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Massive MIMO

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An IEEE 5G and Beyond Technology Roadmap

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This edition of the INGR is dedicated to the memory of Earl McCune Jr., who left us tragically and too soon on 27 May 2020. Earl was a microwave/RF guru, brilliant technologist, major industry/IEEE contributor, global visionary, keen skeptic, and all around fantastic human being. He was a major contributor to the INGR's early work on energy efficiency, millimeter-wave, and hardware. He worked for a technologically advanced yet more energy efficient world, and the contents of the INGR are a tribute to that vision. Rest in peace, Earl!

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Abstract

The use of a large number of antenna elements, known as Massive MIMO, is seen as a key enabling technology in the 5G and Beyond wireless ecosystem. The intelligent use of a multitude of antenna elements unleashes unprecedented flexibility and control on the physical channel of the wireless medium. Through Massive MIMO and other techniques, it is envisioned that the 5G and Beyond wireless system will be able to support high throughput, high reliability (low bit-error-rate (BER)), high energy efficiency, low latency, and an Internet-scale number of connected devices.

Massive MIMO and related technologies will be deployed in the mid-band (sub 6 GHz) for coverage, all the way to mmWave bands to support large channel bandwidths. It is envisioned that Massive MIMO will be deployed in different environments: Frequency Division Duplex (FDD), (Time Division Duplex (TDD), indoor/outdoor, small cell, macro cell, and other heterogeneous network (HetNet) configurations. Accurate and useful channel estimation remains a challenge in the efficient adoption of Massive MIMO techniques, and different performance-complexity tradeoffs may be supported by different Massive MIMO architectures such as digital, analog, and/or digital/analog hybrid. Carrier frequency offset (CFO), which arises due to the relative motion between the transmitter and receiver, is another important topic. Recently, maximum likelihood (ML) methods of CFO estimation have been proposed, that achieve very low root mean square (rms) estimation errors, with large scope for parallel processing and well suited for application with turbo codes.

Massive MIMO opens up a whole new dimension of parameters where the wireless applications or other network layers may control or influence the operation and performance of the physical wireless channel. To fully reap the benefits of such flexibility, the latest advances in artificial intelligence (AI) and machine learning (ML) techniques will be leveraged to monitor and optimize the Massive MIMO sub-system. As such, a cross-layer open interface can facilitate exposing programmability of Massive MIMO through techniques such as network slicing (NS) and network function virtualization (NFV). Finally, security needs to be integrated in the design of the system so the new functionality and performance of Massive MIMO can be utilized in a reliable manner.

Keywords:

5G, Massive MIMO, beamforming, mmWave, HetNet, energy efficiency, channel estimation, CFO estimation, hybrid architecture, beam optimization, average signal-to-noise ratio per bit.