Sets

P Set of providers.

$C = \{cIS, cSM, cEM, cW, cLB\}$ Set of application Components, hardcoded for Scalarm.

$V_c^a = \{vm \in V | p_{vm}^{ghz} \geq r_c^{ghz} \wedge p_{vm}^{cores} \geq r_c^{cores} \wedge p_{vm}^{disk} \geq r_c^{disk} \wedge p_{vm}^{ram} \geq r_c^{ram}\}$ Indexed set of VM types allowed for component that comply with component requirements.

$V_{p,c}^A \subseteq V_c^a, = \{vm \in V_p^P | p_{vm}^{ghz} \geq r_c^{ghz} \wedge p_{vm}^{cores} \geq r_c^{cores} \wedge p_{vm}^{disk} \geq r_c^{disk} \wedge p_{vm}^{ram} \geq r_c^{ram}\}$ Indexed set of VM types provided that are allowed for component c by provider p.

Params

$n_p^{max} \geq 0, \in \mathbb{Z}$ Maximal number of instances at provider p.

$n_c^{max} > 0, \in \mathbb{Z}$ Maximal number of instances of component c.

$n_c^{min} \geq 0, \in \mathbb{Z}$ Minimal number of instances of component c.

$p_{vm}^{price} > 0$ Price of vm per hour in Euros.

$v_{vm} \geq 0$ Throughput of vm VM type (estimated or measured).

$s^{to-go} \geq 0, \in \mathbb{Z}$ Number of simulations in queue.

$t^{current} \geq 0$ Elapsed runtime.

$c^{inc} \geq 0$ Already incured cost.

$v^{min} \geq 0$ Minimal required throughput for constraint (optional).

$c^{max} \geq 0$ Maximal cost for constraint (optional).

$n^{WperEM} > 0, \in \mathbb{Z}$ Maximal number of Workers per Experiment Manager (on given cloud).

Variables

$U_{c,vm} \in \mathbb{Z}, \geq 0, \leq n_c^{max}$ TODO.

Objectives

$$\underset{Throughput}{\text{maximize}} \sum_{vm \in V_{cW}^a} U_{cW,vm} \cdot v_{vm} \tag{1}$$

$$\underset{Cost}{\text{minimize}}\ c^{inc} + \sum_{\substack{c \in C \\ vm \in V_c^a}} p_{vm}^{price} \cdot U_{c,vm} \cdot \frac{s^{to-go}}{\sum_{vm \in V_{cW}^a} U_{cW,vm} \cdot v_{vm}} \tag{2}$$

$$\underset{RunningCost}{\text{maximize}} \sum_{\substack{c \in C \\ vm \in V_c^a}} p_{vm}^{price} \cdot U_{c,vm} \tag{3}$$

$$\underset{TotalRuntime}{\text{minimize}}\ t^{current} + \frac{s^{to-go}}{\sum_{vm \in V_{cW}^a} U_{cW,vm} \cdot v_{vm}} \tag{4}$$

Objectives have the following meaning:

- 1 Maximal throughput
- 2 Maximal cost
- 3 is for debugging
- 4 is for debugging

Constraints

$$\underset{c \in C}{\forall} \sum_{vm \in V_c^a} U_{c,vm} \leq n_c^{max} \tag{5}$$

$$\underset{c \in C}{\forall} \sum_{vm \in V_c^a} U_{c,vm} \geq n_c^{min} \tag{6}$$

$$\underset{p \in P}{\forall} \sum_{\substack{c \in C \\ vm \in V_{p,c}^A}} U_{c,vm} \leq n_p^{max} \tag{7}$$

$$\underset{p \in P}{\forall} \sum_{vm \in V_{p,cIS}^A} U_{cIS,vm} = \sum_{vm \in V_{p,cSM}^A} U_{cSM,vm} \tag{8}$$

$$\underset{p \in P}{\forall} n^{WperEM} \cdot \sum_{vm \in V_{p,cEM}^A} U_{cEM,vm} \geq \sum_{vm \in V_{p,cW}^A} U_{cW,vm} \tag{9}$$

$$\underset{p \in P}{\forall} \sum_{vm \in V_{p,cLB}^A} U_{cLB,vm} \leq 1 \tag{10}$$

$$\underset{p \in P}{\forall} \sum_{vm \in V_{p,cEM}^A} U_{cEM,vm} \geq 2 \cdot \sum_{vm \in V_{p,cLB}^A} U_{cLB,vm} \tag{11}$$

$$\underset{p \in P}{\forall} \sum_{vm \in V_{p,cEM}^A} U_{cEM,vm} - 1 \leq n_{cEM}^{max} \cdot \sum_{vm \in V_{p,cLB}^A} U_{cLB,vm} \tag{12}$$

$$\sum_{vm \in V_{cW}^a} U_{cW,vm} \cdot v_{vm} \geq v^{min} \tag{13}$$

$$c^{inc} + \sum_{\substack{c \in C \\ vm \in V_c^a}} p_{vm}^{price} \cdot U_{c,vm} \cdot \frac{s^{to-go}}{\sum_{vm \in V_{cW}^a} U_{cW,vm} \cdot v_{vm}} \leq c^{max} \tag{14}$$

The constraints have the following meaning:

- 5 and 6 ensure number of component instances within limits. This constraint also covers that all components except *Load Balancer* need to have at least one instance, and *Storage Manager* and *Information Service* exactly one – appropriate values are assigned to parameters n^{min} and n^{max}
- 7 ensures provider instance limit
- 8 ensures that *Storage Manager* and *Information Service* are deployed on the same cloud
- 9 ensures that one *Experiment Manager* is deployed for n^{WperEM} *Workers* (per provider)
- 10 ensures at most one *Load Balancer* per cloud provider
- 11 and 12 ensure to deploy *Load Balancer* when more than one *Experiment Manager* is going to be deployed at particular provider. As I believe it requires a little bit more explanation:

  - constraint 11 says that if there is *Load Balancer* there need to be at least two *Experiment Managers*,
  - constraint 12 says that if we have no *Load Balancer* only one *Experiment Manager* is allowed, otherwise we allow a max number of *Experiment Managers* on that provider.

- 13 ensures that minimal throughput can be achieved (optional)
- 14 ensures that maximal cost doesn't exceed limit (optional)