Energy-Aware Service Execution

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Outline

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• Related Work
• Proposed Architecture
• Quantifying the energy cost of service execution
• Probabilistic Models
• The Cost of Service Execution
• Open issues
• Conclusion
Energy Proportionality

Measurement on June 20, 2008

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Motivation

Energy

Resource

Performance
Related Work

• Qualitative description of the energy consumption of hardware devices
  – CPU, memory, high speed data busses, hard disk, communication

• Dynamic power management algorithms
  – Service consolidation, selective switching, dynamic voltage and frequency scaling
Related Work

• Our focus is mainly on *when* instead of *how* to undertake dynamic power management.

• We undertake adaptation based on *fine grained estimation* of the energy (power) consumption of individual service requests.
  – In other words services are being adapted instead of virtual machines
Related Work

\[ E_j^{\text{saved}} = P_i \left( t_j + t_{i,j} + t_{j,i} \right) - \left[ P_{i,j} \times t_{i,j} + P_{j,i} \times t_{j,i} + P_j \times t_j \right] \]

\[ t_{th,j} \geq \max \left( 0, \frac{(P_i - P_{i,j}) t_{j,i}}{(P_j - P_i)} \right) \]
Transition Cost (Power)

Transition Power: Motherboard: 12V

Transition Power: CPU

CDF
Power in Watt

CDF
Power in Watt
Measurement Setting
Measurement Setting
Measurement Setting
Execution Cost (Power)

CDF

Power in Watt

Write

Transaction

Read
Execution Dependency

• Understanding the way contemporary applications are built offers a new insight into application based energy management

• Consider what a simple request to a YouTube application involves:
  – Search operation
  – Request related filter
  – Context related filter
  – Video streaming
  – Images and their descriptions
  – Ranked comments
Execution Dependency
Execution Model

Diagram:

- **S1** to **S2** with edge label $b_1(k)$
- **S1** to **S3** with edge label $c_{13}(d)$, $s_{13}$
- **S2** to **S4**
- **S3** to **S6**
- **S4** to **S7**
- **S5** to **S6**
- **S6** to **S8**
- **S7** to **S9**
- **S8** to **S9**

Nodes: S1, S2, S3, S4, S5, S6, S7, S8, S9

Labels: $b_1(k)$, $c_{13}(d)$, $s_{13}$
Execution Cost

\[ b_j(k) = P\left( \text{computation cost } \leq k | s_j, r \right) \]

The probability that the computation level of service \( s_j \) is \( k \), given a request class, \( r \)

\[ A = \{ s_{ij} \} = P[s_{ij} | r, \lambda] = \begin{bmatrix} S_{11} & S_{12} & \cdots & S_{1n} \\ S_{21} & S_{22} & \cdots & S_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ S_{n1} & S_{n2} & \cdots & S_{nn} \end{bmatrix} \]

The probability that a communication between service \( i \) and \( j \) exists, given a request class, \( r \), and the model \( \lambda \)

\[ c_{ij}(d) = P\left( \text{data size } \leq d | s_{ij}, r \right) \]

The probability that \( d \) amount of data is exchanged between service \( s_i \) and \( s_j \) given that a communication exists between service \( i \) and \( j \).
Execution Cost (Energy)

\[
PE_j(r) = \sum_{k=1}^{K} b_j(k) E_j(k)
\]

\[
CE_{ij}(r) = s_{ij} \sum_{d=1}^{D} c_{ij}(d) E_{ij}(d)
\]

\[
PE(r) = \sum_{j=1}^{n} PE_j(r)
\]

\[
CE(r) = \sum_{i=1}^{n} \sum_{j=1}^{n} CE_{ij}(r)
\]

The expected
processing cost

The expected
communication cost
Execution Cost (Energy)

The expected processing cost

\[ PE_j(r) = \sum_{k=1}^{K} b_j(k) E_j(k) \]

\[ PE(r) = \sum_{j=1}^{n} PE_j(r) \]

The expected communication cost

\[ CE_{ij}(r) = s_{ij} \sum_{d=1}^{D} E_{ij}(d) E_{ij}(d) \]

\[ CE(r) = \sum_{i=1}^{n} \sum_{j=1}^{n} CE_{ij}(r) \]
Execution Cost (Delay)
Execution Cost (Delay)

Graph showing the execution cost (delay) for different algorithms as a function of the number of services for each subtask.

- Genetic Algorithm
- Simulated Annealing
- Taboo Search

The y-axis represents the rebinding time in milliseconds, while the x-axis shows the number of services for each subtask.
Execution Cost (Delay)

Histogram showing the mean square error for different algorithms: Genetic Algorithm, simulated Annealing, and Taboo Search, as the number of services for each subtask increases.
• The energy consumption of servers or their subsystems (CPU, disk, network, etc.) is never deterministic.

• Probabilistic adaptation strategies enable greater flexibility of trade-off between performance and energy consumption.

• We believe that understanding the dependency between distributed services can be useful to design DPM strategies.

• The cost of adaptation is not properly studied so far and needs further investigation.
Thanks for Listening