CoolEmAll

Optimizing cooling and energy efficiency in Data Centers

A holistic approach

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Outline

• Introduction
• CoolEmAll project
• DEBBs
  (Data centre Efficiency Building Blocks)
• SVD Toolkit
  (Simulation, Visualization and Decision support toolkit)
• Optimizing cooling efficiency
• Summary
Introduction

- Situation today:
  - ICT sector is responsible for around 2% of the global energy consumption, data centres taking large fraction of it
- Energy consumption in a data centre:
  - Result of executing workload (user jobs) on (HPC/Cloud) resources
  - Energy consumptions depends on:
    - workload (jobs) and application type (nature of jobs)
    - Efficiency of HW / resource
    - Resource management strategy
    - Cooling efficiency (depends on environmental conditions, heat load and arrangement of racks)
  - In many data centres, 50% of the energy is consumed by cooling (resulting in bad energy efficiency)
  ➔ potential for improvement, addressed in CoolEmAll project
What is all about?

COOLEMALL PROJECT
CoolEmAll Project

- FP7 ICT Call 7
- Budget: 3614210€ (funded: 2645000€)
- Duration: 30 months
- Start date: 1st Oct 2011
- Web-site: www.coolemall.eu

- Consortium

CoolEmAll consortium

[Image of consortium members]
CoolEmAll EU Project: [www.coolemall.eu](http://www.coolemall.eu)

**Goal:**
evaluate and improve cooling- and energy-efficiency of modular data centers by optimization of their design and operation for a wide range of workloads, IT equipment and cooling options.

**Main results:**
- Optimized ComputeBox Blueprints and Data Centre Efficiency Building Blocks (DEBBs) reflecting HW and facility-configuration/models used by SVD Toolkit
- Simulation, visualization and decision support toolkit *(SVD Toolkit)*, enabling optimisation of modular data centre building blocks for a wide range of options
CoolEmAll Approach

Data Center efficiency Building Blocks (DEBB) – models of IT equipment on various scale level

- **Scale**
  - Server
  - Rack(s)
  - DC/Container(s)

- **Density**
  - High density (up to hundreds nodes in a rack)
  - Low density

- **Cooling**
  - Integrated
  - No integrated cooling

- **Arrangement**
  - Position
CoolEmAll Approach

Application types
- HPC
- Virtual machines

Application characteristics
- CPU-bound
- Mem-bound
- IO-bound
- Scale

Workload mngmt policies
- Workload consolidation
- Energy-aware policies
- Thermal-aware policies
Models of Cooling devices
- CRAC, Chillers, fans, heat-exchanger..

Operation params
- Higher server room temperature
- Free air cooling
- Liquid cooling

CoolEmAll Approach

- Modular Approach
  - Compute Box Blueprint 1
  - Compute Box Blueprint 2

- Energy- and thermal-aware management
  - Application Characteristics
  - Workload Mgmt Policies

- Cooling Approaches
  - Efficiency of Cooling Methods

Simulation, visualisation and decision support toolkit

Next gen efficient data centres
- Efficient airflow
- Thermal distribution
- Optimal arrangement
CoolEmAll Approach

Visualisation
- Air/heat flow distribution map

Evaluation Metrics
- Cooling / Airflow related metrics
- Energy/Power related metrics (PUE)
- Productivity metrics

Interaction
- Rearrangement
- Env. Conditions
  - ...
DATA CENTRE EFFICIENCY BUILDING BLOCKS (DEBB)
What is a DEBB?

- **Data Center Efficiency Building Block**
- The DEBB is an abstraction for computing and storage hardware and describes energy efficiency of data-center building blocks on different granularity levels.

**Purpose**: To find the most energy efficient configuration while planning a data center
- Used for thermodynamic modeling (SVD Toolkit)
- Used for configuration and reconfiguration

**Availability**
- To be publicly available
- Defined according to open specification
DEBB Specification

Hierarchy
- Hierarchy of building blocks
- PLMXML

Component Description
- CIM naming conventions

Power Profile
- Power-Usage
- Under various loads

Energy efficiency metrics
- Productivity
- Power/energy
- Under various load

Geometry for visualization
- Advanced
- VRML

Air-flow profile
- Airflow
- Inlets/Outlets
- Under various load

Thermodynamic
- Geometry for CFD shapes

Geometry for CFD
- Simple, STL
Granularity-levels

- **Node unit**
  - single blade CPU unit
  - (for instance a RECS CPU module)

- **Node group**
  - assembled unit of node units
  - (for instance a complete RECS18)

- **ComputeBox1**
  - reflects a typical rack

- **ComputeBox2**
  - Reflects a container or a Data Centre filled with racks and additional infrastructure
Simulation Visualization and Decision support Toolkit

SVD TOOLKIT
SVD Toolkit

- SVD-Toolkit allows analysis and optimisation of modular IT infrastructure built of DEBBs (level n), taking into account (input parameters):
  - HW-Models (represented by DEBBs on level n)
  - Workloads and Application Models
  - Workload- & Resource Management Policies
  - Cooling methods and environmental conditions
- To be achieved by combining:
  - Coupled simulations of various workloads and applications,
  - CFD simulation to analyze airflow and heat transfer in a data centres
  - Visualization of results
  - Assessment of Results
**Holistic approach**

Integrated analysis of workloads, IT equipment, and heat transfer

**Coupled Simulation**

1. Workload- and HW behavior
2. Simulation of cooling and heat processes (air + liquid)

**Energy-Efficiency Metrics**

- Metrics to assess simulation results

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**Workload and Resource Simulation**

**CFD Simulation**

**Metrics Calculation**

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SVD Toolkit Architecture

1st Prototype

**Repository**
- DEBBs
- Application profiles
- Workload profiles

**Application (with Parameters)**

**Data Center Workload & Resource Management Simulator**

**Database**
- Real Monitoring Data
- Simulation Data

**Metric Calculator**
- Efficiency metrics

**CoolEmAll Web-GUI**
- MOP GUI...

**CFD Simulator**
- CFD Solver
- (OpenFOAM)
SVD Toolkit Architecture

2nd Prototype

COVISE
- Simulation workflow
- integrated post processing
- Remote steering
- Interaction

Data Center Workload and Resource Management Simulator

DEBB

(MOP) Database

Application Profiler

Application (with Parameters)

CoolEmAll Web-GUI
- COVISE GUI
- MOP GUI ...
- DEBB configurator
- Workload Sim GUI

SVD - Toolkit

Metrics Calculator

CoolEmAll Web-GUI

Simulation Interaction & Visualisation (COVISE)

DC-WORMS GUI

MOP GUI

DC-WORMS GUI

MOP GUI

DC-WORMS GUI

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2nd Prototype

- CFD Simulation using COVISE and OpenFOAM
- Rack rearrangement in Compute-Room
- Interactive simulation
- Remote steering
SVD Toolkit 2\textsuperscript{nd} Prototype

- CoolEmAll WEB-GUI – advanced Visualisation Tool
  - Web based GUIs to all components
  - DEBB configurator
  - Selection of Application Profiles, Workloads
  - Workload Selection and Simulation
  - Interactive steering and visualisation
  - ...
  \rightarrow Easy usage of SVD Toolkit

DEBB Configurator

Interactive rack (re)arrangement

Energy usage

Scheduling

COVISE Visualisation

MOP-GUI Visualisation
Validation of models

Simulations based on real measurements and re-usable building blocks

Real monitoring data from execution of experiments on test bed

Comparison of real measurements with simulation models
• Virtual thermal camera
• Heat transfer and air flow processes
• Remote, interactive visualization
• Efficiency metrics
What can it be used for?

OPTIMIZING COOLING EFFICIENCY
Main Use-Cases

• UC1 - Optimization of rack arrangement in a server room using open data centre building blocks
  • Goal: To find an optimal arrangement of racks and aisles containment to prevent hot and cold air mixing and minimize risk of hot spots

• UC2 - Capacity management
  • Goal: To select the optimal configuration of hardware and given application types factoring in performance and energy-efficiency constraints

• UC3 - Analysis of free cooling efficiency
  • Goal: To find a maximum inlet temperature in which data centre can operate safely for given workloads
**Goal:** To find an optimal arrangement of racks and aisles containment

**UC1: Optimisation of rack arrangement**
Optimisation of rack arrangement

Video – interactive rearrangement racks in server-room
• Analysis and Visualization of heat flow distribution
• Identification of hotspots
• (see www.coolermall.eu)
Goal: To select optimal configuration for given workload
Simulating airflow in Servers
Simulating airflow in Servers

Temperature distribution

Airflow distribution
What’s next?

SUMMARY
CoolEmAll delivers two main products:

- Open source SVD toolkit to investigate and assess cooling- and energy-efficiency in data centres based on simulations
- Best practises and open designs ComputeBox blueprints and DEBBs

These outcomes allow assessment and minimising the energy consumption of data centres by:

- Optimisation of their design and operation
- Tuning to specific workloads and conditions

Results available on [www.coolenall.eu](http://www.coolenall.eu):

- Monitoring and control platform, application profiler
- SVD Toolkit - 1st Prototype
- Open DEBB specification

Work in progress on 2nd Prototype of SVD Toolkit
Questions?

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