CS 551 - HW1

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1) Consider a large-scale web site with N servers. Suppose P percent of the network communication to a given server occurs with a browser on the Internet and 100-P percent of the communication occurs with databases and other servers inside the data center. Suppose the data center uses a hierarchical network with a switch at the top of the hierarchy connecting computers in the data center to the Internet and to each other. If the Internet connection supports a maximum of 100 Gigabits per second of traffic, what total capacity will the switch need to allow the internet connection to run at full speed and also handle communication that stays inside the data center?

   Total External Traffic would be P% of 100 times N. This equals **NP Gbps.**

   Total Internal Traffic would be (100-P)% times N. This equals (N(100-P)/100) Gbps.

   We know maximum supported traffic = 100 Gbps

   So:
   100 + (N(100 – P)/100)
   This would be the total capacity with which the switch needs to allow the internet connection to run at full speed and also handle communication that stays inside the data center.

2) A visitor to a cloud data center observes that some of the racks in a given row contain many empty slots (i.e., the rack is almost empty). Explain why a provider would leave empty spaces

   A visitor might see empty slots at a cloud data center since they want to **maintain air flow**. A complete rack doesn't allow air flow from the outside Also if it is full, then heat and air isn't dissipated properly which can lead to **overheating**. Sometimes cooling systems aren't enough, so leaving spaces in racks helps with the servers not overheating. If the airflow isn't dealt with, the **equipment might get damaged**. Apart from this, for technicians who go in these servers' rooms, **high temperatures** might make it unsafe for them to be in the room. Spreading out and leaving empty racks provides **simplicity** and make it safer for workers.

3) Search the web to find the range of power requirements of various size data centers. Also find an estimate of the power used by a city the size of Lafayette and answer the question of what fraction of Lafayette's power use could be satisfied by a small, medium, or large data center.

   Small datacenters (employed by private or enterprises generally) might have a power requirements **under 2 Megawatts of power.**

Medium sized datacenters require between **5 to 50 Megawatts of power.**

Large datacenters generally range from **50 to 160 Megawatts of power.**

As per
https://www.energy.gov/sites/prod/files/2016/09/f33/IN_Energy%20Sector%20Risk%20Profile.pdf
we see Indiana as a state consumes 114.7TWh annually. The population of Indiana is 6.806 million. Now Lafayette, has an average population of 80,000 people.
https://en.wikipedia.org/wiki/Lafayette,_Indiana

Energy per capita in Indiana ≈ 0.01685TWh per person
Energy for Lafayette ≈ 1.348TWh (Assuming we are scaling linearly)
Converting to MW: We can say 153MW is consumed by Lafayette as a city.

So now converting to fractions:
Small datacenter: 2/153 = 0.013 = 1.3% of total power
Medium datacenter: 50/153 = 0.32679 = 33% of total power
Large datacenter: 160/153 = 1.04 = 100% of total power

4) You meet a physics student who claims that physicists invented cloud computing first and that cloud companies, such as AWS, merely uses the same hardware and software as the physicists had used. What are the major differences between the computing systems scientists use and the facilities in a cloud data center.

There are many differences between the computing systems scientists use and the facilities in a cloud data center.

i) **Different use-cases:**
The computing systems used by scientists is typically used for large-scale experiments, simulations, analysis, etc. The cloud systems provide a lot of application scope, from training models to hosting web servers, etc.

ii) **Scalability and Flexibility:**
The systems used by scientists are generally not scalable and can’t adapt to different workloads. They are used for scientific tasks generally. Cloud computing can use Auto-Scaling groups and Load Balancing to scale and provide flexibility and scalability.

iii) **Locations and Availability:**
The systems used by scientists are generally inside research facilities or institutions. Their usage is generally restricted to specific groups within the institution. Cloud facilities are distributed globally so that availability increases, and anyone can access this with low latency.

iv) **Software stack and Cost:**

The systems used by scientists, generally, have only certain libraries or compilers installed which help scientists with their work. Cloud providers have a lot of flexibility when it comes to having an avid software stack. It offers ML, AI, Data Analysis, etc. libraries which provide a lot of use cases for any business. Anyone can avail cloud services when they have an internet connection, and they might pay on subscription basis as per needs whereas systems used by scientists has no direct costs for scientists themselves.

5) Suppose a data center contains N racks filled with servers plus a top-of-rack switch. Also suppose the center has S spine switched and T superspine switches. If each server and switch has an LED to indicate that power is on and the LED consumes 1/8 watt of power, write an equation that specifies the total power that the LEDs consume. What value does your equation specify for N=12,000 racks, S=120 spine switches, and T=50 superspine switches?

Let's assume there are 42 servers in each rack, as per slides. Then, for N racks, there are 42N servers in total.
Total power consumed by LEDs on all servers: 42N/8 Watts.
Total power consumed by LEDs on all top-of-rack switches: N/8 Watts.
Total power consumed by LEDs on all spine switches: S/8 Watts.
Total power consumed by LEDs on all superspine switches: T/8 Watts.
Therefore, the equation that specifies the total power that the LEDs consume:

⇨ **(42N + N + S + T)/8**

Now plugging in values for N=12,000 racks, S=120 spine switches, and T=50 superspine switches:

⇨ (42*12000 + 12000 + 120 + 50)/8
⇨ **64,521 Watts or 64.52 kW**

6) A recent headline announces a data center being constructed in Iceland, far from populated areas. Why would such a location be chosen? Consider a customer in New York who connects to such a data center. If the customer lays an optical fiber cable directly to the data center and sends packets at the speed of light, what is the latency required to reach the data center and receive a reply?

An area like Iceland might be chosen for multiple reasons. First, it has a **cool climate** and since **cooling** is one of the highest costs at a data center, the natural cooling can help them save some costs. Secondly, **cost** of setting up in Iceland is way **cheaper** than in a city which has a lot of population. Also, it is **safer** since it’s in a remote area and Iceland’s **laws might be stronger** which can help them with **data privacy** and collection on the servers. Lastly, the **carbon footprint will also be lower** in Iceland compared to a big city since it has a lot of **renewable energy** which can be a big constraint for data center companies.

The distance between New York and Iceland is approximately 4355000 meters. And speed of light is $3x10^8$ m/s.

Time = Distance/Speed
Time = 4355000 / ($3x10^8$ m/s)
Time = 0.0145 seconds or **14.5 milliseconds**
For a round trip (to the data center and back) = **29.0334 milliseconds**

7) You are building a data center, and a supplier offers you infrastructure pods with 300 racks per pod. The supplier says the large size enables them to deliver pods at lower cost per rack. What reasons would you have for not accepting the offer?

I would give the following reasons for not accepting the offer:

i) Having so many racks in a single pod might increase the risk of a failure due to power, cooling problems and moreover might cause more damage if something goes wrong in a pod.
ii) Big pods like these are hard to maintain when it comes to placement and configuration. Also, smaller pods offer more flexibility when it comes to changing things. Changing things for 300 racks per pod might be very demanding.
iii) 300 racks per pod means it is a financial risk in case the business doesn't need that many or doesn't grow. With smaller pods, we can grow in increments
iv) The maintenance cost of these huge pods might be a factor to consider and why I would also say no. It might involve complicated maintenance processes.

8) A data center network has N top-of-rack switches, S spine switches, and T super spine switches. Write an equation that specifies the total number of network connections needed in such a network. What value does your equation specify for N=1000 racks. S=9 spine switches, and T=10 super spine switches? Indicate how many spine switches attach to each superspine

We would have N connections for N racks for top-of-rack switches. There would be a total of N times S connections between each top of rack switch and every spine switch. Similarly, we will have S times T switches connecting every spine switch to super spine switch.

Hence, we can say total connections are:

N x S + S x T

Now, for N=1000 racks. S=9 spine switches, and T=10:

Total connections = 1000 x 9 + 9 x 10

Total connections = 9090

Given S spine switches attached to T super spine switches, we have S = 9. Hence, we can say 9 spine switches attach to each superspine

9) Customers of a financial company make requests to purchase or sell shares of stock. The financial company has recently moved all their computing to a public cloud, but has found that because the s data center is far away, the stock transactions take almost 150 milliseconds longer than they took before the move (making stock transactions quickly is essential because even a 50 millisecond delay can mean a customer may lose money).
Using the cloud provider has saved financial company saves over $4M per year in IT expenses, an amount so significant that the company doesn't want to move everything back to the original in-house systems. How can the financial company continue to save on IT expenses, but also handle stock trades faster? Suggest multiple options that they should consider.

i) Edge Computing
The financial company can use edge computing or choose cloud regions close to financial hubs. This would help in reducing latency. Many cloud providers have data centers spread out and this financial company can leverage this for reducing latency.

ii) Content Delivery Network
They can make use of content delivery network to route network requests and deal with them in faster way.

iii) Hybrid Cloud
Instead of fully choosing public cloud, they can opt for hybrid cloud. Some of the critical time sensitive operations can be executed on-premises while other less time sensitive operations can be kept on the cloud to deal with. This will also help in handling stock trades faster.

iv) Multi-Cloud
They can also make use of multi-cloud services to deal with different geographic locations. Different data centers from different cloud services can provide optimized routes which can help in faster delivery of content and execute stock trades faster.