Analysis of Netflix architecture and business model

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Abstract

Advances in technology and current capabilities of home networks allow people to watch their favourite shows in the comfort of their own household at any time of the day in exchange for a low fee. Moreover, the same video content is accessible on a range of mobile devices while away from home. Video-On-Demand (VoD) and, specifically, streaming video technology enables its users to access content instantly and provides other convenient functionalities, such as rewind, pause, etc. At the moment the number of companies is large, creating a highly competitive market in respective area. This motivates the market players to innovate, develop their products and provide better service to its customers in order to survive the competition. Among those is Netflix, the leading streaming service provider, who has world's largest customer base. This paper provides an overview of VoD technology and an analysis of Netflix case. The study identifies factors that drove the service provider to its leading position on the streaming video market.

KEYWORDS: Netflix, VoD, streaming video, cloud, CDN

1 Introduction

With continuously rising bandwidth, devices' processing power and advancing communication technologies, VoD has become a viable service for home entertainment purposes, distance learning, as well as digital commerce. VoD offers a possibility to watch TV shows at any time and as many times as desired. Additionally, VoD consumers are able to use VCR functionalities of which they are fond: rewind, pause, fast forward, etc. Moreover, some VoD operators provide their customers with access to multimedia content on the move via their mobile gadgets (smartphones, tablets) as long as their network connectivity quality is high enough for streaming.

VoD is delivered to its consumers in a variety of ways, which results in different user experience and quality of service. Multimedia content is either fully downloaded to a storage and viewed afterwards, or accessed already in the process of its download. In the latter case the first part of media is watched while the following bits of the entire content are being downloaded. This type of VoD is called streaming video. An advantage of such a technology is instantaneous content availability on devices that support it. At the same time the quality depends mostly on the data specifics that the device is enabled with. This means less frustration for users, as the waiting times are considerably reduced comparing to technology where the video is first fully downloaded and becomes available for watching only afterwards.

The market of VoD in Western Europe and North America has a rather wide range of providers that compete for dominance and customer base by providing unlimited content packages at lowest prices, as well as content diversity and exclusiveness (e.g. "House of Cards" accessible on Netflix, which holds exclusive rights to stream the series). Netflix - the world's largest online video service [2], Amazon's LoveFilm, HBO, Warner Bros, Viaplay, Hulu and Voddler, to name a few. Due to fierce competition in the market, these companies try to ensure that their consumers are satisfied and spend the least amount of time on content search and configuration. They do this by using suggestion options that are delivered by the customer's own preferences, as well via social networks.

The purpose of this study is to analyse the deciding factors that contributed to success of the Netflix Internet television network and its VoD service from the technical and business point of view. The paper is divided into the following sections: Introduction, Background, Netflix, Discussion and Conclusion. Introduction and Background parts present the general idea of VoD service, including the technical aspect. The Netflix section focuses on Netflix operability. The Discussion section contains thoughts about how and why Netflix has succeeded. Finally, the last section concludes the paper.

2 Background

VoD grew in popularity enormously over the last years due to convenience and value of its services: entertainment, distance learning, video-conferencing. In essence, VoD represents a mix of services and technologies: video compression, multimedia storage, video transmission and video reception. Each of these components went through several phases of modifications and improvements, which lead to VoD service viability.

2.1 VoD architectures and cost classification

VoD services are categorized by their system architecture. According to Mir et al. [10] following are VoD relevant architecture types: centralized, proxy-based, distributed, peer-to-peer (P2P), Content Delivery Network (CDN) and hybrid. In the first case, a central unit called video server, plays a role of content disseminator and serves requests from content consumers. It also acts as a multimedia repository. Examples of services that utilize similar architecture are YouTube and CNN Pipeline, according to study done by A. Vinay et

al [16]. The distributed architecture, on the other hand, removes the dependency on one central unit and moves the multimedia content to a set of computers which are situated in different geographical locations. This type of architecture is superior in scalability and efficiency over the centralized one.

A hybrid architecture is being considered as another architecture design, in which previous two are combined. Peer-assisted VoD described by Huang et al. in [7] is an example of architecture where traditional client-server model is replaced with a decentralized one. In a peer-assisted network, a client who consumes data is uploading at the same time content to other peers who requested identical multimedia file. In a similar fashion, a peer receiving data from another peer acts as a source provider to the other ones. This approach reduces both the strain put on a server and reduces the bandwidth costs for the provider of the service.

Additionally, VoD services are classified by their cost. Consumers are provided with a choice of pay-per-view in the case of Nearly VoD (NVoD), or are presented with a possibility of unlimited access to content - Subscription VoD (SVoD), a service in which users pay a monthly fee and are not charged per watched piece and its popularity. At the same time, VoD providers could offer free viewings of the less popular or not very recent films as long as they are their customers already. NVoD is currently losing its popularity amongst its customers because of its limiting availability (films could be watched only at a particular time if enough users sign up for them), while SVoD is gaining traction.

2.2 Problems faced and solutions

Although the latest technologies and capabilities of the network provide better possibilities than the older generations, VoD still faces problems related to delivery of content over the network. Additionally, the number of users has increased too. To ensure high quality video for its consumers, VoD providers have to invest in solutions that allow quick and reliable delivery of content, which are costly.

Operation efficiency of a VoD company depends on the architecture that it uses. The scientific literature has studied broadly P2P and hybrid architectures to reduce the price and load on central servers, CDNs and proxy servers. A P2P solution completely removes central units from its architecture, thus nodes share same privileges and responsibilities of a client and a server. This architecture ensures load balancing, but at the same time creates other problems: participants can join and leave the network at unpredictable times, resulting in instability. On the other hand, a hybrid architecture represents a compromise between P2P and centralized models. In such an architecture, participants and consumers of the content play a role of multimedia storage units, as well as its distributors, while keeping central components present.

Besides load balancing and scalability challenges that a centralized VoD system faces, it is, conversely, not utilized to its full capability at other times. Thus, investing in an expensive infrastructure, whose full potential is not always used is wasteful. A paper by Li et al. [9] studies how cloud services, such as Amazon AWS and Microsoft's Azure, are brought into VoD architecture to cope with uneven traffic and save operator's expenses. The paper proposes a cloud-assisted solution, where clients are partly served by provider's servers and partly by the cloud. Thus, such a model is composed of VoD provider's servers, cloud storage, cloud CDNs and clients. Cloud CDNs allow fast content delivery, as the network consists of a multitude of edge servers which serve clients closest to them. They also save costs related to bandwidth (pay by byte), even though renting of a cloud infrastructure could be more expensive than owning one. Furthermore, cloud solutions alleviate traffic bursts.

One of the solutions that Netflix - one of the leading VoD providers - has chosen to solve the above mentioned challenges was to swap from their own infrastructure to cloud in 2010. According to the company's techblog article [4] by J. Ciancutti, such functionalities as search engines, recommendation systems, streaming servers, content stores, database solutions, etc. were deployed in Amazon Web Services (AWS). Migration to cloud was implemented due to necessity of continuous scalability, reliability and availability. AWS allows access to additional storage and other resources almost instantly, in comparison to the data-center solution, where infrastructure has to be planned beforehand and cannot be changed dramatically in a quick way. According to Netflix, predicting the future growth is a complex task and provides imprecise results. Whereas, AWS alleviates challenges related to customer base prediction.

In a different article on the same blog by the same author J. Ciancutti [3], Netflix presents brief overview of challenges it had to undergo in the implementation phases of migration to AWS. Among these are problems related to co-tenancy, because the resources in AWS are shared.

Another factor that has to be taken into account when designing an efficient VoD architecture is video popularity. Obviously, the most popular videos need to be stored in several locations, for fast access of multimedia content. On the other hand, cloud storage is expensive and, additionally, the popularity of videos fades away quickly. More than one tenth of Hulu top videos are replaced by others every hour, according to studies by H. Li et all [9]. Thus, an optimal update algorithm has to be considered, in accordance with which video content needs to be updated on the peripheral servers.

2.3 Competition coming from torrents

An important aspect that fits into context of VoD service is competition between VoD operators that deliver legal content to its consumers versus illegal content sharing sites, enabled by BitTorrent P2P sharing protocol. In order to be profitable, VoD services have to beat its illegal opponents and provide better, more efficient and simple-to-use service, so that people would be willing to choose paying money instead of seeking free alternative delivered by BitTorrent.

As stated by A. Kosnik [8], multimedia streaming services have yet to work on their attractiveness. It appears that it's easier to install a file sharing client and download from a rich selection almost any film.

Overall, file sharing sites are more flexible from many points of view. There is no dependency on regions and the content that is available for them, larger content availability, no time limitations, as most of the multimedia is uploaded

almost immediately after its appearance. On the other hand, VoD customers will have to wait for a definite amount of time before the videos are made available to them.

Besides, VoD providers lack consistency in their user interfaces. Thus, if a client wants to access a media file on one of operators sites, he or she will have to learn first how to use it, what features are available, learn search options, etc. Later, if the same clients decide to switch to another provider, due to lack of desired content, they have to start again from the beginning. Moreover, a video downloaded by P2P file client sharing is not limited to only specific devices and players on which videos can playback, as in case of VoD content (for example products bought on iTunes can be played only on a proprietary iTunes media player on MAC or Windows, while Linux is not supported). Additionally, content uploaded on pirate networks is commercial-free, as these are cut from media usually before being uploaded.

As noted by A. Kosnik [8], VoD technology, could, in fact, benefit and learn from experience shared by the P2P file sharing community. Fortunately, technologies and standards implemented by this community are open and available to the public. Streaming services operators could build on already successful solutions and provide additional functionalities, that would make their services more attractive. One example could be permanent access for any media file, even older ones. This seems to be a problematic task for torrent networks, as there might be no seeders - peers that provide video source - present.

Another big advantage of torrents over streaming is that files are downloaded locally and can be watched offline, which results also in smoother user experience, as there is no latency caused by network congestion. VoD providers might also gain customer base by providing both streaming and download options.

3 Netflix

The main goal of this study is to present a brief overview of technologies, business and marketing decisions Netflix - largest VoD provider - has taken, that made an impact on its current leadership.

3.1 Architecture

A clear and well defined study has been done by Adhikari et al. [1] on Netflix network architecture. According to authors, there are four main components that play a role in the overall system operation: a player (Silverlight for desktop computers), Content Delivery Networks (CDNs) that perform delivery of the streaming content to the client, Amazon's cloud services and data centers that belong to Netflix.

Silverlight player is supported by most browsers. It downloads, decodes and plays the video requested by a consumer. Although this is a problem-free procedure for Windows and Mac users, Linux users still have to face problems when watching videos provided by Netflix. There are several workarounds for accessing VoD content. One of them is installing Windows on a VM and watching Netflix from it. Another one is installing Netflix Desktop App described by [15]. However, neither of these solutions are officially supported by the VoD provider.

Netflix uses three Content Delivery Networks for content streaming: Level3, LimeLight and Akamai. Each of them have a rank specified in the manifest file that is downloaded by the player before the content is being streamed. The rank number determines the order of preference for choosing the CDN by the client.

Netflix's own servers perform the actions of registering users and receiving the payments from its customers. Later they redirect the user for signup or for content streaming from Amazon's cloud machines. Most of the activity happens exactly here - in the cloud: log recording, user sign-in, DRM, CDN routing operations, etc.

3.2 Netflix technologies

Netflix is an innovative company both in the sense of technology and business. This conclusion can be drawn if one follows their Tech Blog available online, as well judging by decisions they have made during the years of business evolution. HTML5 technology is present in Netflix user interface (UI). UI is accessed by customers on their Netflix Ready Devices (PS3, XBOX, etc.). This allows Netflix engineers to modify features of the user interface seamlessly, i.e. consumers will not have to download new software, it will be available at once next time they access the interface. This way Netflix also keeps up with the latest web technologies and innovates its products by implementing them.

However, Netflix is not able to use HTML5 for video playback yet. This is due to challenges related to standardization of adaptive streaming in HTML5. Adaptive streaming is a streaming method over HTTP, which implies video delivery at a suitable bit rate for a client. This bit rate is calculated according to client's bandwidth and CPU characteristics and is being adjusted in real time in conformance with available resources. Currently, Microsoft Silverlight is the only container supported by Netflix for video streaming on web browsers. Mobile devices use native applications for video playback, except Samsung's Chromebook which now streams content provided by Netflix via HTML5. ARM-based Chromebook users do not need to install any plugins or additional software on their Chrome OS as mentioned by Google groups [5] in order to enjoy Netflix streaming service.

Streaming strategy used by Netflix influences the amount of traffic that is being transferred. Engineers have to keep in mind that transferring a huge amount of data at once might overwhelm the client with data. At the same time, it was proven that some of the videos are never watched till the end and are interrupted at some point of time, because their viewers lose interest. Therefore, it is unnecessary to send big chunks of data and waste resources, if there is a significant possibility the data will never be used. Moreover, since 25-40% of data traffic on Internet is due to video streaming, this subject becomes even more relevant. Additionally, authors of Sandvine's report [14] state that Netflix is one of the dominant streaming sources in North America: more than 30% of downstream traffic during peak periods. Moreover, same report provides a clear picture of how Netflix outperforms

its rivals in terms of traffic share. This index is 18, 20 and 60 times higher compared to Amazon Video, Hulu and HBO Go, respectively.

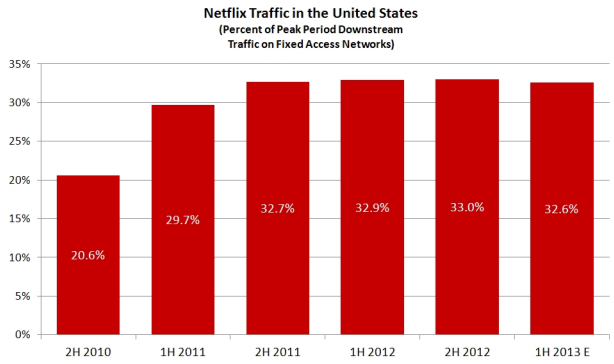

Figure 1: Report[14]

Streaming process happens, typically, in two stages: buffering and steady state. During the buffering phase video is downloaded at full bandwidth capability, whereas at the steady state phase download happens in ON-OFF cycles. Thus during steady state phase a block of data is fetched from the video servers, after which follows a period of idleness. This mechanism saves media player from overload, as well as saves traffic in case user decides to drop video watching.

Rao et al. [13] present results of a study on streaming strategies used by Netflix. According to it, ready state phase is characterized by short ON-OFF cycles in case of streaming on browsers and on native iPad Netflix app. However, in case of Android native app, streaming happens in long cycles. At the same time, data downloaded during buffering stage differs as well for different applications. For instance, for iPad the amount of data fetched while buffering is 4 times smaller than for an Android device.

3.3 Business model

Netflix started as a video rental business in 1997. The business has been adapting, though, during its course of development. A clear example of this is how Netflix has changed the DVD delivery method. Users submit their requests for DVDs online, which are delivered by post to their homes in a day or two in a reusable for return envelope. Moreover, rented content can be kept for as long as desired. All these bring convenience to its end customers, which are more likely to remain loyal to the service.

The subscription model that Netflix chose is another factor that contributes to its success. It removes the trouble with following the amount of watched content and worries related to high bills. Netflix charges 7,99 dollars in the United States and slightly more in Europe for its unlimited content access on any device, - as long as the content is accessed only on one of these devices at the same time. The fee is affordable, and the idea of unlimited watch time explains that it's a leading streaming service. To compare, a bought DVD costs more.

To keep its customers interested, Netflix invests in new and exclusive content. For instance, in the end of 2012 it signed licensing agreement with The Walt Disney Co., according to which films by Disney, Walt Disney Animation Studios, Pixar Animation Studios, Marvel Studios, and Disneynature will be streamed exclusively by Netflix starting in 2016. In fact, the growing video content expenses raise worries among investors, as Netflix customer base will have to increase rapidly in order to cover them.

To prove how valuable is the content that Netflix offers to its subscribers at the moment, the company published an infographic in the letter to its shareholders for the fourth quarter of 2012. The picture presents how many out of top 200 Netflix titles are also streamed by other VoD services.

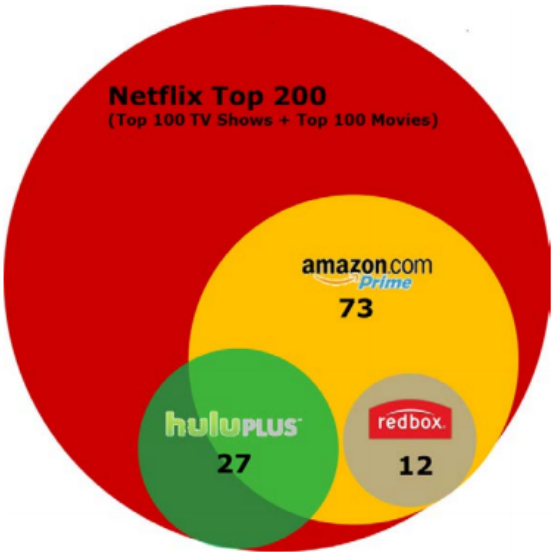

Figure 2: Report[12]

Netflix, whose customer base is more than 33 million streaming members worldwide as stated on its own page [11], considers thoughtfully customers' opinions and satisfaction. In 2006 it announced a "Netflix Prize" competition whose winner got 1 million dollars. Competition's purpose was to find a recommendation algorithm that provided higher results than Netflix's own recommendation system Cinematch. The idea behind the competition was to forecast more precisely videos users would prefer to watch and recommend these on Netflix page. Hence, this results in better customer satisfaction.

Another significant and recent step that Netflix has taken in pleasing its users is introducing to its customers "binge" watching possibility. The whole season of exclusive series "House of Cards", premiered in February and that has received highly positive response from its viewers, was available on its online service. Thus, Netflix has chosen customer satisfaction over short-term profit that could be obtained by releasing one episode per week, as viewers would have to remain connected to the service in order to watch more episodes.

According to S&P 500 stock market index for the first quarter of 2013, Netflix leads the list of best-performing stocks. It's share price grew over 100 percent. Next are presented top 5 best-performing stocks in U.S.

Company	Symbol	Primary Business	Increase
Netflix	NFLX	Movie Rentals	+106.8%
Best Buy	BBY	Electronics Retail	+87.6%
Hewlett-Packard	HPQ	Computer Hardware, Software	+57.0%
H&R Block	HRB	Tax Preparation	+53.0%
Micron Technology	MU	Computer Data Storage	+50.2%

Figure 3: Report[6]

4 Discussion

Marketing and business decisions are key to Netflix corporation's growth. Probably one of the most significant ones is providing unlimited view time of its content at a relatively low monthly subscription fee. Hence, customers are saved from worries about their constantly growing bill. Additionally, films are accessible on a large set of devices. However, Linux is still not officially supported by Netflix service, but this is characteristic to other VoD providers.

Netflix provides a very convenient and affordable service, but if people have not tried or heard of it, they will be outside its loyal customer base. To solve this limitation, Netflix offered a free one-month service in countries where it has just entered the market, for instance in Scandinavian countries. In addition, Netflix non-members, i.e. those who haven't signed up for the service, were also provided with the opportunity to view one episode of its successful "House of Cards" series in order to lure them in to sign-up.

Netflix success stems from several factors. It has proved to be a very adaptive business, which steps in rhythm with technology and latest developments, being among the first to implement newest concepts and, thus, becoming a model for other businesses.

Besides implementing the most recent technologies, Netflix introduces innovative elements in business. One of the examples of its innovative thinking is their DVD by mail rental method, which was copied by other companies, such as Blockbuster, to drive similar high demand in DVD rental. At the same time, the company experiments in a diversity of areas, but then closely watches obtained results in order to minimize its losses in case an idea fails.

Moreover, some of the company's failures serve as a lesson for future improvement, as in the case of AWS outages. These motivate the business to act proactively and implement changes and improvements that will eliminate service loss or reduce it to minimum in force-majeur situations. One of the methods used by Netflix is splitting the service by regions, so that failure in one zone does not affect other zones. Another practice that supports service resiliency is writing an incident report after each service failure and analysing it later to identify aspects that need to be handled better to prevent their further malfunctioning.

5 Conclusion

An increasing number of VoD providers on the market creates favourable conditions for progress and better quality of service, while at the same time creates challenges for the market players. High competition is one of the drivers of innovation and development. Netflix, the leading streaming provider, implements innovative methods and latest technology to keep up with the competition. It is proactive by planning ahead for future growth and investing in high-scalability solutions. It also considers customer satisfaction, by investing in development of recommendation systems, while at the same time enriching its video content database. Although Netflix's customer base grew significantly during the last year, higher than predicted, it still faces challenges posed by competitors and the P2P sharing community. The service will have to develop further and learn from its rivals in some aspects in order to maintain its position.

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