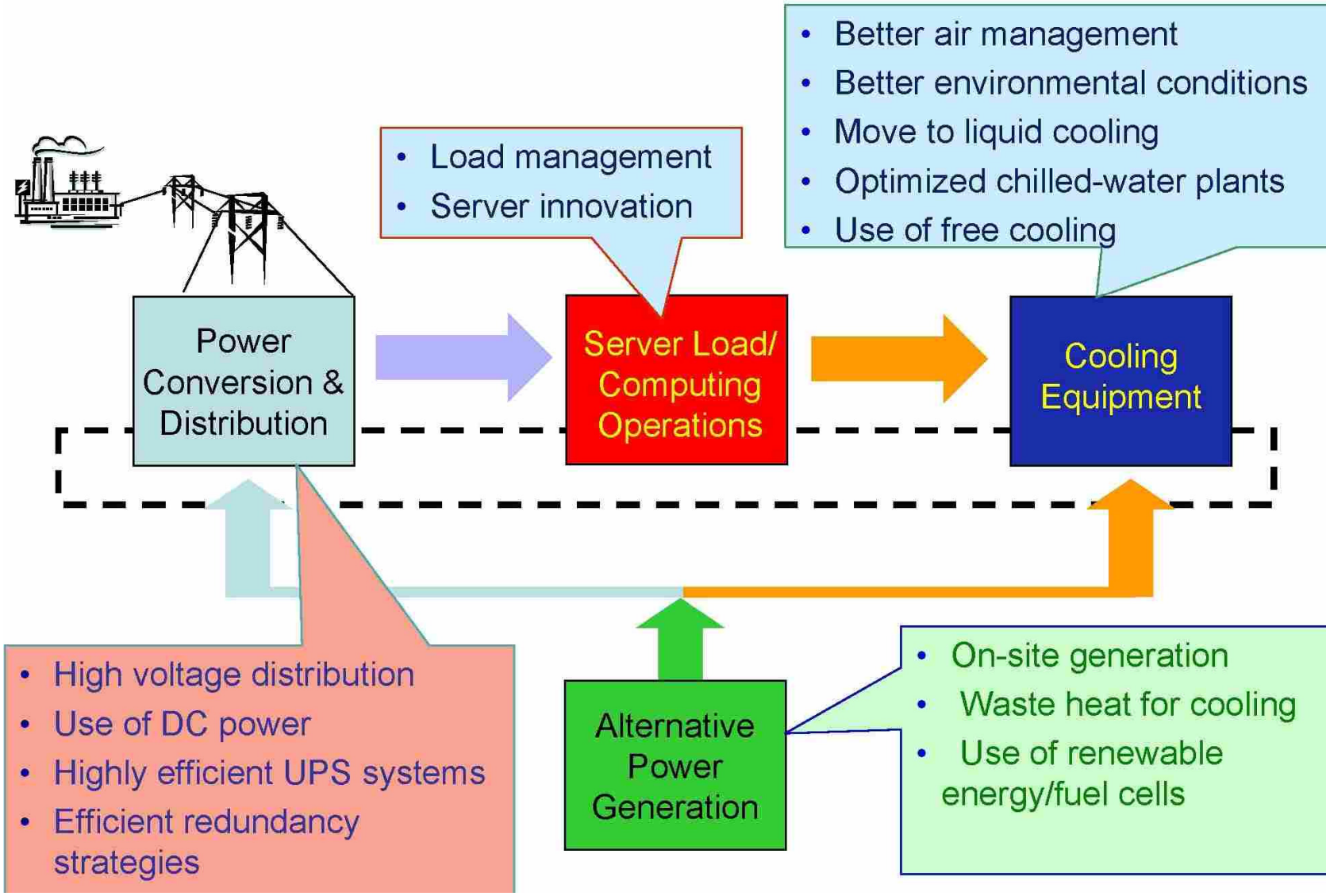
Physicals: Scope (Extrapolate)



Top Challenges for a "Science" of Physicals

- Models, models, models…
  - Understanding power dissipation, heat distribution, cooling, interactions
  - Big "O" for energy
- Optimization, optimization, optimization…
  - Scheduling, multi-variable optimization
  - Formalism for multiple cooperating agents
  - The general power grid versus IT grid
  - Change the incentive structure related to electricity use
- A methodology for experimentation and repeatability
  - Miniature "hobby" data centers + software toolkit
- Explore, incorporate new technologies: cooling, power supplies, materials
  - Liquid, spray cooling
  - Low-loss power supplies
  - High-temperature materials
- Cross-area, cross-domain, cross-tier interactions
  - Materials, packaging, architecture, enclosure, low-level software, applications
  - Define roles and interfaces, co-design and co-optimization, cooperating agents
  - "CAD for data centers"

Models, Formalisms, Methodologies

- Power dissipation and thermals
  - Extend current models to I/O, virtualization, multi-core CPUs, 3D stacking, solid-state storage, thermal cycling (relationship to performance)
  - More broadly: “algorithmic” energy consumption, e.g. big O for energy
- Cooling
  - Model the relationship between power & temperature across tiers & domains
  - Model different types of cooling: air, liquid, free
  - High-temperature data centers: pushing the limits of reliability and new materials (places requirements on the software)
- Power supply
  - Methodologies for properly designing for reliability (tradeoff between costs and UPS system and free cooling, for instance)
  - Models of battery discharge & efficiency according to shape of workload
- Interactions
  - Formalisms to reason about interactions across areas, domains, and tiers

Optimization

- Scheduling, multi-variable optimization
  - Power, energy, and thermal management
- Coordinating and optimizing multiple cooperating agents
  - Multiple controllers (independent, coordinated, centralized?)
- The general power grid versus IT grid
  - Optimize the supply/demand of electricity
- Change the incentive structure related to electricity use
  - Theoretical frameworks to change behaviors of main actors

Methodologies for Experimentation

- In a science, we must be able to experiment and repeat
- For example, for data centers
  - Scaled-down testbed: data centers in a room
  - Software for repeatability
  - Software for extrapolation
  - Software to allow the community to use the testbed

Explore New Technologies

- Cooling and materials technologies
  - Liquid cooling
  - Spray cooling
  - High-temperature materials
- Power supply technologies
  - Smart & reconfigurable supplies (e.g., reconfigurable UPS)
  - Low-loss power storage (avoid conversion from electrical to chemical, back to electrical)
  - New energy sources (e.g., to power PDAs)
  - Co-design power generation and data center
  - Power storage for green energy sources

Cross-* Interactions

- Power source, materials, packaging, architecture, enclosure, low-level software, applications
- Methodologies for determining the responsibilities of different domains and tiers (time granularities may help)
- Co-design and co-optimization of different tiers and domains (e.g., architecture, materials, and cooling)
  - "CAD for data centers"
- Need to do a better job of interacting across areas as well (e.g., architects, VMM, operating system, and application designers)

Questions or Comments?

Physicals Sub-group

- Testbeds to study real data centers: scale-down, repeatability, predictability, software for extrapolation, software to allow community to use
- Cross-domain and tier interactions: methodologies for determining the responsibilities of different domains and tier (time granularities), co-design and co-optimization of different tiers (e.g., architecture, materials, and cooling)
- Radical disruptive approaches: cooling technologies (liquid, spray), power supply technologies (e.g., smart power supplies, low-loss power storage), energy sources (e.g., to power PDAs)
- Power generation, distribution, and delivery
  - AC/DC conversion losses are a problem across the spectrum
  - Methodologies for properly designing for reliability (tradeoff between costs and UPS system and free cooling, for instance)
  - Co-design power generation and data center
  - Power storage for green energy sources
  - Electrical grid, supply/demand, electricity market, optimization
  - Models of battery discharge & efficiency according to shape of workload

Physicals Sub-group

- Heating
  - Models for power consumption and thermals: extend to I/O, virtualization, multi-core CPUs, 3D stacking, solid-state storage, thermal cycling
  - Models for “algorithmic” energy consumption, e.g. big O for energy
  - Time constants may be the key to simplifying models
- Cooling
  - Models for relationship between power and temperature across tiers and domains: formalize current behaviors and predict future ones
  - Model different types of cooling: air, liquid, free
  - Attack heat at source: new techniques to distribute heat
  - High-temperature data centers (doesn’t work for other systems/devices): pushing the limits of reliability and new materials, places requirements on the software
- Power management techniques
  - Formalisms to represent control agents
  - Theory of cooperating agents across tiers and domains
- Materials and enclosure design
  - Allow CPUs to run at higher temps (better materials or software fault tolerance)
  - Metrics for determining the quality of enclosure design
  - Cooling techniques, such as moving air flaps, floor tiles, etc
  - Develop cheaper rechargeable batteries and change the incentive structure
  - CAD for data centers

Top challenges for a "science" to consider

- Models, models, models…
  - Understanding power dissipation & heat distribution (see deep dive)
- Optimization, optimization, optimization – *big "O" for energy*
  - Scheduling, multi-variable optimization (see deep dive)
  - Emerging trends create new challenges: e.g., free-cooling
  - Formalism of multiple cooperating agents
  - The general power grid versus IT grid
  - Change the incentive structure
- A methodology for repeatability and experimentation
  - Miniature "hobby" datacenters + software toolkit
- New technologies: *"make the problem go away"*
  - E.g. – new cooling cool fusion reactors?
  - E.g., - new power supply – low-capacitance…
  - E.g., - high-temperature silicon
- Cross-area interactions
  - Define roles and interfaces, co-design optimization, cooperating agents
  - "CAD for datacenters"
  - Materials and enclosure design, packaging and architecture