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Performance Analysis of MIMO using Machine Learning in 5G Networks

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Resume

Christos Bouras is Professor in the University of Patras, Department of Computer Engineering and Informatics. Also he is a scientific advisor of Research Unit 6 in Computer Technology Institute and Press - Diophantus, Patras, Greece. His research interests include 5G and Beyond Networks, Analysis of Performance of Networking and Computer Systems, Computer Networks and Protocols, Mobile and Wireless Communications, Telematics and New Services, QoS and Pricing for Networks and Services, e-learning, Networked Virtual Environments and WWW Issues. He has extended professional experience in Design and Analysis of Networks, Protocols, Telematics and New Services. He has published more than 450 papers in various well-known refereed books, conferences and journals. He is a co-author of 9 books in Greek and editor of 2 in English. He has been member of editorial board for international journals and PC member and referee in various international journals and conferences. He has participated in R&D projects.

Information About Our Team

- Our website: http://telematics.upatras.gr/telematics/

- The Lab of Distributed Systems and Telematics is one of the Labs of the Department of Computer Engineering & Informatics of University of Patras. The LDST exhibits substantial research activity in the following areas:

- Mobile Networks
- Next Generation Networks
- Cross-layer Design and Mechanisms
- Network Simulations
- LPWAN

Outline

- Introduction
- Related Work
- Machine and Deep Learning Algorithms Comparison
- Performance Evaluation
- Conclusions

Introduction (1/2)

- Network traffic management is expected to be a critical problem, especially in the 5th Generation (5G) and beyond cellular Ultra-Dense Networks (UDNs) and Heterogeneous Networks (HetNets).

- Because of its unique performance and freedom, Massive Multiple-Input Multiple-Output (MIMO) is a critical method for 5th Generation and future mobile wireless networks.

- Massive MIMO is a type of MIMO that requires connecting a base station with hundreds or even thousands of antennas to be able to boost spectral efficiency and throughput.

- Massive MIMO makes use of huge antenna arrays at base stations and Access Points (APs). When combined with millimeter-wave (mm-Wave) communications, which employ a bigger spectrum, this architecture enables for enhanced cellular communications with increased spectral density and reduced complexity.

Introduction (2/2)

- Artificial Intelligence (AI) has emerged as a cutting-edge method with the potential to make major advancements in a variety of telecommunications problems, thanks to the uses of Machine Learning (ML) and furthermore deep Learning, including network management, self-organization, self-healing, and Physical Layer (PHY) improvements (DL).

- We will include a study of how MIMO technology can benefit from the modern application of ML in this paper.

- We'll go through how the components of a single 5G network that uses this combination work, what's been researched so far, and how it might be enhanced in the future.

Related Work - MIMO

- We can think of communicating in a MIMO system as sending a matrix rather than a single vector.
- MIMO is a technique for doubling the capacity of a radio link by taking advantage of multipath propagation by using multiple transmission and receiving antennas.
- Massive MIMO as an enabling technology for future generation of networks, is being showcased as a novel technology that scales up MIMO and offers considerable benefits.
- MIMO can enhance data carrying capacity without requiring more bandwidth due to spatial multiplexing, however, when compared to the classic single antenna antenna-based system, the resource requirements and hardware complexity are higher.

Related Work - Machine and Deep Learning

- Machine learning is a subfield of AI that refers to when computers are using data for learning techniques.

- The work that has been done in [4], [3] and [8] best describes the role of ML and DL in enhancing MIMO. The Partial Learning (PL)-based detection scheme that is proposed in [4] can achieve low Bit Error Rate (BER) with low computational complexity.

- K-NEAREST NEIGHBOR (KNN) has been proven to appear the best ML algorithm performance, second being the Kernel Ridge Regression (KRR) and Random Forest (RF) in all scenarios evaluated.

Related Work - 5G Networks

- 5G is intended to provide data speeds many times faster than the previous classic networks, latency that is being characterized as “ultra-low”, enhanced dependability, massive network capacity, increased availability, larger bandwidth of up to 10 gigabits per second (Gbit/s) ensuring a more consistent user experience for a larger number of people.

- In 5G, the service area is separated into cells, which are small geographical areas. All 5G wireless devices are connected to the Internet and telephone network via radio waves via a local antenna in the cell.

- For massive MIMO systems, they discuss contemporary advances, such as terahertz communication, Ultra-Massive MIMO (UM-MIMO), Visible Light Communication (VLC), ML, and DL.

Machine and Deep Learning Algorithms Comparison

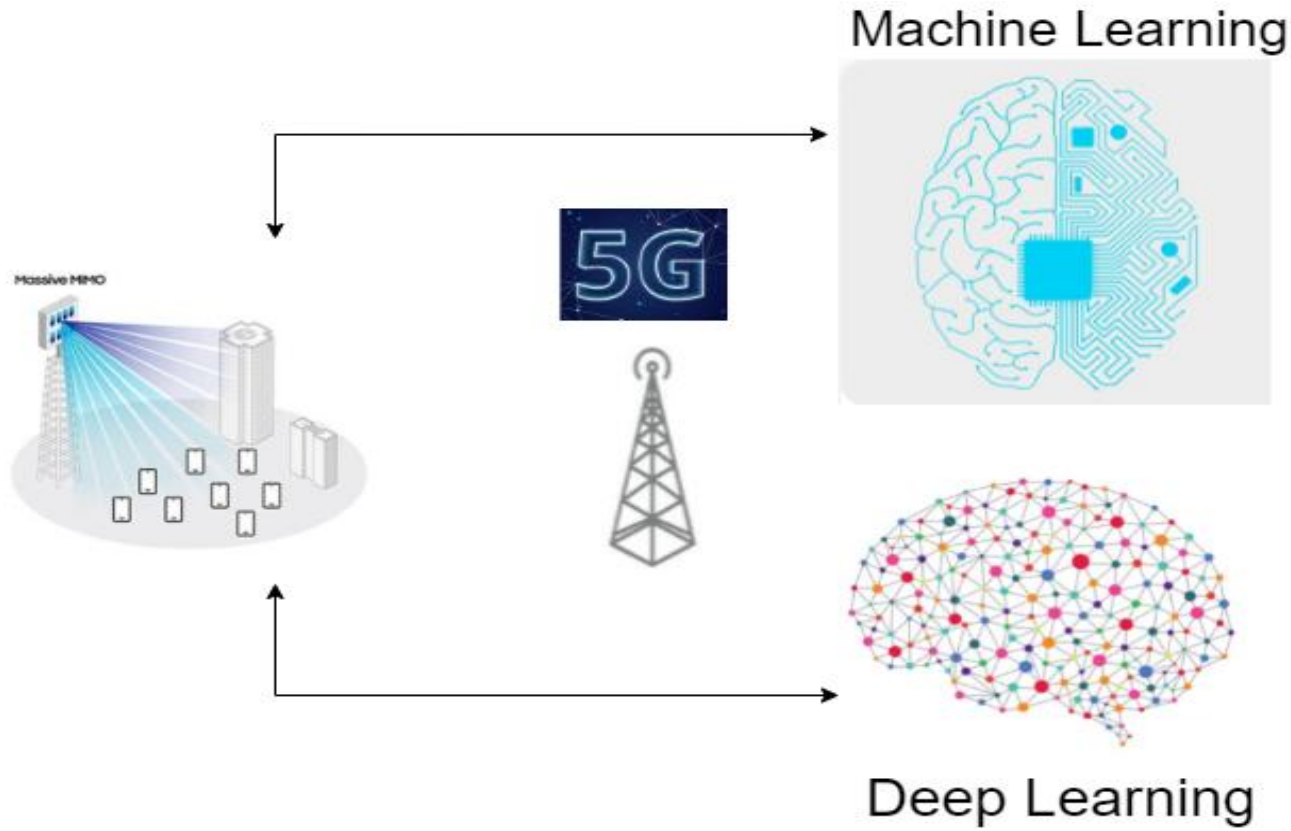
- ML and DL methods' dynamic nature may be advantageous for analysis of complex tasks while also conserving a substantial amount of processing power. Massive MIMO beamforming, channel estimation, signal detection, load balancing, and spectrum optimization can all benefit from ML and DL technology [7].

- Work at [8] indicates that using DL to the channel feedback problem could be a promising path for addressing concerns like codebook size and feedback overhead.

- Work [6] states that improvement can be found if the data set acquisition and selection of the model issues are overcome.

- Work [4] proposes a neural network-based intelligent detection method to strike a balance between cheap computing complexity and low BER.

Machine and Deep Learning Algorithms Comparison



Performance Evaluation (1/3)

Work	Strategy	Results
[2]	In mmWave MIMO, a dataset is used to examine beam selection algorithms for vehicle-to-infrastructure interaction	Channel realizations that simulate 5G scenarios with transceivers and objects moving about.
[10]	Energy and spectrum efficiency, robustness, and reliability analyses	Massive MIMO description
[7]	Overview of core issues in massive MIMO system	MIMO as the solution to the massive increase in wireless data traffic
[8]	Deep-learning-enabled mmWave massive MIMO framework	Successful hybrid precoding
[6]	Overcoming the dataset acquisition and model selection issues	Better results with the progressing use of DL

Performance Evaluation (2/3)

Work	Strategy	Results
[1]	Deep LSTM learning technique for localized traffic load predictions at the UDN base station	Learn and forecast with even greater precision
[4]	Partial Learning (PL)-based detection scheme	Low BER with low computational complexity
[3]	Comparative performance evaluation	KNN was the best ML algorithm performance that could effectively forecast the position of an MT.
[11]	Comprehensively describing massive MIMO systems from several different perspectives	Better BER performance and system capacity while optimizing channel estimates and feedback for massive MIMO and overall energy efficiency gains on NOMA

Performance Evaluation (3/3)

Work	Strategy	Results
[5]	Overview of 5G communications research using DL	DNN and CNN can increase BER performance and system capacity while optimizing channel estimates and feedback for massive MIMO
[9]	Investigating the performance constraints of developing "wireless-powered" communication networks using opportunistic energy harvesting from ambient radio signals or specialized wireless power transfer	To maximize the efficiency of simultaneous information and energy transmission, fundamental compromises must be made when developing wireless MIMO systems.

Conclusion

- We conclude that the use of ML and DL in combination with MIMO in 5G and beyond networks has a lot of benefits and better performance in the variety of the aspects that are being showcased.
- The most promising state-of-the-art techniques consist of the various uses of DL. It is obvious that, such techniques as well as all the principles of learning schemes still have some unclear areas that can be further explored.
- In the future, it is important more analysis to be conducted on DL-based wireless physical layer mechanisms, congestion optimization techniques and precoding strategies.
- It is safe to assume that with exploration and exploitation of the aforementioned artificial intelligence combinations, various benefits can be derived in terms of BER, energy consumption, complexity, throughput, congestion and, in general, overall efficiency.

Thank you!

Questions?

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