Geoffrey Li’s Research Achievements

Dr. Geoffrey Ye Li’s current research interests are in machine learning and statistical signal processing for wireless communications. His research topics in the past couple decades include machine learning for wireless signal detection, big data processing for wireless networks, cognitive radios, cross-layer optimization for spectrum- and energy-efficient wireless networks, OFDM and MIMO techniques for wireless systems, and blind signal processing. In these areas, Dr. Li has published over 250 journal papers in addition to over 250 conference papers and over 40 granted patents. His publications have been cited by around 34,000 times and Thomson Reuters have recognized him as a Highly-Cited Researcher for almost every year. He was an IEEE Fellow for his contributions to signal processing for wireless communications since 2006. He won many awards from IEEE Communications Society (2010 S. O. Rice Prize Paper Award, 2017 Award for Advances in Communication, and three recognition awards from different committees), IEEE Vehicular Technology Society (2013 James Evans Avant Garde Award and 2014 Jack Neubauer Memorial Award), and IEEE Signal Processing Society (2017 Donald G. Fink Overview Paper Award). He also received the 2015 ECE Distinguished Faculty Achievement Award from Georgia Tech. Here is a brief summary of Dr. Geoffrey Li’s research achievements.

Intelligent and Statistical Signal Processing for Wireless Communications

Dr. Li is currently focusing on big data processing and deep learning for intelligent processing and communications. He introduced game theory into optimization and developed a multiple-leader multiple-flower (MLMF) game-based alternating direction method of multipliers (ADMM). Furthermore, he analytically proved that the MLMF game-based ADMM has a linear convergence speed and scalability, which will be a fundamental method for big data processing for 5G networks and Internet of Things (IoT). He has investigated deep learning (DL) in physical communications. DL can improve the performance of each individual (traditional) module in communication systems or optimize the whole transmitter or receiver. Therefore, DL in physical layer communications can be categorized into with and without block processing structures. For DL based communication systems with the block structure, he studied joint channel estimation and signal detection based on a data-driven fully connected deep neural network (FC-DNN), model-driven DL for signal detection. For those without the block structure, he has developed DL based end-to-end transmitter and receiver to maximize the date transmission rate of communication systems. One of his articles in the topic has been most popular among the articles ever published in IEEE Wireless Communications Letters and was among top 100 popular documents of the articles in over 300 journals in IEEE Explore since published. Recently, he is studying reinforcement learning for resource allocation to address high mobility and stringent latency requirements in vehicular communications. His paper based on the initial results in the topic becomes the most popular article among all published in IEEE Vehicular Technology Magazine.

In early 1990’s, Dr. Li investigated blind system identification and equalization. In order to compensate for channel distortion, channel parameters have to be identified explicitly or implicitly. Blind signal processing estimates channel/system parameters only by means of statistics of the system outputs without using any training sequences. Therefore, blind algorithms often have ill-convergence issues if not properly designed. It becomes a critical issue to design a blind equalizer that can always reach global convergence. Among his many outstanding contributions in blind signal processing, Dr. Li pioneered an adaptive blind algorithm for fractionally-spaced equalization (FSE). He revealed global convergence of FSE using the constant modulus algorithm (CMA) under a length-and-zero condition. The FSE-CMA is also with low insensitivity to timing phase error. He also extended blind algorithms to space-time processing. He defined cost- and length-dependent local minima and static and dynamic convergence, which categorize and reveal the properties of the ill-convergence of different blind algorithms. His book, with Prof. Zhi Ding, has been the first one that systematically describes research results in the area of blind equalization and identification.

OFDM and MIMO for Wireless Communications

The success of both Internet access and wireless communications has stimulated the growing interest in high-speed wireless systems, with the ultimate goal of approaching the theoretical channel capability. Dr. Li had the foresight to see the coming importance of increasingly higher speeds and used orthogonal frequency division multiplexing (OFDM) to break through this barrier in the middle of 1990’s. His robust channel estimator for OFDM systems has been used in a fourth-generation cellular architecture design and prototype development at
AT&T Labs. He also developed a general framework to quantify the bounds for *inter-carrier interference* (ICI) to facilitate the design of OFDM for high mobility wireless systems. The methodology has been used as the optimum norm by other researchers and recommended by the IEEE 802.16 standard. Due to his outstanding contribution in the area of OFDM for wireless communications, he received the 2013 *IEEE VTS James Evans Avant Garde Award* for advancing the state-of-art in OFDM-aided wireless communications, the 2013 *IEEE ComSoc WTC Wireless Communications Recognition Award*, and the 2017 *ComSoc SPCE Recognition Award*. In the area of *multiple-input multiple-output* (MIMO) wireless systems, he was among the first to study interference suppression and training for MIMO-OFDM. His work has been referred by almost all subsequent researchers in the area. Due to its substantial impact, his paper in massive MIMO won the 2017 *IEEE SPS Donald G. Fink Overview Paper Award*.

**Cross-Layer Optimization for Spectrum- and Energy-Efficient Networks**

Wireless networks provide users the promise of *anywhere* and *anytime* communications. Dr. Li established a theoretical framework and developed practical algorithms for joint *media access control* (MAC) and physical layers optimization according to each user’s channel condition at different locations and times so that a high *quality-of-service* (QoS) can be provided with limited wireless resources. In particular, Dr. Li innovatively investigated packet scheduling algorithms for streaming of delay-sensitive multimedia contents in OFDMA-based cellular data networks. He not only developed a novel multi-channel packet scheduling approach, *max-delay-utility* (MDU) packet scheduling, based on utility functions in terms of queueing delay, but also analyzed its stability based on the concept of *maximum stability region* (MSR) to reveal the relationship between the scheduling algorithms and queueing stability. With the utility-maximization mechanism, MDU scheduling enables the network to achieve the right balance between capacity enlargement and QoS guarantee according to the channel condition and the level of network congestion. The novel stability analysis can be applied for stationary systems and a much wider range of scheduling algorithms compared to the existing related work. It will facilitate the design of cross-layer scheduling algorithms and QoS provisioning solutions for advanced wireless broadband networks. As a result, his paper based on the above results won the 2010 *IEEE ComSoc Stephen O. Rice Prize Paper Award* in the field of communications theory. The exponentially growing data traffic and the requirement for ubiquitous access have triggered dramatic expansion of network infrastructures and fast escalation of energy demands. He is one of the pioneers to study spectral- and energy-efficiency tradeoff in wireless networks. In particular, he developed a unified framework on green communications with four fundamental trade-offs. His research results in the area won the 2017 *IEEE ComSoc Award for Advances in Communication* for opening a new line of work in the previous 15 years. He also received the 2017 *IEEE ComSoc TCGCC Distinguished Technical Achievement Recognition Award* for his outstanding technical leadership and achievement in green wireless communications and networks.

**Cognitive Radio and Device-to-Device Communications**

Cognitive radio can improve spectrum efficiency by enabling unlicensed users to exploit unused licensed spectrum as long as not to cause any harm to the licensed users, which has become a critical technology to mitigate spectrum scarcity issue in future wireless networks. He is one of the earliest researchers in the area. He developed techniques to detect vacant licensed spectrum bands accurately and quickly and to assign spectrum bands and transmission power to different users to optimize performance while minimizing interference to the licensed users. His work in the area won the 2014 *IEEE VTS Jack Neubauer Memorial Award*. Today, any communication between mobile devices must involve a base station, which can be inefficient when the mobile users are close to each other. Future cellular systems will support device-to-device (D2D) communications, which can be regarded as a special cognitive radio network and can double the spectral efficiency for closely spaced devices. Dr. Li’s fundamental work solved major challenges in D2D communications. He invented an optimal approach to identify when two mobile users should use D2D communications and to allocate frequency and transmission power. He has also revealed potential hop gain, proximity gain, and reuse gain incurred by D2D communications and investigated how to use them to optimize the performance of both cellular and D2D users. Remarkably, Dr. Li’s work in D2D communications was highlighted in the *IEEE ComSoc Technology News* (http://www.comsoc.org/ctn/) in December 2014. Recently, he is investigating intelligent wireless networks based on cognitive radio and machine learning.