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Software Defined 5G Converged Access as a viable Techno-Economic Solution

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Abstract: Software Defined Converged Access represents a feasible solution to effectively address 5G traffic demands. This paper proposes an integrated mobile-optical control for wavelength and bandwidth allocation. Evaluations of bandwidth utilization and techno-economic viability are provided.

1. Introduction

The huge capacity and low latency requirements of the fifth generation mobile networks (5G) imply huge investments for the network operators even in the terrestrial transport network. An envisioned solution to reduce both capital expenditure (CAPEX) and operating expenditure (OPEX) is network *softwareization*. Network softwareization is based on delivering "network functionality via software running on industry-standard commercial off-the-shelf (COTS) hardware" and on logically centralized control and programmability principles [1].

Software Defined Mobile Network (SDMN) [2] has been proposed to enhance the performance of Core and Radio Access Networks through advanced joint management of resources, spectrum and mobility, and by boosting the cooperation among heterogeneous networks. Software Defined Access (SDA) has been proposed for the optical access domain with special focus on the integration between Access and Aggregation networks [3]. NTT proposed Flexible Access System Architecture (FASA) [4] platform which allows software based modularized functions to support different add-on services such as enterprise, wireless and mobile. FASA also supports add-on modules for different optical technologies depending on the required transfer capacity. However, the FASA platform is under evaluation phase. In [5], a mobile Dynamic Bandwidth Allocation (DBA) scheme for TDM-PON that allocates proper time slots by cooperating with mobile scheduling based on the estimated data-arrival period has been proposed. It allows uplink transmission on mobile fronthaul with a latency of about 137 μs. However, it requires strict coordination between the Central Unit (CU) and the UE to exchange mobile scheduling information.

In this work a new SDA and SDMN integrated framework is proposed for a PON-based fronthauling solution. Within this framework a novel Software Defined Wavelength Bandwidth Allocation (SD-WBA) scheme is proposed exploiting the exchange of cell status information between the mobile and the fixed access. Results shows that the proposed SD-WBA reduces the mobile transport network CAPEX by exploiting for other services, in low-load hours (i.e., when mobile cells are off), some of the wavelengths unutilized by mobile fronthaul.

2. System Model

The SDA-SDMN integrated framework is proposed for the scenario shown in Fig. 1 (a) where a Macrocell is overlapped by several small cells deployed in an urban area and connected through a *Fiber To The X* (FTTx) infrastructure. Each cell site is equipped with a DU connected to a CU at the central office location. The fronthaul consists of the existing TWDM-PON infrastructure; thus, each DU is deployed in an Optical Network Unit (ONU).

The PON is under control of a SDA Controller which interacts with agents at the Optical Line Terminations (OLTs). The SDA controller is in charge of taking decisions related to flow modification and integrated QoS with metro network as well as bandwidth and wavelength assignment and activation. The mobile network is under the control of a SDMN Controller, which takes Radio Resource Management decisions, DUs (i.e., cell) activation/deactivation, centralized management and cooperation among DUs. The SDA and SDM controllers exchange respective network status information (e.g., cell activity, wavelengths utilization, wavelength and bandwidth assignment).

The exchanged information is exploited by the proposed SD-WBA. So far Fixed Bandwidth Allocation (FBA) was utilized in TDM-PON based fronthaul to guarantee low latency and assured bandwidth. However, it is characterized by inefficient bandwidth utilization since it allocates bandwidth even when it is not utilized by the DUs. The proposed SD-WBA allocates bandwidth and wavelengths for carrying DU-CU communication (i.e., fronthaul) in the PON only when

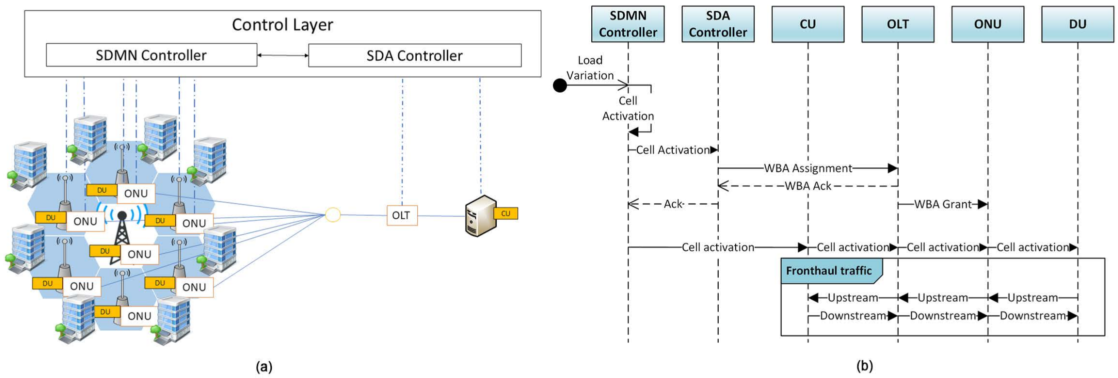

Fig. 1: (a) System Model; (b) Wavelength and Bandwidth Allocation Sequence Diagram

DUs/cells are activated and deallocates it when DUs/cells are deactivated. As shown in Fig. 1 (b), the SDMN controller detects a load variation in the mobile network that requires a new DU activation and notifies the SDA controller. The SDA controller interacts with the OLT that, in turn, acknowledges the SDA controller if enough bandwidth is available to serve the new fronthaul, and if needed activates a new wavelength. Moreover, the OLT sends a grant message to the interested ONU. When the SDMN controller receives acknowledgment from the SDA controller about bandwidth reservation for the fronthaul, the mobile procedure for cell activation takes place and the CU-DU fronthaul communication can start.

3. Performance Evaluation and Results

In our reference scenario a Macrocell is overlapped by 11 small cells (for reader's convenience, in Fig. 1 (a) only 6 small cells are shown). The fronthaul segment is implemented through NG-PON2 that is a TWDM-PON with four wavelengths pairs. Downstream wavelengths support 10 Gbps data rate while upstream wavelengths support 2.5 Gbps. Regarding functional split between DU and CU, we focus on option 7a Intra-PHY split defined in [6]. It requires 666 Mbps upstream bandwidth and a maximum latency of 250 μs for LTE 20MHz MIMO 2x2. The numerical evaluation of the considered scheme is performed in MATLAB environment.

We assume the Macrocell serving an area characterized by the time-variant traffic load illustrated in Fig. 2 (a) [7]. The SDMN controller guarantees that the Macrocell DU is always active and activates/deactivates small cells DUs according to the load of the Macrocell. Fig. 2 (b) shows the number of active DUs during the day corresponding the time-variant traffic loads. Since each new fronthaul segment requires 666 Mbps and an upstream wavelength supports 2.5 Gbps we can accommodate a maximum of 3 fronthaul segments per each wavelength. The remaining bandwidth can be utilized for other services such as FTTx, business with fixed connectivity and Internet of Things (IoT). Fig. 2 (c) shows the available bandwidth gain obtained by the adoption of the proposed SD-WBA. In FBA approach the bandwidth is constantly reserved to all the 12 fronthaul segments. On the other hand it can be noticed that SD-WBA approach provides an increase of the available bandwidth during night hours when mobile traffic is lower and DUs are deactivated. This brings to an average bandwidth required of 63% with respect to FBA.

To provide a reliable Techno-Economic analysis for varying numbers of subscribers, we consider a bigger urban area with a FTTx architecture composed by 10 PONs serving 10000 subscribers with 500 ONUs. Fig. 2 (d) shows the assumed traffic pattern for a single ONU serving 20 subscribers. In Fig. 2 (e) we assume new DUs are deployed and connected through the available infrastructures. It can be noticed how deploying new DUs decreases the average bandwidth per ONU if no additional PON infrastructures are deployed. Moreover, it can be observed that the proposed approach achieves a higher average bandwidth per ONU than FBA.

As shown in Fig. 2 (f) the operator can compensate the reduction of the ONU bandwidth by deploying additional PONs, i.e. making new investments. Assuming a deployment of 5 new DUs per year we show that adopting a converged SD-WBA approach allows a significant reduction of annual investments. This is explainable by the fact that the proposed SD-WBA allows the operator to accommodate a higher number of DUs in a single PON with no impact on ONUs' average bandwidth. This allows an immediate saving on operator's investments that can be utilized for longer-term acquisition of equipment. On the other hand, the higher availability of bandwidth enables the introduction of higher quality services that can result in augmented incomes for the operator, and this would not be possible with the conventional non-converged FBA approach.

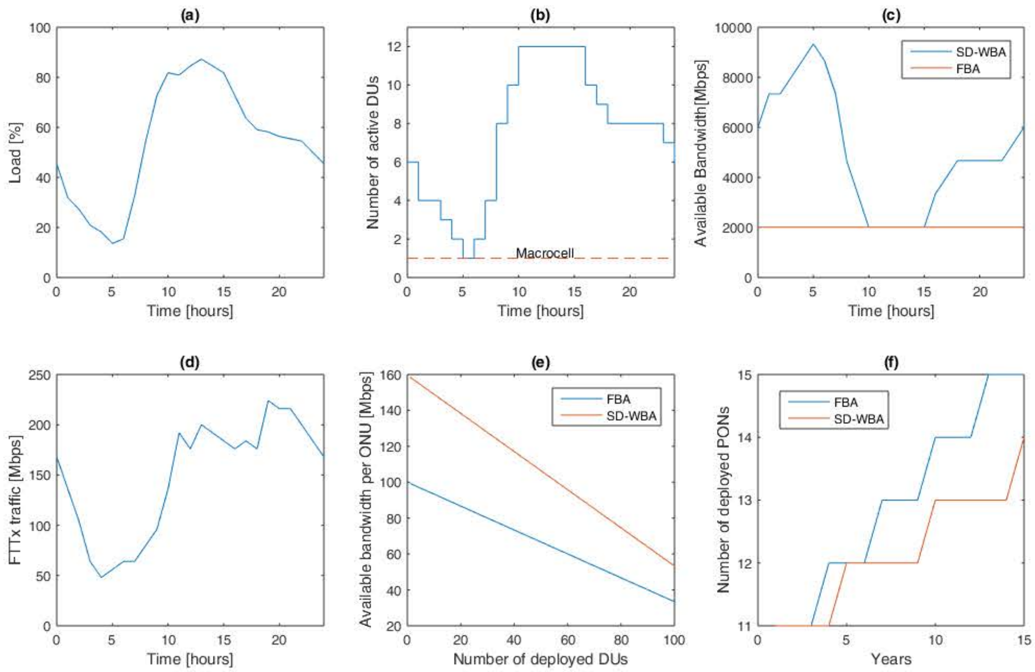

Fig. 2: (a) Macrocell area load; (b) Number of active DUs; (c) Available bandwidth, single PON; (d) ONU FTTx traffic (20 subscribers); (e) Average bandwidth per ONU (10 PONs); (f) Newly deployed PONs

4. Conclusion

We proposed a converged approach between SDMN and SDA control for optimal WBA in TWDM-PON fronthauling. We illustrated a new mechanism for joint wavelength and bandwidth allocation based on cell activation and deactivation. Results show that SD-WBA approach produces an average reduction of bandwidth occupancy of 37%. The proposed converged approach also provides a significant reduction of initial investments for the operator and at the same time leaves space for a promising increase of incomes.

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