

CS528

Energy Efficient Scheduling in Data Center

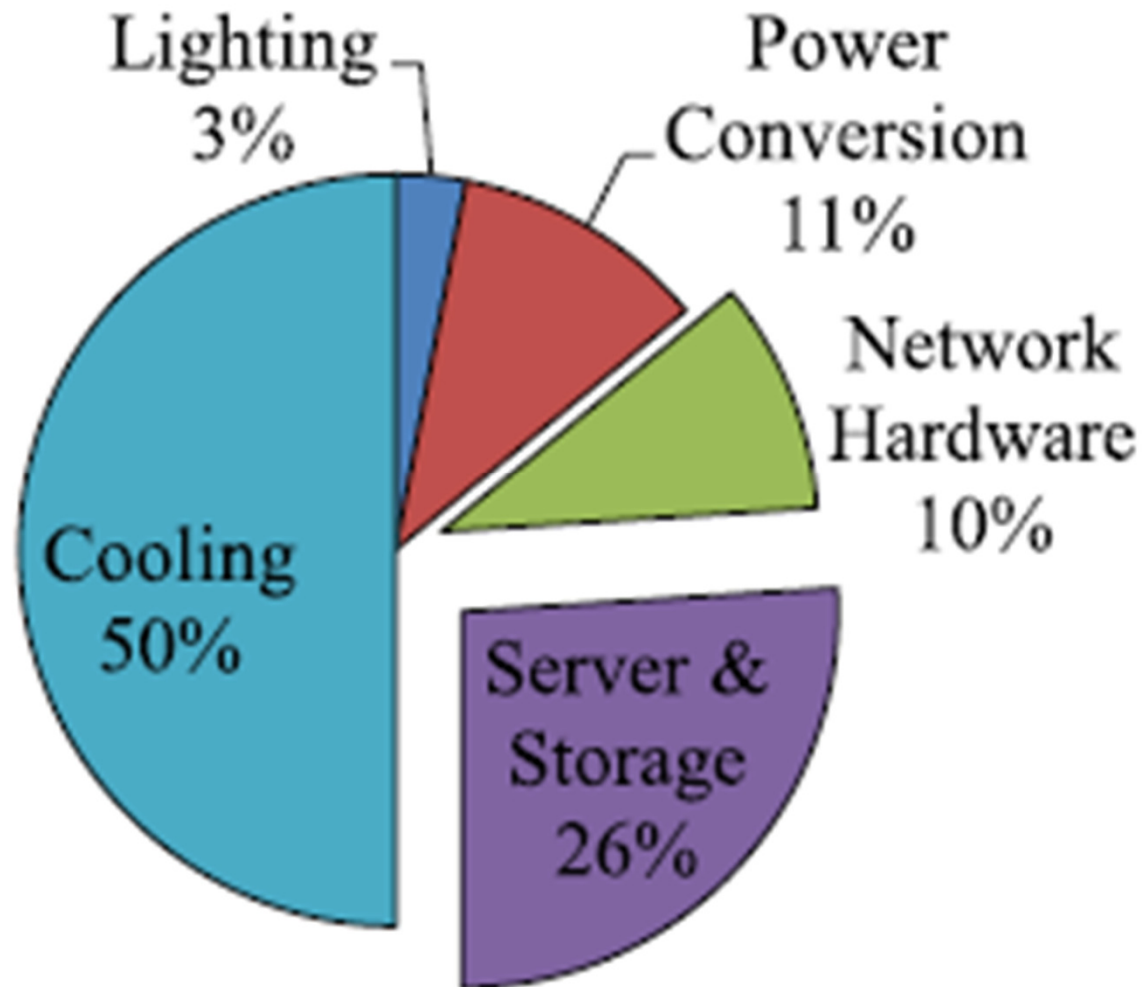
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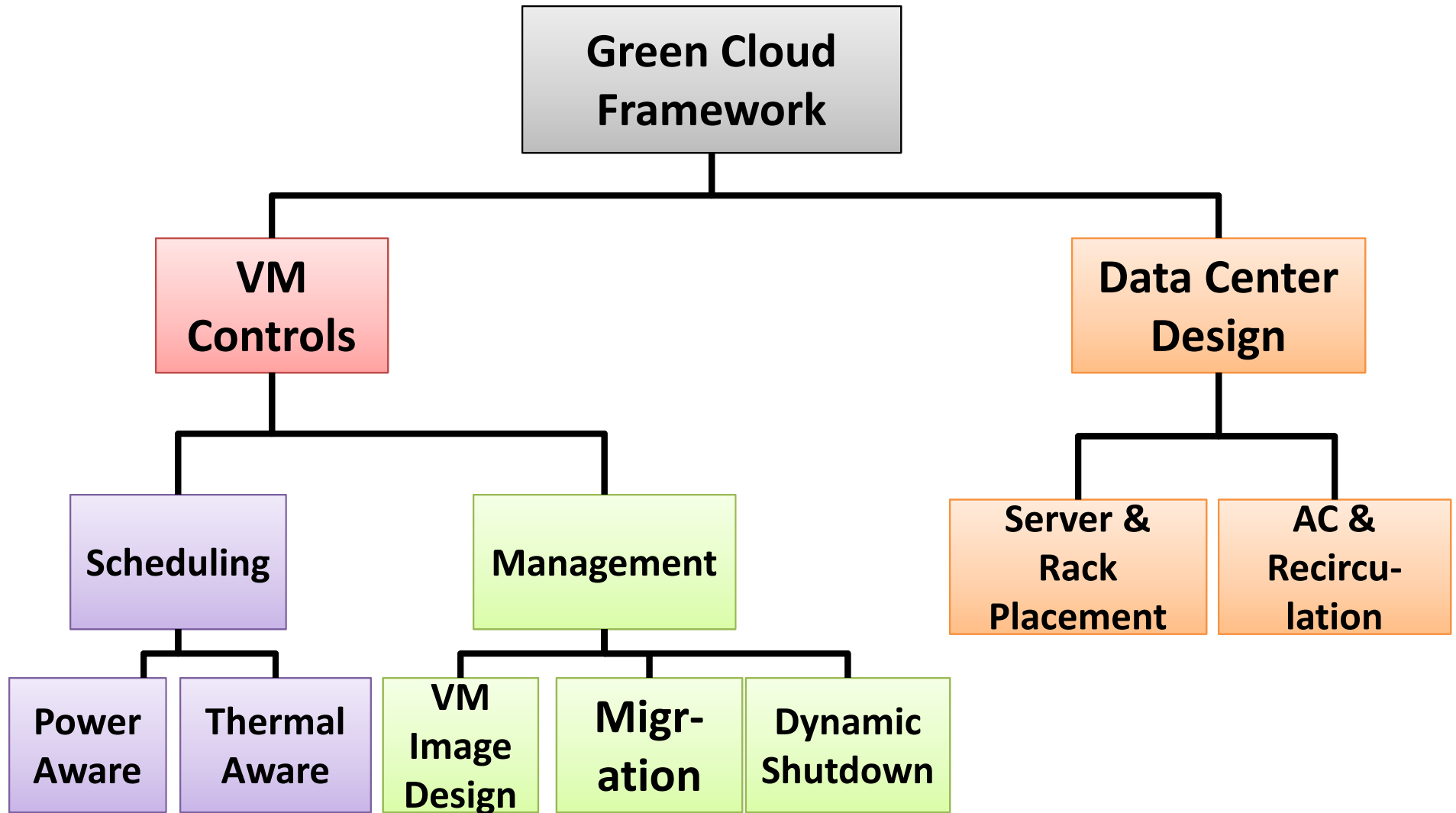
Energy Efficient System: Design and Management

- **Point to consider**
 - ✓ Energy efficient Infrastructure
 - ✓ Energy Model of Infrastructure
 - Blades/Server Machine CPU, Memory
- 1. Energy Efficient Scheduling**
 - How to manage the Jobs

Percentage of Power Consumption in DC



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

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.

Power Aware Computing

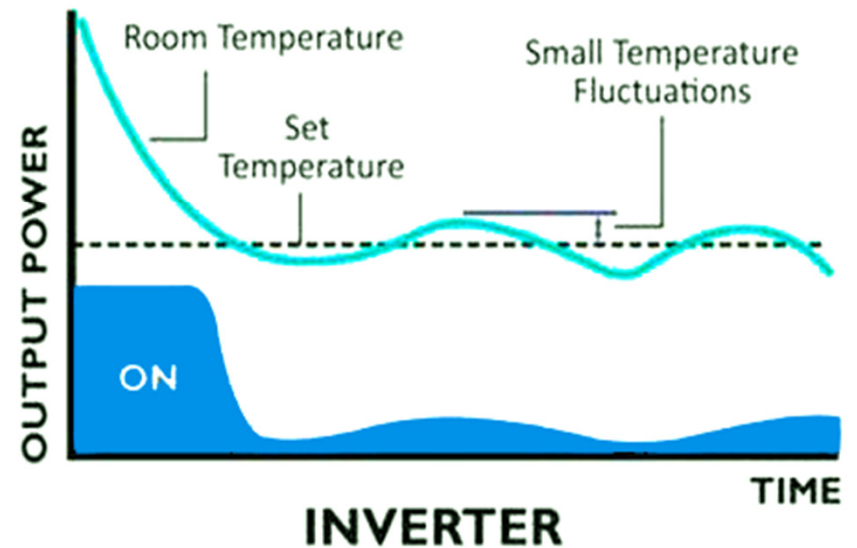
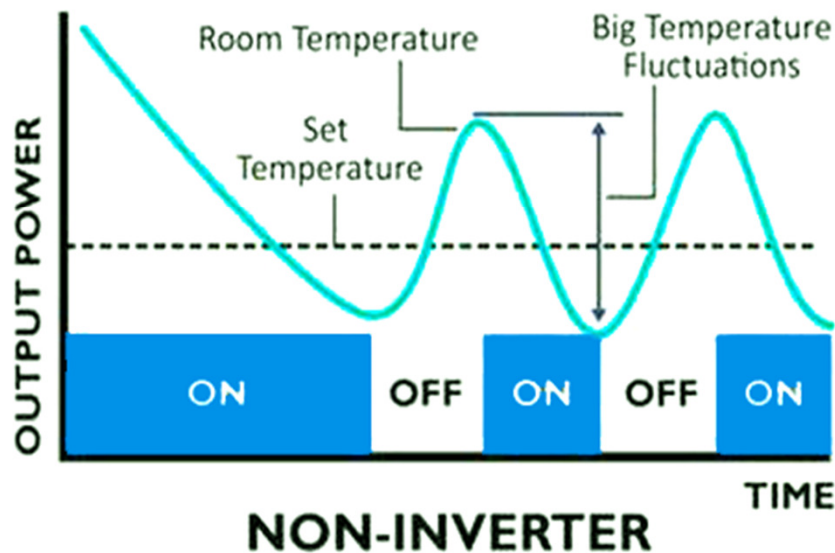
- System level power management
- Recent devices support **multiple power modes**.
 - CPU, disk, communication links, etc.
- **Resource Management and Scheduling Systems**
 - Can use these multiple power modes
 - To reduce the power consumption.

Real Life Issue: Inverter AC

- Inverter AC vs Non-Inverter AC
- Non-Inverter AC : Run fast and rest
- Non-Inverter AC: switch-of and switch-on mode
 - Sound, Fan on-off
- Inverter AC : Quit and required
 - Run at required speed : **Fun to compare with EMI**
 - Quieter than a mosquito

Real Life Issue: Inverter AC

- Eco Friendly, less power consumption
- Makes little sound, Efficient Cooling/Heating
- No Voltage Fluctuation caused by compressor
- Can be run on solar panels



DPM vs DVFS

- Inverter AC vs Non-Inverter AC
- Non-Inverter AC : Run fast and rest
- DPM : switch-of and switch-on mode
 - Sound, Fan on-off
- DVFS : Quit and required mode
 - Quieter than a mosquito
 - Run at required speed

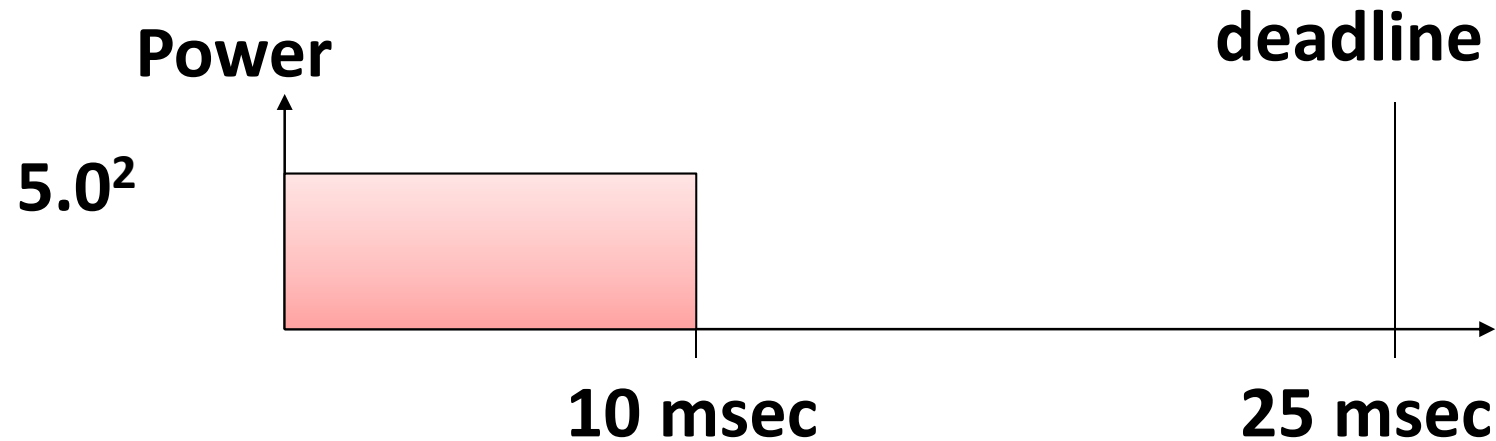
DVFS

- Dynamic Voltage and Frequency Scaling
 - Intel SpeedStep
 - AMD PowerNow
- Started in laptops and mobile devices
- Now used in servers

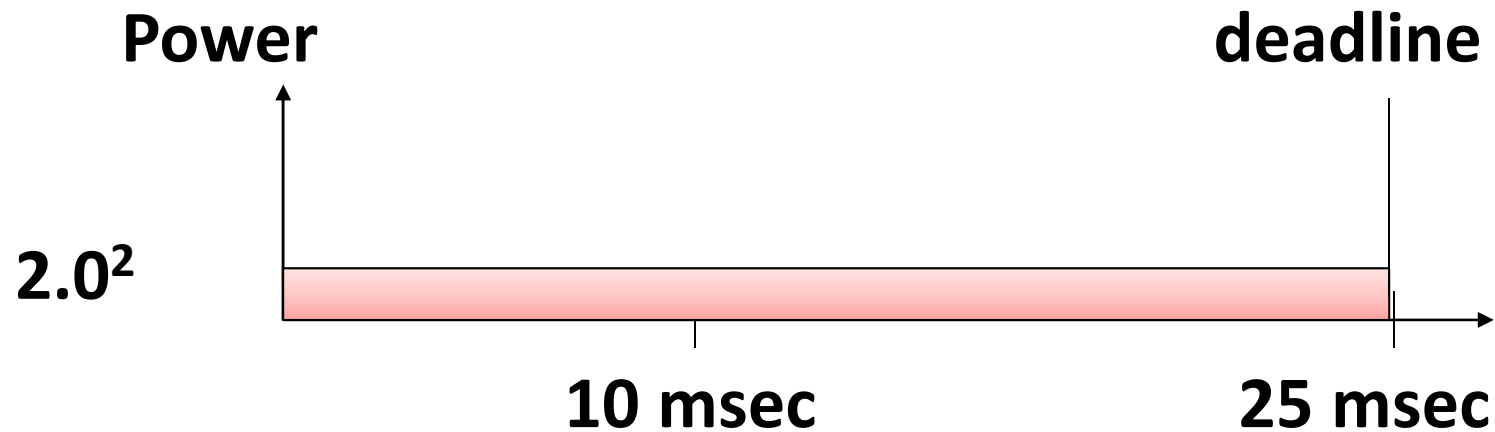
DVS (Dynamic Voltage Scaling)

- Reducing the dynamic energy consumption
 - By lowering the supply voltage at the cost of performance degradation
- Recent processors support such ability
 - To adjust the supply voltage dynamically.
- The dynamic energy consumption
 - $\alpha * V_{dd}^2 * N_{cycle}$
Vdd : the supply voltage, Ncycle : the number of clock cycle

DVS (Dynamic Voltage Scaling)



(a) Supply voltage = 5.0 V



(b) Supply voltage = 2.0 V

DVFS-based Power Aware Scheduling :

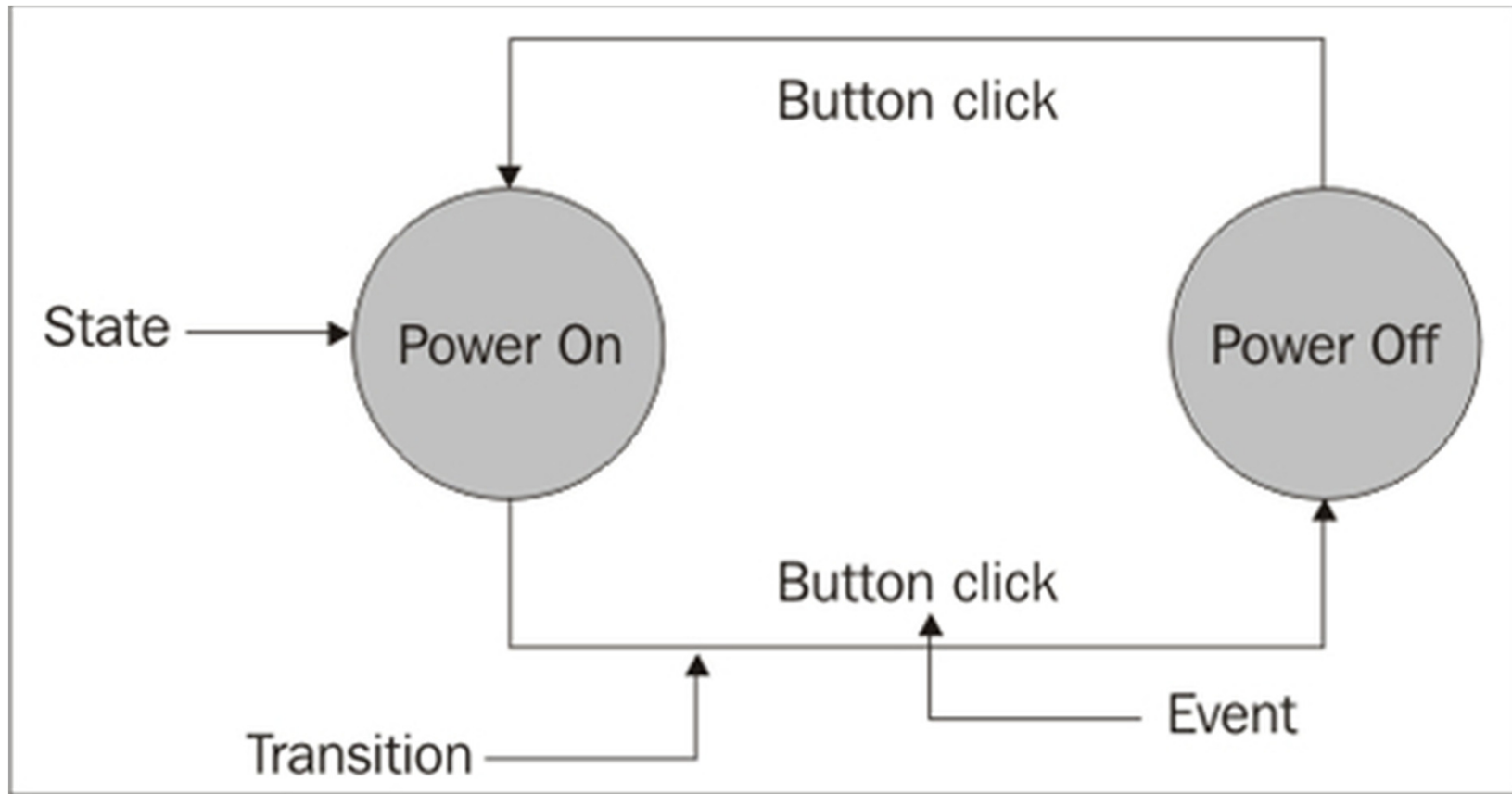
Motivation

- Develop Resource Management and Scheduling Algorithms
 - That aim at minimizing the energy consumption
 - At the same meet the job deadline.
- Exploit industrial move towards
 - Utility Model/SLA-based Resource Allocation for Cloud Computing

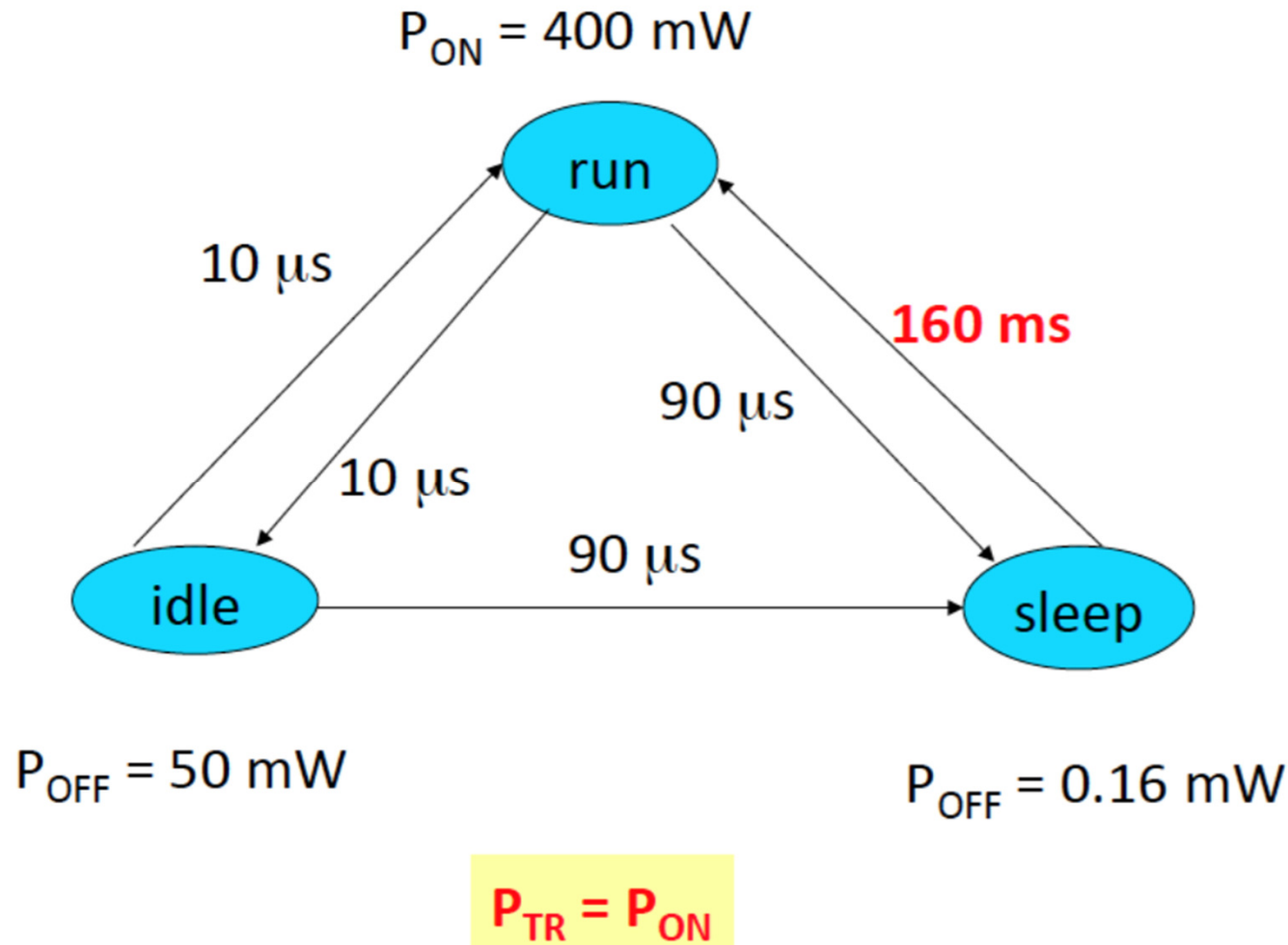
Static PM vs Dynamic PM

- Static PM
 - Invokes by user does not depends on user activities
 - Power down mode: c0, c1, ...cm
 - Off, dose, nap, sleep, run
 - Mode exit upon receiving an interrupt
 - Power State machine
- Dynamic PM
 - Control power based on dynamic activity in CPU
 - Dynamically change freq, shut some parts
 - **Do when in Run State**

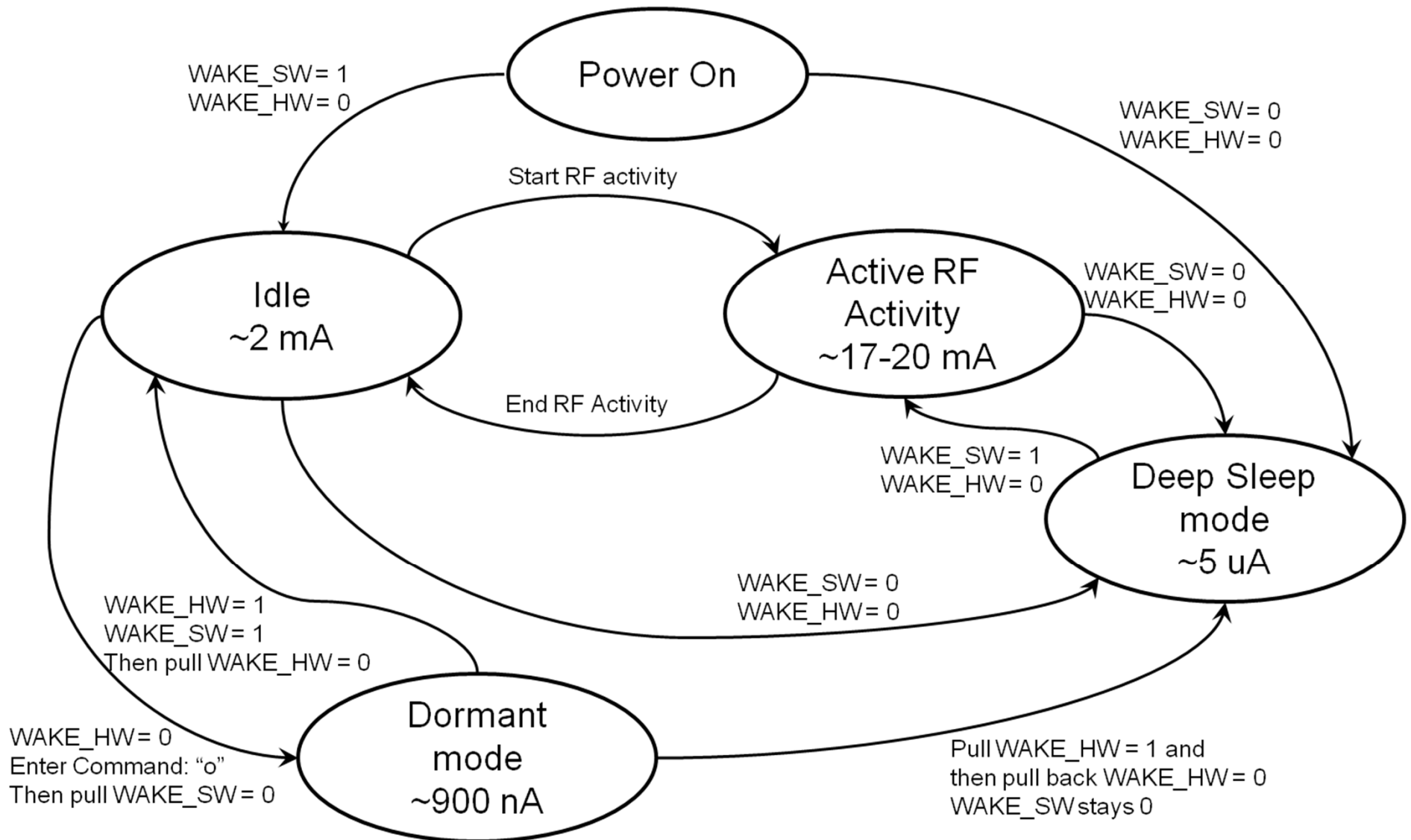
Static PM with Power States



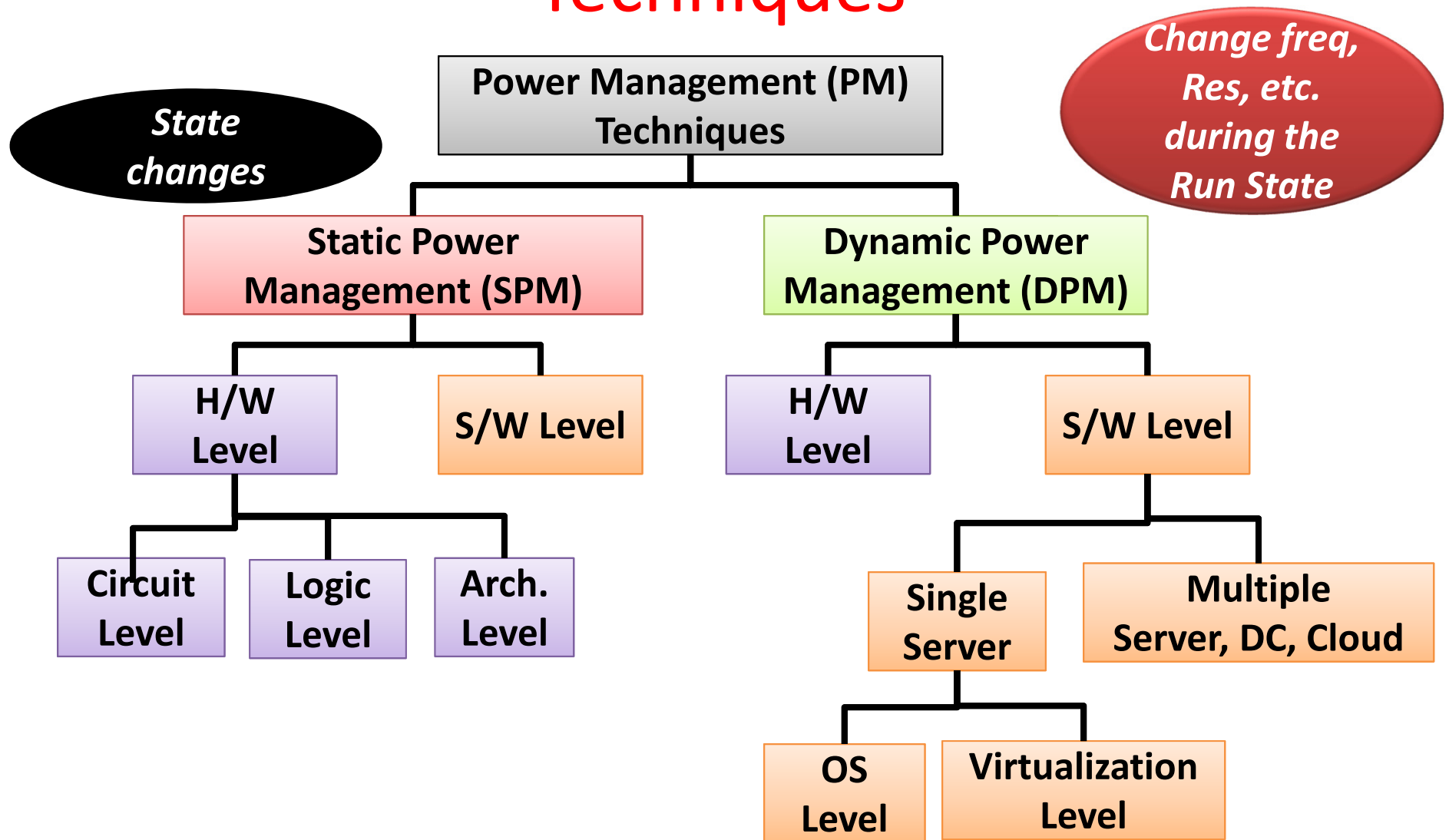
Static PM with Power States



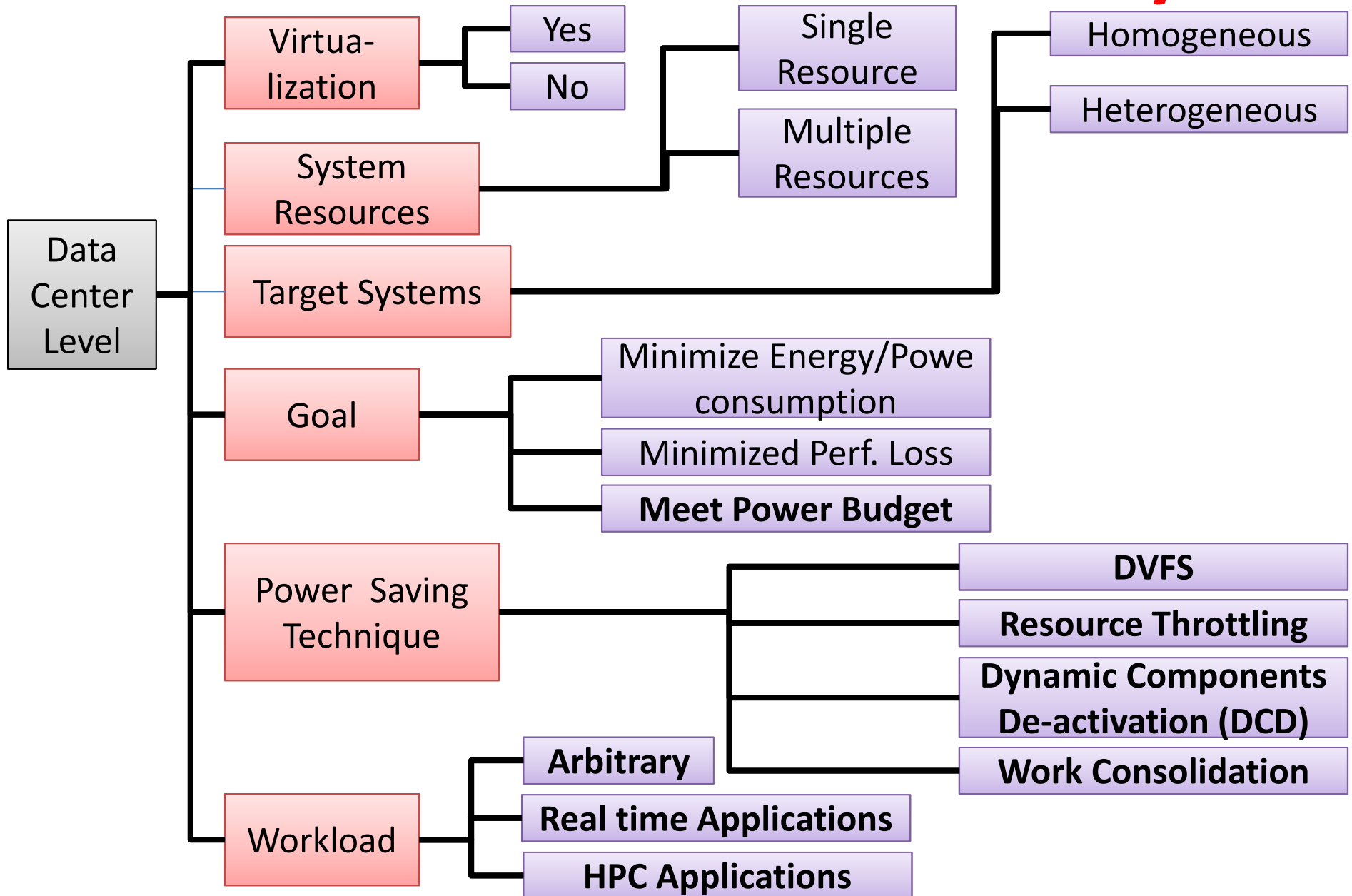
Static PM with Power States



Taxonomy of Power Management Techniques



Data Center Level : Taxonomy



Throttling Vs Over clocking

- Throttling
 - to hold somebody tightly by the throat and stop him/her breathing
 - Put a cut-off mark: Example car governor
 - Some thing going wrong: reduce activity
 - **Thermal/Power Throttling**
- Overclocking (If necessary): Turbo Boost
 - Put maximum doable afford
 - Run at maximum speed
 - Urgency to do more work

Cloud Providers EC Measures

- Cloud service: profit margin is reduced due to high energy costs
- Amazon.com's estimate EC data centres
 - Amount to 42% of the total budget
 - Direct power consumption and cooling infrastructure
 - Amortized over a 15-year period.

Cloud Providers EC Measures

- Google, Microsoft, and Yahoo built Large DCs
 - in barren desert land surrounding the Columbia River, USA
 - to exploit cheap hydroelectric power.
- Increasing pressure from Governments worldwide
 - to reduce carbon footprints, which significant impact on climate change
 - **Carbon Tax on industries**

Green Computing

- Performance/Watt is not following Moore's law.
- Advanced scheduling schemas to reduce energy consumption.
 - **Power aware, Thermal aware**
- Data center designs to reduce Power Usage Effectiveness.
 - **Cooling systems,**
 - **Rack design**

Research Opportunities

- There are a number of areas to explore in order to conserve energy within a Cloud environment.
 - Schedule VMs to conserve energy.
 - Management of both VMs and underlying infrastructure.
 - Minimize operating inefficiencies for non-essential tasks.
 - Optimize data center design.

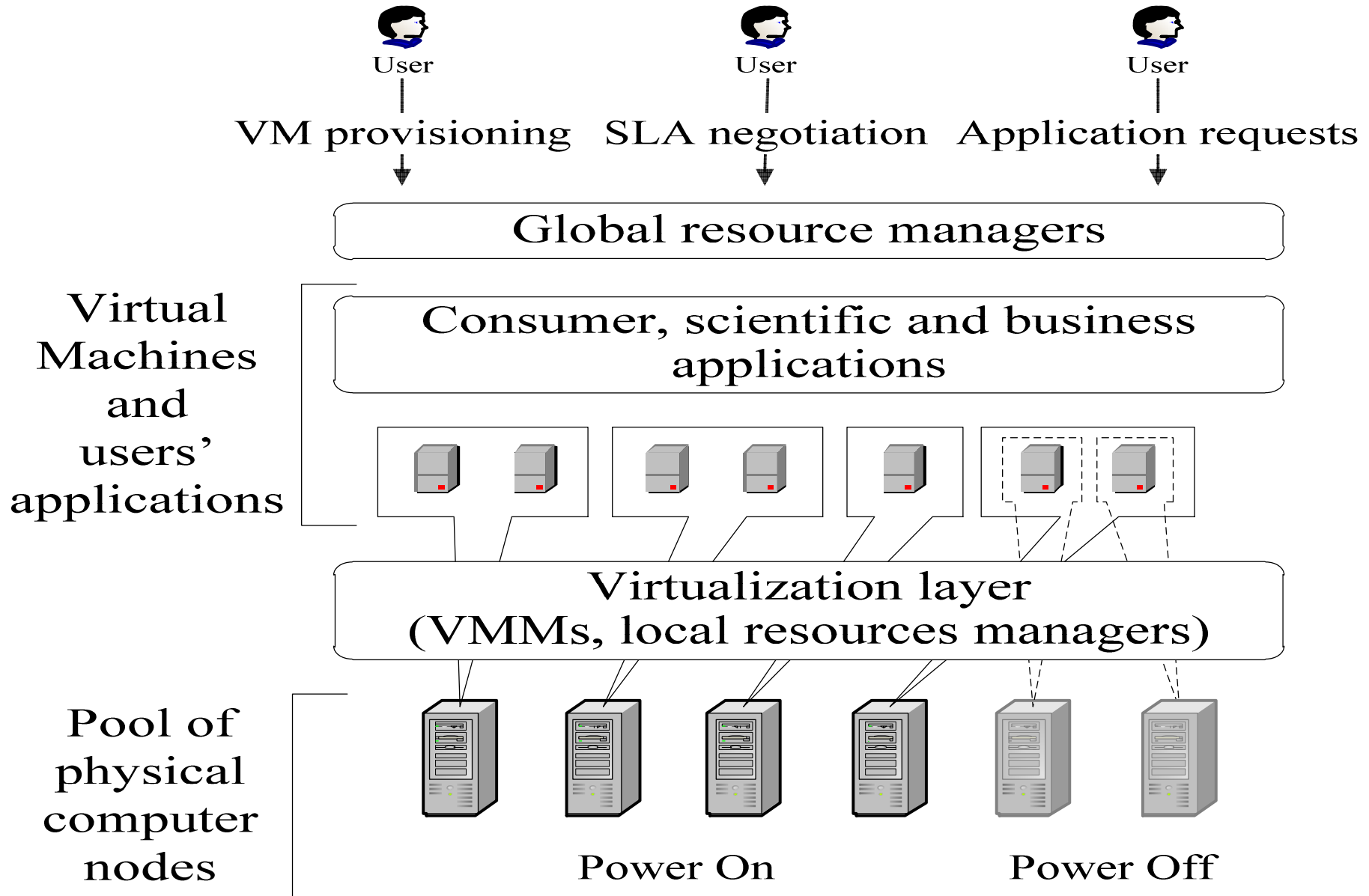
“Power-Aware” Algorithms

- Host overload detection
 - Adaptive utilization threshold based algorithms
 - Regression based algorithms
- Host underload detection algorithms
 - Migrating the VMs from the least utilized host

“Power-Aware” Algorithms

- VM selection algorithms
 - Minimum Migration Time policy (MMT) : **Select VM with small size, so that MT will be minimum**
 - Random Selection policy (RS)
 - Maximum Correlation Policy (MC) : effective VM
- VM placement algorithms
 - **Where to put the selected VMs on the Machines**
 - Heuristic for the bin-packing problem
 - Power-Aware Best Fit Decreasing algorithm (PABFD) : for the current selected VM, choose the best PM for power saving

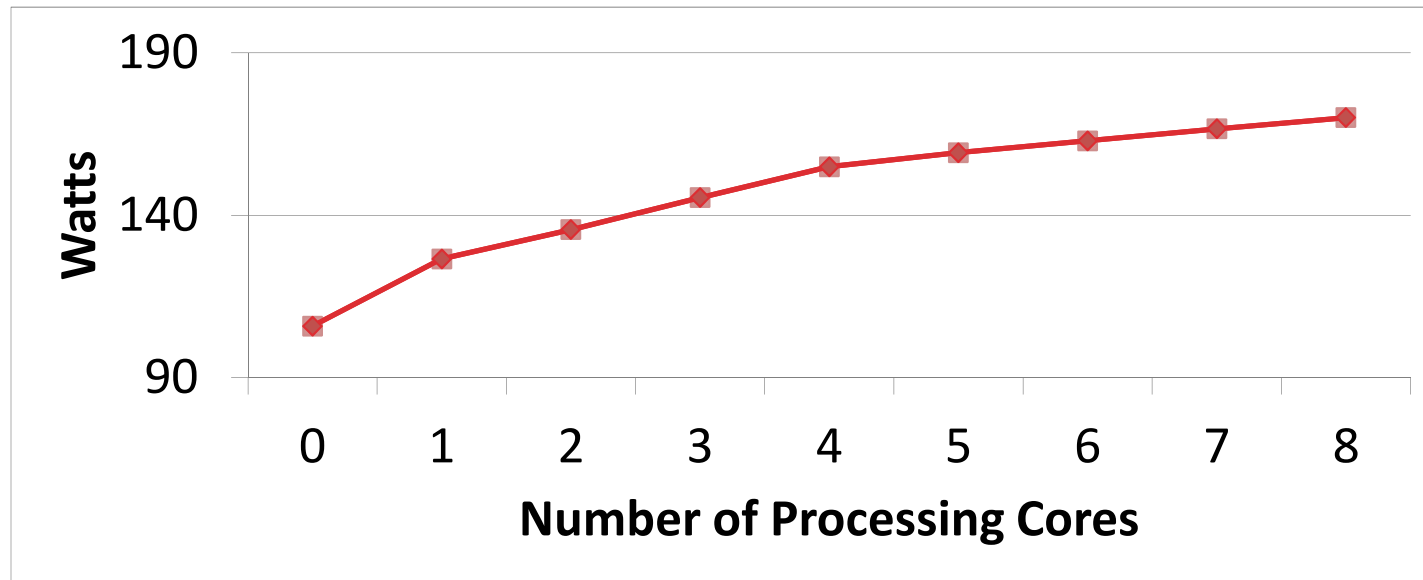
Dynamic VM Consolidation



Three Sub-Problems

- When to migrate VMs?
 - Host overload detection algorithms
 - Host underload detection algorithms
- Which VMs to migrate?
 - VM selection algorithms
- Where to migrate VMs?
 - VM placement algorithms

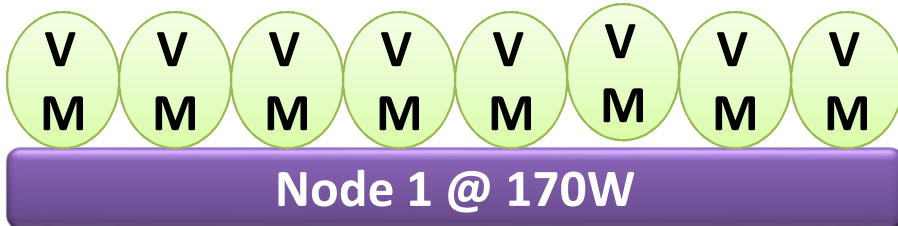
VM scheduling on Multi-core Systems



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

- Nonlinear relationship between the number of processes used and power consumption
- We can schedule VMs to take advantage of this relationship in order to conserve power

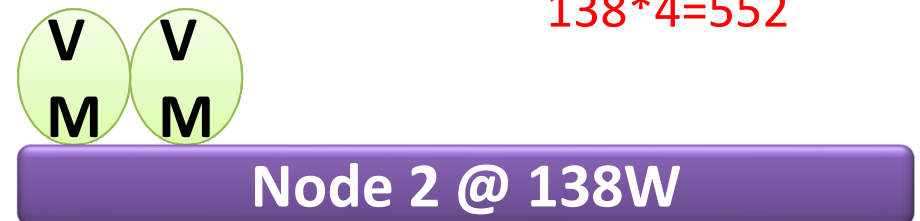
485 Watts vs. 552 Watts



$$105 \times 3 + 170 = 485$$



vs.



$$138 \times 4 = 552$$



VM Management

- Monitor Cloud usage and load.
- When load decreases:
 - Live migrate VMs to more utilized nodes.
 - Live Migration: Service of the VM is undisrupted during migration (in case of web/db/file server)
 - At the time of migration: service continues at both Source and Target
 - Grace full Migration: Suppose you want to shift your shop from IITG CORE I to CORE V, First get Space at CORE V, Start Service from CORE V, after some time Stop Service at CORE I
 - Shutdown unused nodes.
- When load increases:
 - Start up waiting nodes.
 - Schedule new VMs to new nodes.

