DataCenter 2020.
Data Center Management and Efficiency at Its Best.
OpenFlow/SDN in Data Centers for Energy Conservation.

Dr. Rainer Weidmann, DC Architecture & DC Innovation
Deutsche Telekom.
Partner for connected life and work.

Deutsche Telekom delivers one-stop services and solutions: for all customer communications needs – at home, on the move and at work.

T-Mobile

T-Mobile offers cell-phone solutions in the Netherlands, Austria, and the Czech Republic.

Telekom

The Telekom subsidiaries provide products and services for the fixed network, mobile communications, the Internet and IPTV in Europe.

T-Systems

T-Systems delivers ICT solutions for major corporations and public-sector organizations worldwide.
T-Systems delivers ICT: End-to-end IT and telecommunications services.

Example: logistics company
- Receipt of parcel
- Distribution
- Delivery

Datacenter
- Applications, database, archiving

Network
- LAN, FW, WAN, SMS

Logistics
- Desktop, applications

Parcel station
- Scanner, screen, connectivity

Customer
- Internet, mobile device, etc.

End-to-End Monitoring
- Realtime End-to-end Monitoring

ICT expertise:
- a single point of responsibility
- customer-specific price models, e.g. Price per desktop
- dynamic services with flexible up- and down scaling
- replacement of up-front investments with monthly costs
- cost savings of up 30 percent
- easy integration of new technologies
- greater transparency and security
- more growth thanks to new business models
Scalable platforms: unmatched IT infrastructure skills.

### Facts and figures

- 119,900 m² data center space
- 91 Data Center managed by T-Systems
- 118,600 MIPS
- 58,000 open systems server
- 23.6 m installed SAPs
- 3.2 m named SAP user
- 1.5 m managed seats
- 2,343 service desk agents
- 556,551 exchange mailboxes
- 276,697 notes mailboxes

### IT Infrastructure

#### North and South Americas/South Africa
- Data center m²: 19,800
- DC managed TS: 17
- MIPS: 11,100
- Open systems server: 11,400
- Installed SAPs: 3.2 m
- Named SAP user: 186,700

#### Europe
- Data center m²: 96,200
- DC managed TS: 67
- MIPS: 106,900
- Open systems server: 44,700
- Installed SAPs: 24.4 m
- Named SAP user: 3.0 m

#### Asia Pacific
- Data center m²: 3,900
- DC managed by TS: 7
- MIPS: 600
- Open systems server: 1,900
- Installed SAPs: 45,700
- Named SAP user: 14,000

As of May 2011
DC2020 - Motivation/General Duties

Observations & Responsibility
Operational
- Steadily increasing power consumption of Data Centers
- Steadily increasing density in Data Centers

Environment
- Climate Change Group (DTAG)
- T-Systems’ Core Beliefs: Sustainability & Corporate Responsibility.

- Infrastructure Test Lab
  - “Closed Shop” / No limits
  - Testbed for benchmarking

- Optimize Energy efficiency

Definition: energy efficiency of a DC
(PUE, Power Usage Effectiveness, the green grid™)

\[
PUE = \frac{\text{total Facility Power}}{\text{IT-Equipment Power}}
\]
(average value 1 year)

Fields for improvement
- Legacy DC
- Blueprint for DC 2020
- CFD Models
DC2020.
Technical Features.

- Floor space 67 + 67 m²
- Raised Floor 80cm
- 190 real Servers
- 8 Racks & 1 liquid cooled rack
- AC-UPS (250kVA)
- DC-Supply (48V, 600A)
- Adjustable ceiling
- Coated walls
- Smoke generator
- Cold water supply (290kW)
- Free cooling capability
- Plate Heat Exchanger
- CRAC EC
- CRAC FT
- CRAC Humidity
- Cold aisle containment
- Hot aisle containment
- Building mgmt. system (1800 Datapoints)
- Permanent inertization

Basic Idea 2008

- Top view from meeting room
- Raised Floor
- Cooling equipment
- Smoke Generator
- Enclosure and "Cooltrans"
Hot/Cold Aisle Room Layout. General. Hot-/Cold-Aisle.

$\Delta T = T_2 - T_1$

$\Delta Q = c_v \times m \times dT$

$T_1 [^\circ C]$

$T_2 [^\circ C]$

CRAC Unit

Fan

Hot aisle

Cold aisle

Hot aisle

Air short circuit

Leakage

Raised Floor
Hot/Cold Aisle Room Layout – Status Quo.

- **T** - Systems

** Raised Floor

- **Hot aisle**
  - **T₁ = 18°C**
  - **p = 16pa**

- **Cold aisle**
  - **T₂ = 24°C**
  - **ΔT = 6K (ΔQ = c_v × m × dT)**
  - **Leakage**

- **CRAC Unit**
  - **Fan 100%**

**PUE<sub>typ</sub> = 2,20 … 1,80**

- **18°C : 64°F**
- **22°C : 72°F**
- **24°C : 75°F**
Hot/Cold Aisle Room Layout – Improvement I.

Leakage Reduction – **Cold-Aisle Containment** – Fan Speed Adjustment.

- **Cold aisle**: $T_A = 22°C$
- **T2 = 38°C**
- **ΔT = 17K**
  \[ \Delta Q = c_v \times m \times \Delta T \]
- **CRAC Unit**
  \[ T_1 = 21°C \, \text{p} = 4\text{pa} \]

**Hot aisle**

**Raised Floor**

- **21°C : 70°F**
- **22°C : 72°F**
- **38°C : 100°F**

**Fan 30%**
Hot/Cold Aisle Room Layout – Improvement II.
Leakage Reduction – **Cold-Aisle Containment** – Fan Speed Adjustment – Temperature.

Delta T = 19K
\[ \Delta Q = c_v \times m \times dT \]

**CRAC Unit**

**Fan 30%**

**T1 = 26°C**

**T2 = 45°C**

26°C : 79°F
27°C : 81°F
45°C : 113°F

26°C : 79°F
27°C : 81°F
45°C : 113°F

**Hot aisle**

**Cold aisle**

**Raised Floor**
Overview – Free Cooling Period.
Hours of Operation (Loc. Munich).

<table>
<thead>
<tr>
<th></th>
<th>Status Quo</th>
<th>Improvement I</th>
<th>Improvement II</th>
</tr>
</thead>
<tbody>
<tr>
<td>$T_A = 22°C$</td>
<td>3147</td>
<td>5034</td>
<td>7146</td>
</tr>
<tr>
<td>8°C water supply temperature</td>
<td>1936</td>
<td>3132</td>
<td>1533</td>
</tr>
<tr>
<td>14°C water supply temperature</td>
<td>3683</td>
<td>600</td>
<td>5034</td>
</tr>
<tr>
<td>20°C water supply temperature</td>
<td>5034</td>
<td>7146</td>
<td>7146</td>
</tr>
</tbody>
</table>

- Hybrid Heat Exchanger "Dry"
- Hybrid Heat Exchanger "Wet"
- Chiller

8°C : 46°F
14°C : 57°F
20°C : 68°F
22°C : 72°F
27°C : 81°F
Cold- vs. Hot-Aisle Containment.
PUE Improvement I.

22°C Server Inlet Temperature ; 14°C Water Supply Temperature

Energy Savings 20-30%

Density [kW/Rack]

14°C : 57°F
22°C : 72°F
Cold-/Hot-Aisle Containment
Total Outage of Airconditioning.
Critical Reaction Time vs. Density.

22°C → 35°C Server Inlet Temperature $T_A$

<table>
<thead>
<tr>
<th>Density [kW/Rack]</th>
<th>Hot Aisle</th>
<th>Cold Aisle</th>
<th>No Enclosure</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.5</td>
<td>25:00</td>
<td>20:00</td>
<td>15:00</td>
</tr>
<tr>
<td>9.8</td>
<td>22:00</td>
<td>18:00</td>
<td>12:00</td>
</tr>
<tr>
<td>17.5</td>
<td>19:00</td>
<td>15:00</td>
<td>10:00</td>
</tr>
</tbody>
</table>

Typ. UPS autonomic time

Optimum
Lessons Learned Phase 1.

- PUE of 1.3 or better possible with standard techniques already available
- Leakage Reduction and Enclosures necessary (Cold-/Hot-Aisle enclosure)
- Homogenous airflow very important (flow direction, air velocity, pressure)
- Standardized Hardware useful (“Dynamic Services”)
- Room height is of minor interest (in case of enclosures no influence)
- Increase of DC-Availability with Enclosures
- Savings increase with increase of power density in Datacenters

**Recommendations**

→ Reduce Fan speed in CRAC Units
→ Increase Temperatures (ASHRAE 2008)
→ Infrastructure „on demand“ (IT leading)

→ Increase Density to > 10kW/Rack (avg)
  → Increase average CPU utilization
  → Dynamic Load sharing
Next steps for DC2020 - Phase 2
Focused on end-to-end enterprise load management

- Upgrade the data center to use:
  - Private cloud application stacks
  - Equipment: latest CPU generation utilizing Intel Node Manager/Data Center Manager (blade level density)

- Considering infrastructure is already in place to measure power, investigate effectiveness of strategies for server and network power conservation:
  - Power capping vs. other forms of load limiting and distribution
  - Enable power conservation in computing resources
  - Reduce idle power consumption
Potential of OpenFlow/SDN for energy conservation.

- **Server level:**
  - Caching/Proxying requests until wake-up
  - Mapping services to servers in an energy-aware manner
  - Migration and consolidation across 1 or more data centers
  - Workload allocation can be over a limited physical space so as to conserve cooling energy

- **Network device level:**
  - Using centralized control to coordinate across 1 or more data centers such that energy proportionality or multiple energy states at device level (e.g., IEEE 802.3AZ) is effectively used:
    - ElasticTree is an instance where we have only 2 modes: on/off.
      - Pack workload efficiently using OpenFlow/SDN
      - Turn off/on links/switches using config protocols
    - For each workload, move traffic away from elements at high energy mode
DC server power management.
Energy-aware server provisioning and consolidation.

- Many existing ideas, on energy-aware provisioning, load consolidation and migration, for web services hosted across a collection of data centers:
  - Provisioning: NSDI 2008
  - Server consolidation: HotPower 2008
  - Load migration: SIGCOMM 2009

- SDN can enable these actions seamlessly without causing disruption:
  - VM migration without dropping existing sessions
  - Allocate load in a power-aware manner
  - Triggering power on/off of computing nodes
DC network power management.
Simple strategy with interesting power savings.

- ElasticTree work in collaboration with HP and Stanford University
  - Simple topology control can produce noticeable energy savings; savings increase with decrease in load.
Summary

- OpenFlow/SDN has potential to:
  - Intelligently trade-off power, redundancy, workload and performance.
  - Enable Dynamicity, automatic management and evolvability of the DC.

- DC2020 will help evaluate the potential in realistic environments and explore to the desired scale.

- How should the data center network look like, if energy-awareness is enabled by SDN, for maximum energy conservation?
Thank you for your attention!

http://www.datacenter2020.de
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