Bulletin of Networking, Computing, Systems, and Software – www.bncss.org, ISSN 2186-5140
Volume 13, Number 1, pages 59–60, January 2024

Benchmarking Multi-agent Reinforcement Learning-based Access Control using Real-world IoT Traffic

Tien Thanh Le[12], Yusheng Ji[21], Hong-Linh Truong[3], and John C.S Lui[4]
[1]The Graduate University for Advanced Studies (SOKENDAI) - Japan, [2]National Institute of Informatics (NII) - Japan,
[3]Aalto University - Finland, [4]The Chinese University of Hong Kong

I. Introduction

In recent years, the proliferation of Internet of Things (IoT) devices and applications has given rise to massive Machine-Type Communication (mMTC), a critical domain within next-generation wireless communication. mMTC is characterized by a massive number of low-power devices generating data sporadically, posing a formidable challenge in efficiently allocating the limited physical wireless channel resources among them. Conventional centralized allocation methods prove infeasible in mMTC scenarios due to the overwhelming volume of control messages relative to the actual data transmissions required by mmtc devices. To address this challenge, there has been a notable upsurge in research endeavors dedicated to enhancing fully distributed channel access protocols for mMTC, leveraging the power of cooperative multi-agent reinforcement learning. However, an existing research gap becomes evident when we observe that prior studies predominantly tested their algorithms under conditions of either saturated traffic or simulated traffic models. This limited scope fails to accurately capture the dynamics of real-world mMTC networks. In this study, we bridge this gap by utilizing real-world IoT traffic data from a network operator in Vietnam.

II. System model

We adopt the multiple-access problem formulation from Polyanskiy et al. (2017) [1], commonly referred to as unsourced multiple access (UMA), where users share a common codebook and the receiver decodes messages up to a permutation. Specifically, we consider a slotted-time multiple access network with a total of K_{tot} ($\approx$ 1 million) IoT devices participating. In each time slot, a few devices (K_a less than $1,000$) send data to the base station (BS). Assume that each device only have one packet in the buffer, and new packet preempt the stale packet. Let $x_i \in \mathbb{C}^n$ be the signal from device i over n available wireless resource units. The BS receives $y = \sum_{i=1}^{K_a} x_i + z$, where z is Gaussian noise. The BS decodes y to a permutation of the messages x_i. Following [2], with the current K_a and UMA codebook configuration, we obtain achievability bounds on the minimum probability of BS misdetecting messages ϵ_{MD} and probability of false alarm ϵ_{FA}. To ensure reliable delivery to the BS, mMTC devices can resend messages until the probability of misdetecting multiple resent messages is negligible (i.e., less than 10^{-5}).

III. Problem formulation

Let the action of device i at time slot t among T slots be $a_i(t)$. In each slot, devices choose either (1) to wait or (2) to transmit the uplink packet. Each packet can be sent up to r times until the joint probability of all r copies being misdetected by the BS is negligible. The channel access strategies aim to cooperatively minimize the maximum delay:

$$\min_{a_i(t)} \max_{i,t} d_i(t) \tag{1}$$

for all $i \in [K_a]$ and $\forall t \in [T]$. If all devices aggressively send packets in congested channels, K_a increases, leading to higher ϵ_{MD} and eventually requiring more transmissions. However, if devices wait too long, their delay $d_i(t)\ \forall i \in [K_a]$ becomes large. Thus, devices need to intelligently trade-off between waiting and transmitting to jointly minimize the maximum delay.

IV. Experimental Study

A. Experimental Setup

This study addresses a gap by using real-world IoT traffic data from a central Vietnamese network operator [3]. The data include 24-hour timestamps for packets generated by IoT devices, spanning applications like industrial and environmental sensors.

B. Channel Access Strategies for Benchmarking

We perform a comparative analysis on channel access delay and fairness, evaluating four distributed and dynamic strategies: (1) classical multi-channel ALOHA, (2) a heuristic enhancement of multi-channel ALOHA to improve fairness, and (3) the centralized training decentralized execution multi-agent deep reinforcement learning (MADRL) algorithms adapted from [4]. This research aims to provide insights into the practicality and effectiveness of these strategies in addressing challenges unique to mMTC scenarios in real-world wireless communication environments.

This research in supported in part by the Japanese Ministry of Internal Affairs and Communications (MIC) SCOPE project No.JP235006102.

Bulletin of Networking, Computing, Systems, and Software – www.bncss.org, ISSN 2186-5140
Volume 13, Number 1, pages 59–60, January 2024

References

[1] Y. Polyanskiy, "A perspective on massive random-access," in *2017 IEEE International Symposium on Information Theory (ISIT)*, IEEE, 2017, pp. 2523–2527.

[2] K.-H. Ngo, A. Lancho, G. Durisi, and A. G. i Amat, "Unsourced multiple access with random user activity," *IEEE Transactions on Information Theory*, 2023.

[3] H.-L. Truong and N. N. N. Trang, "Haivan: A holistic ml analytics infrastructure for a variety of radio access networks," in *2022 IEEE International Conference on Big Data (Big Data)*, IEEE, 2022, pp. 2389–2393.

[4] Z. Guo, Z. Chen, P. Liu, J. Luo, X. Yang, and X. Sun, "Multi-agent reinforcement learning-based distributed channel access for next generation wireless networks," *IEEE Journal on Selected Areas in Communications*, vol. 40, no. 5, pp. 1587–1599, 2022.