Unit -IV

WSC

- WSC is the foundation of Internet services many people use every day
  - searching, social networking, online maps, video sharing, online shopping, email services so on.
- WSC could be considered a type of datacenter architecture and operation are quite different.
- Datacenters
  - buildings where multiple servers and communication gear are located because of their common environmental requirements and physical security needs, and for ease of maintenance.

WSC

- WSCs act as one giant machine and cost on the order of \$150M
  - the building
  - the electrical
  - cooling infrastructure
  - the servers
  - networking equipment that connects and houses 50,000 to 100,000 servers.

WSC

- WSCs represent a much larger share of the IT market.
- Rapid growth of cloud computing makes WSCs available to anyone with a credit card
- ***WSC architects share many goals and requirements with server architects***:

1. Cost-performance
   - Work done per dollar is critical in part because of the scale. Reducing the capital cost of a WSC by 10% could save $15M.

WSC

2. Energy efficiency

- Power distribution costs are functionally related to power consumption
- you need sufficient power distribution before you can consume power
- need to get out the heat that you put in.
- peak power and consumed power drive both the cost of power distribution and the cost of cooling systems.
- energy efficiency is an important part of environmental stewardship.
- work done per joule is critical for both WSCs and servers.

WSC

3. Dependability via redundancy
   - hardware and software in a WSC must collectively provide at least 99.99% of availability
   - it must be down less than 1 hour per year
   - Redundancy is the key to dependability for both WSCs and servers

WSC

4. **Network I/0**

– WSC architects must provide a good network interface to the external world

– Networking is needed to keep data consistent between multiple WSCs as well as to interface to the public.

WSC

5. Interactive and batch processing workloads
   - highly interactive workloads for services like search and social networking with millions of users
   - run massively parallel batch programs to calculate metadata useful to such services.

WSC

- chars not shared with server architecture

1. Ample parallelism
   - A concern for a server architect is whether the applications in the targeted marketplace have enough parallelism to justify the amount of parallel hardware to exploit this parallelism.
   - A WSC architect has no such concern.
   - Batch applications benefit from the large number of independent datasets that require independent processing.
   - software as a service (SaaS), can benefit from millions of independent users of interactive Internet services.

WSC

2. Operational costs count
   - Server architects usually design their systems for peak performance within a cost budget
   - ignore operational costs of a server
   - WSCs have longer lifetimes-the building and electrical and cooling infrastructure are often amortized over 10 or more years
   - the operational costs for Energy, power distribution, and cooling represent more than 30% of the costs of a WSC in 10 years.

WSC

3. Scale and the opportunities/problems associated with scale
   - extreme computers are extremely expensive because they require custom hardware.
   - when you purchase 50,000 servers to construct a single WSC, you do get volume discounts.
   - WSCs are so massive internally you get economy of scale.

Programming Models WSC

- most popular framework for batch processing in a WSC is Map-Reduce
- its open-source twin Hadoop
- Facebook runs Hadoop on 2000 batch-processing servers of the 60,000 servers it is estimated to have in 2011

Programming Models WSC

- ***Map*** first applies a programmer-supplied function to each logical input record.
- ***Map*** runs on thousands of computers to produce an intermediate result of key-value pairs
- ***Reduce*** collects the output of those distributed tasks and collapses them using another programmer-defined function

Programming Models WSC

- Map and Reduce functions that operate on key-value pairs
- Each map function operates on a collection of records a record is a webpage or a facebook user profile
- The records are in the file system and scattered across several servers thousands of map functions are spawned to work on all records in parallel
- The Reduce function aggregates and sorts the results produced by the Mappers, also performed in parallel

Programming Models WSC

- MapReduce program calculates the number of occurrences of every English word in a large collection of documents
- Below is a simplified version of that program,

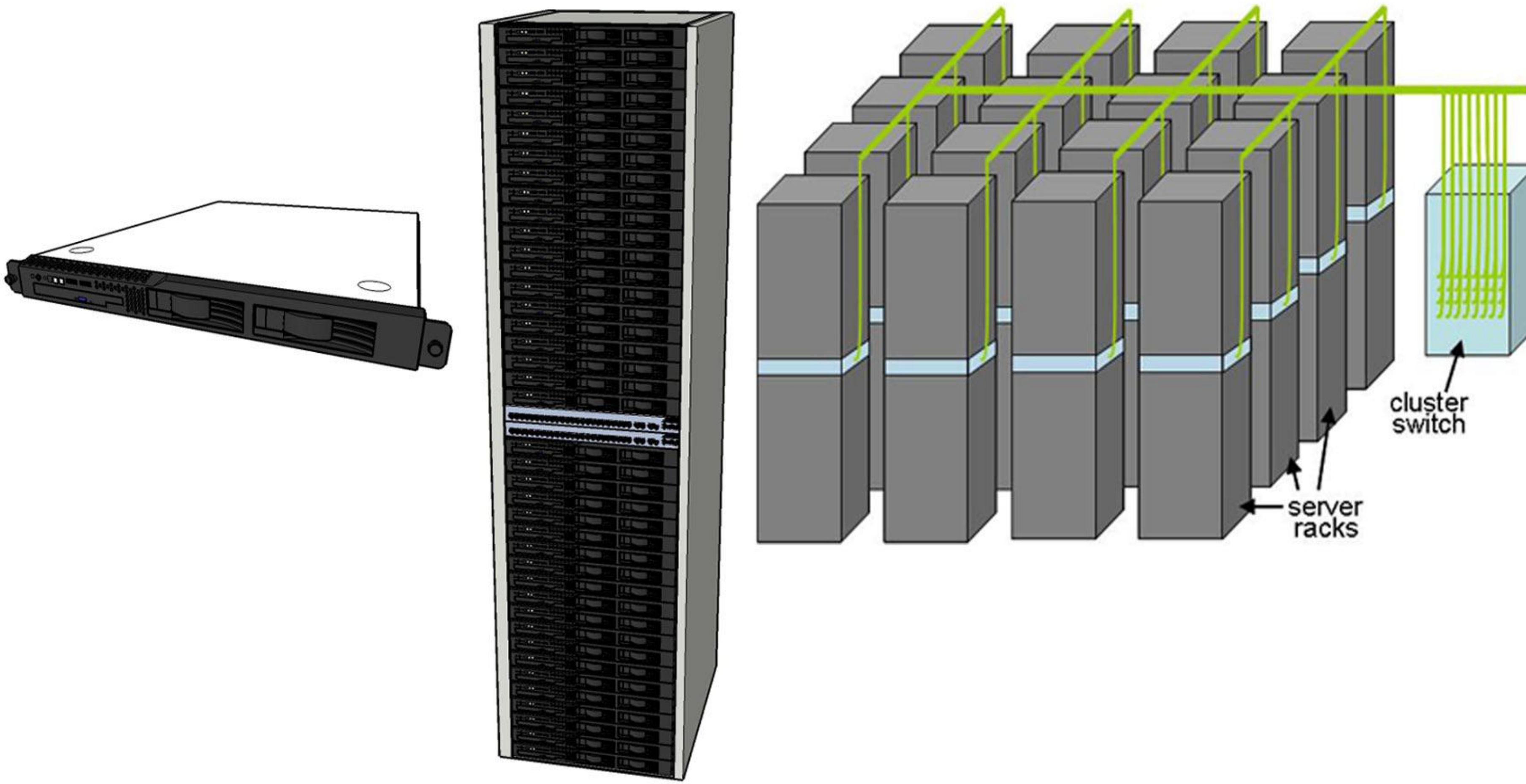
Programming Models WSC

```
map(String key, String value):
// key: document name
// value: document contents for each word w in value:
    EmitIntermediate(w, "1");  // Produce list of all words
reduce(String key, Iterator values):
//key: a word
// values: a list of counts
int result=0;
for each v in values:
result+= ParseInt(v);        // get integer from key-value pair
Emit(AsString(result));
```

Programming Models WSC

- ***EmitIntermediate*** used in the Map function emits each word in the document and the value one
- ***Reduce*** function sums all the values per word for each document using ParseInt() to get the number of occurrences per word in all documents.
- MapReduce can be thought of as a generalization of the SIMD operation

Architecture of Warehouse-Scale Computers



Elements in warehouse-scale systems: 1U server (left), 7´ rack with Ethernet switch (middle), and diagram of a small cluster with a cluster-level Ethernet switch/router (right).

Architecture of Warehouse-Scale Computers

- A set of low-end servers, typically in a 1U or blade enclosure format, are mounted within a rack
- interconnected using a local Ethernet switch.
- These rack-level switches, can use 1- or 10-Gbps links, have a number of uplink connections to one or more cluster-level (or datacenter-level) Ethernet switches.
- This second-level switching domain can span more than ten thousand individual servers

Architecture of Warehouse-Scale Computers

1. Storage

- include disks inside the server, and rely on Ethernet connectivity for access to information on the disks of remote servers.
- The alternative would be to use network attached storage (NAS) like Infiniband.
- NAS solution is generally more expensive per terabyte of storage
- It provides many features, including RAID techniques to improve dependability of the storage.
- WSCs generally rely on local disks and provide storage software that handles connectivity and dependability.

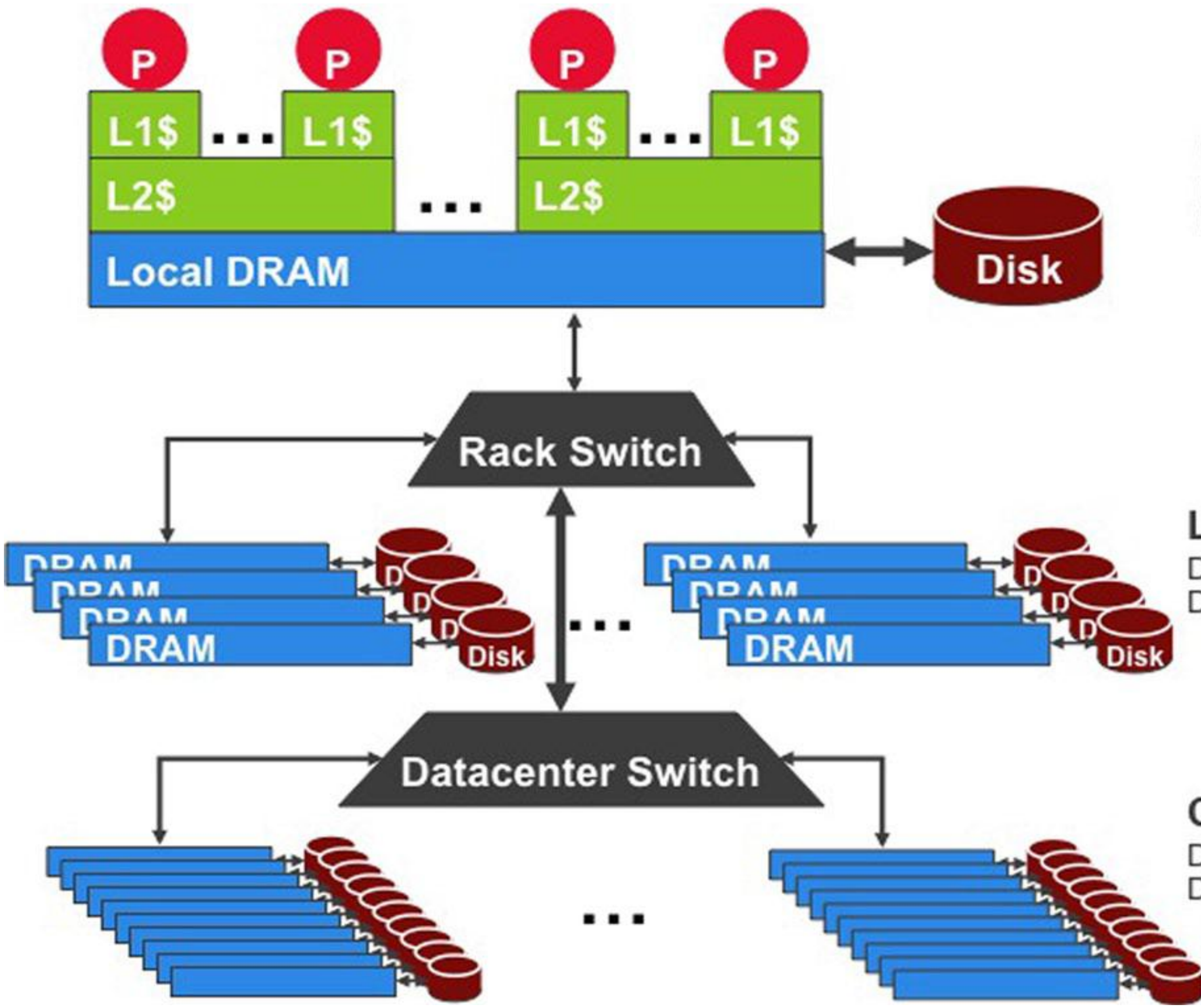
Architecture of Warehouse-Scale Computers

2. Array Switch

- It connects an array of racks is more expensive than the 48-port commodity Ethernet switch
- Network switches with high port counts, which are needed to tie together WSC clusters, have ten times more expensive (per 1-Gbps port) than commodity switches.
- A switch that has 10 times the bi-section bandwidth costs about 100 times as much.
- One reason is that the cost of switch bandwidth for n ports can grow as n^2.

Architecture of Warehouse-Scale Computers

3. **WSC Memory Hierarchy**



One server
DRAM: 16GB, 100ns, 20GB/s
Disk: 2TB, 10ms, 200MB/s

Local rack (80 servers)
DRAM: 1TB, 300us, 100MB/s
Disk: 160TB, 11ms, 100MB/s

Cluster (30 racks)
DRAM: 30TB, 500us, 10MB/s
Disk: 4.80PB, 12ms, 10MB/s

Physical Infrastructure & Costs of WSC

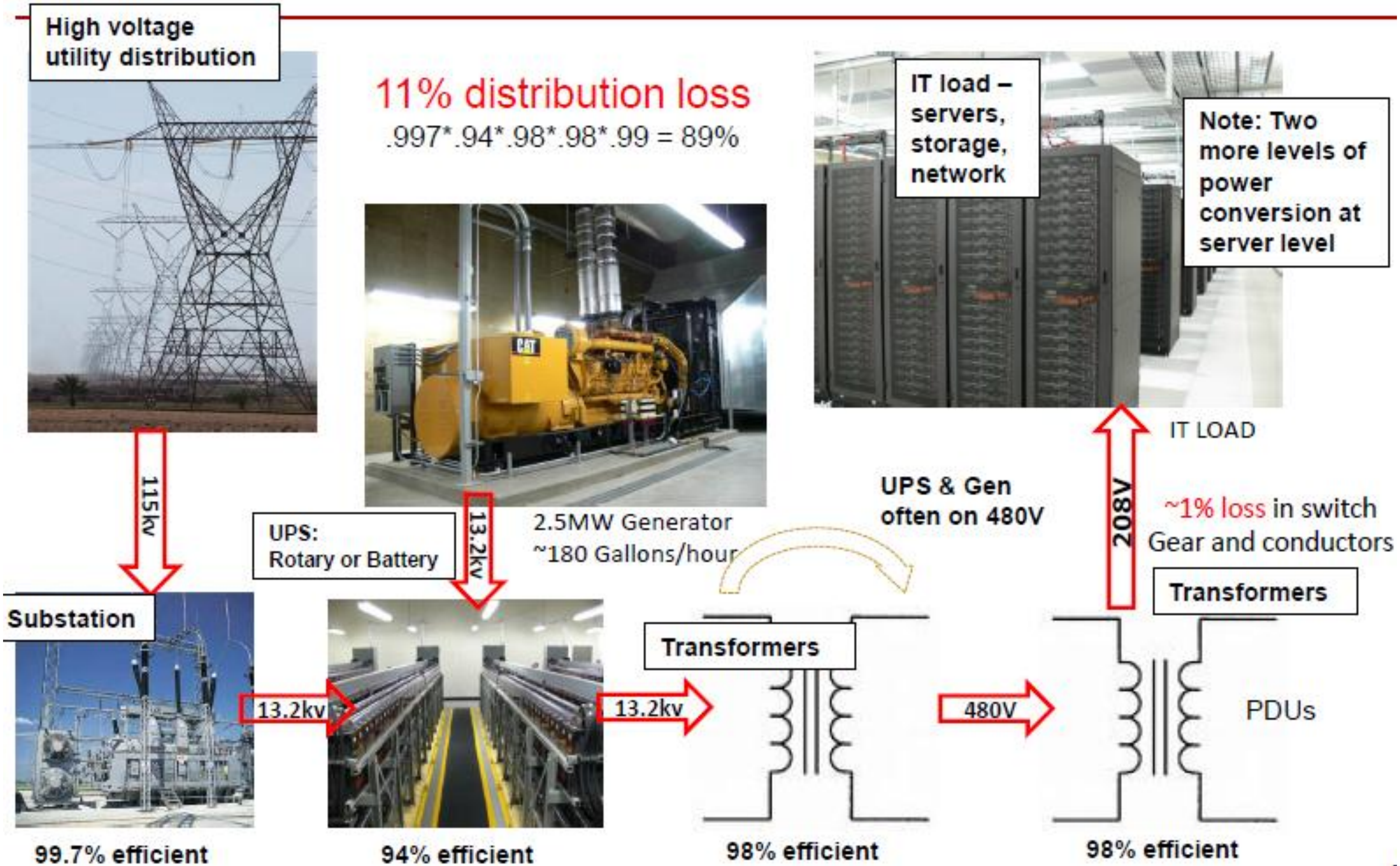


Fig: Power distribution and where losses occur

Physical Infrastructure & Costs of WSC

1. The substation switches from 115,000 volts to medium-voltage lines of 13,200 volts, with an efficiency of 99.7%.
2. To prevent the whole WSC from going offline if power is lost, a WSC has an UPS.
   - it involves large diesel engines that can take over from the utility company

Physical Infrastructure & Costs of WSC

2. UPS plays three roles:

- **power conditioning (maintain proper voltage levels)**
- **holding the electrical load while the generators start and come on line,**
- **holding the electrical load when switching back from the generators to the electrical utility.**
- **Efficiency of this large UPS is 94%, the facility loses 6% of the power by having a UPS.**
- **The WSC UPS can account for 7% to 12% of the cost of all the IT equipment.**

Physical Infrastructure & Costs of WSC

3. Power Distribution Unit (PDU):

- It converts to low voltage, internal, three-phase power at 480 volts.
- The conversion efficiency is 98%.
- A typical PDU handles 75 to 225 kilowatts of load, or about 10 racks.

Physical Infrastructure & Costs of WSC

4. There is yet another down step to two-phase power at 208 volts that servers can use, once again at 98% efficiency.
5. The connectors, breakers, and electrical wiring to the server have a collective efficiency of 99%.

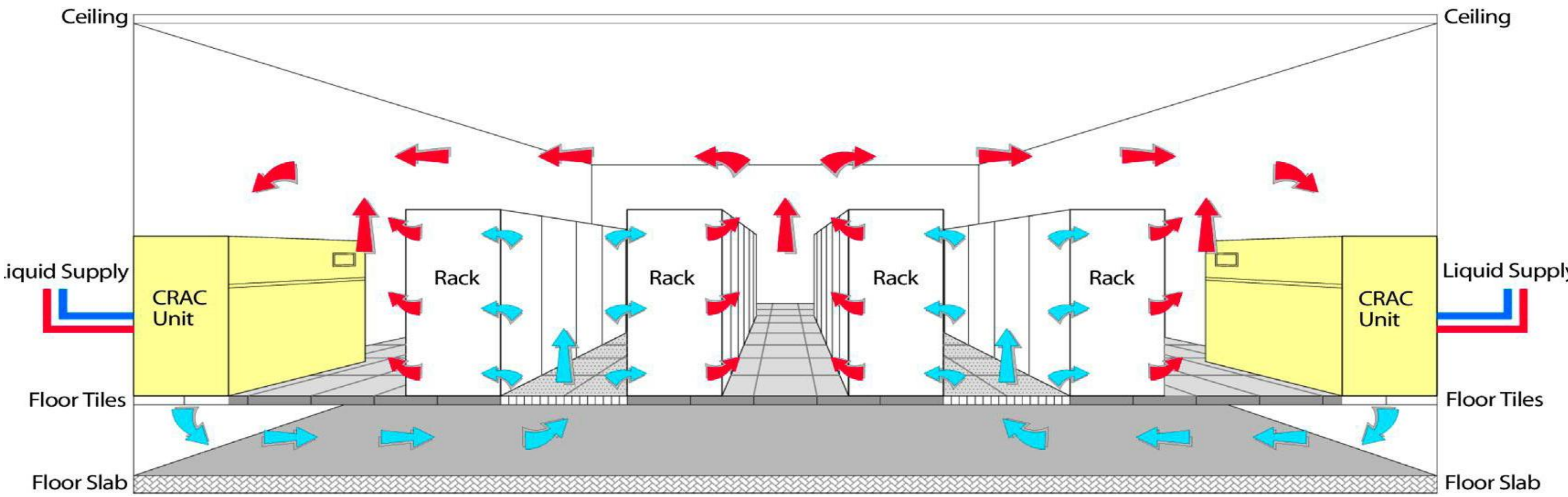
Physical Infrastructure & Costs of WSC

- the efficiency of turning 115,000-volt power from the utility into 208-volt power that servers can use is 89%:

  99.7% x 94% x 98% x 98% x 99% = 89%

- WSCs outside North America use different conversion values, but the overall design is similar.

Physical Infrastructure & Costs of WSC



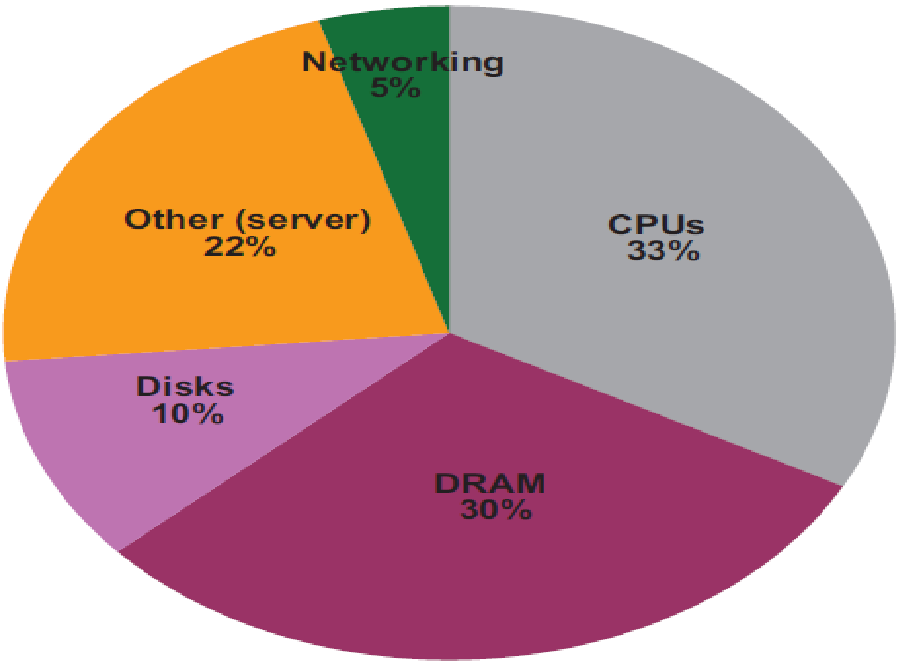
- CRAC = computer room air conditioning
- Cold airs goes through servers and exits in hot aisle
- Cold aisles ~18-22C, hot aisles ~35C
- CRAC units consume significant amount of energy!

Physical Infrastructure & Costs of WSC

- The relative power costs of cooling equipment to IT equipment in a typical datacenter [Barroso and Holzle 2009] are as follows:
  - **Chillers account for 30% to 50% of the IT equipment power.**
  - **CRAC accounts for 10% to 20% of the IT equipment power, due to fans.**

Physical Infrastructure & Costs of WSC

- power usage inside the IT equipment itself, Barroso and Holzle [2009] reported the following for a Google WSC deployed in 2007:



Efficiency of a WSC

- Simple metric to evaluate the efficiency of a datacenter or a WSC is called power utilization effectiveness (PUE)
- PUE = (Total facility power)/(IT equipment power)
- Thus PUE must be greater than or equal to 1
- Ranges from 1.33 to 3.03, median of 1.69
- Bigger the PUE the less efficient the WSC.

Cost of a WSC

- WSCs costs includes :
- Capital expenditure(CAPEK):
  - Infrastructure costs for the building, power delivery, cooling, and servers
- Operational expenditure (OPEK):
  - the monthly bill for energy, failures, personnel, etc
- CapEx can be amortized into a monthly estimate by assuming that
  - the facilities will last 10 years
  - server parts will last 3 years
  - networking parts will last 4 years

Cost of a WSC Case Study

- 8 MW facility : facility cost: $88M, server/networking cost: $79M

- Monthly expense: $3.8M. Breakdown:
  - Servers 53% (amortized CapEx)
  - Networking 8% (amortized CapEx)
  - Power/cooling infrastructure 20% (amortized CapEx)
  - Other infrastructure 4% (amortized CapEx)

  - Monthly power bill 13% (true OpEx)
  - Monthly personnel salaries 2% (true OpEx)

Cloud Computing

- **Cloud Computing** is a general term used to describe a new class of network based computing that takes place over the Internet,
  - basically a step on from Utility Computing
  - a collection/group of integrated and networked hardware, software and Internet infrastructure (called a platform).
  - Using the Internet for communication and transport provides hardware, software and networking services to clients
- These platforms hide the complexity and details of the underlying infrastructure from users and applications by providing very simple graphical interface or API (Applications Programming Interface).

Cloud Computing

- In addition, the platform provides on demand services, that are always on, anywhere, anytime and any place.
- Pay for use and as needed, elastic
  - scale up and down in capacity and functionalities
- The hardware and software services are available to
  - general public, enterprises, corporations and businesses markets

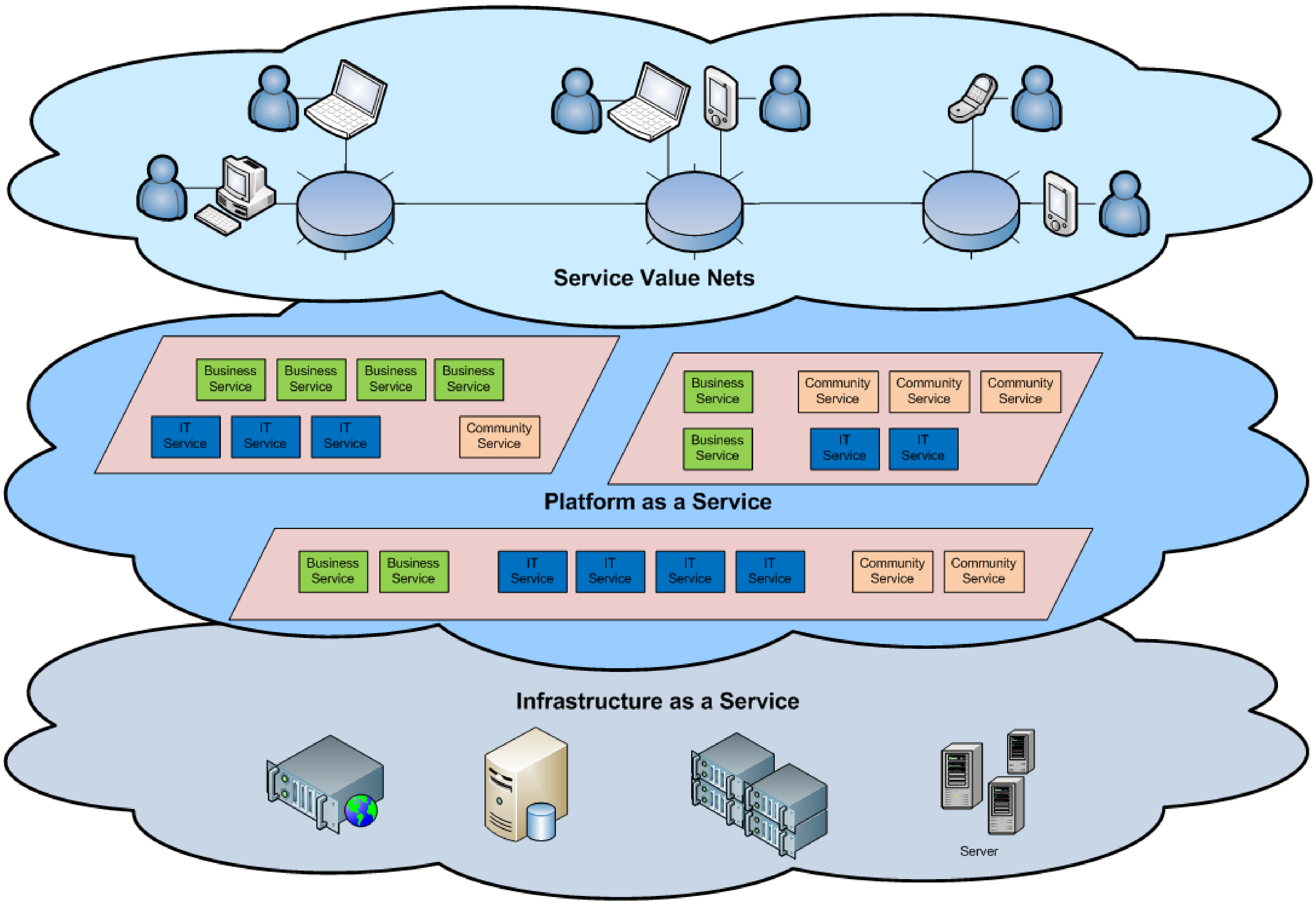
Cloud Computing

- Cloud computing is an umbrella term used to refer to Internet based development and services
- A number of characteristics define cloud data, applications services and infrastructure:
  - **Remotely hosted**: Services or data are hosted on remote infrastructure.
  - **Ubiquitous**: Services or data are available from anywhere.
  - **Commodified**: The result is a utility computing model similar to traditional that of traditional utilities, like gas and electricity - you pay for what you would want!

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.

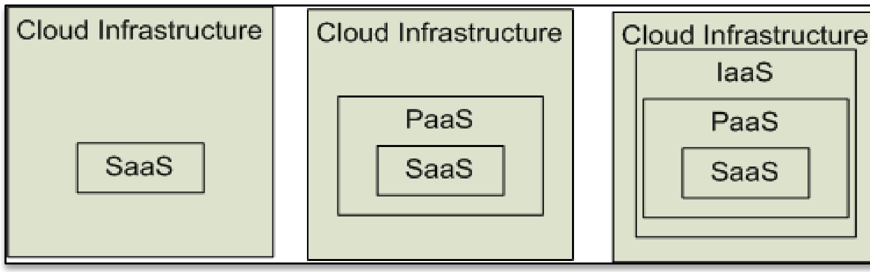
Cloud Architecture



Cloud Service Models

Software as a Service (SaaS)	Platform as a Service (PaaS)	Infrastructure as a Service (IaaS)

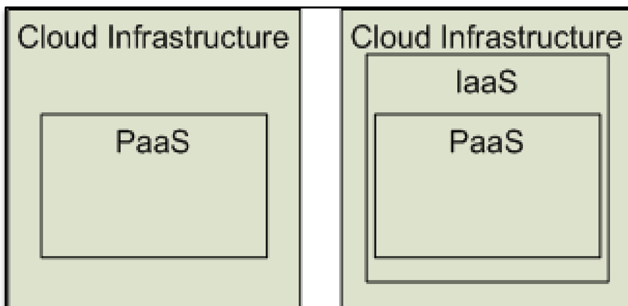
SalesForce CRM
LotusLive



Software as a Service (SaaS)
Providers Applications

Google App Engine

Windows Azure
The Future Made Familiar

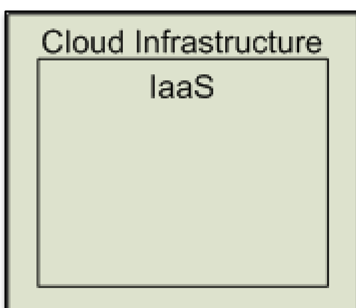


Platform as a Service (PaaS)

Deploy customer created Applications

amazon web services

rackspace HOSTING



Infrastructure as a Service (IaaS)

Rent Processing, storage, N/W capacity & computing resources

Cloud Computing Service Layers

	Services	Description
Application Focused	Services	Services – Complete business services such as PayPal, OpenID, OAuth, Google Maps, Alexa
	Application	Application – Cloud based software that eliminates the need for local installation such as Google Apps, Microsoft Online
	Development	Development – Software development platforms used to build custom cloud based applications (PAAS & SAAS) such as SalesForce
Infrastructure Focused	Platform	Platform – Cloud based platforms, typically provided using virtualization, such as Amazon ECC, Sun Grid
	Storage	Storage – Data storage or cloud based NAS such as CTERA, iDisk, CloudNAS
	Hosting	Hosting – Physical data centers such as those run by IBM, HP, NaviSite, etc.

Basic Cloud Characteristics

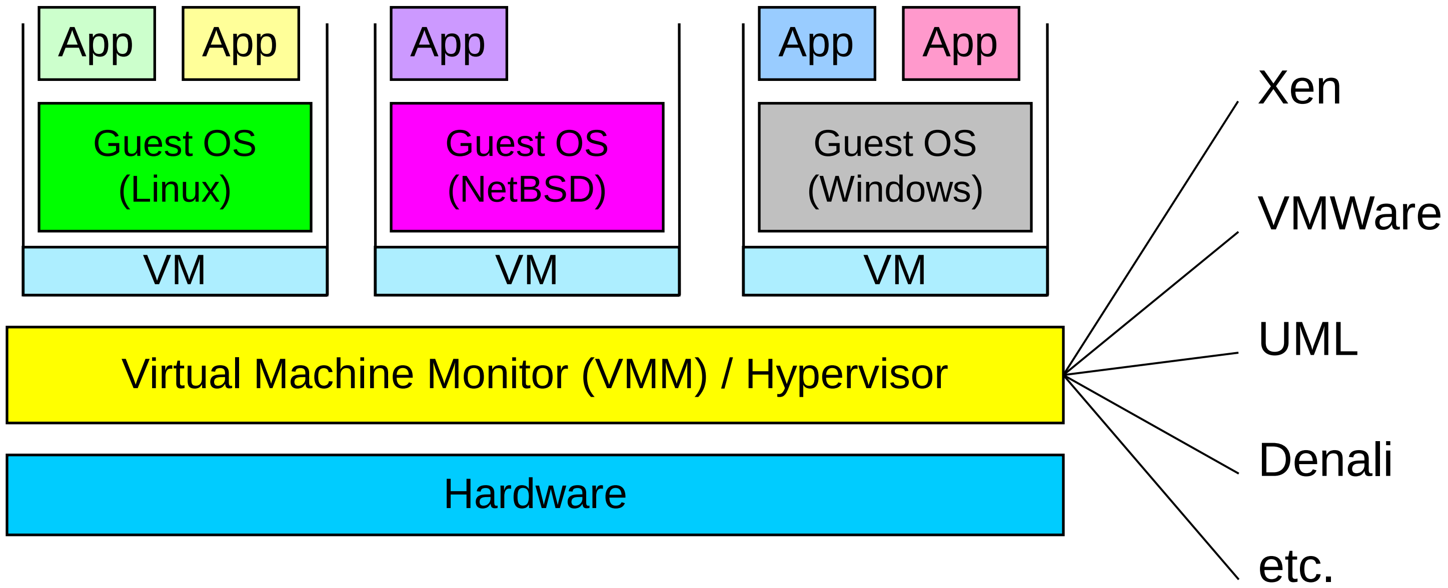
- The "**no-need-to-know**" in terms of the underlying details of infrastructure, applications interface with the infrastructure via the APIs.
- The "**flexibility and elasticity**" allows these systems to scale up and down at will
  - utilising the resources of all kinds
    - CPU, storage, server capacity, load balancing, and databases
- The "**pay as much as used and needed**" type of utility computing and the "**always on!, anywhere and any place**" type of network-based computing

Basic Cloud Characteristics

- Cloud are transparent to users and applications, they can be built in multiple ways
  - branded products, proprietary open source, hardware or software, or just off-the-shelf PCs.
- In general, they are built on clusters of PC servers and off-the-shelf components plus Open Source software combined with in-house applications and/or system software.

Virtual Machines

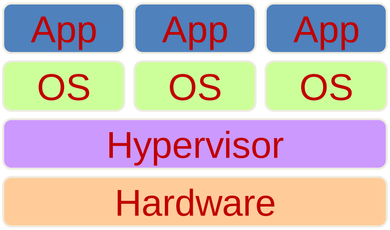
- VM technology allows multiple virtual machines to run on a single physical machine.



Performance: Para-virtualization (e.g. Xen) is very close to raw physical performance!

Virtual Machines

- VM technology allows multiple virtual machines to run on a single physical machine.
- Virtual workspaces:
  - An abstraction of an execution environment that can be made dynamically available to authorized clients by using well-defined protocols,
  - Resource quota (e.g. CPU, memory share),
  - Software configuration (e.g. O/S, provided services).
- Implement on Virtual Machines (VMs):
  - Abstraction of a physical host machine,
  - Hypervisor intercepts and emulates instructions from VMs, and allows management of VMs,
  - VM Ware, Xen, etc.
- Provide infrastructure API:
  - Plug-ins to hardware/support structures



Virtualized Stack

Virtual Machines

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

Cloud Storage

- Several large Web companies are now exploiting the fact that they have data storage capacity that can be hired out to others.
  - allows data stored remotely to be temporarily cached on desktop computers, mobile phones or other Internet-linked devices.

- Amazon’s Elastic Compute Cloud (EC2) and Simple Storage Solution (S3) are well known examples
  - Mechanical Turk

Amazon Simple Storage Service (S3)

- Unlimited Storage.
- Pay for what you use:
  - $0.20 per GByte of data transferred,
  - $0.15 per GByte-Month for storage used,
  - Second Life Update:
    - 1TBytes, 40,000 downloads in 24 hours - $200

Opportunities and Challenges

- The use of the cloud provides a number of opportunities:
  - It enables services to be used without any understanding of their infrastructure.
  - Cloud computing works using economies of scale:
    - It potentially lowers the outlay expense for start up companies, as they would no longer need to buy their own software or servers.
    - Cost would be by on-demand pricing.
    - Vendors and Service providers claim costs by establishing an ongoing revenue stream.
  - Data and services are stored remotely but accessible from “anywhere”.

Opportunities and Challenges

- In parallel there has been backlash against cloud computing:
  - Use of cloud computing means dependence on others and that could possibly limit flexibility and innovation:
    - The others are likely become the bigger Internet companies like Google and IBM, who may monopolise the market.
    - Some argue that this use of supercomputers is a return to the time of mainframe computing that the PC was a reaction against.
  - Security could prove to be a big issue:
    - It is still unclear how safe out-sourced data is and when using these services ownership of data is not always clear.
  - There are also issues relating to policy and access:
    - If your data is stored abroad whose policy do you adhere to?
    - What happens if the remote server goes down?
    - How will you then access files?
    - There have been cases of users being locked out of accounts and losing access to data.