Cloud Computing and Datacenters

Vivek Shah

Based on slides by Andrew W. Moore and Ian Taylor

Cloud Computing

- Traditional Sever Concept
- Virtual Server Concept
- Cloud Computing
- Data Centers

Source: Taylor

Two Technologies for Agility

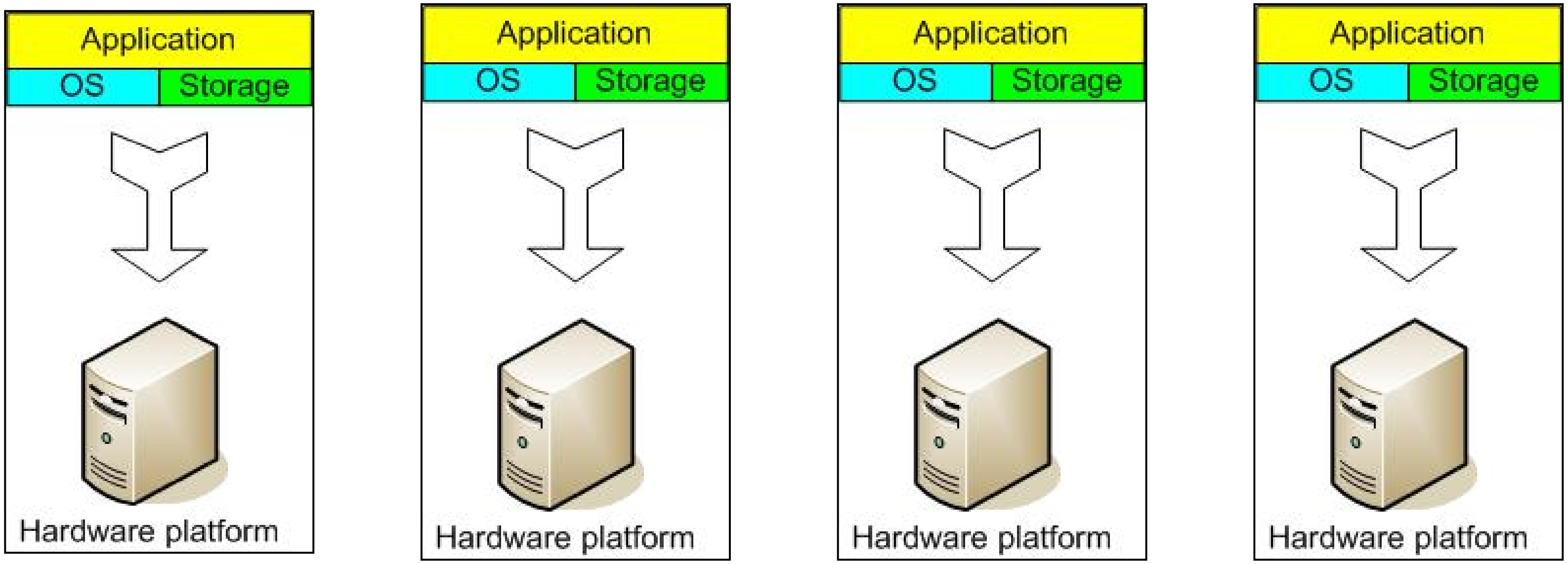
- Virtualization:
  - The ability to run multiple operating systems on a single physical system and share the underlying hardware resources*
- Cloud Computing:
  - The provisioning of services in a timely (near on instant), on-demand manner, to allow the scaling up and down of resources"**

* VMware white paper, *Virtualization Overview*

** Alan Williamson, quoted in *Cloud BootCamp March 2009*

Source: Taylor

The Traditional Server Concept



Web Server	App Server	DB Server	EMail
Windows	Linux	Linux	Windows
IIS	Glassfish	MySQL	Exchange

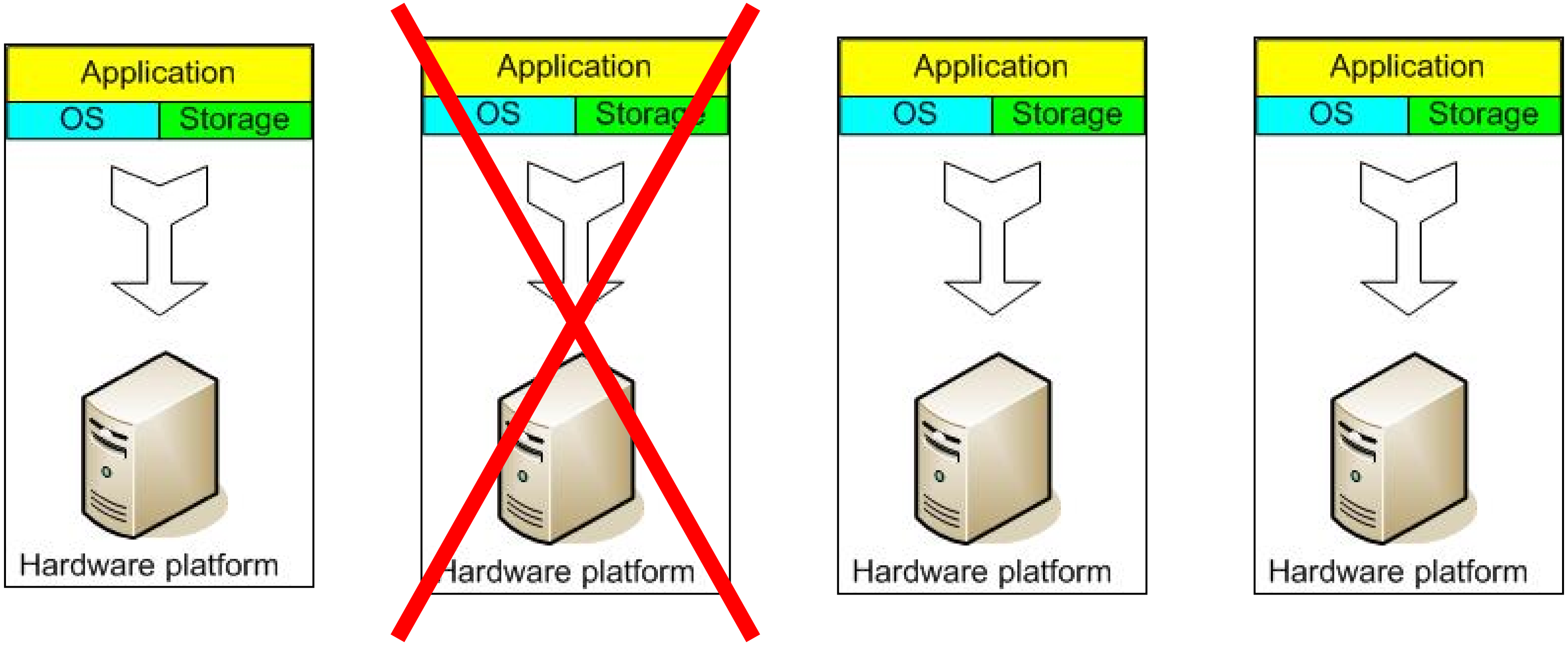
Source: Taylor

The Traditional Server Concept

- System Administrators often talk about servers as a whole unit that includes the hardware, the OS, the storage, and the applications.
- Servers are often referred to by their function i.e. the Exchange server, the SQL server, the File server, etc.
- If the File server fills up, or the Exchange server becomes overtaxed, then the System Administrators must add in a new server.

Source: Taylor

And if something goes wrong ...



Web Server	App Server	DB Server	EMail
Windows	DOWN!	Linux	Windows
IIS		MySQL	Exchange

Source: Taylor

The Traditional Server Concept

- Unless there are multiple servers, if a service experiences a hardware failure, then the service is down.

- System Admins can implement clusters of servers to make them more fault tolerant. However, even clusters have limits on their scalability, and not all applications work in a clustered environment.

Source: Taylor

The Traditional Server Concept

- Pros
  - Easy to conceptualize
  - Fairly easy to deploy
  - Easy to backup
  - Virtually any application/service can be run from this type of setup
- Cons
  - Expensive to acquire and maintain hardware
  - Not very scalable
  - Difficult to replicate
  - Redundancy is difficult to implement
  - Vulnerable to hardware outages
  - In many cases, processor is under-utilized

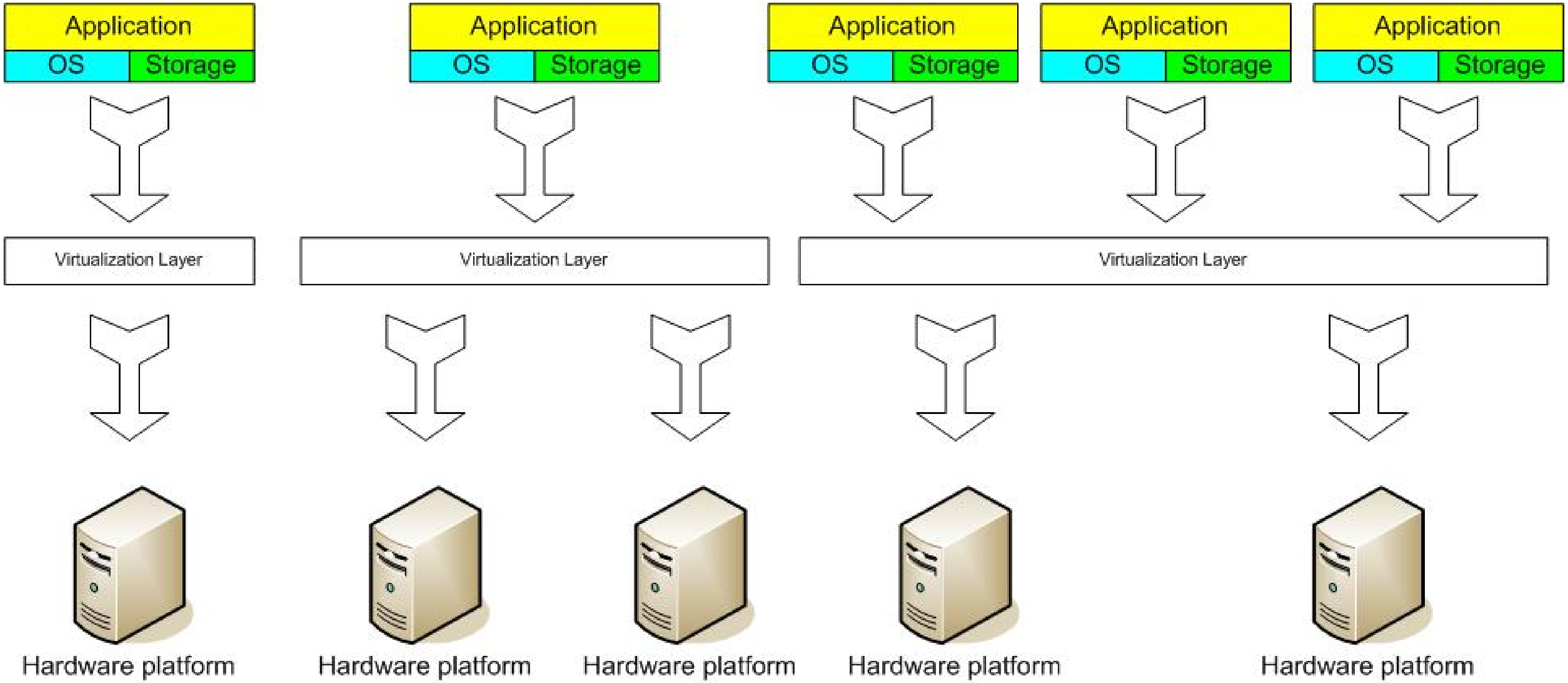
Source: Taylor

The Virtual Server Concept

- Virtual servers seek to encapsulate the server software away from the hardware
  - This includes the OS, the applications, and the storage for that server.
- Servers end up as mere files stored on a physical box, or in enterprise storage.
- One host typically house many virtual servers (**virtual machines or VMs**).
- A virtual server can be serviced by one or more hosts e.g. storage, services, etc

Source: Taylor

The Virtual Server Concept



Hypervisor layer between *Guest OS* and hardware

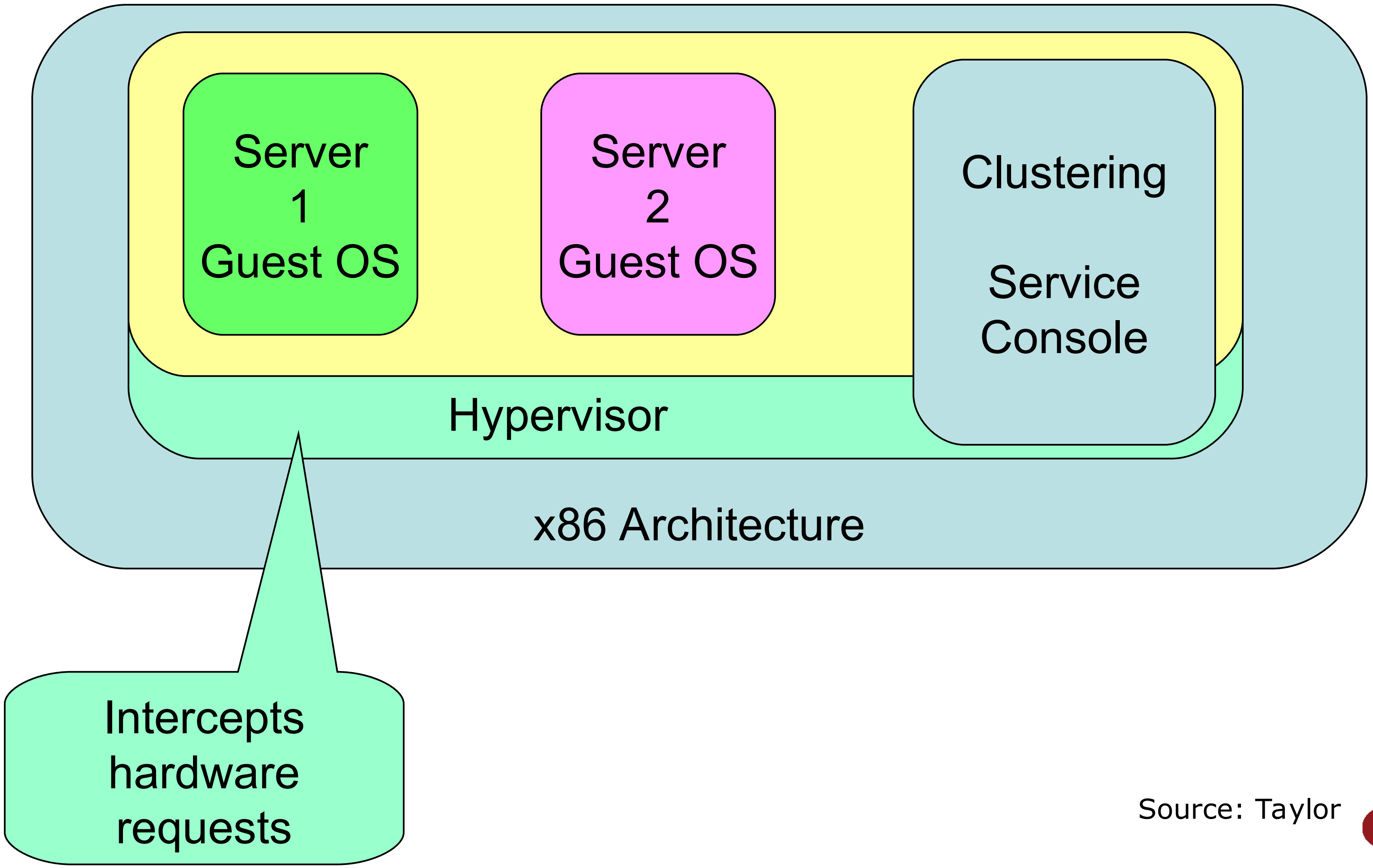
Source: Taylor

Hypervisors And Hosts

- A **hypervisor** is a piece of computer software, firmware or hardware that creates and runs virtual machines.
- A computer on which a hypervisor is running one or more virtual machines is defined as a **host machine**.
- Each **virtual machine** has a **guest operating systems**, which is managed by the hypervisor.
- Multiple instances of a variety of operating systems may share the virtualized hardware resources.

Source: Taylor

Hypervisors and Virtual Machines



Source: Taylor

The Virtual Server Concept

- Virtual servers can still be referred to by their function i.e. email server, database server, etc.
- If the environment is built correctly, virtual servers will not be affected by the loss of a host.
- Hosts may be removed and introduced almost at will to accommodate maintenance.

Source: Taylor

The Virtual Server Concept

- Virtual servers can be scaled out easily.
  - If the administrators find that the resources supporting a virtual server are being taxed too much, they can adjust the amount of resources allocated to that virtual server
- Server templates can be created in a virtual environment to be used to create multiple, identical virtual servers
- Virtual servers themselves can be migrated from host to host almost at will.

Source: Taylor

The Virtual Server Concept

- Pros
  - Resource pooling
  - Highly redundant
  - Highly available
  - Rapidly deploy new servers
  - Easy to deploy
  - Reconfigurable while services are running
  - Optimizes physical resources by doing more with less
- Cons
  - Slightly harder to conceptualize
  - Slightly more costly (must buy hardware, OS, Apps, and now the abstraction layer)

Source: Taylor

Cloud Computing?

- The cloud is Internet-based computing, whereby shared resources, software, and information are provided to computers and other devices on demand – pay per use.

- Cost-effective means of virtualising and making use of resources more effectively
  - Low start-up costs – pay for use helps to kick-start companies
  - Scaling is proportional to demand (revenue) so it's a good business model
- Vast range of Cloud Computing applications
  - Virtual private servers, Web hosting, data servers, fail-over services, etc

Source: Taylor

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.

Source: Taylor

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.

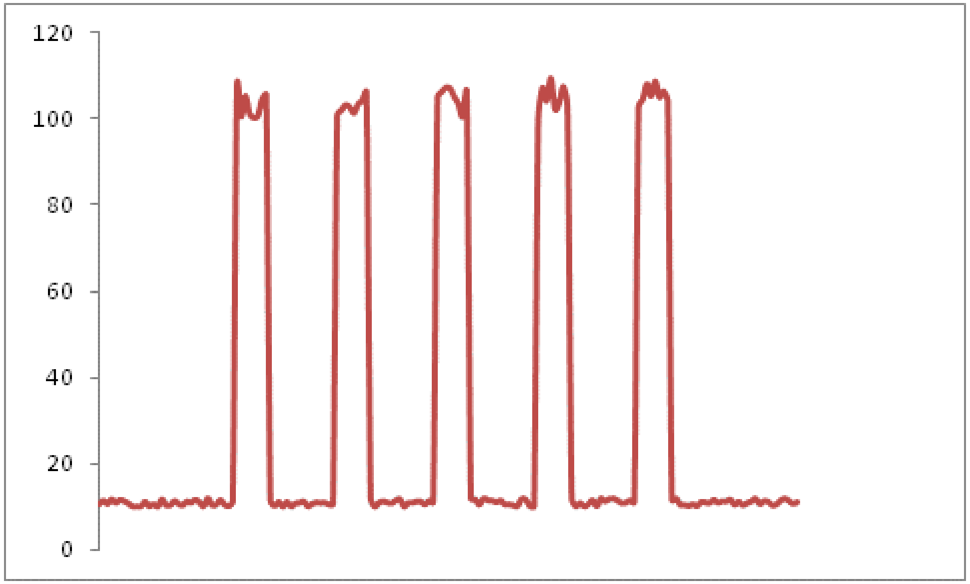
- In general, they are built on clusters of PC servers and off-the-shelf components plus Open Source software combined with in-house applications and/or system software.

Source: Taylor

Motivation Example: Forbes.com

- You offer on-line real time stock market data
- Why pay for capacity weekends, overnight?

Rate of Server Accesses



9 AM - 5 PM, M-F

ALL OTHER TIMES

Source: Taylor

Forbes' Solution

- Host the web site in Amazon's EC2 *Elastic Compute Cloud*
- Provision new servers every day, and deprovision them every night
- Pay just $0.10* per server per hour
  - * more for higher capacity servers
- Let Amazon worry about the hardware!

Source: Taylor

Cloud Computing takes virtualization to the next step

- You don't have to own the hardware
- You "rent" it as needed from a cloud
- There are public clouds
  - e.g. Amazon EC2, and now many others (Microsoft, IBM, Sun, and others ...)
- A company can create a private one
  - With more control over security, etc.

Source: Taylor

Goal 1 – Cost Control

- Cost
  - Many systems have variable demands
    - Batch processing (e.g. New York Times)
    - Web sites with peaks (e.g. Forbes)
    - Startups with unknown demand (e.g. the *Cash for Clunkers* program)
  - Reduce risk
    - Don't need to buy hardware until you need it

Source: Taylor

Goal 2 - Business Agility

- More than scalability - ***elasticity***
  - Ely Lilly in rapidly changing health care business
    - Used to take 3 - 4 months to give a department a server cluster, then they would hoard it
  - Using EC2, about 5 minutes
    - And they give it back when they are done
- Scaling back is as important as scaling up

Source: Taylor

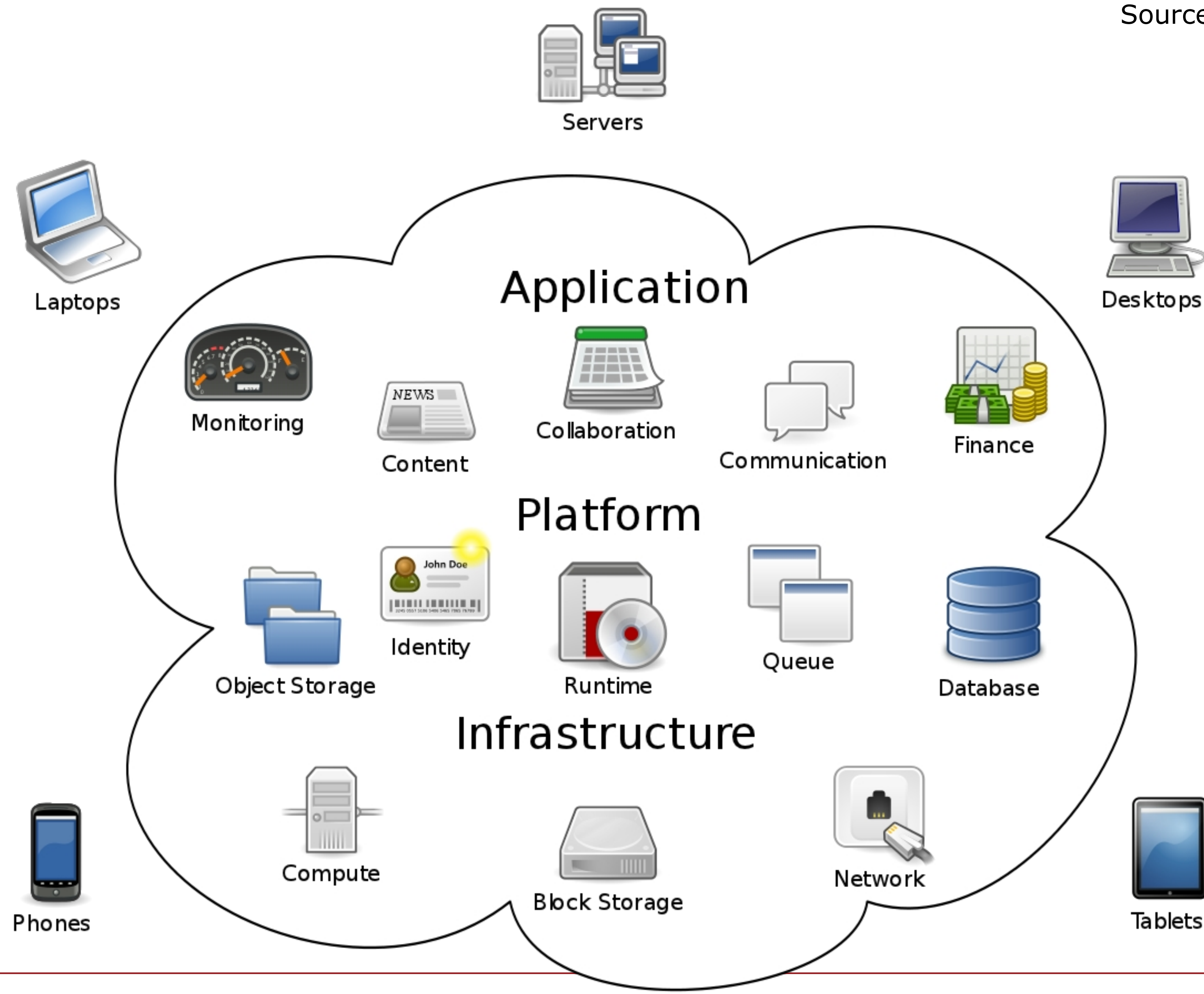
Goal 3 - Stick to Our Business

- Most companies don't WANT to do system administration
  - Forbes says:
    - *We are is a publishing company, not a software company*
- *But beware:*
  - *Do you really save much on sys admin?*
  - *You don't have the hardware, but you still need to manage the OS!*

Source: Taylor

Cloud Computing Overview

Source: Taylor



IaaS

- IaaS providers offer virtual machines, virtual-machine image libraris, raw (block) and file-based storage, firewalls, load balancers, IP addresses, virtual local area networks (VLANs), and software bundles.

- Pools of hypervisors can scale services up and down according to customers' varying requirements

- All infrastructure is provided on-demand

Source: Taylor

SaaS and PaaS

- SaaS is where an application is hosted as a service provided to customers across the Internet.
  - Saas alleviates the burden of software maintenance/support
  - but users relinquish control over software versions and requirements.

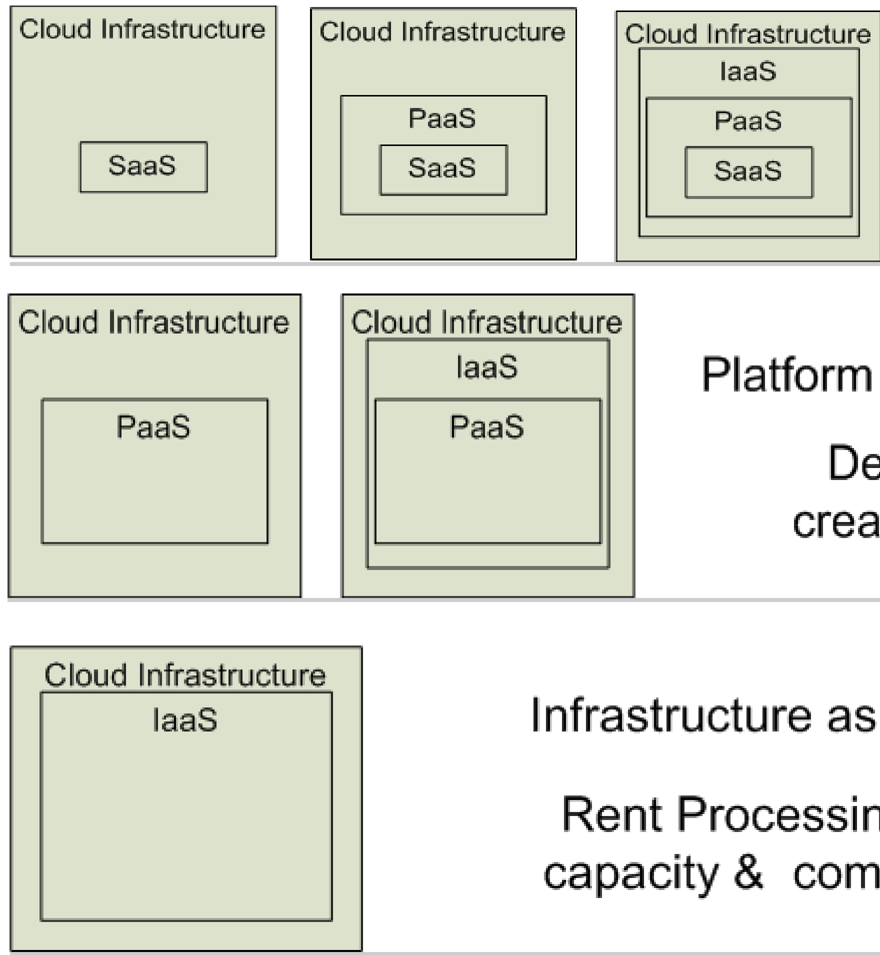
- PaaS provides a computing platform and a solution stack as a service.
  - Consumer creates the software using tools and/or libraries from the provider.
  - The consumer also controls software deployment and configuration settings. The provider provides the networks, servers, storage and other services.

Source: Taylor

Cloud Service Models

Source: Taylor

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

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

Adopted from: Effectively and Securely Using the Cloud Computing Paradigm by peter Mell, Tim Grance

Some Commercial Cloud Offerings

amazon webservices™ Amazon Elastic Compute Cloud (Amazon EC2) - *Beta*

GOGRID beta A ServePath Company

Sun microsystems TAP INTO THE POWER OF NETWORK.COM

3tera™ info@3tera.com (949) 305-0050 CAREERS | SU

APPLOGIC | UTILITY COMPUTING | TECHNOLOGY | PARTNERS | GRID UNIVERSITY | COMPANY

Cloud Computing

Cloudware - Cloud Computing Without Compromise

b-hive

MOSSO® the hosting cloud

Engine Yard™

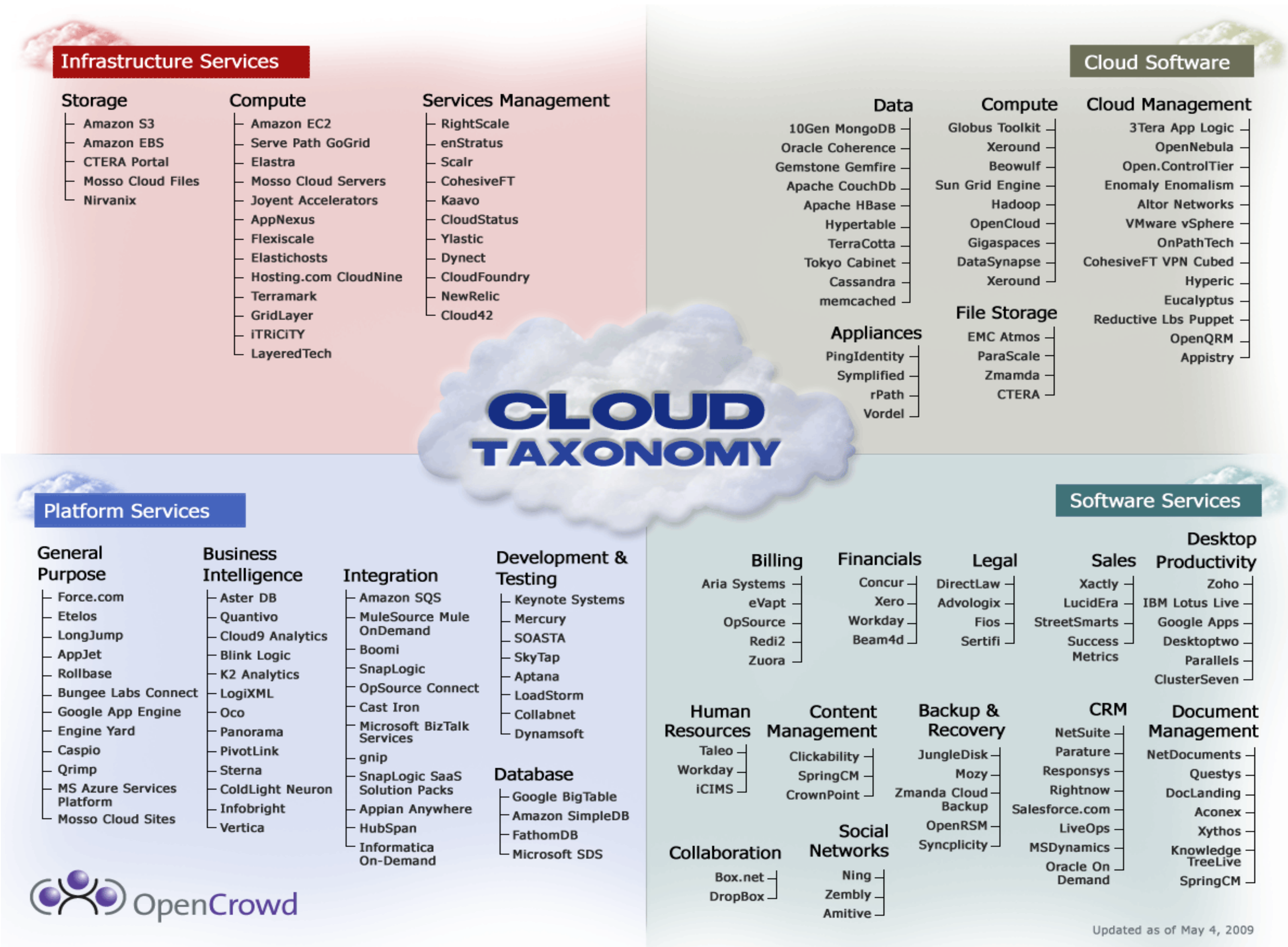
Joyent

VERIO An NTT Communications Company

rackspace® HOSTING

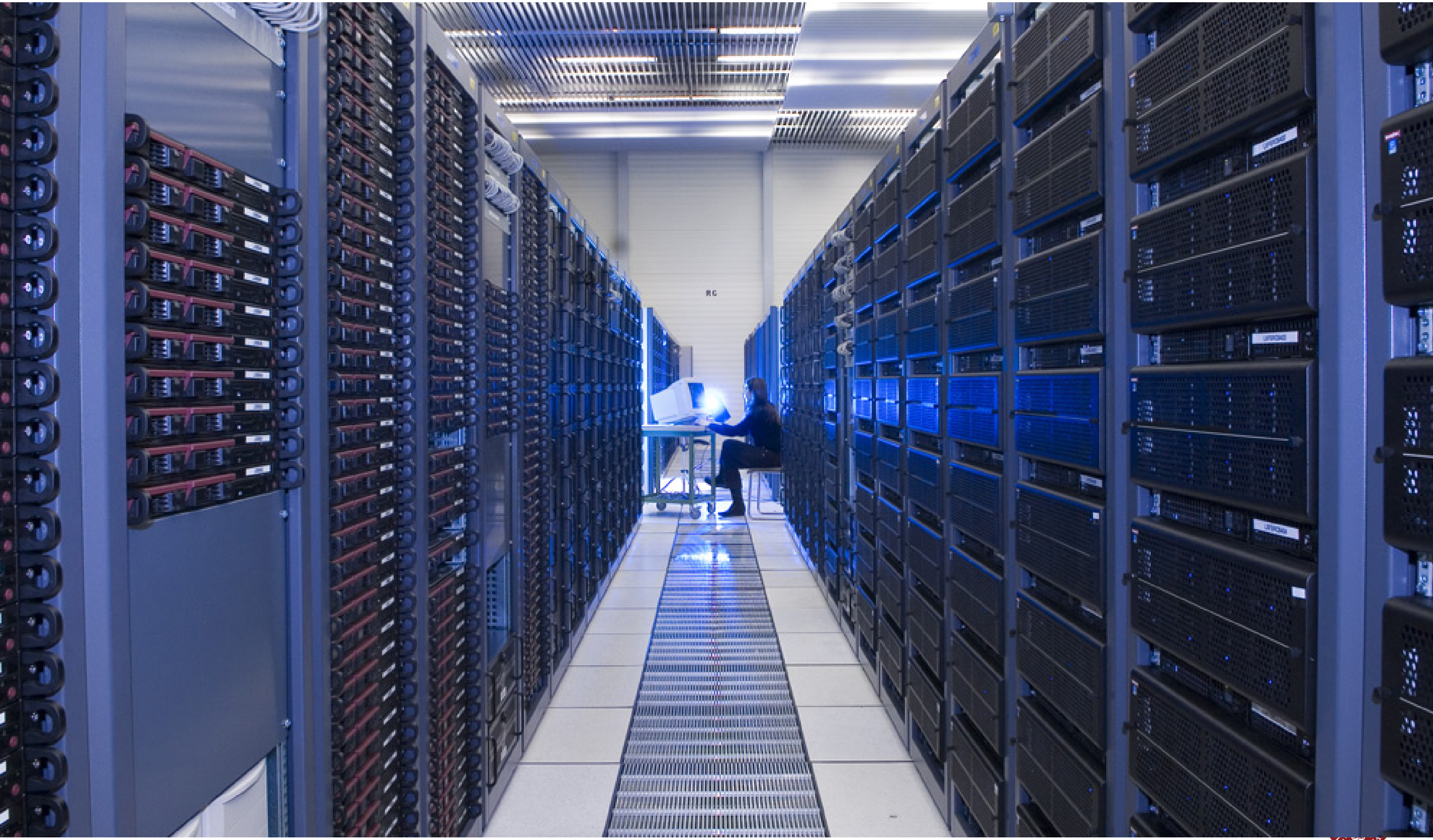
Source: Taylor

Cloud Taxonomy



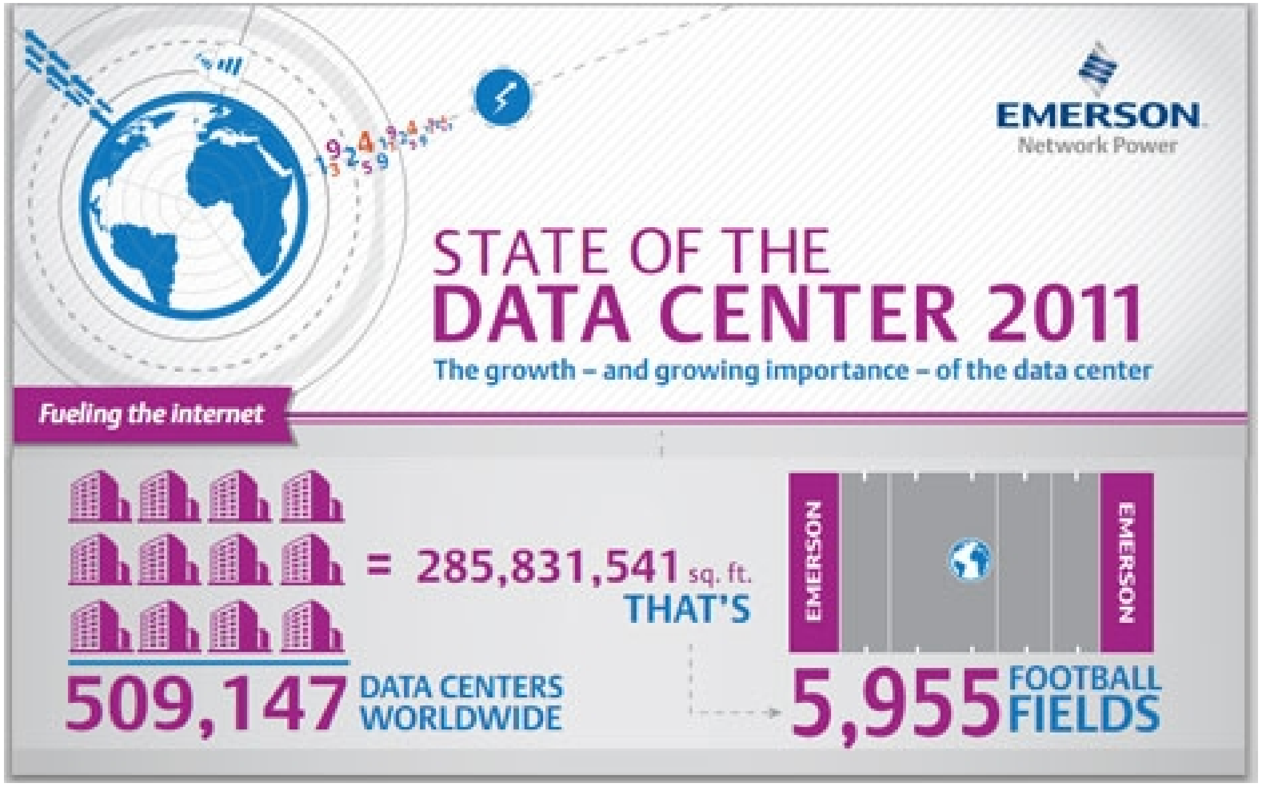
Source: Taylor

Where is all of this?



Source: Taylor

Data Centers



- 10 billion spent on electricity per year for data centers
- 3% of global energy use
- Clouds are the future of the way companies do business on the Internet

Source: Taylor

Data Centers By Size and Region

Sum of Sites		Year						
Region	**Site Class**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Asia/Pacific	Single	769,012	769,455	780,252	792,999	819,342	851,068	900,039
	Rack/Computer Room	58,702	60,311	63,183	66,916	70,173	72,564	74,249
	Midsize DC	4,478	4,656	4,989	5,455	5,892	6,260	6,559
	Enterprise DC	984	1,026	1,110	1,239	1,379	1,523	1,666
	Large DC	106	110	120	136	156	179	204
Canada	Single	66,519	66,012	64,384	62,311	61,575	62,246	63,956
	Rack/Computer Room	14,390	14,194	13,828	13,241	12,686	12,068	11,328
	Midsize DC	650	643	631	613	599	584	564
	Enterprise DC	210	209	208	210	217	228	241
	Large DC	22	22	23	25	28	32	37
Eastern Europe	Single	147,274	151,468	161,916	176,398	194,389	213,602	238,792
	Rack/Computer Room	28,750	28,892	28,829	28,761	28,799	29,077	29,380
	Midsize DC	1,102	1,112	1,121	1,134	1,149	1,172	1,197
	Enterprise DC	196	198	202	208	216	228	243
	Large DC	44	44	46	49	53	58	65
Japan	Single	286,416	274,109	251,600	225,292	212,947	213,494	222,012
	Rack/Computer Room	27,532	27,050	25,885	23,673	21,100	18,334	15,706
	Midsize DC	380	372	354	324	294	264	236
	Enterprise DC	346	341	330	313	301	294	292
	Large DC	85	84	83	83	86	92	101
Latin America	Single	195,547	196,703	199,196	204,643	216,169	233,087	253,961
	Rack/Computer Room	13,325	13,541	13,786	13,957	13,939	13,846	13,774
	Midsize DC	821	832	845	858	868	881	899
	Enterprise DC	213	216	222	230	241	258	278
	Large DC	18	18	19	20	22	25	28
Middle East and Africa	Single	108,868	114,214	126,323	143,733	162,834	182,687	207,031
	Rack/Computer Room	21,549	21,793	22,133	22,412	22,650	22,793	22,963
	Midsize DC	871	881	894	908	921	934	952
	Enterprise DC	120	122	126	131	139	148	159
	Large DC	21	21	22	23	24	26	27
United States	Single	770,925	769,095	749,290	716,352	685,760	664,601	660,355
	Rack/Computer Room	184,457	182,963	179,818	174,492	168,593	162,051	154,496
	Midsize DC	2,506	2,483	2,435	2,372	2,319	2,276	2,223
	Enterprise DC	2,404	2,392	2,377	2,382	2,438	2,539	2,660
	Large DC	571	571	574	589	621	669	724
Western Europe	Single	536,090	531,772	528,022	525,520	545,062	583,768	647,273
	Rack/Computer Room	139,790	138,022	133,181	125,030	116,790	109,967	105,045
	Midsize DC	4,860	4,788	4,608	4,337	4,093	3,921	3,822
	Enterprise DC	1,196	1,181	1,148	1,106	1,089	1,105	1,153
	Large DC	244	243	242	244	256	280	313
Grand Total		**3,391,592**	**3,382,159**	**3,364,353**	**3,338,716**	**3,376,208**	**3,469,231**	**3,645,002**

Source: Taylor

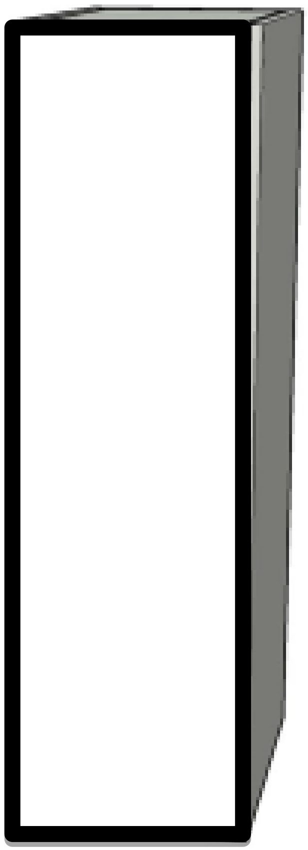
Google Oregon Warehouse Scale Computer

Source: Moore

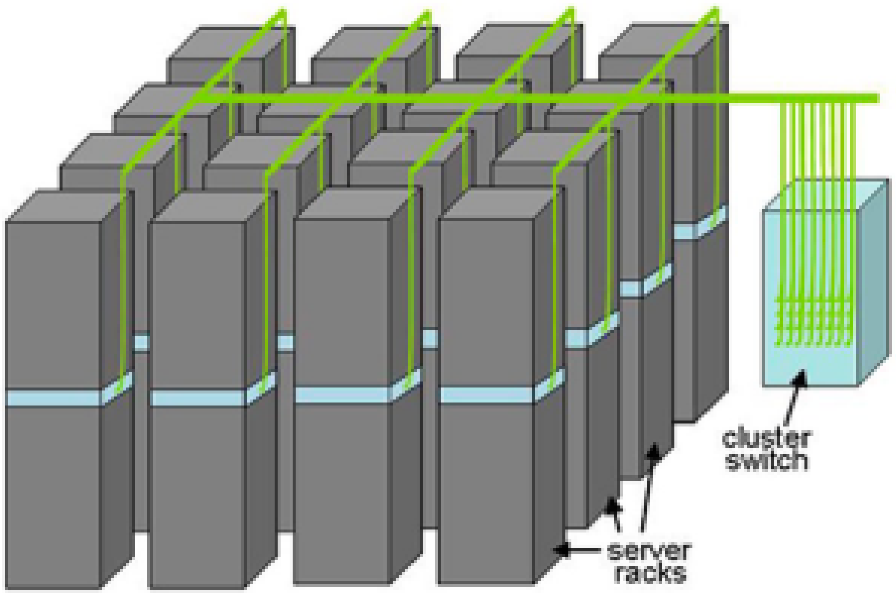
Equipment Inside a WSC

Server (in rack format):
1 ¾ inches high “1U”,

x 19 inches x 16-20 inches: 8 cores, 16 GB DRAM, 4x1 TB disk



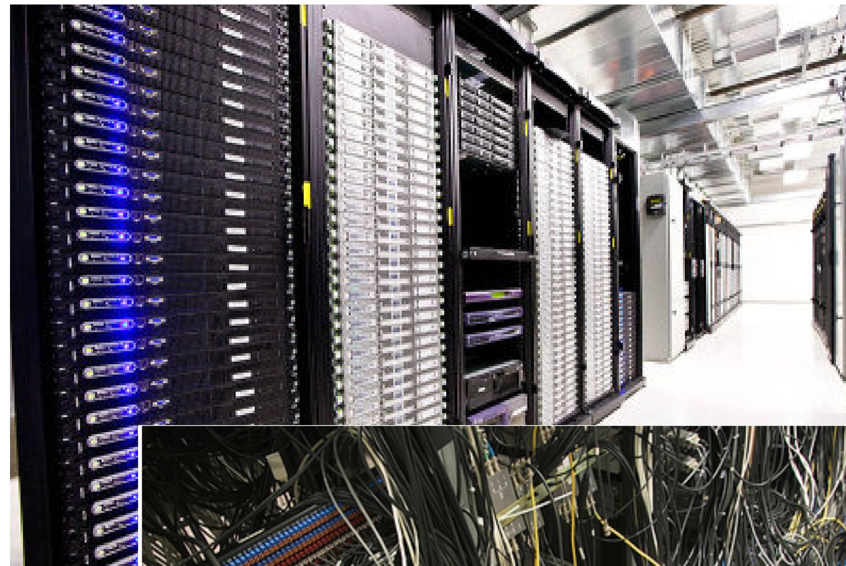
7 foot Rack: 40-80 servers + Ethernet local area network (1-10 Gbps) switch in middle (“rack switch”)



Array (aka cluster): 16-32 server racks + larger local area network switch (“array switch”) 10X faster => cost 100X: cost $f(N^2)$

Source: Moore

Server, Rack, Array



Source: Moore

Data warehouse?

If you have a Petabyte,

you might have a datacenter

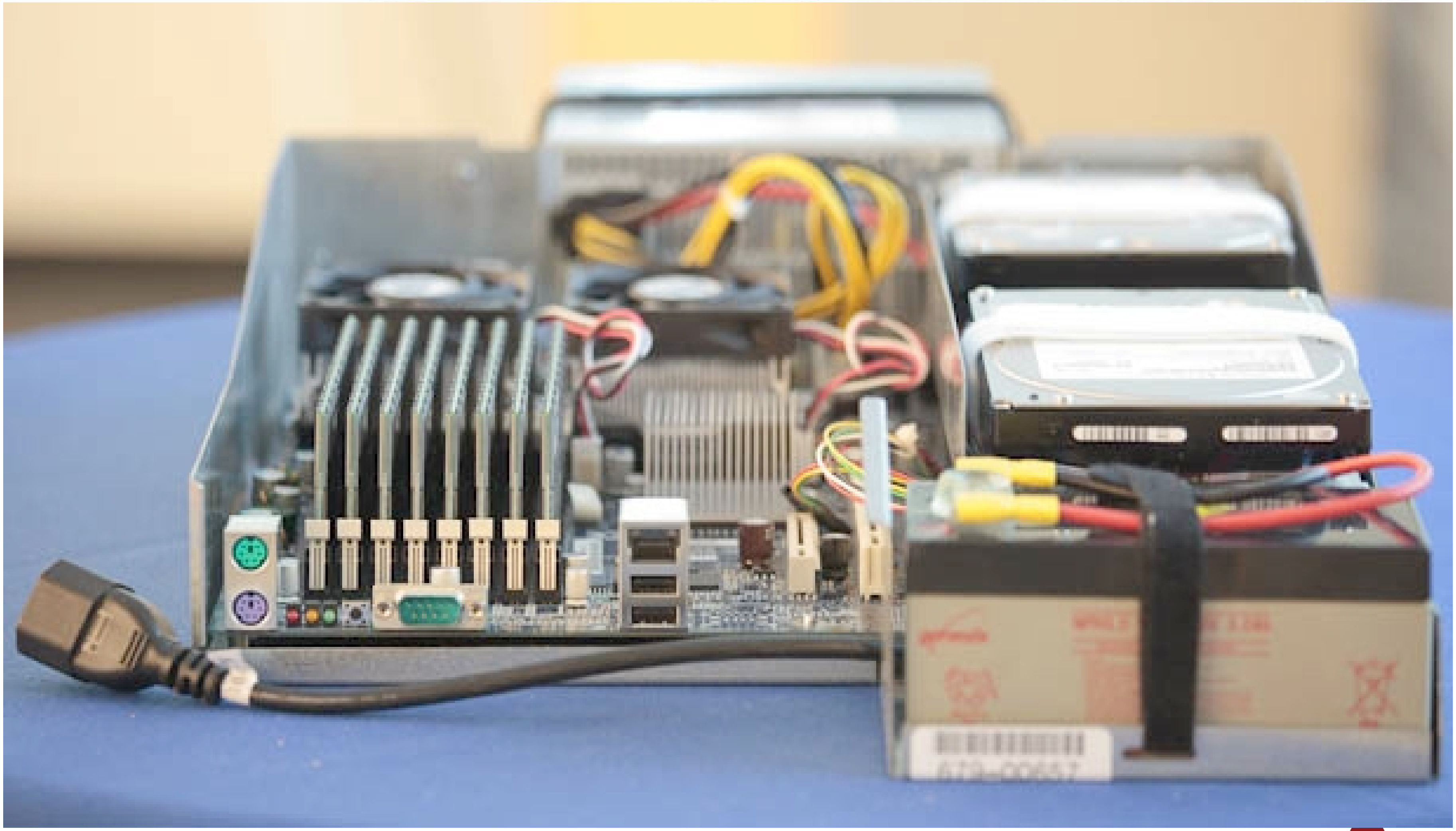
If your paged at 3am because you only have a few Petabyte left,

you might have a data warehouse

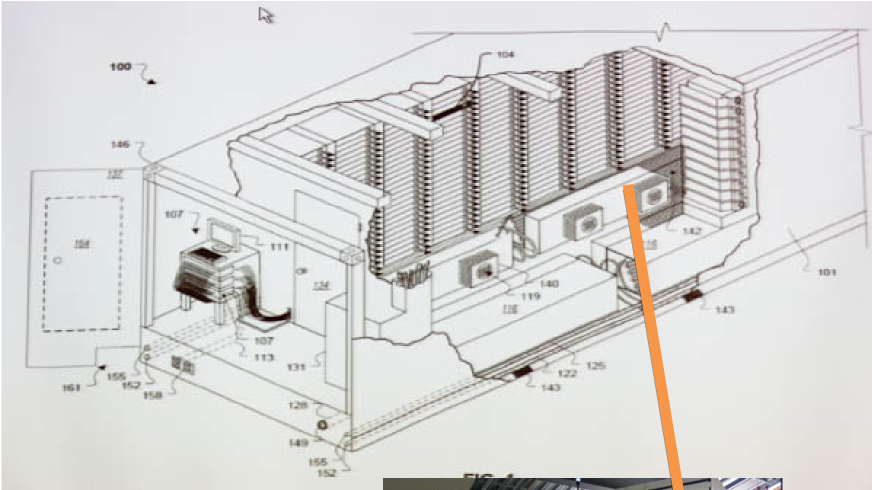
Luiz Barroso (Google), 2009

Source: Moore

Google Server Internals

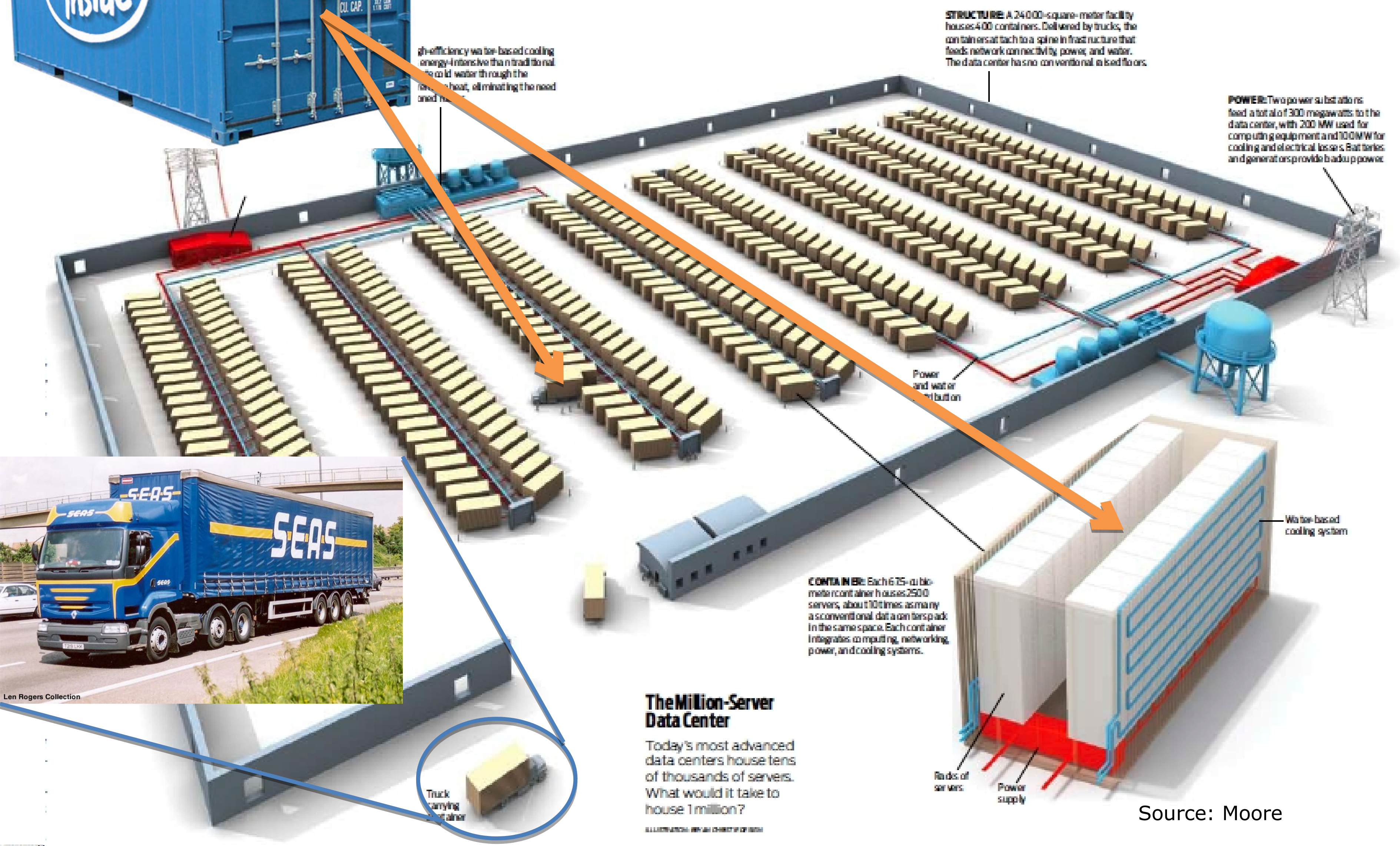


Source: Moore



Source: Moore

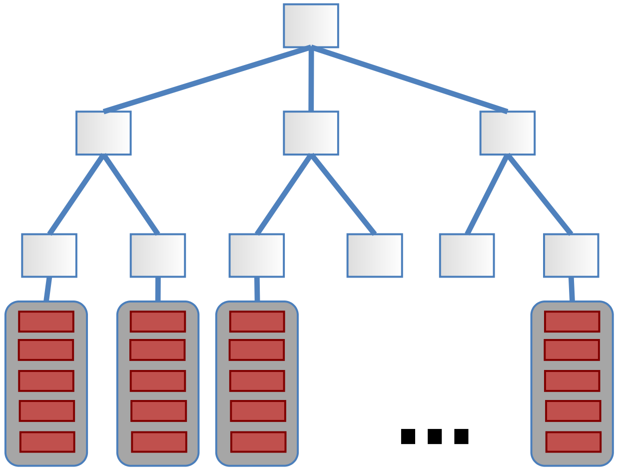
Microsoft's Chicago Modular Datacenter



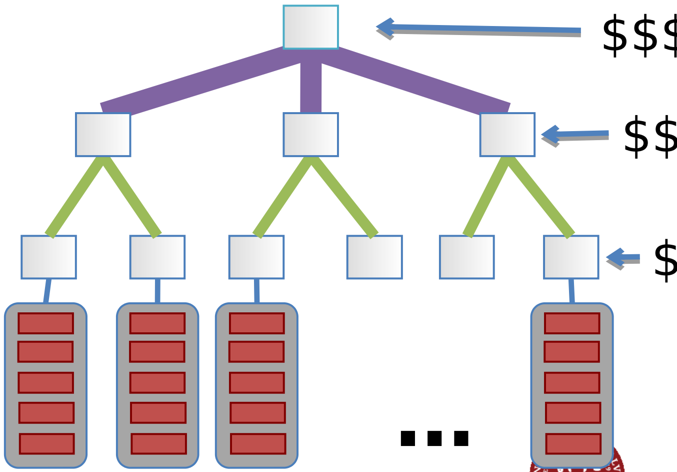
Source: Moore

Datacenter design 101

- Naive topologies are tree-based
  same boxes, and same b/w links
  - Poor performance
  - Not fault tolerant



- An early solution; speed hierarchy (fewer expensive boxes at the top)
  - Boxes at the top run out of *capacity (bandwidth)*
  - but even the $ boxes needed
    $$$ abilities (forwarding table size)



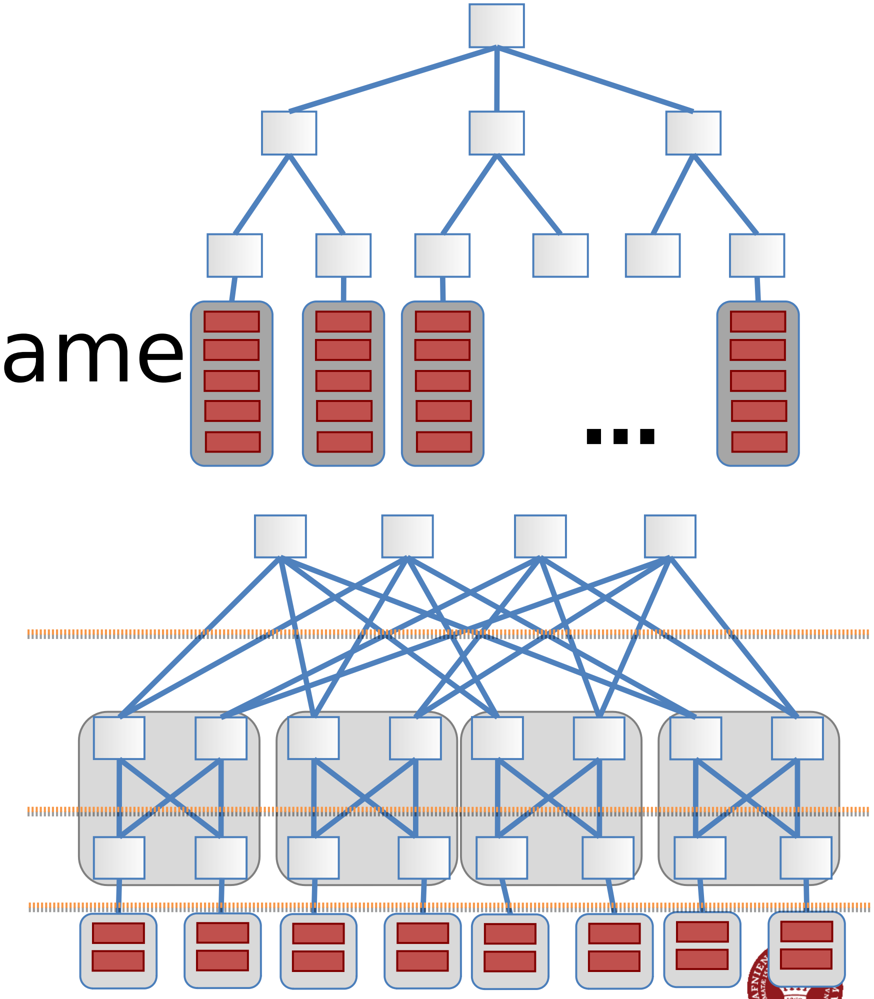
Source: Moore

Data Center 102

- Tree leads to FatTree

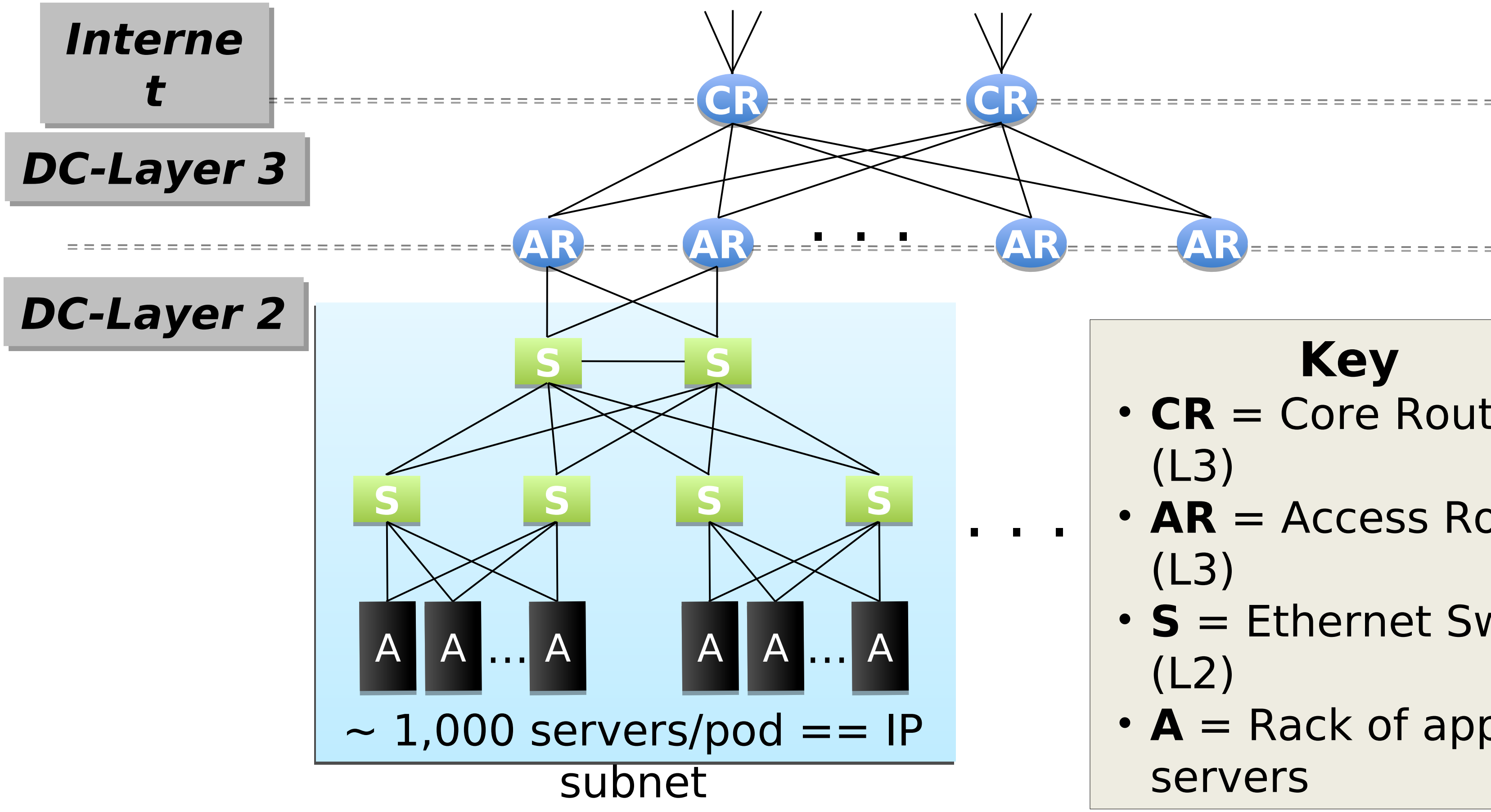
- All bi-sections have same bandwidth

This is not the only solution…



Source: Moore

DC: lets add some of redundancy
The 3-layer Data Center



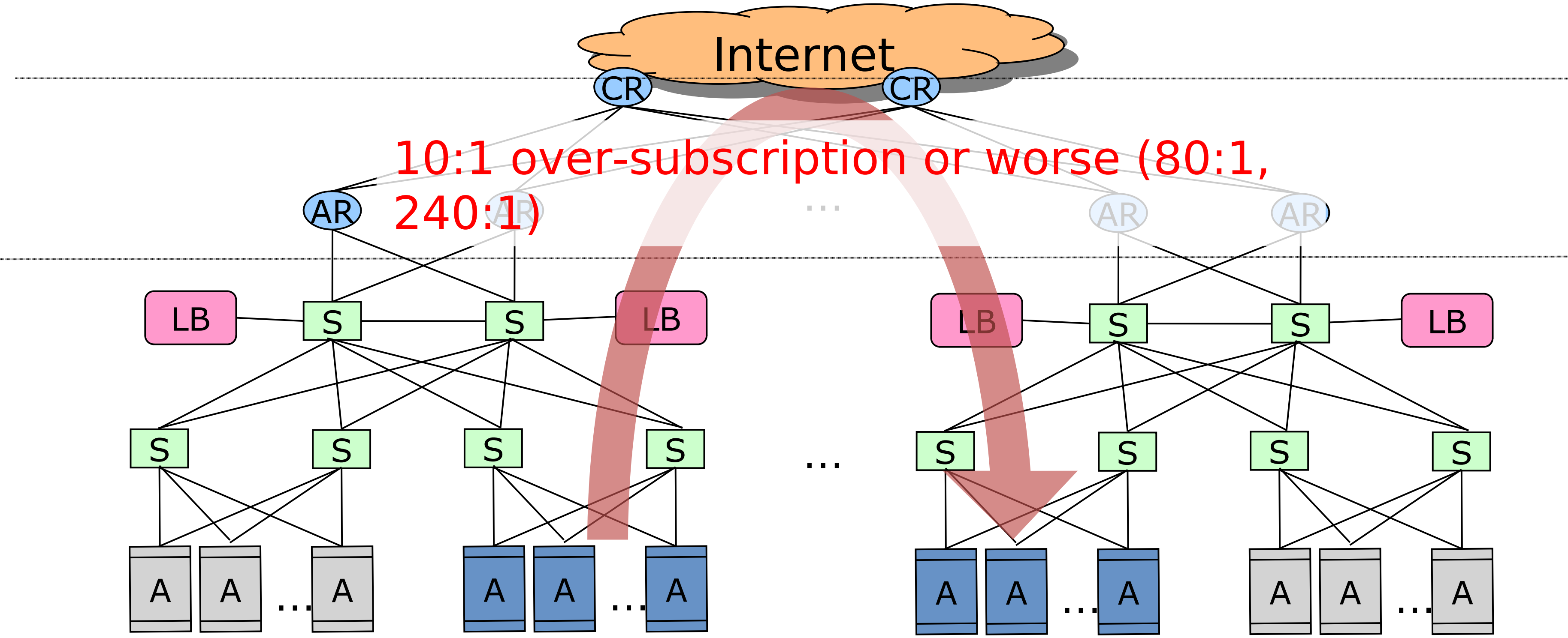
Key

- **CR** = Core Router (L3)
- **AR** = Access Router (L3)
- **S** = Ethernet Switch (L2)
- **A** = Rack of app. servers

Reference – "Data Center: Load balancing Data Center Services", Cisco 2004

Source: Moore

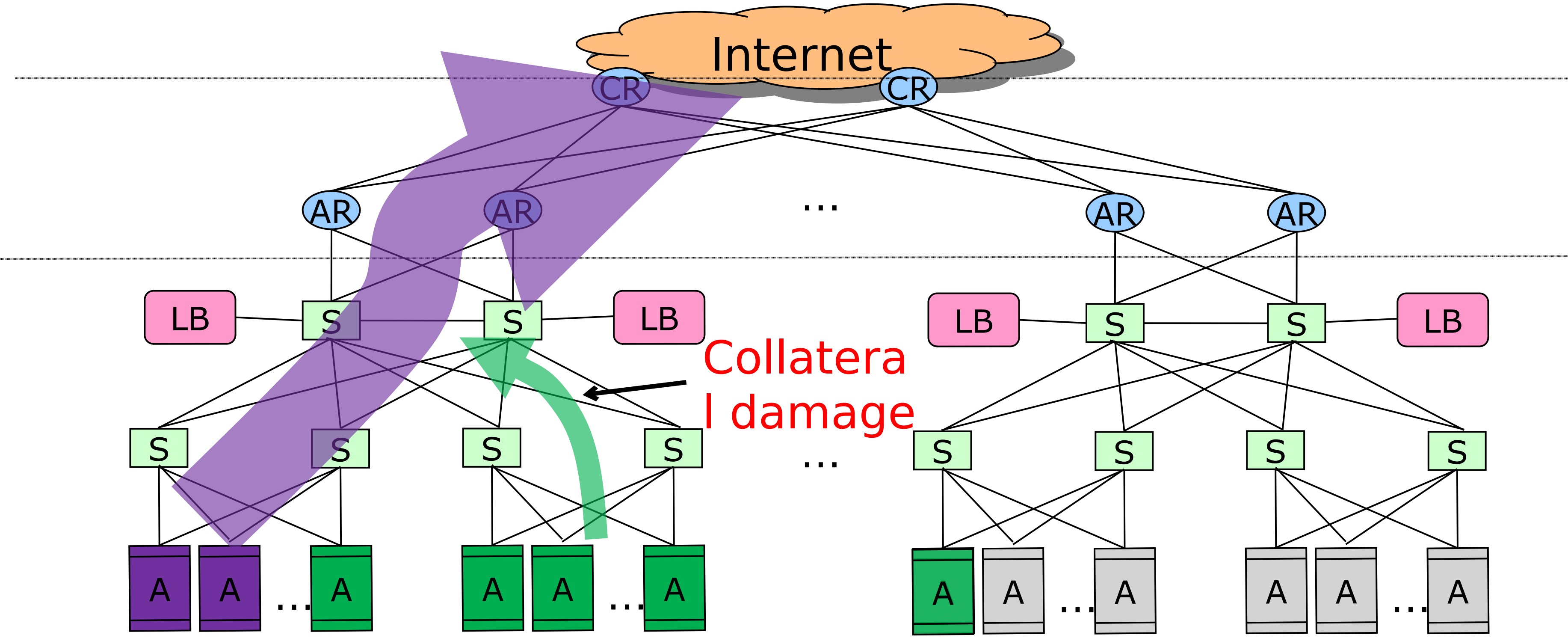
Network has Limited Server-to-Server Capacity, and Requires Traffic Engineering to Use What It Has



- Data centers run two kinds of applications:
  - Outward facing (serving web pages to users)
  - Internal computation (computing search index – think HPC)

Source: Moore

No Performance Isolation

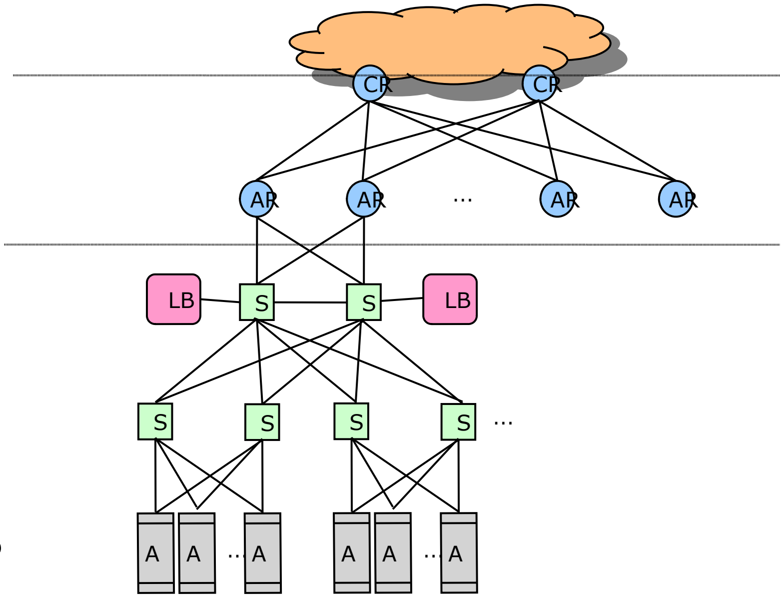


- VLANs typically provide reachability isolation only
- One service sending/receiving too much traffic hurts all services sharing its subtree

Source: Moore

What Do Data Center Faults Look Like?

- Need very high reliability near top of the tree
  - Very hard to achieve
    - Example: failure of a temporarily unpaired core switch affected ten million users for four hours
  - 0.3% of failure events knocked out all members of a network redundancy group



Ref: Data Center: Load Balancing Data Center Services, Cisco 2004

Source: Moore

Data Center: Challenges

- From a large cluster used for data mining and identified distinctive traffic patterns
- Traffic patterns are **highly volatile**
  - A large number of distinctive patterns even in a day
- Traffic patterns are **unpredictable**
  - Correlation between patterns very weak

Source: Moore

Some Differences Between Commodity DC Networking and Internet/WAN

Characteristic	Internet/WAN	Commodity Datacenter
Latencies	Milliseconds to Seconds	Microseconds
Bandwidths	Kilobits to Megabits/s	Gigabits to 10’s of Gbits/s
Causes of loss	Congestion, link errors, …	Congestion
Administration	Distributed	Central, single domain
Statistical Multiplexing	Significant	Minimal, 1-2 flows dominate links
Incast	Rare	Frequent, due to synchronized responses

Source: Moore

Source: Moore

Coping with Performance in Array

Lower latency to DRAM in another server than local disk

Higher bandwidth to local disk than to DRAM in another server

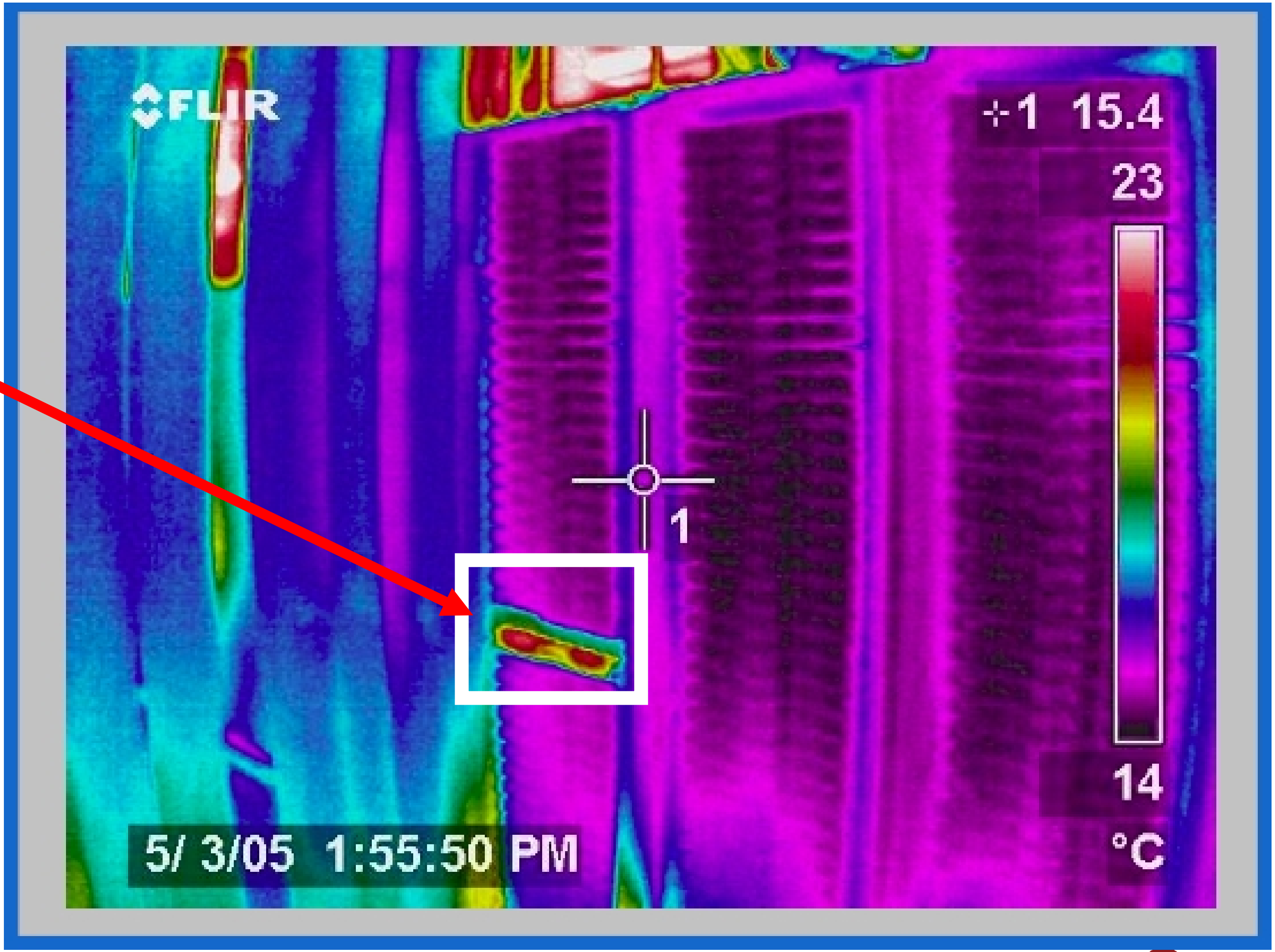
	Local	Rack	Array
Racks	--	1	30
Servers	1	80	2400
Cores (Processors)	8	640	19,200
DRAM Capacity (GB)	16	1,280	38,400
Disk Capacity (GB)	4,000	320,000	9,600,000
DRAM Latency (microseconds)	0.1	100	300
Disk Latency (microseconds)	10,000	11,000	12,000
DRAM Bandwidth (MB/sec)	20,000	100	10
Disk Bandwidth (MB/sec)	200	100	10

Google Oregon Warehouse Scale

Source: Moore

Thermal Image of Typical Data Centre Rack

Rack Switch



Source: Moore

M. K. Patterson, A. Pratt, P. Kumar,
"From UPS to Silicon: an end-to-end evaluation of datacenter efficiency", Intel Corporation