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Cloud Computing: Evolution to Hyperscale Computing

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Abstract:

Cloud computing has been a dominating force within the IT industry for the past 20 years or so. Within those last 20 years we have seen a huge change in the industry, and advancement of technologies that have launched Cloud Computing into the main stage of IT (information technology). We can recognize the shift to the Cloud as one of the biggest changes in the industry. Advancement of technology within Cloud Computing has led to the popularity of a sector of Cloud Computing called Hyperscale Computing. We will be touching base in this paper on the History of Cloud Computing, along with Cloud Basics to set a foundation of understanding. Moving towards a more complex topic of Hyperscale Computing, answering key questions: What is Hyperscale Computing? How does Hyperscale Computing work? Who are the Hyperscalers? There are numerous projects that display the power and enormous potential of Hyperscale computing. At the end of this paper our goal is to make sure readers have a surface level understanding history on Cloud Computing, fundamental understanding of Hyperscale Computing, Hyperscalers, and real life applications of Hyperscale computing.

Keywords: *Hyperscale Computing, Cloud Computing, Cloud, Hyperscalers.*

Brief History of Cloud Computing:

Cloud computing has been highly publicized in the last 20 years since probably the early 2000s. But its roots go back even further than that to the 1960's, we will start at that point and move forward to the present.

1960s:

The credit of the idea of Cloud Computing/ Cloud in general goes to a man named John McCarthy, who was an American Computer Scientist from MIT (Massachusetts Institute of Technology). McCarthy first proposed that the computing services could be sold as a utility.(Borgoni, *The Evolution of Cloud Computing: From the Early Ideas of John McCarthy to Modern Platforms*) Stemming off of that idea, in other words just how utilities such as electricity, water, natural gas are sold, so could computer services. Which ties closely to the idea of "Cloud Computing" which can be further understood in the section of this essay highlighted "Basics of Cloud Computing". During this era, there are two projects that are linked as the ancestors or

foundations of the Cloud as we know it. Those two projects areThe MAC Project and ARPANET.

The MAC Project (Project on Mathematics and Computation) was introduced in 1963 by DARPA (The Defense Advanced Research Projects Agency), as they donated over $2 million dollars to MIT for this project with some stipulations. (Foote, *A Brief History of Cloud Computing*) Those stipulations being that MIT needed to create a device or computer system that could be accessed at the sametime by 2-3 people. (Foote) This could be recognized as an early cloud environment as they had achieved time-sharing capabilities. With multiple people accessing/using this platform at the same time. This project within the first couple of years was seen to have taken off as it was the first online community, which included an email, online bulletins, and even hackers. (*Project MAC*) There are conflicting sources on the matter of how well this project ran, but what was created was a network of around 100 terminal devices, with around 200 users that had been created. (*CSAIL 20/60 Timeline | MIT CSAIL*) The project was a step in the direction of cloud, it was a small, primitive cloud but regardless it was the foundation. Another fascinating fact to highlight is the fact that when they started this project they were building one of those huge archaic looking computers, the ones that you see can take up whole rooms. Some notable people of this time period that worked on this project were John MacCarthy, the director of Project MAC: J. C. R. Licklidler, and Robert Fano.

ARPANET was another project that was very influential in setting the foundation of modern day cloud computing. It was introduced in 1969 but work started on this project as of 1966. The same computer scientists that worked on the Project MAC were also very influential in the development of ARPANET. This project stands for Advanced Research Projects Agency Network, it first debuted in 1969 and was an early form of the internet.(Foote) What drove the research behind this project was how expensive and how big computer systems were. Before ARPANET computers were large mainframe systems, and were all individually owned by the universities, private companies, and governments. (Wright) So there was a need to connect all of these computer systems. That leads to J.C.R Licklidler idea of an “Intergalactic Computer Network” which transpired to be ARPANET.(Foote) During this project development, participating organizations were sent hardwares which were early forms of modems and routers. (Wright) The first organizations to participate in this were Universities as they wanted to utilize this for research and academic purposes. The first communication on ARPANET happened Oct.

29th 1969 when a student from UCLA tried to login to the mainframe at SRI (Stanford Research Institute), but that ended in the computer crashing and they persevered and had successful login that day. (Wright) Due to the academic nature of this network lots of Universities started utilizing it.(Wright). We can credit ARPANET with a lot of underlying technology of modern day internet as some of those are still in use today. But why is this important in cloud development? Well since this project was a precursor to the internet we like to highlight it because you cannot access the cloud without internet. This was a pivotal project which helped shape our modern day internet, as well as the real first development of the concept of cloud computing.

1970s:

As we move along in the timeline the 1970s were still home to some great technological discoveries but as for cloud computing history we have a few notable events happening during this time. The 1970s can be called the shift to virtualization, meaning the concept of Virtual Machines (VMs) was first introduced during this time. Virtual Machines allow users to run more than one Operating System in an isolated environment. IBM can be largely credited with the first development of a VM in their product VM/370, which gave end users the option to not have to choose an operating system to run their applications but gave them one where they could run their applications under one OS.(*IBM: VM 50th Anniversary*) This is important in the development of the Cloud Computing concepts. Along with the idea of "VPN" and the idea of "Internet" the 1970s was really a time of virtualization as shown by IBM. These took the idea of timeshare model to the next level as it allowed multiple applications to be ran under one roof which really set another foundation for cloud computing

1990s:

Excuse the jump in the timeline as this paper isn't a paper on the history of Cloud computing, but the 1990s is a huge decade for the concept of Cloud Computing. So far as we have dove through the timeline of Cloud Computing we have mostly been seeing the infrastructure/technological advancements to get us to the more modern era of the Cloud. At the beginning of the 1990s it is worth mentioning the invention of the World Wide Web by a Computer Scientist Tim Berners Lee. The internet had been around but localized to certain networks and was an invention stemming from ARPANET. But what Tim Berners Lee did was not just create another network to send files to one another, but he created a web where anyone and everyone could access information that was available. The creation of the World Wide Web

greatly influenced Cloud Computing concepts further now into the 1990s. As of early/mid 1990s the word “Cloud” is starting to be utilized in the modern form today, it was described as “the space between users and providers”. (Foote) Professor Ramnath Chellepa, is credited with being the first person to use the term “Cloud Computing”, in a lecture he gave in 1997. (Intel) Chellepa defined it as “computing paradigm where the boundaries of computing will be determined by economic rationale rather than technical limits alone”. (Intel) Which we can see that in the modern context of things the Cloud Computing usage is determined by “economic rationale” which we can touch on later in this essay.

As the internet grew so did the idea of the “Cloud”, companies began to innovate. Take a company called “SalesForce” who in 1999 utilized a simple website to deliver software to businesses over the internet. (Foote) This can be seen as the first successful use of Cloud Computing as SalesForce successfully delivered Software as a service (SaaS). The events highlighted in the 1990s were not the only big events that occurred, but they were notable as you can see +20 years ago people were thinking about the idea of the modern day cloud we utilize today.

2000s:

This is where the Cloud really takes off and is quite exciting as most people can now understand and relate to what is going on. We can largely credit and really coin the term, “Cloud” and its usage to Amazon. In 2002 Amazon launched its web based retail services as it is still in the market for selling books.(Foote) Amazon thought of utilizing their computer power more efficiently hence they followed a Cloud Computing Model to do so much like Salesforce. A lot of other companies started to follow suit after Amazon’s success. Well Amazon again in 2006 changed the landscape of Cloud Computing with the release of ESC2 (Elastic Cloud Compute), this was the first release of AWS and really publicized the idea of the Cloud.(Biswas) Since Amazon was the first to use the term “Cloud” they are often referred to as the creators of the term. Most companies such as Google, Microsoft follow suit after with their own Clouds. Google in 2008 launched its own platform for hosting web applications. (History of Cloud Computing) And Microsoft in 2009 came out with Azure. All of these events set the stage for modern Cloud Computing.

2010s:

We mostly see that the real foundation is set for Cloud Computing, the concept is now a practice and has real life applications. Most big players have tapped their resources into Cloud Computing developing their own data centers to sell their services to other companies. Since the foundation for the modern cloud was set, questions started to rise about the security of the Cloud. We have notable events such as the two terms “Public vs. Private Clouds”, being promoted. We will touch on both later on in the essay. Another term that is being promoted is the Hybrid Cloud which is a mixture of both public and private clouds. (Foote) We also see the emergence of Apple’s “iCloud” as that was released in 2011, along with Microsoft promoting its Cloud computing capabilities.(Foote)

Another technological advancement that is worth mentioning is Containers, which are files that can contain all of the necessary code, runtime libraries, etcetera to run softwares in any environment. This is an important innovation as containers had been around since the early 2000s. A company named Docker in 2014 created a container that was highly functional, which influenced the growth of Cloud Computing.(Foote) With all of that you needed tools to interact with containers, Google developed Kubernetes (2017) which was a tool that allowed an end user to orchestrate containers, scale the softwares up and down, along with deploying them.(Foote) By 2014 the cloud is well known, and is being utilized in the industry heavily. Although we could go on and on through the 2010s, till 2020, the last event that is really worth mentioning is the global pandemic of COVID-19. COVID-19 really accelerated the use of cloud, with the push to work remotely. So as more and more people started to work from home the Cloud has been utilized in all industries that need Cloud resources. This leads us to the present day and how Cloud Computing is so widely utilized.

Cloud Basics:

There is some confusion on what exactly the cloud is. There are a lot of ways to define the cloud, one could say that there data is up in the cloud above them. That assumption isn’t wrong but here is a simpler way to think about the cloud. The cloud can be defined as using virtual servers over physical ones, all of the data you are accessing is not stored on prem, but is rather stored in some cloud providers data center.(datacenterHawk, 2020) It can also be defined as the common thought that the cloud is just someone else's computer. Cloud providers offer a

number of services over the cloud such as Iaas(Infrastructure as a Service), Saas(Software as a Service), and Paas(Platform as a Service).

There are many reasons why an organization chooses to utilize the Cloud over having their own DC (Data Center) in this paper we will highlight a few. One of the driving factors is reducing infrastructure cost. Infrastructure costs, we can think of it as the physical building that would house a company's servers, the hardware itself, and once you have all of that you have to have people who really know the ins and outs of all the machines that are on prem.(datacenterHawk, 2020) Cloud providers offer a solution to all of that by just letting an organization or user store their data in data centers that are owned by Cloud providers therefore cutting down infrastructure costs. Companies or organizations like the scalability that the cloud offers. Scalability is referring to the ability to scale up and down on storage space without having to down right buy all of the hardware. They can also scale back to fit their needs without having to assume the risk of expanding.(Singh) Disaster recovery is a huge reason why companies choose the cloud route. When a company is breached and data is lost that could be very detrimental to business. In the Cloud the data is backed up on multiple servers, therefore in the event that disaster struck, business could run regularly.(Singh) These are only some reasons why companies or organizations choose the Cloud, there are many more to be discussed.

While there are many pros to having a Cloud solution but we need to highlight the cons as well to fully understand how the cloud works. Release of control is a hard thing for companies to do, when outsourcing to a Cloud provider whether you are outsourcing for SaaS, IaaS, or PaaS, there happens to be some control taken directly from the end user. This is appealing to some but it can be seen as con of utilizing the Cloud. Another con that comes up quite a bit and is a huge topic surrounding Cloud is the security aspect. There are some questions that surround the Cloud and if your data or companies data is safe. Due to poor Cybersecurity practices by some companies this issue presents itself as a con for Cloud reliance. As highlighted earlier in the essay, to access the Cloud you are completely reliant on the Internet. The Internet can be slow, especially when Cloud providers are backing up their services provided to you. When services are slow we can relate this to slowing business down, when business is slow and halted in any way it can be a con.

Cloud Types:

There are essentially two types of clouds, Public and Private Clouds. The way to differentiate the two is the public cloud is more like an apartment, the utilities are shared upon all of the tenets of that complex. Each tenant has access to water, electricity, and gas and they pay for what they use. In a Public Cloud setting you have all services that make up the Cloud (Iaas, Saas, and Paas) but everything is accessed over the internet.(*What Is a Public Cloud? | Public Vs. Private Cloud | Cloudflare*, n.d.) While Private clouds can be compared to a home, a home's maintenance, utilities cost a lot more. But the key here is that it is private, you do not have no one living under the same roof as you. Private clouds are under a company's internal data center.(Bairagi and Bang) With private clouds you have more control of over your data, the company or organization pools together all resources and applications and manages them.(Bairagi and Bang) With a Public Cloud you are leaving all of the management of resources up to a third party. One important notation to highlight with Public cloud is multiple companies outsource to a Public Cloud provider to access one of their services, but their data is all secure from one another. No one company can see each other's data.

Hyperscale Computing:

Hyperscale Computing is a branch of Cloud Computing, the golden child of Cloud Computing. It can be defined as easily as the ability of a data center infrastructure to scale rapidly to be able to handle large amounts of work load. An example of that mostly everyone can understand is Netflix. Say a new show comes out and everyone in the U.S region wants to access this show at one time. How does one's infrastructure handle the workload of a whole region and give end users the ability to access? Well Hyperscale Computing is the answer. We can start talking about Hyperscale Data Centers and how they achieve Hyperscale computing. The gist as this can get really technical is that these data centers contain a vast amount of servers that are horizontally structured.(Dynatrace, 2023) This type of architecture ties all layers together such as compute, storage, and virtualization; with the help of load balancer it allows organizations at the flip of switch to distribute resources efficiently and effectively.(Dynatrace, 2023) We can relate this back to the Netflix example and really see how they utilize Hyperscale Computing. These data centers are very different from regular data centers but they can seem to be compared to them as one in the same. While regular data centers are very centralized, Hyperscale Data

Centers run at a global level, this will also be explained more in depth in the next part of our essay. Another key thing to discuss while introducing Hyperscale Computing is the big companies that run the Hyperscale world can be referred to as Hyperscalers. Some key characteristics of these Hyperscalers that are able to to achieve Hyperscale computing are: distributed architecture of data center, large scalability, high energy efficiency, and global reach.(Dynatrace, 2023)

Hyperscale Data Centers:

As hyperscale companies keep growing and increasing their efforts to claim as much of the marketspace as possible, they see an exponential need to scale their physical infrastructure. The main focus will be on the hyperscale companies, but to begin with, let's revisit what a typical enterprise data center looks like and what it's used for. The basic definition for a data center would read something along the lines of: *a physical location where cloud service providers house the machinery that are used to run their web applications.* Any companies who wish to have an online presence or rely on a digital infrastructure in any capacity will have to outsource their operations to a cloud service provider (assuming they don't have the capital or reason to build their own), and these physical facilities are the engines that allow for that infrastructure to exist. The three subjects that we'll focus on to highlight the monumental differences in the scale of these operations between a cloud provider and a hyperscale provider are: power requirements, cooling requirements and redundancy.

Data centers alone globally use approximately 3 percent of the world's power. For the machinery to run efficiently the requirements for power are staggering even on the smaller scale. Each one of the data center buildings will be connected to an electricity substation, and the power gets broken down into lower levels of voltage as it enters the facility. Most importantly the power will be fed through a UPS-system that allows for continuous running of the computers even in the case of short interruptions in the flow of electricity.

Generally speaking even smaller data centers will consume at least 1 MW of electricity continuously. Over the course of a calendar year this type of demand will carry a seven figure price tag. Where we see the difference with hyperscale data centers is exactly here, in the power demand. A typical AWS data center will demand in the north of 100 MW of power to operate around the clock. This obviously requires a tremendous amount of capital and an extremely

complex infrastructure. For this reason these companies will go the extra mile to minimize their power consumption. The easiest way to do that is to cut down on cooling costs.

To allow the servers inside a data center to function properly, you have to have a sophisticated cooling system in place. The heat that hundreds of thousands of computers produce running side by side indefinitely has become an increasingly big issue, in fact so big that up to 45 percent of the electricity consumption will be used to power the machines that cool the computers down either by air or water. Many environmental factors will also play a role in the cooling costs. Building your data center in a naturally cool climate will certainly help. Building your data center near large bodies of water will cut the effort it takes to supply the cooling systems with water.

The larger companies, that have the most capital, also have the added advantage to get more creative with the ways in which they try to cut cooling costs. Microsoft has recently launched a project to test out the feasibility of subsea (underwater) data centers, called Project Natick. In their first effective mission, July of 2020, they found that this experimental underwater data center showed 1/8th of the failure date respective to the inland counterpart.

Physical Locations:

To understand the scale at which these hyperscale cloud providers operate we have to take a look at the Amazon Web Services data center ecosystem, and analyze the structure of it. The global infrastructure is divided into four different distinct categories. Regions, availability zones, local zones and edge/cache locations. A region refers to a large geographical location that includes multiple Availability Zones within it. Currently Amazon Web Services has 33 global regions, 7 of them in the United States.

As we go down the list, an Availability Zone is a small cluster of two or more data centers. These centers will be located close to each other within a zone in order to utilize redundant power, networking and connectivity. As of right now AWS has more than 100 AZ’s, with 11 new ones being scheduled for 2024. Since Amazon takes pride in having created by far the most extensive global footprint, this data center ecosystem goes even deeper. In order to meet the current low latency needs for all types of web applications, it’s imperative for a cloud service provider to be located as close to the end user as possible. This is really where we start seeing why there are only a few recognizable names in the game, the ones that we call “hyperscale”.

Building data centers and edge/cache locations near highly populated cities, in order to reduce latency, requires enormous amounts of capital, since the land and power will be significantly more expensive. Smaller companies cannot compete with this standard. Currently AWS has more than 600 physical locations of any kind around the globe. This overwhelming presence combined with the most comprehensive portfolio of services, makes AWS the most notable player in the industry.

A Look Towards East

Although a few companies in the Western world share the marketspace quite equally, the Asian market is being dominated by the biggest whale of them all, the Alibaba Group. For the purposes of our context, specifically the Alibaba Cloud. Established in 2009, Alibaba Cloud provides the same services as any of the other cloud providers does, but more importantly is being almost exclusively used by Chinese businesses and enterprises. Even though it is not officially a fact, it's widely understood that the Chinese government regularly subsidizes Alibaba's operations in order to cement their place as the leading cloud provider in East/Pacific Asia.

To demonstrate how companies like Alibaba can leverage the incredible scalability of their applications, at the 2019 "11.11 Global Shopping Festival" Alibaba Clouds *Elastic Compute Service* (ECS) servers were able to handle a record breaking 544,000 transactions per second without crashing, or experiencing significant latency. This type of service can provide a single customer in a single region with access to tens of thousands of CPUs, which indicates the robustness and elasticity of their platform.

The Practical Capabilities of a Hyperscale Cloud Provider: ET City Brain

Lastly we'll take a look at how the infrastructure of a hyperscale cloud provider and all of its computing power can make a real impact on people's lives. To demonstrate that, let's visit the ET City Brain project, funded by Alibaba Cloud.

Big metropolitan areas around the world are growing in alarming numbers, this phenomenon is especially apparent in the East/South-East Asian countries. The city limits are expanding, and new residential districts are popping up left and right, but a large number of the workers will still have to commute into and out of the city center on a daily basis, even if they

don't live there. This creates a lot of traffic congestion, and many other problems alongside it, such as light pollution, smog and power distribution issues. Haphazard city planning isn't an issue that can be solved easily, but with the aid of new emerging technologies, and a platform to support the incoming data, sustainable and functional "smart cities" can still be a reality. What the ET City Brain project will aim to do is arm city governments with millions of IoT devices, to help collect data in real time to help solve issues related to the growing traffic congestion. Here are some of the targets:

Traffic congestion and signal control

Many large cities in Asia still require manual traffic control, and street signals cannot keep up with the constant flow of traffic from all directions. ET City Brain will install smart automatic traffic lights that draw data that then gets processed in real time. This data will be integrated with mapping applications and traffic police Weibo accounts, which'll help figure out the recurring causes of congestion. These improvements in the flow of traffic can be leveraged for when big social gatherings happen, and cars wish to be re-routed by their navigation application, or when emergency vehicles need to find the quickest way to the hospital or police station.

Structural integrity and power management

This part of the world is not foreign to natural disasters and extreme weather conditions, so structural integrity management will be a massive key in the future to ensure safe living and commuting conditions for everyone. Sensors and actuators will be placed in the sides of buildings to monitor vibrations in real time, so that the lack of structural integrity of any building or bridge can be detected as quickly as possible. Power outages are also common when dealing with harsh weather conditions and creating a more redundant power grid will keep the electricity running for essential sectors.

Urban natural resource management

Natural resources in the midst of a concrete jungle are essential for maintaining a reasonable air quality. The part that ET City Brain is able to contribute to in order to manage natural resources inside large cities is, first of all, smart stormwater management. Analyzing the

nutrient contents of the soil will help the agriculture sector to work more efficiently. They'll also install real time monitoring thermal cameras and fire alarm devices to prevent large scale forest fires.

Why this project is relevant to us, is because when operating on such a large scale, cities will require an enormous amount of processing power and data storage to utilize all the information that these IoT devices are gathering. This is where Alibaba Cloud comes in, because they recognize the lack of technological and financial support, as well as the challenges of scaling up a project like this. The large amounts of capital, as well as a robust, "hyperscaling" infrastructure are the only way to put innovation such as ET City Brain into fruition.

Conclusion

Earlier in this essay we went back in time to show the history of Cloud Computing, along with the meaning of the concept, how it is practiced with examples of different uses of Cloud computing. This set a strong foundation for understanding Hyperscale computing and how Hyperscalers utilize their infrastructure to dominate the industry. As for the future of Hyperscale Computing it really is endless. Referring back to Professor Chellepa, he defined it as, "computing paradigm where the boundaries of computing will be determined by economic rationale rather than technical limits alone". The take away from this, is that as the demand for Cloud services increases, it can only be satisfied if the economics around building and maintaining data centers allows it.

Hyperscalers are changing the market by investing in a global reach to make their presence felt all over. This includes smaller markets as they are decentralizing their data centers and moving them closer to end users to achieve Hyperscale capabilities, including data redundancy and low latency.

As the electricity demands have increased significantly in just the last few years, Hyperscale companies will need to carefully rethink what markets are feasible to invest into. The electricity might only cost 2 cents per kw/h in Buenos Aires, but as of now the utility companies there won't be able to supply the hyperscale data center with more than a few MW's of power. This begs the question, is it time for Hyperscalers, such as AWS, Microsoft and Alibaba to start supplying the power themselves? The capital, innovation, demand and technology are there. It will simply be a matter of who goes first.

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