Exploring Architectural Strategies for Mobility Experimentation: A Simulation-Based Study

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Agenda

1. **Introduction**
2. Related Work
3. Proposed Experimentation
4. Experimental Results
5. Conclusion and Future Directions

Introduction

- From large-scale environments like VANETs to smaller settings, IoT plays a crucial role
- Microservices architecture expands system design
  - It facilitates the development of complex systems through modular, independent services.
  - Dinamically
- Fog-based architectures operate closer to end-users, optimizing data processing
  - By processing data near the source, these architectures enable real-time responsiveness and context-awareness.
- In literature, there is a combination of Fog and Clusters for IoT architectures
  - Clusters facilitate task sharing and reduce service overload and enhances context-awareness

Introduction - Problem

- Within the workload placement logic, there are two main placement algorithms
  - Clustered placement
  - Edge wards
- Most of the placement algorithms are originated from outdoor positioning systems
- However, within the indoor positioning systems (IPS), users have different behaviors, presenting a distinct characteristic from VANETs and other smart city nodes

Introduction - Objective

- To evaluate the effectiveness of the proposed microservice clustered-fog service placement in various environments, and comparing it to the edgewards-fog placement, taking into comparison a base case (OPS), analyzing:
  - fog configurations
    - number of clusters
    - Cluster grouping
  - mobility parameters
    - number of users
    - random mobility pattern

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Related Work

	Resource allocation	IPS env.	OPS env.	FC	Experimentation	Clustered approach	Edgewards approach	Mobility pattern
[3]	×		×	×				×
[8]	×		×		×	×	×	
[17]	×		×	×	×	×		
[18]	×		×	×	×			
Our proposal	×	×	×	×	×	×	×	×

Table 1. Comparision of the proposed to the related works

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Proposed Experimentation

- Classic three-layer FC model (edge, fog, cloud)
- Indoor and outdoor simulations
- Horizontal (clustered) and Vertical (edgewards) approaches comparison
- Environments simulated using IFogSim v2 *

* Available @ https://github.com/vyk1/exploring-architectural-strategies-for-mobility-experimentation-a-simulation-based-study

Proposed Experimentation – Application Model

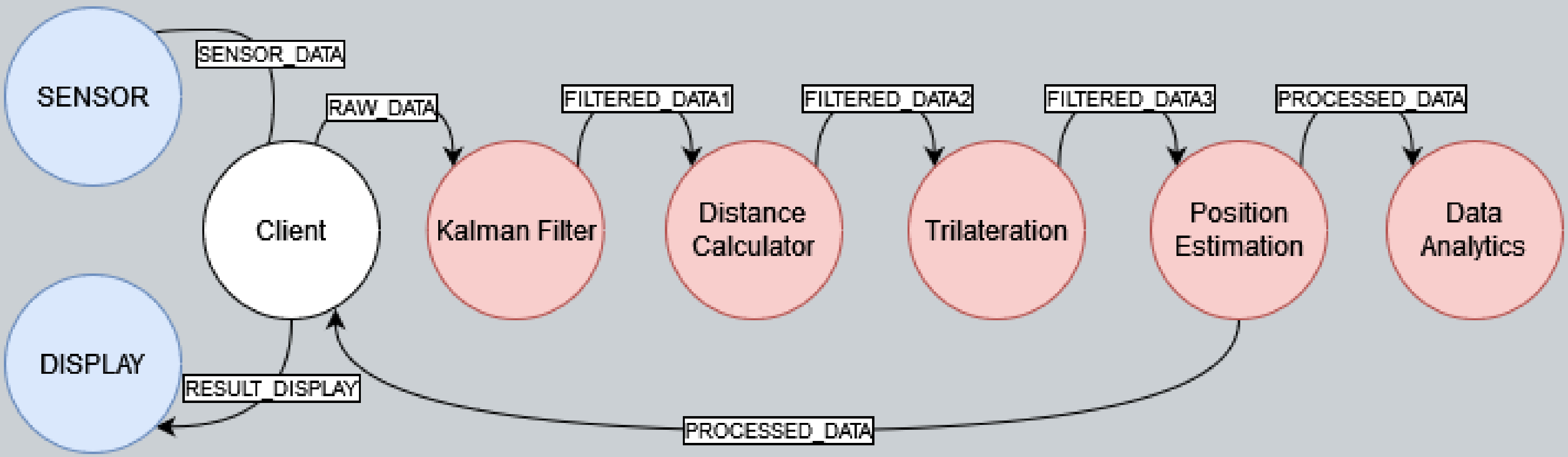


Figure 1. Application Model for the Indoor Positioning System Case Study based on the modules of [14, 15]

Proposed Experimentation – Module Placements

- Clustered microservices approach
  - Provides horizontal scalability of application modules
  - Block => groups => regions
  - 3 layers and 4 tiers
    - Cloud (0)
    - Fog proxies (1)
    - Fog gateways (2)
    - IoT devices (3)
- Edgeward approach
  - Provides vertical scalability of application modules
  - Iteration through fog devices towards the cloud and placing the remaining operators on alternative devices

Space-application-agnostic environment for wireless contexts

Proposed Experimentation – Mobility Pattern

- Random mobility pattern provided by the iFogSim simulator for both indoor and outdoor
- Code modifications for the indoor experiments
  - Also based on the Gauss-Markov mobility model available at the simulator
- Indoor-Outdoor equivalence scenarios
  - Step distance
  - Boundary limits

Proposed Experimentation – Fog Configurations

- For the development of both indoor and outdoor scenarios:
  - Centrality of the proxy was preserved
  - Definition of zone dimensions, entry points and user interactions (walks)

Proposed Experimentation – Fog Configurations - OPS

- OPS cluster configurations
  - eight, twelve (default EUA dataset) and twenty-eight cluster

Figure 2: Eight, twelve and twenty-eight clusters' configurations

Proposed Experimentation – Fog Configurations - IPS

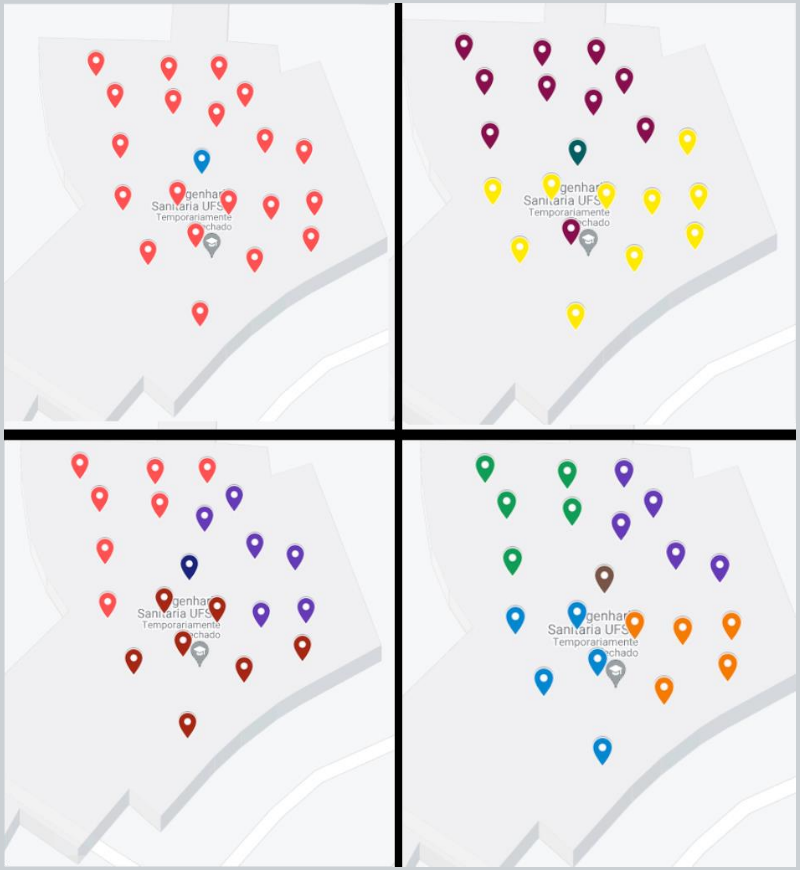


Figure 3. Snapshot of ENS Scenario with Different Clustering: Monocluster to Quadruple Cluster (1-4 clusters)

Gateways	Proxies	**Total**	Nodes by Region
19	1	20	20
18	2	20	10
17	3	20	≈ 7
16	4	20	5

Table 2. Correlation of Fog Nodes in the IPS experiment

Experimental Results

- Application Loop Delay (ALD)
  - Measures the time to complete the application model.
  - Lower delay indicates efficient placement decisions and resource coordination.
- Migration Time (MT)
  - Evaluates service migration efficiency within application modules.
  - Measures delay during service migration between fog nodes.
- Network Usage (NU)
  - Quantifies bandwidth consumption by the architecture.

The mean and standard deviation were used

Experimental Results - Base Case OPS – ALD + NU

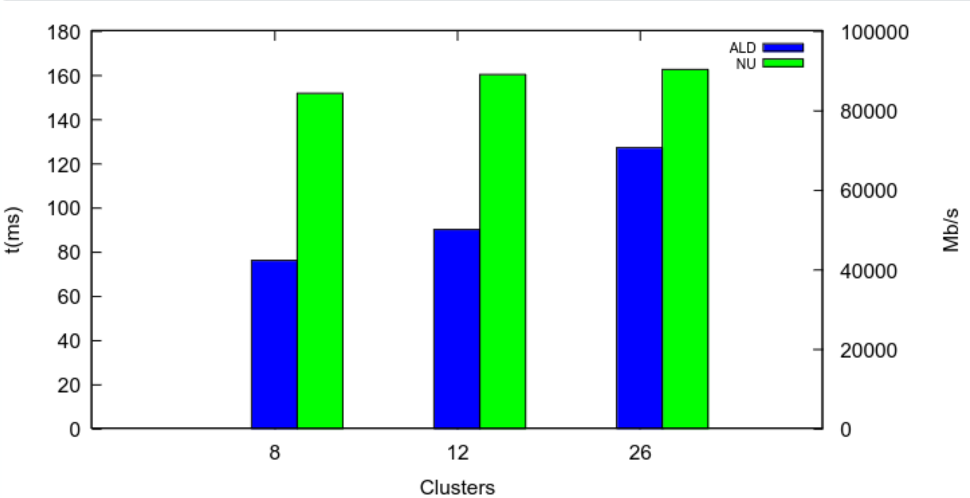


Figure 4 (left): Application loop delay and network usage per number of clusters in eight-users scenario

- Lower clusters, higher performance

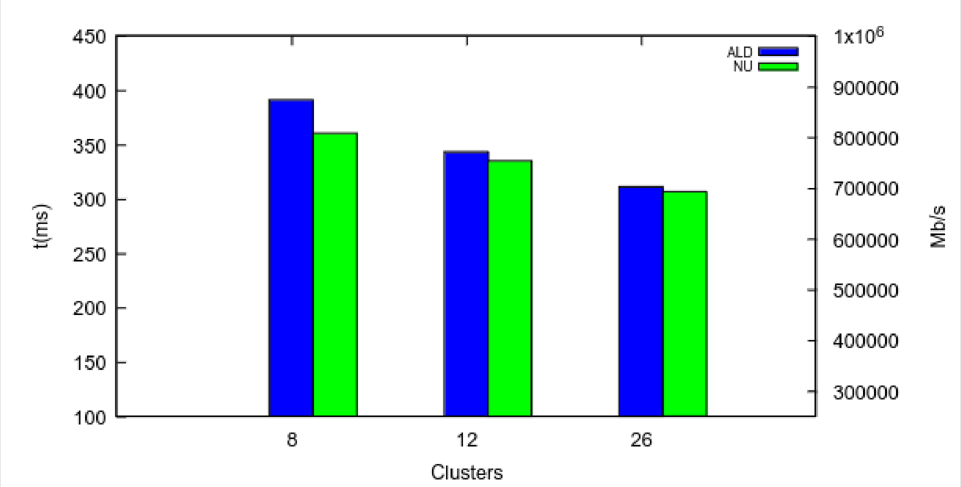


Figure 5 (right): Application loop delay and network usage per number of clusters in fifty-users scenario

- Lower clusters, lower performance

Experimental Results - Base Case OPS - MT

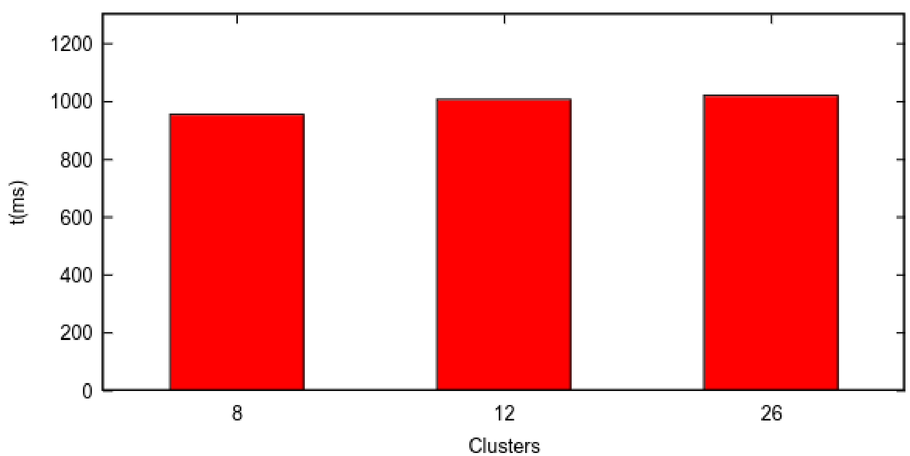
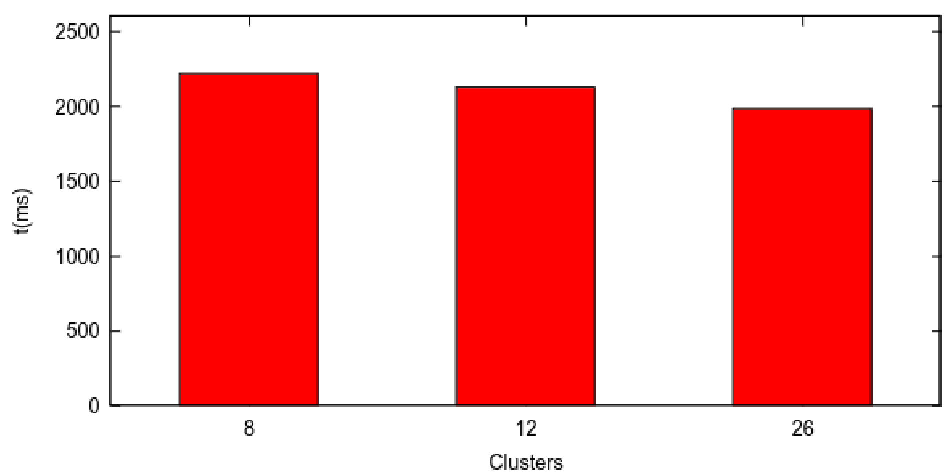


Figure 6 (left): Migration time per number of clusters in eight-users scenario

- Lower clusters, higher performance

Figure 7 (right): Migration time per number of clusters in fifty-users scenario

- Lower clusters, lower performance



Experimental Results - IPS – ALD

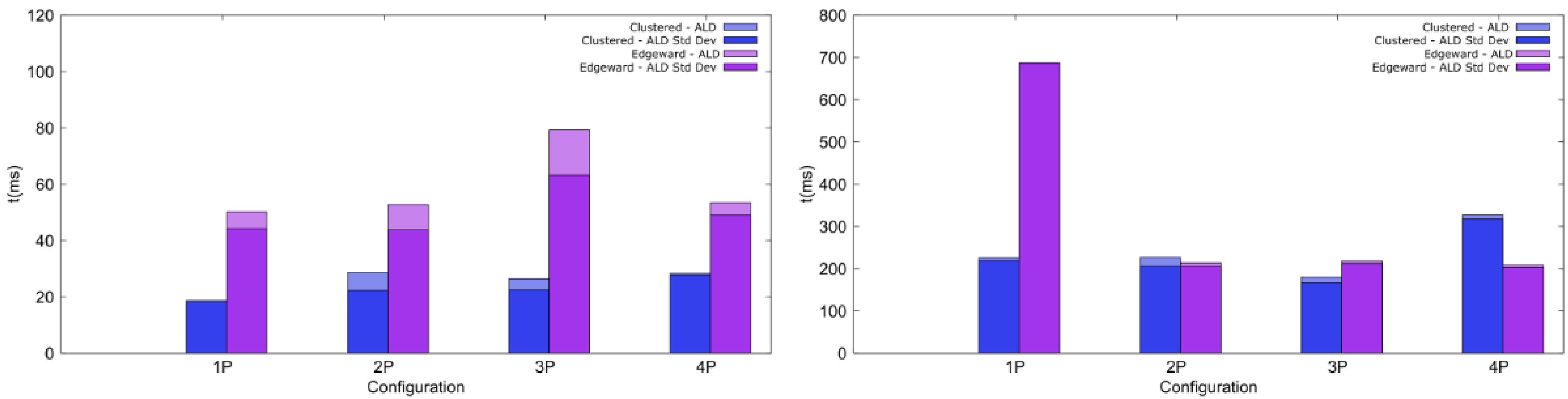
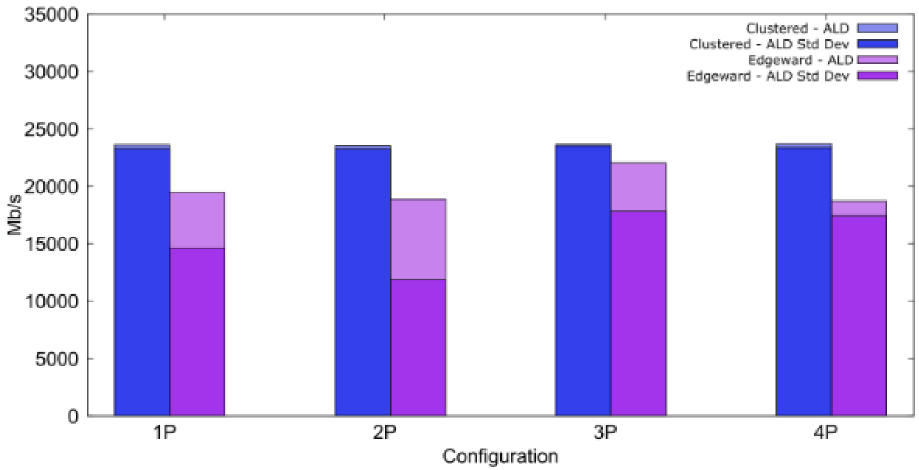


Figure 8: Average ALD per configuration in IPS with 5 and 25 users

Experimental Results - IPS – NU



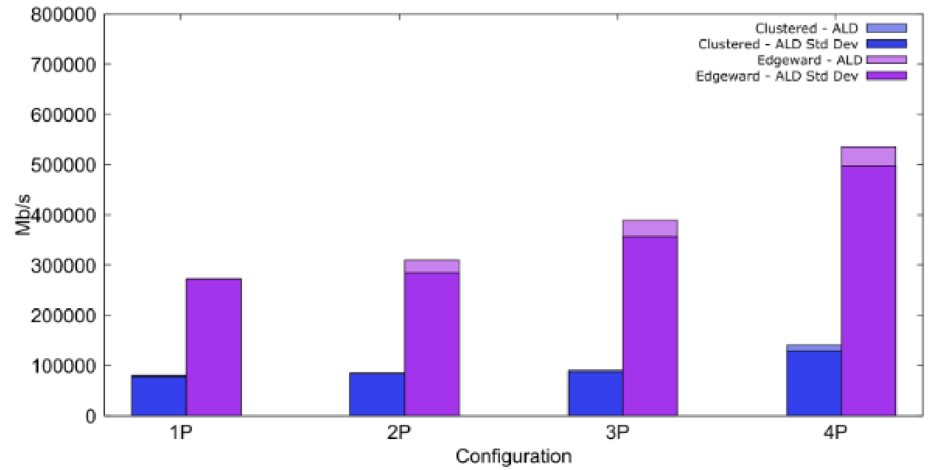


Figure 8: Average NU per configuration in IPS with 5 and 25 users

Conclusion and Future Directions

- Through extensive simulations and analysis, we were able to investigate architectural approaches in location systems.
- Impact of number of clusters and regions: Significant influence on performance.
  - Fewer regions perform better in scenarios with fewer users.
  - Multiple regions lead to shorter execution times in larger user numbers.
- Importance of regionality in architectural design and deployment for location systems.
- Reflections on Lessons Learned:
  - Supremacy of clustered approach offers guidance for future research.
  - Need for cautious generalization due to context-specific nature of findings.
  - Importance of understanding scalability implications and considering deployment scenarios.

Conclusion and Future Directions

- Plans for broader validation across diverse scenarios, larger-scale deployments, and real-world contexts.
- Exploration of different mobility patterns and behaviors (periodic, directional, group-based movements) for enhanced adaptability and efficiency.
- Incorporation of new performance metrics (energy consumption, reliability, fault tolerance) for holistic evaluation.
- Integration of emerging technologies (edge computing, machine learning, blockchain) for further improvements in system performance, security, and resource optimization.

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Thank you

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