Paper Title*

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***Abstract*—**

***Index Terms*—**

I. Introduction

II. System Model

V^c is set of cloud nodes. V^f is set of fog nodes. V^e is set of edge nodes. V^s is set of sensor nodes.

$$V^c = \{v_1^c, v_2^c, ..., v_{l_c}^c\} => |V^c| = l_c \tag{1a}$$
$$V^f = \{v_1^f, v_2^f, ..., v_{l_f}^f\} => |V^f| = l_f \tag{1b}$$
$$V^e = \{v_1^e, v_2^e, ..., v_{l_e}^e\} => |V^e| = l_e \tag{1c}$$
$$V^s = \{v_1^s, v_2^s, ..., v_{l_s}^s\} => |V^s| = l_s \tag{1d}$$

C^c is set of capacity of cloud nodes. C^f is set of capacity of fog nodes. C^e is set of capacity of edge nodes.

$$C^c = \{c_1^c, c_2^c, ..., c_{l_c}^c\} \tag{2a}$$
$$C^f = \{c_1^f, c_2^f, ..., c_{l_f}^f\} \tag{2b}$$
$$C^e = \{c_1^e, c_2^e, ..., c_{l_e}^e\} \tag{2c}$$

T is set of tasks.

$$T = \{t_1, t_2, ..., t_{l_t}\} => |T| = l_t \tag{3a}$$
$$\tag{3b}$$

$$P_i(u_i) = P_i^{idle} + (P_i^{max} - P_i^{idle})u_i \tag{4}$$

So each IaaS provider try to solve following optimizaiton problem:

$$\max_{p_i, U_i, \Lambda_S^i} \varphi_i(p_i, U_i, \Lambda_S^i) \tag{5a}$$

subject to:

$$0 \le u_s^i, \forall s \in \{1, \ldots, N_S\} \tag{5b}$$
$$\sum_{s=1}^{N_S} u_s^i \le 1 \tag{5c}$$
$$P_{idle}^i + (P_{max}^i - P_{idle}^i) \sum_{s=1}^{N_S} u_s^i \le \bar{P}^i \tag{5d}$$
$$\Lambda_s^i \in SOL(F_s), \forall s \tag{5e}$$

$$\pi(x^i, x^{-i}) - \pi(y^i, x^{-i}) = \varphi_i(x^i, x^{-i}) - \varphi_i(y^i, x^{-i}) \tag{6}$$

It's easy to show that any global minimum of function π is a nash equilibrium of corresponding game.

show or not??? For IaaS providers exact potential function can be writen as:

$$\pi(x^i, x^{-i}) = \sum_{i=1}^{N_I} \varphi_i(x^i, x^{-i}) \tag{7}$$

III. Problem Formulation

$$\max_{p^i, U^i, \Lambda_S^i, \sigma_S^i, \gamma_S^i, \nu_S^i,, \eta_S^i} \varphi(p_i, U^i, \Lambda_S^i) \tag{8a}$$

subject to:

$$\sum_{s=1}^{N_S} u_s^i \leq 1 \tag{8b}$$

$$0 \leq u_s^i, \forall s \in \{1, \ldots, N_S\} \tag{8c}$$

$$P_{idle}^i + (P_{max}^i - P_{idle}^i) \sum_{s=1}^{N_S} u_s^i \leq \bar{P}^i \tag{8d}$$

$$0 \leq \lambda_{s,i}^i \tag{8e}$$

$$\lambda_s^{min} - \sum_{j=1}^{N_I} \lambda_{j,s}^i \leq 0, \forall s \in \{1, \ldots, N_S\} \tag{8f}$$

$$\lambda_{j,s}^i R_s \leq 0.9 \mu_{j,s} C_j, \forall s \& j \tag{8g}$$

$$\sum_{j=1}^{N_I} \lambda_{j,s}^i (t_{j,s}^{sensors} + \frac{1}{\mu_{j,s}^i - \lambda_{j,s}^i} + t_{j,s}^{actuators} - t_s^{\max}) \leq 0, \forall s \tag{8h}$$

$$\sigma_{j,s}^i \lambda_{j,s}^i = 0, \forall j \& s \tag{8i}$$

$$\gamma_s^i (\lambda_s^{min} - \sum_{j=1}^{N_I} \lambda_{j,s}^i) = 0, \forall s \tag{8j}$$

$$\nu_{j,s}^i (\lambda_{j,s} R_s - 0.9 \mu_{j,s} C_j) = 0 \forall j \& s \tag{8k}$$

$$\eta_s^i \sum_{j=1}^{N_I} \lambda_{j,s}^i (t_{j,s}^{sensors} + \frac{1}{\mu_{j,s} C_j - \lambda_{j,s} R_s} + t_{j,s}^{actuators} - t_s^{\max}) = 0, \forall s \tag{8l}$$

$$\frac{1}{\sum_{k=1}^{N_I} \lambda_{k,s}^i} - p_j R_s + \sigma_{j,s}^i + \gamma_s^i - R_s \nu_{j,s}^i - \eta_s^i (t_{j,s}^{sensors} + t_{j,s}^{actuators} - t_s^{max} + \frac{\mu_{j,s} C_j}{\mu_{j,s} C_j - \lambda_{j,s}^i R_s}) = 0, \forall s \& j \tag{8m}$$

$$0 \leq \sigma_{j,s}^i, \sigma_{j,s}^i, \nu_{j,s}^i \& \sigma_{j,s}^i, \forall s \& j \tag{8n}$$

Here $\lambda_{s,i}$ is $[\lambda_1^i, \cdots, \lambda_{N_S}^i]$ and λ_s^i is conjecture of λ_s by PaaS provider i, u^i is $[u_{i,1}, \cdots, u_{i,N_S}]$ and $u_i = \sum_{i=1}^{N_S} u_{i,s}$. A potential function can be defined for this game.

Function π is potential function of this game:

$$\pi(x^i, y^i, x^{-i}, y^{-i}) = \sum_{i=1}^{N_I} P(u_i) - p_i u_i \tag{9}$$

here x^i and y^i are a tuple of (p^i, u^i) and $(\lambda_{s,i}, \nu_S^i, \gamma_S^i)$

References