Green Days @ Anglet

# A Discrete Particle Swarm Optimization for IoT services placement over Fog infrastructures


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# Outline

| Introduction | Problem formulation | Strategies | Experimental approach & results | Conclusion |
| --- | --- | --- | --- | --- |
| • Smart cities<br>• Internet of Things applications<br>• Large scale computing infrastructures | • Fog hierarchical Infrastructures<br>• IoT applications graphs<br>• Objective function | • CloudOnly<br>• FogOnly<br>• FogCloud<br>• IoTCloud<br>• DCT<br>• DPSO | • Methodology<br>• Results | • Current Work<br>• Future prospects |

Heterogeneity

Dynamicity

Users number

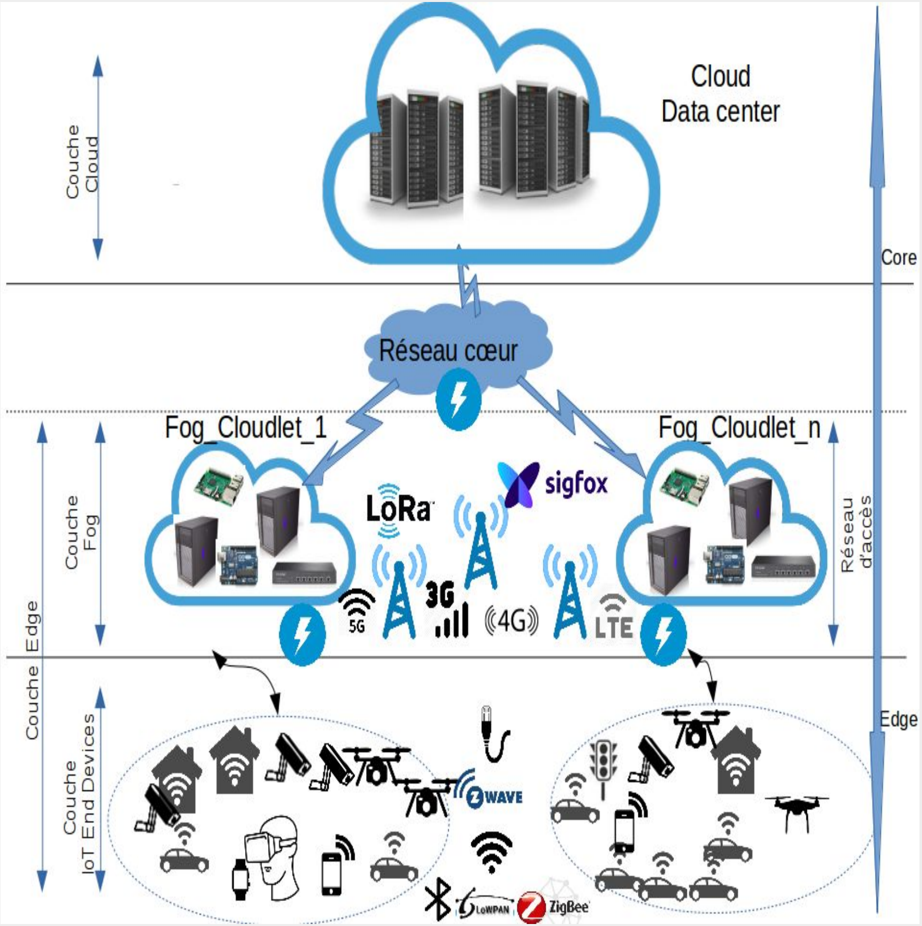
Energy greedy

# Fog Infrastructures

"Fog computing is a horizontal, physical or virtual resource paradigm that resides between smart end-devices and traditional cloud or data centers." [NIST 2017]

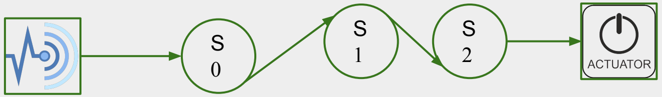
**Toplogy**

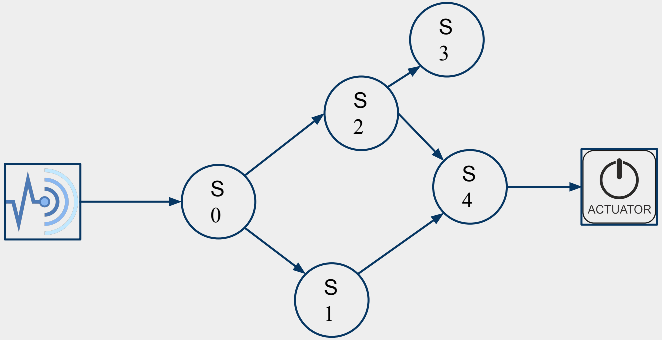
We consider a Hierarchical Three-Layered Fog infrastructure represented with a non oriented gaph $G_{\mathcal{M}} = (\mathcal{M}, \mathcal{L})$.



# IoT applications

| Class \QoS | Delay-sensitivity | Bandwidth demande | Communication frequency | CPU demande | Data Location | Mobility | Priority | Example |
|---|---|---|---|---|---|---|---|---|
| Interactive-Real Time | High <50ms | High | High | High-Medium | Local-vVcinity | High-medium-low | 1 | Augmented reality games |
| Mission-crintcal | High <20ms | High | High | High-Medium | Local-Vicinity | High-medium-low | 0 | EEG |
| Streaming | Medium <150 | High | Medium | Medium-Low | Local-Vicinity-Remote | High-medium-low | 2 | Visoconference, Camera suerveillance |
| Best effort | Low -- | Low | Low | Low | Remote | High-medium-Low | 3 | File sharing etc. |
| | | | | | | | | |



# Energy & delay violation

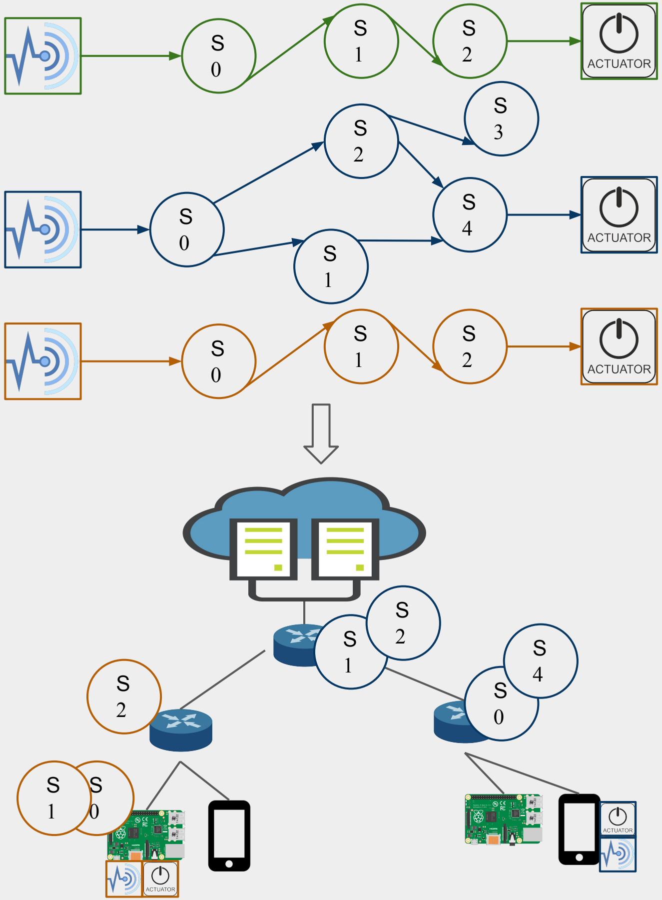
**objective function**

$\forall k, t \in \mathbb{N}:$

$f = min_{i \in [0,N-1], j \in [0,M-1]}[(1+\lambda)E_T]$

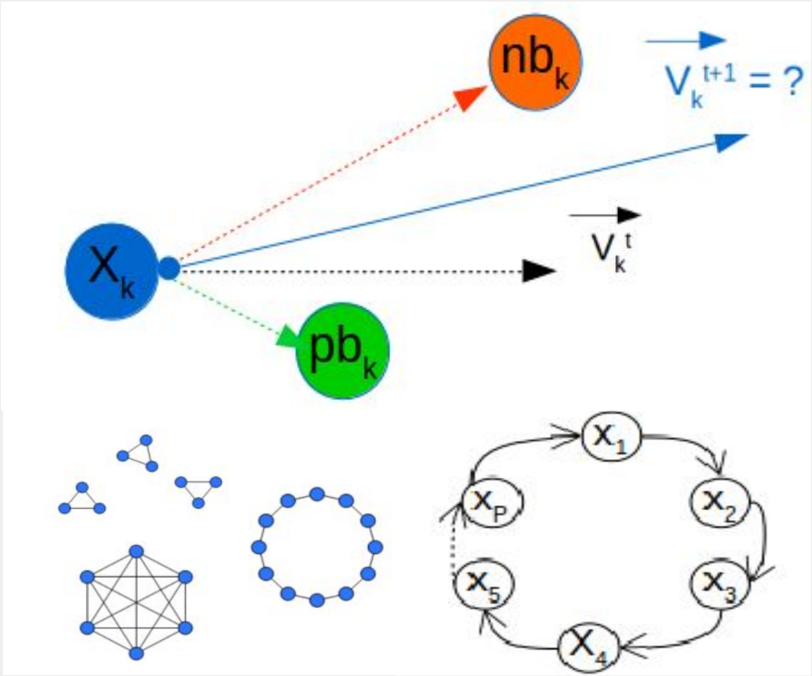
$$s.t \begin{cases} ram_i \leq ram_j \forall i \in [0, N-1], \forall j \in [0, M-1]...(i) \\ mi_i \leq cpu_j \forall i \in [0, N-1], \forall j \in [0, M-1]...(ii) \\ \sum_{j \in [0,M-1]} y_k^t(i,j) = 1, \forall i \in [0, N-1]...(iii) \end{cases}$$

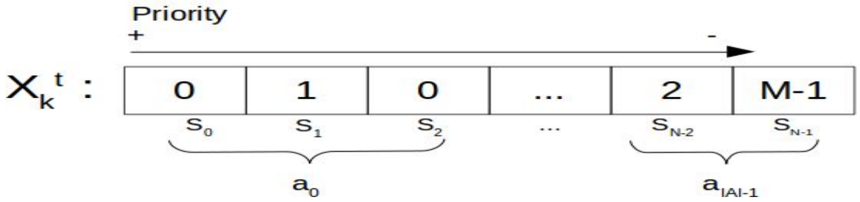
- (i) and (ii) are respectively memory and computing constraints for placing service $i$ on machine $j$.
- (iii) means that a service $s_i$ should be placed only in one device.



# Discrete Particle Swarm Optimization approach

- Semi-stochastic population-based approach.
- Inspired by the collective behavior of social animals (Birds flocking,Fish schooling).
- A set of particles with a position, velocity and a set of neighbors exploring the multidimensional search space throug iterations.
- The particle's movement (direction and speed) between each iteration is a consequence of its own experience (local search method) and its neighboring one (semi-global or global search).






## Velocity particle's position updating

We compute each particle new velocity matrix according to Eq (1).

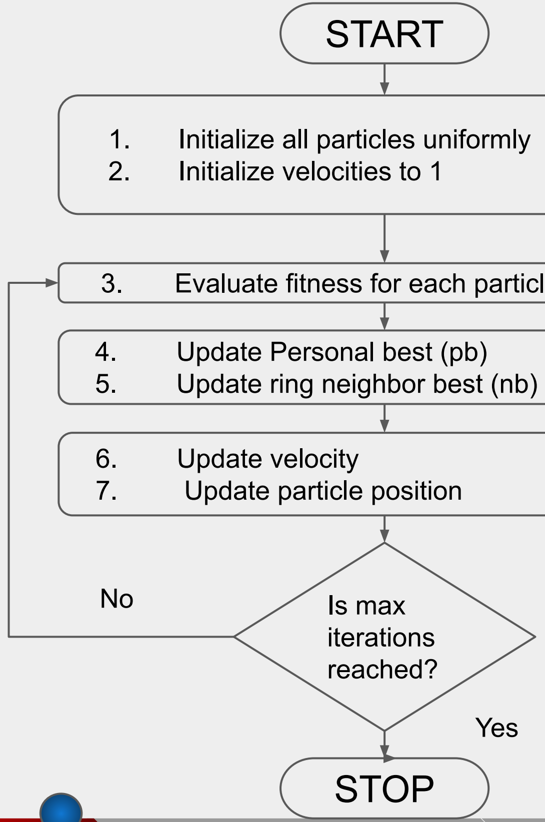
$$v_k^{t+1}(i,j) = \omega^{(t+1)} v_k^t(i,j) + \varphi_1 \omega_1^{t+1}(i,j)[f(Pb_k^t) - f(X_k^t)] + \varphi_2 \omega_2^{t+1}(i,j)[f(Nb_k^t) - f(X_k^t)] \quad (1)$$

After new velocity computation, we deduce particle's new position vector with Eq (2)

$$x_k^t(i) = Z \iff v_k^t(i,Z) = \max_{\forall j \in [0,M-1]} \{v_k^t(i,j)\} \quad (2)$$

Physical topology constraints can reduce placement possibilities for a service $s_i$.

$$\forall k \in [0, P-1], \forall t \in [0, T_{max}-1] \Rightarrow v_k^t(i,j) = -\infty \quad (3)$$



**CloudOnly**

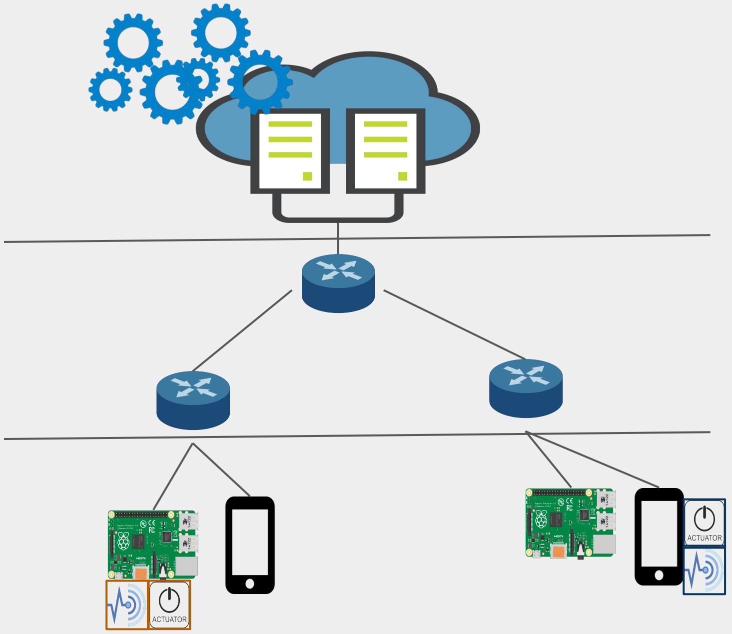
**IoTFogOnly**

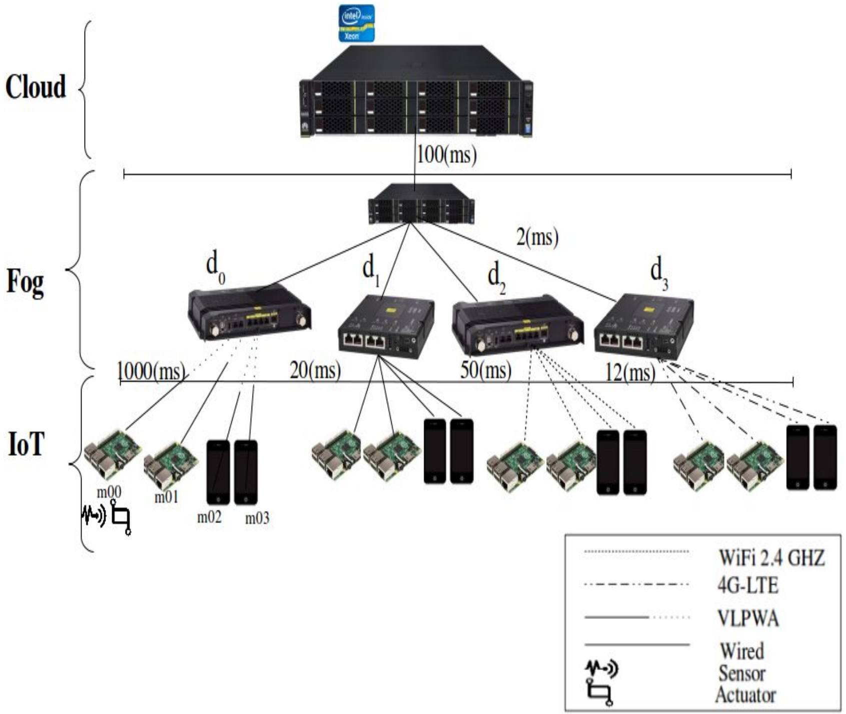
**IoTCloud(IC)**

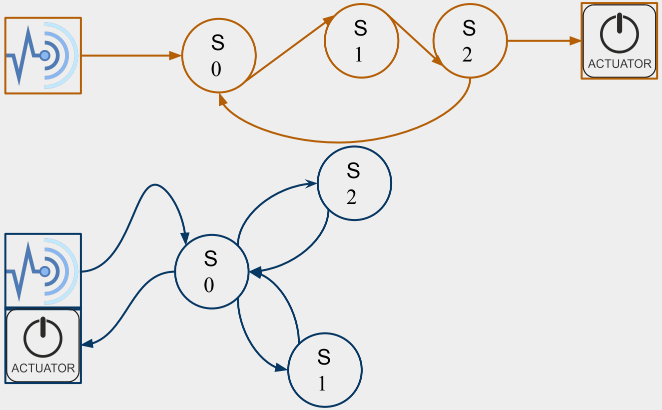
**FogCloud(FC)**

**Dicothomous (DCT)**

**Discret Particle Swarm Optimization (DPSO)**





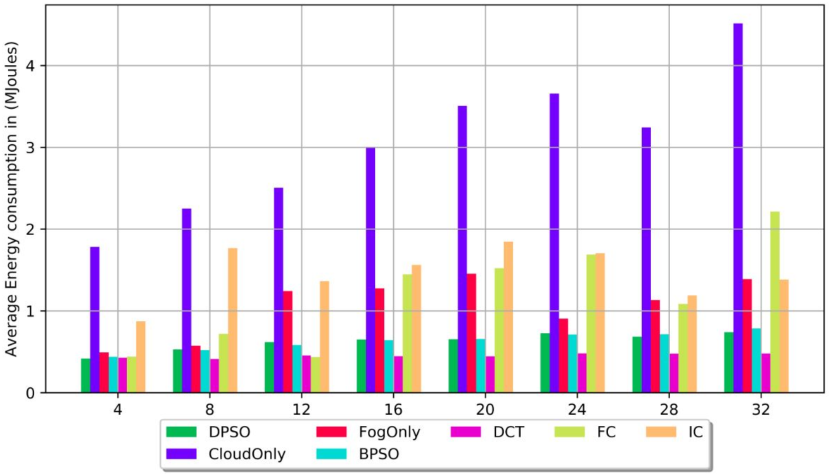



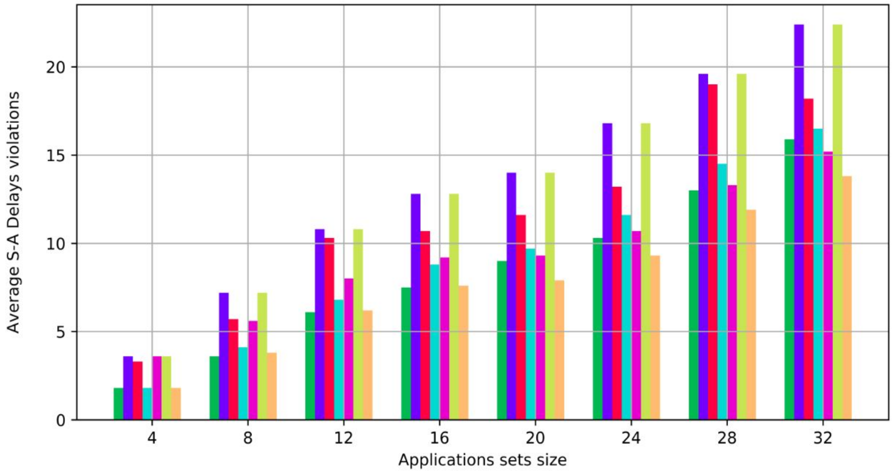

(1) Real Time (RT)

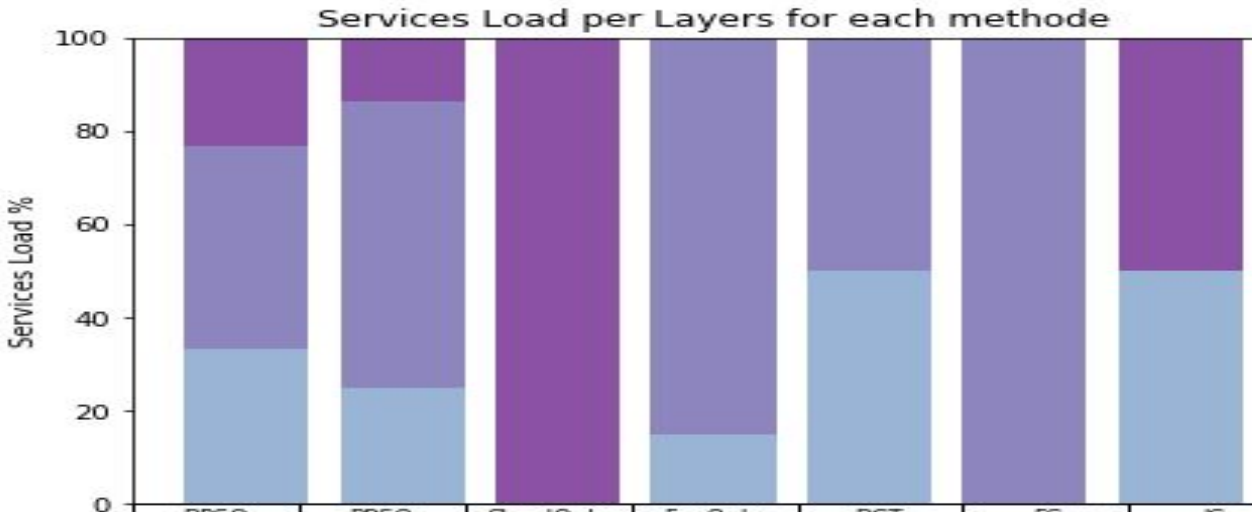
(2) Mission Critical (MC)

(3) Streamin (ST)

(4) Best Effort (BE)


Average Energy consumption in (MJoules)
0
1
2
3
4
4
8
12
16
20
24
28
32
DPSO
CloudOnly
FogOnly
BPSO
DCT
FC
IC


Average S-A Delays violations
0
5
10
15
20
4
8
12
16
20
24
28
32
Applications sets size

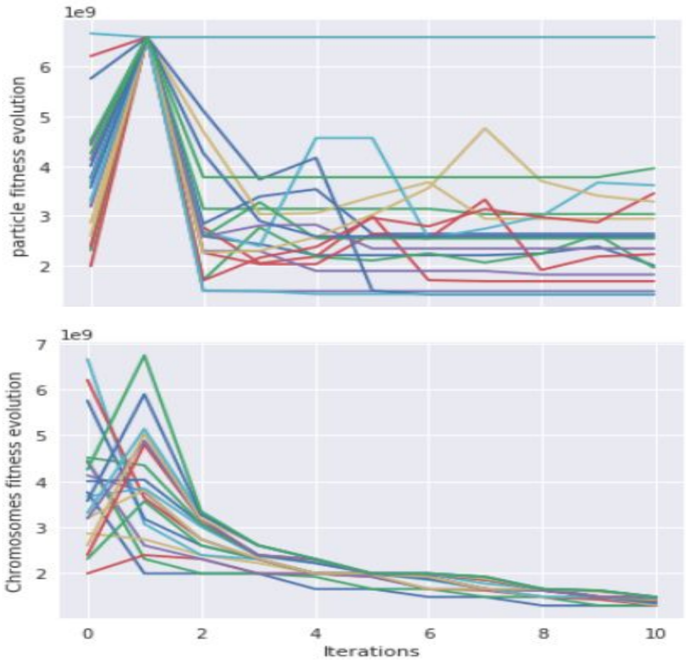


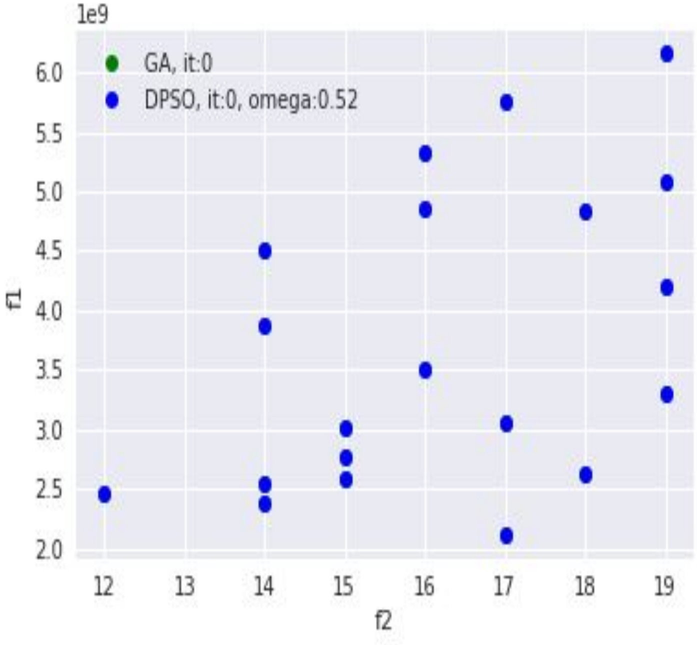

| | DPSO | BPSO | CloudOnly | FogOnly | DCT | FC | IC |
|---|---|---|---|---|---|---|---|
| Cloud Layer | 23.1 | 13.7 | 100.0 | 0.0 | 0.0 | 0.0 | 50 |
| Fog Layer | 43.7 | 61.3 | 0.0 | 85.2 | 50.0 | 100.0 | 0 |
| IoT Layer | 33.2 | 25.0 | 0.0 | 14.8 | 50.0 | 0.0 | 50 |

# Conclusion (1)

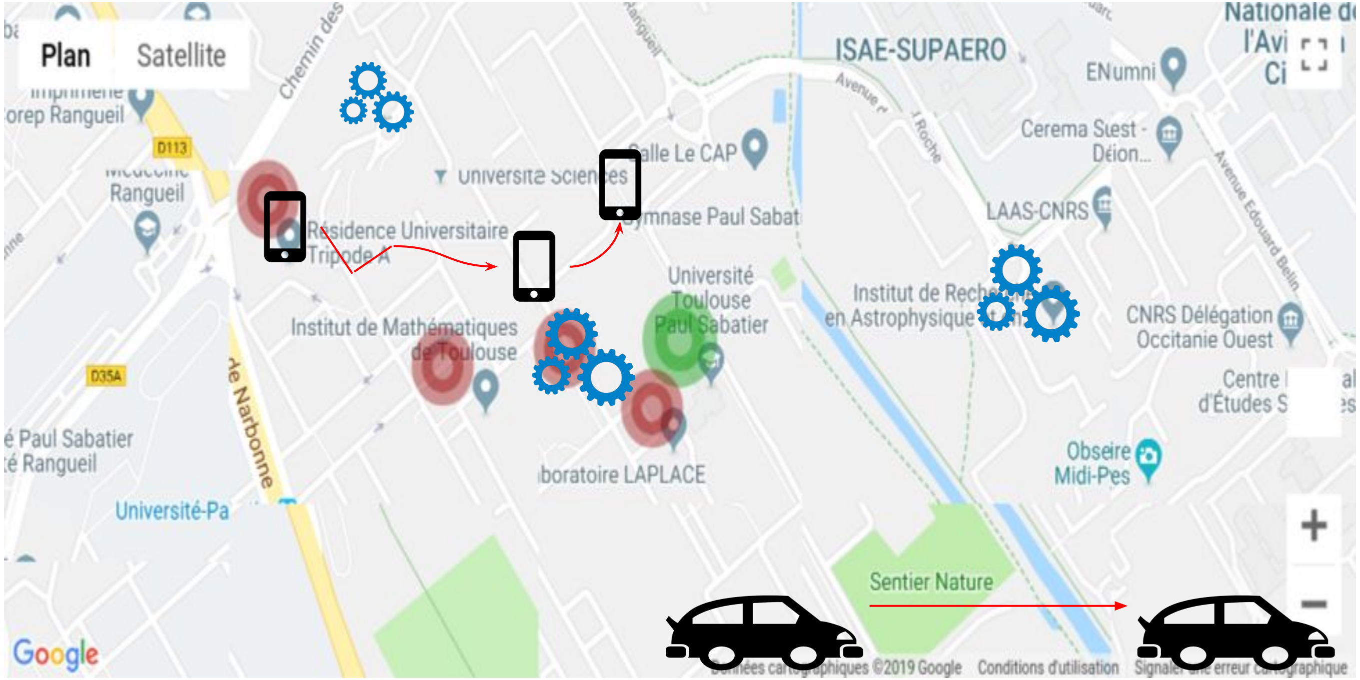
1. Evolutionary approach and basic placement strategies.
2. DPSO gives a good tradeoff between energy and delay values.
3. Execution time.
4. Centralized approach.
5. Hierarchical topology.
6. Linear energy consumption profile.
7. Static infrastructure and VMs.

# Conclusion (2)



# Conclusion (3)




**Solution quality impacted by time.**

**Users mobility estimation**

**Efficient handover and migrations approches Evaluation**

**Services availability.**

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