Comparing energy-aware vs. cost-aware data replication strategy

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**Models**
- Profit
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Context

Increase of data volume
ex: data traffic forecast for Cloud

source: cisco, 2016
Context

Increase of data volume
ex: data traffic forecast for Cloud

Needs
- Availability
- Performance
- Processing Capacity

source: cisco, 2016
Introduction

Context

Increase of data volume

ex: data traffic forecast for Cloud

 Needs

- Availability
- Performance
  → Data replication
- Processing Capacity
  → Cloud

source: cisco, 2016
Cloud Characteristics

Resources
Seemingly Unlimited
Cloud Characteristics

Resources
Seemingly Unlimited

Elasticity
Resources are automatically adapted
Available → Needed
Cloud Characteristics

Resources
Seemingly Unlimited

Elasticity
Resources are automatically adapted
Available \(\rightarrow\) Needed

Pay-As-You-Go
Users pay what they consumed
Cloud Characteristics

Resources
- Seemingly Unlimited

Elasticity
- Resources are automatically adapted
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Pay-As-You-Go
- Users pay what they consumed

Service Level Agreement
- Contract
- Provider and tenant
Cloud Characteristics

Resources
Seemingly Unlimited

Elasticity
Resources are automatically adapted
Available → Needed

Pay-As-You-Go
Users pay what they consumed

Service Level Agreement
Contract
Provider and tenant

Content
- Price
- Service Level Objective
- Penalties: SLOs not satisfied
Data Replication

Technique

Needs

- Availability
- Performance
- Fault tolerance
Introduction

Data Replication

Technique Needs
- Availability
- Performance
- Fault tolerance

Objectives
Beside answering to needs
- Profit
- Reduce energy consumption
- Reduce carbon footprint
## State of the Art

<table>
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<tr>
<th>Strategies</th>
<th>Availability</th>
<th>Perf.</th>
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<th>Energy</th>
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**Table:** Data replication strategies features for cloud
There are only few strategies that takes into account the provider’s profit and the energy consumption simultaneously.
Provider’s profit model

Proposed model in [Tos et al., 2017]:

Profit

\[ \text{Profit} = \text{Revenues} - \text{Expenditure} \]
Provider’s profit model

Proposed model in [Tos et al., 2017]:

Profit

\[ \text{Profit} = \text{Revenues} - \text{Expenditure} \]

Revenues

\[ \text{Revenues} = \sum_{P=0}^{N_P} \text{Price}_{\text{Location}}(\text{Instance}) \]
Provider’s profit model

Proposed model in [Tos et al., 2017]:

**Profit**

\[ \text{Profit} = \text{Revenues} - \text{Expenditure} \]

**Revenues**

\[ \text{Revenues} = \sum_{P=0}^{N_P} \text{Price}_{Location}(\text{Instance}) \]

**Expenditures**

\[ \text{Expenditures} = \text{C}_{\text{Computation}} + \text{C}_{\text{Network}} + \text{C}_{\text{Storage}} + \text{C}_{\text{Penalties}} + \text{C}_{\text{Others}} \]
Provider’s profit model

Expenditure details

- $C_{\text{Computation}}$: Execution cost of one task
- $C_{\text{Network}}$: Data transfer cost
- $C_{\text{Storage}}$: Data storage cost
- $C_{\text{Penalties}}$: SLO violations penalty cost
- $C_{\text{Others}}$: Any other costs (salary, energy, ...)

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Energy consumption model

In order to compare different strategies → extend PEPR strategy to estimate the energy consumption
Energy consumption model

In order to compare different strategies → extend PEPR strategy to estimate the energy consumption

**Energy consumption**

\[ E_{Tot} = E_{Idle} + E_{Dynamic} \]
In order to compare different strategies → extend PEPR strategy to estimate the energy consumption

Energy consumption

\[ E_{Tot} = E_{Idle} + E_{Dynamic} \]

Idle

\[ E_{Idle} = (P_{CPU_{idle}} + P_{RAM_{idle}} + P_{HDD_{idle}} + P_{NIC_{idle}}) \times T_{tot} \]
Energy consumption model

Task execution

\[ E_{Pro} = E_{CPU_{Act}} + E_{RAM_{read}} \]
Energy consumption model

Task execution

\[ E_{\text{Pro}} = E_{\text{CPU}_{\text{Act}}} + E_{\text{RAM}_{\text{read}}} \]

File reading

\[ E_{\text{FT}} = E_{\text{HDD}_{\text{read}}}^{\text{src}} + E_{\text{RAM}_{\text{wr}}}^{\text{tgt}} + 1_{\text{src} \neq \text{tgt}} \ast (E_{\text{RAM}_{\text{wr}}}^{\text{src}} + E_{\text{RAM}_{\text{read}}}^{\text{src}} + E_{\text{NIC}}^{\text{src}} + E_{\text{Network}} + E_{\text{NIC}}^{\text{tgt}}) \]
Energy consumption model

Task execution

\[ E_{Pro} = E_{CPU_{Act}} + E_{RAM_{read}} \]

File reading

\[ E_{FT} = E_{HDD_{read}^{src}} + E_{RAM_{wr}^{tgt}} + 1_{src\neq tgt} \times (E_{RAM_{wr}^{src}} + E_{RAM_{read}^{src}} + E_{NIC}^{src} + E_{Network} + E_{NIC}^{tgt}) \]

Data replication

\[ E_{Repl} = E_{RAM_{read}^{src}} + E_{HDD_{write}^{tgt}} + 1_{src\neq tgt} \times (E_{NIC}^{src} + E_{Network}^{tgt} + E_{NIC}^{tgt} + E_{RAM_{write}^{tgt}} + E_{RAM_{read}^{tgt}}) \]
Setup

Simulator
Cloudsim → Extended: Data replication and profit [Thèse Tos]
   → Extended: Energy consumption
Setup

Simulator
Cloudsim → Extended : Data replication and profit [Thèse Tos]
→ Extended : Energy consumption

Architecture parameters
[Tos et al., 2017]

Power parameters
CloudMip platform from IRIT

Economic parameters
Google cloud pricing - 04/08/2019

Experiments available
Github : https://github.com/MorganSeguela/IGSC_2019_XPS
PEPR - [Tos et al., 2017]

**Objectives**

1. Performance constraints
2. Taking profit into account

**Architecture**

Peer to Peer
Objectives
1. Performance constraints
2. Taking profit into account

Replication
Trigger:
Response time > Threshold
Decision:
Profit > 0
Objectives

1. Performance constraints
2. Taking profit into account

Replication

Trigger:
Response time > Threshold

Decision:
Profit > 0

Replica management
Remove replicas with the latest access
Objectives

- Minimizing energy consumption
- Minimizing bandwidth usage

Architecture

Three Tier Fat Tree
Objectives

- Minimizing energy consumption
- Minimizing bandwidth usage

Replication

Trigger:
Requests number > Threshold

Decision:
Energy and Bandwidth consumption lower in the level below
MORM - [Long et al., 2014]

Multi-objectives Optimization Replication management

- Reduce file unavailability
- Reduce service time
- Reduce latency
- Reduce load variance
- Reduce energy consumption

Static strategy

- Replication done before the execution
- Do not adapt to the ongoing execution

Architecture
Peer to Peer

Energy vs. Profit

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No Replication

Peer to Peer Architecture (P2PNorep)
Uniformly randomized distribution of data between nodes

Three Tier Fat Tree Architecture (HNorep)
Data stored in the Central DB
Results

Replications during the experiment

Violations during the experiment

Strat
- Boru et al.
- HNoRep
- MORM
- PEPR
- P2PNoRep
Results

Energy consumed

- Boru et al.: Overhead made by replication
- PEPR: Significantly lower from the lack of replication
- MORM: Replication already done before the experience and made a lot of replicas that reduce the transfer energy consumption
Results

Energy consumed

Analyses

- Boru et al. : Overhead made by replication
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Evaluation

Results

Total expenditure

- Boru et al.: Replicates in regions first → Reduction of transfer cost
- PEPR: Replicates closer to the processing node and removal mechanism → More transfer between regions
- MORM: Lot of replicas → Less transfers but high storage usage

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Energy vs. Profit
**Evaluation**

**Results**

**Total expenditure**

![Graph showing total expenditure across different strategies](image)

**Explanation**

- Boru et al.: Replicates in regions first
  - Reduction of transfer cost
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  - More transfer between regions
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  - Less transfers but high storage usage

- \[\text{Total Expenditure} (\text{\$})\]
Results

Total expenditure

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Explanation
Results

Total expenditure

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Conclusion and future works

Conclusion
BORU : Low Expenditure but High Energy consumption
MORM : High Expenditure but Low Energy consumption
PEPR : Bit High Expenditure and bit Low Energy consumption

Guidelines :
• Replication during the execution
• Replica management mechanism
Conclusion and future works

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Guidelines:
• Replication during the execution
• Replica management mechanism

Future works
Proposing a data replication strategy that takes into account provider’s profit and energy consumption
Thank you for your attention!
Any questions?


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