

## Research Interests – Prof. Dr. Giuseppe Caire

---

Giuseppe Caire has focused his research activity at the intersection of the areas of Information Theory, Channel Coding and Modulation Techniques, and Wireless Communications. Information Theory provides a powerful and rigorous mathematical framework to investigate the fundamental limits of information transmission. In particular, it quantifies precisely the trade-off between data rate and distortion in representing an information source (e. g., speech, audio, and video) in digital format, i. e., as a stream of bits, and the ultimate data rate in bit per second achievable over a communication channel such that the transmitted message can be correctly decoded at the receiver side. Furthermore, it generalizes this concept to networks of multiple sources, transmitters, and receivers, including the interaction between them, i. e., the mutual interference and the protocol and coding strategies to keep such interference under control. Through the lens of Information Theory, it is possible to compare the performance of actual systems to such ultimate limits, and find out what can be further enhanced with a better design.

Giuseppe Caire started his research career in the mid-90s, during the transformation of wireless communications from telephone networks (voice-oriented) to data networks. He has contributed to the evolution of wireless communication systems in several ways. For example, he developed the first comprehensive information theoretic analysis of the coded-modulation scheme known as BICM (Bit-Interleaved Coded Modulation), which has become the scheme implemented in virtually all modern wireless communication standards such as IEEE 802.11 (Wi-Fi) and LTE.

Further, he has greatly contributed in the area of multiuser multiantenna (the so-called MIMO) communications, providing the optimal scheme to pre-code information from a base station to multiple users using multiple transmit antennas. These ideas have become very popular and in recent years, thanks to the ever-increasing processing power available in base station processors, they are finally implemented in practice under the nickname of “massive MIMO” and “Cloud Radio Access Network (C-RAN)”, and form one of the cornerstones of 5G systems. Another remarkably successful research topic initially developed by Giuseppe Caire is the concept of caching in wireless networks. Most of the data traffic in wireless networks is generated by on-demand media streaming (especially video), which is indeed pre-stored in video servers. While the on-demand nature of this traffic prevents

straightforward simultaneous broadcasting (as in the old-fashioned live TV), by leveraging memory in the user devices, which is an abundant and relatively cheap network resource, it is possible to turn the individual user demands into a common multicast coded stream, such that a single transmission is simultaneously useful for a multitude of users. Giuseppe Caire is among the pioneers of this very fruitful line of work, that stays at the intersection of information theory, network coding, algebraic coding, and protocol design, and obtained an ERC Advanced Grant in 2019, to develop further such idea and eventually devise scalable coding methods that can be used in practice for large networks.

In conclusion, the guiding direction of Giuseppe Caire's research has always been to focus on practically relevant problems, supported by a solid theoretical framework grounded in the principles of information theory. His research has contributed in part to the amazing development of wireless communication systems, that have evolved from simple mobile telephone networks to the critical role of the "digital glue", keeping together our highly digitalized world. The fundamental role played by wireless communication networks has emerged with particular strength in the year 2020, where because of the COVID pandemic, distance working and distance learning has played a fundamental role in our society.