Pushing the limits of Datacenter Efficiency: Challenges and Opportunities

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Factors for Datacenter “Green-ness”

- Power delivery source (Coal, Hydro, Solar, ...)
- Power delivery efficiency (PUE)
- Construction materials (Concrete, Steel ...)
- Cooling techniques (Air, Water, Freon, ...)
- Power consumption (Server, Network, ...)
- Equipment disposal at decommissioning time
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Power delivery sources

“Dirty” sources
- Fossil fuels (Coal, Natural Gas), Nuclear

Renewable sources
- Solar, Wind, Hydro
- Biofuel, Geothermal, Marine

Tradeoffs
- Energy costs and variability over time
- Energy Provisioning costs and Infrastructure depreciation
- Available options at Datacenter site location
- Energy source reliability (max, avg, min)
- Tax credits, PR
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Power delivery efficiency

- PUE = Total Facility Power / IT Equipment Power
- Measure PUE at Server Inlet
- Components affecting efficiency: PDUs, UPS, Transformers, PSUs

Utility → Xfmer → UPS → PDU/Xfmr → PSU → IT load

- Inefficient designs could have PUE ~2.0
  - i.e. for 1 watt available for IT load, 1 watt is wasted in overhead!
- Achieving high efficiencies
  - Minimize levels of power conversion
  - E.g. 480V 3Ø distribution, In-rack UPS, 95%+ Eff. PSUs
  - Facility PUE < 1.2 already achievable
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Traditional Datacenters (2007 era)

$500M+ investment

3000 construction related jobs

707,000 sq ft

1.5 million man-hours-of-labor

3400 tons of steel

190 miles of conduit

2400 tons of copper

60 MW Total Critical Power

PUE 1.4 – 1.6

7.5 miles of chilled water piping

26,000 cubic yards of concrete

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Airside economized Data Center (2011)

- Modular Datacenter design
- Steel structure, concrete pad
- No mechanical cooling
- Ultra efficient water utilization
- Focus on renewable materials
- PUE < 1.2 achievable
Optimization across Multiple functional Domains (Mechanical/Electrical & IT Utilization)
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Datacenter Energy usage breakdown

Power consumption reduction across all domains is necessary

Highest ROI for Server Power reduction
Reducing system power footprint

- Rightsizing systems design, E.g. LV CPU/Mem, SSDs for IOPS/W

- Power-aware applications and system software
  - E.g. Core parking, Transaction load-balancing

- Silicon power reduction techniques
  - E.g. V-f scaling across independent domains, Aggressive clock gating

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Summary so far

- Industry has made several advances on multiple aspects of datacenter efficiency for driving Green Computing
  - But work has mostly been done in independent silos

- Need to drive convergence and vertical integration for exploiting opportunities across functional silos
  - Challenging at industry level given diversity of solutions, lack of standardization, redundancy requirements etc.

- What role can the Large-scale Cloud Service providers play for spearheading the next wave of Green computing?
  - Open knowledge sharing for sharing best practices with industry
  - Solutions still inconsistent across providers, but industry may benefit as a whole from advancements
What next?
Pushing the limits – *The Disappearing Datacenter*

Brick-and-mortar
Chilled Water cooling

Concrete pad, Steel structure
Adiabatic cooling

Possible only via HW/SW co-design

No structure, open frame
Free Air-cooling

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Simplify Datacenter construction
Improve Datacenter PUE
True Free-Air cooling

Centralized Power Management
Rightsizing Server Components
Efficient Power Systems

Energy Efficient Applications
Self-healing and resiliency

Platform Power Management
Low-power system design

Need to think holistically across the entire services stack
True Free-Air Cooling

- Use unconditioned outside air for cooling servers

- Benefits
  - Water-free operation → Environmental friendly
  - Reduced datacenter capex and opex costs

- High temperature operation has implications
  - Silicon Leakage Power
  - Component Reliability
    - High Temperature failures
  - Particulates/Contaminants
  - Heat removal and Airflow
Climate zones and Worst case temperature

Chart shows typical temperature trends for three high temperature climates zones:
-- Tropical
-- Humid
-- Northern Desert

Very few hours of the year go over 35C/95F

Should adapt well to Server Rating of 10-35C/50-95F
System operation at High Temperatures

Airflow to Cool a Server $\propto \frac{Server\ Power}{(Exhaust\ Temp - Inlet\ Temp)}$

More airflow is required with increase in temperature to compensate for ...
- Increased heat removal
- Higher dynamic power (leakage)

One possible mitigation: Use System Power Capping
- Invoked above specific Inlet Temperature (e.g. 35C/95F)
- Reduces Server Power and hence Exhaust Temperature
- Slight performance impact under high workload conditions
What about reliability?

- HDDs most sensitive to temperature related failures
- Max rated temp 60C; but AFR increases 2x from 40C→60C!
- Mitigate via server design, e.g. HDD temp < Ambient+4C
Architectural Innovations for system power reductions

- SoC designs – x64 and ARM
- NVRAM in memory hierarchy
- Distributed switching - Integrated on-chip fabric
- Packaging and cooling innovations

Application manages Data locality
Self-Healing infrastructure

- 100% Availability doesn’t exist - Hardware will fail

- Building reliable cloud services involves planning for failures
  - Hardware failures (e.g. hard drives, power supplies)
  - Software bugs (e.g. BIOS, Drivers, App)
  - Human errors (e.g. Maintenance, Config changes)
  - Design for nuisance outages (maintenance) and utility power outages

- “Green” Benefits
  - Simplified Datacenters /IT gear → fewer materials and maintenance
Summary

Progress has been made over past decade for Datacenter efficiency
...but mostly in independent functional silos

Opportunities for further efficiency advances are in vertically integrating the HW/SW ecosystem
Simple/Cheap Hardware & Reliable Software
Drive Open knowledge sharing for best practices with broader industry
Resources:

Datacenter infrastructure best practices:

Microsoft Datacenter Blogs
http://blogs.technet.com/b/msdatacenters/