Cognitive SLOs* Management in IoT Platforms.

*Service Level Objectives

Clovis OUEDRAOGO
Doctorant 2A (ED MITT / INSA)
Équipe SARA / LAAS-CNRS

Directeurs de thèse : C. CHASSOT, S. MEDJIAH, K. DRIRA
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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1. Context

- IoT ecosystem has evolved: dedicated platforms ⇒ shared integrated platforms

- 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
2. Problem

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

<table>
<thead>
<tr>
<th>V2N Applications [2]</th>
<th>Service Level Objective (SLO)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Latency</td>
</tr>
<tr>
<td>Teleoperated driving</td>
<td>5-20 ms</td>
</tr>
<tr>
<td>Cooperative maneuvers</td>
<td>100 ms</td>
</tr>
<tr>
<td>Traffic efficiency</td>
<td>1s</td>
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</tbody>
</table>

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

3. Considered approach

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

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

Applications

- IoT Platform
- Things
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1. Softwarization of Network Functions

> Dynamic deployment in extremely heterogeneous

⇒ Generalization of the current instantiation of the softwarized NF
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.
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.
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
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?
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Algorithm 1: NSGAII-based evolutionary strategy

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

1. begin
2. \hspace{1em} Set $t = 0$ Initialize $P_0$ and set $Q_0 = \emptyset$.
3. \hspace{1em} while $t < T$ do
4. \hspace{2em} Calculate fitness for $P_t$ and assign rank based on Pareto dominance
5. \hspace{2em} Perform selection on $P_t$ to fill mating pool
6. \hspace{2em} Apply crossover and mutation operators to obtain the offspring population $Q_t$
7. \hspace{2em} Select the best $N$ non-dominated solution from $P_t \cup Q_t$ by the two-step procedure to form $P_{t+1}$
8. \hspace{1em} Set $t = t + 1$
9. return $P_t$
Dans cette zone, $f_2$ est minimal.

Solutions dominées

Solutions Pareto optimales

Dans cette zone, $f_1$ est minimal.
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.