

Poster: Tiny-twin: A Lightweight and Verifiable Digital Twin of NextG Cellular Networks

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Digital Twin, Cellular networks, multimedia applications

1 INTRODUCTION

The next generation of cellular networks, driven by applications like large-scale autonomy, extended reality, and IoT-based control, demands high network performance in terms of throughput, latency, and jitter, along with quick network adaptability. Developing these applications and corresponding network algorithms on commercial radio access networks (RAN) or through large-scale frameworks such as [1, 2] is often prohibitively expensive and time-consuming. Currently, the norm is to use simpler, simulated environments for initial testing, followed by real-world network evaluations. This approach simplifies testing but may not accurately capture the cellular network's complexities that can significantly impact application performance. Can we optimize both?

■ **Requirements and Related Work:** Our research focuses on developing a Digital Twin that is a comprehensive yet *lightweight* framework utilizing open-source software and hardware, aimed at facilitating rapid application testing on radio networks during the development phase. We also focus on the critical aspect of *verifiability*, where we aim to ascertain whether real-world observations align well with their virtual counterparts, ensuring the digital twin's reliability. Such a framework would permit continuous refinement and evaluation of both application-level and network-level algorithms. Current twin frameworks [3, 4] often involve fine-grain wireless channel modeling, encompassing delay-Doppler behavior, which requires computationally complex, FPGA-aided channel modeling, yet fail to verify the digital twin on metrics relevant to an application (e.g. stall duration and jitter). Our inquiry, however, centers around determining the optimal level of wireless environment artifacts that balance capabilities, accuracy, and simplicity, also capturing the intricacies of RAN timing and control impacts effectively.

■ **Tiny-Twin:** We present Tiny-twin, a lightweight and verifiable digital twin that is essentially a clone of a real 5G network, the wireless environment represented with coarse channel artifacts obtained from real world measurements and replayed on the framework. *In Tiny-twin, we contend that high-level channel artifacts such as the channel quality (CQI), and block error rates (BLER) are sufficient to reasonably capture the underlying channel effects that are relevant*

from an end-end application perspective such as video streaming. CQI captures the channel strength and leads to optimal Modulation and Coding Scheme (MCS) selection, and BLER accounts for packet drops and retransmissions. We playback these channel artifacts on Tiny-twin while running an end-to-end application with the full cellular software stack up until the baseband (IQ-samples). Such a split between replayed artifacts and real-time events would enable network algorithms, such as application and network functions, to be developed with high fidelity, and ensure that applications can be run end-to-end to collect realistic performance measurements while not having to collect or maintain large-scale IQ data traces.

■ **Results:** Figure 1 shows that our approach accurately captures real network behavior. We benchmark various Adaptive Bitrate (ABR) algorithms using the DASH protocol for video streaming applications. We also examine metrics such as latency and jitter, critical metrics for real time streaming applications such as video conferencing, on the twin, replaying channel artifacts collected from over-the-air experiments. Observations from Tiny-twin closely mirrors the values obtained from real world tests, thus affirming the twin's verifiability.

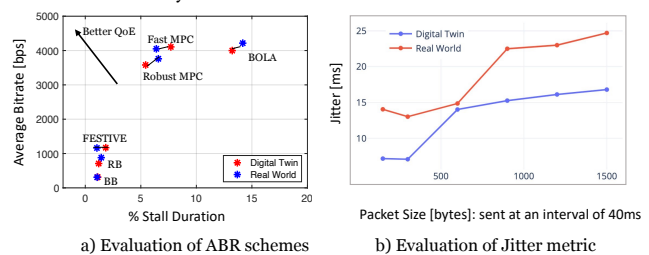


Figure 1: Evaluation of Tiny-twin framework

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