GreenClouds

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Towards Hybrid Networking!

- Costs of photonic equipment 10% of switching 10% of full routing
  - for same throughput!
  - Photonic vs Optical (optical used for SONET, etc, 10-50 k$/port)
  - DWDM lasers for long reach expensive, 10-50 k$

- Bottom line: look for a hybrid architecture which serves all classes in a cost effective way
  - map A -> L3, B -> L2, C -> L1 and L2

- Give each packet in the network the service it needs, but no more!

- Lower == greener

\[
\begin{align*}
L1 & \approx 2-3 \text{ k$/port} \\
L2 & \approx 5-8 \text{ k$/port} \\
L3 & \approx 75+ \text{ k$/port}
\end{align*}
\]
How low can you go?

Application Endpoint A

Router
Ethernet
SONET
DWDM
Fiber

Local Ethernet
POS
MEMS
Regional dark fiber

15454 6500 HDXc

Trans-Oceanic

Application Endpoint B

Router
Ethernet
SONET
DWDM
Fiber

Local Ethernet
POS
MEMS
Regional dark fiber

15454 6500 HDXc

Trans-Oceanic

Application Endpoint B

Router
Ethernet
SONET
DWDM
Fiber

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Application Endpoint B
Hybrid computing

Routers ↔ Supercomputers

Ethernet switches ↔ Grid & Cloud

Photonic transport ↔ GPU’s

What matters:

Energy consumption/multiplication

Energy consumption/bit transported
DAS-3 Cluster Architecture

2006!!!

10 Gb/s Ethernet lanphy

To local University

1 Gb/s Ethernet

Local interconnect

85 (40+45) compute nodes

Fast interconnect

To SURFnet

8 * 10 Gb/s from bridgenodes

UvA-node

Nortel

Myrinet

Head node (2)
Power is a big issue

- UvA cluster uses (max) 30 kWh
- 1 kWh ~ 0.1 €
- per year -> 26 k€/y
- add cooling 50% -> 39 k€/y
- Emergency power system -> 60 k€/y
- per rack 10 kWh is now normal

**YOU BURN HALF THE CLUSTER OVER ITS LIFETIME!**
VM opportunity

- Head node
- Memory rich VM holder
- CPU nodes
- Switchable power strip
- Network
VM opportunity - B

- Head node
- switchable power strip
- CPU nodes
- network
Dutch Science Foundation (NWO)

Smart Energy Systems call

- Spring 2010
- Awards in september 2010
- Start in 2011
- UvA & VU teamed up to submit GreenClouds
- http://www.nwo.nl/SES
Four focus areas

1. Smart ICT methods for energy saving, storage and generation in building environments
2. Smart control systems for flexible electricity networks (smart grids)
3. Energy reduction in processing and storing of information
4. Energy reduction in communication
Focus area 1: Energy management in buildings

• Ultimate goal is to create
  – a zero energy building (ZEB) (no energy import or export)
  – or energy neutral buildings (ENB) (net energy import and export over a year is zero)

... without reduction in Quality of Living (QoL) and with acceptable costs

• Why interesting
  – 40 % of all energy is consumed in houses

• Consensus
  – ZEB and ENB with equal QoL is only possible with ICT technology
Added green power sources
Plug-in (hybrid) electric cars
Real-time and green pricing signals
Smart thermostats, appliances and in-home control devices
Customer interaction with utility
High-speed, networked connections

Smart House
ICT challenges

- Reduce stand-by power (10% of all power)
- Prediction of energy profile
- When to store electricity locally, when to export when to import
- Sensor networks to sense / predict / control energy consumption and production
- Efficient in-building communication infrastructures to control white-good & brown-good appliances & lighting and micro-generators
- Create energy-awareness of house owners
- Trade-off between energy-efficiency and Quality of Living
- …. 
Focus area 2: Flexible electricity networks

• Goal
  – Create ICT technology for smart grids
Today's electricity grids and efficiency

Transmission & distribution

production

-7%

consumption

CHP

35-60%

90%
The future: smart grids
Some ICT challenges ahead

• Using ICT for efficiency implies efficient ICT
• Dependability of ICT
  – Smart grids are the life lines of our society
  – Should continue even when some parts fail
• Load balancing in the home / neighborhood
• Compensate for dynamics of generation (e.g. windmills)
• Scalability
  – Grid with thousands / millions of generators/consumers
  – Real-time control of thousands / millions of appliances
• Online optimization problems
  – Do I store energy locally or give it back to the grid?
  – Do I get energy from the battery or from the grid?
Focus area 3: Energy reduction in processing

• Goal
  – Reduce energy consumption of ICT
Microprocessor Trends

- Single Thread performance power limited
- Multi-core throughput performance extended
- Heterogeneous extends performance and efficiency

Slide from Peter Hofstee IBM
Future is in heterogeneous MPSoC Platforms

~ 2 mm²

- Heterogeneous
- Simple tiles
- NoC
- Distributed Memory
ICT challenges

• Efficient processing platforms
• Efficient memory hierarchy
• Efficient software / compilers
• How to program multi-core systems
• Make applications, compilers and operating systems energy aware
• System can adapt (at run-time) to the environment
• Promote energy awareness of PC users
Focus area 4
Energy reduction in communication

• Goal
  – Energy reduction in communication by using
    • Optical communication techniques
    • Wireless communication techniques
    • Intelligent networking techniques
ICT challenges

• Optical fiber access networks
  – optical access by GPON consumes about 18x less energy per user than VDSL2
  – all-optical packet switching by avoiding power-hungry EO conversions

• Optimum combination of radio technologies with optical fiber technologies

• Low power cognitive radio transceivers

• Wideband transceivers and wake-up radios for small and adaptive cell sizes

• Low-power transceivers with strong spatial selectivity, MIMO and adaptive beamforming
Partners in GreenClouds

• Free University of Amsterdam
  – Henri Bal
• (really free) University of Amsterdam
  – Paola Grosso, Cees de Laat
• SARA
  – Axel Berg
• In context of:
  – ASCI
  – DAS4
GreenClouds @ VU & UvA

• The GreenClouds project studies how to reduce the energy footprint of modern High Performance Computing systems (like Clouds) that are distributed, elastically scalable, and contain a variety of hardware (accelerators and hybrid networks). The project takes a system-level approach and studies the problem of how to map high-performance applications onto such distributed systems, taking both performance and energy consumption into account.

• We will explore three ideas to reduce energy:
  1. Exploit the diversity of computing architectures (e.g. GPUs, multicores) to run computations on those architectures that perform them in the most energy-efficient way;
  2. Dynamically adapt the number of resources to the application needs accounting for computational and energy efficiency;
  3. Use optical and photonic networks to transport data and computations in a more energy-efficient way.
GreenClouds @ VU & UvA

• The project will create the GreenClouds Knowledge Base System (GKBS) based on semantic web technology, which will provide detailed information on the energy characteristics of various applications (e.g., obtained from previous execution runs) and the different parts of the distributed system, including the network. Also, the project will study a broad range of applications and determine which classes of applications can reduce their energy consumption using accelerators. Finally, it will study energy reductions through dynamic adaptation of computing and networking resources. The project will make extensive use of the DAS-4 infrastructure, which is a wide-area testbed for computer scientists, to be equipped with many types of accelerators, a photonic network, and energy sensors.

• The results of the project will be utilized by the SARA national HPC center that operates a supercomputer, clusters, accelerator systems, and an HPC cloud. Today, the costs of energy over the lifetime of these systems are already larger than their acquisition costs, so reducing energy is vitally important for centers like SARA. Moreover, the results will be utilized in DAS-4 itself.
DAS-4 @ UvA

Head node
- 40 Gb/s
- 4 U nodes
- dual proc
- quad core

Twin nodes
- ORACLE/SUN
  - 50 Tbyte Thumper
- ORACLE/SUN
  - 50 Tbyte Thumper

 Phase 1: SURFnet to other DAS sites

local network exp. equipment

Phase 2 = phase 2

Photonic Network
- SURFnet
- DELL R815
  - 48 core server

Network
- 10/40/100 Gb/s
- WAN link switch

= phase 2
Within this benchmark, measured the power consumption & performance of the twin-node with various fixed frequencies by disabling the CPU-frequency-scaling feature and fixing the CPU frequency to one of available frequencies.
Figure 1(a) and Figure 1(b) are the performance and energy efficiency graphs for the CPU-Frequency-Scaling experiments, from where we may conclude that:

- Idle power consumption remains a constant regardless of its CPU frequency;
- Higher CPU frequency results in better energy efficiency;
- CPU consumes the most significant power within a system.
# of threads 1-16

![Graph showing CPU stress and power consumption across different numbers of threads.](image)
Each benchmark is run with the same amount of memory. The degradation in energy efficiency of VMs is around 30% compared with the host.
Memory dependence

![Memory Stress Graph](image)

- **Memory Stress**: Graph showing power consumption (W) against the number of threads.
- **Axes**:
  - Y-axis: Power (W), ranging from 70.00 to 150.00.
  - X-axis: # of threads, ranging from 0 to 16.
- **Lines**:
  - Blue line: Host.
  - Red line: Guest VM.
- **Observations**:
  - The power consumption increases with the number of threads.
  - The Host consumes more power compared to the Guest VM at all thread counts.

This graph illustrates the memory dependence and power consumption under different thread counts for Host and Guest VM.
Semantic web approach in GreenClouds

• Distributed info system describing current and historical load on infrastructure including parameters of jobs running
• Describe contextual parameters (energy sources, etc.)
• Dynamically optimize and migrate if context changes
The VM Turntable Demonstrator

The VMs that are live-migrated run an iterative search-refine-search workflow against data stored in different databases at the various locations. A user in San Diego gets hitless rendering of search progress as VMs spin around.
Network Description Language

- From semantic Web / Resource Description Framework.
- The RDF uses XML as an interchange syntax.
- Data is described by triplets:
NDL + PROLOG

Research Questions:
- order of requests
- complex requests
- usable leftovers

• Reason about graphs
• Find sub-graphs that comply with rules
Applications and Networks become aware of each other!
RDF describing Infrastructure

Application: find video containing x, then trans-code to it view on Tiled Display
ECO-Scheduling
Future research

• Parametrize energy usage
• Describe energy properties of infrastructure
• (automatically) determine footprint of applications
• Dynamically optimize and migrate
• First order:
  \[ E = a \times CPU + b \times GPU + c \times mem + d \times trans + e \times rw \]
Q&A

http://ext.delaat.net/smartgreen/index.html