CS528

Power and Energy Aware Design and Scheduling

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Energy Efficient System: Design and Management

- **Point to consider**

✓ Energy efficient Infrastructure

✓ Energy Model of Infrastructure

  – Blades/Server Machine CPU, Memory

1. Energy Efficient Scheduling

  – **How to manage the Jobs**

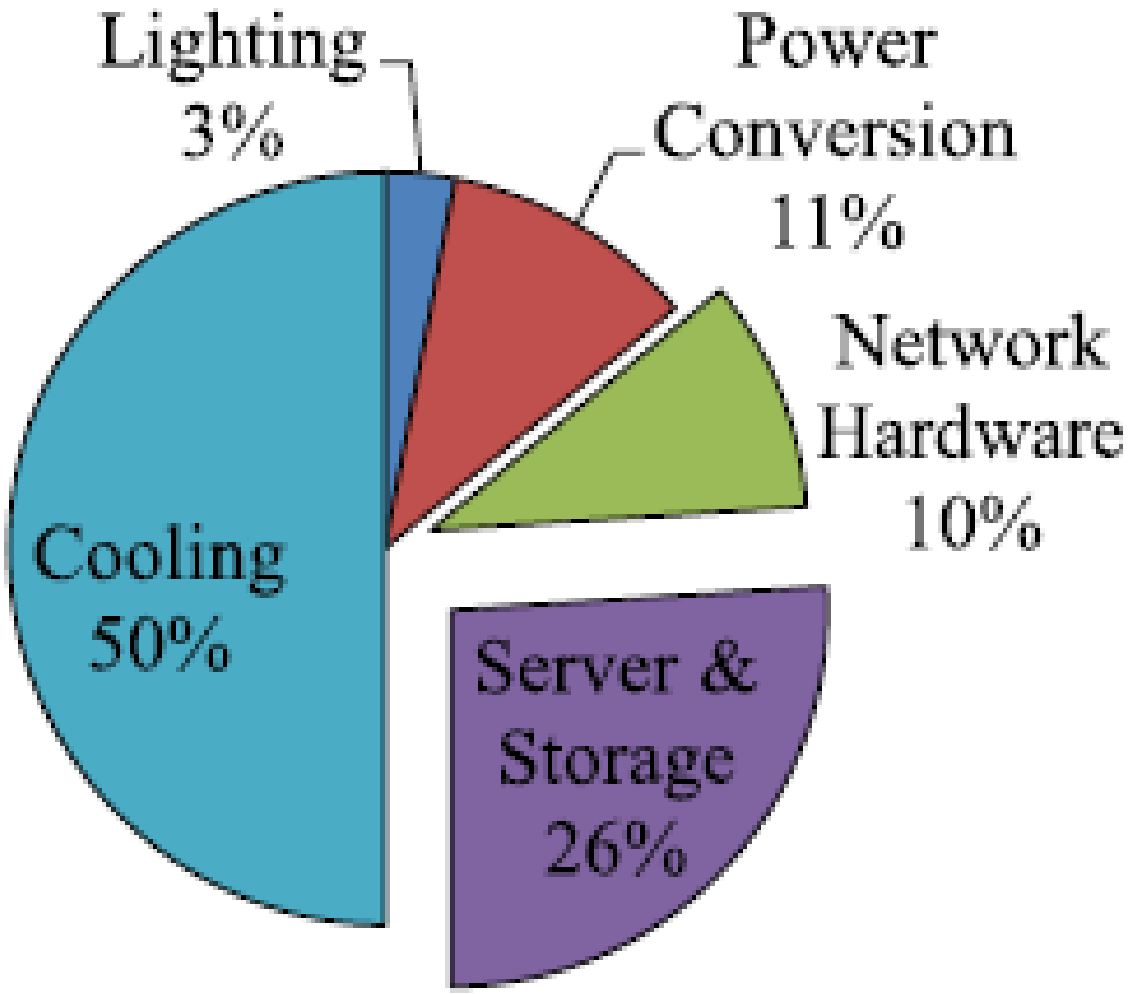
Outline

- Power/Energy Consumption Model
- Power Aware Computing
- Thermal Aware Computing
- Power Aware Scheduling in Cloud
- Migration and Management

Data Center Power Consumption

- Currently it is estimated that servers consume 0.5% of the world's total electricity usage.
  - Closer to 1.2% when data center systems are factored into the equation.
- Server energy demand doubles every 4-6 years.
- This results in large amounts of CO_2 produced by burning fossil fuels.
- What if we could reduce the energy used with minimal performance impact?

Percentage of Power Consumption in DC



Motivation for Green Data Centers

- Economic
  - New data centers run on the Megawatt scale, requiring millions of dollars to operate.
  - Recently institutions are looking for new ways to reduce costs, no more “blank checks.”
  - Many facilities are at their peak operating envelope, and cannot expand without a new power source.

Motivation for Green Data Centers

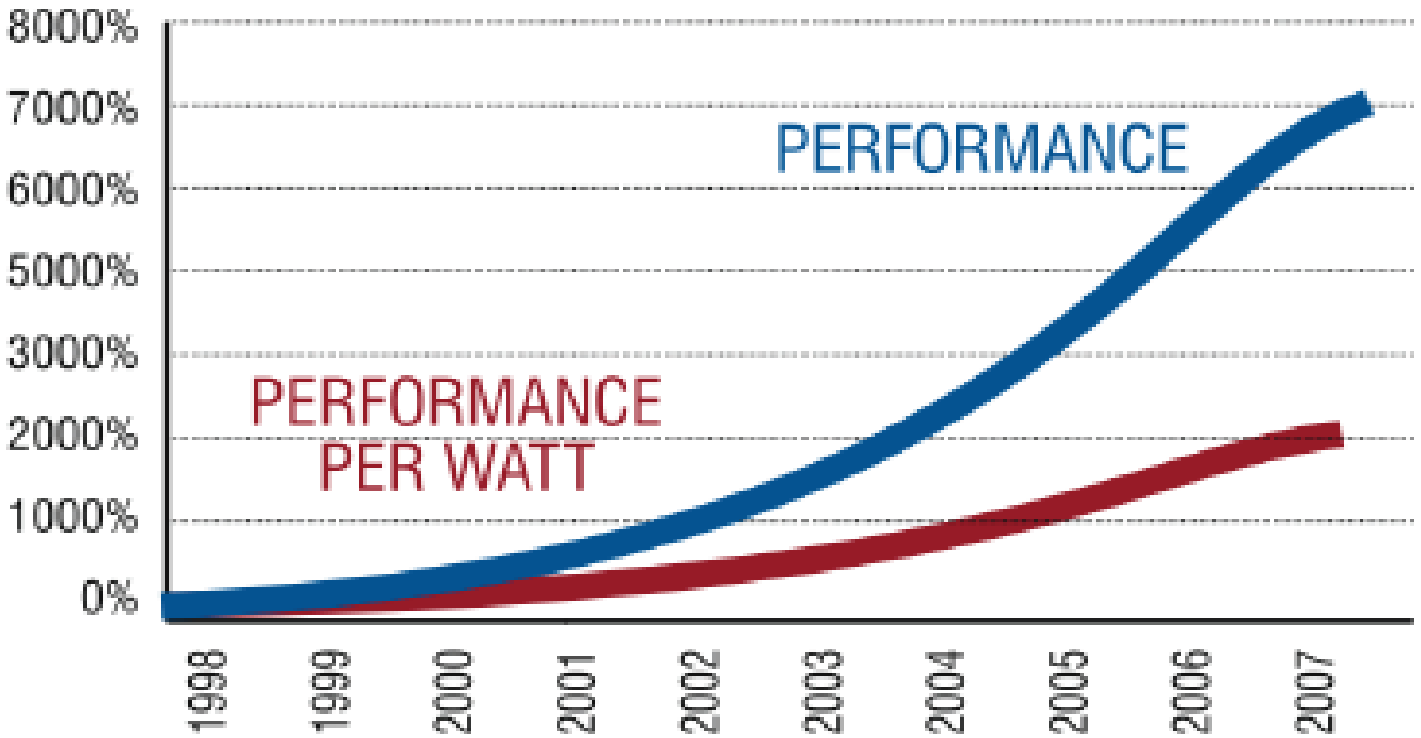
- Environmental
  - 70% of the U.S. energy sources are fossil fuels. In India 66% is from Coal Plant (NTPC)
  - 2.8 billion tons of CO_2 emitted each year from U.S. power plants.
  - Sustainable energy sources are not ready.
  - Need to reduce energy dependence until a more sustainable energy source is deployed.

Green Cloud Goal Shift: "performance" → "energy efficiency"

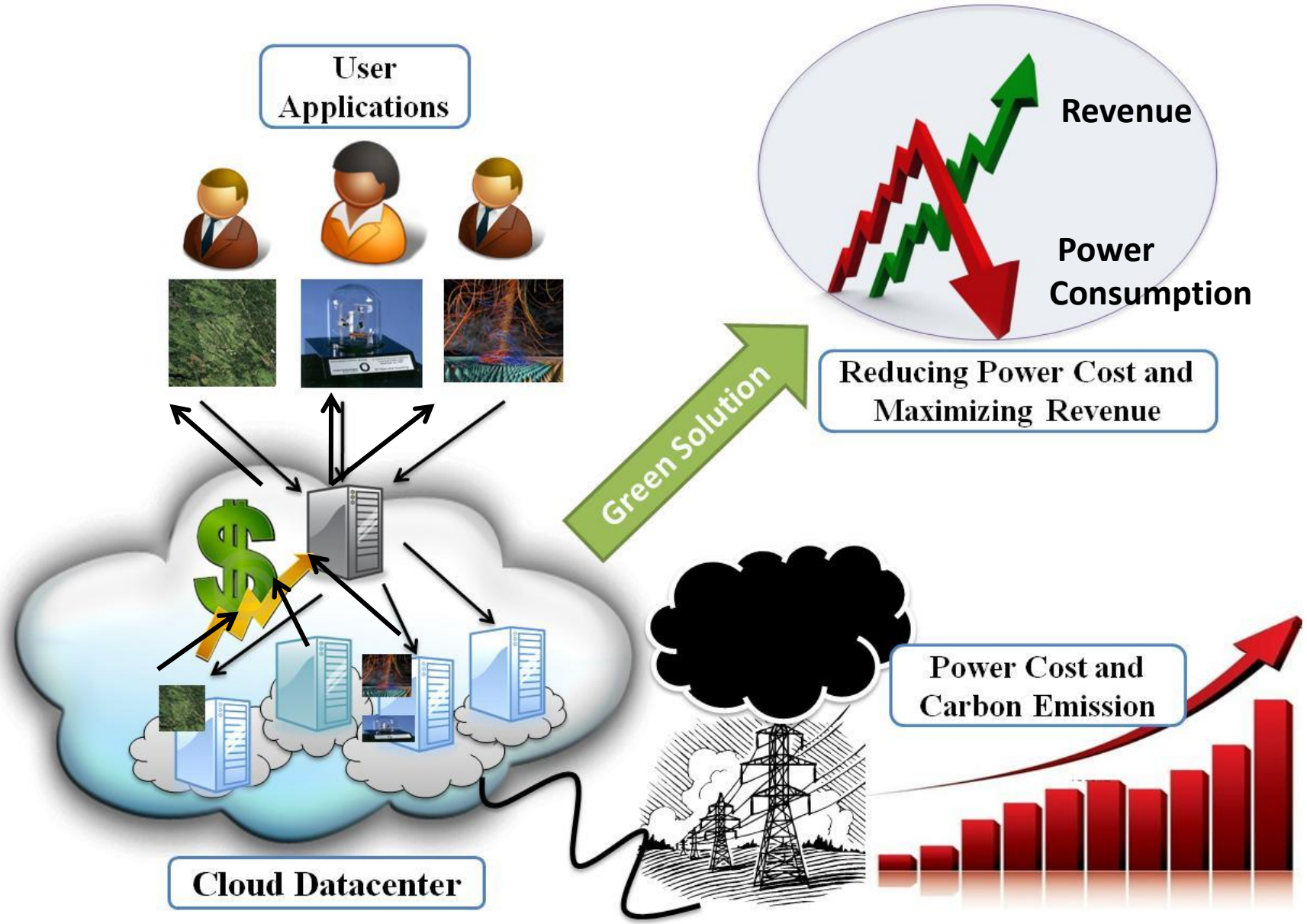
- As **energy costs** are **increasing** while **availability dwindles**
- Need to **shift focus** optimising data center Resource management
  - **From** pure **performance** alone **to** optimising for **energy efficiency**
  - While maintaining high service level performance.
- **Green Cloud computing** model that achieves
  - not only efficient processing and utilisation of computing infrastructure,
  - but also minimise energy consumption.

Green Computing

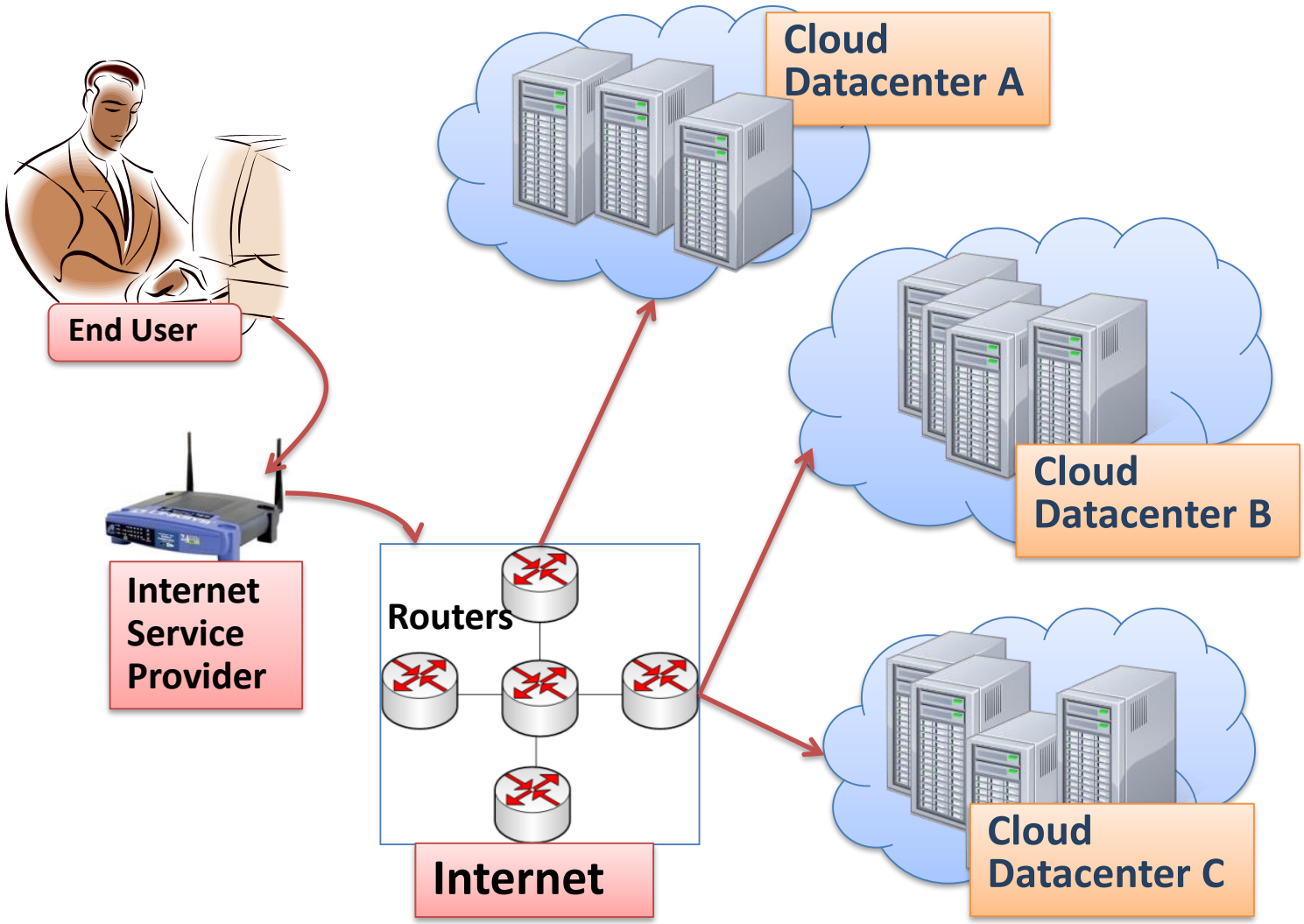
- In the past 15-20 years of supercomputers
  - performance has doubled > 3000 times
  - performance per watt has doubled 300 times
  - performance per square foot has doubled 65 times



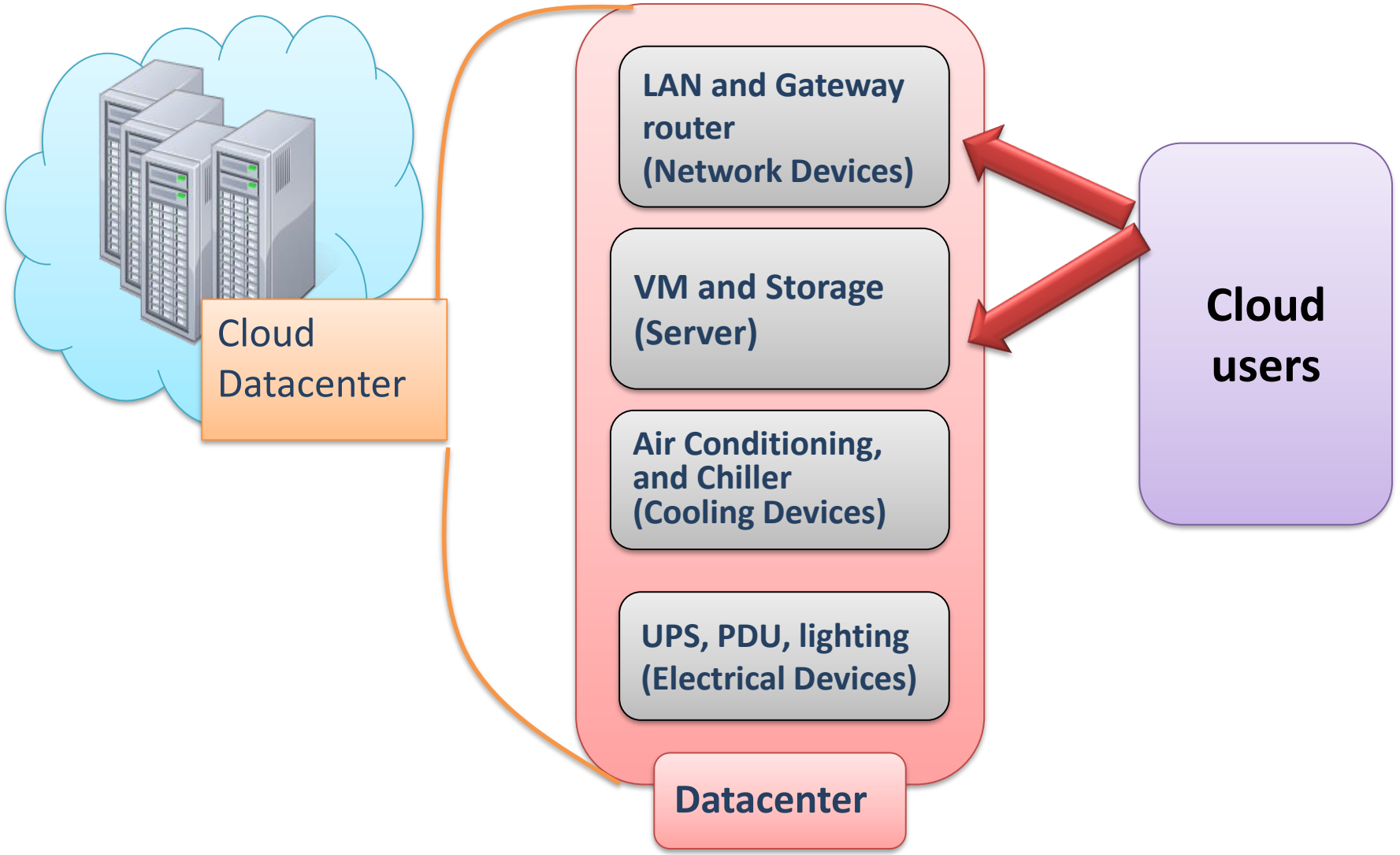
Green Cloud Computing



Cloud Usage Model

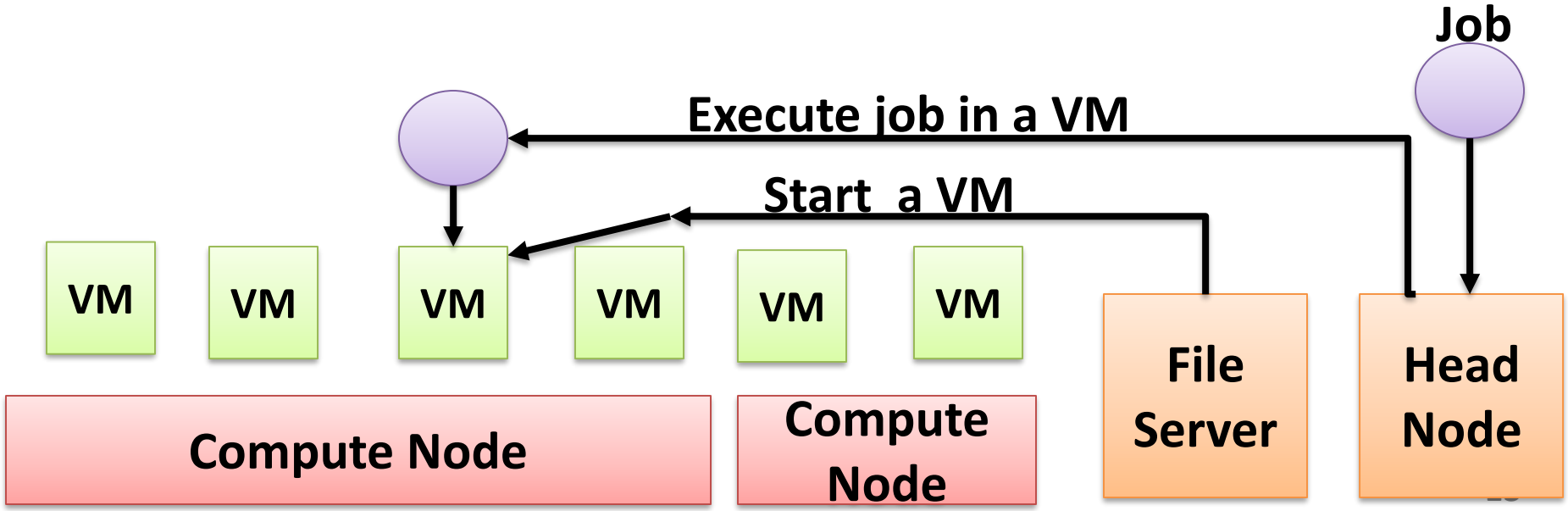


Cloud Usage Model

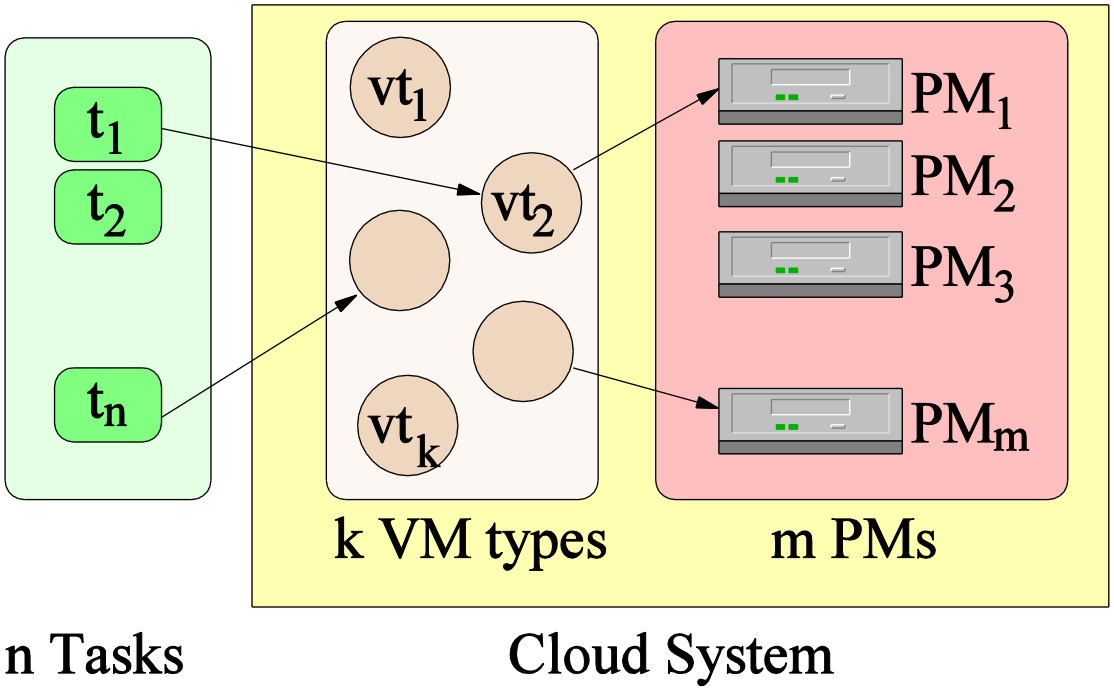


Cloud Computing

- Features of Clouds
  - Scalable, Enhanced Quality of Service (QoS)
  - Specialized and Customized, Cost Effective
  - Simplified User Interface



System model



- Considered IaaS paradigm
- Consists of *m* homogenous hosts (*m* is large)

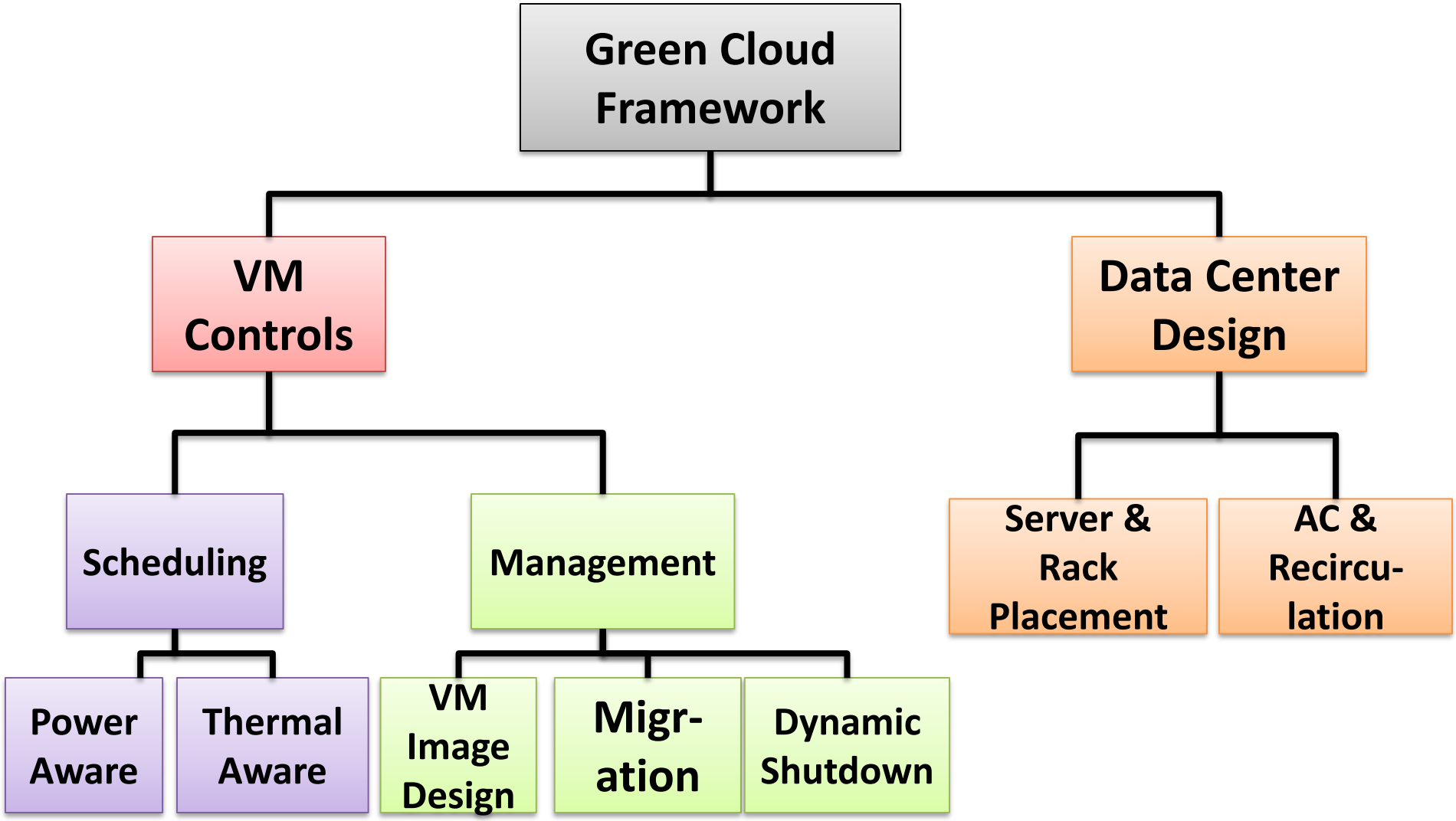
System Model

- Every Task comes with
  - Execution time (e_i), deadline (d_i)
  - CPU requirement (c_i), memory requirement (m_i)
  - and any other
- SLA (Service Level Agreement) Violation
  - SLAV
  - If the task do not get require amount CPU, memory
  - If competition time extend the deadline
  - Cloud service provide may need to pay penalty

System Model

- Some time SLA comes with
  - Infra oriented: Amount of CPU, memory, bandwidth
  - Service oriented: number of request/task per time, throughput: #web/db request per time
- SLA (Service Level Agreement) Violation **(SLAV)**
  - If the task do not get require amount CPU, memory
  - If competition time extend the deadline
  - Not able to provide required throughput
  - Cloud service provide may need to pay penalty

Green Cloud Computing Framework



Green Cloud Framework (cont.)

- Goal : Maximize **performance per watt** in Cloud
  - VM Scheduling
  - VM Image Management
  - Data Center Design

- Scheduling
  - Placement within cloud infrastructure
  - Energy use of server equipment
  - datacenter temperature important

Green Cloud Framework (cont.)

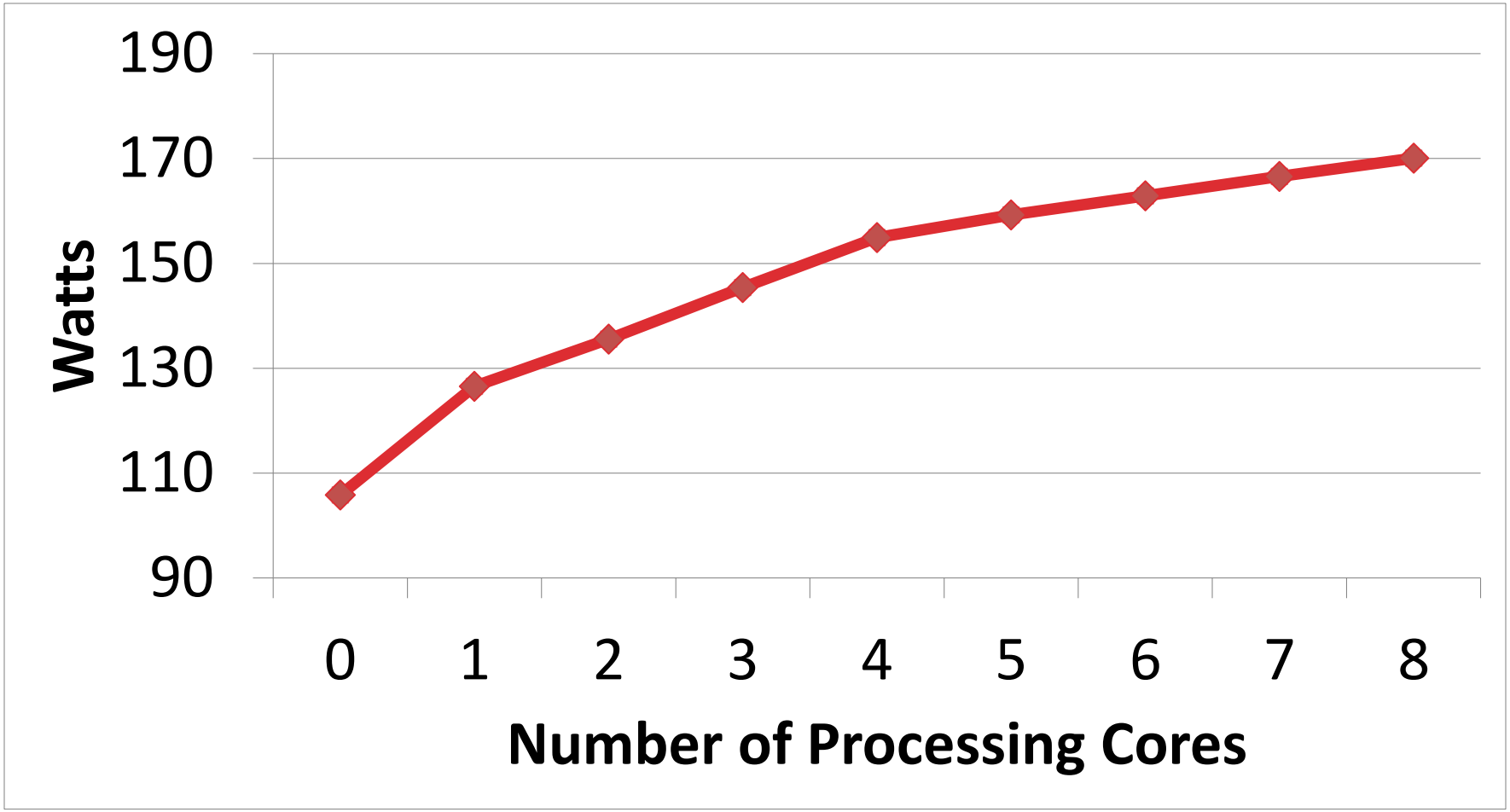
- Image Management
  - Small Size
  - Few unnecessary processes/services
  - Migration
  - Dynamic Shutdown

- Data Center Design
  - More efficient A/C, power supplies
  - Hot and cold aisles
  - Utilizing external cooling

Virtual Machine Scheduling

- Power-Aware Scheduling (PAS)
  - Minimize total power used by servers
  - Power to servers is the larger cost
- Thermal-Aware Scheduling (TAS)
  - Minimize overall temperature
  - Reduces energy used for cooling

Virtual Machine Scheduling

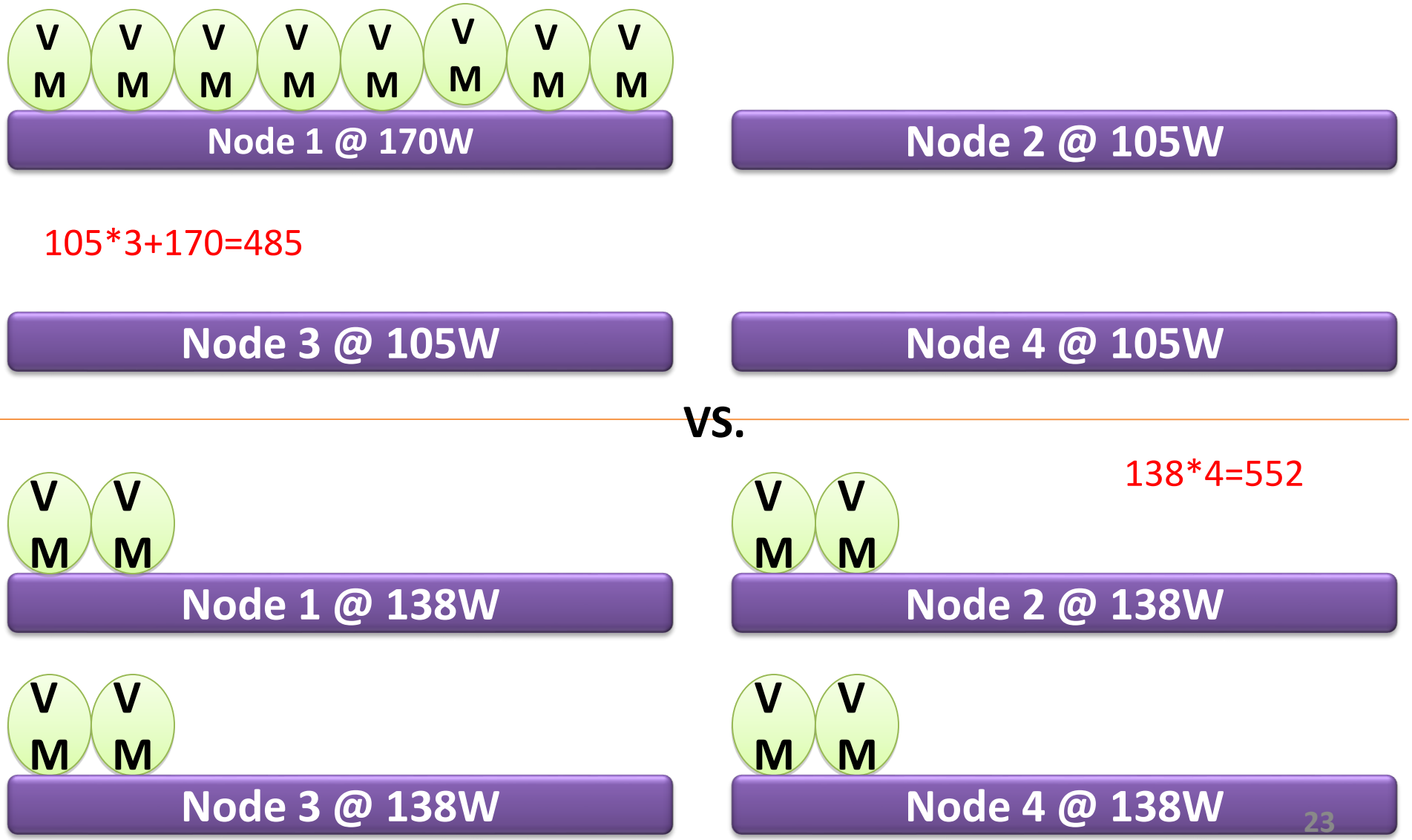


Power consumption curve on an Intel Core i7 920 Server
(4 cores, 8 virtual cores with Hyperthreading)

Power Aware (PA) Computing

- Objective of PA computing/communications is
  - To improve power management and consumption
  - Using the awareness of power consumption of devices.
- Power consumption is most important considerations
  - In mobile devices due to limitation battery life.

485 Watts vs. 552 Watts



Scheduling EARH

for each task t_i in set Q **do**

$findTag \leftarrow$ FALSE; $findVM \leftarrow$ NULL;

for each VM v_{jk} in the system **do**

Calculate the start time st_{ijk} and execution time et_{ijk}

If $st_{ijk}+et_{ijk} \leq d_i$ **then** $findTag \leftarrow$TRUE; Compute ec_{ijk}

if $findTag$ == FALSE **scaleUpResource()**;

if $findTag$ == TRUE **then**

Select v_{sk} with min energy consumption to execute t_i

$findVM \leftarrow v_{sk}$

else Reject task t_i

Update scheduling decision of t_i and remove it from Q