CS528
Cloud System Economic Model
&
Energy Consumption Model

A Sahu

Dept of CSE, IIT Guwahati

Outline

- Cloud Economic Model
  - CAPEX, OPEX
  - Energy Cost
- Cloud (DC) Energy Model

In Compute System Model

- CAPEX : Cost of the System + Places
- OPEX : Operational Cost
  - Energy Cost, Cooling Cost (significant)
- How to Reduce OPEX
  - **Energy Efficient Scheduling of JOBs to machines**
  - **Efficient Cooling of System**
  - **Next some lecture will be based on this**
- **Many house designs are Energy Efficient**
  - **Get good natural lighting at day time for all the rooms**
  - **Design for proper ventilation: AC/Fan requirement is less**

IIT Guwahati HPC Example

- Capital Expenditure CAPEX (Rs 12 Crores)
  - 12 Crores for 3800 processors HPC System
    - 3-5 Year Life time, Need to be upgraded after 5 year
  - Space and AC Cost : 1 Crores
- Operational Cost OPEX
  - Electricity 50 Lakhs/Annum
  - AMC to OEM : 1.5 Crores/Annnum
  - Software 1 Crores/Annum
- Cost of Computing : 13+5*3=28 Crores/5 Years
- Cost of Computing : 5.6 Crores/Years

IIT Guwahati HPC Example

- Cost of computing : 5.6 Crores/Years
  - Rs 14,736 per CPU Cores/Year
  - Rs 40.37 per CPU Core /Day
  - Rs 1.68 per CPU core/Hour
- https://aws.amazon.com/savingsplans/pricing/
- HPC Service Provide in Cloud Models in India http://www.serc.iisc.ac.in/services/for-non-iisc-users/
  - Rs 1.18 per CPU hour (Academic)
  - Rs 4.72 per CPU hour (Industries)

IIT Guwahati HPC Example

- Cost of computing : 5.6 Crores/Years
  - Rs 14,736 per CPU Cores/Year
  - Rs 40.37 per CPU Core /Day
  - Rs 1.68 per CPU core/Hour
- https://aws.amazon.com/savingsplans/pricing/
- https://www.cloudoye.com/cloud-hosting-plan
- HPC Service Provide in Cloud Models in India http://www.serc.iisc.ac.in/services/for-non-iisc-users/
  - Rs 1.18 per CPU hour (Academic)
  - Rs 4.72 per CPU hour (Industries)

IIT Guwahati HPC Example

- Cost of computing of IITG HPC
  - 5.6 Crores/Years
- Instead by taking Rent from IISc Cloud
  - Rs 1.18 per CPU hour (Academic)
  - Rs 3.92 crores /Year for 3800 CPU per year
  - **IIT G could have Save 1.7 crores**
- Many Cloud provider offer at lesser price
  - Rs 0.6 per CPU hours
  - Rs 1.96 crores /Year for 3800 CPU per year
  - Instead of Spending 5.6 crores at IITG

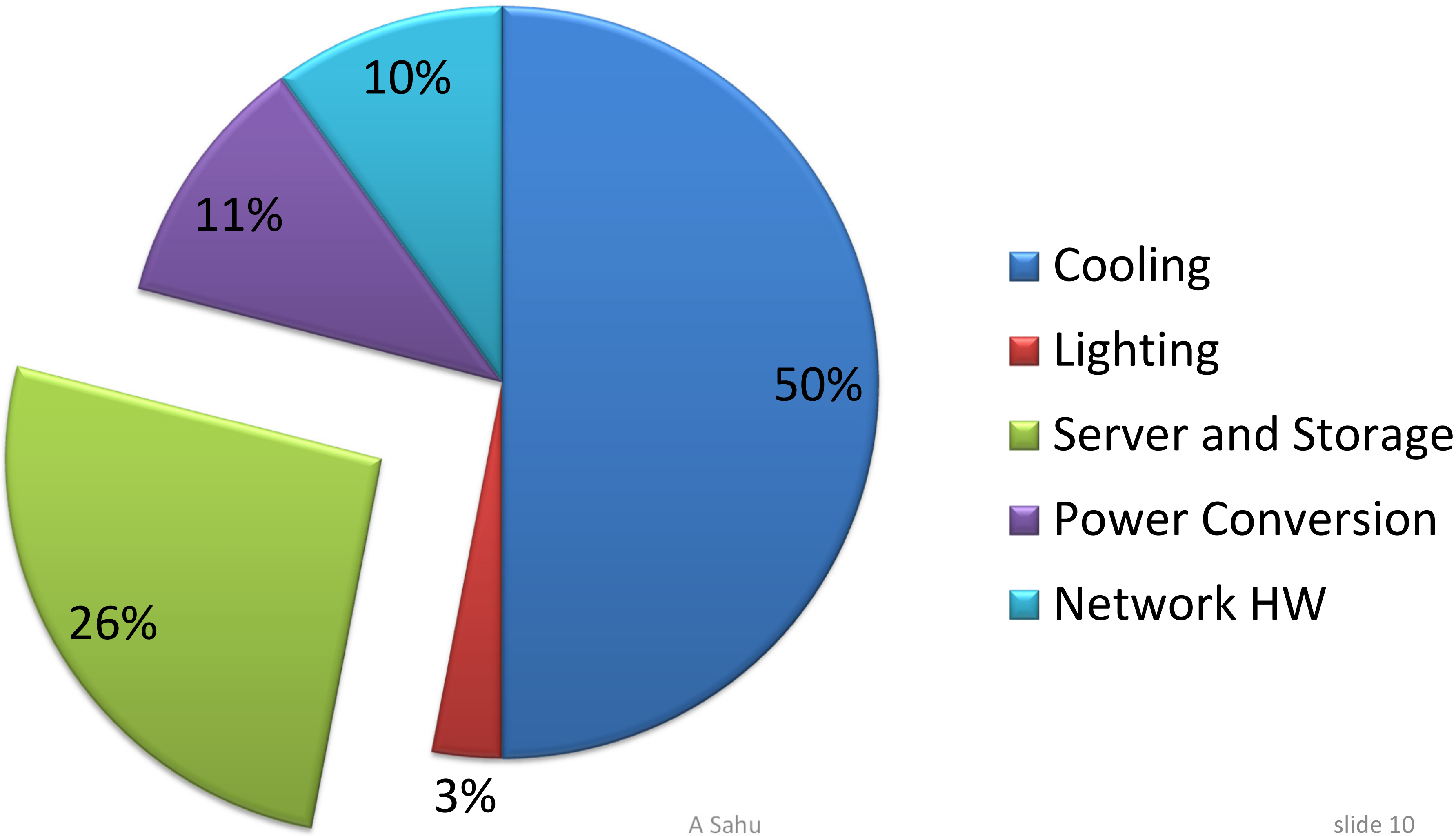
How CPU hour from cloud provider can be cheaper?

- Same as Reebok Shoes is cheaper in Amazon.in/Flipkart.com as compared to Showrooms of the City
  - No show room for Amazon/Flipkart, save a ton in CAPEX
  - No AC, Electricity for Showroom: save OPEX
  - Store room can be at Remote Places where cost of land is low
  - **Website and delivery : mass scale cheaper**

How CPU hour from cloud provider can be cheaper?

- Same as Reebok Shoes is cheaper in Amazon.in/Flipkart.com as compared to Showrooms of the City
- Get the product from company in Bulk,
  - eligible for higher discount from Manufacturer : reduced supply chain
- For most of the Item
  - **Manufacturing cost is around 14%-22% of MRP**
  - **Company spend a lot in Advt (15-25%), and Supply chain**
  - **Bulk purchase : up to 50% of MRP**

Energy Consumption Breakdown of Data Center



How to Reduce compute cost IIT Guwahati

- Capital Expenditure CAPEX (Rs 12 Crores)
- 12 Crores for 3800 processors HPC System
  - **Sol : Bargain with OEM not with middle man: deal could have in 8-9 crores**
- Space and AC Cost : 1 Crores
  - **Sol : Get a remote cheaper and Cooler location, may be in Tawang, AP**
  - **AC consume huge amount of Power ☺ ☺**
  - **Fun: "Google INC have put CLOUD System in the SEA"**

How to Reduce compute cost IIT Guwahati

- Operational Cost OPEX : 3 Crores/Annum
- Electricity 50 Lakhs/Annum
  - **Use Green Energy, solar, wind, etc.**
  - **Good Scheduler to reduce Energy**
- AMC to OEM : 1.5 Crores/Annnum
  - **Most Significant OPEX cost**
  - **Sol: Train your own man power to do the AMC instead of giving to third party**
    - **Example: Cost of repairing at OEM service center is costly. Get pricing feedback of service at OEM service center**
- Software 1 Crores/Annum :
  - **Shared license with others**

Cloud Computing Economic Benefits

- Most identifiable economic benefit of cloud computing is
  - direct cost savings, which occur from changes within the organization and the data centers that house the IT infrastructure.
  - **Supply Side – Large scale data centers lower cost due to superior buying power**

Cloud Computing Economic Benefits

- Other economic benefit of cloud
  - Demand Side – Allowing multiple users across varying industries regions & time zones allowing for server utilization
  - **Multi-user efficiency – Increasing # of users lowers server cost per tenant**
  - **Data center efficiency – Advanced data center designs reduce power loss and improved cooling**

Energy Efficient System: Design and Management

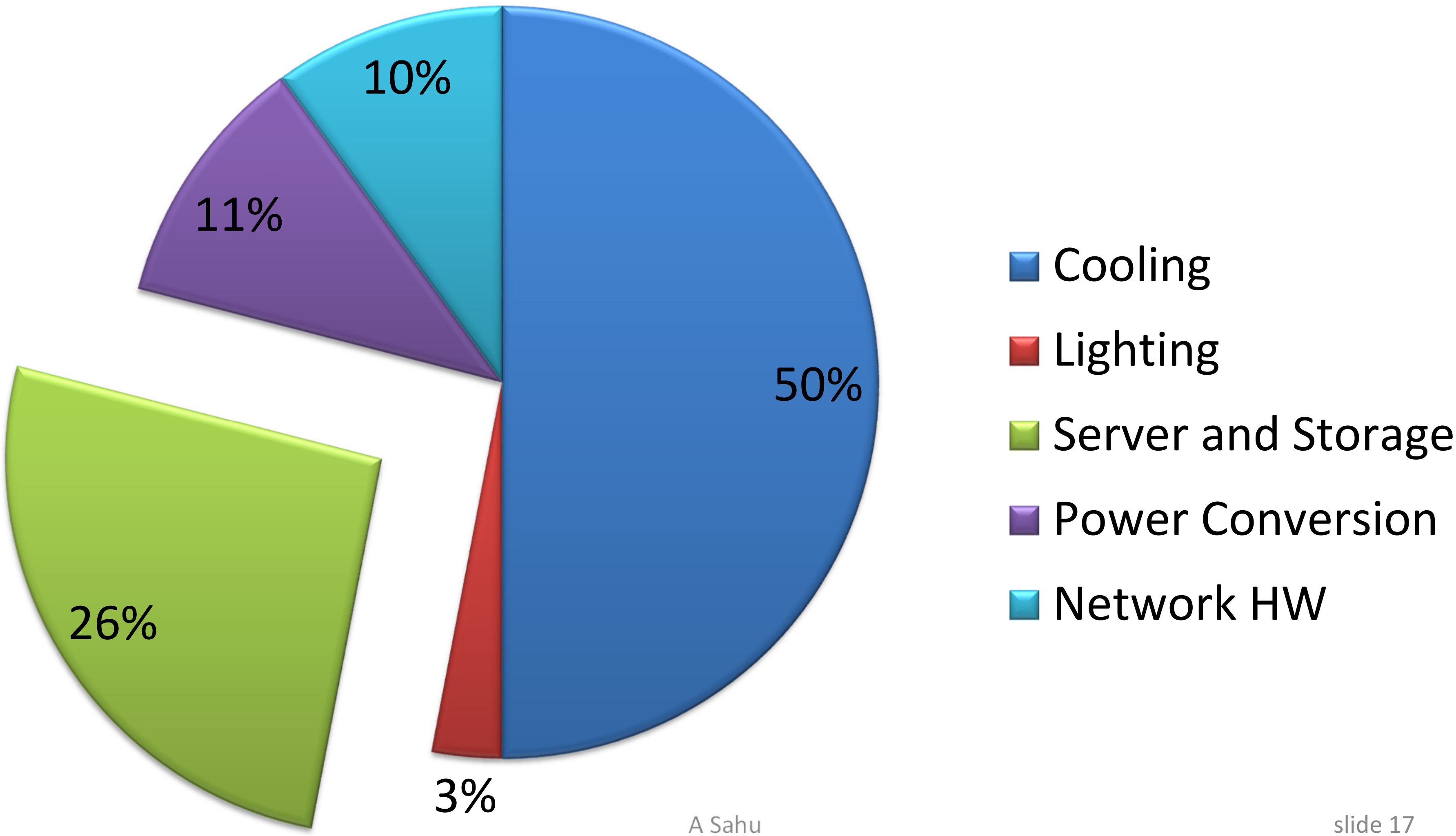
- **Point to consider**

1. Energy efficient Infrastructure
2. Energy Model of Infrastructure
   - Blades/Server Machine CPU, Memory
3. Energy Efficient Scheduling
   - How to manage the Jobs

Data Center Energy Consumption Modeling

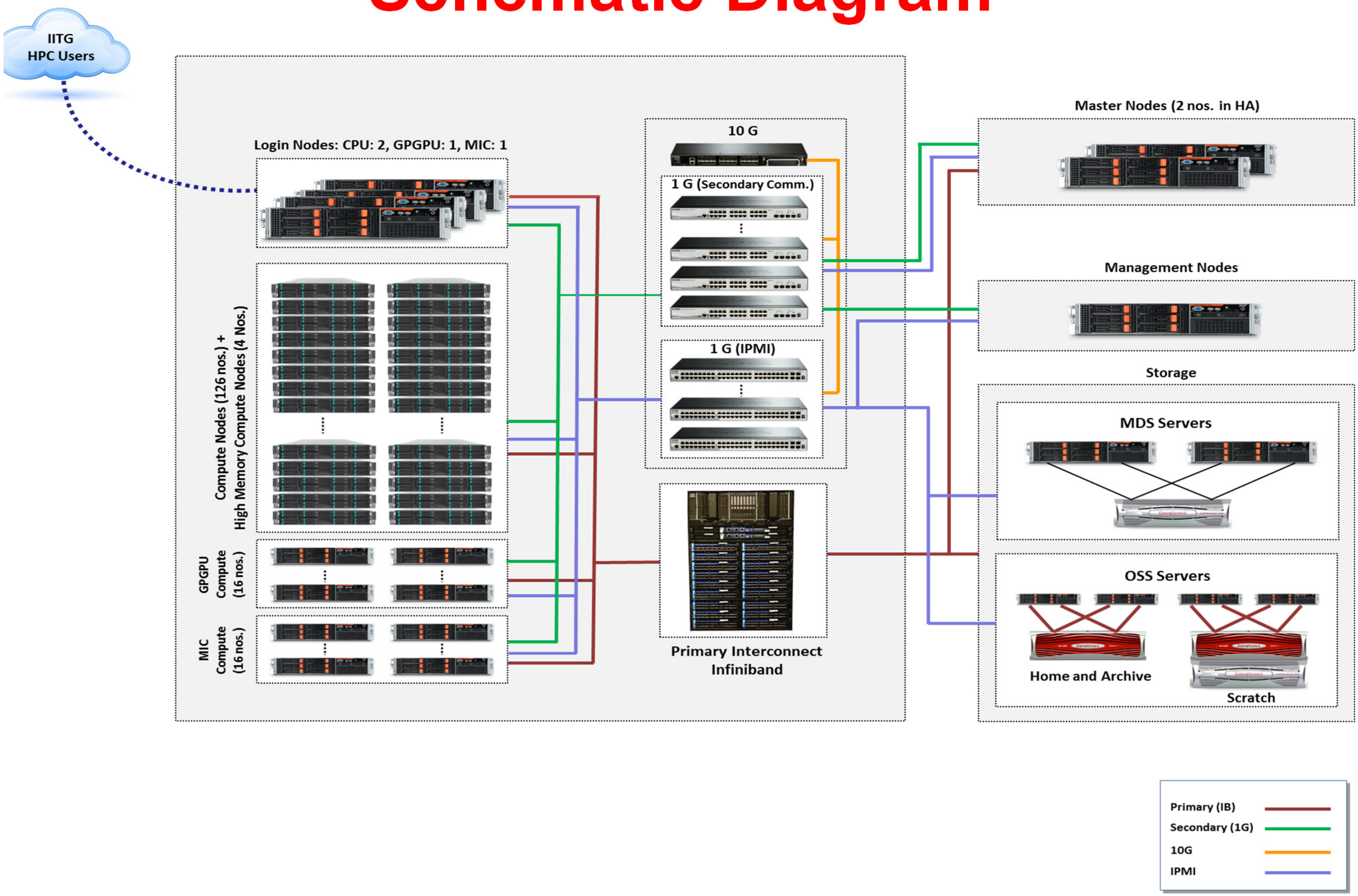
Ref: Dayaratna et. al., IEEE Comm. Survey, 2016

Energy Consumption Breakdown of Data Center

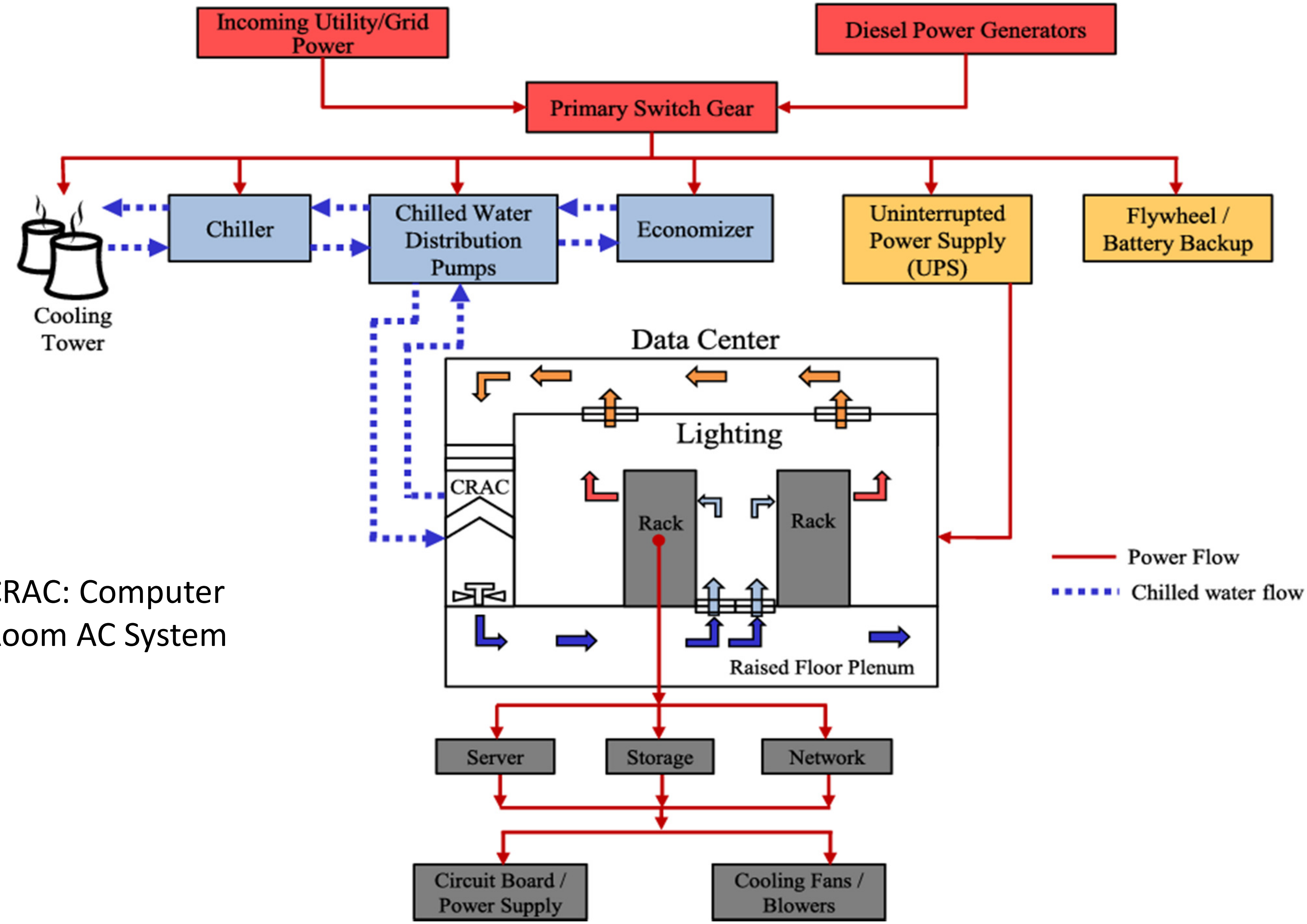


PARAM ISHAN

Schematic Diagram



Power Flow in typical Data Center



CRAC: Computer Room AC System

Metrics for Data Center Efficiency

- Data energy consumption : IT and Non-IT
- IT Parts
  - Server, Storage and Networking
- Non-IT Parts
  - Cooling, Lighting and Loss Power Conversion and Transmission

Metrics for Data Center Efficiency

- Most widely used DC energy efficiency metric is *Power Usage Effectiveness (PUE)*
- The PUE

$$\eta_{PUE} = \frac{\text{Total data center annual energy}}{\text{Total IT annual energy}}$$

- The term $\eta_{PUE} \geq 1$, since data centers draw considerable amount of power as non-IT power
- A higher PUE : A greater portion electricity spent on cooling and the rest of the infrastructure

Metrics for Data Center Efficiency

- *Data Center Infrastructure Efficiency (DCiE)*

$$\eta_{DCiE} = 1/\eta_{PUE} = \frac{\text{IT Device Power Consumption}}{\text{Total Power Consumption}} \; X \; 100\%$$

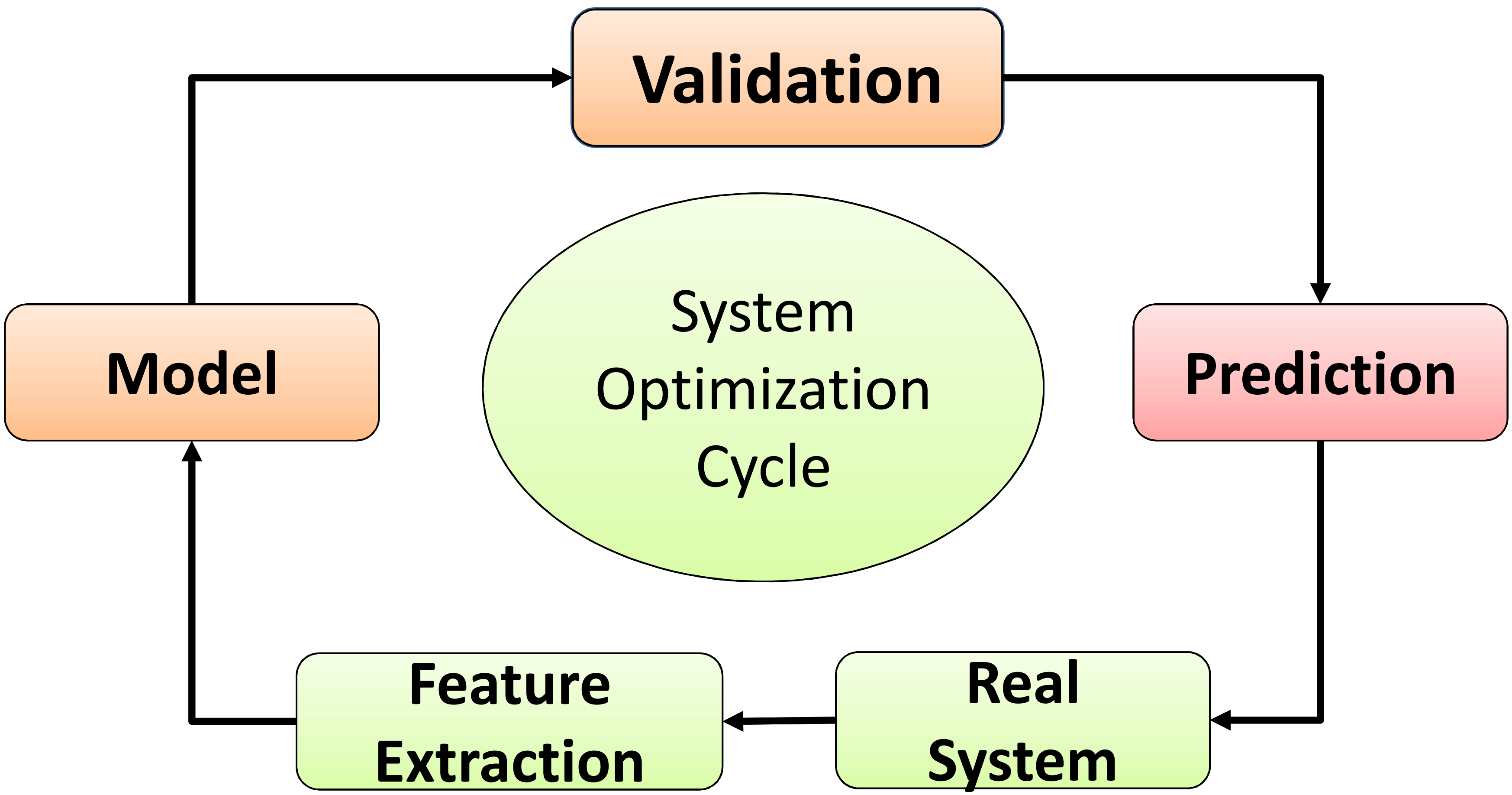
- *Data center Performance Per Energy (DPPE)*

$$\eta_{DPPE} = \frac{Throughput\ at\ Data\ Center}{Energy\ Consumption}$$

- Data Center Green Energy Coefficient

$$\eta_{GEC} = \frac{Energy\ from\ Green\ Source\ (solar, wind, etc)}{Energy\ Consumption}$$

EC modeling and prediction in DC



Organizational Framework for Power Models

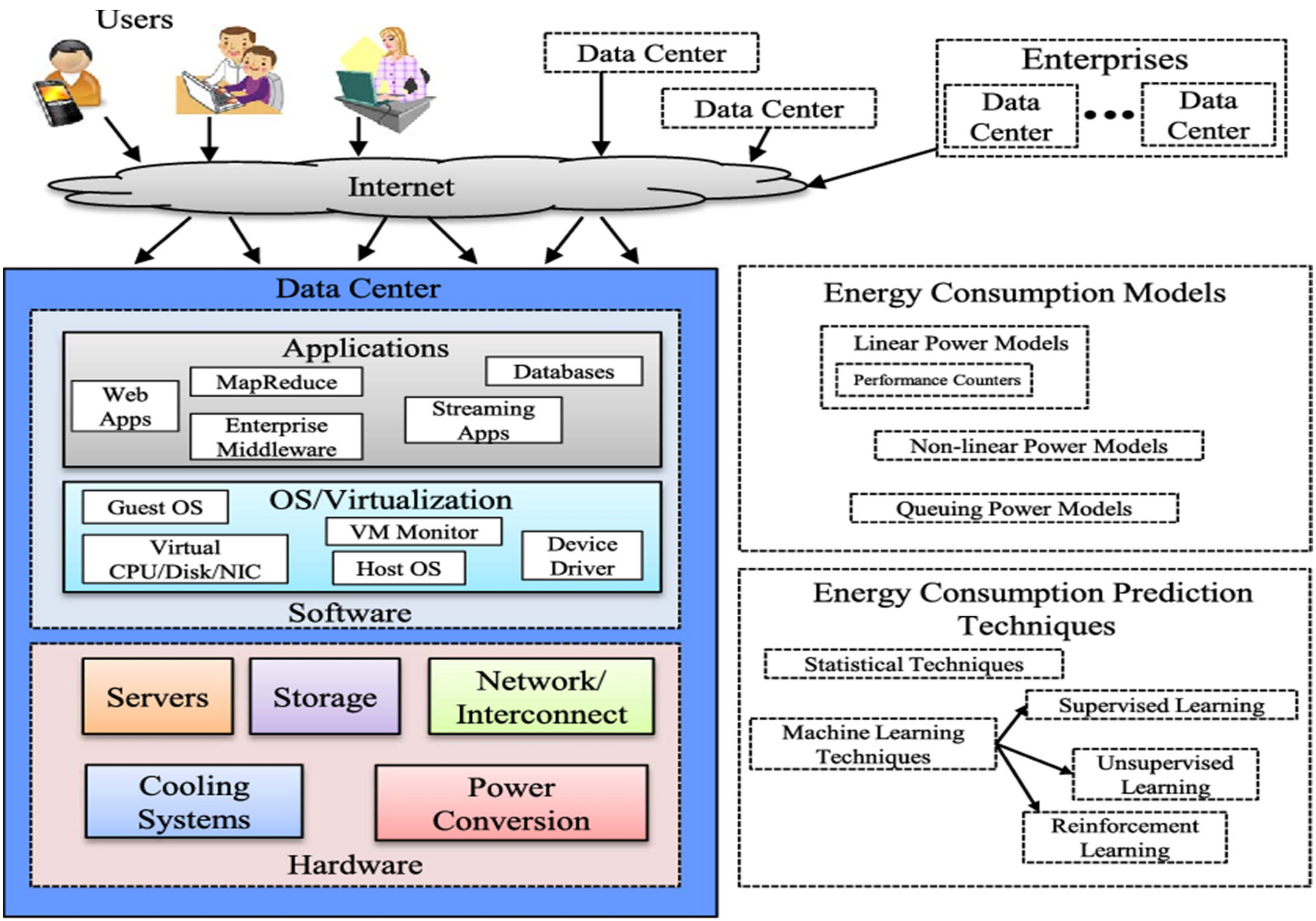
- Instantaneous Power Consumption at time t

  $P_t = f(S_t, A_t, E_t)$
- S_t : internal state at time t
  - Physical HW, OS, Application
  - HW config of processor, amount of mem, disk, NIC
  - Raw power measurement and Perf. CTRs at time t
- A_t : input to application at time t, request rate
- E_t : Execution and Scheduling Strategy
  - Control CPU freq, Power Off/On, Software uses, Apps→Core, Load balancing rule **at time t**,
- Prediction : $P_{t+1} = f(S_t, A_t, E_t)$

EC modeling and prediction in DC

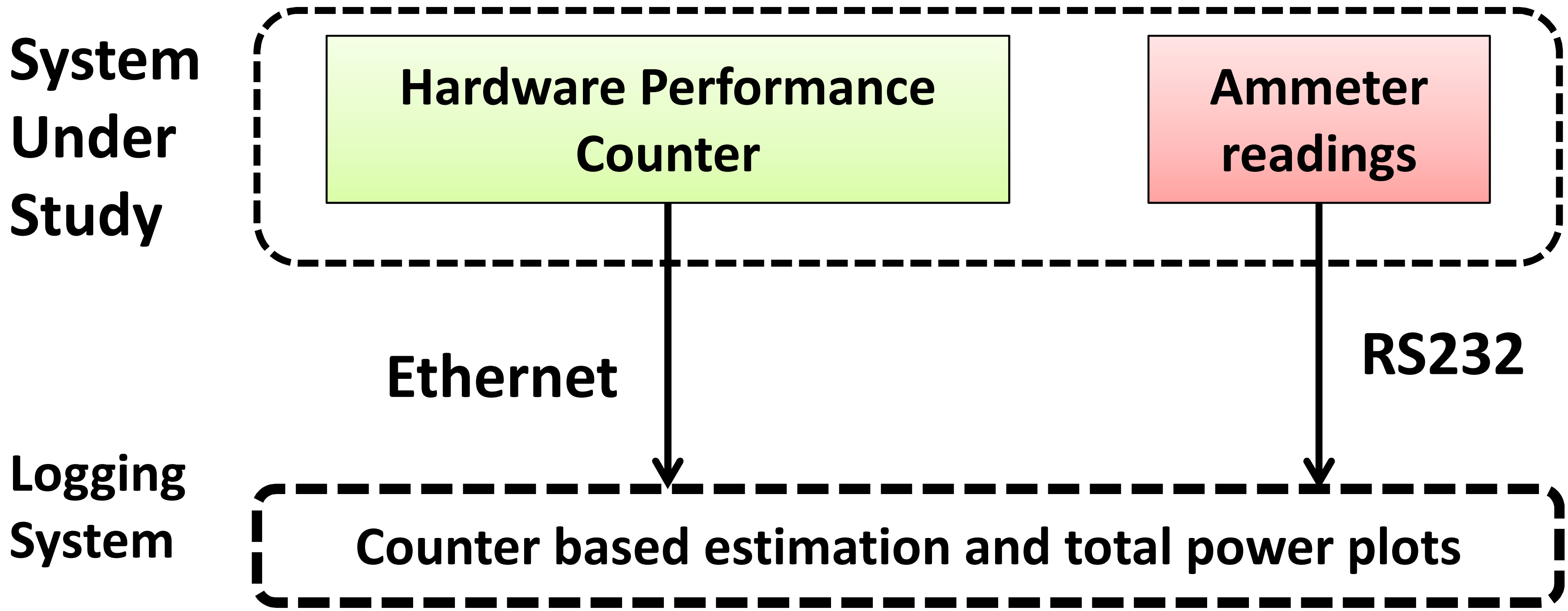
- A systematic view of the energy consumption modeling and prediction process.
- The data center system optimization cycle consists of four main steps
  - feature extraction
  - model construction
  - model validation,
  - and usage of the model.

Holistic view of EC modeling and Prediction in DC



Hybrid Approach for system PC Estimation

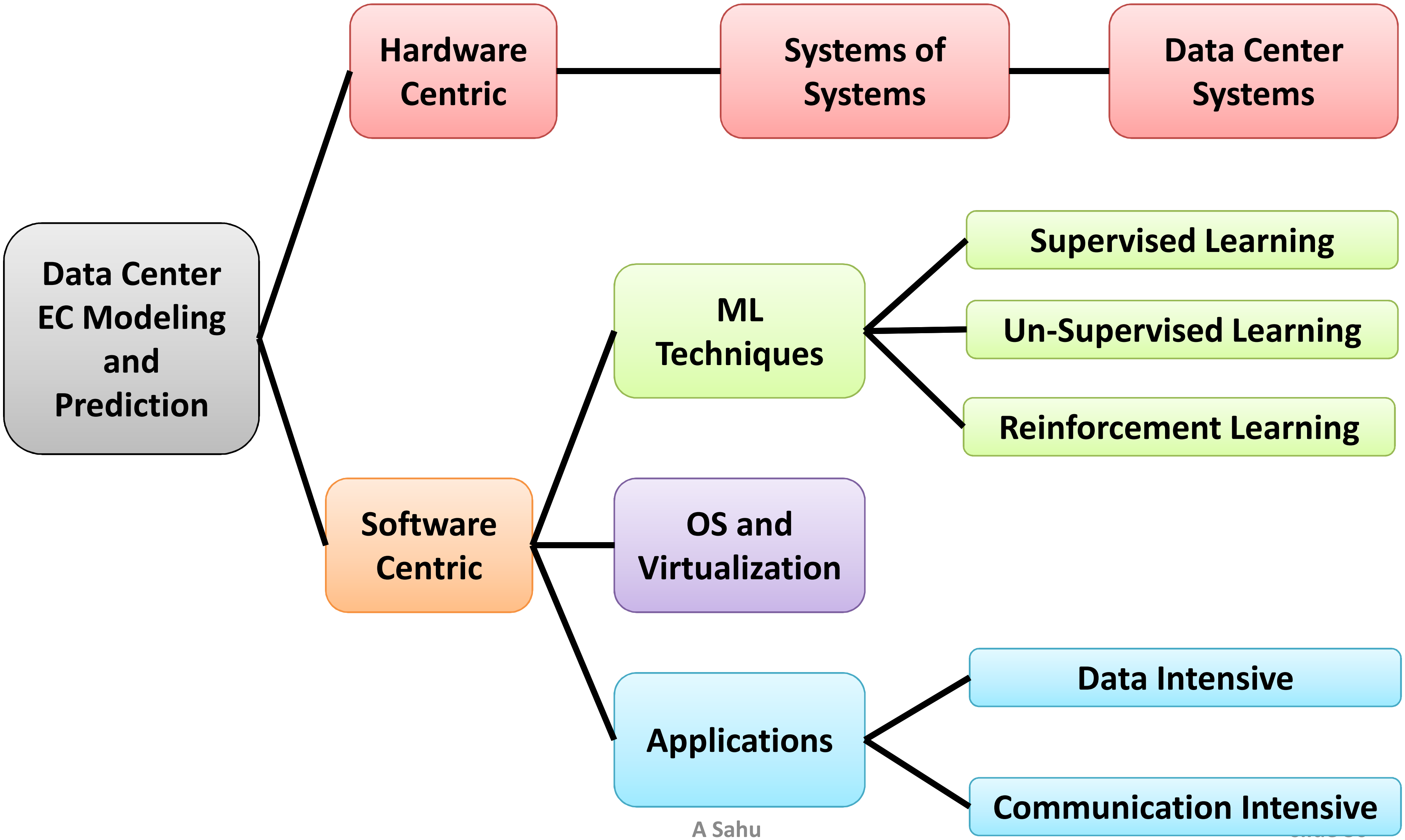
- Performance CTRs and Ammeter Reading
- PC Estimation



Taxonomy of EC Modeling and Pred in DC

- EC Modeling & Prediction in DC
- Software centric
  - ML Technique
    - Supervised/Unsupervised/Reinforcement ML
  - OS/Virtualizations
  - Applications
    - Data Intensive and Compute Intensive
- Hardware Centric

Taxonomy of EC Modeling and Prediction in Data Center



Taxonomy of EC Modeling and Pred in DC

- Hardware Centric: Infrastructure and IT
- Infrastructure
  - Cooling System and Power Conditioning System
- IT
  - Compute Components
    - Group of Server
    - Server: Processor(Single, Multi), Memory, FAN, NIC, Disk (HDD, SDD)
  - Storage
  - Network

Taxonomy of EC Modeling and Pred in DC