Performance Measurements-based Estimation of Radio Resource Requirements for Slice Admission Control

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***Abstract*— The network slicing capability introduced in 5G systems facilitates the realisation of flexible multi-tenant networks. Network slicing enables the partition of a common shared network in several logical networks, each configured to fulfil specific service requirements. In scenarios where the lifecycle of network slices has to be managed dynamically (e.g. allocation, modification and deallocation of network slices in response to changing tenants' needs), slice admission control becomes a central function to assure that the set of slices concurrently activated count with the sufficient resources to fulfil their service requirements. Slice admission control is particularly challenging for the Radio Access Network (RAN) part of a slice, because the amount of required radio resources is highly dependent on the characteristics of the deployment environment and type of cells. In this context, this paper presents a functional data-analytics framework along with a new analytical methodology for estimating the radio resource requirements for RAN slice admission control. Specifically, in order to characterise the propagation and interference conditions in each cell, the proposed resource estimation method leverages statistical information extracted via data analytics from the cell performance measurements collected at the management plane. Results show the benefits of the proposed estimation method under different types of cell deployments.**

Keywords—RAN slicing; Slicing Admission Control; Data Analytics.

I. Introduction

The design efforts of Fifth Generation (5G) systems focus on the support of a wider range of application scenarios and vertical industries (e.g. automotive, e-health, utilities, smart cities, high-tech manufacturing) with distinct and variate requirements (i.e. peak data rate, latency, mobility, etc.) [1]. In addition, 5G networks are envisioned to enable the evolution of current business models by providing more flexible network sharing models [2]. This is the case of neutral host infrastructure services, where multiple tenants, e.g. mobile network operators (MNO), Over-the-top (OTT) service providers or private enterprises from vertical industries, may provide services to their own users by sharing a common infrastructure, whose deployment, operation and management is responsibility of a 3rd party provider. This 3rd party provider, referred to hereafter as the Infrastructure Provider (InP) could be e.g. the owner of the venue where the shared infrastructure is deployed or a MNO [3] that provides network slicing services to business customers on top of its own infrastructure. In such a context, the *network slicing* feature [4] incorporated in 5G systems is anticipated to play a central role for the realization of cost-efficient multi-tenant solutions able to accommodate the foreseen heterogeneity of requirements by the diverse types of tenants. Network slicing allows sharing a common infrastructure among diverse end-to-end logical networks [5], referred to as *network slices*, which can be tailored to a particular system behaviour with optimised characteristics for a specific application.

In a multi-tenant scenario, the InP can provide each tenant operating in its infrastructure with a network slice, whose characteristics will be based on a Service Level Agreement (SLA). The SLA records a common understanding about the service offered by the InP and specifies measurable target values characterising the level of the offered service (e.g. transfer rate, latency, aggregate capacity) as well as related cost considerations.

The lifecycle of network slices (e.g. allocation, modification and deallocation of network slices) can be dynamically managed over time through a network slicing management system [6], so that the number and configuration of the activated network slices remains closely matched to the needs and dynamics of the sharing scenario. Specifically, when a new slice for a tenant has to be allocated, the slicing management system shall assess that the infrastructure has enough resources to satisfy the requirements of the new slice established in the SLA without causing SLA violations in other concurrent slices. Therefore, admission control of network slices becomes a fundamental function of the network slicing management processes and affects both the Core Network and the Radio Access Network (RAN) parts of the slice.

The slice admission control (SAC) problem in 5G has been addressed at different levels in the literature such as in [7], which identifies SAC as one of the stages of slice creation and establishes the information required for this function or in [8], which proposes a Markov model for asynchronous SAC considering slice required resources as general units with an assigned cost. Similarly, [9] presents an economic model that evaluates the profit of the MNO for accepting a certain slice and [10] maximises the time-average revenue by a SAC for delay-tolerant slices. In relation to RAN slicing, RAN SAC for slice requests that need to support a given number of users for a certain time is proposed in [11][12] aiming at optimising the infrastructure providers' revenue, and in [13], which optimises the network utilisation by incorporating traffic forecasting capabilities. In the above-mentioned works, the amount of required radio resources for a given slice is either taken as an input parameter or computed assuming a fixed capacity per cell. However, the variability in the radio propagation and interference conditions experienced by the users when operating in different cells, the cell location (e.g., indoor, urban, rural environments), the cell deployment (e.g., cell radius, transmitted power, frequency of operation, modulation, antennas, etc.) together with the diverse users' mobility patterns strongly affect the cell's capacity and, consequently, the amount of required radio resources to support a given RAN slice.

In this context, this paper presents a novel methodology for estimating the required radio resources by a RAN slice. This is an essential stage of the SAC process because an underestimation of the radio resources needed may result in SLA breaches while an overestimation may lead to overprovisioning. The proposed approach is based on the extraction of data analytics information from the cell performance measurements collected at the management plane and is fully aligned with the 3GPP vision for Next Generation RAN (NG-RAN) management exploiting Management Data Analytics Function (MDAF) and RAN Slicing Management Function (RSMF). The novel methodology relies on a mathematical model and considers both Guaranteed Bit Rate (GBR) and non-GBR services. Diverse cell environments are considered for evaluation purposes, including 3GPP reference models as well as some representative cells and performance measurements extracted from a LTE commercial network.

The rest of the paper is organised as follows. Section II formulates the problem of radio resource estimation for RAN SAC and Section III describes the considered functional framework for analytics-based RAN slicing management encompassing SAC. Based on this, Section IV presents the proposed methodology to estimate the amount of required resources by a RAN slice whereas Section V includes the results obtained for different cell deployment scenarios. Finally, Section VI summarises the conclusions.

II. Problem Formulation

A multi-tenant scenario with a common NG-RAN infrastructure operated by a InP is considered [14]. The NG-RAN infrastructure is composed of multiple cell sites with different deployment characteristics. The InP provides each tenant with a RAN Slice Instance (RSI) encompassing a set of cell sites during a certain time and is responsible of the Lifecycle Management (LCM) of the different RSIs deployed in the NG-RAN infrastructure. Each tenant n can provide Guaranteed Bit Rate (GBR) services, which ensure its users with a bit rate value GBR_n (also referred to as Guaranteed Flow Bit Rate (GFBR) in 5G New Radio's (NR) terminology), and non-GBR services. The SLA established between the InP and the n-th tenant comprises the following system level indicators:

- **Maximum number of GBR and non-GBR services per cell:** each cell has to support $u_{GBR,n}$ GBR flows and $u_{nGBR,n}$ non-GBR flows.
- **Degradation probability of GBR services:** The percentage of session time that GBR services may experience transfer bit rates lower than its requirement GBR_n must not exceed a maximum value, defined as a degradation probability $P_{d,GBR,n}^{max}$.
- **Average throughput of non-GBR services:** non-GBR flows with buffered traffic need to be provided with a minimum average throughput $\overline{Th_{nGBR,n}^{min}}$ measured over a certain averaging window time.

When a tenant requires to be allocated with a new RSI, the SAC function determines its acceptance or rejection based on the estimation of the required radio resources by the RSI and on the resource occupancy in the NG-RAN infrastructure. Assuming 5G NR technology, radio resource requirements are expressed in terms of the number of Physical Resource Blocks (PRB). If the required PRBs can be utilised in the NG-RAN infrastructure without impacting on the SLAs of already established RSIs, the SAC function admits the new RSI. Otherwise, the RSI is rejected.

III. Functional Framework for Analytics-based RAN Slicing Management

Fig. 1 depicts the functional framework for the management of network slicing in a NG-RAN infrastructure leveraging data analytics functions for supporting RAN SAC.

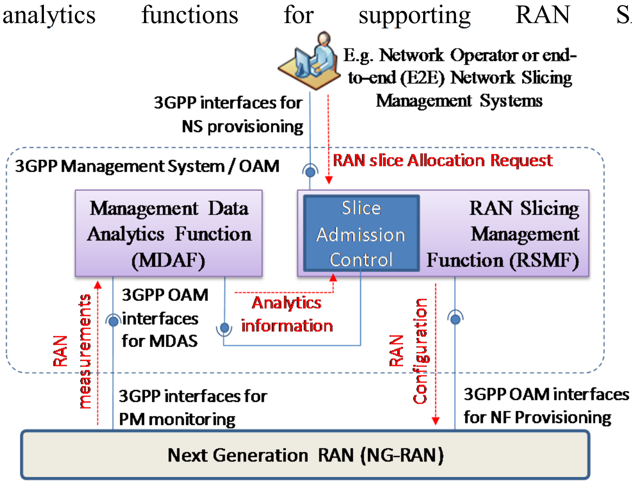

Fig. 1. Proposed functional framework for analytics-based RAN SAC.

The core functionality consists of a set of management functions, collectively referred to as *RAN Slicing Management Function (RSMF)*. The *RSMF* is in charge of the LCM of the RSIs, including the admission control of new RSIs to be allocated in the NG-RAN infrastructure and its further creation, modification and termination. In this regard, the *RSMF* is expected to expose a set of management services for provisioning, performance monitoring and fault management of the RSIs. Accordingly, and in line with the terminology and service-based management concepts adopted by 3GPP, the RSMF plays the role of a producer of management services that can be accessed by one or multiple management service consumers. On the other hand, in order to interact with the underlying infrastructure components and carry out the SAC and LCM of RSIs, the RSMF has to be able to consume the services provided by the diverse management systems specific to each of the function types composing the NG-RAN infrastructure (i.e. gNB functions, Network Function Virtualisation Infrastructure (NFVI), Radio Frequency (RF) systems and Transport Network

(TN) nodes). In this respect, for the management of the gNB Network Functions (NFs), the 3GPP specifications include the Network Resource Model (NRM) definitions that, apart from attributes used for configuring the operation of the NR cells (e.g. cell identifiers, channel frequencies), contains also attributes for the configuration of the network slicing behaviour of gNB NFs [15].

As part of the 3GPP management system, the Management Data Analytics Function (MDAF) is the component in charge of providing Management Data Analytics Services (MDAS). For example, the MDAF can retrieve Operations, Administration and Management (OAM) data from the network functions and produce management analytics information that can be used to recommend appropriate management actions to the network operator. In turn, with the advances in Machine Learning (ML) and big data technologies for the implementation of MDAS, the 5G management functions might have access to a richer set of MDAS information extracted from raw data collected over days, weeks, months and even beyond. In this sense, the data analytics services delivered by the MDAS are proposed to be used here for supporting the SAC function at the RSMF. Specifically, the MDAF will provide the statistical characterisation of the spectral efficiency in the different cells of the NG-RAN, which can be derived from OAM performance measurements collected from gNB NFs [16]. This information will be consumed by the RSMF to estimate the PRB requirements of the new RSIs.

IV. Required PRB Estimation Methodology

This section describes the proposed methodology for the estimation of the required PRBs to fulfil the SLA of a new RSI admission request associated to tenant n under the described management framework. This number of required PRBs is denoted as $N_{th,n}$. Given that the new RSI may operate in diverse cell sites with variety of deployment characteristics and, consequently, users experience different propagation conditions, the proposed methodology is performed on a per cell-basis using the cell characterisation provided by the MDAF. Given that requirements of GBR and non-GBR services are of different nature, the methodology assumes that $N_{th,n}$ is decoupled into $N_{GBR,n}$ and $N_{nGBR,n}$, which are the required PRBs to fulfil GBR and non-GBR requirements, respectively, so that $N_{th,n} = N_{GBR,n} + N_{nGBR,n}$.

Considering the above, and taking into account the SLA terms specified in Section II, the proposed methodology is devised as a three-step procedure:

- **Step 1 – Data analytics:** The MDAF gathers information from the cell environment, processes it and provides it to the RSMF.
- **Step 2 – Resource estimation of GBR services:** $N_{GBR,n}$ is determined by considering that the $u_{GBR,n}$ GBR flows need to be always provided with GBR_n while respecting a maximum degradation probability $P^{max}_{d,GBR,n}$.
- **Step 3 – Resource estimation of non-GBR services:** Additionally to the obtained $N_{GBR,n}$, some extra PRBs $N_{nGBR,n}$ may be needed to fulfil the average $\overline{Th^{min}_{nGBR,n}}$ requirement of the $u_{nGBR,n}$ non-GBR flows.

In the following, more insights into the three steps of the proposed methodology are provided.

A. Step 1: Data analytics

The MDAF is in charge of providing the cell characterisation to the RSMF for the estimation of the required PRBs. The deployment and configuration of a certain cell within the NG-RAN infrastructure (radius, transmitted power, location, frequency operation, etc.) and the propagation conditions that users experience in different cell locations result in fluctuations in the spectral efficiency S_{eff} (bits/s/Hz). Therefore, S_{eff} can be treated as a random variable, which is used for the characterisation of each cell environment.

Specifically, and following the 5G Performance Measurements (PM) specified in [16], it is assumed that the MDAF gathers, from each cell, a sample of the wideband Channel Quality Indicator (CQI) distribution with a certain time periodicity (e.g. every 15 minutes). This sample distribution has been previously generated at each cell by accumulating the CQI reports provided by the different users in the cell during the e.g., 15 minutes interval. Each CQI is an integer index that indicates the modulation and coding scheme that a user can use in accordance with its experienced propagation and interference conditions. Each CQI index is mapped to a spectral efficiency value according to the tables presented in section 5.2.2 of 3GPP TS 38.214 [17]. The MDAF gathers samples of the wideband CQI distribution and averages them for a longer time period in order to get the adequate statistical validity to be representative of the cell conditions. Then, the averaged distribution of the CQI indices is directly mapped to the distribution of the S_{eff} values experienced by the users in the cell. Specifically, the probability density function (pdf) of S_{eff}, denoted as $f_{Seff}(s)$, is obtained by associating the probability of a CQI index to the probability of the S_{eff} value corresponding to this CQI index.

Based on $f_{Seff}(s)$, the MDAF computes the following metrics to be provided to the RSMF for carrying out the subsequent steps 2 and 3 of the PRB estimation process: (a) average spectral efficiency $\overline{S_{eff}}$ of the cell, (b) probability density function (pdf) of the random variable Y=1/(S_{eff}·B), denoted as $f_Y(y)$, where B is the PRB bandwidth and is obtained as:

$$f_Y(y) = f_{S_{eff}}\left(\frac{1}{y \cdot B}\right)\frac{1}{y^2 B} \tag{1}$$

B. Step 2: Resource estimation of GBR services

The required PRB estimation performed in the RSMF firstly computes the required $N_{GBR,n}$ to fulfil the GBR services requirements. In order to achieve GBR_n, each GBR flow requires a number of PRB $N_{req,GBR,n}$, given by:

$$N_{req,GBR,n} = \frac{GBR_n}{S_{eff} \cdot B} \tag{2}$$

Considering that Y=1/(S_{eff}·B) is a random variable, the number of required PRB $N_{req,GBR,n}$ is another random variable. Then, based on the pdf $f_Y(y)$ provided by the MDAF, it is possible to derive the pdf of $N_{req,GBR,n}$ by:

$$f_{N_{req,GBR,n}}(k) = f_Y\left(\frac{k}{GBR_n}\right)\frac{1}{GBR_n} \tag{3}$$

Assuming that each user experiences independent propagation conditions, the pdf of the aggregate number of required PRBs $r_{GBR,n}$ by all the GBR flows of the n-th tenant can be computed as:

$$f_{r_{GBR,n}}(k) = \left(\frac{1}{GBR_n}\right)^{u_{GBR,n}} \cdot \underbrace{f_Y\left(\frac{k}{GBR_n}\right) * \ldots * f_Y\left(\frac{k}{GBR_n}\right)}_{u_{GBR,n}} \qquad (4)$$

where * represents the convolution operator.

Considering that the degradation probability is given by the probability of requesting more PRBs than the available ones (i.e. $r_{GBR,n} > N_{GBR,n}$), the $N_{GBR,n}$ value that fulfils the $P_{d,GBR,n}^{max}$ requirement is taken as the minimum value that satisfies the following condition:

$$P_{d,GBR,n}^{\max} = \int_{N_{GBR,n}}^{\infty} f_{r_{GBR,n}}(k)dk \qquad (5)$$

C. Step 3: Resource estimation of non-GBR services

Once $N_{GBR,n}$ has been obtained, the following step is to determine if the tenant n is required to be provided with some additional PRBs $N_{nGBR,n}$ to satisfy the requirements of non-GBR services, which need to be provided with $\overline{Th_{nGBR,n}^{min}}$. In this sense, the average throughput of a non-GBR flow is defined as follows:

$$\overline{Th_{nGBR,n}} = \frac{\overline{a_{nGBR,n}} \cdot \overline{S_{eff}} \cdot B}{u_{nGBR,n}} \qquad (6)$$

where $\overline{a_{nGBR,n}}$ is the average aggregated assigned PRBs to the non-GBR flows of tenant n and $\overline{S_{eff}}$ has been provided by the MDAF. Then, in order to fulfil the minimum throughput requirement $\overline{Th_{nGBR,n}} \geqslant \overline{Th_{nGBR,n}^{min}}$, the minimum average aggregated assigned PRBs that should be available to non-GBR flows of tenant n, $\overline{a_{nGBR,n}^{min}}$, is given by:

$$\overline{a_{nGBR,n}^{\min}} = \frac{\overline{Th_{nGBR,n}^{\min}} \cdot u_{nGBR,n}}{\overline{S_{eff}} \cdot B} \qquad (7)$$

The average aggregated assigned PRBs to non-GBR flows is defined as follows:

$$\overline{a_{nGBR,n}} = \int_0^{\infty} k \cdot f_{a_{nGBR,n}}(k) \cdot dk \qquad (8)$$

where $f_{a_{nGBR,n}}(k)$ is the pdf of the aggregated assigned PRBs to all non-GBR flows of tenant n. It is assumed that the allocation criteria allocates the remaining PRBs after the allocation of GBR flows to the non-GBR flows. Therefore, $f_{a_{nGBR,n}}(k)$ depends on the pdf of the aggregated assigned PRBs to all GBR flows, $f_{a_{GBR,n}}(k)$, which is given by:

$$f_{a_{GBR,n}}(k) = f_{r_{GBR,n}}(k) \cdot H(k, N_{GBR,n}) + \delta(k - N_{GBR,n}) \cdot \int_{N_{GBR,n}}^{\infty} f_{r_{GBR,n}}(t)dt \qquad (9)$$

where $\delta(\cdot)$ is the Dirac delta function and $H(x,y)$ an step function defined as follows:

$$H(x,y) = \begin{cases} 1 & x < y \\ 0 & x \geq y \end{cases} \qquad (10)$$

Note that $f_{a_{GBR,n}}(k)$ equals $f_{r_{GBR,n}}(k)$ for all those values lower or equal than $N_{GBR,n}$, as each flow gets the required resources (i.e. $a_{GBR,n} = r_{GBR,n}$). In turn, when the aggregated required PRBs exceed $N_{GBR,n}$ (i.e. $r_{GBR,n} > a_{GBR,n}$) the aggregated assigned PRBs are $a_{GBR,n} = N_{GBR,n}$, as no more PRBs are available. Consequently, all $f_{r_{GBR,n}}(k)$ values where $r_{GBR,n} > N_{GBR,n}$ are cumulated in $a_{GBR,n} = N_{GBR,n}$. Once $f_{a_{GBR,n}}(k)$ has been obtained, $f_{a_{nGBR,n}}(k)$ can be derived by considering the remaining PRBs after the allocation of GBR flow (i.e., $N_{GBR,n} - a_{GBR,n}$). Accordingly, $f_{a_{nGBR,n}}(k)$ is defined as:

$$f_{a_{nGBR,n}}(k) = f_{a_{GBR,n}}(N_{GBR,n} + N_{nGBR,n} - k) \qquad (11)$$

where $N_{nGBR,n}$ is added to $N_{GBR,n}$ in order that $f_{a_{nGBR,n}}(k)$ satisfies the $\overline{a_{nGBR,n}^{min}}$ requirement, so that $\overline{a_{nGBR,n}} \geq \overline{a_{nGBR,n}^{min}}$. Then, the additional PRBs, $N_{nGBR,n}$, can be obtained by performing the iterative procedure in Algorithm 1, where $N_{nGBR,n}$ is progressively increased in steps of Δ until fulfilling the $\overline{a_{nGBR,n}^{min}}$ requirement.

Algorithm 1 Iterative procedure for $N_{nGBR,n}$ computation

Initialisation
Set $N_{nGBR,n}$=0 and the PRB iteration step Δ
Iteration
  Obtain the pdf $f_{a_{nGBR,n}}(k)$ by (11)
  Calculate $\overline{a_{nGBR,n}}$ by (8)
  If ($\overline{a_{nGBR,n}} < \overline{a_{nGBR,n}^{min}}$)
    Upgrade $N_{nGBR,n} = N_{nGBR,n} + \Delta$
  Else
    Exit iteration loop
  End if
End

V. PERFORMANCE EVALUATION

This section presents an analysis of the estimation of PRB requirement procedure for new RSI admission requests in diverse cell environments.

A. Considered scenario

The scenario under test considers that two new tenants, referred to as *Tenant 1* and *Tenant 2*, request the allocation of a RSI in the NG-RAN infrastructure of an InP. Both tenants intend to use the RSI to provide GBR and non-GBR services with the SLA parameters summarised in Table I. Note that different values of the maximum number of services per cell are considered in the assessment.

The analysis has been performed in the following selected types of cells: an Indoor Hotspot (InH), a Urban Micro-cell (UMi), a Urban Macro-cell (UMa) and a Rural Macro-cell (RMa) [18]. The cell configuration parameters are summarised in Table II. The S_{eff} distribution of these cells configurations have been obtained by simulating users at different random positions uniformly distributed within the cells and extracting their spectral efficiency.

Additionally, a LTE network deployment in a large European city has been considered in the study. From the available dataset, which includes the CQI distribution of about 60 cells, three representative cells, referred to as cell#1, cell#2 and cell#3, have been selected. These cells correspond to a UMa-like environment.

B. Required PRB estimation results

In order to gain a first insight of the PRB estimation methodology behaviour, Fig. 2 and Fig. 3 show the required values of $N_{th,1}$ for Tenant 1 and $N_{th,2}$ for Tenant 2 when increasing the maximum number of GBR and non-GBR flows in the InH cell. Results show the implications of the SLA requirements in Table I on the proposed methodology. On the one hand, it is observed that $N_{th,1}$ and $N_{th,2}$ experience a greater impact due to the increase of the number of GBR flows than due to the increase of non-GBR flows. The reason is that, since the average throughput requirement $\overline{Th^{min}_{nGBR,n}}$ for both tenants is low, just a small value of $N_{nGBR,n}$ in addition to the already computed $N_{GBR,n}$ is enough to fulfil the $\overline{Th^{min}_{nGBR,n}}$ requirement. On the other hand, it can be observed that the PRB requirement $N_{th,n}$ of Tenant 1 is higher than that of Tenant 2. For instance, for $u_{GBR,1}$=$u_{nGBR,1}$= $u_{GBR,2}$= $u_{nGBR,2}$=50 flows, Tenant 1 requires $N_{th,1}$=280 PRBs whereas Tenant 2 requires $N_{th,2}$=140 PRBs. This is due to two main factors: firstly, the GBR services of Tenant 1 have a higher GBR_n requirement than those of Tenant 2 and, secondly, the maximum degradation $P^{max}_{d,GBR,n}$ allowed to Tenant 1 is stricter than that of Tenant 2.

TABLE I. SERVICES PER TENANT

Service Type	SLA/QoS	Tenant 1	Tenant 2
GBR	GBR_n	10 Mb/s	5 Mb/s
	$P^{max}_{d,GBR,n}$	1%	5%
	$u_{GBR,n}$	From 20 flows to 50 flows.	
Non-GBR	$\overline{Th^{min}_{nGBR,n}}$	1 Mb/s	0.5 Mb/s
	$u_{nGBR,n}$	From 20 flows to 50 flows.	

TABLE II. CELL ENVIRONMENTS CONFIGURATION

Environment	InH	UMi	UMa	RMa
ISD (Inter-Site distance)	20 m	200 m	500 m	1732 m
gNB height	3 m	10 m	25 m	35 m
UE height	1 m	1.5 m	1.5m	1.5 m
Minimum gNB-UE distance	0 m	10 m	35m	35 m
Average building height (*h*)	-	-	-	5 m
Average Street width (*W*)	-	-	-	20 m
Path Loss and Shadowing model	Model of Sec. 7.4 of [18]			
Shadowing standard deviation in LOS	3	4	4	4
Shadowing standard deviation in NLOS	8.03	7.82	6	8
Frequency	24.9 GHz	3.6 GHz	3.6 GHz	704 MHz
gNB transmitted power (dBm/PRB)	-3 dBm	11 dBm	22 dBm	20 dBm
gNB antenna Gain	Omnidirectional antenna with 5 dBi gain			
UE noise figure	9 dB	9 dB	9 dB	9 dB
Average Spectral efficiency ($\overline{S_{eff}}$)	5.8 b/s/Hz	5 b/s/Hz	4.5 b/s/Hz	4.1 b/s/Hz
Link-level model to map SINR and bit rate	Model in Sec. 5.2.7 of [19] with maximum SINR= 30 dB and minimum SINR= -10 dB with alpha parameter=0.6			
Nº of spectral efficiency samples for $f_{S_{eff}}(s)$ generation	10^7 samples			
PRB Bandwidth (*B*)	360 kHz			

In order to gain further insight, the effect of the cell environment is analysed in Fig. 4, which includes the PRB requirements $N_{th,1}$ and $N_{th,2}$ for each of the tenants in the different cells of Table II and in the selected cells from the LTE dataset (i.e. cell#1, cell#2 and cell#3) for a fixed number of flows $u_{GBR,1}$=20, $u_{nGBR,1}$=20 for Tenant 1 and $u_{GBR,2}$=20, $u_{nGBR,2}$=20 for Tenant 2. In the figures, $N_{th,n}$ has been decoupled into the required PRBs due to GBR requirements $N_{GBR,n}$ and to non-GBR requirements $N_{nGBR,n}$. As previously observed, Tenant 1 has higher PRB requirement than Tenant 2 for all the selected cells due to its higher GBR_n and stricter $P^{max}_{d,GBR,n}$ values.

Furthermore, Fig. 4 reveals that the PRB requirement $N_{th,n}$ of a tenant can vary considerably among different cells. Differences are highly notable when comparing the results for the diverse simulation-based cells of Table II. Taking as reference the InH cell, which is the cell with the best propagation conditions (i.e. higher $\overline{S_{eff}}$) and, consequently, lower PRB requirement, significant differences of 50% and 55% are obtained in comparison with UMi and UMa cells, respectively. Differences grow until around 100% when comparing with the RMa cell, which is the one with the worst propagation conditions. As a matter of fact, PRB requirements of cells #1, #2 and #3 selected from the real LTE deployment

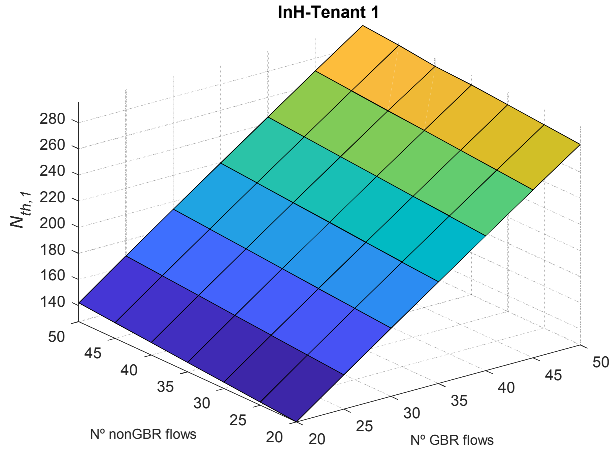

Fig. 2. Required resources for Tenant 1 $N_{th,1}$ for InH environment.

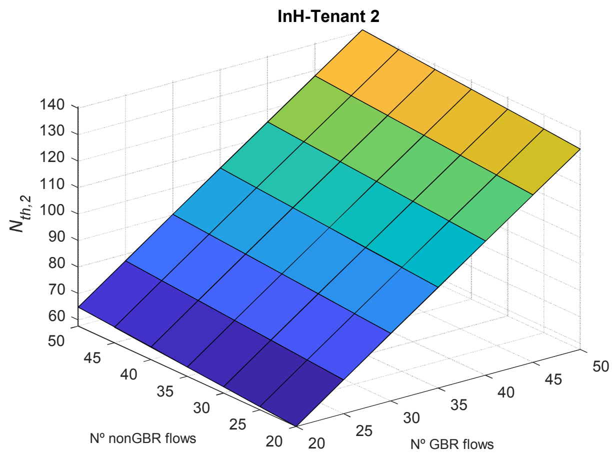

Fig. 3. Required resources for Tenant 2 $N_{th,2}$ for InH environment.

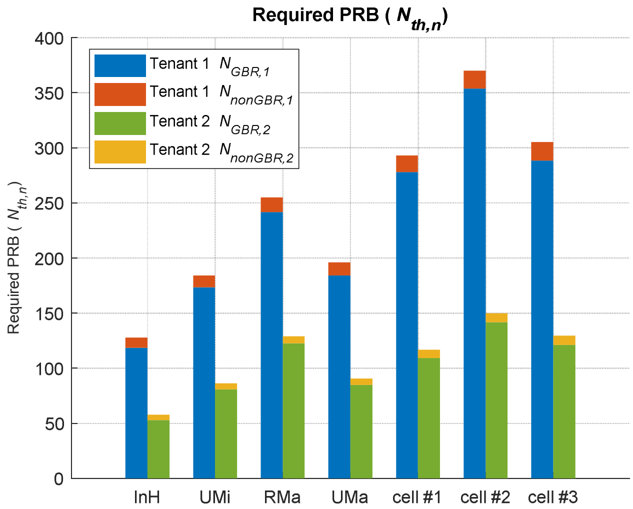

Fig. 4. $N_{GBR,n}$ and $N_{nonGBR,n}$ required PRBs per cell and tenant.

dataset also present large differences among them, even though all could be assimilated to an UMa environment. For example, the PRB requirement in cells #1 and #3 only differs a 10%, but a difference of 30% is observed between cells #1 and #3.

The results obtained emphasise that the estimation of PRB requirements not only suffers variations when considering different environment cells, but also significant differences can take place between cells in the same environment. Consequently, the consideration of data analytics fed by CQI measurements extracted on a per cell basis allows an estimation of the required PRBs by a tenant tailored to the specificities of each cell.

VI. Conclusions

This paper has proposed an analytical methodology for estimating the required number of PRBs by a RAN slice for slice admission control decision making. To capture the cell specificities in the estimation, the characterisation of each cell in terms of spectral efficiency probability density function is derived by means of data analytics, after gathering and processing OAM cell performance measurements. Based on the obtained cell characterisation, the estimation of the required PRBs is performed on a per-cell basis in order to meet the SLA requirements of both GBR and non-GBR services.

Four different simulation-based cell environments (i.e. indoor hot-spot, urban micro-cell, urban macro-cell and rural-macro cell) and three cells selected from a real LTE deployment dataset have been considered for evaluating the proposed methodology. Results have revealed large differences in the estimated PRB requirements among different cell environments, presenting much lower PRB requirements the indoor hot-spot than the rural macro-cell. Also, significant differences can occur in cells with similar environments, particularly when data from real scenarios are considered. Therefore, the cell-tailored estimation of the required radio resources, as achieved with the proposed methodology fed by cell CQI measurements, is a must for proper SAC.

Acknowledgment

This work has been supported by the EU funded H2020 5G-PPP project 5G ESSENCE under the grant agreement 761592, by the Spanish Research Council and FEDER funds under SONAR 5G grant (ref. TEC2017-82651-R) and by the Secretariat for Universities and Research of the Ministry of Business and Knowledge of the Government of Catalonia under grant 2018FI_B_00412.

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