Framework for Federated Learning and Edge Deployment of Real-Time Reinforcement Learning Decision Engine on Software Defined Radio

Jithin Jagannath

Marconi-Rosenblatt AI Innovation Lab, ANDRO Computational Solutions, LLC, 111 Dart Circle, Rome, NY, 13441
Department of Electrical Engineering, University at Buffalo, The State University of New York, Buffalo, NY 14260
jjagannath@androcs.com

Extended Abstract - Invited Talk

Machine learning promises to empower dynamic resource allocation requirements of Next Generation (NextG) wireless networks including 6G and tactical networks. Recently, we have seen the impact machine learning can make on various aspects of wireless networks (Jagannath, Jagannath, and Melodia 2021; Jagannath et al. 2019). Yet, in most cases, the progress has been limited to simulations and/or relies on large processing units to run the decision engines as opposed to deploying it on the radio at the edge. While relying on simulations for rapid and efficient training of deep reinforcement learning (DRL) may be necessary, it is key to mitigate the sim-real gap while trying to improve the generalization capability.

To mitigate these challenges, we developed the Marconi-Rosenblatt Framework for Intelligent Networks (MR-iNet Gym), an open-source architecture designed for accelerating the deployment of novel DRL for NextG wireless networks (Farquhar et al. 2023). MR-iNet Gym leverages ns3-gym, which utilizes ns-3 as an environment within the OpenAI Gym framework (Gawłowicz and Zubow 2019) and currently focuses on distributed tactical networks.

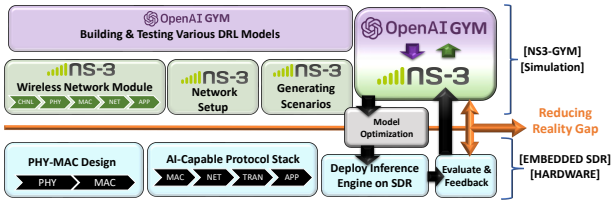

Figure 1: MR-iNet Gym Framework

To demonstrate its impact, we tackled the problem of distributed frequency and power allocation while emphasizing the generalization capability of DRL decision engine (Kafle et al. 2023). To accomplish this, we build a custom DS-CDMA ns3 module within the MR-iNet GYM environment. Next, we train the DRL agents that perform frequency and power selection in a distributed manner. MR-iNet GYM is configured to replicate our hardware deployment environment which includes hostile jamming. We demonstrated our approach of federated training improved link survivability under active jamming. The decision engine also demonstrated better generalization, i.e. improved performance when tested on previously unseen environments.

Furthermore, the end-to-end solution was implemented on the GPU-embedded software-defined radio and validated using over-the-air evaluation to prove practical impact. To the best of our knowledge, these were the first instances that established the feasibility of *deploying DRL for optimized distributed resource allocation for next-generation of GPU-embedded radios* (Jagannath et al. 2022; Kafle et al. 2023).

References

Farquhar, C.; Kafle, S.; Hamedani, K.; Jagannath, A.; and Jagannath, J. 2023. Marconi-Rosenblatt Framework for Intelligent Networks (MR-iNet Gym): For Rapid Design and Implementation of Distributed Multi-agent Reinforcement Learning Solutions for Wireless Networks. *Computer Networks*, 222: 109489.

Gawłowicz, P.; and Zubow, A. 2019. ns-3 meets OpenAI Gym: The Playground for Machine Learning in Networking Research. In *ACM Intl. Conf. on Modeling, Analysis and Sim. of Wireless and Mobile Systems*.

Jagannath, A.; Jagannath, J.; and Melodia, T. 2021. Redefining Wireless Communication for 6G: Signal Processing Meets Deep Learning with Deep Unfolding. *IEEE Transaction on Artificial Intelligence*.

Jagannath, J.; Hamedani, K.; Farquhar, C.; Ramezanpour, K.; and Jagannath, A. 2022. MR-iNet Gym: Framework for Edge Deployment of Deep Reinforcement Learning on Embedded Software Defined Radio. In *Proc. of ACM Workshop on Wireless Security and Machine Learning (WiseML)*. San Antonio, Texas, USA.

Jagannath, J.; Polosky, N.; Jagannath, A.; Restuccia, F.; and Melodia, T. 2019. Machine Learning for Wireless Communications in the Internet of Things: A Comprehensive Survey. *Ad Hoc Networks (Elsevier)*, 93: 101913.

Kafle, S.; Jagannath, J.; Kane, Z.; Biswas, N.; Kumar, P. S. V.; and Jagannath, A. 2023. Generalization of Deep Reinforcement Learning for Jammer-Resilient Frequency and Power Allocation. *IEEE Communications Letters*, 1–1.