technology
Thesis Defense

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Francesco LINSALATA – XXXV Cycle

IMPROVED BEYOND 5G PHYSICAL LAYER DESIGN TO ENABLE V2X SYSTEMS AT HIGH FREQUENCIES

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Abstract:

Beyond fifth generation (B5G) research has recently started and this thesis aims at contributing to it.

The advances in the automotive industry with the ever-increasing request for connected and autonomous vehicles (CAVs) are pushing for a new era of network systems. Vehicular communications, or vehicle-to-everything (V2X), are expected to be the main actors of the new network technology. The hard requirements of the enhanced V2X applications demand a radical transformation of the design of the network physical layer (PHY). Indeed, high frequency communications with large antenna arrays are the main candidate solutions to satisfy the high rate and low latency requirements.
However, the high mobility of vehicles and high frequencies introduce new challenges that are firstly presented, and then, addressed with novel solutions in this thesis. The first problem that is considered regards the waveform design. The current 5G new radio (NR) waveform Orthogonal Frequency Division Multiplexing (OFDM) suffers inter carrier interference (ICI). Mobility introduces Doppler, and, thus, ICI. The high frequencies lead to high phase noise (PN). PN introduces further ICI. Thus, the combination of the two effects could be damaging for OFDM. Nevertheless, this aspect is not well-addressed in the current solutions. The first result of this thesis is a low complex joint PN and channel maximum likelihood estimation algorithm. The proposed solution outperforms the state-of-the-art approaches in terms of block error rate, requiring lower pilots' overhead to estimate the channel.
Fast and optimized initial access (IA) spatial synchronization methods for the vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) are among the main contributions of this work. A non-uniform distribution of the communication directions due to road topology constraints motivates the design of Probabilistic Codebook (PCB) techniques with prioritized beams during V2V IA. The proposed approach outperforms the 5G NR exhaustive space scanning technique in terms of training time and requires less signalling than the literature position-assisted methods.
Simulation results, supported by a set of experimental evidence, demonstrate that there is no winning method for IA in the V2I system. Even if the base station is equipped with radar or relies on the vehicle's onboard positioning systems. Numerical evaluations show that they provide complementary performance based on the position of the user in the served cell, moving the proposal to optimally combine radar and positioning information in a multi-technology integrated solution, which demonstrates to be optimal in terms of training time and gain losses.
Lastly, the thesis focuses on the problem of link and relay selection in V2X. The thesis proposes a novel proactive relaying strategy that exploits the cooperation between CAVs and environment information to predict the dynamic line of sight evolution, which is vital at high frequencies. The numerical results prove that the proposed approach can counteract the blockage and provide high network connectivity.

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