An integrated testbed for full-stack 5G experimentation

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ABSTRACT

We describe the new integrated mobile network testbed that we are developing by merging CTTC's GEDOMIS Testbed with the ns-3 based LENA LTE-EPC emulated protocol stack running over CTTC's EXTREME Testbed. This new integrated testbed will allow full-stack experimentation of novel 5G technologies. We provide a description of the architecture of the integrated testbed and discuss some of its possible use cases.

Categories and Subject Descriptors

1.6.5 [**Simulation and Modeling**]: Model Development—*Modeling methodologies*; 1.6.7 [**Simulation and Modeling**]: Simulation Support System—*Environments*

Keywords

5G, LTE, Experimentation, Emulation, NFV

1. INTRODUCTION

The availability of full-stack mobile network testbed allowing experimentation from PHY up to applications and services is currently rare. In fact, experimental research for mobile network technologies is often limited to either 1) PHY layer platforms with minimal MAC layer support, due to the cost of commercial protocol stacks, and the limitations of open source ones, or 2) IP-level testbeds with limited access to low-level PHY configuration.

To overcome this limitation, we are developing an integrated mobile network testbed that merges CTTC's GEDOMIS ®testbed [1] with the ns-3 based LENA LTE-EPC emulated protocol stack [2, 3] running over CTTC's EXTREME Testbed ®[4]. The merge of LENA and GEDOMIS will allow full-stack experimentation of multiple 5G use cases that exploit the flexibility of SDN/NFV when applied to mobile networks (e.g., virtual base stations or self-organized networking). This may consider, for example, the virtual base station use case defined by the ETSI NFV group, or experiments on coverage and capacity optimization involving the whole radio protocol stack and its interactions with core network elements and real applications.

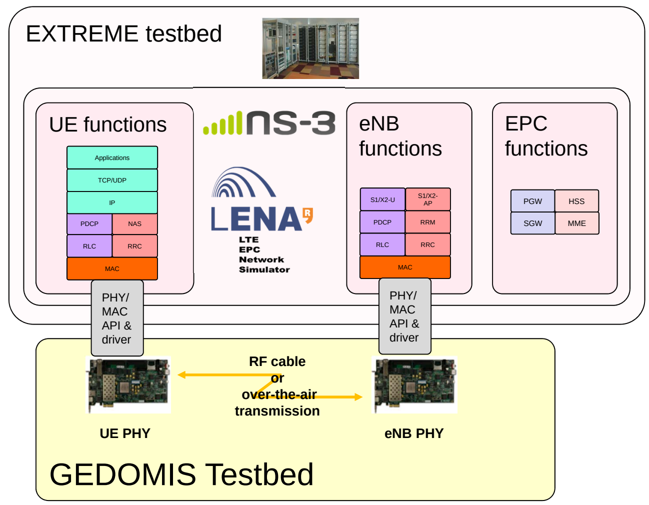

Figure 1: Architecture of the proposed integrated testbed

Our integrated testbed will allow evaluating full-stack NFV solutions in a real wireless propagation environment, with the possibility of combining both emulated and real (e.g., fiber) backhaul/aggregation network links and applications, and of including additional emulated cells in order to achieve a larger experiment scale.

2. ARCHITECTURE

The architecture of this solution is depicted in Figure 1. In this architecture, LENA is used to provide Layer 2 and above of the mobile network protocol stack, and GEDOMIS is used to provide a real-time implementation of Layer 1, thereby entirely replacing the simplified PHY simulation model provided by LENA, and allowing baseband transmission over cables or, with the inclusion of an appropriate RF frontend and antenna, over the air transmissions. Additionally, LENA-based network entities are to be split across several physical and virtual machines over the EXTREME testbed, in order to realize not only different network topologies but also different Network Function Virtualization (NFV) configurations.

A new PHY-MAC API is being developed to interface LENA and GEDOMIS. In the development of this interface

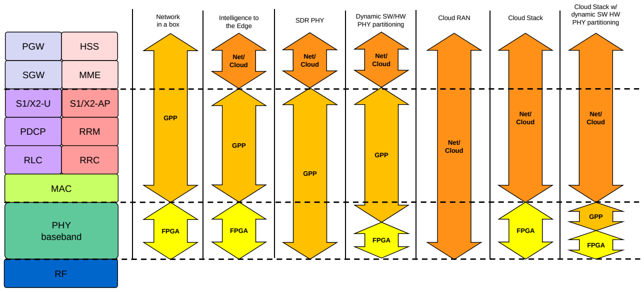

Figure 2: 5G HW/SW function split aspects

we are considering the current PHY SAPs already implemented in LENA, as well as industry standard PHY-MAC APIs such as the LTE L1 interface standardized by the Small Cell Forum.

3. USE CASES

Flexible HW-SW partitioning is widely perceived nowadays as a key technology enabler for fully exploiting the network programmability brought by SDN and NFV. In this way, the software programmable data plane combined with intelligent hardware that dynamically collaborates with control plane software, will allow addressing the performance, flexibility, energy efficiency and security challenges of 5G mobile networking. At the same time, the requirements for low latency communications (including signal processing), low power operation and high performance parallel computation will be made more stringent, thus imposing dedicated hardware solutions for some functions. On this matter, energy consumption issues have to be taken in consideration in order to help reduce the footprint of ICT in terms of greenhouse gas emissions. There are three main issues related to the HW-SW split: i) the physical location where communication stacks are implemented (e.g., base station, cloud), ii) the technology of the processing elements that is used (e.g., entirely programmable system-on-chip -SoC-, FPGAs, general purpose processors -GPP-) and iii) the granularity of the partitioning (e.g., at communication stack level, at function or process level).

In this context, it is interesting to investigate how to 1) to flexibly distribute functions of the communication stack among different processing elements (e.g., SoCs, FPGAs, GPPs), which are physically residing either in communication nodes (e.g., base stations) or in cloud processing architectures, and 2) to adaptively change processing topologies (e.g., base stations, intermediate nodes or cloud processing architectures). The decision for the distribution of the HW-SW functions will be made based on experiments made at design time (static mode), which will reflect specific 5G operating scenarios. Such function distribution may be done based on multiple criteria, such as high performance, low energy, low communication latency or a tradeoff of the previous. For instance, from an energy perspective, it would be interesting to have a more detailed model of the energy consumed by a BS respect to the reference used one [5]. An energy model that might include different modes of operations for each function in the available processing elements. This will enable to optimize the network configuration dynamically according to jointly energy and performance needs. Some different approaches for the HW-SW mobile network

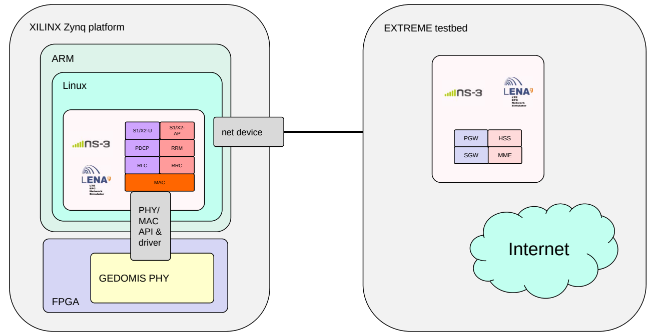

Figure 3: Use case 1: Intelligence to the Edge approach

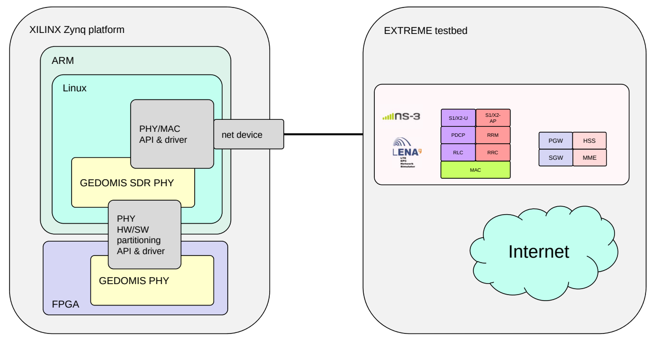

Figure 4: Use case 2: Cloud Stack with Dynamic HW/SW PHY partitioning approach

function split are depicted in Figure 2.

Our integrated testbed will allow the prototyping of such advanced HW-SW partitioning solutions, and such activity will be mainly framed under the umbrella of the 5G-PPP Flex5Gware project. As an example, in Figure 3 we show how a traditional intelligence-to-the-edge approach can be realized, and in Figure 4 we describe how a rearrangement of the component layout, together with the addition of a couple of new interfaces, can bring to the realization of a novel Cloud Stack paradigm together with dynamic HW/SW PHY function partitioning.

4. REFERENCES

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