Scheduling dependent tasks within a smart city's fog/edge infrastructure powered by renewable energy

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Introduction

- Cloud-edge continuum
    - Edge nodes with lower latency
    - Possible to offload tasks to the cloud
- Green energy
    - Low power consumption of edge nodes
- Smart-cities
    - Applications often require low response time

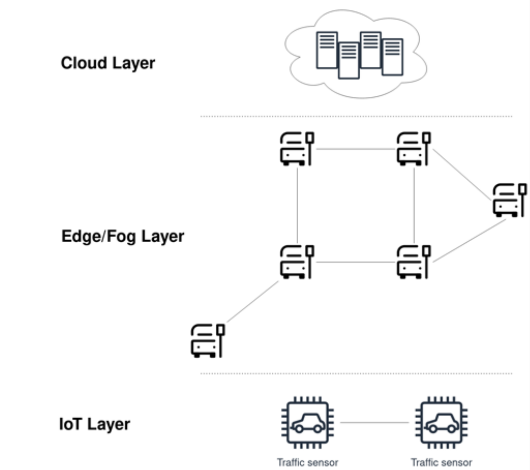

Figure 1: Cloud-Edge continuum in our context.

Introduction

- VILAGIL project : improve mobility in Toulouse with smart city approach
- Schedule tasks in the distributed edge/fog computing infrastructure
- PV panels installed at the hosts
- Optimize QoS, energy consumption, non-renewable energy consumption

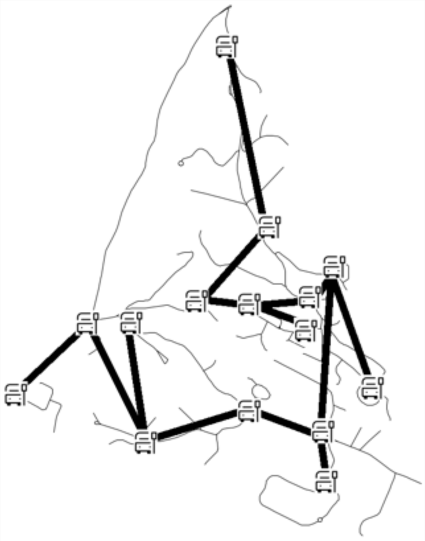

Figure 2: Edge/Fog infrastructure

Requests and task model

Figure 3: Street graph of Vieille-Toulouse.

Representing a city as a graph:

- Vertices are the streets
- Edges are the interconnections between the streets

Requests and task model

Figure 4: Street graph of Vieille-Toulouse.

User request:

- How long it takes going from one location to another in the city?

Requests and task model

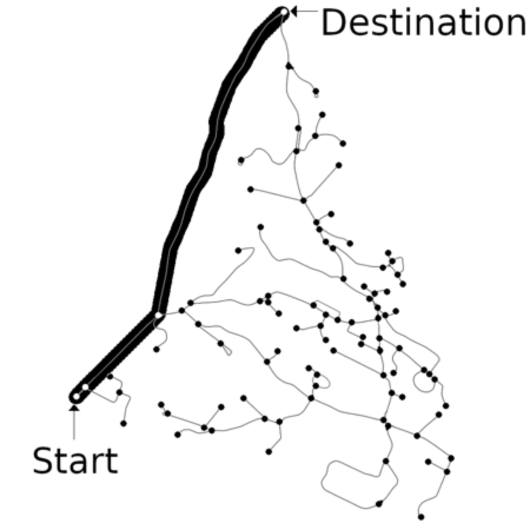

Figure 5: Example of one request.

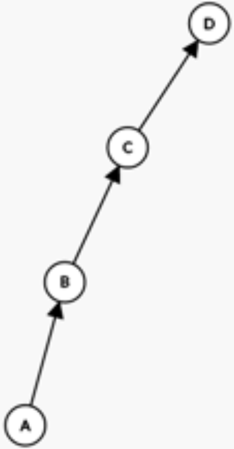

Figure 6: Tasks of the request.

Requests and task model

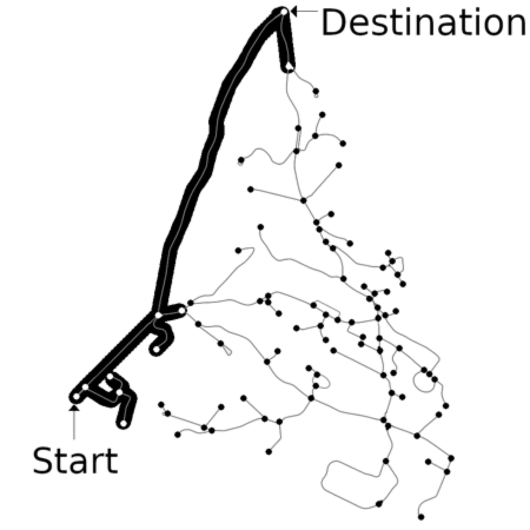

Figure 7: Example of one request.

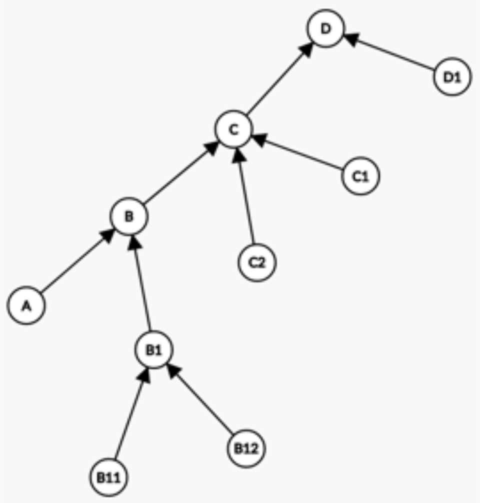

Figure 8: Tasks of the request.

Requests and task model

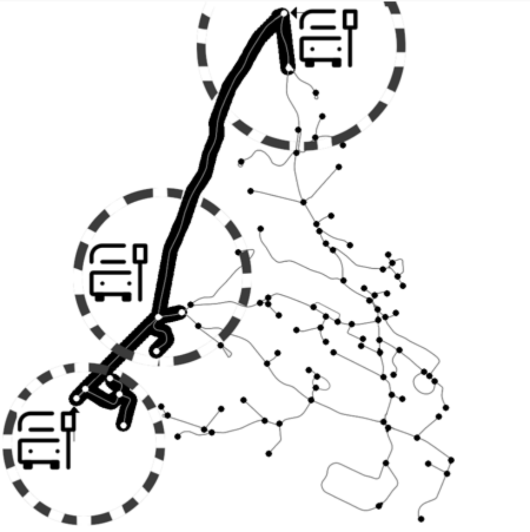

Figure 9: Example of one request.

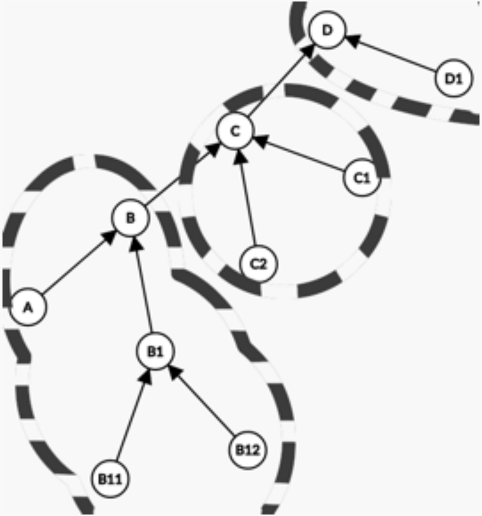

Figure 10: Tasks of the request.

Requests and task model

- A user request for a path is represented as a Directed Acyclic Graph (DAG) of tasks
- Each task represents computation of a segment (street traffic info)
- Each edge/fog node (bus stop) has local information of the streets (nearest streets)

How to schedule the tasks to the fog/edge infrastructure aiming to reduce response time and non-renewable energy consumption ?

Initial Experiments

Baseline

- task is allocated to the bus stop that have its required data
- (less communications)

Green Earliest Finish Time (GEFT)

- task is allocated to the bus stop that have green energy and the earliest finish time
- (considering computation time and communications)
- inspired in the HEFT algorithm[1]

[1] Topcuoglu, Haluk; Hariri, Salim; Wu, M. (2002). 'Performance-effective and low-complexity task scheduling for heterogeneous computing". IEEE Transations on Parallel and Distributed Systems. 13 (3): 260–274

Computational infrastructure modeling

- SimGrid framework
- 17 edge/fog nodes
- 146 streets nodes managed by the hosts
- Raspberry PI with 4 CPU cores
- Network links latency:
  - 10 ms for edge/fog
  - 100 ms for cloud
- Hosts have PV panels and batteries
- Electricity from the grid is assumed to be carbon intensive, cloud DC is green

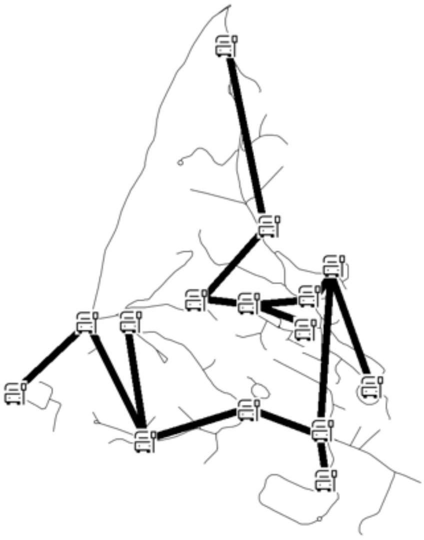

Figure 11: Edge/Fog infrastructure

Solar energy traces

- Small variation between the different hosts (considering a city)
- Values per minute (NASA MERRA-2)[3]

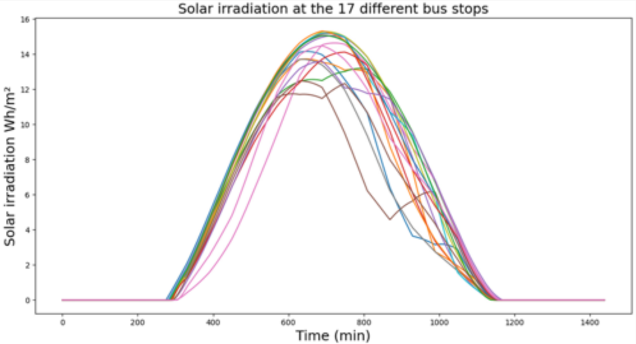

Figure 12: Solar irradiation values

[3] Global Modeling and Assimilation Office (GMAO) (2015), MERRA-2 tavg1_2d_slv_Nx: 2d,1-Hourly,Time-Averaged,Single-Level,Assimilation,Single-Level Diagnostics V5.12.4, Greenbelt, MD, USA, Goddard Earth Sciences Data and Information Services Center (GES DISC), Accessed: 26032024 DOI:10.5067VJAFPLI1CSIV

Workload

- Inspired by real mobility data [2]
- Computation:
  - 100 ms (edge)
  - 50 ms (cloud)
- 30000 tasks

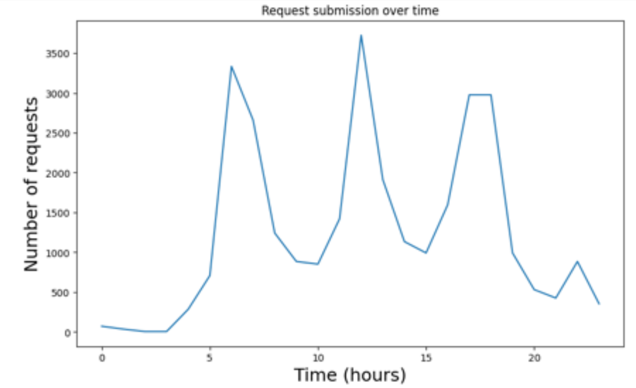

Figure 13: Workload distribution

[2] Metro SP, Pesquisa Origem e Destino 2017.

Results - Requests makespan

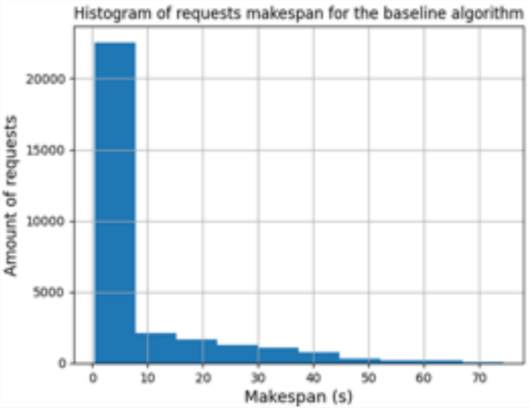

Figure 14: Makespan for the baseline algorithm.

Figure 15: Makespan for the GEFT algorithm.

Results

- GEFT consumes approximately 2% less non-renewable energy
- Small workload
- The hosts become idle outside of rush hours

Summary

- Scheduling dependent tasks into a fog/edge infrastructure
- Presence of renewable energy in the hosts
- Reduce response time
- Increase renewable energy usage

Future Research directions

- Shutdown idle hosts and manage the workload to the other hosts
- Caching
- Other scheduling strategies
- Information of the climate conditions and users requests in the scheduling decision
- Offload tasks to the cloud

Acknowledgments

- GIS neOCampus of Université Toulouse III Paul Sabatier
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Figure 16: Funding projects and agencies

Thank you !

Thank you for your attention!

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