Saturation Problem Formalization

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1 Scenario Components Definition

- Macrocell (MC)
  - MC Micro Data Centers: $S' = \{A', B', ...\}, |S'| = n_{s'} | n_{s'} \in \mathbb{N}$
  - MC Antennas: $M' = \{1', ..., N'\} | \forall m' \in M' : m' \in \mathbb{N}$
  - Link Budget: L' (mbps), $L' \in \mathbb{N}$
- Smallcell (SC)
  - MC Micro Data Centers: $S = \{A, B, ...\}, |S| = n_s | n_s \in \mathbb{N}$
  - SC Antennas: $M = \{1, ..., N\}, \forall m \in M : m \in \mathbb{N}$
  - Link Budget: L (mbps), $L \in \mathbb{N}$
- Micro Data Center (MDC)
  - $s \rightarrow s \in S \bigcup S'$
- Cover Area
  - Distance, in kilometers (km), between MC antennas
- User Equipment (UE)
  - Static or Dynamic (moving)
- Number of allocated vBBU's (Virtual Base Band Unit) in time t (hour)
  - $a_{s_i}(t) \in \mathbb{Z}^+$: vector of real numbers between 0 and 1 indicating the percentage of usage for each cell in time (hour)
- Machine classes and specifications
  - Classes $I = \{1, 2, ..., N_i\} | N_i \in \mathbb{N}$: set of $c = |I|$ machine classes

  - Computational power $P = \{P_{s1}, P_{s2}, ..., P_{sc}, P_{s'1}, P_{s'2}, ..., P_{s'c}\} | \forall p \in P : p \in \mathbb{N}$: vector of positive integers in Million Instructions Per Second (MIPS) for each machine class $i \in I$ and each type of MDC $s \in S \bigcup S'$
  - Number of cores $N = \{N_{s1}, N_{s2}, ..., N_{sc}, N_{s'1}, N_{s'2}, ..., N_{s'c}\} | \forall n \in N : n \in \mathbb{N}$: vector of positive integers indicating the number of cores for each machine class $i \in I$ and each type of MDC $s \in S \bigcup S'$
  - Pricing $A = \{A_{s1}, A_{s2}, ..., A_{sc}, A_{s'1}, A_{s'2}, ..., A_{s'c}\} | \forall a \in A : a \in \mathbb{Z}^+$: vector of positive real numbers indicating the pricing in United States Dollar (USD) for each machine class $i \in I$ and each type of MDC $s \in S \bigcup S'$

- Association
  - b_{sm}: vetor of zeros (not associated) and ones (associated) to represent the association between an MDC $s \in S \bigcup S'$/machine class and an antenna

- Workload
  - $\Gamma_m(t)$: matrix m x t to represent the throughput

2 Problem Formalization

2.1 Parameters

- Macrocell (MC)
  - MC Micro Data Centers: $S' = \{A', B', C', D', E', F', G'\}$
  - MC Antennas: $M' = \{1', 2', 3', 4', 5', 6', 7'\}$, one MC for each MC MDC
  - Link Budget: 900 mbps

- Smallcell (SC)
  - MC Micro Data Centers: $S = \{A, B, C, D, E, F, G\}$
  - SC Antennas: $M = \{1, 2, 3, 4, ..., 25, 26, 27, 28\}$, four SC for each SC MDC
  - Link Budget: 300 mbps

- Micro Data Center (MDC)
  - $s \rightarrow s \in S \bigcup S'$

- Cover Area (3 scenarios)
  1. 1 km (urban)
  2. 25 km (urban-countryside)
  3. 50 km (countryside)

- User Equipment (UE)

  - Static

- Number of allocated vBBU's (Virtual Base Band Unit) in time t (hour)
  - $a_{s_i}(t)$: vector of numbers between 0 and 1 indicating the percentage of usage in time (hour) following a **normal distribution**

- Machine classes and specifications
  - $I = \{1, 2, 3\}$
  - First column for machine specification values of MDC's $s \in S$ and the second column for the power values for MDC's $s' \in S'$

$$P_{is} = \{0.5, 1.0, 1.5, 1.0, 2.0, 3.0\} = \begin{bmatrix} 0.5 & 1.0 \\ 1.0 & 2.0 \\ 1.5 & 3.0 \end{bmatrix}, N_{is} = \{4, 8, 16, 16, 32, 64\} = \begin{bmatrix} 4 & 16 \\ 8 & 32 \\ 16 & 64 \end{bmatrix},$$

$$A_{is} = \{20, 30, 40, 30, 50, 90\} = \begin{bmatrix} 20 & 30 \\ 30 & 50 \\ 40 & 90 \end{bmatrix}$$

- Association
  - b_{sm}: vetor of zeros (not associated) and ones (associated) to represent the association to an MDC $s \in S \bigcup S'$

- Workload
  - $\gamma_m(t)$: matrix m x t to represent the throughput in time

2.2 Objective

Minimize the cost and the number of allocated vBBU's:

$$min \sum_{t}^{T} \sum_{s}^{S} \sum_{i}^{I} a_{s_i}(t) A_{is}$$

2.3 Constraints

2.3.1 Horizontal Alocation

$$\sum_{i}^{I} (a_{si} P_{is} N_{is} - \sum_{m}^{M} b_{smi}(t) w \Gamma_m(t)) \geq 0$$

2.3.2 Vertical Alocation

$$b_{smi}(t) \frac{P_{sm}}{P_{is}} \leq 1$$

3 Tradeoffs

- Centralize (minimizing the number of MDC's in use) or distribute the workload?
- Association decision: why associate with a specific MDC and not with another?
- Workload transfer decision: keep the workload in one MDC or send to another?