# Coordinated vDU relocation for an Energy Efficient PON-based Open SD-RAN

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**ABSTRACT** Because of the foreseen widespread deployment of B5G cells, due to the small cell size, optimizing the radio access network (RAN) energy consumption is of paramount importance for both the service providers and the environment. This paper proposes a solution for decreasing the overall energy consumption of an Open Software Defined RAN (SD-RAN) considering not only the wireless segment but also the PON-based transport network. The solution is based on jointly performing the following actions: turning OFF selected RUs based on the offered UE traffic, migrating the most of the DU closer to the CUs, reallocating the capacity to the ONUs to support the midhaul traffic. The proposed solution presents high energy saving potentials for the whole RAN. Indeed, the energy consumption is moved closer to the central office (where most the functions cannot be deactivated) reducing the amount of energy consumed at the network periphery.

## 1. INTRODUCTION

Optimizing communications network energy consumption benefits network operators by decreasing their operational expenditures (OPEX). Moreover, it helps reducing greenhouse gas (GHG) emissions, if the utilised energy comes from non-renewable sources.

Open and virtualised radio access networks (Open RAN) offer the opportunity of modulating their energy consumption as a function of the carried data traffic. Indeed, by exploiting different gNB functional split options and network function virtualisation it is possible to (de)allocate resources when needed [1]. Several papers addressed already the issue of energy consumption in open virtualised Radio Access Networks (RAN).

In [2] the energy consumption of virtualised DU and CU is evaluated showing that different split options cause different DU and CU energy consumption and that the higher is the number of utilized Physical Resource Blocks (PRBs) the higher is the CU energy consumption. In addition, a framework, named apt-RAN, is proposed to optimally allocate CUs based on the DU traffic to minimize CU energy consumption and ensure Quality of Experience (QoE). Results show that the proposed method is capable of saving 30% more energy than state of the art methods while reducing the number of handovers, the number of DU relocations, and it affects less Guaranteed Bit Rate (GBR) flows. However, the study does not consider the impact of the proposed method and its interaction with the underlying RAN transport network.

The energy consumption issue is also addressed in the O-RAN architecture. In [3] the authors propose an multi-objective integer linear programming model to minimize the number of active RUs capable of guaranteeing a specific coverage given a specific traffic pattern from UEs. They show that a cost reduction, and as a consequence an energy reduction, up to 70% is achievable when the traffic is low. However, even in this case the impact on the interaction with the underlying transport network is not considered.

In O-RAN WG1 use cases related to energy consumption are defined in [4]. They include carrier and cell switch OFF/ON, RF Channel Reconfiguration, Advanced Sleep Mode Selection, O-Cloud Resource Energy Saving Mode. However, although these uses cases are very well detailed for what concerns the wireless segment and their potential impact, the interaction with the transport network is not considered.

The study reported in [5] proposes a scheme for coordinating the Time Division Duplexing (TDD) utilised in the air interface with the TDM-PON scheduling to save energy in transport network by turning OFF some ONU elements when data transmission in a specific direction is not required. However, this study focuses on the transport network equipment only and not jointly with energy saving schemes utilised in the wireless segment.

Finally, the study reported in [6] shows the benefit achievable when coordination between RIC and PON SDN controller is implemented, that is when an SD-RAN is implemented. Results show that a software defined converged approach to wavelength and bandwidth management guarantees the optimal allocation of optical resources. However, no considerations are made for what concerns energy efficiency.

This study proposes to coordinate, by means of an SDN-based approach, (i) RU switch OFF, (ii) vDU relocation, (iii) midhaul transport capacity reallocation with the purpose of saving energy in the whole RAN. Indeed, cell switch OFF allows to reduce RU energy consumption by reducing the number of active RUs; vDU relocation allows to reduce the energy consumed at the periphery by consolidating the numebr of active vDUs and moving them in the RAN central office; midhaul transport capacity reallocation supports vDU reallocation by guaranteeing the necessary capacity for the midhaul transport.

## 2. SD-RAN ARCHITECTURE

The considered architecture stems from the one proposed in O-RAN [7] and the one proposed [6] and it is depicted in Fig. 1. The next generation eNB (gNB) is split into Remote Unit (RU), Distributed Unit (DU), and

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Central Unit (CU). Split option 7.2x, proposed in [7], is considered between RU and DU while, between DU and CU, F1 interface is considered. DUs and CU are virtualised (e.g., vDU and vCU deployed in containers).

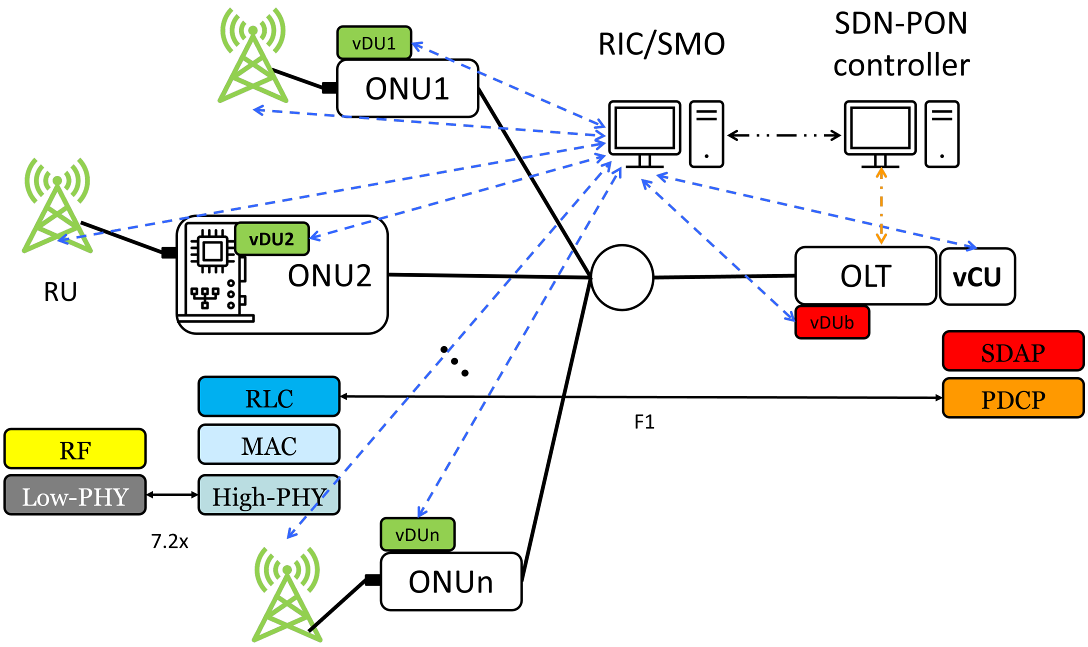


*Figure* 1: SD-RAN Architecture

The transport network is a Passive Optical Network (PON). Many technologies can be considered, such as higher speed passive optical networks [8] and Ethernet PONs [9]. For the sake of generality a PON where optical resources are shared in time (i.e., Time Division Multiplexed — TDM) is considered in this study. The vDU can be deployed in either ONUs or OLTs while the CU is assumed to be deployed at the OLT. The ONU implementation is assumed to be based on a virtualised approach, as described in [10] where ONU functions and DU functions share the same white box.

For what concerns the RAN control and management plane a RAN Intelligent Controller (RIC)/Service Management Orchestration Framework (SMO), incorporating both the Near-Real-Time RAN Intelligent Controller (NR-RIC) and the SMO including the Non-Real-Time RAN Intelligent Controller (Non-RT RIC), is considered for simplicity. The RIC/SMO is in charge of interacting with the O-RAN functional elements through the interfaces defined by O-RAN (i.e., A1, O1, E2, F1-c) [7] for orchestrating the RU switch-OFF, the vDU (de)allocation and relocation, and the x-haul management. In addition the RIC/SMO interacts with the PON SDN controller to coordinate bandwidth allocation to support the x-haul interface.

The PON control plane, in addition to the standardized control planes by ITU and IEEE, features an additional SDN-PON controller. The SDN-PON controller interacts with the RAN RIC/SMO to coordinate the bandwidth allocation to support the x-haul between RAN functional elements deployed at the ONU and at the OLT. The exchange of information between the RIC/SMO and the PON SDN controller is based on an *ad hoc* interface as proposed in [6].

## 3. Proposed solution workflow

The proposed scheme is based on the workflow depicted in Fig. 2, in a simplified version that does not take into account of negative acknowledgements (i.e., unsuccessful requests). The workflow aims at bringing the RAN from the normal working condition state, depicted in Fig. 1, to the energy saving state depicted in Fig. 3.

In the normal working condition state each vDU serves the corresponding RU while the backup vDU (i.e., vDUb) is OFF. In the energy saving state not only some RUs are switched OFF, as described in [4], but also some VDUs are turned OFF to save energy at the RAN periphery and they are consolidated into the backup vDUb that is deployed in the OLT where other mobile functions, such as the CU, are running.

As depicted in Fig. 2, once the RIC/SMO switches OFF the RU and it receives a positive acknowledgment from the RU controller, it switches the backup vDU (vDUb) ON. This make-before-break approach is chosen to avoid RAN failure.

After activating the vDUb the RIC/SMO interacts with the PON SDN controller (SDN-PON ctrl) to allocate the necessary capacity between the RUs that are still ON and the vDUb. Indeed, by relocating the vDU to which

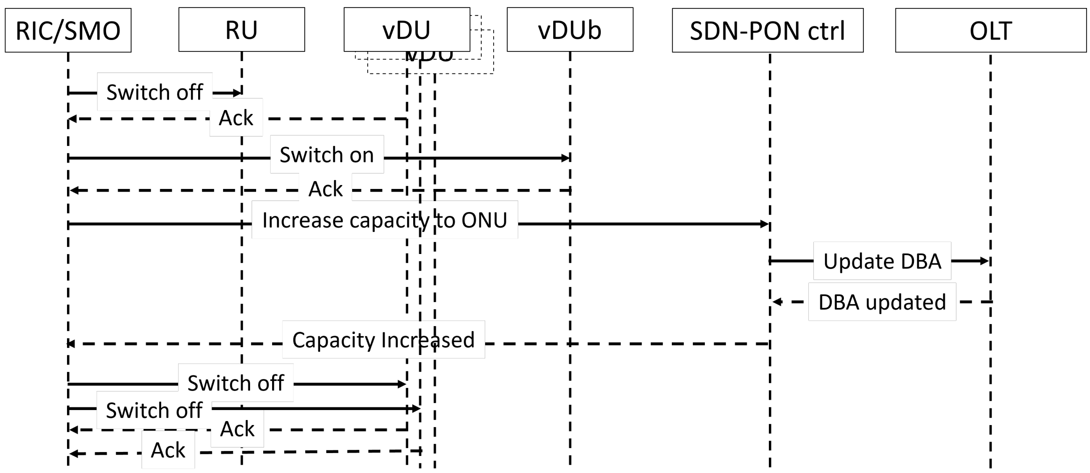


*Figure* 2: Proposed scheme workflow.

the RUs where connected an additional capacity to carry the 7.2x interface (as depicted in Fig. 3) is necessary. In addition, a specific scheduling of this transmission shall be implemented to meet the 7.2x interface latency requirement. After the capacity has been successfully allocated the RAN energy saving state in reached.

Once the requested capacity is assigned to the ONUs connected to the RUs that are still ON, a selected set of vDUs is turned OFF. This decision is taken by the RIC/SMO and it is done after PON capacity reallocation to make sure that enough capacity is available to carry the fronthaul interface between RU and DU.

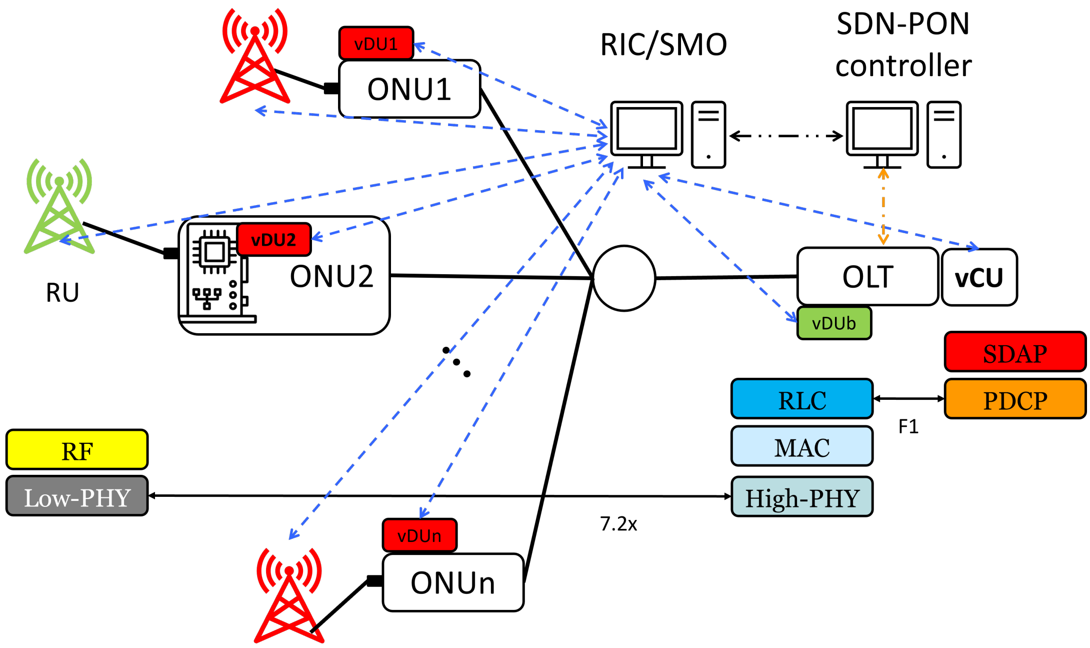


*Figure* 3: Energy saving state.

## 4. Considerations

Several aspects shall be considered to evaluate the proposed solution. First of all, RU (de)activation depends on the user traffic fluctuations. For example, if we consider a typical scenario, such as a stadium where spectators come and leave at specific times and they stay for a relative long time in the premises, such fluctuations have a relative long time scale. Thus, requirements on the reconfiguration time are quite loose.

However, in other use cases, where traffic/user fluctuations are quite fast, reconfiguration time requirements might be very strict. Thus, the described workflow shall be characterized by a fast completion time.

Moreover, the expected energy savings depend on the resources that can be turned on and off. Certainly, vDU consolidation during low mobile traffic periods contributes to energy efficiency by reducing the number of active virtual machines/containers. In addition, selected parts of the of the transport network, such as ONUs, can be synchronously turned off to save additional energy.

To perform an accurate evaluation though, a model shall be developed. Such model shall take into account the aforementioned considerations and additional ones that might emerge during the model construction.

## 5. Conclusions

This paper proposed a solution for decreasing the overall energy consumption of both the mobile and the transport network of a software-defined mobile access network. The solution coordinates the (de)activation of physical and virtual functional elements with the mobile user traffic fluctuations. However, to perform a detailed evaluation a model must be built that takes into account the time taken by the workflow execution.

## Acknowledgment

This work was partly supported by the project CLEVER (Project ID 101097560), that is supported by the Key Digital Technologies Joint Undertaking and its members (including top-up funding by Italian Ministry of University and Research — MUR), and partly by the European Union under the Italian National Recovery and Resilience Plan of NextGenerationEU, partnership on "Telecommunications of the Future" (PE00000001 - program "RESTART")."

The author would like to thanks Alessandro Pacini and Andrea Sgambelluri for the useful discussion.

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