Machine Learning and Wi-Fi: Confluences, Ongoing Activities, and Ways Forward

Francesc Wilhelmi, Szymon Szott, Katarzyna Kosek-Szott, Boris Bellalta

October 6th, 2023
ACM Mobicom

Francesc Wilhelmi

- Research Engineer at Radio Systems Research (RSR), Nokia Bell-Labs Germany
- PhD from Universitat Pompeu Fabra (UPF)
- Interests:
  - Wi-Fi networks & unlicensed wireless technologies
  - AIML for communications
  - DLT & blockchain
- Contact: francisco.wilhelmi@nokia.com

Szymon Szott

- Associate professor at AGH University of Kraków, Poland
- Research interests
  - Wireless local area networks
  - Channel access
  - Quality of service
  - Security
  - Inter-technology coexistence
- **ML interest:** clever ways to improve performance
- Contact:
  - szott@agh.edu.pl
  - https://szymonszott.github.io/

Katarzyna Kosek-Szott

- Associate Professor at AGH University of Krakow
- Major interests
  - Novel IEEE 802.11 amendments
  - Coexistence of radio technologies in unlicensed bands
  - Application of ML in IEEE 802.11 networks
- Contact: kks@agh.edu.pl

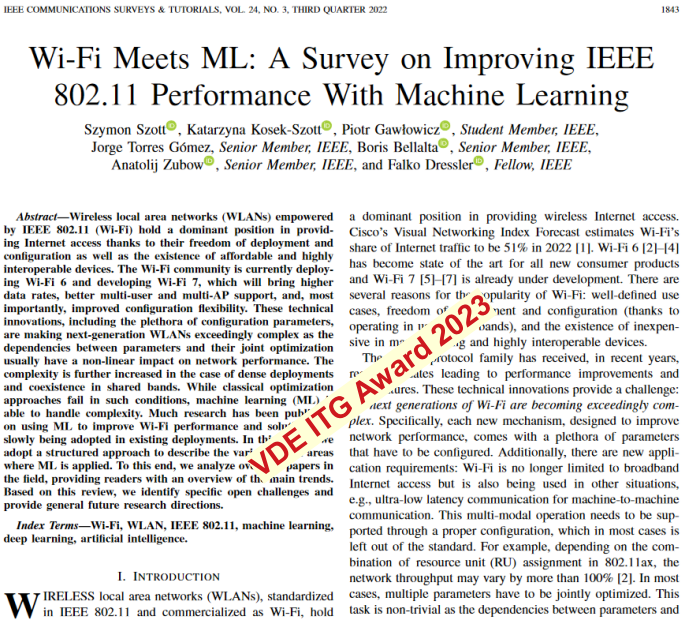
Boris Bellalta

- Full-professor at UPF
- Head of the Wireless Networking group
  - Unlicensed bands, Wi-Fi
  - XR Immersive Communications (over Wi-Fi)
- **ML interest**: ‘intelligent’ adaptive systems; low-complexity but responsive RL agents; interplay between ML agents;
- Contact: boris.bellalta@upf.edu

Acknowledgements

- Piotr Gawłowicz, Jorge Torres Gómez, Anatolij Zubow, Falko Dressler, co-authors of the survey paper "**Wi-Fi Meets ML: A Survey on Improving IEEE 802.11 Performance with Machine Learning**" in IEEE Communications Surveys & Tutorials, vol. 24, no. 3, pp. 1843-1893, third quarter 2022, doi: 10.1109/COMST.2022.3179242. [1]

- From projects:
  - National Science Centre, Poland, under Grant DEC-2020/39/I/ST7/01457
  - WI-XR PID2021-123995NB-I00 (MCIU/AEI/FEDER,UE)



IEEE COMMUNICATIONS SURVEYS & TUTORIALS, VOL. 24, NO. 3, THIRD QUARTER 2022 1843

Wi-Fi Meets ML: A Survey on Improving IEEE 802.11 Performance With Machine Learning

Szymon Szott, Katarzyna Kosek-Szott, Piotr Gawłowicz, *Student Member, IEEE*, Jorge Torres Gómez, *Senior Member, IEEE*, Boris Bellalta, *Senior Member, IEEE*, Anatolij Zubow, *Senior Member, IEEE*, and Falko Dressler, *Fellow, IEEE*

***Abstract*—Wireless local area networks (WLANs) empowered by IEEE 802.11 (Wi-Fi) hold a dominant position in providing Internet access thanks to their freedom of deployment and configuration as well as the existence of affordable and highly interoperable devices. The Wi-Fi community is currently deploying Wi-Fi 6 and developing Wi-Fi 7, which will bring higher data rates, better multi-user and multi-AP support, and, most importantly, improved configuration flexibility. These technical innovations, including the plethora of configuration parameters, are making next-generation WLANs exceedingly complex as the dependencies between parameters and their joint optimization usually have a non-linear impact on network performance. The complexity is further increased in the case of dense deployments and coexistence in shared bands. While classical optimization approaches fail in such conditions, machine learning (ML) is able to handle complexity. Much research has been published on using ML to improve Wi-Fi performance and solutions are slowly being adopted in existing deployments. In this survey, we adopt a structured approach to describe the various areas where ML is applied. To this end, we analyze over 200 papers in the field, providing readers with an overview of the main trends. Based on this review, we identify specific open challenges and provide general future research directions.**

***Index Terms*—Wi-Fi, WLAN, IEEE 802.11, machine learning, deep learning, artificial intelligence.**

I. Introduction

WIRELESS local area networks (WLANs), standardized in IEEE 802.11 and commercialized as Wi-Fi, hold a dominant position in providing wireless Internet access. Cisco's Visual Networking Index Forecast estimates Wi-Fi's share of Internet traffic to be 51% in 2022 [1]. Wi-Fi 6 [2]–[4] has become state of the art for all new consumer products and Wi-Fi 7 [5]–[7] is already under development. There are several reasons for the popularity of Wi-Fi: well-defined use cases, freedom of deployment and configuration (thanks to operating in unlicensed bands), and the existence of inexpensive in mass production and highly interoperable devices.

The IEEE 802.11 protocol family has received, in recent years, numerous updates leading to performance improvements and new features. These technical innovations provide a challenge: *the next generations of Wi-Fi are becoming exceedingly complex*. Specifically, each new mechanism, designed to improve network performance, comes with a plethora of parameters that have to be configured. Additionally, there are new application requirements: Wi-Fi is no longer limited to broadband Internet access but is also being used in other situations, e.g., ultra-low latency communication for machine-to-machine communication. This multi-modal operation needs to be supported through a proper configuration, which in most cases is left out of the standard. For example, depending on the combination of resource unit (RU) assignment in 802.11ax, the network throughput may vary by more than 100% [2]. In most cases, multiple parameters have to be jointly optimized. This task is non-trivial as the dependencies between parameters and

VDE ITG Award 2023