Improvements of the SMTP-Routing Architecture at Google

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Thanks

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Introduction

This document is google confidential. It should be read only by people who have signed the Google Non Disclosure Agreement. If you did not sign this document, please stop reading now. You are still with me ? Great, let us get into the world of Google....

This internship last six month in Google London, in the UK. The student was in the Sysops team (corporate systems administrators). In the first chapter, we will learn some facts about Google. Facts that maybe a lot of people already know, but this is always good to refresh memory. You can also find ten rules Google has found to be true in the appendix.

The second chapter presents the details of the internship : work context, planning, short description of the projects and the objectives. Thirds chapter is more technical and describes some details about projects the student achieved at Google. Finally, in the conclusion, we will focus on the main results, skills learned and problems encountered during the internship.

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Chapter 1

Company Overview

1.1 Google's mission

> Google's mission is to organize the world's information and make it universally accessible and useful.

As a first step to fulfilling that mission, Google's founders Larry Page and Sergey Brin developed a new approach to online search that took root in a Stanford University dorm room and quickly spread to information seekers around the globe. Google is now widely recognized as the world's largest search engine – an easy-to-use free service that usually returns relevant results in a fraction of a second.

When you visit www.google.com or one of the dozens of other Google domains, you'll be able to find information in many different languages; check stock quotes, maps, and news headlines; lookup phonebook listings for every city in the United States; search billions of images and peruse the world's largest archive of Usenet messages – more than 1 billion posts dating back to 1981.

We also provide ways to access all this information without making a special trip to the Google homepage. The Google Toolbar enables you to conduct a Google search from anywhere on the web. And for those times when you're away from your PC altogether, Google can be used from a number of wireless platforms including WAP and i-mode phones.

Google's utility and ease of use have made it one of the world's best known brands almost entirely through word of mouth from satisfied users. As a business, Google generates revenue by providing advertisers with the opportunity to deliver measurable, cost-effective online advertising that is relevant to the information displayed on any given page. This makes the advertising useful to you as well as to the advertiser placing it. We believe you should know when someone has paid to put a message in front of you, so we always distinguish ads from the search results or other content on a page. We don't sell placement in the search results themselves, or allow people to pay for a higher ranking there.

Thousands of advertisers use our Google AdWords program to promote their products and services on the web with targeted advertising, and we believe AdWords is the largest program

Figure 1.1: Google Logo

Figure 1.2: Google offices - Les bureaux Google

of its kind. In addition, thousands of web site managers take advantage of our Google AdSense program to deliver ads relevant to the content on their sites, improving their ability to generate revenue and enhancing the experience for their users.

To learn more about Google, click on the link at the left for the area that most interests you. Or type what you want to find into our search box and hit enter. Once you do, you'll be on your way to understanding why others say, "Google is the closest thing the Web has to an ultimate answer machine."

1.2   What's a Google?

"Googol" is the mathematical term for a 1 followed by 100 zeros. The term was coined by Milton Sirotta, nephew of American mathematician Edward Kasner, and was popularized in the book, "Mathematics and the Imagination" by Kasner and James Newman. Google's play on the term reflects the company's mission to organize the immense amount of information available on the web.

1.3   Google Philosophy

Never settle for the best "The perfect search engine," says Google co-founder Larry Page, "would understand exactly what you mean and give back exactly what you want." Given the state of search technology today, that's a far-reaching vision requiring research, development and innovation to realize. Google is committed to blazing that trail. Though acknowledged as the world's leading search technology company, Google's goal is to provide a much higher level of service to all those who seek information, whether they're at a desk in Boston, driving through Bonn, or strolling in Bangkok.

To that end, Google has persistently pursued innovation and pushed the limits of existing technology to provide a fast, accurate and easy-to-use search service that can be accessed from anywhere. To fully understand Google, it's helpful to understand all the ways in which the company has helped to redefine how individuals, businesses and technologists view the Internet.

Chapter 2

Internship

2.1   Subject Before the Arrival

The subject of the internship was originally to improve the performances of the corporate mail routers performances, especially regarding anti-spam features. The subject has been slightly modified.

2.2   Real Subject

The final subject of the internship was to improve the performances of the corporate core mail routers, but also to do a complete upgrade of the operating system of the mail servers. A couple of side projects have been added to the internship. The first one was the improvement of the archive file delivery service. The second one was related to freenxng, an open source thin client.

2.3   Role of the Student regarding the Service

The figure2.1shows the position of the student in the Company. The two teams of the student was the Ubiquity Team and the SMTP-team.
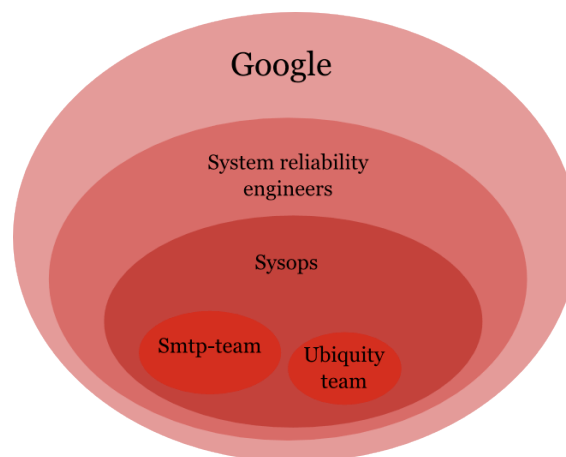

Figure 2.1: Place of the student regarding google - Place de l'étudiant au sein de Google

2.3.1   System Reliability Engineers

The system reliability engineers is the group of Google system administrators. They are in charge of the production side but also in charge of the corporate system administration.

2.3.2   Corporate system administrators

The corporate system administrators (usually called 'sysops') is a team of about 200 engineers in charge of the corporate services (Internal employees directory, employees emails, source repositories...). Sysops are split in a couple of sub-teams.

2.3.3   Role in the SMTP-team

The SMTP-team is in charge of maintaining Google's employees E-mails related Services. Various services are provided, from mailing lists to webmail, from IMAP to Archive file delivery, but a key point in the SMTP team is Mail routing. The role in this team was basically a junior Sysops in charge of upgrading/improving the performances of the mail routing system.

2.3.4   Role in the ubiquity team

The Ubiquity team is in charge of the internal thin clients for Google's employees. The team is much younger than the SMTP team, indeed, Ubiquity is a very recent project. The role in this team was more software oriented, since the tasks were to implement some features of an existing commercial software to an open source clone.

2.4   Main Objectives

2.4.1   Personal objectives

The main personal objectives of the student were to learn how to work in a group such big as Google in an English spoken country.

2.4.2   SMTP team

Two projects have been achieved in the SMTP-team :

- The first one was a 'warm up' : a little project of service performance improvement related to Email file archive delivery. The objective was to get a valid solution to replace the actual service and to deploy it in the company.

- The second project was slightly bigger : the improvement and the migration of all the internal (corporate) SMTP-routers at Google. The objective was to design a valid solution for replacement of all the routers, and to deploy them in the company (couple of data-centers spread all over the world).

2.4.3   Ubiquity team

Only one project have been achieved in the Ubiquity team :

- The objective was to implement a feature (see this an open source thin-client software called Freenx[1].

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[1]http://freenx.berlios.de

2.5 Personal history regarding these objectives

2.5.1 Studies

The UTC degree provides strong networking/engineering theoretical skills regarding networking and system administration. Furthermore, the student spent six months in Canada studying studying network and signal analysis. Spending this time in an non native speaking environment was very helpful for the first days at Google.

2.5.2 Clubs/Work experience

The final studies project is the second long-term internship of the UTC degree. Even if the previous internship has been done in a really small group, some parts of the previous internship were helpful to understand relationships between system administrators and software engineers and this is a keypoint at Google. A previous experience in a couple of clubs at the university has been very helpful too (Sysadmins clubs, Computer science club, Open source club).

The main point where the student will have to learn skills during this internship is strictness and rigour because of course of the scale of the company.

2.6 Work context

2.6.1 Working at Google

Working at Google is a great once in the lifetime experience. Life in Google offices is really made easy with for instance free food for breakfast, lunch and dinner. There are games room, a lot of various interesting tech talks, and the most important thing is that people are very good in their field of area. We can see Google offices as campuses. It's even possible to find clubs (go, chess, rolegames...) inside Google.

A lot of things which are usually very hard to do in regular companies (communicate efficiently with Human Resources people, dealing with different teams all over the world...) are really easy thanks to a lot of internal web tools and a very efficient ticket system.

2.6.2 Different work locations

During the internship, work has been done from these various locations :

- London (80%)

- Zurich (10% - 2 weeks)

- Dublin (10% - 2 weeks)

- Paris (<1% - one day)

The student had the occasion to work with a lot of different teams and to meet a lot of different work cultures, but always connected through the Google way of seeing things and problems (see the Google philosophy in the appendices).

2.6.3 Different team locations

System admins are spread all over the world, even among the same team. This allows efficient and decent work hour for 24/7 on-call rotations. Working with so many different people all around the world is a strong cultural experience, and it is sometimes really hard due to time offsets. Here are some examples of team locations we worked with in London :

- Mountain view (SMTP-team)

- Seattle (SMTP-team)

- Dublin (Ubiquity team)

- Zurich (Ubiquity team)

- San-Diego (Ubiquity team)

2.6.4   Internal communication tools

Various internal communication tools are used internally at Google, which allow employees to communicate very efficiently. A couple of them are presented here :

- A *ticket system* is used for general purposes (administrative problems, technical issues etc).

- *Emails and mailing lists* are massively used in the company. We have to be very careful because a lot of Mailing lists are consuming a lot time.

- *Code-reviews* is a great tool to communicate and to allow your team to see how your work is going. Let's take this example : you just finish a code for a configuration file. You send the code review to your team, your team sends you back some comments about your work, saying if yes or no it can be submitted in the main source version control repository. It's very efficient and as an intern, we are able to learn a lot from the critics of the full time employees reviewing our code (from documentation to scripts, configuration files etc.)

- *GHR - Google human resources -* is a web interface which allows you to communicate efficiently with HR people for logistic and financial purposes.

- *Video Conference* : from the London Sysops office, most of the meetings are done via visio conference. Indeed, the London Sysops team is very small.

- *Google Talk* : this technology (instant messaging) is very useful to talk with co-workers, especially from other countries

- *Instant Relay Chat* (IRC) - This technology is broadly used in the Sysops community. Some robots even write monitoring events on dedicated channels (ones for on-call Sysops).

- The *Change request system* is used for any big change. The system is very efficient for planning changes and incident recovery. Sysops are aware of your changes and can help you in case of any problem.

- *Weekly snippets* : each week, each engineer have to write a synthesis of his work. This synthesis is sent to his boss. This allows to understand to keep precise tracks of the work done by the employee.

2.7   Work Planning

The figure 2.2 shows the plans for the work during the whole Internship. The first project was a short term one allowing the student to learn the company habits. This project represented about 15% of the time spent during the Internship. The main project really was the SMTP-routers migration, this project represented 65% of the whole work. The last project took about 20% of the time.
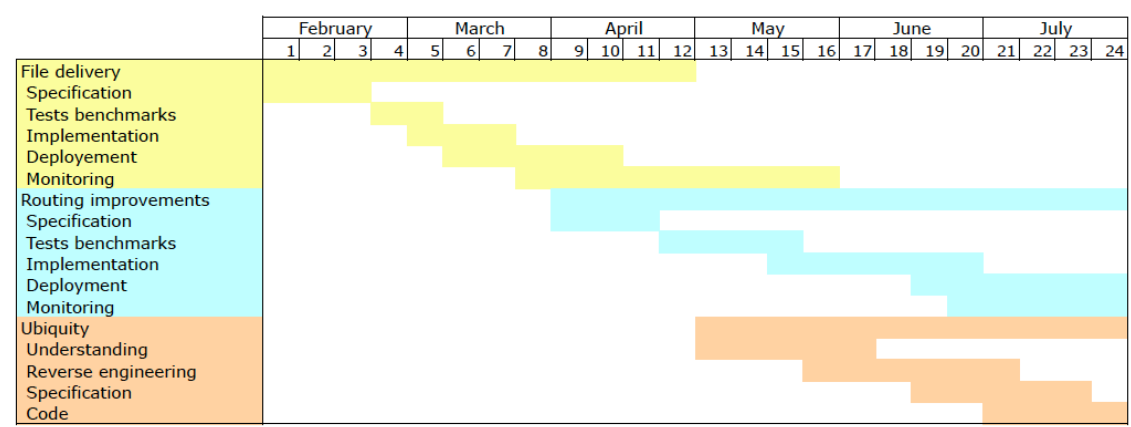
Figure 2.2: Planning of the internship - Emploi du temps du stage

Chapter 3

Details of the projects

3.1 Email Archive delivery improvements

This first project achieved at google was the improvements of the Email archive delivery.

3.1.1 Description of the service

The file-delivery servers provide dedicated delivery into mbox-style mailboxes in a specific directory and a small number of other locations. These file archives are used for backups and archival copies of mailing lists and also as input into various processing scripts. The customers of file delivery are effectively all Googlers, since the primary use of this service is to archive and backup mailing lists and externally facing addresses such as help@google.com.

3.1.2 Specification

The objectives have been defined previously. First step was to understand the service to make a precise specification of the needs of the service. Among theses, we have, for instance :

- Email delivery delays
- Service Level Agreement
- Mail-rate
- Geographic location (Mountain view, Atlanta, Europe...)

3.1.3 Base configuration - automation

A couple of automation tools are used at Google. The base configuration is not directly done on the machine, but via the automatic configuration tool (which allows System Admins to check files in a source version control system). A base configuration has been set implementing the base specification.

3.1.4 Benchmarks

Once we got a ready configuration, benchmark scripts have been designed in order to test the overall performance of the configuration. Then we proceed to cycles of benchmarks/tweaks. Various metrics have been set in order to achieve this :

- Size of mail queue

- Delivery delay

- Load of the servers

Since the objectives were to replace and improve an existing solution, tests have been performed on both the old and the new configuration. Data collected have been graphed to allow us to compare the performance of the two different configurations (see figures 3.1 and 3.2). On these two graphs, we can clearly see that the performance is much better and less sporadic with the new configuration than the first one (at least ten times better).
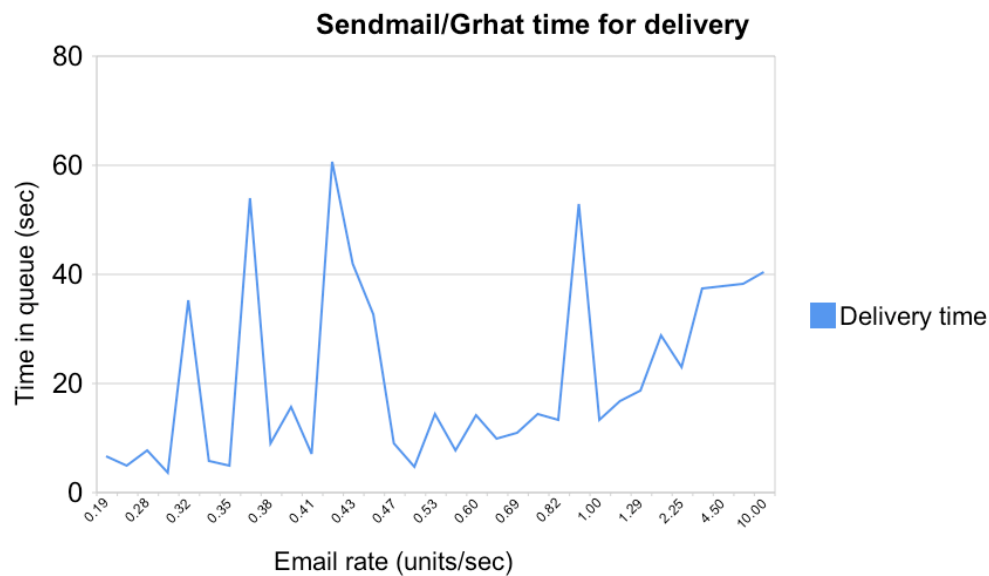

Figure 3.1: Performances of old configuration - Performances de l'ancienne configuration
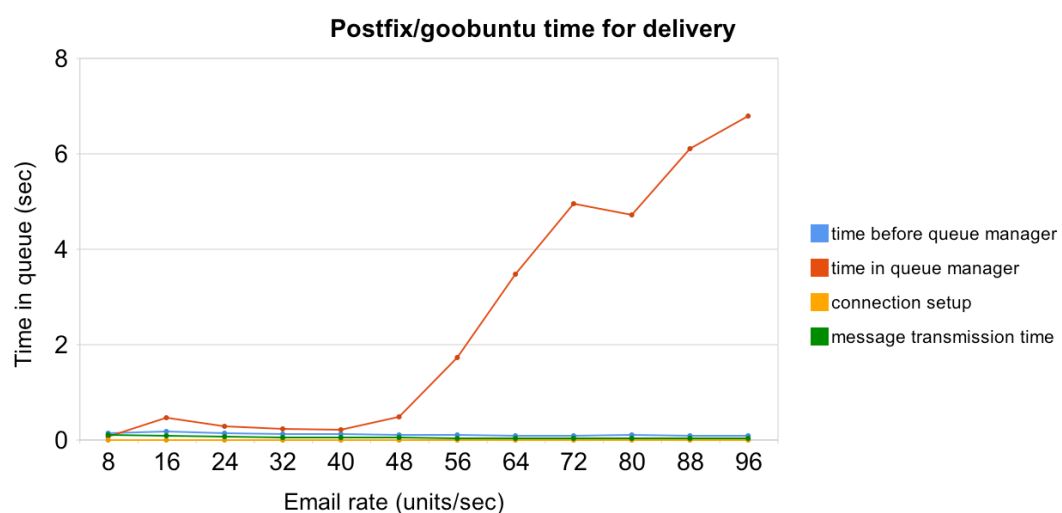

Figure 3.2: Performances of new configuration - Performances de la nouvelle configuration
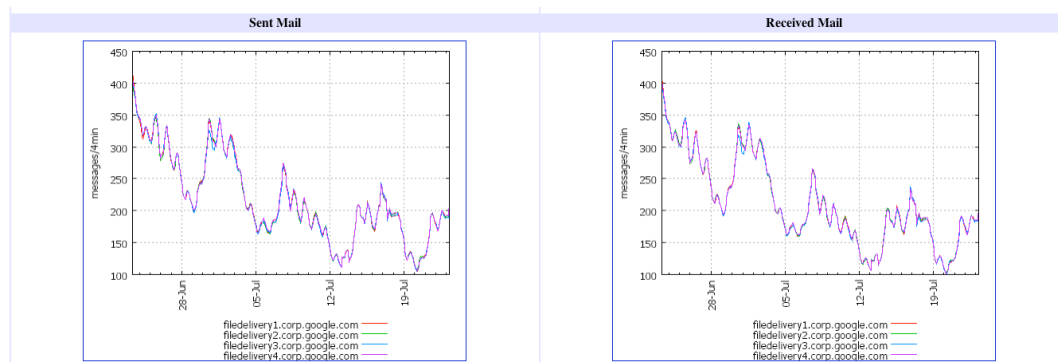
Figure 3.3: Filedelivery monitoring (mailrate). Monitoring du service "filedelivery"

3.1.5 Monitoring

Once the optimal configuration has been found, it is time to set monitoring agents in order to supervise the machine once they are in production and in order to graph the metrics too. See figure 3.3.

3.1.6 Canarying

The process of canarying consists of replacing just one machine with the new configuration to avoid any global outage of the service in case of malfunction. After a period of quarantine (two weeks in our case) the configuration is considered good and the rest of the machines are deployed in the cluster.

3.2 SMTP-routing architecture improvements

3.2.1 Description of the service

The corporate mail routers provide highly available reliable delivery of email for corporate senders and recipients. They accept mail from the google.com Internet MX servers, from corporate users, and from other corporate mail systems. They deliver mail to corporate email delivery targets and to the Internet. Most email from or to corporate users pass through these systems. Corp mail virus scanning happens on these systems. Some provide spam tagging for messages from the Internet.

Any outage or degradation of the service has a serious and wide-spread impact on the general productivity of all employees, as well as our ability to communicate with external customers. Many of the numerous systems that rely on email, such as Mongoogle and Remedy, will also be affected.

The customer(s) of this service include all Google employees. Additionally, the Corp Mail Routers handle administrative and system email, such as that used by monitoring systems such as Mongoogle and ticketing systems such as Remedy and Keystone. Email is a critical service at Google and tends towards a 99.999% uptime requirement.

The Corp Mail Routers must offer optional server side STARTTLS+AUTH. If AUTH is requested, STARTTLS must be used.

The time between receipt of a message by the Corp mail routers and their first attempt to pass the message on to another server depends on whether or not the message must be scanned for spam. If the message was received from the Internet by the corporate-external SMTP routers (and thus requires spam scanning), then the median time to the first routing attempt should

be less than 45 seconds for messages up to 10 megabytes in size. For mail received from other sources, including Google Corp and Google Production, the median time to the first routing attempt should be less than 30 seconds for messages up to 10 megabytes in size.

During the SOBIG.F virus outbreak, we determined that the maximum safe peak load for a dual P4 2.8Ghz server is approximately 30,000 messages per hour. This assumes a significant number of messages contain viruses. On servers not performing spam or virus scanning, this number will be higher, over 50,000 messages per hour, but the upper bound has not yet been determined.

3.2.2   Specification

The specification is really close than the one from the mail archive delivery service. Metrics are :

- Email delivery delays

- Service Level Agreement

- Mail rate

- Geographic location (Mountain view, Atlanta, Europe...)

3.2.3   Benchmarks and tests

Once again, a benchmark script forked from the one used with the archive file delivery project has been designed. Python was used because for simplicity and efficiency purposes. Monitoring tools have been implemented too.

3.2.4   Deployment

The deployment was slightly more complicated than the archive file delivery service. Indeed, the SLA is very high and the communication of all the Google employees depend on the reliably of the email service. This service is composed of six sets of ten servers. The load balancers are based on Citrix netscalers (Virtual IP addresses). Furthermore, the six VIP are spread all over the world (four in the USA and one in Europe. This avoids global world outages.

The canary method described in the previous section has been used to check if everything was set up correctly. Then, only one VIP has been set with the new configuration. After a quarantine period, all the VIPs have been replaced.

Once the project is finished, it is time to write documentation. Few sections are mandatory, like a general section explaining what is the service used for, how to build it, the common operations usually made with the service, and finally a special page for disaster recovery, which explains what to do in case of problem.

3.3   Portage of a feature from nx-nomachine

Google usually offers 20% of users time to work on any project they want, or even initiate a project. Ubiquity was a good project for a 20% time project since the intern's job was more software development oriented. Nx nomachine is a software used to take control of a distant computer. It's comparable to the VNC suite. The server runs on Linux and the client runs on Mac OS X, Windows, and Linux.
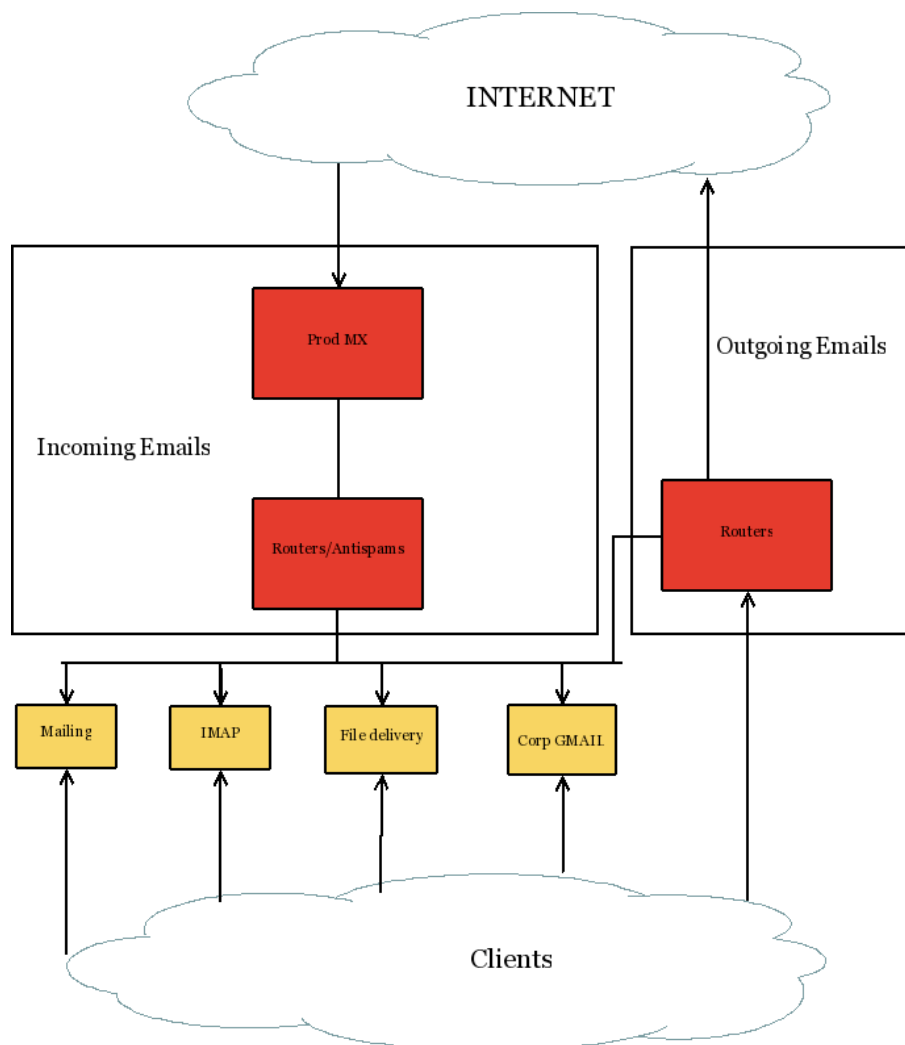
Figure 3.4: SMTP architecture at Google

3.3.1 What is Ubiquity?

A Ubiquity instance is a virtual Linux workstation, hosted in a data center and on the same local network as the filer, and other engineering services. Ubiquity is accessible via NX, SSH & SSHFS.

3.3.2 Needs for a free software

Nx nomachine is a proprietary software. An open source version called Freenx is being developed by the community[1] and by Google Sysops. The main advantage is to get the whole code source to improve performances and allow us to debug everything in case of problem. A feature called shadowing was missing in this open source software. Work consisted in the implementation of this feature from reverse engineering on the proprietary software.

3.3.3 Overview of the NX technology

The core ideas behind NX are to compress X protocol traffic using differential compression and also reduce the number of X protocol round trips across the network by using a proxy X server. The differential compression idea was first introduced by the Differential X Protocol Compressor (DXPC) project back in 1995. Since then, NoMachine have expanded on the idea and built a commercial (but mostly open source) product.

NX also has a proxy X server which serves to dramatically reduce the number of X roundtrips on the network. In place of the proxy X server NX also allows you use a VNC or RDP client and so display non X based sessions over NX.

3.3.4 X Protocol Compression

NX doesn't just blindly compress the X protocol stream and hope for the best. Better results are achieved by virtue of the fact that the algorithm understands the semantics of the messages being compressed. Using this knowledge, it is possible to discard useless information, cache parts of the message which are likely to be re-usable, apply different image compression algorithms based on the type of image and so forth.

Compressing a given X protocol message begins by first splitting the message into two parts - a fixed length identity part and a variable length data part. The example given in the NX documentation is the PolySegmentRequest which consists of a header followed by a list of segments. In this example the header is the identity part and the list of segments is the data part.

The algorithm then looks up the identity and data parts separately from the message cache using an MD5 sum to index the hash. However, the MD5 sum of the identity part is not calculated using the entire contents of the identity, but rather a specific set of fields which are chosen differently for each message type. These specific fields have been carefully chosen to include only those parts which are likely to not change across message instances, thereby increasing the potential for more cache hits.

If a matching message was already found in the message cache, a message indicating the location in the cache of the message is sent in place of the actual message. If the message was not found to be in the cache, the message is first added to the cache and then sent to the recipient along with its location in the cache. This way the encoding side manages the remote peer's cache explicitly rather than having to query the peer about the state of its cache.

A point worth noting about the message cache is that on the encoding side the cache need only contain MD5 sums and on the decoding side the cache contains only the actual message contents and not the MD5 sums. This cuts down on the amount of memory required to maintain the cache and also the amount of processing the decoder must do since it does not need to MD5 sum the messages.

Non-cached messages aren't sent in the standard X protocol format, the messages are sent using NX's differential encoding - whereby encoder does its best to compress the message as much

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[1]see http://freenx.berlios.de

as possible by discarding padding and implicit data. An example is with the PolySegmentReq message it can use co-ordinates relative to the previous co-ordinates to try and get down to 8 bit co-ordinates rather than the full 16 bit co-ordinates.

Integer values like XIDs are also cached using a simple "move-to-front" algorithm. This way, successive messages containing the same XIDs can encoded the XID with as little as a single byte.

Images are sent using any one of a number of packed encodings negotiated between encoding and decoding sides. A nice side effect of this is that the encoder can choose to use a lossy encoding (like JPEG) for large images and still use a lossless encoding so as to not screw up things like text. NX also implements extra cleverness for handling large images on low bandwidth connections - large images may be split up into smaller chunks and streamed with other X messages interleaved with the chunks, thereby allowing the connection to be efficiently shared between mutliple clients.

3.3.5 Beyond Theory, How Its Used

First a bit of NX terminology:

- *NX Proxy*: this is the bit which does the actual compression and de-compression. In client mode it encodes requests from X clients and decodes replies from the X server. In server mode it does the very opposite - it decodes requests from X clients and encodes the replies from the X server.

- *NX Agent:* the term agent is used to describe a component to which the screen is rendered before being proxied across the network to the actual X server. The core NX agent is a proxy X server similar to Xnest.

- *NX Viewer:* this is basically a VNC agent. Its a VNC client which proxies the RFB protocol as X protocol messages (encoded using the differential encoding) across the network to actual X server.

- *NX Desktop:* same thing as the NX viewer, but its a RDP client rather than a VNC client.

NX can be setup to be used in a variety of different ways. The first way is where you interpose a pair of proxy peers between the X clients and the X server:
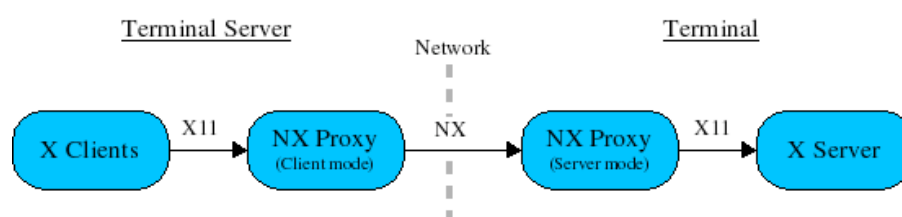

Figure 3.5: NX technology without agent

In this configuration X protocol traffic between the clients and the server is cached and compressed by the proxies. However, this configuration does nothing to reduce the number of roundtips across the network. However, you can also introduce the NX Agent (a proxy X server) on server :
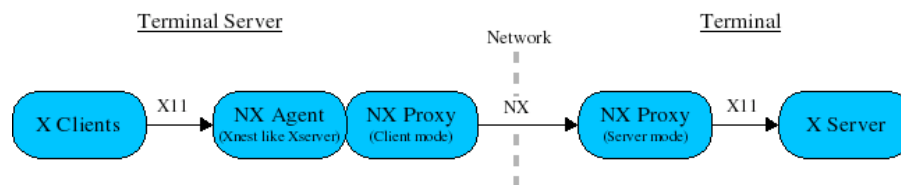
Figure 3.6: NX technology with agent

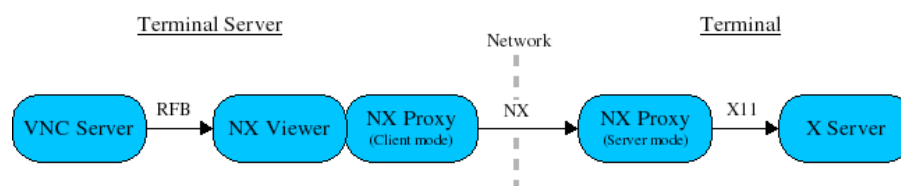In place of NX Agent, you can use NX Viewer or NX Desktop to allow VNC or RDP to be used :

Figure 3.7: NX technology with nx viewer
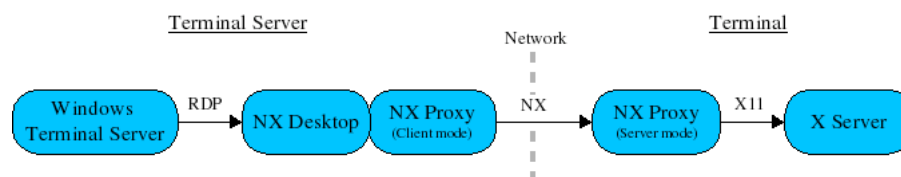
Figure 3.8: NX technology with nxdesktop

3.3.6   More details about the shadowing

The shadowing is a feature which allows an user connected to his instance to share his session with another user (it can be useful for training or even for meetings purposes). Freenx-ng is a python script which is a wrapper to handle all the signals sent by the client and to launch the open source libraries that nomachine provides. The work of reverse engineering was straightforward : understand how the commercial software handled this feature (thanks to debug mode, tcpdump, and various other tools), specify, and implement the feature.

3.3.7   Strong coding standards

There are strong coding standards at Google, and this is great to have guidelines for readability purposes and constancy when more than one person are working on the same code. Furthermore, it's impossible to submit a code which is not compliant to the coding standards (post commit hooks are present in the source management tool). A person with language readability is needed for the last review. Once again, if the reviewer does not give his approval, the code can not be submitted in the repository.

3.3.8   Agile methodology

In the ubiquity project, we used agile mothodology. Agile methods are a family of development processes, not a single approach to software development. In 2001, prominent figures in the field of agile development (then called "light-weight methods") came together at the Snowbird ski resort in Utah to discuss ways of creating software in a lighter, faster, more people-centric way. They created the Agile Manifesto, widely regarded as the canonical definition of agile development and accompanying agile principles.

Some of the principles behind the Agile Manifesto are:

- Customer satisfaction by rapid, continuous delivery of useful software

- Working software is delivered frequently (weeks rather than months)

- Working software is the principal measure of progress

- Even late changes in requirements are welcomed

- Close, daily cooperation between business people and developers

- Face-to-face conversation is the best form of communication (Co-location)

- Projects are built around motivated individuals, who should be trusted

- Continuous attention to technical excellence and good design

- Simplicity

- Self-organizing teams

- Regular adaptation to changing circumstances

3.3.9   Documentation

All the results obtained after the reverse engineering operations were synthesized in a document.

Chapter 4

Conclusion

4.1 Main results

All the projects have been finished. The main interesting result is of course the migration of all the corporate routers at Google. This represents 60 servers. This result is even more interesting for Google because one of the main goals in corp is to migrate all the obsolete red-hat based operating systems to a more recent distribution (ubuntu based in that case). Performances have also been improved of about 20 percent regarding the delay delivery metric.

The second result is of course the migration of the filedelivery service. Once again, some old distro based machines have been removed from the corporate Google machine set.

Finally, the feature added to freenx made a significant improvement to it.

4.2 Skills learned, Encountered problems

First days at Google are very impressive : working with so many smart people can be very intimidating. After one or two months, we just notice that people are very open and that is a real pleasure to work with them. That can sound cliché, but that is true. Among so many things I learned at Google, here are the ones important to remember :

- It is possible to find a company which is not based on a vertical model. By this, I mean that in other companies, the hierarchy is almost the most important thing you have to be aware of. At Google, this is different. Indeed, managers are willing to make your life easier, not to give you strict orders about how you have to do things. Managers are really here to help you to extract the best of you in order to achieve your projects. This make relationships really healthy in the company.

- I also learned a lot of strictness and rigour during this internship. Google can indeed appear as a company where you can get a lot of fun, but when it's about work, people are working very seriously and dutifully.

- I never realy got the occasion to work with high productivity software methods (agile, extreme programing) before this Internship. I learned how powerful these methods can be.

To be honest, I did not encountered a lot of problems during this internship. Except maybe the fact that in such a big company, it is sometimes very difficult to understand everything at the beginning. I had to forget my old little company habit which were to try to understand everything at the beginning (network map, etc).

To conclude, this experience was really great. This really is a once in a lifetime experience to meet so many smart people and to work with them.

Chapter 5

Appendix

5.1 Ten things Google has found to be true

5.1.1 Focus on the user and all else will follow.

From its inception, Google has focused on providing the best user experience possible. While many companies claim to put their customers first, few are able to resist the temptation to make small sacrifices to increase shareholder value. Google has steadfastly refused to make any change that does not offer a benefit to the users who come to the site:

The interface is clear and simple. Pages load instantly. Placement in search results is never sold to anyone. Advertising on the site must offer relevant content and not be a distraction. By always placing the interests of the user first, Google has built the most loyal audience on the web. And that growth has come not through TV ad campaigns, but through word of mouth from one satisfied user to another.

5.1.2 It's best to do one thing really, really well.

Google does search. With one of the world's largest research groups focused exclusively on solving search problems, we know what we do well, and how we could do it better. Through continued iteration on difficult problems, we've been able to solve complex issues and provide continuous improvements to a service already considered the best on the web at making finding information a fast and seamless experience for millions of users. Our dedication to improving search has also allowed us to apply what we've learned to new products, including Gmail, Google Desktop, and Google Maps. As we continue to build new products* while making search better, our hope is to bring the power of search to previously unexplored areas, and to help users access and use even more of the ever-expanding information in their lives.

5.1.3 Fast is better than slow.

Google believes in instant gratification. You want answers and you want them right now. Who are we to argue? Google may be the only company in the world whose stated goal is to have users leave its website as quickly as possible. By fanatically obsessing on shaving every excess bit and byte from our pages and increasing the efficiency of our serving environment, Google has broken its own speed records time and again. Others assumed large servers were the fastest way to handle massive amounts of data. Google found networked PCs to be faster. Where others accepted apparent speed limits imposed by search algorithms, Google wrote new algorithms that proved there were no limits. And Google continues to work on making it all go even faster.

5.1.4   Democracy on the web works.

Google works because it relies on the millions of individuals posting websites to determine which other sites offer content of value. Instead of relying on a group of editors or solely on the frequency with which certain terms appear, Google ranks every web page using a breakthrough technique called PageRank™. PageRank evaluates all of the sites linking to a web page and assigns them a value, based in part on the sites linking to them. By analyzing the full structure of the web, Google is able to determine which sites have been "voted" the best sources of information by those most interested in the information they offer. This technique actually improves as the web gets bigger, as each new site is another point of information and another vote to be counted.

5.1.5   You don't need to be at your desk to need an answer.

The world is increasingly mobile and unwilling to be constrained to a fixed location. Whether it's through their PDAs, their wireless phones or even their automobiles, people want information to come to them. Google's innovations in this area include Google Number Search, which reduces the number of keypad strokes required to find data from a web-enabled cellular phone and an on-the-fly translation system that converts pages written in HTML to a format that can be read by phone browsers. This system opens up billions of pages for viewing from devices that would otherwise not be able to display them, including Palm PDAs and Japanese i-mode, J-Sky, and EZWeb devices. Wherever search is likely to help users obtain the information they seek, Google is pioneering new technologies and offering new solutions.

5.1.6   You can make money without doing evil.

Google is a business. The revenue the company generates is derived from offering its search technology to companies and from the sale of advertising displayed on Google and on other sites across the web. However, you may have never seen an ad on Google. That's because Google does not allow ads to be displayed on our results pages unless they're relevant to the results page on which they're shown. So, only certain searches produce sponsored links above or to the right of the results. Google firmly believes that ads can provide useful information if, and only if, they are relevant to what you wish to find.

Google has also proven that advertising can be effective without being flashy. Google does not accept pop-up advertising, which interferes with your ability to see the content you've requested. We've found that text ads (AdWords) that are relevant to the person reading them draw much higher clickthrough rates than ads appearing randomly. Google's maximization group works with advertisers to improve clickthrough rates over the life of a campaign, because high clickthrough rates are an indication that ads are relevant to a user's interests. Any advertiser, no matter how small or how large, can take advantage of this highly targeted medium, whether through our self-service advertising program that puts ads online within minutes, or with the assistance of a Google advertising representative.

Advertising on Google is always clearly identified as a "Sponsored Link." It is a core value for Google that there be no compromising of the integrity of our results. We never manipulate rankings to put our partners higher in our search results. No one can buy better PageRank. Our users trust Google's objectivity and no short-term gain could ever justify breaching that trust.

Thousands of advertisers use our Google AdWords program to promote their products; we believe AdWords is the largest program of its kind. In addition, thousands of web site managers take advantage of our Google AdSense program to deliver ads relevant to the content on their sites, improving their ability to generate revenue and enhancing the experience for their users.

5.1.7 There's always more information out there.

Once Google had indexed more of the HTML pages on the Internet than any other search service, our engineers turned their attention to information that was not as readily accessible. Sometimes it was just a matter of integrating new databases, such as adding a phone number and address lookup and a business directory. Other efforts required a bit more creativity, like adding the ability to search billions of images and a way to view pages that were originally created as PDF files. The popularity of PDF results led us to expand the list of file types searched to include documents produced in a dozen formats such as Microsoft Word, Excel and PowerPoint. For wireless users, Google developed a unique way to translate HTML formatted files into a format that could be read by mobile devices. The list is not likely to end there as Google's researchers continue looking into ways to bring all the world's information to users seeking answers.

5.1.8 The need for information crosses all borders.

Though Google is headquartered in California, our mission is to facilitate access to information for the entire world, so we have offices around the globe. To that end we maintain dozens of Internet domains and serve more than half of our results to users living outside the United States. Google search results can be restricted to pages written in more than 35 languages according to a user's preference. We also offer a translation feature to make content available to users regardless of their native tongue and for those who prefer not to search in English, Google's interface can be customized into more than 100 languages. To accelerate the addition of new languages, Google offers volunteers the opportunity to help in the translation through an automated tool available on the Google.com website. This process has greatly improved both the variety and quality of service we're able to offer users in even the most far flung corners of the globe.

5.1.9 You can be serious without a suit.

Google's founders have often stated that the company is not serious about anything but search. They built a company around the idea that work should be challenging and the challenge should be fun. To that end, Google's culture is unlike any in corporate America, and it's not because of the ubiquitous lava lamps and large rubber balls, or the fact that the company's chef used to cook for the Grateful Dead. In the same way Google puts users first when it comes to our online service, Google Inc. puts employees first when it comes to daily life in our Googleplex headquarters. There is an emphasis on team achievements and pride in individual accomplishments that contribute to the company's overall success. Ideas are traded, tested and put into practice with an alacrity that can be dizzying. Meetings that would take hours elsewhere are frequently little more than a conversation in line for lunch and few walls separate those who write the code from those who write the checks. This highly communicative environment fosters a productivity and camaraderie fueled by the realization that millions of people rely on Google results. Give the proper tools to a group of people who like to make a difference, and they will.

5.1.10 Great just isn't good enough.

Always deliver more than expected. Google does not accept being the best as an endpoint, but a starting point. Through innovation and iteration, Google takes something that works well and improves upon it in unexpected ways. Search works well for properly spelled words, but what about typos? One engineer saw a need and created a spell checker that seems to read a user's mind. It takes too long to search from a WAP phone? Our wireless group developed Google Number Search to reduce entries from three keystrokes per letter to one. With a user base in the millions, Google is able to identify points of friction quickly and smooth them out. Google's point of distinction however, is anticipating needs not yet articulated by our global audience, then meeting them with products and services that set new standards. This constant dissatisfaction with the way things are is ultimately the driving force behind the world's best search engine.

Chapter 6

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