Cloud Computing / Netflix Case Study

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Abstract

Cloud computing involves relocating a business's data and applications into a highly sophisticated series of redundant servers strategically geographically located to serve that business's purposes. The redundant servers allow users near perfect up time, accurate and timely data, and the ability for portable access. Some security issues of cloud computing resemble security issues of traditional computing; some are new or enhanced due to the cloud. Shifts in costs are cyclical; therefore, cost savings may not be the most impressive reason to adopt cloud computing. Ease of retrieval of data and nationwide access, for example, are likely to be drivers for this change. The technical configuration of Netflix's cloud existence is discovered, documented, and discussed. From the understanding drawn from this exercise, the benefits of cloud computing for a very large company appear to outweigh the risks and provide a strong back drop for a business person to consider employing cloud computing in their organization. (Wolf, 2010)

Introduction to the Cloud Computing / Netflix Case Study

Cloud computing is an ever growing, popular term in the world of electronic data and in the IT industry. Is there one accepted definition of cloud computing in the industry? Or are there different levels of cloud computing and perhaps some confusion about what's actually 'in the cloud' and what is just off site hosting? We believe there is some confusion and we'll try to clarify.

A major concern with cloud computing is security. Of course, security is an issue no matter how or where your data is stored; however, there seems to be a heightened level of sensitivity toward security when you are operating in the cloud. We will examine the pros and cons of cloud computing from a security point of view.

What about costs? Are there any cost differentials from operating in the cloud rather than operating either in an off site hosting environment or a local environment? Surely, at first glance, it appears there would be a cost savings if a company can eliminate local hardware, software, updates, and maintenance. But what are the additional costs?

Finally, what does a company look like that is operating fully in the cloud? How does operating in the cloud affect the end user's experience? If it is a company that operates in the public eye, are members of the public able to ascertain they are functioning in the cloud rather than communicating directly with the company using their local, dedicated servers? Or is the experience seamless and transparent? Our case study will be to analyze and critique the technical configuration of Netflix, the world's leading internet service for movies and television programs. (http://www.Netflix.com)

Definition and Brief explanation of Research Issues

What is Cloud Computing?

Business leaders are being asked to consider the pros and cons of cloud computing and the impact it has on their organizations. Are all business leaders actually getting accurate information from which to decide? For example, what is the difference between cloud computing and off-site hosting? All cloud computing is a form of off site hosting; however, not all off site hosting qualifies as cloud computing, or 'being in the cloud.'

Hosting off site or on the web simply means you're one step closer to being in the cloud, but it doesn't mean you'll actually ever be in the cloud. In order to truly be operating in the cloud, a series of redundant servers need to be in place like nationwide, or worldwide, and users are automatically redirected to the one closest to them. If the server they typically access goes down, they are automatically redirected to another server. Users don't even know it.

An analogy of operating in the cloud is a cell phone call 'jumping' cell phone towers. Cell phone towers have been erected, for example, so that users can drive from on region to the next and maintain access to cell phone provider's signal. For the most part, when a user is on a call and travels between towers, the call is not disrupted, yet the source of the signal has changed. (Yes, sometimes the call is dropped. That doesn't fit this example very well, so we're going to disregard dropped calls.) The same is true when you are accessing data that is redundant on multiple servers spread throughout various regions. A user may be accessing Server A located in Albany, New York, one moment, and it may have a failure. The user's work has been duplicated through the redundancy arrangement onto Server B located in Chicago, Illinois; Server C located on Phoenix, Arizona; Server D located in Las Angeles, California, etc. The user will be redirected seamlessly to the next, most conveniently located server, and the user will continue as if there had been no server outage. (Wolf, 2010)

There are three flavors of cloud services. The first, and likely most well known, is Software-as-a-Service (SaaS). This indicates the vendors are providing and developing software to be used by customers when and where they need it. The second is Platform-as-a-Service (PaaS), which allows a user to duplicate their entire site, or platform, in the cloud. The third is Infrastructure-as-a-Service, better known as Hardware-as-a-Service (HaaS.) The most valuable service this type of service provides are cloud data backups and cloud security. (Courtney, 2010) (TM Group, 2010)

Not all applications can be in the cloud, or even hosted off site. Martin Courtney, in the September 8 issue of Computing, reviews government quango Remploy's uses of cloud computing. (Courtney, 2010) Although they are investing in a £5m, five year contract for a subscription-based on-demand cloud-based service for their enterprise resource planning, supply chain management, case management, back-office and finance applications, they have a legacy BARN application running on Unix kit which will have to stay on a local server. It's not built on a platform that allows it to be accessed off site and/or from the cloud.

Cloud Security

There are three types of security and privacy issues when operating in the cloud: traditional security issues, availability of data, and third-party data control. Traditional security issues include:

1. VM-level attacks. These are especially challenging in multi-tenant architectures.
2. Cloud provider vulnerabilities. Examples include SQL-injection or cross-site scripting vulnerability. Google, IBM, and other cloud providers have realigned their scans and security techniques to monitor vulnerabilities more closely.
3. Phising cloud provider.
4. Expanded network attach surface. Connections to the cloud are typically outside the firewall, requiring new and different levels of protection.
5. Authentication and Authorization. Users are usually forced to resolve to the provider's authentication and authorization, forgoing their own.
6. Forensics in the cloud. Because data is overwritten at such a fast and furious rate, it is more difficult to recover older data, if subpoenaed or requested by clients for an internal investigation.

Availability of data fears stem from the following three areas:

1. Uptime.
2. Single point of failure. According to one article, there are more single points of failure and attack in the cloud than not.
3. Assurance of computational integrity. Validity of data can be tested by performing the same operation by multiple clients.

Third party data control can provide concern in the cloud due to regulatory compliance issues, among other concerns. This has prompted some clients to develop private clouds, rather than be exposed to the public cloud. Examples of third party data control concerns are:

1. Due diligence. Timely response to subpoenas or other legal actions.
2. Auditability. If there isn't sufficient transparency in the cloud, it is highly unlikely traffic will be traceable.
3. Contractual obligations. Some of the legal aspects of using the cloud lead to uncertainty for businesses, which most businesses do not appreciate.

4. Cloud Provider Espionage. Proprietary information could be easily stolen by the provider.
5. Data Lock-in. This involves not being able to access data because it has been translated to a format for the provider's benefit.
6. Transitive nature. This can be a challenge when providers subcontract to other providers and the clients lose control of their data. (Chow et al, 2009)

Cost Savings

Cost savings can be a bit temporary in nature. The cost structure is similar to the difference between leasing an automobile and buying an automobile. Leasing is more of a renewable cost; purchase payments do eventually come to an end. The most noticeable benefit of leasing an automobile is the ability to continually renew into a newer model. This is similar to the SaaS type of cloud computing. A cloud user of Microsoft products, for example, will likely have the most recently updated version available without additional cost. The monthly fee for access to the programs will likely be similar, disregarding the version. The user that purchases the software, however, would need to purchase the upgrade to continue to use the latest version.

There are cost savings relative to network and software administration team members at the user's site. Some clients choose to discontinue their reliance on external IT services, if they move into the cloud. Some also choose to either eliminate internal IT positions or redirect the focus of their positions to developing other applications or ways to make their current applications more efficient.

Overall, it has been estimated that the breakeven point, the point at which cloud computing becomes more costly than local computing, is between 3 – 5 years. (TM Group, 2010) During this initial 3 – 5 years, the company can use the cost savings to increase their marketing dollars and sales efforts. This should result in additional sales which then will make the investment into the Cloud cost effective. The investment should become a revenue center, if managed correctly. This makes the entry into the Cloud a wise business investment.

Case Study Design

Netflix leverages cloud computing systems infrastructure to deliver high quality, highly available video to your home over the Internet. The electronic distribution model that leverages "the cloud" mimics their physical distribution model of DVD's by mail and regional distribution centers. We will attempt to document the Netflix Internet distribution model by uncovering the Netflix cloud infrastructure's physical layout and the 3rd party vendors they use to outsource for content delivery which make it all possible.

We will be using tools that are natively built into modern operating systems, Internet tools and news articles. Any Internet connected network or service infrastructure serves clues which can be revealed by tracing network paths, resolving IP addresses, using DNS queries to further reveal information about their systems and by simply using your web browser. With these tools sets we will uncover the Netflix Cloud, how it works and how large it is. If a user simply views a Netflix video on a device connected to the Internet the user never realizes the complexity and robustness of the network they're tapping into while watching a movie or video clip. The Netflix cloud is made up of 3rd party DNS services and 3rd party content hosting services; each Netflix partner manages their piece of the cloud respectively thus making the Netflix cloud a true Internet Cloud.

Case Study Presentation

We chose Netflix for our case study because it claims to be the leading subscriber of movies and TV programs streaming on the internet, from the cloud. A review of their website also made us realize how their efforts to be completely in the cloud have changed their hiring strategies. Their employment opportunities consisted, almost exclusively, to software and hardware candidates with cloud computing and related communication skills. It was clear they are taking full advantage of the cloud's capabilities and stocking up on talent to stay in the lead.

Also in the case study, notice how quickly the cloud is changing. As recent as November 11, 2010, Netflix announced their intention to couple with two new, very large, international based hosting providers. These two new providers, Akamai and Layer 3 Communications, may be poised to take Netflix globally. (Munarriz) Let's wait and see.

"*With more than 16 million members in the United States and Canada, Netflix, Inc. [Nasdaq: NFLX] is the world's leading Internet subscription service for enjoying movies and TV shows. For $8.99 a month, Netflix members in the U.S. can instantly watch unlimited movies and TV episodes streaming right to their TVs and computers and can receive unlimited DVDs delivered quickly to their homes. In Canada, streaming unlimited movies and TV shows from Netflix is available for $7.99 a month. There are never any due dates or late fees with Netflix. Among the large and expanding base of devices streaming from Netflix are Microsoft's Xbox 360, Nintendo's Wii and Sony's PS3 consoles; Blu-ray disc players from Best Buy's Insignia brand, LG and Samsung; Internet TVs from LG, Samsung, Sony and VIZIO; the Roku digital video player and TiVo digital video recorders; and Apple's iPhone, iPad and iPod touch. All of these devices are available in the U.S. and a growing number are available in Canada. For more information, visit http://www.Netflix.com/.*" (http://www.Netflix.com/)

Our technical search begins with finding a starting point for Netflix. Where does Netflix live on the Internet? All interconnected computers on the Internet need an IP address. If we use the ping command in Windows we can begin to peel back the layers of the Netflix infrastructure.

ping Netflix.com

Reply from 208.75.76.17: bytes=32 time=71ms TTL=245

We've determined that Netflix uses IP address 208.75.76.17. Typically companies with a large Internet presence use DNS servers starting with the name “NS” and a number. An example is ns1.Netflix.com. The NS here stands for “name server;” they provide name resolution to users on the Internet. This is how we can use the ping command to “ping Netflix.com.” Our computers make a request to a DNS server looking for the IP address of Netflix.com, it then gets a response telling us that Netflix.com is IP address 208.75.76.17 and our web browser then displays web content from a server at that IP address. One can either use http://208.75.76.17 or http://Netflix.com. We can gather more IP information from Netflix by now pinging the Netflix name servers.

ping ns1.Netflix.com

Reply from 69.53.255.10: bytes=32 time=69ms TTL=55

ping ns2.Netflix.com

Reply from 69.53.254.10: bytes=32 time=70ms TTL=55

ping ns3.Netflix.com

Ping request could not find host ns3.Netflix.com.

ping ns3.Netflix.com

Ping request could not find host ns3.Netflix.com.

Typically large Internet based companies have more than two DNS servers and they have them on diverse IP ranges on separate networks for redundancy. We have now gathered that Netflix uses:

208.75.76.17 – Netflix.com (also resolves as www.dc1.Netflix.com)

69.53.255.10 – ns1.Netflix.com

69.53.254.10 – ns2.Netflix.com

We must now determine and gather a bit more data about the Netflix infrastructure by querying IP information. For this we can use several tools. If you visit intoDNS it will query and check name server information for any given domain revealing further information about the Netflix cloud computing philosophy and infrastructure.

http://intodns.com/Netflix.com

Nameserver records returned by the parent servers are:

pdns3.ultradns.org. ['199.7.68.1'] (NO GLUE) [TTL=172800]
pdns4.ultradns.org. ['199.7.69.1'] (NO GLUE) [TTL=172800]
pdns1.ultradns.net. ['204.74.108.1'] [TTL=172800]
pdns2.ultradns.net. ['204.74.109.1'] [TTL=172800]
ns1.p19.dynect.net. ['208.78.70.19'] [TTL=172800]
ns3.p19.dynect.net. ['208.78.71.19'] [TTL=172800]
ns2.p19.dynect.net. ['204.13.250.19'] [TTL=172800]
ns4.p19.dynect.net. ['204.13.251.19'] [TTL=172800]

The SOA record is:
Primary nameserver: **ns1.p19.dynect.net**

(Email DNS records are called “MX”, “Mail eXchange”)

Your MX records that were reported by your nameservers are:

10 **mail.messaging.microsoft.com** 65.55.88.22 (no glue)

Your reverse (PTR) record:
22.88.55.65.in-addr.arpa -> **mail.global.frontbridge.com**

Netflix only hosts two DNS servers; it's highly likely those servers are used minimally for “internal” corporate networking infrastructure and not for their world wide cloud computing infrastructure. What's telling is Netflix's use of a 3rd party DNS service, UltraDNS.org and dynect.net which both offer hosted DNS services.

> *“NeuStar's UltraDNS provides solutions to organizations that rely on DNS for their critical business processes, applications and services, delivering superior security, reliability and performance. With the growth in e-commerce and the emergence of advanced DNS-based communication services, organizations can no longer rely on traditional approaches to DNS.”* (UltraDNS)

Using another DNS tool from IP2Location found here: http://www.ip2location.com/free.asp, we can now turn out attention to showing how UltraDNS.org's DNS cloud is dispersed and redundant. Because dynect.net shares the same business model we know they too have a dispersed and redundant network but with brevity in mind we focus on one of Netflix's DNS providers. DNS hosting by two different DNS hosting companies is the core component of the Netflix Cloud.

208.78.70.19 US UNITED STATES **NEW HAMPSHIRE** MANCHESTER DYNAMIC NETWORK SERVICES INC

204.74.108.1 US UNITED STATES **CALIFORNIA** SAN MATEO ULTRADNS CORP

204.74.109.1 US UNITED STATES **ARIZONA** TEMPE INTERNET MEDIA NETWORK

UltraDNS.org's network is geographically located in densely populated regions of the United States hosted on the West Coast, East Coast and Arizona. In addition, they have multiple servers in each location. Assuming Tempe, Arizona goes “offline,” our queries would redirect to a California or New Hampshire server. Moreover, queries to Netflix.com rely on a user’s local Internet Service Providers DNS servers that have “copies” of the UltraDNS.org's Netflix.com records. These records are refreshed incrementally every few hours. If we were to delve into Netflix's hosted Exchange server infrastructure we'd reveal that Microsoft, too, has a geographically dispersed infrastructure on multiple IP subnets with servers located throughout North America or perhaps even the world. At this point in our search, the importance of DNS is not yet realized but it is at the core of how Netflix can control their content, where users access it and how their content is distributed in their cloud.

We've determined that Netflix also uses hosted mail services compliments of Microsoft Exchange Hosted Services in addition to UltraDNS.org's and dynect.net's DNS infrastructure. If we browse to http://frontbridge.com we are redirected to http://www.microsoft.com/online/exchange-hosted-services.aspx. Using 3rd party infrastructure seems to be a basic business strategy of Netflix and they leverage cloud computing for more than entertainment delivery services.

We've discovered that Netflix uses 3rd party clouds and that the use of multiple vendors is an important component in cloud computing infrastructure. Netflix seemingly has a philosophy that outsourcing cloud infrastructure makes business sense. Where does Netflix store the video? If we use Netflix.com, where are we streaming the video from? We can use another interesting tool built into Windows to help us determine where that might be or at least to make an educated guess. The "tracert" command traces a path from your computer to the destination. Below we execute the tracert command and "redirect" the output to a text file on our C: drive for easy reading.

```
tracert 208.75.76.17 >c:\tracert.txt


Tracing route to Netflix.com [208.75.76.17]
over a maximum of 30 hops:
  1     1 ms     1 ms     1 ms  192.168.1.1
  2     8 ms     8 ms     8 ms  10.178.32.1
  3     8 ms     7 ms    11 ms  swc02klmzmi-gbe-2-15.klmz.mi.charter.com
[96.34.32.149]
  4    11 ms    12 ms    10 ms  96-34-32-194.static.unas.mi.charter.com
[96.34.32.194]
  5    10 ms     9 ms    10 ms  bbr01aldlmi-0-2-0-6.aldl.mi.charter.com
[96.34.2.172]
  6    15 ms    21 ms    15 ms  bbr01chcgil-0-3-0-6.chcg.il.charter.com
[96.34.0.160]
  7    15 ms    15 ms    15 ms  prr01chcgil-tge-1-1.chcg.il.charter.com [96.34.3.9]
```

8 15 ms 15 ms 24 ms tge15-2.fr3.ord.llnw.net [208.111.156.65]

9 17 ms 17 ms 25 ms tge2-1.fr4.ord.llnw.net [69.28.172.42]

10 73 ms 73 ms 73 ms tge1-3.fr4.sjc.llnw.net [69.28.172.77]

11 71 ms 68 ms 70 ms **Netflix.tge7-4.fr4.sjc.llnw.net** [69.28.179.74]

12 70 ms 69 ms 70 ms xe-2-2-0-954.jnrt-edge01.prod1.Netflix.com
[69.53.225.26]

13 71 ms 69 ms 69 ms te1-8.csrt-agg01.prod1.Netflix.com [69.53.225.6]

14 75 ms 69 ms 69 ms www.dc1.Netflix.com [208.75.76.17]

Trace complete.

What's telling about our use of tracert is how it "crawls" the path to the destination. We notice on our way to Netflix.com we crawl through 4 - llnw.net routes, one is called "**Netflix**.tge7-4.fr4.sjc.llnw.net". We have now determined that llnw.net is hosting something for Netflix.com but we have yet to determine just what that might be. The suspense is building. Let's now turn our attention to llnw.net.

What is llnw.net? We can first note that our speed to llnw.net is fast, from our network which is represented as a "1" - 192.168.1.1 to llnw.net's infrastructure is a total of 8 hops, if you "bundle" all the fast charter hops; 1 – 7 and count that as a "network"; llnw.net is right next door. Llnw.net is not simply a "client" on an Internet Service Providers network like 192.168.1.1 is; they are a provider and are seemingly part of the Internet fabric like any large provider would be, such as ATT, Verizon, Sprint, Microsoft, etc. If we type llnw.net into our web browser we are redirected to http://www.limelightnetworks.com, Limelight Networks is a Tier 1 provider of hosted online media services.

> *"Limelight's CDN solution enables content providers to provide their end-users with high-quality experiences across any digital media type, content library size or audience scale without expending the capital and developing the expertise needed to build and manage their own networks."* (Limelight)

It would appear that Netflix has been aggressively courting several content delivery networks like Limelight Networks. They also house (or will be housing) data on Akamai and Level 3 Communications networks. (Munarriz)

Let's now revisit the first component of the Netflix cloud; DNS, and how Netflix leverages two different DNS hosting companies to host Netflix.com DNS records. We can now see how Netflix also uses multiple content providers in this exact same way they use their DNS providers; they thus balance load and distribute their content in a highly available manner that can potentially yield enormous capacity. We've only uncovered a piece of the Netflix cloud (DNS, Email and video content delivery).

Also interesting to note is how the user experiences the cloud based videos and television programs. The rented programs are displayed using a 'cache' model, just like watching a You Tube video on the Internet. The caching allows for downtime errors to occur on server, DNS to find the user's rented product on another server, and redirection to occur before the user realizes there's a problem.

Discussion

The business strategy of cloud computing for Netflix is to warehouse their data in geographically dispersed areas by means of outsourcing to different content providers on networks that are highly connected and fast. Netflix builds a cloud infrastructure by leveraging the resources of other companies while focusing on its core business of developing the applications to access the media from those content providers. For Netflix, the content is the commodity. Netflix relies most heavily on UltraDNS.org's infrastructure so it can point the records for that content at any content provider at any given moment while keeping the applications on their customer devices (XBox's, Wii's, Samsung TV's, phones, etc) relatively static. This allows for an extremely high level of flexibility as the naming of the location of the videos and television programs are handled by DNS. The DNS variables are 'defined' as their current locations. That definition directs the entire DNS system and allows all videos to be cataloged for the end user. If Netflix relocates their product to a new provider's server, all that need be adjusted is the definition of the variable, not the variable itself. The new definition would reflect the new server. This should be a relatively quick change and keeps Netflix in the driver's seat, with various host providers competing for their business.

The following map provides a visual display of the results of this case study. Clearly, Netflix uses cloud computing to build its business and exponentially increase their ability to serve many more customers that possible. And, due to the redundancy of the servers utilized, users will experience high quality, constant uptime, and are likely to be returning customers.

Conclusion

After examining Netflix as a case study to better understand the business applications of cloud computing, it is clear cloud computing can make a positive impact on a business. The impact relies heavily on investment from the company and faith in their hosting providers. As noted in the Netflix case, their entire business strategy converted to the cloud. This had a ripple effect on their hiring methodology and, surely, has had an impact on their operations.

The complexity and transparency of cloud computing cannot be ignored. As demonstrated by the exercise designed to flush out the Netflix cloud from the rest of the cloud world, the Cloud resembles a large open source model of the internet. It was not especially difficult to trace down how and where Netflix is living on the web. None of us would be that difficult to trace, in the cloud or not. Of utmost importance were the revolutionary discoveries involving DNS. It was incredibly interesting to determine the pivotal role DNS plays in the location and relocation of data files. Clearly, the cloud is a highly complex environment demanding a high caliber professional in order to make the most strategic of any particular piece of the cloud.

The Netflix model can be applied to any business that is large enough to take advantage of the cloud environment. Anyone with applications appropriate to be hosted in the cloud can build a similar networking model on redundant servers hosted by cloud providers and take advantage of the speed in which users can provide and request. The opportunities in the cloud are limitless. It appears the cloud is here to stay. The costs incurred on the front end to get into the cloud appear to enhance your marketing and sales position, if Netflix is an accurate representation, and more than cover the initial investments. Also, even after the 3 – 5 years breakeven proposed earlier in this paper, would only be accurate if the election was not made to make the leap into the next generation of technology, which always seems to cycle on a 3 – 5 year pattern. Security is no more an issue in the cloud than it is normally; steps can be taken to deter loss of data, intrusion, or data compromise. Clearly, Netflix is a very large company; the benefits to a very small organization that does not rely so heavily on nationwide or worldwide notoriety may not benefit and therefore should consider not entering the cloud.

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