A Computation- and Network-Aware Energy Optimization model for Virtual Machine Allocation

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Motivation

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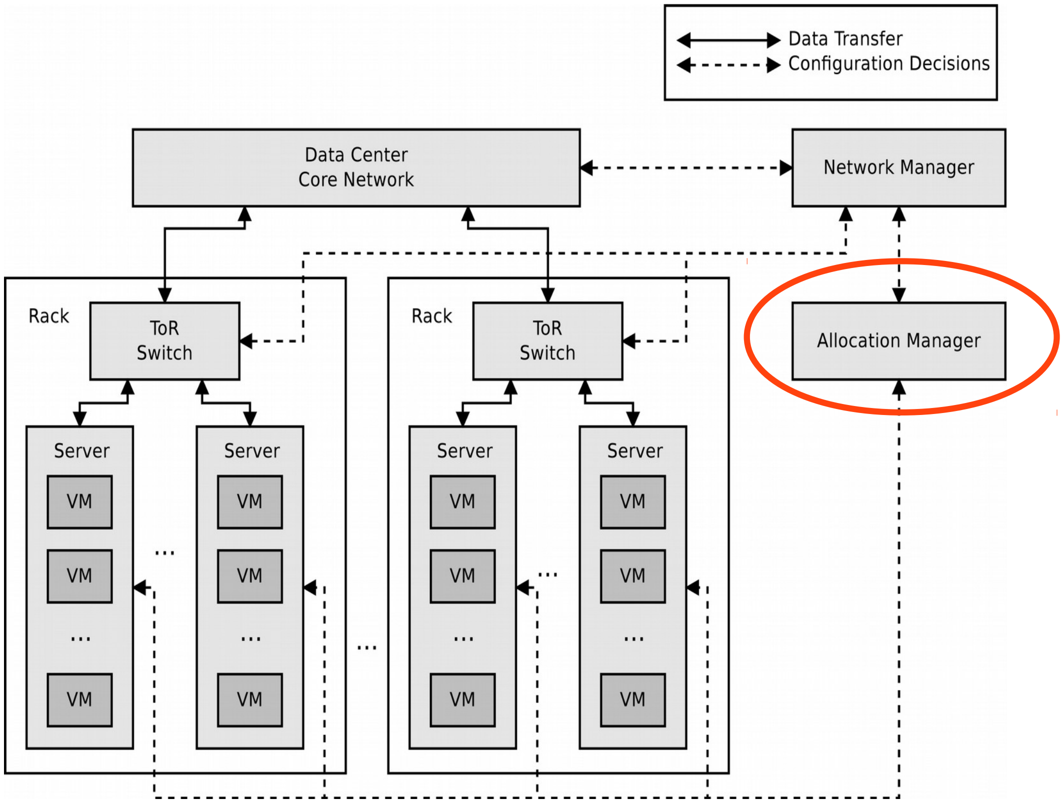
- Energy consumption in Cloud
  - Typical problem of server consolidation, *but...*
  - Network-related energy is often neglected
  - VMs migration: additional energy consumption
- Challenges of future Cloud systems
  - Network softwarization: SDN → SDDC
  - Dynamic VMs behavior → VMs migrations

Reference Scenario



- Complex network topology
- Interaction between network and allocation mgr.

Model

- Multi-dimensional bin packing problem
- Use of dynamic programming:
  - Time divided in *time slots*
  - Start from placement at previous time slot
  - Define migrations of VMs
  - Turn ON/OFF servers
- Goals
  - Minimize energy consumption
  - No parameters to tune

Objective function

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- E_{obj}: 3 components (in most complete form)

$$\min \sum_{i \in \mathcal{M}} \mathcal{E}_{C_i}(t) + \mathcal{E}_D(t) + \sum_{j \in \mathcal{N}} \mathcal{E}_{M_j}(t)$$

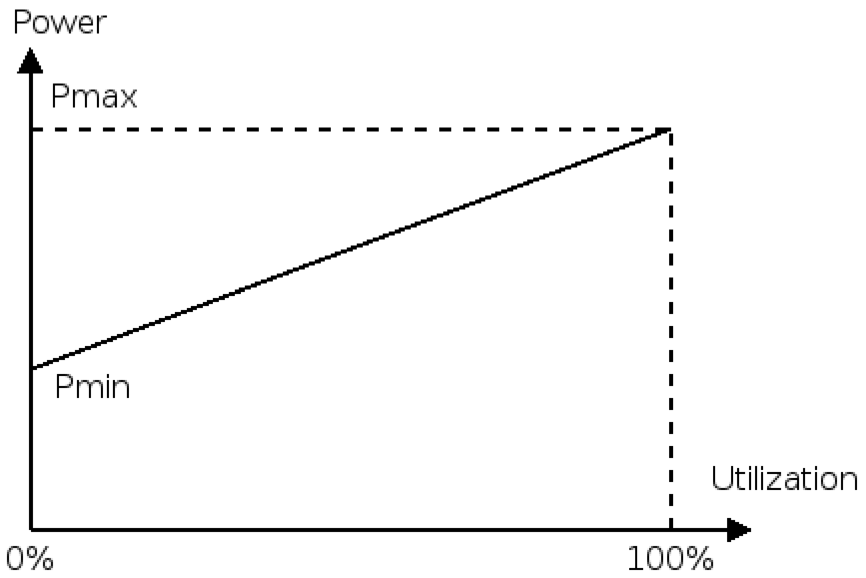
- Energy for computation E_C
- Energy for data transfer E_D
- Energy for VMs migrations E_M

Objective function

- Energy for computation E_C

$$\mathcal{E}_{C_i}(t) = O_i(t)\mathcal{T}P_i^m\left(K_{C_i} + (1 - K_{C_i})\frac{\sum_{j\in\mathcal{N}} x_{i,j}(t)c_j(t)}{c_i^m}\right)$$

- Minimum energy consumption for servers turned ON
- Linear dependence from the CPU utilization of servers



Objective function

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- Energy for data transfer E_D

$$\mathcal{E}_D(t) = \sum_{i \in \mathcal{M}} O_i(t) \mathcal{T} P_i^d + \sum_{j_1 \in \mathcal{N}} \sum_{j_2 \in \mathcal{N}} \sum_{i_1 \in \mathcal{M}} \sum_{i_2 \in \mathcal{M}} x_{i_1,j_1}(t) x_{i_2,j_2}(t) d_{j_1,j_2}(t) \mathcal{T} \mathcal{E}_{d_{i_1,i_2}}$$

- Minimum energy for network interfaces in servers turned ON
- Linear dependence on data exchanged among servers
- Captures network topology through parameter $E_{di1,di2}$

Objective function

- Energy for VMs migrations E_M

$$\mathcal{E}_{M_j}(t) = \sum_{i_1 \in \mathcal{M}} \sum_{i_2 \in \mathcal{M}} g^-_{i_1,j}(t) g^+_{i_2,j}(t) \Big(m_j(t)\mathcal{E}_{d_{i_1,i_2}} + (1-K_{C_{i_1}})P^m_{i_1} K_{M_{i_1}} \mathcal{T} + (1-K_{C_{i_2}})P^m_{i_2} K_{M_{i_2}} \mathcal{T} \Big)$$

- Computational overhead for servers
- Data transfer of VM memory

Constraints

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- Resource requests by VMs on a server must not exceed server capacity:
  - CPU $$\sum_{j \in \mathcal{N}} x_{i,j}(t) c_j(t) \leq c_i^m O_i(t) \quad \forall i \in \mathcal{M}$$
  - Memory $$\sum_{j \in \mathcal{N}} x_{i,j}(t) m_j(t) \leq m_i^m O_i(t), \quad \forall i \in \mathcal{M}$$
  - Network: no data exchange within the server

$$\sum_{j_1 \in \mathcal{N}} \sum_{j_2 \in \mathcal{N}} \left(x_{i,j_1}(t) + x_{i,j_2}(t) - 2x_{i,j_1}(t) x_{i,j_2}(t) \right) d_{j_1,j_2}(t) \leq d_i^m O_i(t), \quad \forall i \in \mathcal{M}$$

- VMs allocation only on servers turned ON

Constraints

- Each VM is placed one and only one server

$$\sum_{i\in\mathcal{M}} x_{i,j}(t) = 1, \quad \forall j \in \mathcal{N}$$

- Consistency of VMs migrations

$$\sum_{i\in\mathcal{M}} g^{+}_{i,j}(t) = \sum_{i\in\mathcal{M}} g^{-}_{i,j}(t) \leq 1, \quad \forall j \in \mathcal{N}$$

$$g^{-}_{i,j}(t) \leq x_{i,j}(t-1), \quad \forall j \in \mathcal{N}, i \in \mathcal{M},$$

$$g^{+}_{i,j}(t) \leq x_{i,j}(t), \quad \forall j \in \mathcal{N}, i \in \mathcal{M}$$

$$x_{i,j}(t) = x_{i,j}(t-1) - g^{-}_{i,j}(t) + g^{+}_{i,j}(t), \quad \forall j \in \mathcal{N}, i \in \mathcal{M}$$

- Boolean nature of the problem

$$x_{i,j}(t), g^{+}_{i,j}(t), g^{-}_{i,j}(t), O_i(t) = \{0,1\}, \quad \forall j \in \mathcal{N}, i \in \mathcal{M}$$

Considered Alternatives

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- Our proposal
  - Migration Aware (MA)
    $E_{obj}=E_C+E_D+E_M$

- Existing solutions:
  - No Migration Aware (NMA)
    $E_{obj}=E_C+E_D$
  - No Network Aware (NNA)
    $E_{obj}=E_C$

Simulation Setup

- Resource requests from real VMs
  - Default: 80 VMs
- Power consumption from datasheets
- Two network behavior scenarios:
  - Network 1: Random interaction
  - Network 2: Pareto law interaction
    (20% of destination IPs receive 80% of traffic)
- AMPL problem formulation
  - CPLEX 12 solver

Comparison

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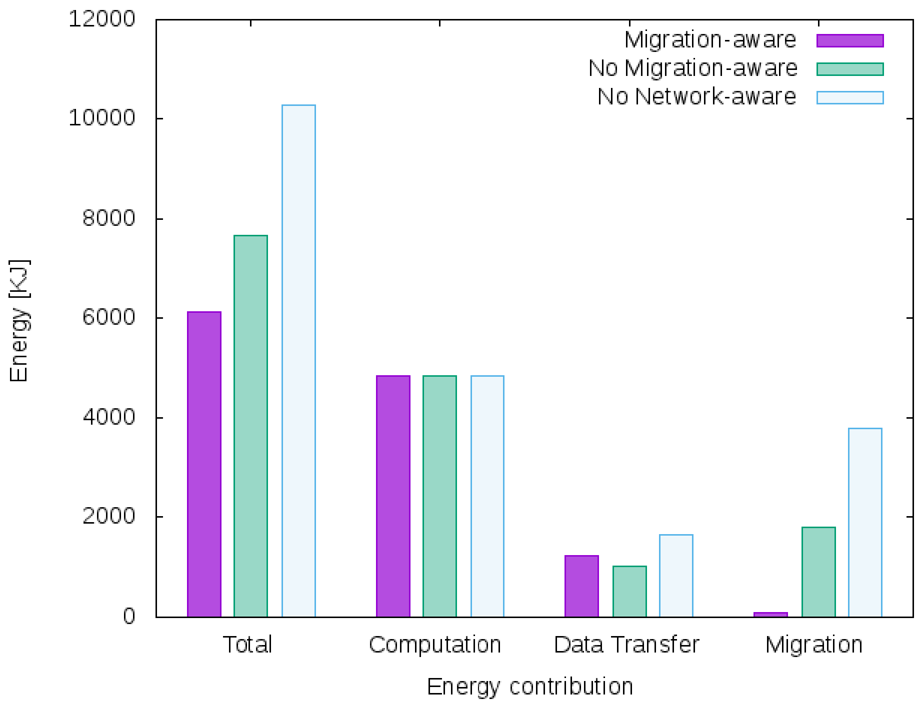
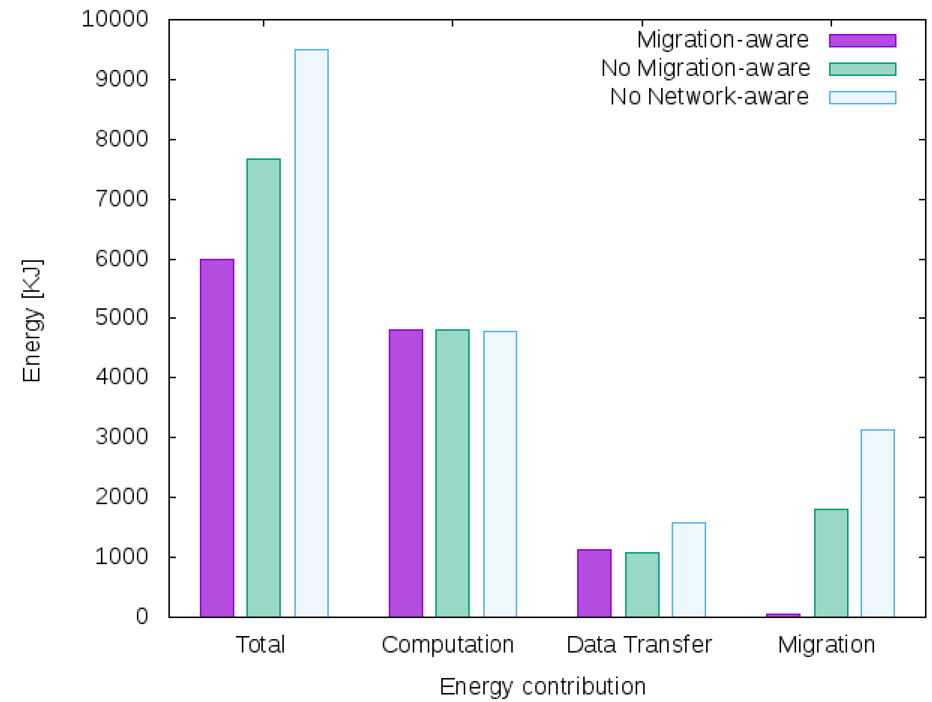
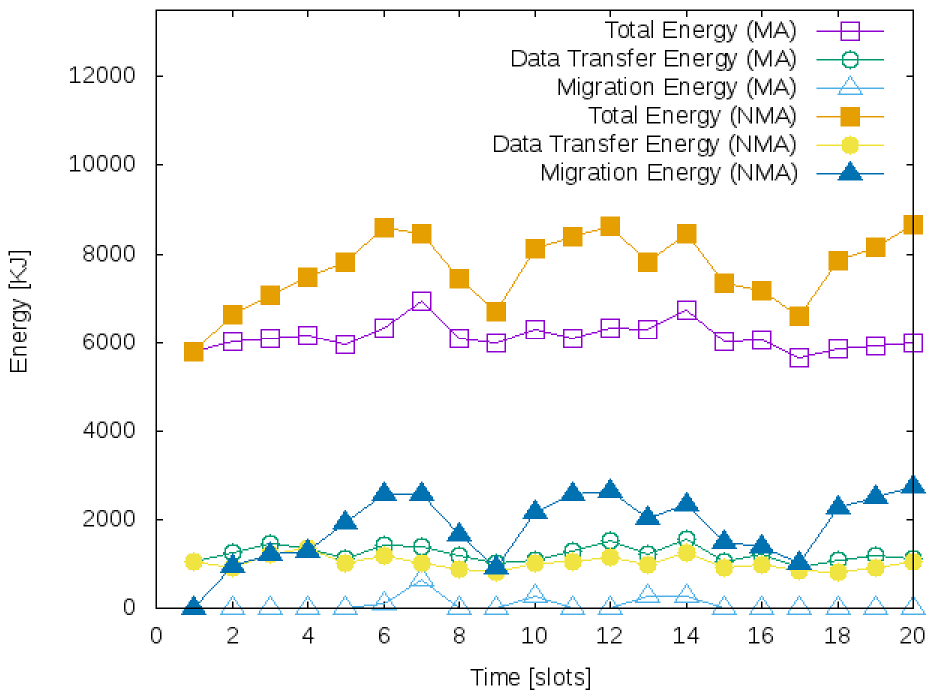


Network 1

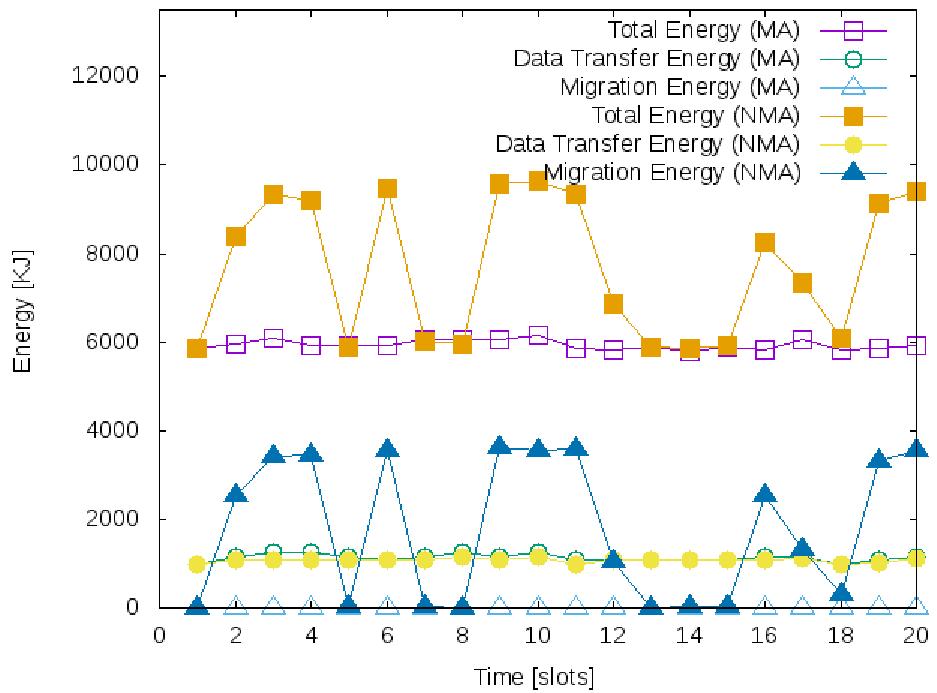


Network 2

Impact of Migration



Network 1



Network 2

Results stability

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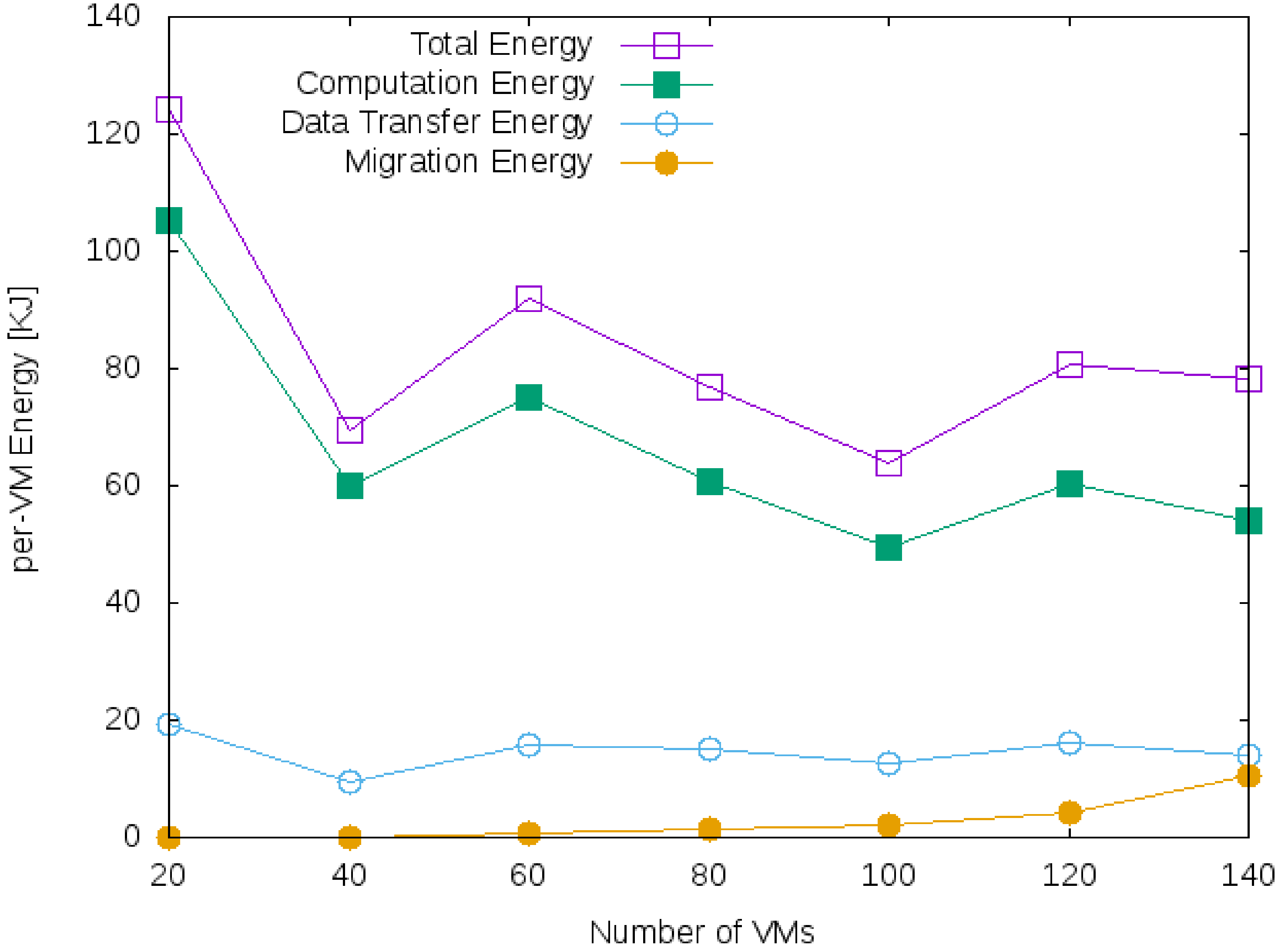

Conclusions

- Challenges of VMs placement in cloud
  - Network becomes more important (SDDC)
  - More dynamic VMs behavior (migrations)
- Limitation of existing models
- → Migration-Aware model for VMs placement
  - No parameter tuning required
- Future work:
  - More focus on SDDC, model improvement
  - Heuristics for scalability

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