Creating a testing environment for the SIRT problem

A market and business simulation framework is hereby designed to create a testing environment for the SIRT problem that can stand for real-life cases. First it is required to create scenarios prior to the planning stage. These set the grounds on which the home operator must make its decisions: how many countries to steer traffic to, how many providers operate in each country, how are they grouped, what type of commercial agreement applies and its respective details. Those details include the number of volume-price tiers, as well as the price and volume of each tier. Additionally, diversity in the profiles of destination countries, operators and groups is required. Therefore, different volumes of traffic, outgoing and incoming, market-share structures, and seasonality of traffic features are invoked to shape the characterization of those entities in the year prior to the planning year. To ensure the necessary level of coherence of the instances, a relation has to be established between traffic sent to an operator in the previous year and the commercial conditions in place with that operator for the planning year.

During the planning year, two main issues arise. One refers to the actual traffic registered in each period, how it may differ from the operator's forecast and how this difference is then assimilated by the operator in its future operating information. The other concerns the incoming traffic. Although the behavior of the destination operators only plays a supporting role in the optimization objective of the models, it is unrealistic to disregard that decisions of the home operator on its outgoing traffic will somehow influence the volume of traffic received from its counterpart operators in later periods. Therefore, destination operators are attributed different levels of responsiveness to the steering decisions of the home operator.

The parameters that define each instance are presented next, considering both pre-planning and during planning features. Some, marked in bold in Tables 1 and 2, are used in the MILP models developed for the SIRT problem while the others are needed for the generation of the first ones. The values and interval ranges used create commercial and market circumstances that can plausibly be encountered by a planning operator. Whenever probability functions are required, and unless noted otherwise, uniform distribution is used.

1 Pre-planning

In the pre-planning stage, the full characterization of instances can be split into features that define the destination countries and features that define the operator(s) and respective commercial agreements.

1.1 Countries' features

First, for a selected instance dimension, given by the number of destination countries I (#1), it is necessary to determine the number of operators in each country i, according to #2 of Table 1 [1]. Each country is further defined by the volume of traffic received from the home operator in the year prior to the planning year (#4, for which four main profiles of

[1] According to GSMA, not considering countries with just 1 operator (not relevant for the SIRT problem) the actual distribution is 28% with 2 operators, 39% with 3 operators, 21% with 4 operators, and 12% with 5 or more operators, in a total of 195 countries or territories (GSMA full members). www.gsma.com/membership/who-are-our-gsma-members/full-membership/

#	Parameters	Description	Origin	Rules
1.	I	Number of countries	R	$I \in (2, max\_I)$
2.	J_i	Number of operators of Country i	G	Determine number of operators per country according to the following criteria: $P(J_i = 2) = 0.30 \quad P(J_i = 3) = 0.40 \quad P(J_i = 4) = 0.20 \quad P(J_i = 5) = 0.10$
3.	J	Total number of operators	G	$J = \sum_i J_i$
4.	t_py_i	Traffic volume sent to Country i in previous year	G	Randomly generate parameter value within selected traffic volume tier (vt_i) $vt1$=[0; 100,000] P($vt_i = vt1$)=0.25 $vt2$=[100,001; 500,000] P($vt_i = vt2$)=0.35 $vt3$=[500,001; 1,000,000] P($vt_i = vt3$)=0.30 $vt4$=[1,000,001; 50,000,0000] P($vt_i = vt4$)=0.10
5.	s_i	Seasonality of Country i	G	Randomly assign seasonality type to each country $s_i \in \{sw, sa, ss\}$

$p =$		1	2	3	4	5	6	7	8	9	10	11	12
Weak	sw	7.5%	7.5%	8.0%	8.0%	8.5%	9.0%	9.5%	9.5%	9.0%	8.5%	8.0%	7.0%
Average	sa	6.0%	6.5%	8.0%	9.0%	9.0%	10.5%	12.0%	11.5%	8.5%	7.0%	6.0%	6.0%
Strong	ss	3.0%	5.0%	10.0%	5.0%	8.0%	14.0%	18.0%	15.0%	11.0%	6.0%	3.0%	2.0%

#	Parameters	Description	Origin	Rules
6.	ms_c_i	Market-shares in Country i	G	Randomly classify market-share distribution of each country as Even or Uneven: $ms\_c_i \in \{e, ue\}$
7.	ms_o_{ij}	Market-share of Operator j of Country i	C	For $ms\_c_i = e$ and $j = 1, ..., J_i$ $\quad ms\_o_{ij} = 1/J_i 100\%$; for $ms\_c_i = ue$ and $j = 1, ..., J_i$ $\quad ms\_o_{ij} =$

$J_i =$	2	3	4	5
$j = 1$	20%	10%	5%	5%
$j = 2$	80%	30%	20%	10%
$j = 3$		60%	30%	20%
$j = 4$			45%	30%
$j = 5$				35%

#	Parameters	Description	Origin	Rules
8.	$t\_py^p_{ij}$	Traffic volume sent to Operator j of Country i in Period p of previous year	C	$t\_py^p_{ij} = t\_py_i ms\_o_{ij}$, given s_i
9.	$k\_py^p_{ij}$	Traffic volume received from Operator j of Country i in Period p of previous year	G	1. Randomly generate parameter value within selected traffic volume tier (tiers with 1/4 volume of vt_i) 2. Attribute to each Operator j of Country i the same seasonality s_i used for determining traffic sent to it
10.	$\delta\_t^{FY}_i$	Initial (yearly) evolution of traffic forecast sent to Country i	G	Randomly generate parameter value within interval $\delta\_t^{FY}_i \in [0.75; 1.25]$
11.	G	Total number of groups	C	From Procedure to create groups of operators (Figure 1)
12.	n_g_g	Number of operators of Group g	C	From Procedure to create groups of operators (Figure 1)
13.	g_{ij}	Group of Operator j of Country i	C	From Procedure to create groups of operators (Figure 1)
14.	at_g	Agreement type of Group g	G	Randomly select a type of agreement for each group $at_g \in \{QNT, INC, Q\_SOP, I\_SOP, BUB\}$
15.	n_r_g	Number of volume-price tiers in agreement of Group g	G	Randomly determine number of volume-price tiers of agreements $n\_r_g \in \{3, 5\} \quad \forall g : at_g \in \{QNT, INC, Q\_SOP, I\_SOP\}; n\_r_g = 2 \quad \forall g : at_g = BUB$
16.	cl_rv	Reference value of price level	R	1.0
17.	δ_cl	Range of first tier price	R	0.1
18.	cl_g	First tier price of Group g agreement	G	Randomly determine price of first volume-price tier of Group g $\quad cl_g \in [(1 - \delta\_cl)cl\_rv, (1 + \delta\_cl)cl\_rv]$
19.	$\boldsymbol{vpt^{rQ}_g}$	**volume-price tier r in Quantity type agreement of Group g : $vpt^{rQ}_g = (c^r_g, l^{rQ}_g, u^{rQ}_g)$**	C	$r \in \{1, 2, 3\}$ for $n\_r_g = 3$ or $r \in \{1, 2, 3, 4, 5\}$ for $n\_r_g = 5$ and $t\_py_g = \sum_{p=1}^{\vert P \vert} t\_py^p_g$
	$\boldsymbol{vpt^{rI}_g}$	**volume-price tier r in Incremental type agreement of Group g : $vpt^{rI}_g = (c^r_g, l^{rI}_g, u^{rI}_g)$**	C	

	Quantity type agreements (QNT, Q_SOP)			Incremental type agreements (INC, I_SOP)		
	c^r_g	l^{rQ}_g	u^{rQ}_g	c^r_g	l^{rI}_g	u^{rI}_g
3 tiers agreement						
1st tier	cl_g	0	$0.9t\_py_g$	cl_g	0	$0.9\ t\_py_g$
2nd tier	$0.9cl_g$	$0.9t\_py_g$	$1.1t\_py_g$	$0.9cl_g$	0	$0.2t\_py_g$
3rd tier	$0.8cl_g$	$1.1t\_py_g$	M^p	$0.8cl_g$	0	M^p
5 tiers agreement						
1st tier	cl_g	0	$0.8t\_py_g$	cl_g	0	$0.8t\_py_g$
2nd tier	$0.95cl_g$	$0.8t\_py_g$	$1.0t\_py_g$	$0.95cl_g$	0	$0.2t\_py_g$
3rd tier	$0.85cl_g$	$1.0t\_py_g$	$1.2t\_py_g$	$0.85cl_g$	0	$0.2t\_py_g$
4th tier	$0.75cl_g$	$1.2t\_py_g$	$1.3t\_py_g$	$0.75cl_g$	0	$0.1t\_py_g$
5th tier	$0.70cl_g$	$1.3t\_py_g$	M^p	$0.70cl_g$	0	M^p

#	Parameters	Description	Origin	Rules
20.	e_sop_g	Send-or-pay commitment effort of Group g	G	Randomly determine commitment effort of Group g $e\_sop_g \in 0.75, 1, 1.25$ for $g : at_g \in \{Q\_SOP, I\_SOP\}$
21.	$\boldsymbol{sop_g}$	**Send-or-pay volume commitment of Group g**	C	$sop_g = e\_sop_g t\_py_g$ for $g : at_g \in \{Q\_SOP, I\_SOP\}$
22.	$\boldsymbol{c^B_g}$	**Price of balanced traffic in agreement of Group g**	G	Randomly determine price of balanced traffic of Group g $c^B_g \in [(1 - \delta\_cl)cl\_rv, (1 + \delta\_cl)cl\_rv]$ for $g : at_g$ =BUB
23.	δ^{UB}_g	Relation between prices of balanced and unbalanced traffic in agreement of Group g	G	Randomly determine balanced-unbalanced traffic price ratio of Group g $\delta^{UB}_g \in \{0.25, 0.50, 0.75\}$ for $g : at_g = BUB$
24.	$\boldsymbol{c^{UB}_g}$	**Price of unbalanced traffic in agreement of Group g**	C	$c^{UB}_g = \delta^{UB}_g c^B_g$ for $g : at_g = BUB$

C - Calculated; G - Generated; R - Read

Table 1: Generation of structured semi-random instances. Pre-planning

countries are considered), its seasonality (#5, with three different profiles) and market-share structure (two profiles foreseen in #6 that, together with #2, allow for several different cases of individual operator's market-shares in #7). From those initial features it is possible to determine how much traffic was sent to each operator in each destination country in the previous year, per period (#8). Conversely, by #9, traffic received from each of those same operators in the previous year, also per period, is determined. The same seasonality is used for outgoing and incoming traffic. Finally, #10 sets the evolution of outgoing traffic forecast in the planning year within a given percentage interval of the traffic of the previous year.

1.2 Groups' features

Operators of different countries may belong to the same group of operators and share the same commercial conditions. Therefore, after the characterization of the countries, it is necessary to group operators from different countries under the same agreement. Notice that, while grouping operators from different countries, single-operator groups are allowed and a variable maximum number of operators in a group is permitted. The procedure to create groups of Figure 1 provides the necessary structure to the instances by guaranteeing that all operators are included in a group and that a group does not have more than one operator in the same country. From this procedure, the total number of groups (#11), the number of operators in a group (#12), and the identification of each operator in a group (#13) are derived.

1. Create as many groups as the number of operators not allocated to a group in a country not closed
2. For each created group g randomly generate its temporary number of operators ($temp\_n\_g_g$) subject to the maximum number of operators (max_n_g) allowed in a group: $1 \leq temp\_n\_g_g \leq max\_n\_g$
3. Sequentially allocate operators in countries not yet closed to the next group not yet full
4. Close countries when all operators have been allocated to a group
5. Repeat from Step 3 if some groups are not yet full or from Step 1 otherwise until all countries are closed
6. Count the number of groups created and their respective operators

Figure 1 Procedure to create groups of operators

Other features of the groups relate to traffic and commercial agreement. Concerning traffic, from #13 it is possible to calculate, per period, traffic sent to ($t\_py_g^p$ with #8) and received from ($k\_py_g^p$ with #9) each group in the previous year and the initial traffic forecast for the planning year (t_g^{Fp} with #8 and #10). These parameters are not included in Table 1 but are instrumental in the calculation of key parameters. The characterization of groups is completed with the assignment, by #14, of a type of commercial agreement to each group. In case all types of agreements may coexist, each of the five types of agreements modeled has the same probability of being assigned to a group of operators.

For each type of agreement, #15 thru #24 provide the specific commercial conditions: number of volume-price tiers (#15, where two options, 3 and 5, without loss of generality, are considered for QNT, INC, Q_SOP, and I_SOP models), volume and price material to each tier (#19) and existence and level of SOP commitment clause (#20 and #21). Prices for each tier (#19) are built upon the price of the first tier, obtained from #16 to #18, and consistent with the volume requirements of each tier, in that tiers with higher volumes of traffic have lower prices associated with. Consistency of volume requirements of each agreement's tier is achieved by basing them on given percentages of the group's previous year traffic (#19). For BUB deals only the price for balanced traffic (#22) and the balanced-unbalanced traffic price ratio (#23) need to be generated, given that the price for unbalanced traffic (#24) is calculated from those two.

2 During planning

The traffic forecast to each destination country is the initial basis for optimization. However, during the planning year, the home operator will be faced with unforeseen deviations to that forecast. The resulting actual traffic sent to each destination operator is a key element of all the models. Also, decisions made regarding the outgoing traffic will impact the volume of incoming traffic towards the home operator. This traffic is required both in the individual BUB model and in the Global model. Thus, these two aspects need to be injected in the generated instances.

2.1 Actual traffic

At the beginning of the planning exercise, the home operator has an initial forecast for the evolution of traffic towards each destination country during the planning year ($\delta\_t_i^{FY}$, #10 of 1). For the first planning period traffic forecast is, necessarily, based only on that information (first expression of #28). However, as actual traffic generated by customers in each period becomes known, the expected evolution of traffic for the rest of the year must be updated. In order to do this, first the level of deviations from the initial forecast are required. Three cases, corresponding to minor corrections, major corrections and disruptions over the initial forecast for the evolution of traffic are possible (#26). These cases have the occurrence probabilities stated at #25. Note that disruptions are allowed but not imposed and that they are restricted to given periods.

Corrections over the initial evolution of traffic forecast originate revisions to the expected evolution of traffic for the next periods (#27). Naturally, these revisions only occur after the first period, so #27 is only defined for periods after the first. In order to achieve a more accurate update, the revisions use a weighted memory factor of the deviations of past periods, as per the definition of $\delta\_t_i^{Rp}$. Accordingly, for traffic forecasts after the first period, the second expression of #28 is used. From #28, the forecast, at each period p, for each of forthcoming periods until the end of the year is obtained ($t\_py_i^p$ is derived from #8 of Table 1). Actual traffic for each country (#29) results from the most updated forecast for each period ($t_i^{Fp\bar{p}}$), made at the beginning of the period, and the corrections registered on that period ($\delta\_t_{\varphi(i)}^{Ap}$). Finally, the annual forecast made in each period p (#30) is the sum of the actual traffic registered until the last period with the forecast for the remaining periods until the end of the year.

#	Parameters	Description	Origin	Rules
25.	$\varphi(i)$	Cases of actual evolution of traffic volume for Country i	G	Randomly divide countries in 3 groups and attribute actual evolution of traffic case $P(\varphi(i) = minor) = 0.75$ $P(\varphi(i) = major) = 0.20$ $P(\varphi(i) = disruption) = 0.05$
26.	$\delta\_t\varphi(i)^{Ap}$	Correction over initial forecast for actual evolution traffic volume for Country i in Period p	G	Randomly determine correction parameter for each country according to its case $\delta t^{Ap}_{minor} \in [0.9; 1.10]$ $\delta t^{Ap}_{major} \in [0.75; 0.90] \cup [1.10; 1.25]$ $\delta t^{Ap}_{disruption} \in [0.0; 5.0]$ for $p = 4, 5, 6$ and $\delta t^{Ap}_{disruption} \in [0.75; 1.25]$ for other p
27.	$\delta\_t^{Rp}_i$	Revised evolution of traffic volume for Country i in Period p ($p \geq 2$)	C	$\delta\_t^{Rp}_i = \sum_{p'=1}^{p-1} \left(\frac{p'}{\sum_{p''=1}^{p-1} p''} \delta\_t^{Ap'}_{\varphi(i)} \delta\_t^{FY}_i \right)$
28.	$t^{Fp\bar{p}}_i$	Traffic volume forecast for Country i in Period p for Period $\bar{p}$	C	$t^{Fp\bar{p}}_i = \delta\_t^{FY}_i t\_py^{\bar{p}}_i, \quad \bar{p} \geq p$, for $p = 1$ $t^{Fp\bar{p}}_i = \delta\_t^{Rp}_i t\_py^{\bar{p}}_i, \quad \bar{p} \geq p$, for $p = 2, \ldots, \lvert P \rvert$
29.	$\boldsymbol{t^{Ap}_i}$	**Actual traffic volume sent to Country i in Period p**	C	$t^{Ap}_i = \delta\_t^{Ap}_{\varphi(i)} t^{Fp\bar{p}}_i, \quad \bar{p} = p$
30.	$\boldsymbol{t^{Fp}_i}$	**Annual traffic volume forecast for Country i in Period p**	C	$t^{Fp}_i = \sum_{p'=1}^{p-1} t^{Ap'}_i + \sum_{\bar{p}=p}^{\lvert P \rvert} t^{Fp\bar{p}}_i$
31.	k^p_{ij}	Traffic volume received from Operator j of Country i in Period p	C	$k^p_{ij} = k\_py^p_{ij} \left(1 + \alpha_{ij} h^p_{ij} + (1 - \alpha_{ij})\varepsilon_{ij}\right)$, $k^p_{ij} \geq 0$
32.	α_{ij}	Responsiveness of Operator j of Country i	G	$\alpha_{ij} \in \{0.20, 0.50, 0.80\}$
33.	ε_{ij}	External influencing factors of Operator j of Country i	G	$\varepsilon_{ij} \in$ [-2,2]
34.	h^p_{ij}	Influence ratio of traffic sent on traffic received with Operator j of Country i in Period p	C	$h^p_{ij} = 1 \quad$ for $p = 1$ $h^p_{ij} = 0.60a + 0.4b - 1 \quad$ for $p = 2, \ldots, \lvert P \rvert$ $a = \left(\frac{\sum_{p'=2}^{p} x^{p'-1}_{ij}}{\sum_{p'=2}^{p} t\_py^{p'-1}_{ij}} \right)$ $b = \left(\frac{\sum_{p'=2}^{p} x^{p'-1}_{ij} / \sum_{p'=2}^{p} \sum_j x^{p'-1}_{ij}}{\sum_{p'=2}^{p} t\_py^{p'-1}_{ij} / \sum_{p'=2}^{p} \sum_j t\_py^{p'-1}_{ij}} \right)$
35.	$\boldsymbol{k^p_g}$	**Traffic volume received from Group g in Period p**	C	$k^p_g = \sum_{i=1}^{I} \sum_{j=1}^{J_i} k^p_{ij}$, for $i, j : g_{ij} = g, g = 1, \ldots, G$

C - Calculated; G - Generated

Table 2 Generation of structured semi-random instances. During planning

2.2 Incoming traffic

Regarding the incoming traffic, it is fair to expect that traffic sent by the home operator to each destination operator in a given period will somehow influence the traffic that that operator sends in return in future periods. This is understood as an internal factor to the planning exercise of the home operator. Additionally, external factors to the home operator steering policy, such as the total traffic foreign operators have available to the home operator's country and the commercial conditions they have in place with the local competitors of the home operator, will also influence the volume of traffic received by the home operator. Accordingly, #31 considers both internal and external factors. Different weights for both factors are allowed and they are determined by the responsiveness levels of the visited operators to the volume of traffic received from the home operator (#32). Concerning the internal factor, #34 considers two main causes influencing the ratio of traffic sent on traffic received: traffic volume growth versus the same period of the previous year, (a), and evolution of share of traffic received, (b). It is assumed that the first, having a more straightforward impact and being more easily measured by the visited operator, accounts for 60% of the factor, while the latter, based on more uncertain information from the visited operator's perspective, represents the remaining 40%. Regarding the external factors influencing the incoming traffic, they may have a positive or negative impact; the interval range in #33 is used to randomly generate individual parameter values for each operator.