Weekly meetings @ SARA
16/09/2019

Cognitive SLOs* Management in IoT Platforms.

Thèse ehorizon #19

*Service Level Objectives

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Agenda

- Context, Problem and Approach
- Solution
  - Softwarization of Network Functions
  - GA-Based Multi-objective Optimization
- A Connected Vehicles Case Study
  - Test case 1 (Effectiveness of Functions)
  - Test case 2 (Effectiveness of Actions)
  - Test case 3 (Effectiveness of joint optimization of Functions and Actions)
- Conclusion & Next Steps

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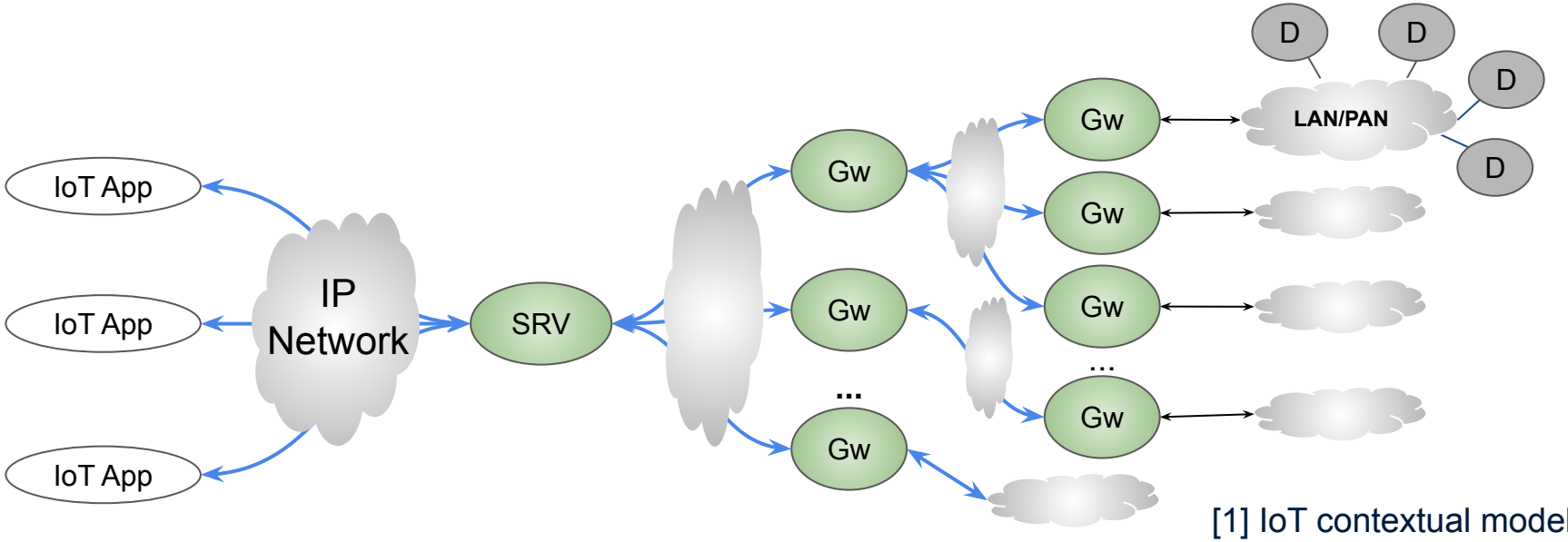
Thesis: Context, Problem and Approach

1. Context

> IoT ecosystem has evolve : dedicated platforms ⇒ shared integrated platforms



[1] IoT contextual model

> Future IoT platforms will be
- connected to billions of devices
- extremely heterogeneous (in technology, resource capacity and connectivity).

[1] ETSI TS 102 690 V1.1.1 “Machine-to-Machine communications (M2M); Functional architecture”, october 2011, p15

Thesis: Context, Problem and Approach

2. Problem

1. IoT applications and their QoS requirements (bounded response time, availability, etc.)

V2N Applications [2]	Service Level Objective (SLO)	
	Latency	Availability
Teleoperated driving	5-20 ms	>99%
Cooperative maneuvers	100 ms	>99%
Traffic efficiency	1s	<90%

2. The amount of data generated will cause an enormous burden on conventional networking infrastructures.
3. Only best effort service is provided in current IoT platforms (despite the fact that the supported applications have different E2E SLO)
4. Two bottlenecks facing QoS
   a. at the level of IP networks
   b. at the level of IoT platforms

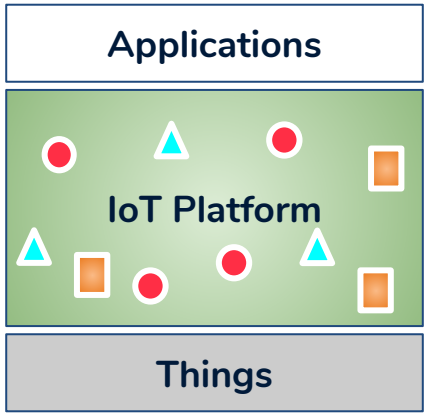
[2] Boban, Mate, et al. "Connected roads of the future: Use cases, requirements, and design considerations for vehicle-to-everything communications." IEEE Vehicular Technology Magazine 13.3 (2018): 110-123.

Thesis: Context, Problem and Approach

3. Considered approach

Endow dynamically the IoT Platform with mechanisms allowing it to sustain the SLOs required by applications.

General Requirements		Primitive Mechanisms
Resource management R1	Horizontal Scalability R1.1	Replication, Load Balancing
	Vertical Scalability R1.2	Computation, Memory and Network Scaling
Traffic management R2	Traffic Identification R2.1	Classification and marking
	Service Differentiation R2.2	Dropping, Shaping, Scheduling, Redirecting
Cognitive management R3		Search/Optimization Metaheuristics, (Un)Supervised Learning-based Classifiers, etc.



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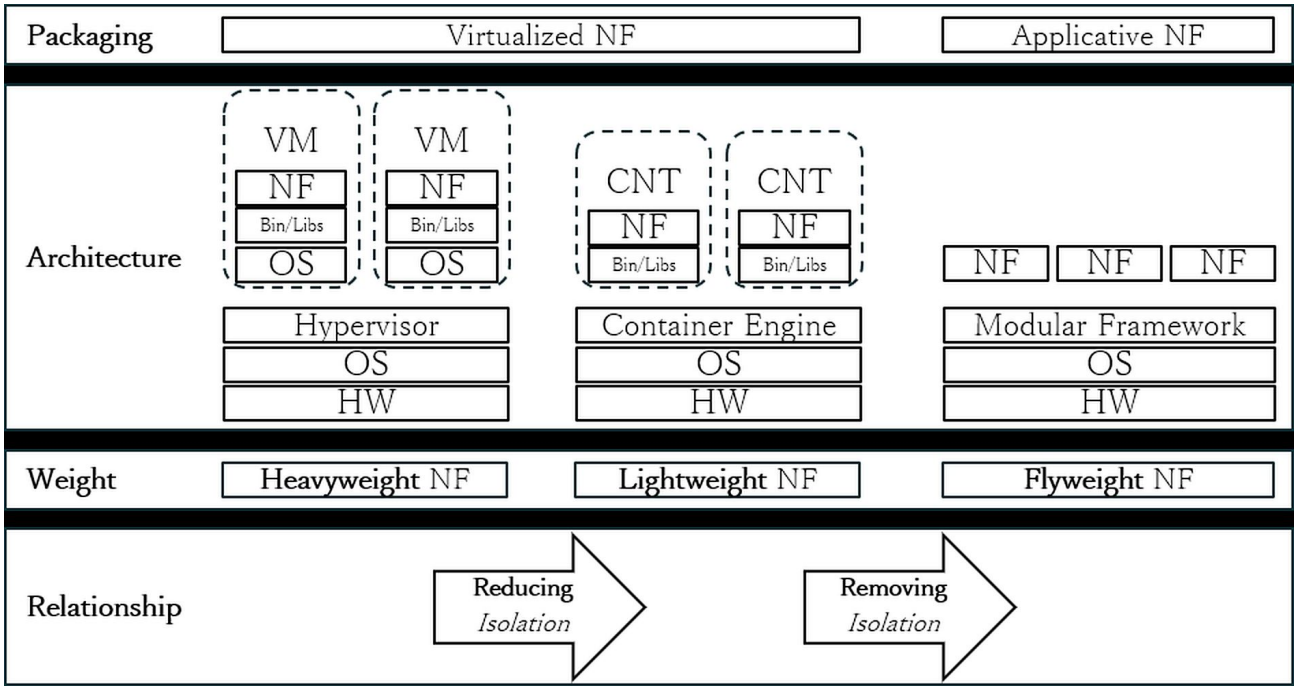
Solution (R2)

1. Softwarization of Network Functions

> Dynamic deployment in extremely heterogeneous

⇒ Generalization of the current instantiation of the softwarized NF



Solution (R3)

2. Optimization problem

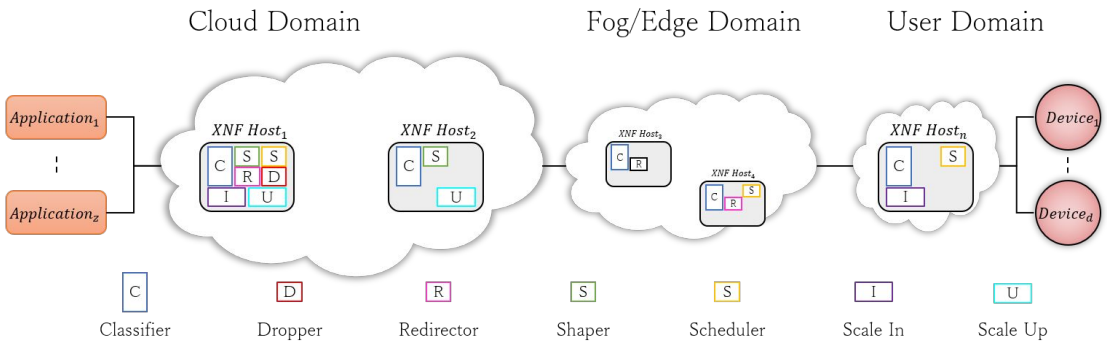
- Sustain the End-to-End SLO in a given condition:
  - Determine the appropriate Function to deploy (or to remove)
  - Determine appropriate Action to execute
- Provide usable near-optimal solutions in a short amount of time (<<1s)

  ⇒ and efficient heuristic is needed.
- For evaluation purposes we built for a GA-based heuristic.

Solution (R3)

2. GA-Based Multi-objective Optimization

> System model (assuming that the IoT platform is composed of XNF hosting nodes):



> Application SLO satisfaction in an IoT platform is a Multi-Objective problem that rises a set of optimal solutions (Pareto-optimal solutions)

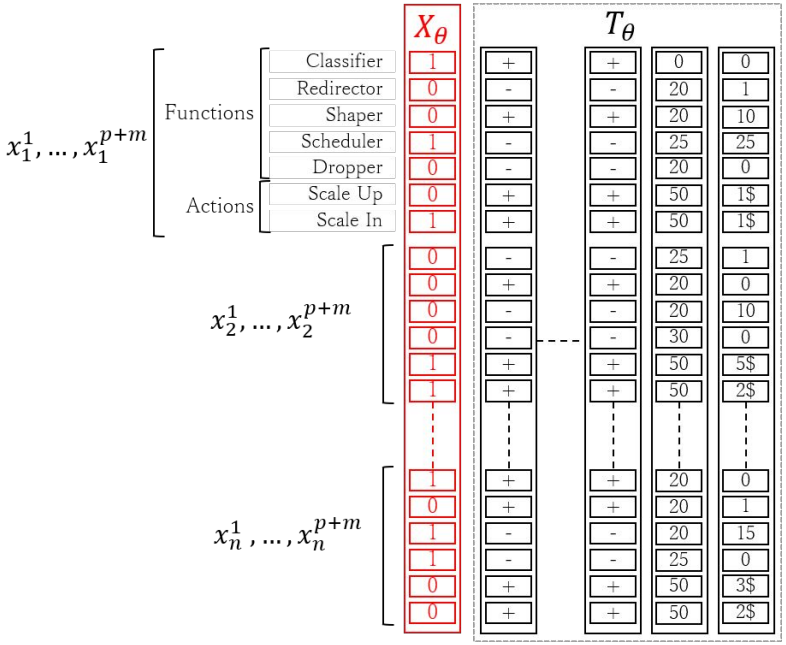
> On the choice of the applied solution:

- *Random* Selection
- *SLO objectives-based* Selection
- *Non SLO objectives-based* Selection: Complexity-based, Cost-based, etc.

Solution (R3)

2. GA-Based Multi-objective Optimization

> Genotype:



> Genetic operators: Bit-flip (mutation), HUX (crossover), Tournament Selector (selection)

> Evolutionary strategy: NSGA II (Non-dominated Sorting Genetic Algorithm II)

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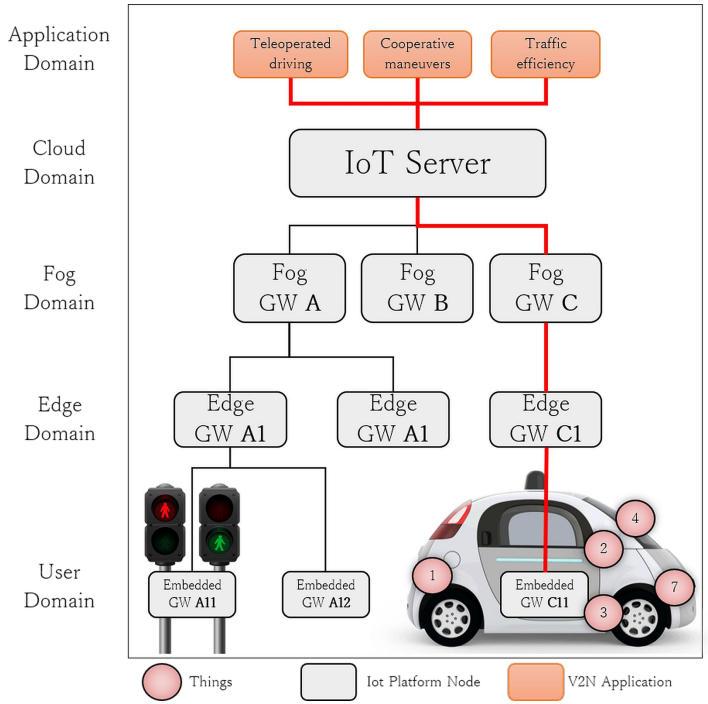
A Connected Vehicles Case Study

0. Overview



Population size = 100
Crossover probability pc= 1
Mutation probability pm= 1
Chromosome length = 28
Run = 10000

REPRESENTATIVE V2N APPLICATIONS

V2N Application	Description	SLO		
		Throughput*	Latency	Unavailability
Teleoperated driving	An external operator drives the vehicle using a live-stream video.	25 req/sec	20 ms	<1%
Cooperative maneuvers	A set of vehicles communicating and behaving as a system for performing coordinated actions.	10 req/sec	100 ms	<1%
Traffic efficiency	Optimization of traffic parameters (traffic lights, speed limit, etc.).	10 req/sec	1s	<10%

*request size = 1Mb.

(a)

INITIAL SNAPSHOT s_0 PARAMETER SETTINGS

Parameter	Test Case 1	Test Case 2	Test Case 3
Teleoperated driving	L_i=10 ms T_i=25 req/sec	L_i=10 ms T_i=25 req/sec	L_i=10 ms T_i=25 req/sec
Cooperative maneuvers	L_i=20 ms T_i=10 req/sec	L_i=20 ms T_i=10 req/sec	L_i=20 ms T_i=10 req/sec
Traffic efficiency	L_i=20 ms T_i=10 req/sec	L_i=20 ms T_i=10 req/sec	L_i=20 ms T_i=10 req/sec
Resources Usage	$H_{i_{cpu}}$=5-10% $H_{i_{ram}}$=5-10%	$H_{i_{cpu}}$=50-70% $H_{i_{ram}}$=50-70%	$H_{i_{cpu}}$=50-100% $H_{i_{ram}}$=50-100%

(b)

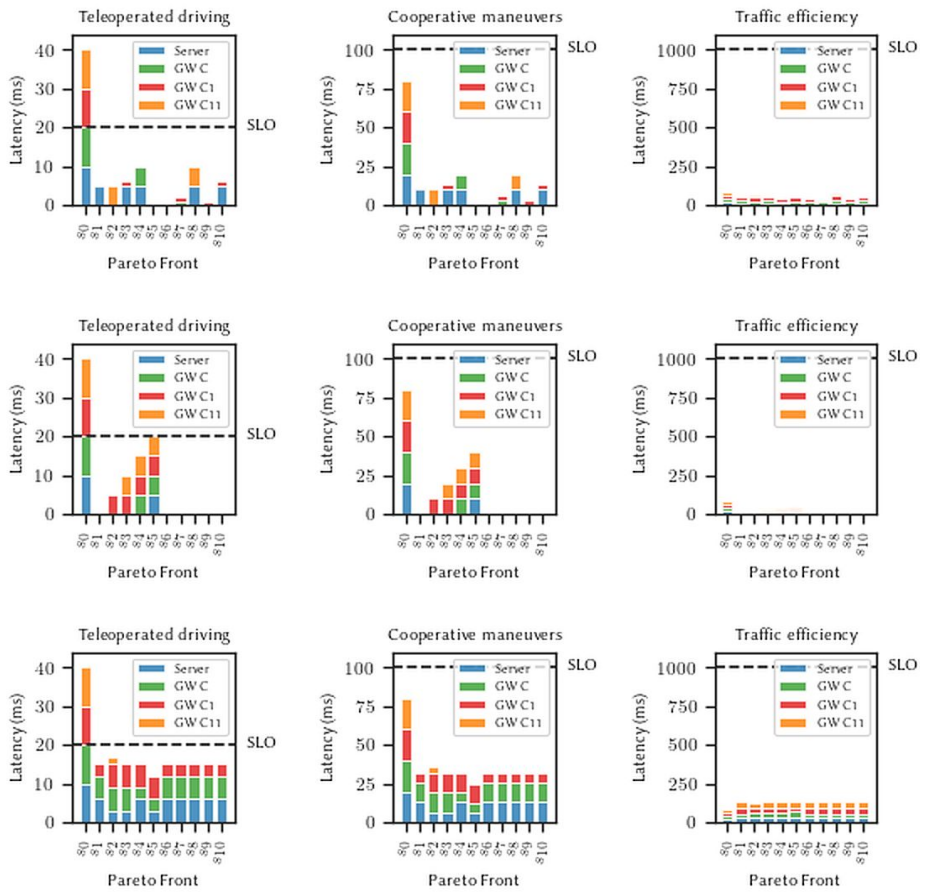
A PRIORI BENEFITS

SLOs Enabling		Benefit	Description
Fuction	Classification	0%	Deploy a classifier on an XNF Host
	Redirection	0%	Deploy a redirector on an XNF Host
	Scheduling	35%	Deploy a scheduler on an XNF Host
	Delaying	35%	Deploy a delayer on an XNF Host
	Dropping	41%	Deploy a dropper on an XNF Host
Action	Scale in	50%	Replicate an XNF Host
	Scale up	50%	Double resources of an XNF Host

(c)

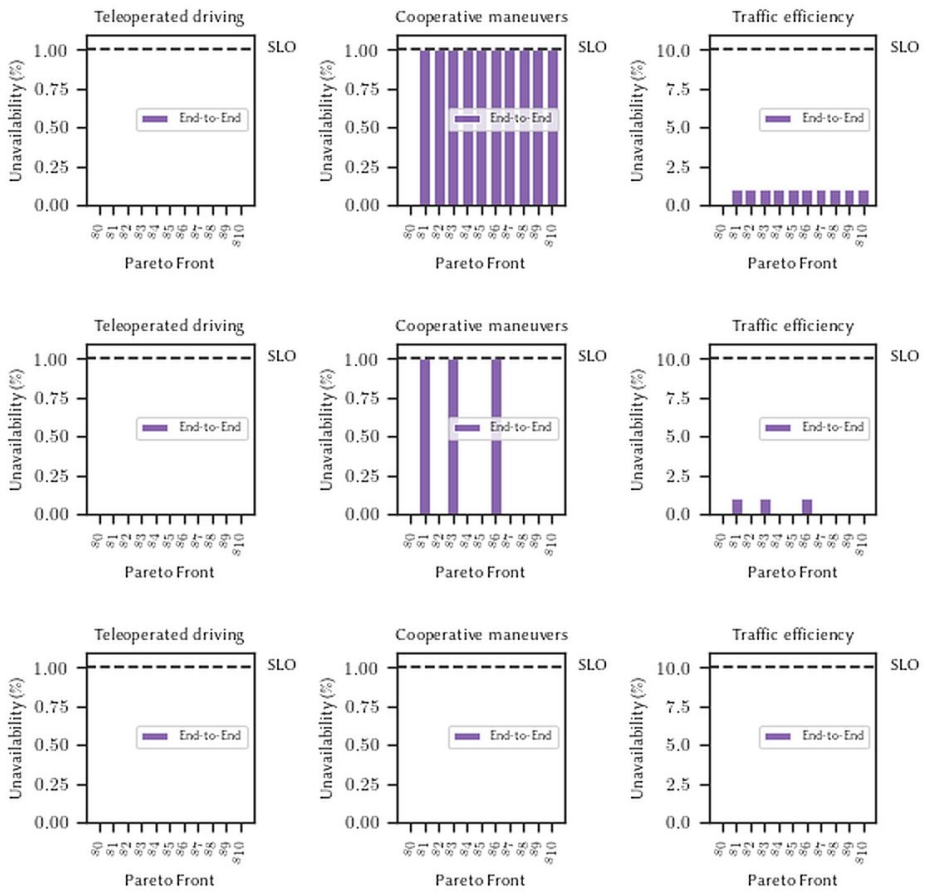
A Connected Vehicles Case Study

1. Latencies



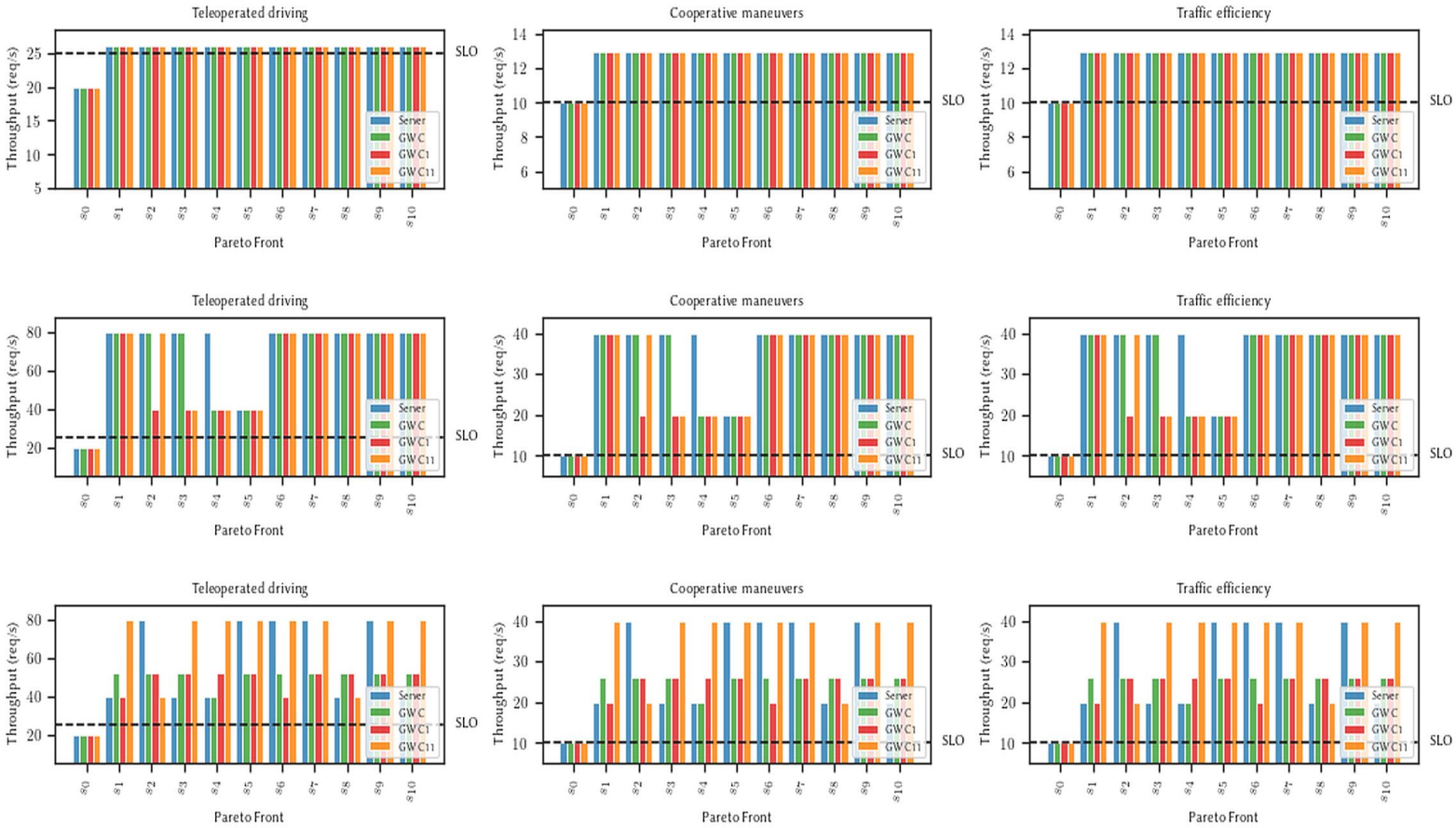
A Connected Vehicles Case Study

2. Unavailabilities



A Connected Vehicles Case Study

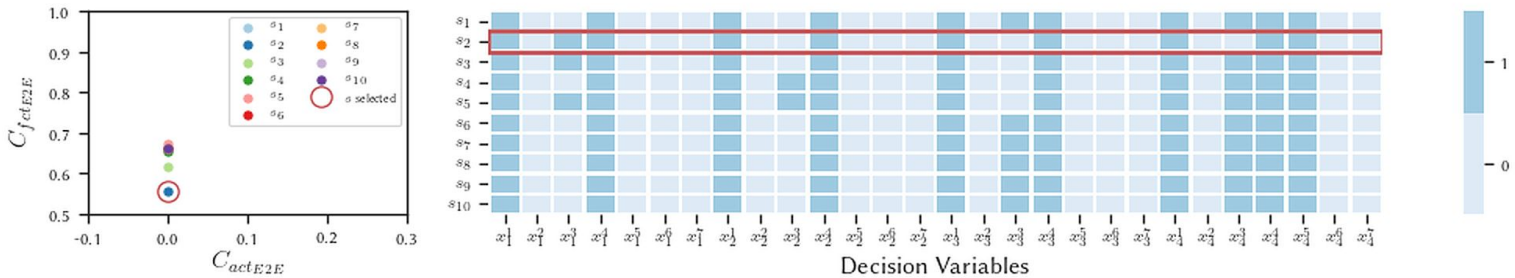
3. Throughputs



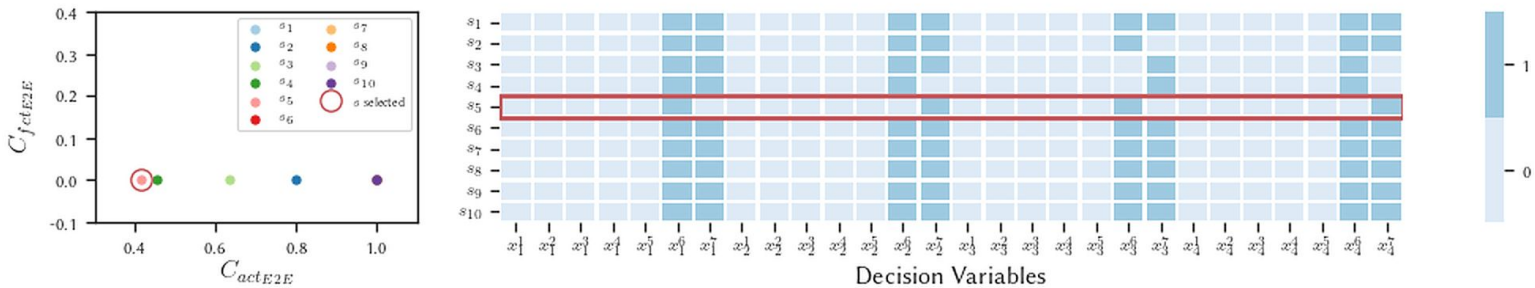
A Connected Vehicles Case Study

4. Cost-based selection

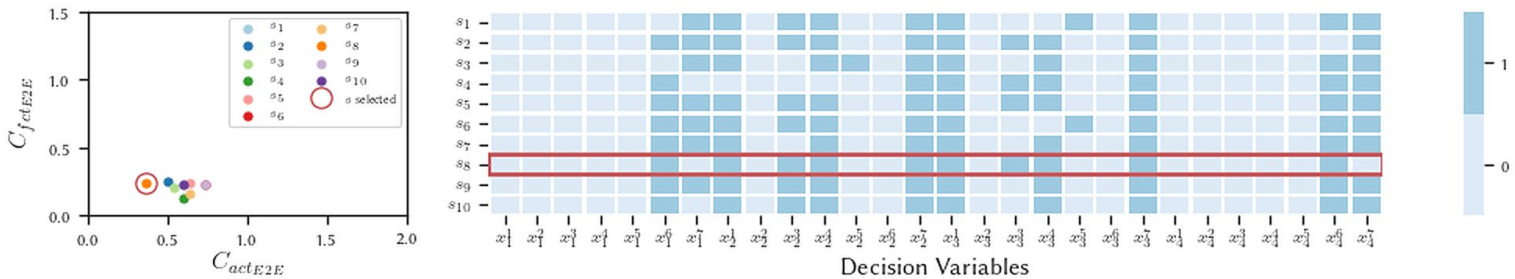
(a)



(b)



(c)



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Conclusion & Next Steps

1. Used tools

- IoT Platform: OM2M
- NFV: OpenBaton + Docker
- MOEA Framework: Platypus
- Programming: JAVA + Python + Bash

2. Conclusion & Next Steps

- We propose an approach taking advantage of all the new opportunities to make 5G mission-critical applications a reality with a focus on the IoT platform level.

- Next Steps
  - can we build the optimal combination in a formal way?
  -

Journée des thèses eHorizon @ SARA
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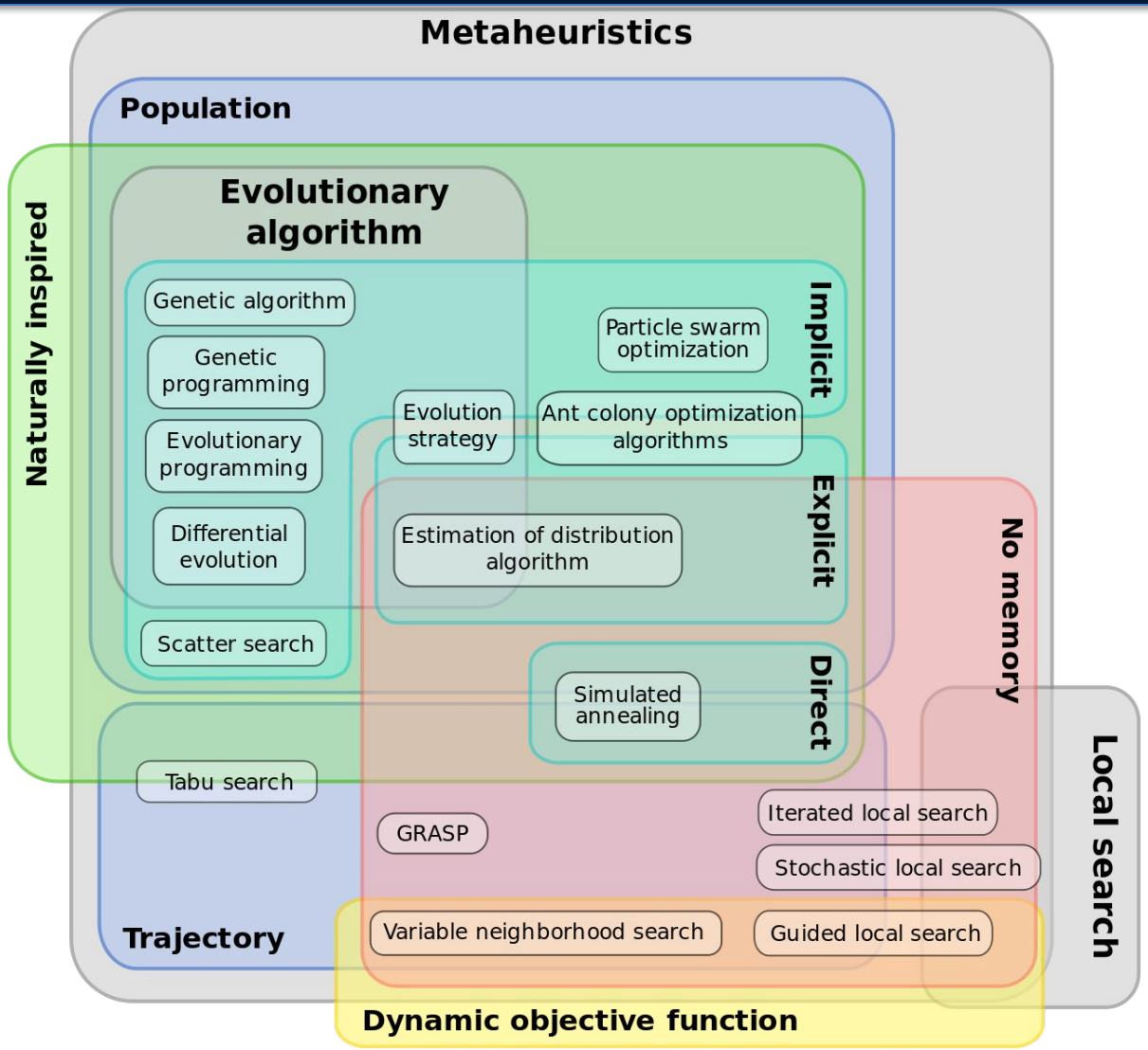
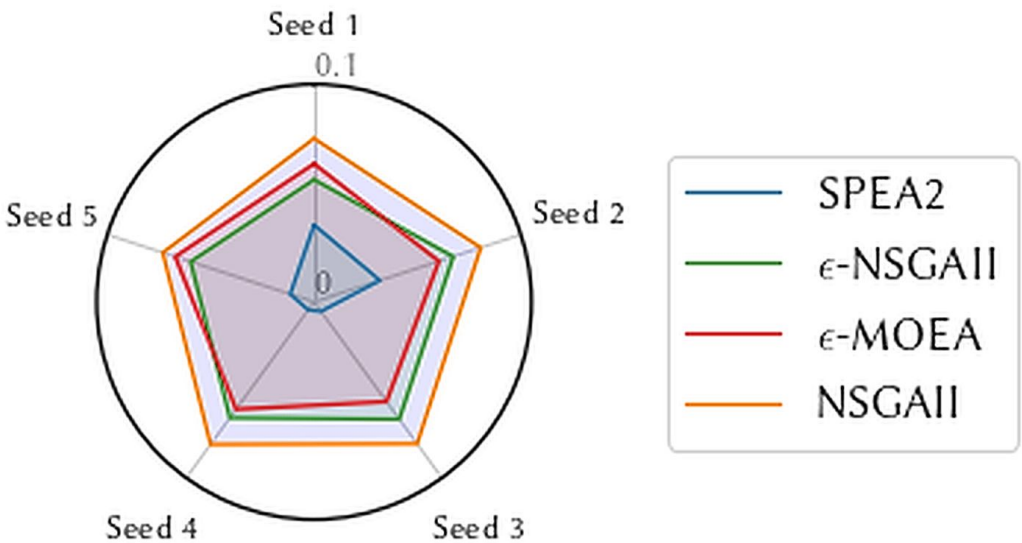
Back-up 1


Metaheuristics
Population
Naturally inspired
Evolutionary algorithm
Genetic algorithm
Genetic programming
Evolutionary programming
Differential evolution
Scatter search
Implicit
Particle swarm optimization
Evolution strategy
Ant colony optimization algorithms
Explicit
Estimation of distribution algorithm
Direct
Simulated annealing
No memory
Local search
Tabu search
GRASP
Iterated local search
Stochastic local search
Trajectory
Variable neighborhood search
Guided local search
Dynamic objective function

Back-up 2

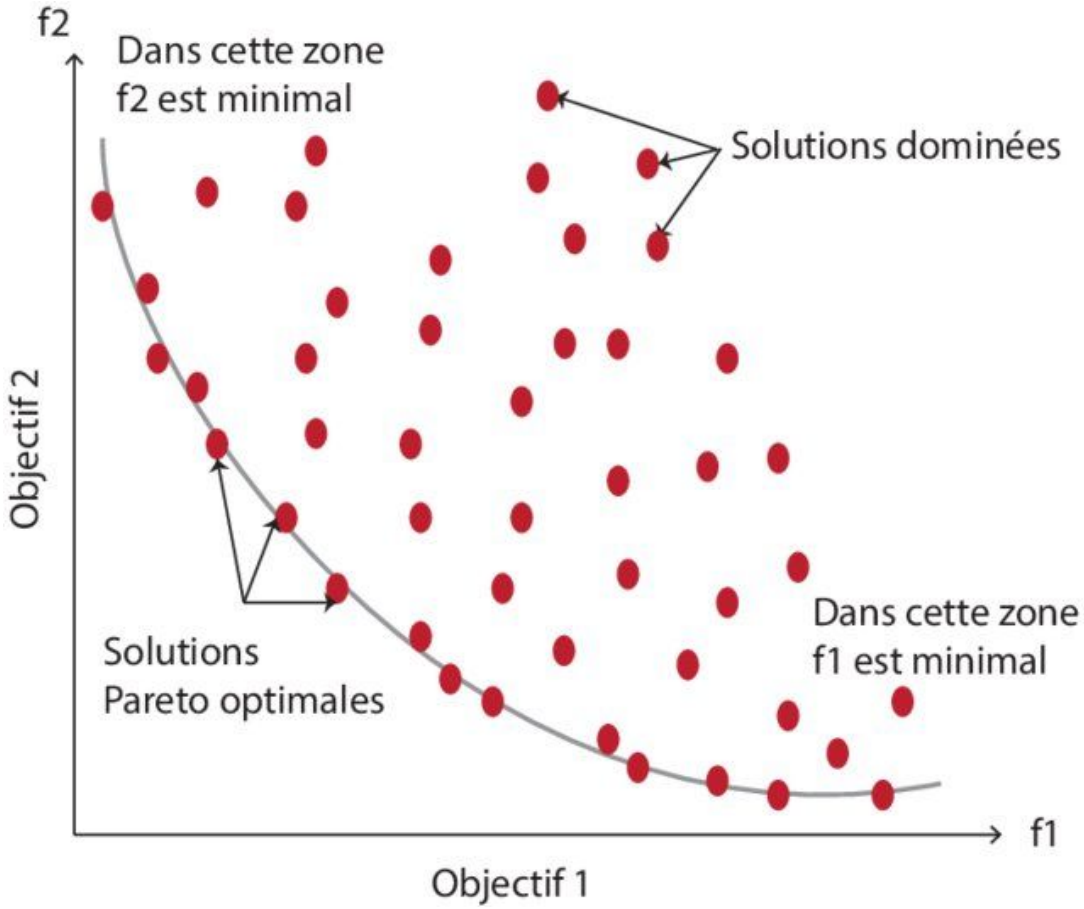


Algorithm 1: NSGAII-based evolutionary strategy

Input: N: population size; T: maximum number of generations
Output: P_t

```
begin
    Set t = 0 Initialize P_0 and set Q_0 = ∅.
    while t < T do
        Calculate fitness for P_t and assign rant based on Pareto
          dominance
        Perform selection on P_t to fill mating pool
        Apply crossover and mutation operators to obtain the
          offspring population Q_t
        Select the best N non-dominated solution from P_t ∪ Q_t by
          the two-step procedure to form P_{t+1}
        Set t = t + 1
    return P_t
```

Back-up 3


f2
Dans cette zone
f2 est minimal
Solutions dominées
Objectif 2
Solutions
Pareto optimales
Dans cette zone
f1 est minimal
f1
Objectif 1

Back-up 4

Why look beyond the VNF:

- Some (constrained) environments do not support VNF deployment
- The IoT PF entities can be deployment environment for a lighter version of NF.
- (in the form of a software component that will be injected in the entity)
- The packaging in VNF may be counterproductive because more expensive in management / resource consumption.