

Analyzing the video delivery strategies of video providers

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1. INTRODUCTION

Video providers such as YouTube and Netflix are well understood today. This is because of the attention they have received due to a large user base. A number of research studies have explored their various aspects including network architecture, user engagement and video delivery mechanism etc. However, Internet video ecosystem consists of a large number of small scale video providers which haven't received much attention. While the bulk of the video traffic today is formed by big providers, these small scale providers can be considered the tail of the video traffic. The end goal of this project is to analyze the video delivery strategies of these smaller providers and compare and contrast them with popular providers.

Importance. This project is interesting to the field, because it can provide insight to the technologies used for video content delivery by small providers, where video plays a supporting role in their businesses, such as news outlets or online learning platforms. Additionally by analyzing and comparing these data with what major providers are doing, such as YouTube or Netflix, we can provide suggestions that will benefit the smaller ones. Finally, from this project I will get a good understanding of how the video content delivery pipeline works, and familiarize myself with data analysis tools.

Challenges. First, video delivery technologies differ between providers, because they are trying to match them to their own needs and delivery strategies. Due to this, we need to discover and specify a common way of retrieving metadata, relevant to the delivered content, so we can automate the acquisition process. Second, in order to provide useful and reliable insights to the video delivery strategies we need to acquire data for multiple videos and from as many video providers as possible. This identifies the scale of the suggested analysis, and could be the most challenging part of this project.

2. BACKGROUND

In order to serve video, providers typically use a *Streaming Protocol*. There are at least four well known streaming protocols which differ in popularity. These include 1. HTTP Live Streaming (HLS) [5] from Apple, 2. MPEG-DASH which is the Industry standard protocol developed by the Motion Picture Experts Group (MPEG) [9], 3. HTTP Dynamic

Streaming Protocol (HDS) [4] implemented by Adobe and 4. The Smooth Streaming Protocol [17] which is implemented by Microsoft.

These streaming protocols specify a number of different characteristics which are vital to video delivery. These include the network encapsulation format for the video chunks, the set of available bitrates, the duration of an individual chunk and the URL to fetch the video content from. These are specified in what is called a *Manifest file*. Before a video player start playback, it downloads the manifest file which informs the player about these attributes hence enabling it to request video content and intelligently adapt bitrates based on the network throughput.

Video providers use a number of different strategies to serve video content. Their strategies can vary along a number of dimensions including the choice of streaming protocol, the number of available bitrate levels for adaptation, chunk duration and the content distribution network (CDN). Their diversity along these dimensions can be understood by analyzing the manifest files. We next describe our methodology for selecting a candidate set of providers and obtaining video manifest files for their video content.

3. METHODOLOGY

To bootstrap our measurement study we first need a list of content providers that serve video. Second, we need a way to crawl through these selected providers' websites to access the manifest files associated with their video content.

3.1 Selecting Video providers to study

We collect a set of video providers of interest by going through Alexa top 500 website list [15]. Alexa provides a ranking of websites based on the traffic, it also provides a ranking of websites based on the type of content they serve. To pick popular video providers we select websites from the "Sports" and "News" category. These categories are important because most websites in this category primarily serve video content. We pick a total of 15 websites.

3.2 Automated crawling and data collection

We use and extend a number of open source tools to build a pipeline that enables automated collection of the video manifest files. The following steps constitute the pipeline. First, we extend an open source tool called Googler [18] to harvest web links that contain video content. Second, we

use the harvested links to drive a Google Chrome browser that loads the link and outputs the network requests while it completes the page download. We do this by using the chrome-remote-interface [7] which allows us to remotely interact with a Google Chrome instance. Third, we filter and collect the manifest URLs from the network log captured by Chrome. Finally, we use custom scripts to download and process the manifest files (and any sub-manifest files referenced in the main manifest file) to record data of interest along the dimensions described above. We now describe each of these steps in more detail and concretely define our extensions to the different open source tools we use.

Googler. Googler [18] is a tool written in Python that enables us to perform google searches with custom queries. Googler has support for regular google searches and searches targeting the “News” tab of the results. Additionally it can navigate over the search results (with a starting point and a total count of urls) and return them in either plain text or json format. For our needs we have extended Googler to perform searches targeting the “Videos” tab of the results. This way we can narrow down the returned urls to the ones that contain videos in them. An example of how we are using Googler in this project is the following:

```
googler -noprompt -nocolor -json -V -start 10 -count 10 -w www.cnn.com ""
```

Chrome-Remote-Interface. Chrome-Remote-Interface [7] is an interface for the Chrome Debugging Protocol that helps instrument Google Chrome and access its monitoring tools, such as console or networking, via Javascript code. For our needs we are utilizing this tool to interact with a Chrome browser instance, access the web pages that contain video and log the network requests while the page loads. Since we are mainly interested in obtaining the manifest files we do not need to wait for the video to finish. The manifest file is downloaded before the video starts to play. So we set a timeout of 30 seconds, a long enough value for the manifest file to download. After the 30 seconds we terminate the browser to free memory and continue the manifest file retrieval for the next video.

Chrome. Chrome is a web browser developed by Google. We are using Google Chrome v.65 as a standard way of accessing urls containing video, in order to hide our crawler behind a common web browser, interpret javascript at runtime (sometimes it’s required for the playback) and start the video playback automatically. Also on the instance we are running we have installed the Adblock extension v.3.27.0, which is really useful in avoiding advertisements where possible.

Custom Crawler. Our crawler is responsible for combining all these individual components into a single pipeline. It takes as input a text file that contains the websites to be searched for pages that contain video, along with starting points for the search and the total number of urls that are going to be accessed. Currently the steps that the crawler takes to retrieve

the manifest files are the following:

1. Retrieve X number of urls for each website in the input file
2. Startup a Google Chrome instance in remote debug mode
3. For each url collected, interact with Google Chrome using chrome-remote-interface, access the url and retrieve the network requests
4. After the timeout period (currently 30 seconds) search the network requests for video manifest files based on known extensions (".m3u8", ".mpd", ".f4m")
5. Retrieve and store the contents of the manifest files with a simple HTTP GET

It’s important to state that we have implemented a simple logging and checkpointing logic. From our crawler’s execution we log the urls fetched with googler, the accessed urls with their generated network requests, and Google Chrome’s debug output. With this approach we can request to get more urls and access them without starting over by simply increasing the number of urls we want to access. This can be achieved because the crawler is aware of the working directory and checks the logs and created files before performing an action.

4. EXAMPLE MANIFEST FILE

Figure 1 presents an example of an HLS master manifest file collected from a video delivered by CNN.COM, and Figure 2 presents a portion from one of its sub-manifest files. The master and the sub manifest files contain a wealth of information describing the publisher’s video delivery strategy for the given video. By parsing and analyzing its content we can derive information such as:

- The CDN that hosts the manifest files. In this case the CDN is Akamai, as evident by the fully qualified domain name (<https://cnnios-f.akamaihd.net>) in the URL. If the URL doesn’t directly provide information about the origin we can perform a `whois` lookup to determine the owner the domain.
- The number of alternative video bitrates offered for the specific video, by counting the unique index files. In this case seven different bitrates are offered.
- The exact bitrate levels (BANDWIDTH tag), codecs and video resolution used for each alternative stream, by interpreting the "preamble" of each index file.

On the other hand the sub-manifest file contains the actual chunks streamed to the device for the video playback. From this file we can get information about:

- The CDN that hosts the actual chunks of the video streamed

```
#EXTM3U
#EXT-X-STREAM-INF:PROGRAM-ID=1,BANDWIDTH=621000,RESOLUTION=640x360,CODECS="avc1.66.30, mp4a.40.2",CLOSED-CAPTIONS=NONE
https://cnnios-f.akamaihd.net/i/cnn/big/cnn10/2017/11/14/caption/ten-1115.cnn_1738140_ios_440,650,840,1240,3000,5500,,mp4.csmil/index_1_av.m3u8?null=0

#EXT-X-STREAM-INF:PROGRAM-ID=1,BANDWIDTH=434000,RESOLUTION=400x224,CODECS="avc1.66.30, mp4a.40.2",CLOSED-CAPTIONS=NONE
https://cnnios-f.akamaihd.net/i/cnn/big/cnn10/2017/11/14/caption/ten-1115.cnn_1738140_ios_440,650,840,1240,3000,5500,,mp4.csmil/index_0_av.m3u8?null=0

#EXT-X-STREAM-INF:PROGRAM-ID=1,BANDWIDTH=807000,RESOLUTION=640x360,CODECS="avc1.66.30, mp4a.40.2",CLOSED-CAPTIONS=NONE
https://cnnios-f.akamaihd.net/i/cnn/big/cnn10/2017/11/14/caption/ten-1115.cnn_1738140_ios_440,650,840,1240,3000,5500,,mp4.csmil/index_2_av.m3u8?null=0

#EXT-X-STREAM-INF:PROGRAM-ID=1,BANDWIDTH=1193000,RESOLUTION=640x360,CODECS="avc1.77.30, mp4a.40.2",CLOSED-CAPTIONS=NONE
https://cnnios-f.akamaihd.net/i/cnn/big/cnn10/2017/11/14/caption/ten-1115.cnn_1738140_ios_440,650,840,1240,3000,5500,,mp4.csmil/index_3_av.m3u8?null=0

#EXT-X-STREAM-INF:PROGRAM-ID=1,BANDWIDTH=2887000,RESOLUTION=1280x720,CODECS="avc1.77.30, mp4a.40.2",CLOSED-CAPTIONS=NONE
https://cnnios-f.akamaihd.net/i/cnn/big/cnn10/2017/11/14/caption/ten-1115.cnn_1738140_ios_440,650,840,1240,3000,5500,,mp4.csmil/index_4_av.m3u8?null=0

#EXT-X-STREAM-INF:PROGRAM-ID=1,BANDWIDTH=5229000,RESOLUTION=1920x1080,CODECS="avc1.640028, mp4a.40.2",CLOSED-CAPTIONS=NONE
https://cnnios-f.akamaihd.net/i/cnn/big/cnn10/2017/11/14/caption/ten-1115.cnn_1738140_ios_440,650,840,1240,3000,5500,,mp4.csmil/index_5_av.m3u8?null=0

#EXT-X-STREAM-INF:PROGRAM-ID=1,BANDWIDTH=38000,CODECS="mp4a.40.2",CLOSED-CAPTIONS=NONE
https://cnnios-f.akamaihd.net/i/cnn/big/cnn10/2017/11/14/caption/ten-1115.cnn_1738140_ios_440,650,840,1240,3000,5500,,mp4.csmil/index_0_a.m3u8?null=0
```

Figure 1—Master Manifest File Example

```
#EXTM3U
#EXT-X-TARGETDURATION:10
#EXT-X-ALLOW-CACHE:YES
#EXT-X-PLAYLIST-TYPE:VOD
#EXT-X-VERSION:3
#EXT-X-MEDIA-SEQUENCE:1
#EXTINF:10.000,
https://cnnios-f.akamaihd.net/i/cnn/big/cnn10/2017/11/14/caption/ten-1115.cnn_1738140_ios_440,650,840,1240,3000,5500,,mp4.csmil/segment1_0_a.ts?null=0
#EXTINF:10.000,
https://cnnios-f.akamaihd.net/i/cnn/big/cnn10/2017/11/14/caption/ten-1115.cnn_1738140_ios_440,650,840,1240,3000,5500,,mp4.csmil/segment2_0_a.ts?null=0
#EXTINF:10.000,
https://cnnios-f.akamaihd.net/i/cnn/big/cnn10/2017/11/14/caption/ten-1115.cnn_1738140_ios_440,650,840,1240,3000,5500,,mp4.csmil/segment3_0_a.ts?null=0
#EXTINF:10.000,
https://cnnios-f.akamaihd.net/i/cnn/big/cnn10/2017/11/14/caption/ten-1115.cnn_1738140_ios_440,650,840,1240,3000,5500,,mp4.csmil/segment4_0_a.ts?null=0
#EXTINF:10.000,
https://cnnios-f.akamaihd.net/i/cnn/big/cnn10/2017/11/14/caption/ten-1115.cnn_1738140_ios_440,650,840,1240,3000,5500,,mp4.csmil/segment5_0_a.ts?null=0
.
.
#EXT-X-ENDLIST
```

Figure 2—Sub Manifest File Example

Publisher	Category	Alexa Rank
www.cnn.com	News	2
www.nytimes.com	News	3
www.bbc.com	News	6
www.foxnews.com	News	10
www.weather.com	News	11
www.huffingtonpost.com	News	14
www.usatoday.com	News	16
www.bloomberg.com	News	17
www.cnbc.com	News	19
www.wsj.com	News	20
www.espn.com	Sports	1
www.nba.com	Sports	7
www.premierleague.com	Sports	14
www.wwe.com	Sports	31

Table 1—The providers we study, their Alexa categories and rank within the category

- The type of video that is being viewed. In this case the video is pre-recorded on demand video (VOD) as given by the EXT-X-PLAYLIST-TYPE tag. Alternatively it could have been a live stream.
- The time segment of the video each chunk covers, by parsing the preamble of the file. Specifically the EXT-X-TARGETDURATION tag provides us information about the duration of the chunk. In this case the chunk duration is 10 seconds.

5. ANALYSIS AND RESULTS

Our analysis is performed on 15 different content providers. As discussed in §3 these providers were selected based on the Alexa top websites ranking within different categories. Table 1 shows the content providers, their categories and the

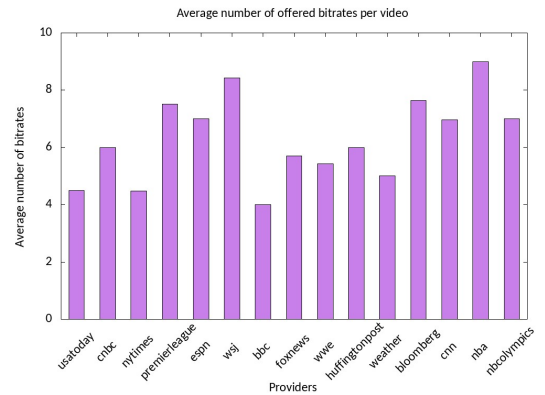


Figure 3—Number of bitrate levels offered by providers

rank in their respective categories. In particular, of the 15 providers we study, 11 primarily serve News content and the remaining 4 serve Sports content. Further, notice that all the providers are prominent in their categories as shown by their Alexa rank.

5.1 Bitrate Values

Figure 3 presents the average number of different bitrates offered per video by the providers. Almost all the provider have on average more than 4 bitrates available for a specific video and some of them offer over 8 different options. Additionally observing Figure 4 we can tell the distribution of bitrates.

5.2 CDNs

In Figure 5 we present the number of different CDNs used by the providers, that we discovered. Most of the providers

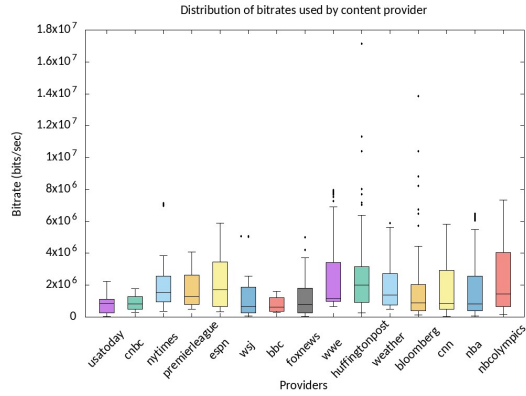


Figure 4—Levels of different bitrates offered by providers

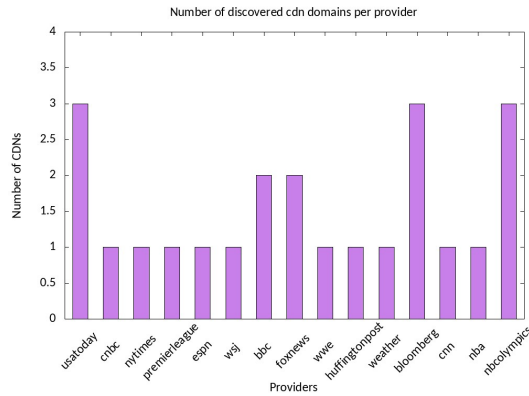


Figure 5—Number of CDNs used by different publishers

use at most one CDN, but there are others opting for two or three. However, as we observed, this was done for different sections of their video categories. In Figure 6 we show which CDNs we found to be more by the providers. Akamai Technologies is used by 73% of the crawled providers, in second place there is Fastly that appeared in 20% of the providers, Limelight and Brightcove appeared in 13% of the providers and Amazon AWS in just under 7%.

5.3 Chunk Target Duration

Chunk size can vary from video to video and from chunk to chunk. However, each provider specifies a target chunk size

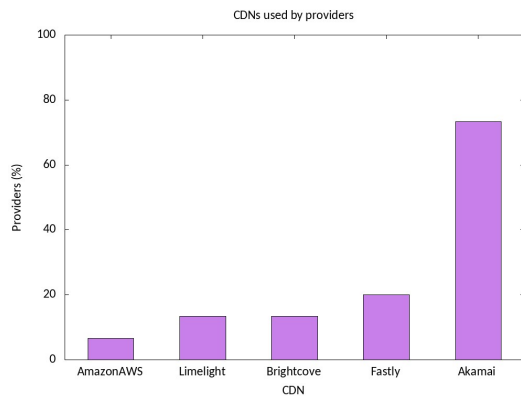


Figure 6—Most popular CDNs among different providers

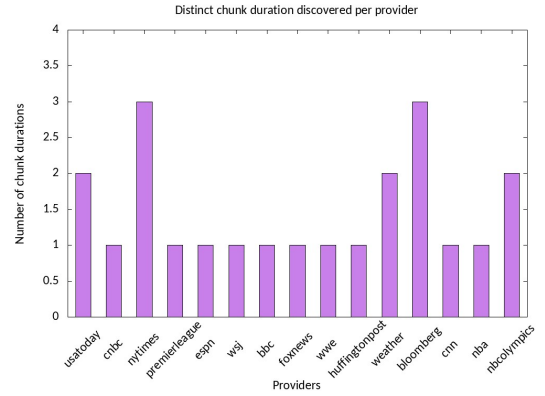


Figure 7—Number of different chunk durations used by different publishers

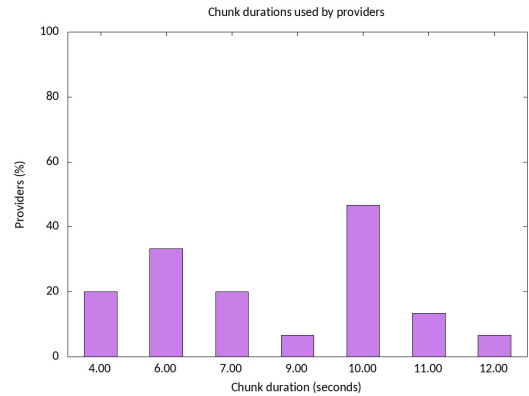
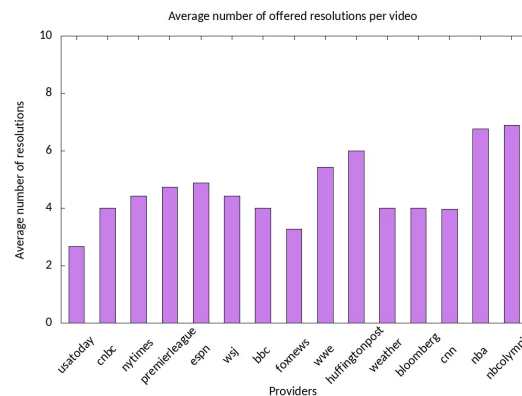
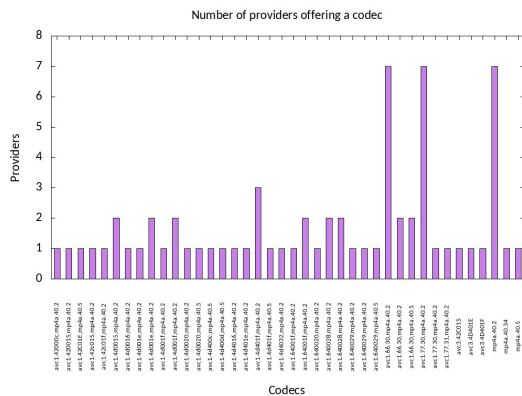
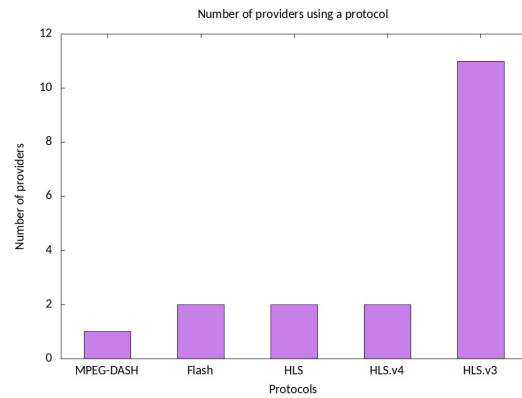
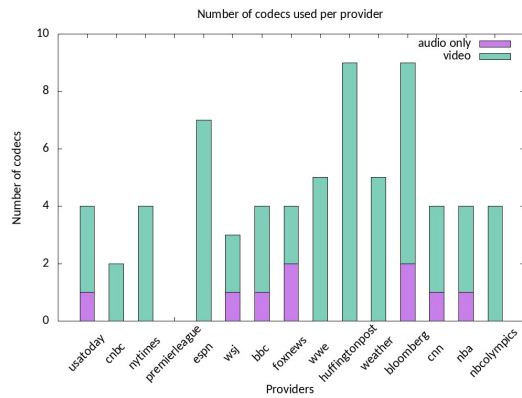


Figure 8—Popularity of different chunk duration used by publishers

that video chunks tend to converge to. In Figure 7 we present the number of different video chunk sizes offered by each provider. The majority of the providers is using one target chunk size, but there are some providers offering multiple chunk target durations throughout their videos, probably because of the video length. Also, by analyzing the individual step of each chunk in videos, some of the providers offer smaller chunks in the beginning of the video for faster playback start. Figure 8 presents how many providers are using a target chunk duration. 46% of the providers is using chunks of 10 seconds, 33% uses chunks of 6 seconds, 20% uses chunks of 4 and 7 seconds, 13% uses chunks of 11 seconds, and under 7% uses chunks of 9 seconds and 12 seconds.

5.4 Codecs

With Figure 9 we present the number of different codecs used by the providers. This graph breaks down the codecs to audio only and video. There are 7 providers offering audio only streams, and usually these were marked with captions as well. Most of the providers offer their content in about 4 different codec configurations, and there are two (Huffingtonpost and Bloomberg) where we discovered 13 different codec configurations. Here we should note that for “www.premierleague.com” we haven’t tracked codecs because they were missing from the manifest files. In Figure 10 we present the codecs and their popularity



among the providers. For video “avc1.66.30, mp4a.40.2” and “avc1.77.30, mp4a.40.5” were the most popular, and for audio only “mp4a.40.2”.

5.5 Protocols

Figure 11 depicts the protocols used by the providers. The most popular protocol used among them is HTTP Live Streaming (HLS). Almost all the providers are using HLS, and the dominant version is HLS.v3. BBC on the other hand is using MPEG-DASH for its new videos and for the old ones (before 2015) is still using Flash. We also considered Fifa.com in this study, which is using Flash for all its videos, but we don't have more data, because it was extremely difficult to study how they transfer the video files. Note: {There were some of the providers that didn't specify the HLS version in their manifest files, and that's why there is one HLS entry with no version.}

5.6 Resolution

Along with different bitrates providers also give options for different video resolutions in their manifest files. Figure 12 shows the average number of resolutions offered from each provider per video. All providers give more than two resolution options and sport sites, such as “www.nba.com” and “www.nbcolympics.com” offer more than six. Observing Figure 13, we can tell that there are providers offering

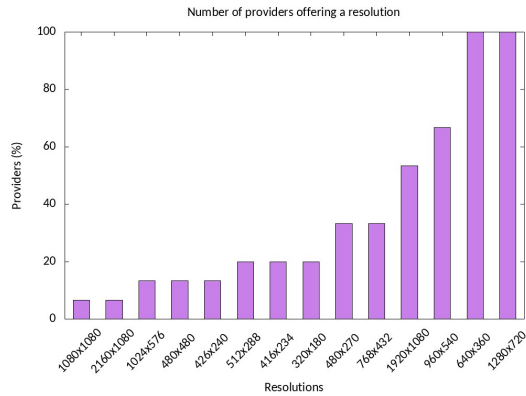


Figure 14—Number of providers offering a resolution

Due to their popularity, video serving systems have been the subject of a large body of work. YouTube alone has been the subject of numerous studies over the years. [3, 6, 13, 23, 8, 12, 20, 10, 22]. Together these works have studied a number of YouTube’s aspect, including the architecture and its evolution, serving strategy, characterization of videos and the user access patterns etc. Netflix, another major provider has also received much attention, where researchers have characterized its delivery strategy in [2, 14].

In addition to these well known systems, researchers have also focused on a on-demand TV publisher [1, 16], as well as novel video delivery systems which allow users to broadcast live streams [21, 19]. The thread that unites these works is their specific focus on one or a handful of online providers, in contrast this project focuses on understanding the diversity at a macro level across a large number of online video providers. One piece of work that is somewhat closer to this project is [11]. This work analyzes video traffic generated from a large number of users of a prominent cellular services provider. Their results show that in 2011, HLS, a video streaming protocol contributed to one third of the total video traffic.

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