CS528
Virtualization and
Cloud System Economic Model

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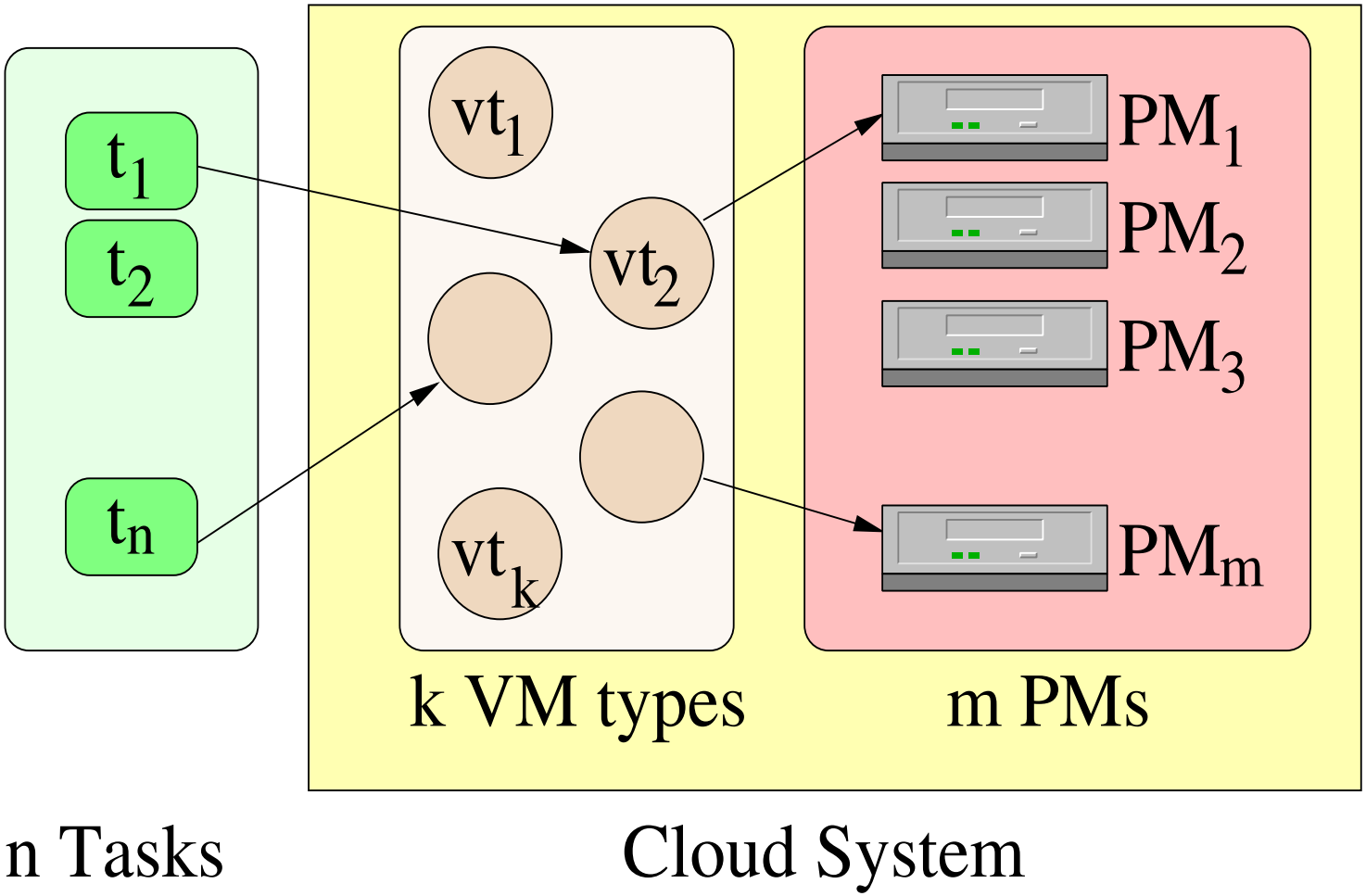
Outline

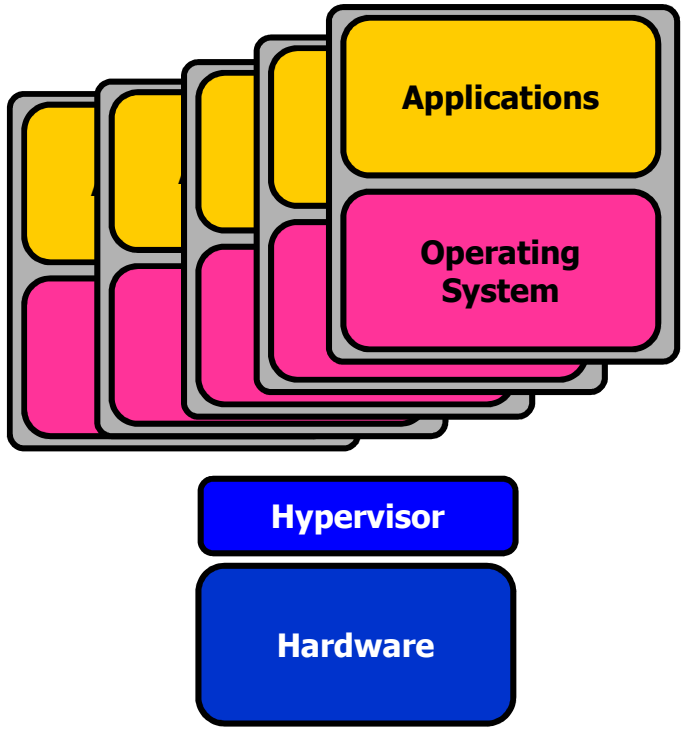
- Virtualization : Driving factors
- Cloud Economic Model
  - CAPEX, OPEX
  - Energy Cost

Logical view of Cloud System



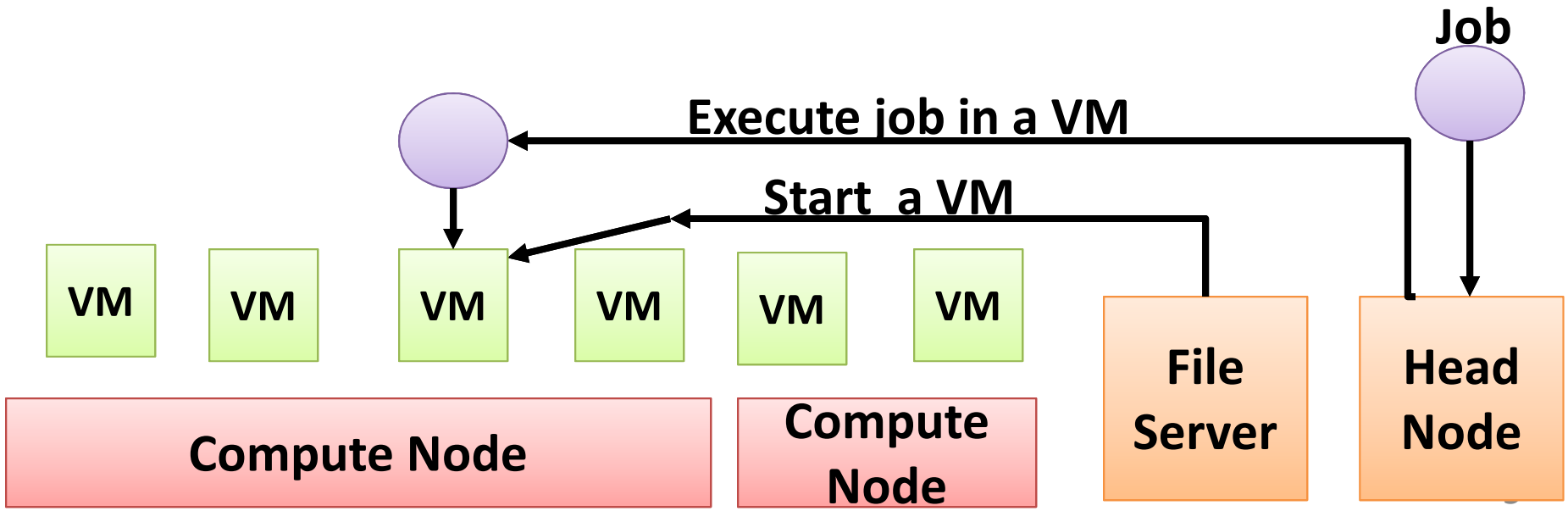
Running multiple OS and applications

- Virtualization: One physical hardware can run multiple OS and applications through a hypervisor.
- A hypervisor is the virtualization manager on a physical hardware.

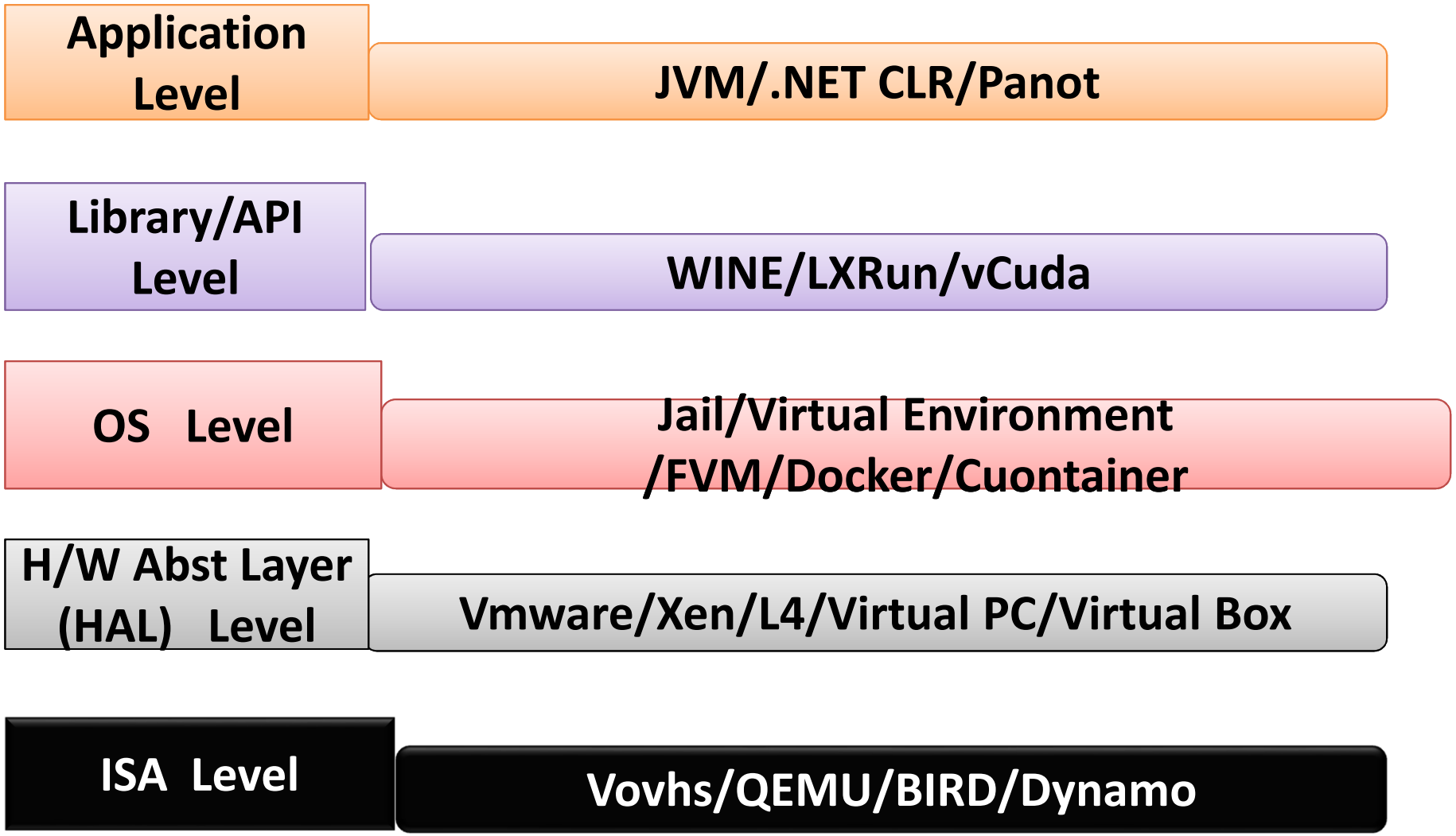


Cloud Computing

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



Virtualization in Five Abstraction Levels



Emulation vs. Virtualization

- **Emulation technique**
  - Simulate an independent environment where guest ISA and host ISA are different.
  - Example: Emulate x86 architecture on ARM platform.
- **Virtualization technique**
  - Simulate an independent environment where guest ISA and host ISA are the same.
  - Example : Virtualize x86 architecture to multiple instances.

Virtualization at ISA (Instruction Set Architecture) level

- With the help of ISA emulation
  - Example : MIPS binary code can run on an x-86 host
  - Typical systems: Bochs, Crusoe, Quemu, BIRD, Dynamo, Simic/Gems
- Advantage
  - It can run a large amount of legacy binary codes written for various processors on any given new hardware host machines
  - best application flexibility
- Shortcoming & limitation
  - One source instruction may require 10-100 of target instructions to perform its function, which is relatively slow.

Virtualization at Hardware Abstraction level

- Generates virtual hardware envts for VMs,
  - And manages the underlying hardware through virtualization.
  - Typical systems: VMware, Virtual PC, Xen, Virtual Box
- Advantage:
  - higher performance and good application isolation
- Shortcoming & limitation:
  - Very expensive to implement (complexity)

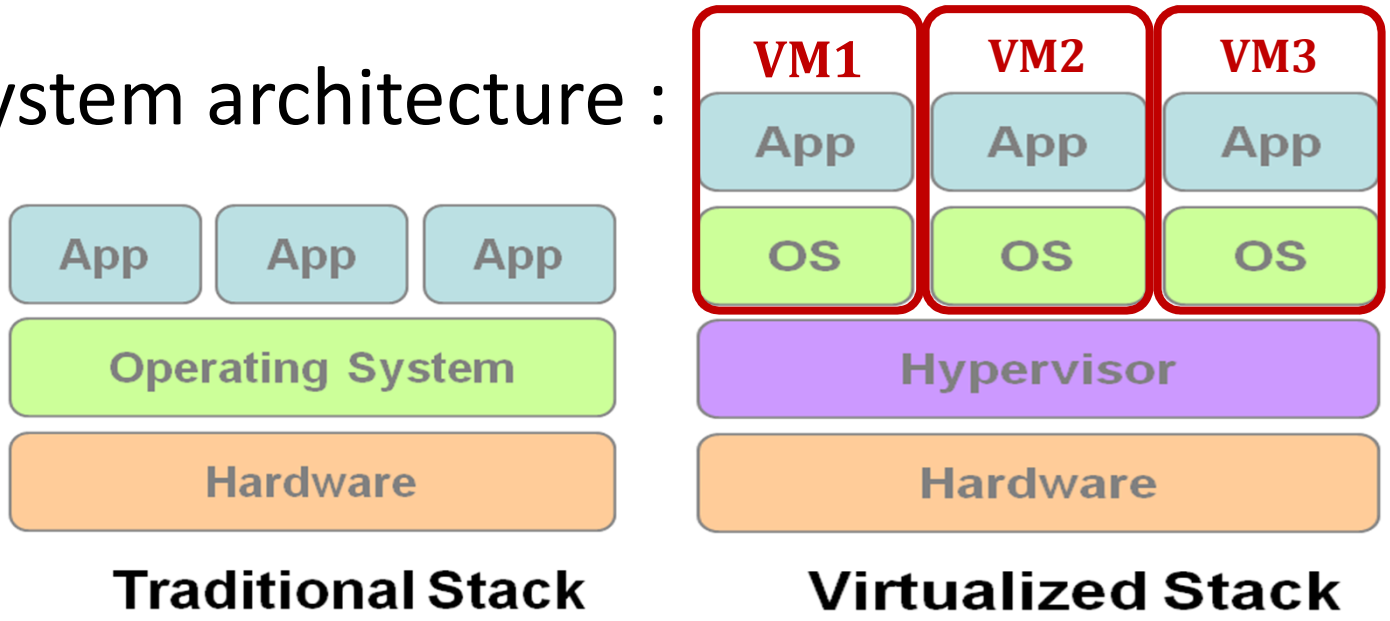
Virtualization at Operating System (OS) level

- This virtualization creates isolated containers on a single physical server and the OS-instance to utilize the hardware and software in datacenters.
  - Typical systems: Jail / Virtual Environment / FVM/
  - **Docker/Container/Kubernet**
- **Advantage**
  - Has minimal starup/shutdown cost, low resource requirement, and high scalability; synchronize VM and host state changes.
- **Shortcoming & limitation:**
  - All VMs at the operating system level must have the same kind of guest OS
  - Poor application flexibility and isolation.

Virtual Machine Monitor

- What's Virtual Machine Monitor (VMM) ?
  - **VMM** or **Hypervisor** is the software layer providing the virtualization.

- System architecture :



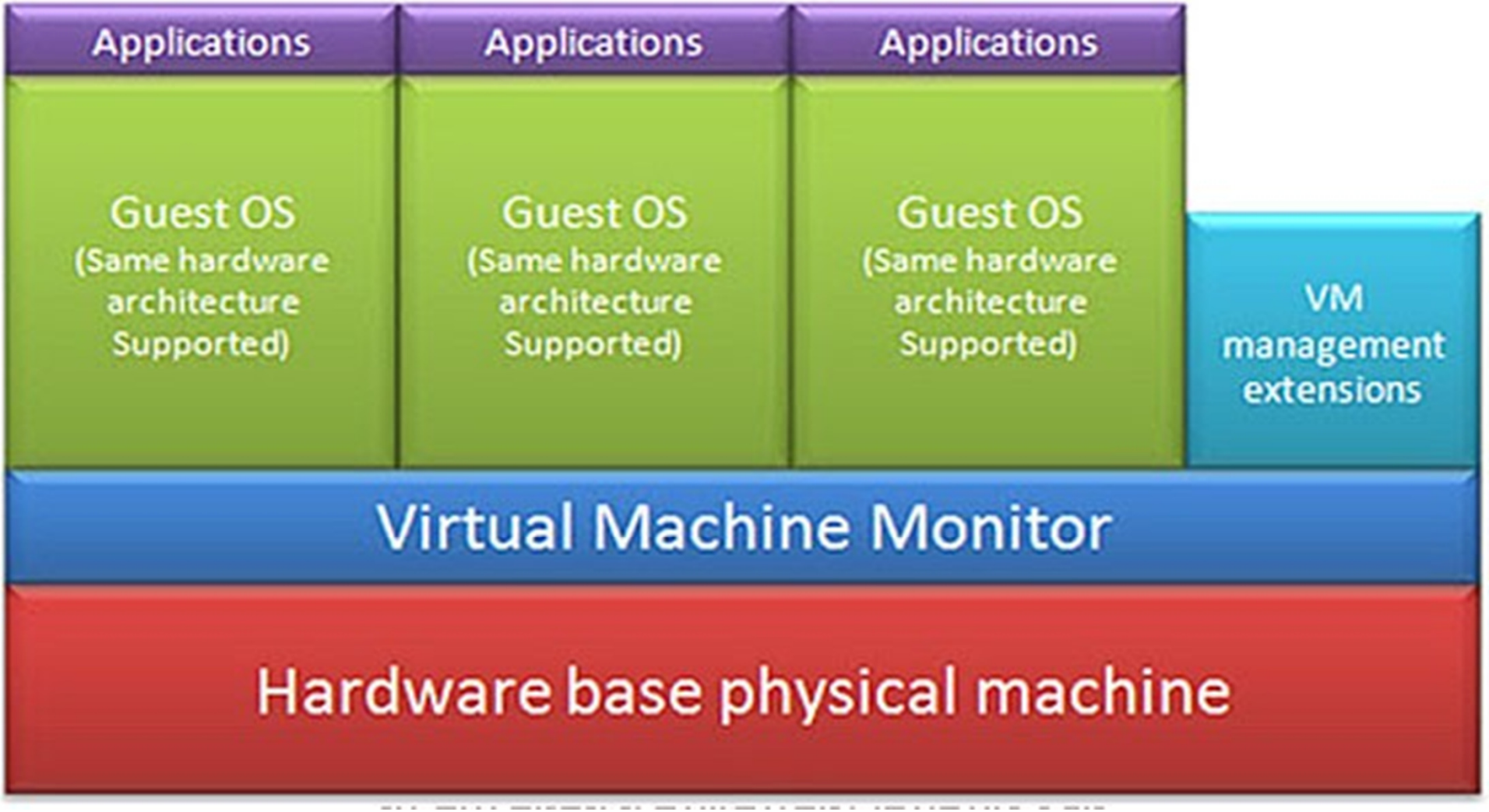
Virtualization Types

- Virtualization Types :
  - Type 1 – Bare metal
    - VMMs run directly on the host's hardware as a hardware control and guest operating system monitor.
  - Type 2 – Hosted
    - VMMs are software applications running within a conventional operating system.

Virtualization Approaches

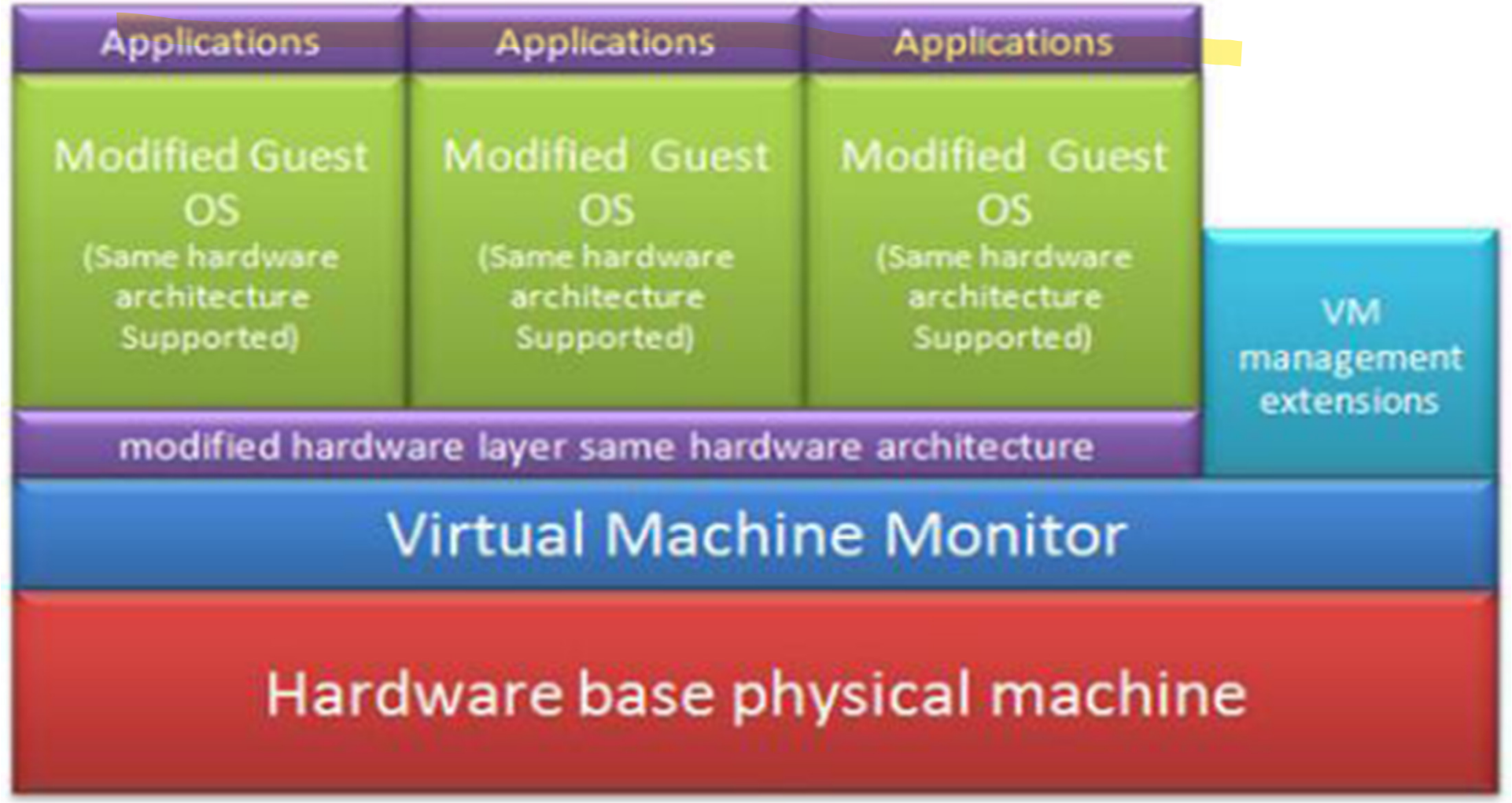
- Virtualization Approaches :
  - Full-Virtualization
    - VMM simulates enough hardware to allow an unmodified guest OS.
  - Para-Virtualization
    - VMM does not necessarily simulate hardware, but instead offers a special API that can only be used by the modified guest OS.

Full-Virtualization



Pros	**Need not to modify guest OS**
Cons	**Significant performance hit**

Para-Virtualization



Pros	**Light weight and high performance**
Cons	**Require modification of guest OS**

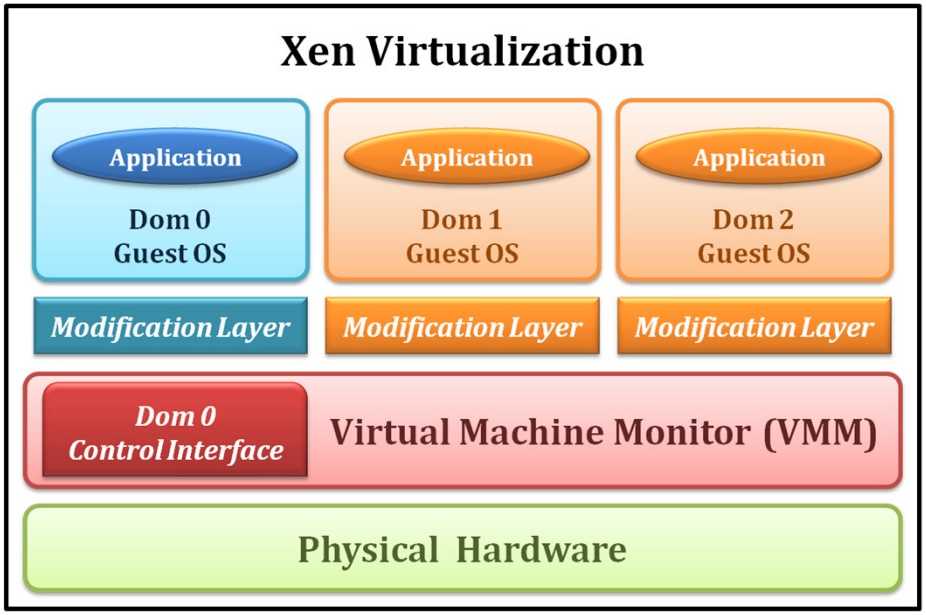
Examples

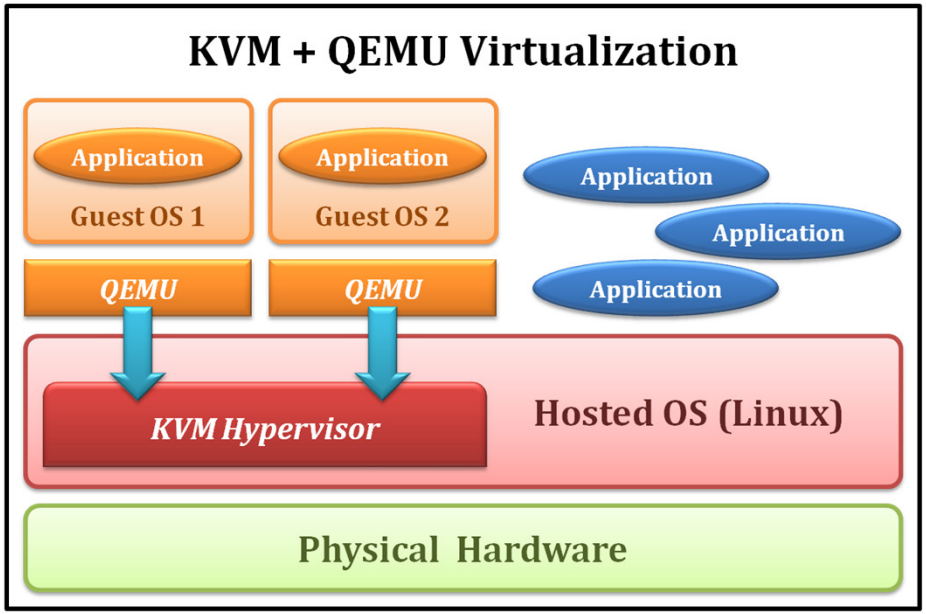
Xen

- Type 1 Virtualization
- Para-Virtualization

KVM

- Type 2 Virtualization
- Full-Virtualization





Advantages of Virtualization

- Run operating systems where the physical hardware is unavailable,
- Easier to create new machines, backup machines, etc
- Software testing using “clean” installs of operating systems and software,

Advantages of Virtualization

- Emulate more machines than physically available,
- Timeshare lightly loaded systems on one host,
- Debug Problem : (suspend/resume the problem machine),
- Easy migration of VM (shutdown needed or not).
- Run legacy systems!

What is the purpose and benefits?

- Cloud computing enables companies and applications, which are system infrastructure dependent, to be infrastructure-less.
- By using the Cloud infrastructure on “pay as used and on demand”, all of us can save in capital and operational investment!
- Clients can:
  - Put their data on the platform instead of on their own desktop PCs and/or on their own servers.
  - They can put their applications on the cloud and use the servers within the cloud to do processing and data manipulations etc.

Disadvantages of Virtualization

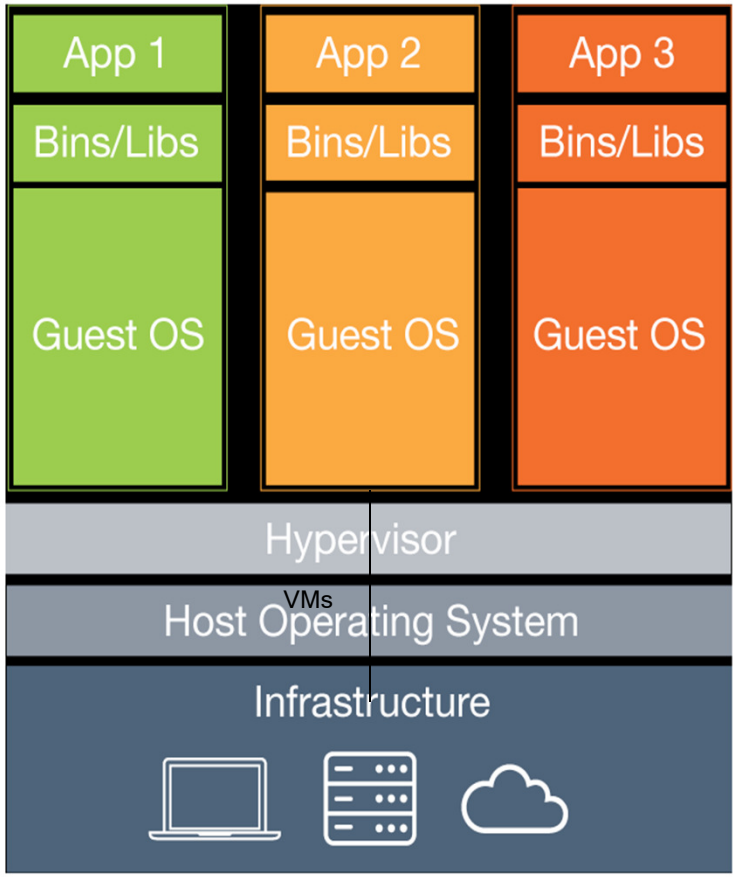
- Running task on VMs are slow
- Overhead due to virtualization can be upto 15-40% : can not be ignored
- Waste of resources
  - Reduce profit of Cloud Provider
- Solution : Simple Isolation, container based

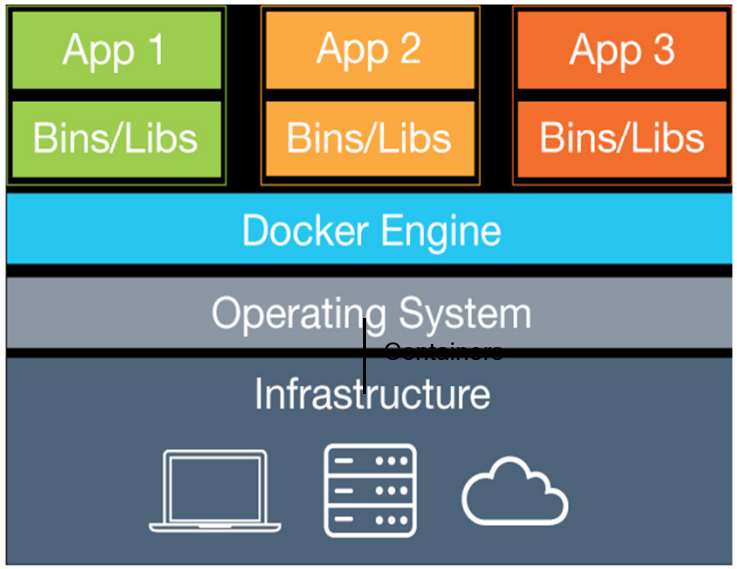
Containers : Docker

- What is a container?
  - a container consists of an application and all its dependencies which can be run in an isolated way
  - make uses of kernel features (cgroups, namespaces, ...)
- Benefits include
  - independence from host OS & libraries
  - can be run anywhere, regardless of kernel version or host Linux distribution

Containers vs Virtualization

- VM is complete OS
- Container is App with required Lib and tools





Singularity : isolation

- Project from Berkeley Labs (http://singularity.lbl.gov/)
- Designed to allow non-privileged users on HPC systems to provide their own OS
  - isolates filesystem & processes
  - no daemon, no UID switching
- Being pushed by Traceability & Isolation Working Group
  - seen as a (future) alternative to glexec
  - provides isolation but not traceability
    - payload cannot attack pilot or other payloads on same host

Kubernetes

- Open source container cluster manager, originally developed at Google
- Can be installed on-prem (bare metal or on a cloud), also available on public clouds
  - "click a button" on Google & Azure
  - straightforward to install on AWS, ...

Why Kubernetes?

- Standard open-source software (not HEP-specific)
- Using it as a means of abstracting differences between on-prem (bare metal) resources & different public clouds
- Eliminate vendor lock-in by avoiding any cloud or vendor specific APIs
  - No need to write software to talk to different cloud APIs, just use the Kubernetes API only
- Also has federation functionality making it easy
  - To deploy workloads across multiple clusters (new)

Container Verdicts

- Use of containers beneficial for both VOs and sites
  - jobs no longer depend on OS version or software installed on worker nodes
  - easier to provide a consistent environment at multiple sites
- Singularity seems to be a simple way for sites to run jobs in containers
- Container cluster managers (**Mesos**)
  - **C**an be used to provide an efficient platform for long-running services & multiple compute activities
  - Kubernetes can be used to provide portability between local resources & multiple public clouds

Cloud System Economic Model

Economic: Cloud Computing

- **Lower computer costs**
- To run cloud computing's web-based applications
  - You do not need a high-powered and high-priced computer
- Since applications run in the cloud, not on the PC
  - Your PC does not need high processing power or hard disk space demanded by traditional desktop software.
- When you are using web-based applications
  - Your PC can be less expensive, with a smaller hard disk, less memory, more energy efficient processor
  - PC does not even need a CD/DVD drive,
  - No software programs have to be loaded
  - No document files need to be saved.

Economics: Cloud Computing

- **Instant software updates**
- You are no longer faced with choosing between obsolete software and high upgrade costs.
- When the application is web-based
  - Updates happen automatically
  - Available the next time you log into the cloud.
- When you access a web-based application
  - You get the latest version
  - Without needing to pay for or download an upgrade.

Economics: Utility Model

- Do we require to own a car to ride?
- Rent a CAR for 1 month (schedule your self how you will use)
- Rent a CAR for 1 Day (schedule your self how you will use)
- Use Pickup or Drop service, personalized
  - Src-Dst defined
- Use shared services: Piggy back with others

OLA/UBER Economic Model

- OLA/UBER maintain website and logistics
- Car Driver need to register to OLA/UBER
- Without registering to OLA/UBER
  - 2 to 3 trip request per day, Benefit is less, he need to charge more : Rs 600/ to airport trip
- With OLA/UBER Car driver
  - 10-30 trip per day, car utilization is higher
  - Benefit is higher, can afford to give at cheaper price

OLA/UBER Economic Model

- Profit win-win for all:
  - To users (cheaper), no need to keep the car for whole day
  - drivers (more request and get higher profit)
  - OLA/UBER provider (charge money to driver without actually doing the work)

CAR Rental Economic Model

- CAPEX : Cost of the CAR
  - 3-5 lakhs for Small Cars
  - 5-12 lakhs for mid-size Cars
- OPEX : Operational Cost
  - Petrol/Diesel Cost
  - Higher Mileage: Profit is higher, Diesel engine mileage is higher
  - AMC Service cost, Reparing cost
- Once you purchase a CARs, try to reduce the OPEX
  - How to increase Mileage or reduce Fuel cost

Efficient Economic Model

- A Guy spend CAPEX : Spend 10 Lakhs on purchasing a new CAR
  - **Got his status elevated, proud owner of CAR**
- OPEX : Operational Cost
  - Petrol/Diesel Cost : Rs 5/KM
  - Service (10K) and Insurance (10K), paid extra 20K per Annum for Parking
- He drove for 7 year, 30,000 Km and sold the same car for 3 lakhs
  - OPEX for 7 Years: 30K*5+40K*7=Rs 4.30L
- **Cost per KM: (10L+4.3L-3L)/30K=Rs 37.8/KM**
- **He takes 7L loans to purchase the car: Rs 46.5/KM**

Efficient Economic Model

- A Guy spend CAPEX : Spend **3 Lakhs on purchasing a 2nd hand CAR**
  - **Got his status elevated, proud owner of second hand CAR**
- OPEX : Operational Cost
  - Petrol/Diesel Cost : Rs 5/KM
  - Service (10K) and Insurance (10K), paid extra 20K per Annum for Parking
- He drove for 5 year, 30,000 Km and sold the same car for 1 lakhs
  - OPEX for 5 Years: 30K*5+40K*5=Rs 3.5L
- Cost per KM: (3L+3.5L-1L)/**30K=Rs 18.3/KM**

Efficient Economic Model

- A Guy do not spend CAPEX (Rs 10L)+OPEX and used OLA/UBER
  - **No headache of driving**
  - **OLA Rs 12-15/KM**
  - Giving community service by using public CAB, some guy is getting earning
- Saved his money and invested some where?

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