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# Switching off unused bands and optimal DUs placement on O-RAN multi-band system

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## Abstract

Currently, the Open Radio Access Network (O-RAN) architecture is the best solution for deploying Radio Access Network (RAN). This architecture presents several challenges, i.e., function splitting, function placement and energy consumption. The aim of this study is to satisfy user demand while minimizing costs. In this work we combine the O-RAN architecture and the multiband system. We consider that the RAN network load varies during the day, and we study the optimal placement of the Distributed Unit (DU) function and switch off unnecessary frequency bands. First, we propose an algorithm to find the number of frequency bands needed to satisfy user demand for different smoothing periods. Based on these results, we formulate the problem of DU placement and frequency band switch-off as an Integer Linear Programming (ILP) whose objective is to minimize computing and routing cost while respecting delay and capacity constraints. Evaluation of our model on real topology has shown that our model with frequency band extinction has a much lower system cost than our model without band extinction.

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# 1 Introduction

Currently, the world is becoming more and more connected, which increases the demand for service. The challenge is to satisfy user demand while respecting time constraints. Nowadays, operators need to deploy more base stations to meet user demand with current architecture. This makes D-RAN no longer the best solution, because it has huge operating costs. This is why the O-RAN architecture has been proposed in the literature.

The O-RAN architecture has been proposed by the O-RAN Alliance as a promising solution for future radio access networks [3, 2]. As a reminder, this architecture is composed of three units: Radio Unit (RU), DU and Centralized Unit (CU) [12]. In this work we combined the multi-band system and the O-RAN architecture to increase network capacity and flexibility of DU function placement. In this study, we focus on the optimal placement of DUs and disabled of unnecessary frequency bands. The possibility of switching off frequency band has an impact on the total cost of the system, because it allows us to use the frequency band required instead of using all bands.

**Contributions.** In this paper, we propose a solution that deals with DUs placement and extinction of unused frequency bands. In this work we have a network load that varies during the day and we want to distribute the load over the different frequency bands. We consider a model in which each RU has a set of frequencies, the CU is placed on the core network and DU can be placed anywhere in the network. First, we propose an algorithm to select the number of frequency bands needed to satisfy user demand. Secondly, we formulate our problem as an Integer Linear Program (ILP), whose objective is to distribute the load over the different bands, switching off unused bands and finding the optimal placement of DUs in the network while minimizing the cost of the system. Thirdly, we evaluate our model on a topology and analyze the impact of switching off unused bands on system costs throughout the day.

**Paper organization.** We present the state of the art of function placement and system cost optimization in Section 2. We propose an algorithm for selecting the number of bands required. in Section 3. In Section 4, we formulate the problem statement, then model the problem. We analyze the impact of band extinction and optimal DUs placement on total system cost in Section 5.

## 2 Related Work

O-RAN architecture currently presents a number of challenges. In this section, we will present some works from the literature on function splitting, system cost optimization and function placement.

Garcia-Saavedra et al. [8] propose a model with one CU and several RUs close to the users. Their objective is to maximize the number of functions placed on the CU in order to minimize the cost of the system. Ojaghi et al. [13] propose Sliced-RAN, a similar approach to FluidRAN [8]. In this model, each user's function placement can be different from the others depending on what he does. For example, someone sending messages will not have the same slice as someone watching a movie. Both studies consider neither DU placement nor O-RAN, even though optimizing the placement of DUs improves performance.

Murti et al. [10] proposed a model with several CUs that can be placed in any network node and virtualized. Their objective is to maximize the number of functions in the CU, thus minimizing the number of active nodes. The authors consider fixed DUs close to RUs which reduces flexibility. In [6] the authors propose a model with several RUs and one CU, which can sometimes be co-located with the core network or placed in another node. Their objective is to minimize the computing cost by maximizing the number of functions that can be placed in the CU.

Morais et al. [9] proposed a model with O-RAN architecture. DU and CU are virtualized and can be placed in any network node. Their objective is to reduce the number of active nodes.

Almeida et al. [4] have a similar approach as PlaceRAN [9]. In their model, the flow is split to avoid congestion on the links. Fraga et al. [7] propose a similar model as [4], but they add the Multi-access Edge Computing (MEC), enabling traffic and services to be moved from a centralized cloud to an edge network, closer to the customer.

In [14] the authors propose a model with O-RAN architecture. In their model, they consider that RUs, DUs and CUs are virtualized. The authors begin by formulating a multi-objective problem which consists in jointly optimizing the selection of the functional split, the processing and the allocation of transmission resources for the slices.

In [12], we proposed a model based on the O-RAN architecture. We consider a single CU placed at the core network and several DUs that can be placed on all nodes. Our objective is to minimize the processing cost depending on the placement of the DUs. The limitation of this model is that when the network load becomes too great, our model no longer provides a solution because the link constraints are reached. In [11], we have proposed a model similar to [12] but with the addition of the multiband system, which increases network capacity. The objective is to optimize DU placement while minimizing computing and routing costs.

In [5] the authors minimize the energy consumed by base stations on the basis of real measurements for a commercial multiband LTE network. They seek to deactivate certain frequency bands when the network load is low. Switching off certain bands during low-load periods reduces the energy consumed.

In all the papers presented in this article, including ours, the authors have not considered the combination of O-RAN architecture and multiband systems, with the emphasis on frequency band extinction.

### 3 Band pre-selection algorithm

The algorithm proposed in this section enables us to determine the number of frequency bands required as the network load evolves over the day. In radio networks, low frequencies have a much higher coverage than high frequencies. In this algorithm, we prioritize the lower frequencies to get more coverage to serve all users. Unnecessary frequency bands can be deactivated to reduce system costs. The main idea is to transfer users connected in the high-frequency bands to the low-frequency bands.

Our objective is to use the number of frequency bands needed to satisfy user demand. In our study, we consider a reallocation period of 10 ms, 30 ms, 100 ms and 1s. The reallocation period is the time during an allocation that can be modified.

The first step in the study is to determine the number of bands actually needed for a given reallocation period. The second step is to determine the number of bands for an activation period. The activation period is the time interval during which the frequency band remains active or deactivated. In our study, we consider activation periods of 30 minutes and 1 hour.

Let  $S_j$  be the number of Physical Resource Block (PRB) for each frequency band for a reallocation period. Let  $F$  be the number of frequency bands available in the cell and  $f \in \{1, 2, \dots, F\}$  denote the frequency band number, where  $f = 1$  is the lowest frequency band and  $f = F$  is the highest frequency band.

$$S_j = \sigma \sum_{f=1}^j PRB_f \quad (1)$$

where  $\sigma$  is the duration of the reallocation period in milliseconds and  $PRB_f$  is the number of PRBs per TTI in the band  $f \in \{1, 2, 3, 4\}$

Let  $h_i$  be the number of required frequency bands in the reallocation period  $i$ :

$$h_i = \begin{cases} 1 & \text{if } PRB_i \leq S_1 \\ 2 & \text{if } S_1 \leq PRB_i \leq S_2 \\ 3 & \text{if } S_2 \leq PRB_i \leq S_3 \\ 4 & \text{if } otherwise \end{cases} \quad (2)$$

where  $PRB_i$  is the total number of PRBs allocated in the reallocation period  $i$

Let  $N_t$  be the number of frequency bands required in the activation period  $t$

$$N_t = \max\{h_0, h_1, \dots, h_{I-1}\} \quad (3)$$

Figure 1 shows the evolution of the number of bands used for different reallocation periods for each 30 minutes. As explained above, the number of bands needed to satisfy user demand depends on the reallocation period and the activation period. For a high reallocation period (e.g. reallocation period equal to 1s) the number of bands needed to satisfy user demand at peak times is three, whereas for off-peak times we need just one band to satisfy user demand. For a low reallocation period the number of bands needed for peak hours is four, while for off-peak hours the number of bands needed to satisfy user demand is two.

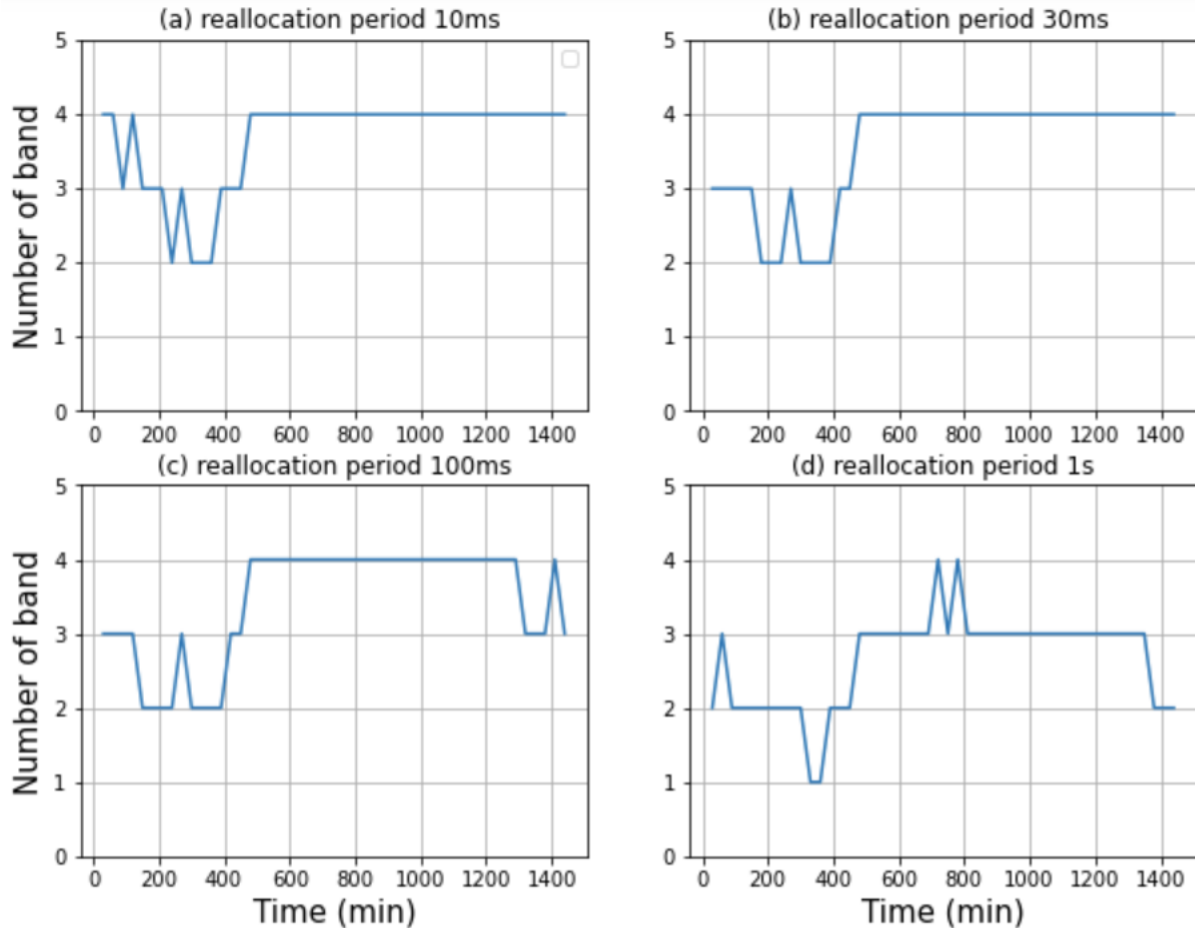


Figure 1: Number of frequency band for every 30 minutes

Figure 2 shows the number of hours that the frequency bands are switched on during the day. For the different reallocation periods used, we can see that the 800 MHz band is on throughout the day, giving us much greater coverage than the other frequency bands. The 1800 MHz band is on all day for reallocation periods of 10 ms, 30 ms and 100 ms. When the reallocation period becomes longer, equal to 1 s, the 1800 MHz band is switched off for two hours, corresponding to off-peak hours, when the 800 MHz band can meet user demand. For the 2100 MHz and 2600 MHz bands, the number of hours they are switched on gradually decreases as the reallocation period increases.

Figure 3 shows the evolution of the number of bands for a period of one hour with different reallocation periods. For a low reallocation period (10 ms) the four frequency bands are used throughout the day, whereas for a high reallocation period (1 s) two frequency bands are used at off-peak and four frequency bands at peak. For the intermediate reallocation period (30 ms and 100 ms), the number of frequency bands varies during the off-peak period, while it remains constant for the rest of the day, equal to four bands.

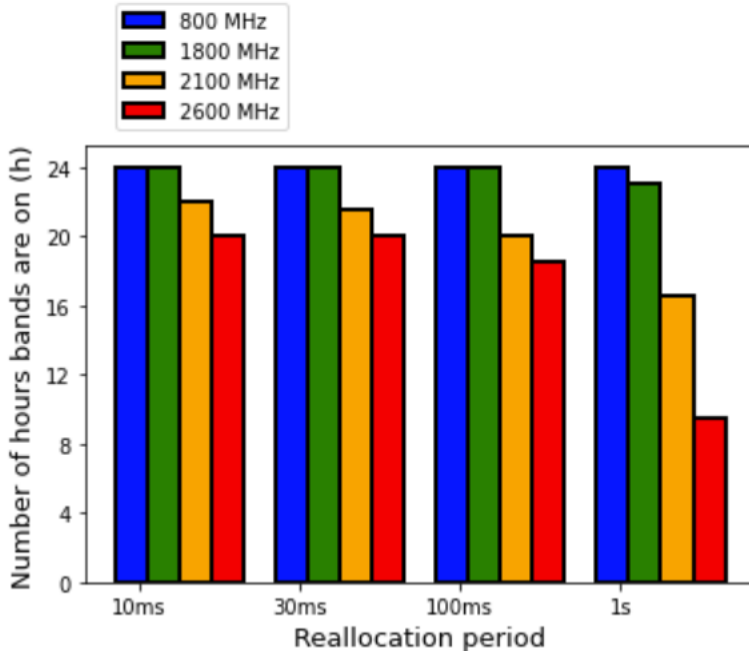


Figure 2: Number of hours frequency bands are used for a period of 30 mn

Figure 4 shows the evolution of the number of hours the frequency bands are switched on as a function of the reallocation period for a duration of one hour. We have observed that for a reallocation period of 10 ms all frequency bands are switched on because for a low reallocation period we can have high traffic peaks, which means we need more bands to satisfy user demand. For reallocation periods of 30 ms, 100 ms and 1 s, we found that the 800 MHz and 1800 MHz bands are used all day long, while the number of hours the 2100 MHz and 2600 MHz bands are switched on decreases when the reallocation period is reduced.

## 4 Problem statement and Model

### 4.1 Problem statement

In this study, we consider a directed graph  $G = (V, A)$  composed of a set of nodes  $V$  and a set of links  $A$ . Each node of the network has a maximum processing capacity  $C_v$ . Each arc  $a$  of the network has a maximum capacity  $B_a$ , a fixed transmission delay  $\delta_a$  and a routing cost  $\gamma_a$ . In this work, the RUs are already deployed in the network and the CU is placed on the network core. Our challenge in this paper is to switch on the minimum possible frequency band while satisfying user demand and find an optimal placement of DUs when the network load varies over the day. We denote  $V_R$  the set of nodes containing an RU. Let  $F$  be the set of frequencies for each RU and  $\lambda_n$  the load of each RU  $n$ .

We denote  $\alpha_v$  (monetary units) the upkeep cost, the fee to pay each time we place a DU on a network node, a request service cost called  $\beta_v$  (monetary units/cycle) (as in [8]) and DU function processing load as  $\rho$  (cycle per Gbps).

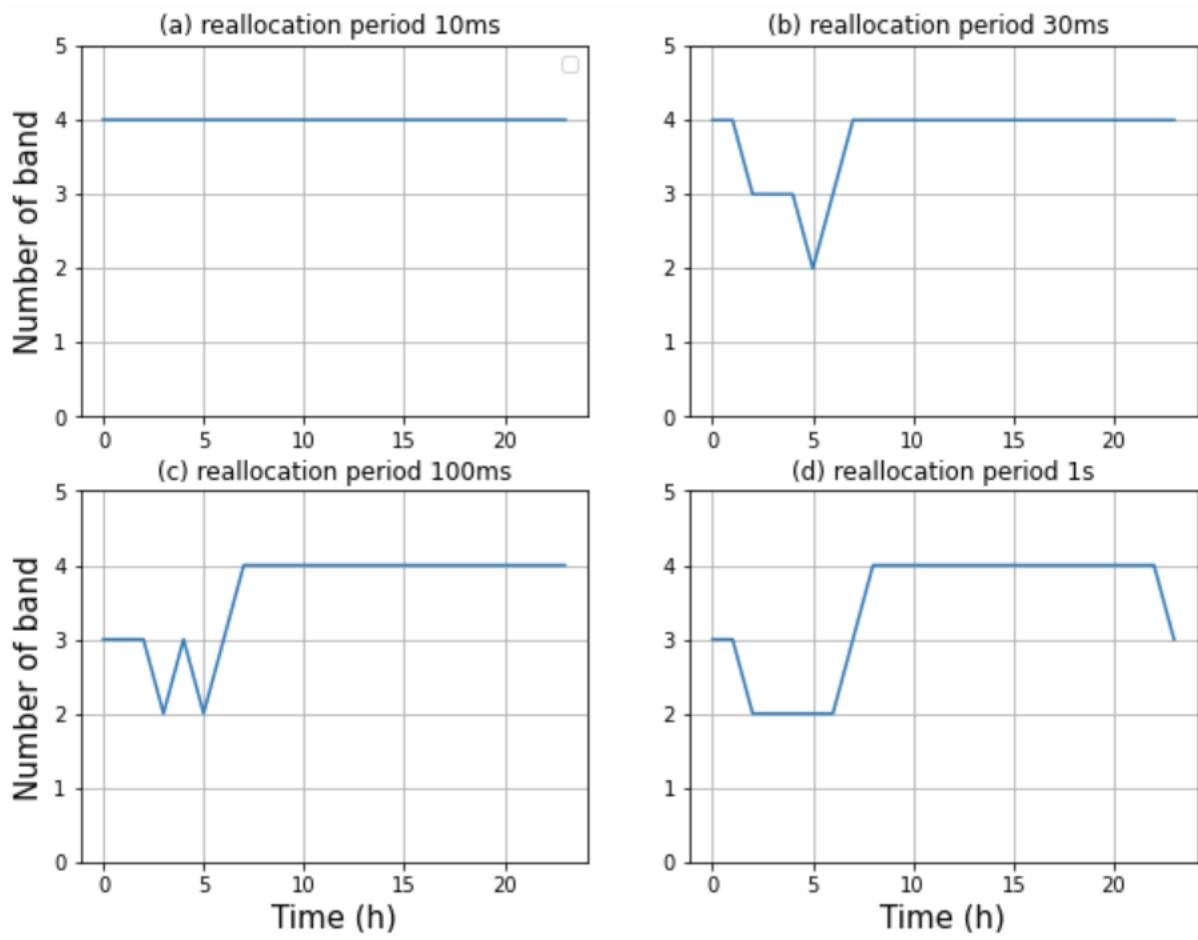


Figure 3: Number of frequency band for every hour

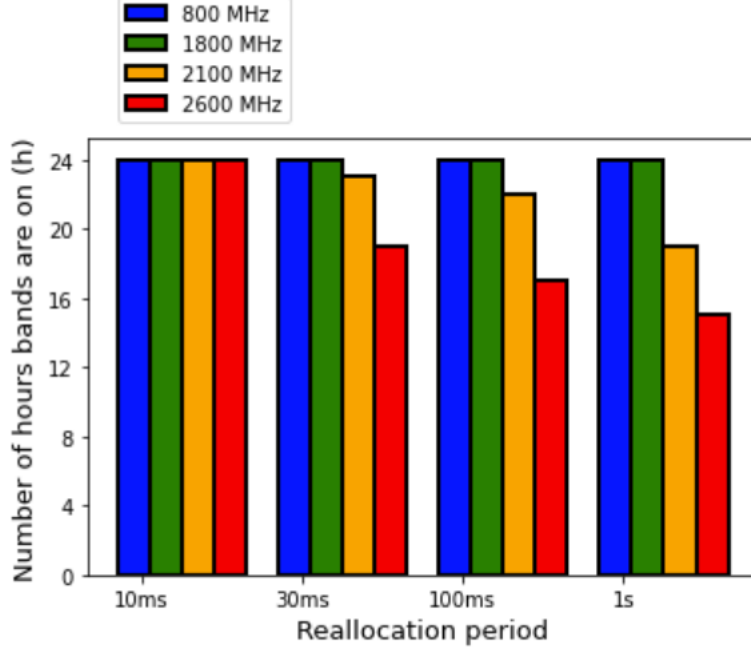


Figure 4: Number of hours frequency bands are used for a period of one hour

## 4.2 Problem Formulation

### 4.2.1 Function placement

Let  $y_{nvf}$  be a binary variable that indicates the placement of a DU that serves RU  $n$  with frequency  $f$  at node  $v$  of the network and denote  $l_{nf}$  the load for each RU  $n$  with frequency  $f$ . Each node has a maximum capacity. The capacity constraint for each node is defined below:

$$\sum_{n \in V_R} \sum_{f \in F} l_{nf} y_{nvf} \rho \leq C_v \quad \forall v \in V. \quad (4)$$

Since the variables  $y_{nvf}$  and  $l_{nf}$  are decision variables, multiplications of these variables give something non-linear. To linearize we denote  $w_{nvf} \in \mathbb{R}^+$  the load of node  $v$  for RU  $n$  with frequency  $f$ . Table ?? shows more detail when the variable decision  $y_{nvf}$  changes.

$$w_{nvf} = l_{nf} y_{nvf} \quad \forall f \in F, \quad \forall n \in V_R, \quad \forall v \in V \quad (5)$$

$$w_{nvf} = \begin{cases} l_{nf} & \text{if } y_{nvf} = 1 \\ 0 & \text{otherwise.} \end{cases} \quad (6)$$

### 4.2.2 Frequency band capacity constraints

Let  $K_f$  be the factor for calculating fronthaul bit rate.

$$k_f = \frac{L_{IP} + L_H}{r_f Q_f M} \times \frac{1}{L_{IP}} \quad \forall f \in F \quad (7)$$

where  $L_{IP}$  is the size of the user IP packet,  $H_{F_2}$  the total header size due to CPRI and companion protocols,  $H_{F_1}$  the sum of the headers of the various protocols used on the fronthaul,  $r_f$  is the code rate of each

frequency,  $Q_f$  the number of bits per symbol of each frequency,  $M$  represents the number of symbols in a PRB and  $\theta$  the number of bits quantifying an I or a Q symbol.

The number of PRBs per second of each frequency band is equal to the factor  $k_f$  multiplied by the load of each frequency band  $l_{nf}$ :

$$k_f l_{nf} \quad \forall f \in F, \forall n \in V_R \quad (8)$$

Let  $T$  be the duration of the subframe. To obtain the number of PRBs per subframe, multiply by the factor  $T = 10^{-3}$ . Table 1 shows the bandwidth of each frequency band and the number of PRBs for each subframe. The number of PRBs per subframe is defined as follows.

$$k_f T l_{nf} \leq N_f \quad \forall f \in F, \forall n \in V_R \quad (9)$$

Table 1: Number of PRBs for each frequency

Freq (MHz)	Bandwith(MHz)	$N_{PRB}$
800	10	50
1800	20	100
2100	15	75
2600	15	75

### 4.2.3 Routing decisions

We use two sets of binary variables for routing decisions:  $x_{an}^M \in \{0, 1\}$  indicates the arcs taken between CU and DU, and  $x_{an}^F \in \{0, 1\}$  indicates the arcs taken between DU and RU. Each link has a maximum capacity. The constraint for link capacities is defined below:

$$\sum_{n \in V_R} k l_{nf} x_{anf}^M + C k_f l_{nf} x_{anf}^F \leq B_a \quad \forall a \in A \quad (10)$$

where  $k=1.026$  (see [12]),  $C$  is the total length of a CPRI frame .

As the variable  $l_{nf}$  is a decision variable, the multiplication of  $x_{anf}^F$  and  $l_{nf}$  at the fronthaul level and the multiplication of  $x_{anf}^M$  and  $l_{nf}$  at the midhaul level give something nonlinear. To linearize, we denote  $g_{anf}^M \in \mathbb{R}^+$  as the load on the link  $a$  for RU  $n$  with frequency  $f$  in the middle of the journey and  $g_{anf}^F \in \mathbb{R}^+$  as the load on link  $a$  for RU  $n$  with frequency  $f$  in the front of the journey.

$$g_{anf}^M = l_{nf} x_{anf}^M \quad \forall f \in F, \quad \forall n \in V_R, \quad \forall a \in F \quad (11)$$

$$g_{anf}^M = \begin{cases} l_{nf} & \text{if } x_{anf}^M = 1 \\ 0 & \text{otherwise.} \end{cases} \quad (12)$$

$$g_{anf}^F = l_{nf} x_{anf}^F \quad \forall f \in F, \quad \forall n \in V_R, \quad \forall a \in F \quad (13)$$

$$g_{anf}^F = \begin{cases} l_{nf} & \text{if } x_{anf}^F = 1 \\ 0 & \text{otherwise.} \end{cases} \quad (14)$$

Table 2: Linearization of routing decision function on the midhaul

$x_{anf}^M$	$g_{anf}^M \leq \lambda_n x_{anf}^M$	$g_{anf}^M \geq l_{nf} - \lambda_n(1 - x_{anf}^M)$
0	$g_{anf}^M \leq 0$	$g_{anf}^M \geq l_{nf} - \lambda_n$
1	$g_{anf}^M \leq \lambda_n$	$g_{anf}^M \geq l_{nf}$

Table 3: Linearization of routing decision function on the fronthaul

$x_{anf}^F$	$g_{anf}^F \leq \lambda_n x_{anf}^F$	$g_{anf}^F \geq l_{nf} - \lambda_n(1 - x_{anf}^F)$
0	$g_{anf}^F \leq 0$	$g_{anf}^F \geq l_{nf} - \lambda_n$
1	$g_{anf}^F \leq \lambda_n$	$g_{anf}^F \geq l_{nf}$

#### 4.2.4 Objective function

Our objective is to minimize the number of bands needed to satisfy user demand and place the set of DUs in the network while minimizing the computation and routing costs. When a DUs is placed in a node we have the processing cost and the routing cost of the flow to the destination. These two costs depend on the load of the network.

**Computation cost.** The deployment of DUs in network nodes entails a cost that is made up of processing cost and upkeep cost. The processing cost depends on the load and the upkeep cost is a fixed cost paid each time a node is active. The formulation of this cost is defined below:

$$R_v(z, w, p) = \alpha_v z_v + \rho \beta_v \sum_{n \in V_R} \sum_{f \in F} w_{nvf} + \sum_{n \in V_R} \sum_{f \in F} \mu_f p_{nf} \quad (15)$$

where  $w_{nvf}$  is the load on node  $v$  for RU  $n$  with frequency  $f$ ,  $\alpha_v$  the upkeep cost,  $z_v$  the activation variable of a DU on node  $v$ ,  $\rho$  the processing load of DU,  $\beta_v$  the average cost for serving each request and  $\lambda_{nf}$  the load of RU  $n$  with frequency  $f$ ,  $p_{nf}$  is a binary variable and indicate activation band.

**Routing cost.** This cost depend on the distance between the nodes and the load of the network. We denote  $\gamma_a$  the cost for arc  $a$  (monetary units/Gbps)

$$R_a(g) = \gamma_a \sum_{n \in V_R} \sum_{f \in F} (K g_{anf}^M + C K_f g_{anf}^F) \quad (16)$$

where  $g_{anf}^M$  indicates the load on the link  $a$  taken in the Midhaul (between CU and DU),  $g_{anf}^F$  the load on the link  $a$  taken in the Fronthaul (between DU and RU),  $k$  the factor for calculating Midhaul bite rate (see chapter 3) and  $k_f$  the factor for calculating fronthaul bit rate.

By combining computing cost, routing cost and band extinction, we formulate our problem to minimize total cost, as shown in (17) and all variables used in our model are defined in Table 4. Equation (18) ensures that the sum of the loads of each frequency band does not exceed the load of the base station. Equation (19) ensures that the number of PRBs of each frequency band does not exceed the maximum number of PRBs of each frequency band. Equation (21) and (22) ensure that the 800 MHz band remains active throughout the day. In our model, we made an assumption that an RU  $n$  with frequency  $f$  cannot be affected to several DUs as shown in (23). Equation (24) ensures a node is active when the DU function is placed in that node. Equation (25) and (26) represent the conservation of flow and allow us to know which arcs are taken in the Fronthaul and Midhaul. Equation (27) represents the delay constraint on the midhaul and (28) the delay constraint on the fronthaul. Equation (29) ensures the computation capacity needed to process the DU

function is less than the available capacity in node  $v$ . The constraints defined in equation (32) ensures that the capacity of each link is not exceeded in order to guarantee correct flow routing.

Table 4: Summary of notations used in our model

<b>Sets</b>	<b>Definition</b>
$A$	The set of links
$V_R$	the set of nodes containing RUs
$V$	the set of nodes that can contain DUs
$F$	the set of frequency band
<b>Data</b>	<b>Definition</b>
$B_a$	Maximum bandwidth of link $a$
$C_v$	Processing capacity of node $v \in V$
$N_f$	Maximum number of PRB for each frequency $f$
$\delta_a$	The delay of arc $a$
$\lambda_n$	The load for each RU $n$
$\rho$	Processing load of DU
$\tau_{800}$	Maximum throughput in the 800 MHz frequency band
$\mu_f$	The priority of frequency band $f$
<b>Variables</b>	<b>Definition</b>
$y_{nvf}$	DU placement on $v$ for RU $n$ with frequency $f$
$l_{nf}$	The load for each RU $n$ with frequency $f$
$x_{anf}^M$	Arc $a$ between CU and DU for RU $n$ with frequency $f$
$x_{anf}^F$	Arc $a$ between DU and RU for RU $n$ with frequency $f$
$w_{nvf}$	The load of node $v$ for RU $n$ with frequency $f$
$g_{anf}^M$	The load on link $a$ on the midhaul
$g_{anf}^F$	The load on link $a$ on the fronthaul
$p_{nf}$	Indicate active band $f$ for RU $n$

## 5 Evaluation and Analysis

### 5.1 Definition of topology

In this study, we use a real topology to evaluate our model. As a reminder, this topology is located in the northern region of Italy and it is composed of 51 nodes and 61 links. For the nodes we have two categories: Access node (AC) and Aggregation node (AG). The capacities of the aggregation nodes are superior to the access node. Link capacities vary according to node type (see TABLE ??). For aggregation nodes (AG), link capacities range from 40 Gbps to 400 Gbps, and from 10 Gbps to 40 Gbps for access nodes (AC) [1, 9]. Figure 5 shows the topology used to evaluate our model.

### 5.2 Analysis of DUs placement on the network

In this subsection we evaluate our model on real topology. Figure 6 shows the location of the DUs at 11 am. The white nodes represent the location of the DUs, the red nodes represent the RUs, and the white red nodes show that on this node we have one RU and one DU. We notice that 21 nodes are active at peak times and that each node can contain several DUs, allowing resources to be shared. We also noticed that a set of DUs placed on the same node can serve several RUs. For off-peak hours, we noticed that the number of active nodes is constant and equal to 19. In summary, we can say that network load plays an important role in the location of DUs on the topology. This is because we have link constraints and node capacities that demand load.

$$\min_{g,p,w,z} \sum_{v \in V} R_v(z, w, p) + \sum_{a \in A} R_a(g) \quad (17)$$

$$s.t. \quad \sum_{f \in F} l_{nf} = \lambda_n \quad \forall n \in V_R \quad (18)$$

$$k_f T l_{nf} \leq N_f \quad \forall n \in V_R, \forall f \in F \quad (19)$$

$$l_{nf} \leq \lambda_n p_{nf} \quad \forall f \in F, \forall n \in V_R \quad (20)$$

$$if \quad \lambda_n \leq \tau_{800} \quad l_{n,800} = \lambda_n \quad \forall n \in V_R \quad (21)$$

$$if \quad \lambda_n \geq \tau_{800} \quad l_{n,800} = \tau_{800} \quad \forall n \in V_R \quad (22)$$

$$\sum_{v \in V} y_{nvf} \leq 1 \quad \forall n \in V_R, \forall f \in F \quad (23)$$

$$y_{nvf} \leq z_v \quad \forall f \in F, \forall n \in V_R, \forall v \in V \quad (24)$$

$$\sum_{a \in W^+(u)} x_{anf}^M - \sum_{a \in W^-(u)} x_{anf}^M = \begin{cases} 1 - y_{nvf} & u=v_0 \\ -y_{nvf} & \text{otherwise.} \end{cases} \quad (25)$$

$$\sum_{a \in W^+(u)} x_{anf}^F - \sum_{a \in W^-(u)} x_{anf}^F = \begin{cases} y_{nvf} - 1 & u = n \\ y_{nvf} & \text{otherwise.} \end{cases} \quad (26)$$

$$\sum_{a \in A} \delta_a x_{anf}^M \leq 30 \text{ ms} \quad \forall f \in F, \forall n \in V_R \quad (27)$$

$$\sum_{a \in A} \delta_a x_{anf}^F \leq 0.25 \text{ ms} \quad \forall f \in F, \forall n \in V_R \quad (28)$$

$$\sum_{n \in V_R} \sum_{f \in F} w_{nvf} \rho \leq C_v \quad \forall v \in V \quad (29)$$

$$w_{nvf} \leq \lambda_n y_{nvf} \quad \forall f \in F, \forall n \in V_R, \forall v \in V \quad (30)$$

$$w_{nvf} \geq l_{nf} - \lambda_n (1 - y_{nvf}) \quad \forall f \in F, \forall n \in V_R, \forall v \in V \quad (31)$$

$$\sum_{n \in V_R} \sum_{f \in F} (k g_{anf}^M + C k_f g_{anf}^F) \leq B_a \quad \forall a \in A \quad (32)$$

$$g_{anf}^M \leq \lambda_n x_{anf}^M \quad \forall f \in F, \forall n \in V_R, \forall a \in A \quad (33)$$

$$g_{anf}^M \geq l_{nf} - \lambda_n (1 - x_{anf}^M) \quad \forall f \in F, \forall n \in V_R, \forall a \in A \quad (34)$$

$$g_{anf}^F \leq \lambda_n x_{anf}^F \quad \forall f \in F, \forall n \in V_R, \forall a \in A \quad (35)$$

$$g_{anf}^F \geq l_{nf} - \lambda_n (1 - x_{anf}^F) \quad \forall f \in F, \forall n \in V_R, \forall a \in A \quad (36)$$

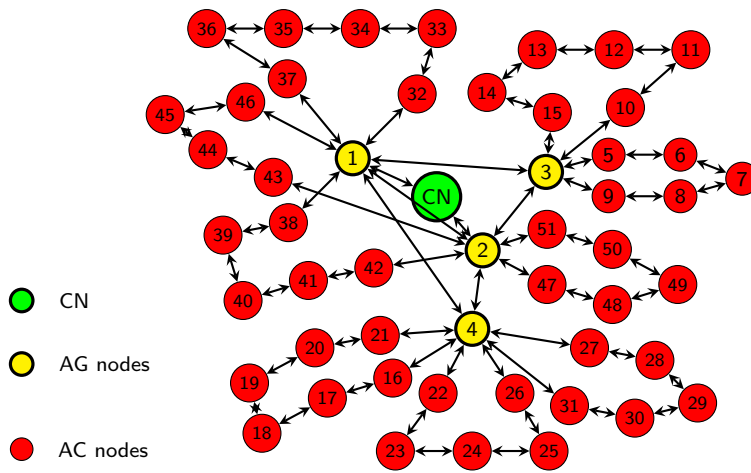


Figure 5:  $T_{5Gx}$  topology

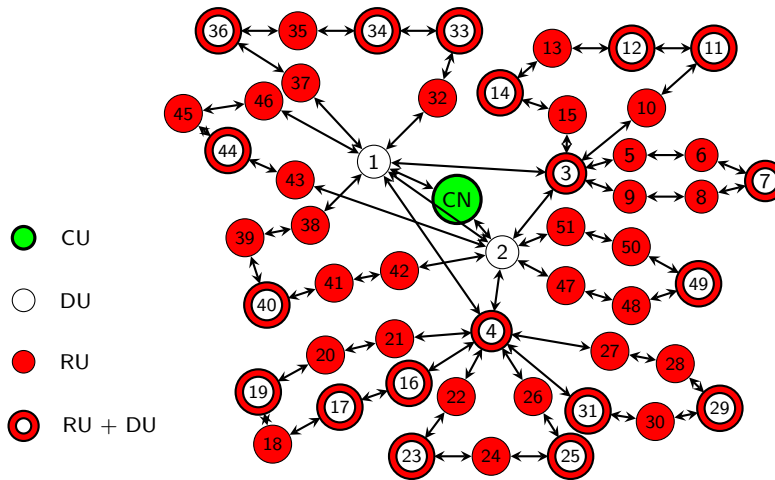


Figure 6: DU placement on the network at 11 am

### 5.3 Analysis of system cost

Figure 7 shows the evolution of the system cost for the different reallocation periods for an activation period of 30 minutes. We notice that for all reallocation periods, the system cost is much lower at off-peak times, and increases progressively at peak times. This is because at off-peak times the network load is low and fewer bands are used, whereas at peak times the network load rises, increasing the number of frequency bands needed to satisfy user demand. We also noticed that the cost of the system decreases as a function of the reallocation period: the longer the reallocation period, the lower the cost of the system. To sum up, we can say that there are several factors that influence the total cost of the system: load, reallocation period and duration of the reallocation period. When one of these factors changes, the cost of the system will increase or decrease.

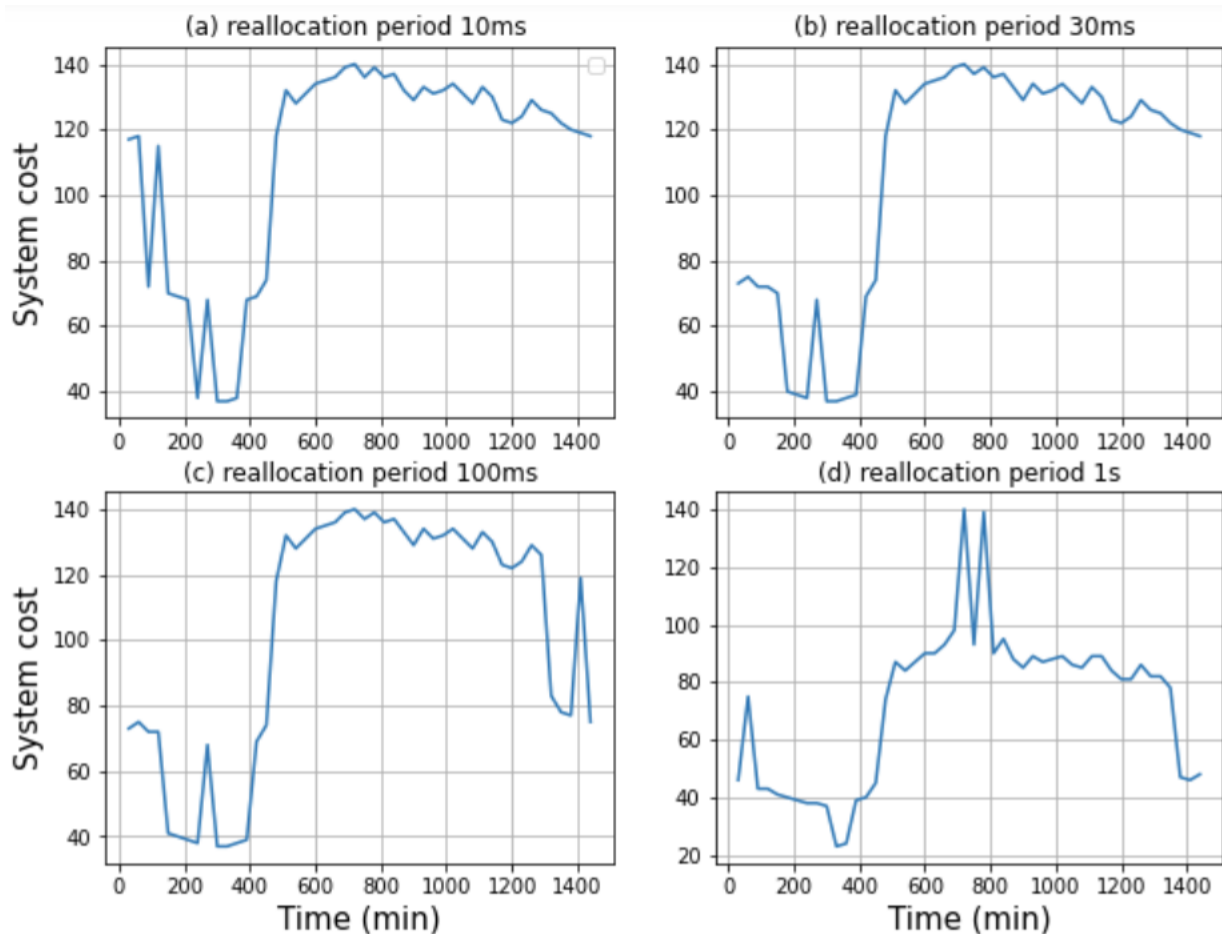


Figure 7: Evolution of system cost for every 30 minutes

Figure 8 shows the evolution of the system cost of a period of one hour for the different reallocation periods but we also compare our model with extinction of the frequency bands and our model without extinction of the frequency band that means the four bands are switch on all day. We noticed that for a low reallocation period our model with extinction of frequency bands is similar to our model without extinction of frequency bands. Because for a reallocation period of 10 ms we have the four band frequencies that are switch on throughout the day. For a reallocation period of 30 ms, our model with band extinction has a much lower cost of the system at off-peak time. Because at dead time our model uses less frequency band to satisfy

user demand. For the rest of the day, both models have the same cost of the system. For a reallocation period equal to 1 s, the gap increases at off-peak time. Because for a period of high reallocation sometimes the number of bands needed to satisfy user demand can be reduced up to one band. This also means that the cost of the system is reduced.

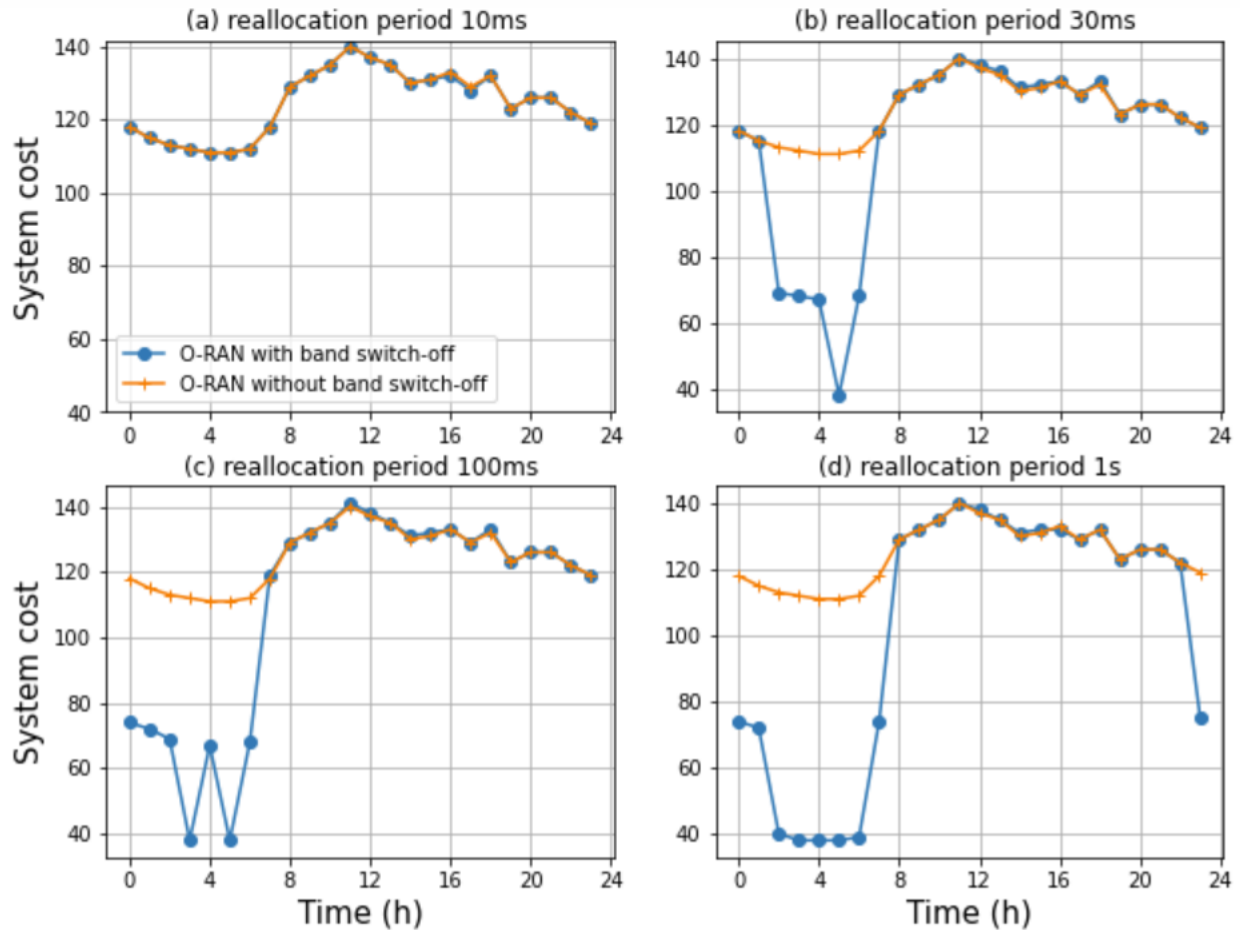


Figure 8: Evolution of system cost for every hour

## 6 Conclusion

In this work, we have combined the O-RAN architecture and the multi-band system. We first proposed an algorithm to select the number of frequency bands required for different reallocation periods. We noticed that as the reallocation period becomes longer, the number of frequency bands decreases. Then we formulated the band extinction problem and the optimal placement of DUs as an ILP. The evaluation of our model showed that the total cost of the system varies with the length of the reallocation period. But we also noticed that our model with band extinction has a lower system cost than our model without band extinction. In future work we can add a frequency band switch-on cost.

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