IABEST: An Integrated Access and Backhaul 5G Testbed for Large-scale Experimentation

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ABSTRACT

Millimeter wave (mmWave) communications have the potential to dramatically increase the throughput of 5G-and-beyond wireless networks. However, the challenging propagation conditions typical of higher frequencies require expensive base station densification to guarantee reliable Radio Access Networks (RANs). Integrated Access and Backhaul (IAB), a solution where wireless access and backhaul use the same waveform, spectrum, and protocol stack, has been proposed and standardized as a highly effective means of decreasing these costs. While IAB is considered a key enabler for high-frequency RANs, experimental research in this context is hampered by the lack of accessible testing platforms. In this demonstration, we showcase IABEST, a large-scale end-to-end IAB testbed based on open-source software and compatible with off-the-shelf hardware. We show how to deploy IABEST capabilities at scale on Colosseum, a publicly available massive channel emulator. Finally, we show how IABEST can support researchers in data collection and algorithm testing from the highest levels of network abstraction down to scheduling decisions.

CCS CONCEPTS

• **Networks** → **Network architectures**; **Network experimentation**.

KEYWORDS

IAB, wireless networks, large-scale experimentation

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1 INTRODUCTION

Millimeter wave (mmWave) communications, one of the key new features of 5G-and-beyond networks, promise to enable multi-gigabit mobile throughput while solving the sub-6GHz spectrum shortage [10]. However, mmWaves are characterized by high propagation and penetration losses and poor diffraction, which reduce link reliability. As such, transitioning Radio Access Networks (RANs) from a low-frequency, interference-limited domain to a high-frequency, propagation-limited domain requires careful network planning to maintain the same reliability level [4]. Base station densification can naturally provide high robustness against random blockage while increasing throughput [6]. However, denser base station deployments result in increased installation and operational costs that might slow down or even halt the adoption of mmWave communication for large-scale RANs. Integrated Access and Backhaul (IAB) has been proposed as an effective means of cutting down on some of these costs. In an IAB network, only a few base stations, called IAB-donors, are cabled to the core network, and in-band wireless backhauling is used to create a network of base stations by leveraging the large capacity of mmWave communications. Consequently, most of the base stations, the IAB-nodes, can be deployed without a wired connection to the core network. The resulting dramatic reduction in dense deployment costs positions IAB as a key enabler for mmWave RANs [9].

IAB networking has generated a flourishing research area, where efforts are made to improve IAB networks from radio resource scheduling to route selection, topology formation and deployment planning. Most these works are limited to theoretical analysis or simulations [11] due to a lack of experimental testbeds. To the best of the authors' knowledge, experimental research is currently limited to operator's field trials [12]. The only documented IAB testbed makes use of expensive equipment and is arguably challenging to scale [3].

In this demo, we showcase our Integrated Access and Backhaul Experimental large-Scale Testbed (IABEST), which focuses on flexibility and customization. The testbed is based

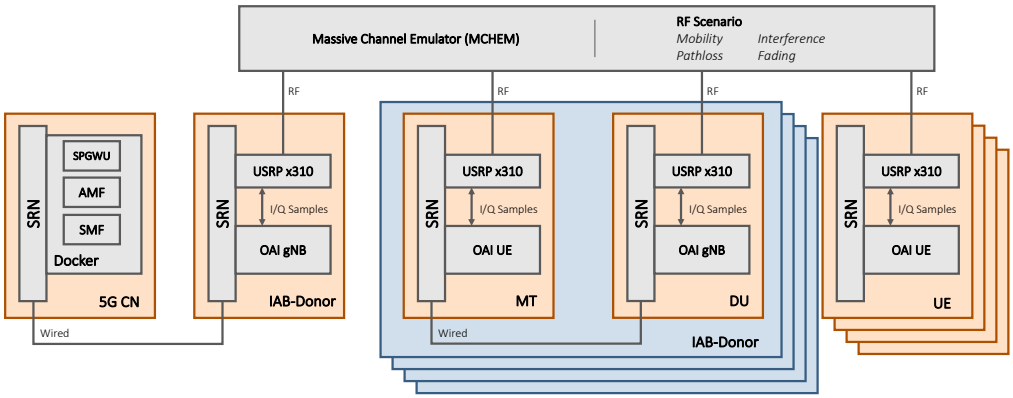

Figure 1: Overview of the Integrated Access and Backhaul (IAB) testbed on Colosseum.

on a custom version of OpenAirInterface (OAI) [7], an open software platform that provides an implementation of the full 5G NR stack, and on fundamental 5G Core (5GC) network functions. The demo tests IAB solutions over hundreds of radio nodes leveragin the large-scale experimentation capabilities and Software-defined Radios (SDRs) of Colosseum [2], the world's largest publicly accessible wireless emulator.

2 SYSTEM DESIGN

According to the 3GPP [9], an IAB-donor hosts a Central Unit (CU) and multiple Distributed Units (DUs). An IAB-node is split into two functional blocks, i.e., the DU, which offers connectivity to downstream IAB-nodes and User Equipments (UEs), and the Mobile Termination (MT), through which the node connects upstream. As OAI's implementation of the CU/DU functional split is not ready for large scale testing [8], our IAB testbed employs a full OAI's gNB in place of both CU and DU, as shown in Figure 1. An OAI UE acts as MT in each IAB-node, connecting upstream and establishing a GPRS Tunneling Protocol (GTP) tunnel for the IAB-node's DU to reach the 5GC. This architecture requires UEs to work as intermediate nodes, which is not supported by GTP. Therefore, we have implemented a minimal version of framed routing [1] in the OAI's 5GC SPGWU packet gateway function.

While the proposed software architecture is compatible with commercial off-the-shelf hardware, our testbed is based on the Colosseum experimental platform, where each IAB entity runs on a dedicated server called Standard Radio Node (SRN). Every SRN is remotely accessible and equipped with an USRP X310 SDR. Colosseum's Massive Channel Emulator (MCHEM) interconnects all the SDR and can emulate complex wireless environments through a tapped delay line channel model that can be customized according to the experiment requirements. At the time of writing, a pool of 128 SRNs is available to the academic community, allowing accessible large-scale testing of IAB networks.

3 DEMO DESCRIPTION

This demo will run live on the Colosseum emulator, with custom interfaces that display live metrics and the topology of the network in real time, and with testing of different wireless scenarios. The goal is to showcase how to instantiate and test end-to-end IAB networks on Colosseum by deploying a minimal set of 5GC functions, an IAB-donor, multiple UEs and multiple IAB-nodes arranged in a tree topology.

First, we show how to use the `IAB-manager` [5], a command-line tool developed to manage the entire network life-cycle with few simple commands. The `IAB-manager` acts as a single control interface to all the SRNs used in the experiment. It exposes an API that can be used to automate high-level network control operations (e.g., topology reconfiguration).

Additionally, we show how our custom OAI UE can let its parent node know whether the UE is an MT or not using UE Capability messages. This crucial information can be used by the parent node to optimize the performance of the 5G stack, down to the physical and Medium Access Control (MAC) layers, e.g., through IAB-aware scheduling or routing.

We conclude the demonstration by discussing future expansions and test-case applications.

4 CONCLUSIONS

We have described and showcased a large-scale and open IAB testbed based on OAI and capable of running on commercial off-the-shelf hardware. In this demonstration, we have used Colosseum, whose channel emulation capabilities allow testing IAB networks in virtually any wireless environment. Thanks to a network-level control API and low-layer information exchange, our testbed is ready for flexible, large-scale data collection and experimentation, as researchers can plug and test algorithms and solutions at all levels of abstraction.

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