# Streaming media over the Internet: Flow based analysis in live access networks

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*Published in:*
[Host publication title missing]

2011

# Streaming media over the Internet: Flow based analysis in live access networks

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*Abstract*— **Multimedia service delivery over the Internet is a success. The number of services available and the number of people accessing them is huge. In this paper, we investigate multimedia streaming services over the Internet. Our analysis is based on traffic measurement in live access fiber-to-the-home networks. We study parameters like traffic volume and flow characteristics for selected services. Especially the Swedish P2P video service Voddler and the Swedish P2P music service Spotify are studied. We show that indeed these services are widely used (20% of local hosts using Voddler, 65 % of local hosts using Spotify). We also show that they are different concerning the flow characteristics, with many short flows for Voddler and longer flows for Spotify. One thing that they have in common in our measurements is that the outbound, or uplink, traffic volume is larger than the inbound.**

*Index Terms*— ***Traffic monitoring, Internet TV, VoD, multimedia streaming, TCP connections***

## I. Introduction

The multimedia landscape available over the Internet is diverse and rich. New services emerge, and the usage of Internet streaming services is wide spread. It has increased tremendously in popularity and bandwidth over the last years, and we see no signs that this trend is going to stop. Higher access speeds to private end users have made this change possible. The role of traditional broadcast TV is likely to change in competition with emerging TV-like services delivered over the Internet. Internet based video streaming services are mainly based on TCP, see e.g. [12] and [13]. The first emerging services were delivered on a client-server basis. Nowadays, it is also common to deliver streaming services with peer-to-peer (P2P) techniques. This is confirmed in our measurements, where we see that there are several peer-to-peer based video and audio services available, and that they constitute a significant share of the streaming traffic.

We investigate the prevalence and characteristics of Internet based streaming services in a fiber based high speed access network. We study metrics like bandwidth, penetration and connections for the most popular streaming services. We will in particular analyze flow behavior, since the number of flows in the Internet traffic has increased dramatically with the advent of P2P based content delivery. Apart from the bandwidth per link, the flow characteristics are important parameters for understanding the traffic patterns. This information is important for analyzing user and service specific behavior as well as studying locality of traffic and overall energy consumption of the network.

From private conversations with network operators, we also know that a very high number of concurrent flows may cause problems in the access network, due to the fact that some devices are not designed to accommodate this high number of concurrent TCP flows.

Manuscript received May 6, 2011. The work has partly been financed by the CELTIC project IPNQSIS, with the Swedish Governmental Agency for Innovation Systems (VINNOVA) supporting the Swedish contribution. Maria Kihl is financed in the VINNMER programme at VINNOVA. Andreas Aurelius and Christina Lagerstedt are partly financed by the European Regional Development Fund Fund (ANT2) and the Swedish National Strategic Research Area (SRA) within the program TNG (The Next Generation) and the project eWIN.

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## II. Measurement procedure

The measurements in this paper were performed with the PacketLogic (PL) [1] traffic management device. It is a commercial device used for traffic filtering, shaping and statistics. It classifies traffic based on contents of packets and flow characteristics. This means that the device performs deep-packet inspection, but it also uses flow based information in the classification process. An internal “signature” database is kept, with signatures of known applications and protocols, e.g. Skype, Bit Torrent transfer, HTTP, RTSP, etc. This database is continuously updated, to add new applications. The flow and packet information is matched towards the signature database, and in 90-99 % of the traffic, a match is found. The device keeps track of all flows, established (two-way flows) as well as un-established (one-way flows). Volume based traffic statistics is stored in a statistics database. In addition to this, flow based statistics may be stored in a connection log. The flow information stored in the connection log is, apart from the commonly used 5-tuple (source address, dest address, source port, dest port, protocol), also start time, end time, bytes in, bytes out, application signature, server host name. The term client is used to denote the host IP that initiates the connection, i.e. sends the first packet in the connection.

The measurement data is retrieved through collaboration with a Swedish Municipal network operator, and the actual measurements are performed by the network operator. The data is stored internally in the PL. In order to extract data for analysis, a python API is used. A python script is used to fetch the data from the PL to a local server, for post processing. At the same time as fetching the data, the script performs three important actions.

Firstly, it retrieves geographical information about the source and destination IP, through the GeoLiteCity open source database [2] provided by Maxmind. It has a stated accuracy of over 99.5% on a country level, and 70 % correctly resolved within 25 miles of true location on the city level in Sweden.

Secondly, since the ‘client’ can be either a local host IP or a remote host IP, also a Boolean variable is added to the database, ‘clientislocal’. This is set to 1 if the client IP matches any of the local host IPs.

Thirdly, the script anonymizes the IPs, in order to preserve the privacy of end users.

After these steps, the data is stored in a MySQL database. The data in this paper is TCP data from one week of streaming traffic, from the 25th of March 2011 to the 31st of March 2011.

One important thing to point out when describing the length of the measurement is the following. The database investigated in this paper contains start and end time of the flow, measured in seconds. It contains all flows that were active during the measurement time of one week. Some flows were started before the measurement time, and some flows were ended after the measurement time. This means that the database may contain flows with a longer duration than the actual measurement time. This is not an error, it only reflects the way that the PL handles flows, keeping the active connections in memory.

The categorization of which signatures to include in the streaming category is performed by the PL, and its built in application categorization [3]. There were 1779 local IPs in the database, which consists of more than 80 million rows.

Video and audio content may be delivered over the internet in different ways, either downloading, real time streaming or pseudo streaming. Since this paper does not go into the performance or architectural issues of streaming, all these methods are covered in the measurement database. Hence, we do not distinguish between the services or protocols depending on delivery method, and we use the term “streaming” to refer to all video or audio delivered over the Internet for instant viewing or listening.

## III. TARGET NETWORK

The network, in which the measurements are performed, is a medium sized municipal network in Sweden. There are approximately 2500 fiber-to-the-home (FTTH) households connected to the network, and a small number of DSL lines as well as some enterprise and campus traffic. Only the residential FTTH based traffic was taken into account in this paper. The residential fiber access speeds in the network range from 2 Mbps symmetrical to 100 Mbps symmetrical, all depending on which subscription the customers have chosen. It is an open network, so there are several internet service providers (ISP) to choose from, and each ISP offers several different subscription types with varying access speeds. There are several PLs installed in the network. They are all placed at the Internet edge, meaning the location where the traffic is handed over to the ISP. This means that i) traffic captured at one PL interface covers a subset of the customers in the network, ii) a subset of the traffic may be local within the access network, i.e. exchanged by local peers and thus not visible by the measurement device.

See Fig. 1 for a schematic picture of the network and the placement of the PL. In the figure, it can also be seen that the measurement device is connected to the network via optical 50/50 splitters. These devices merely split the optical power in two equal copies with half the power. This means that the live traffic is not interrupted by the measurement device. It is just monitoring a copy of the traffic.

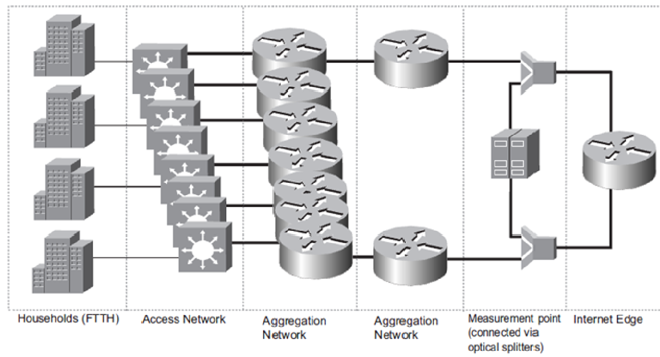


Fig. 1. Schematic overview of the Swedish municipal network in which the measurement data is retrieved. Thick lines denote 1 Gbps line rates and thin lines denote 100 Mbps line rates.

It is stated above that there are several measurement devices in the network. The database of flow level data for streaming media services analyzed in this paper is built from measurements at one of these devices. This means that a subset of the local users are represented in the database. Nevertheless, some high level data, like percentage of traffic per service, etc, is available, covering all monitored local hosts in the network. This data is presented in the beginning of next section, in order to give a high level view of the traffic mix in the network.

## IV. TRAFFIC CHARACTERISTICS

First, looking at some high level statistics for the network in total (i.e. for all monitored local hosts in the access network), 5174 client IPs used 404 services/ protocols, out of which 39 were streaming services. 24 % (9 %) of the incoming bytes (connections) were transmitted by streaming applications. The corresponding numbers in the uplink direction were 2 % (11 %). The unknown traffic (no match found in signature database) makes up 3.7 % of the total traffic. Among the streaming services and protocols, the majority were used for video streaming (32), whereas 7 were used for audio streaming. 10 of the services/protocols were P2P based (9 video and 1 audio). The streaming applications are dominated by video. In the downlink direction, Youtube stands for 46 % of the streaming traffic counted in bytes, but measured in connections, its share is negligible.

Now, turning the focus to the flow based database with streaming services, we will investigate the dominant characteristics of those services present. As stated above, this database covers a subset of the local hosts in the network. There are 1779 local host IPs in the database, and it covers 25 streaming services and protocols. The streaming video connections are totally dominated by one Swedish P2P based video application, Voddler, generating 78.9 million connections during the measurement period of one week. This is further shown in Fig. 2, where the number of flows per service for the top services, is shown.

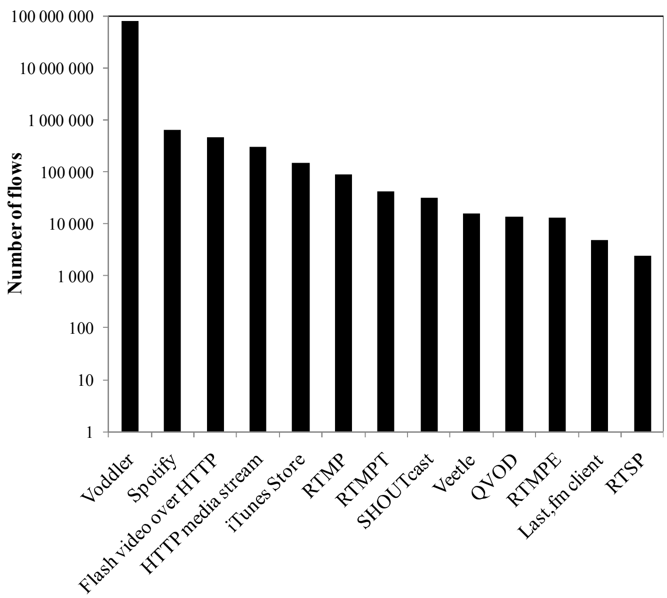


Fig. 2. Number of flows ( logarithmic scale) per service for the top streaming services. The services are ordered according to total number of flows. The measurement time period is one week, and this goes also for the graphs below.

The next service in the figure is Spotify, a Swedish P2P music streaming service. Several of the other services, or rather protocols, are used for streaming content (mainly video) from servers, mostly accessed through web browsers. Among these protocols, are Flash video, HTTP streaming, RTMP, RTMPT, RTMPE, RTSP. Itunes store delivers music, whereas SHOUTCAST delivers Internet radio. Veetle and QVOD are both used for P2P based video streaming. Last FM is a Swedish music service.

As can be expected, the flow statistics follow a periodic daily pattern, with peaks in the evening, around 21. This can be seen in Fig. 3, where the number of concurrent flows in the database is shown.

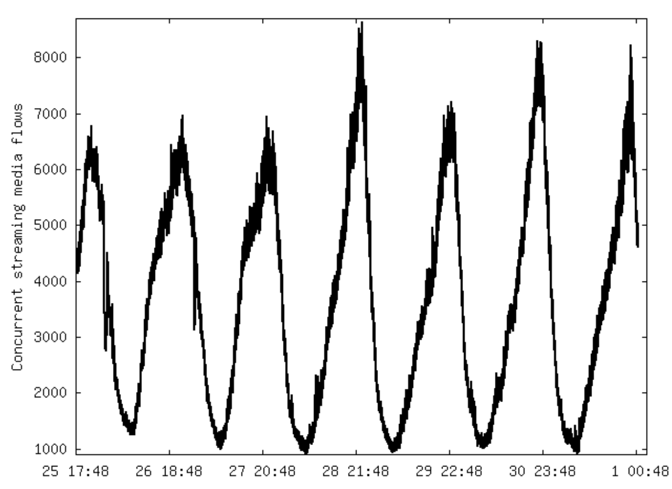


Fig. 3. Concurrent flows in the streaming media database for the measurement period of one week.

Looking at the bytes instead, Fig. 4, one can see that there are several services that generate a huge amount of flows, but not much data. The most striking example is Voddler, which is a P2P based video service. It totally dominates the flow count, but is an order of magnitude below several other video services when counting the generated number of bytes. The reason for the vast number of connections is the very nature of the P2P protocol. Since there is no centralized architecture, many packets must be sent to locate and keep track of peers, and to download and upload content from multiple peers.

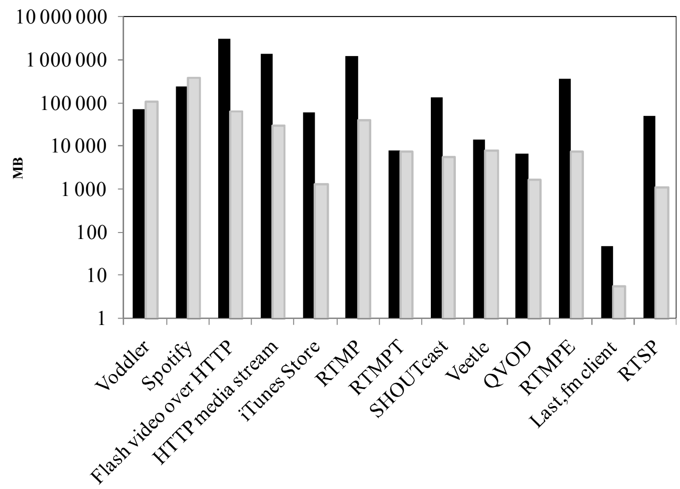


Fig. 4. Bytes transmitted (MB, logarithmic scale) per service, inbound and outbound. The services are ordered in the same way as in Fig. 2.

Even though the P2P based services generate a large amount of connections, the greatest number of users is found when looking at the client server based streaming services/protocols. This is clearly seen in Fig. 5, where Flash and HTTP streaming is dominant, in terms of the number of local host IPs. The P2P based music service Spotify has a large amount of users, with 65% of the local host IPs. In this calculation we count all host IPs that have been seen generating one flow for a specific service during the measurement period of one week.

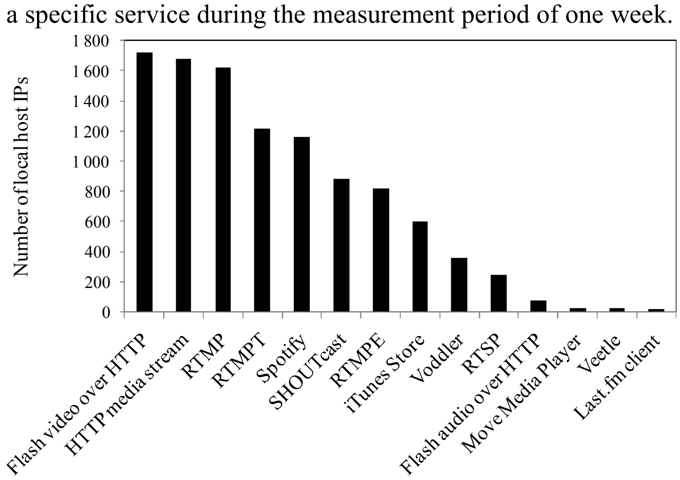


Fig. 5. Number of local host IPs per service/protocol for the most popular services during the measurement period.

For all flows, the end points are tagged with geographical information on city and country. Out of the 80718608 flows in the database, 58392410 (72 %) were initiated by the remote host IP. The volume of the streaming traffic is dominated by download traffic, which is shown in Fig. 6. In this figure we also show the share of traffic by volume, which was initiated from local or remote host IPs. We can see that the inbound traffic volume (i.e. traffic coming in to the local network) is dominated by the flows initiated locally. This is not the case, looking at the outbound traffic volume. Here the flows initiated by the remote hosts make up for two thirds of the volume.

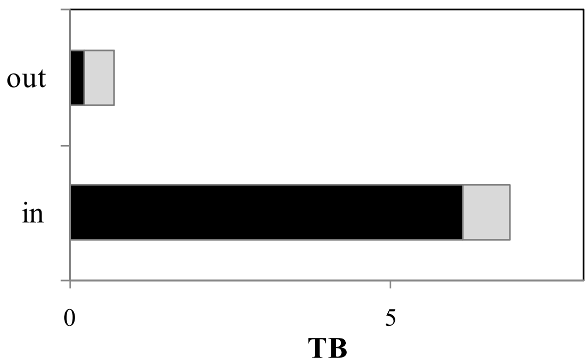


Fig. 6. Traffic volume inbound (i.e. downloads, traffic coming into the local network) vs outbound. The black area denotes traffic initiated by local hosts.

The flows initiated locally are to a large extent directed to Swedish, other Nordic destinations and to the USA. This is shown in Fig. 7.

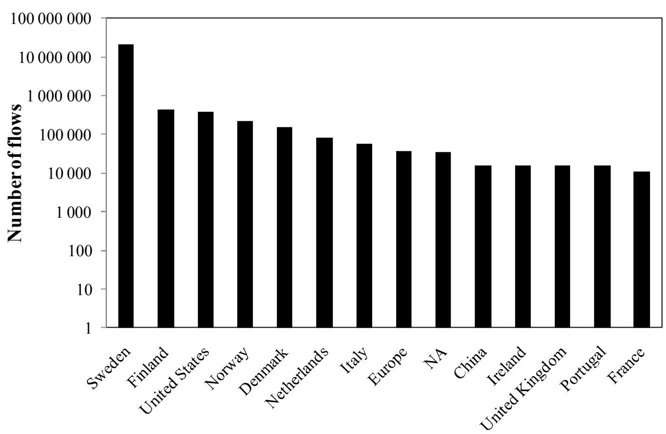


Fig. 7. Number of flows per host country for the flows initiated from local host IPs.

Looking at the length of the flows, we can reveal some interesting characteristics. Flow length statistics for the most used services/protocols are shown in TABLE 1. Some flows are very long, with a duration over one week, see e.g. Spotify, with the longest flow lasting for 851450 seconds (more than 9 days). For an explanation on why the database contains flows longer than one week, please refer to section II. Also Shoutcast (internet radio) has some very long flows, the longest almost five days. The average Spotify flow is 1838 seconds, i.e. roughly half an hour. Since the average is not the best way to characterize the flows, some services are investigated in more detail in the next section, looking at cumulative distribution functions. Another interesting fact revealed by the table below is that the average Voddler flow length is 6 seconds. The long Spotify flows may be explained by the nature of music listening behavior, i.e. long, uninterrupted sessions. Voddler, on the other hand, is a P2P based video service, and it generates a very large amount of short flows, to handle peer discovery and tracking.

The average Flash video flow is over two minutes, long enough to download a short video clip, with progressive download.

TABLE 1
FLOW TIME STATISTICS FOR SELECTED SERVICES/PROTOCOLS, MEASUREMENT UNIT AND MINIMUM RESOLUTION: SECONDS.

| Service/protocol | Average | min | max | stdev |
|---|---|---|---|---|
| Spotify | 1838 | 5 | 851450 | 5697 |
| RTSP | 1039 | 5 | 89631 | 3594 |
| RTMPE | 661 | 5 | 256775 | 3950 |
| RTMP | 550 | 5 | 306812 | 3101 |
| SHOUTcast | 390 | 5 | 431043 | 3958 |
| Move Media Player | 228 | 11 | 11016 | 583 |
| QVOD | 205 | 5 | 13752 | 732 |
| Flash video over HTTP | 143 | 5 | 520204 | 1636 |
| STTV | 143 | 10 | 11757 | 673 |
| HTTP media stream | 107 | 5 | 332143 | 904 |
| RTMPT | 69 | 5 | 39178 | 414 |
| iTunes Store | 27 | 5 | 12036 | 141 |
| Voddler | 6 | 4 | 16692 | 26 |

## V. VODDLER AND SPOTIFY

This section will provide a deeper analysis of the Voddler and Spotify traffic. These applications are chosen, since they dominate the flow count, but also since they are not so well investigated in previous work.

In the previous section, we noted that the average flow lengths differed significantly between Voddler and Spotify. In order to investigate this further, we derive some individual statistics of flow lengths for Voddler and Spotify. From this statistics, the cumulative distribution functions of flow lengths are derived. These are shown in Fig. 8. Here, we can see e.g. that 98 % of the Voddler flows are shorter than 7 seconds. However there are also long flows, almost as long as five hours. In the Spotify case, only 10 % of the flows are shorter than one minute. 50 % of the flows are longer than 8 minutes, and 10 % of the flows are longer than 70 minutes. For the sake of comparison, a client server based protocol is also investigated, namely Flash video, which is used for the majority of the short video clips started via web browsers. A CDF for Flash video over HTTP flow lengths is also shown in the same figure. Here, we see that 50 % of the flows are shorter than 25 seconds, and 10 % of the flows are longer than 3.4 minutes.

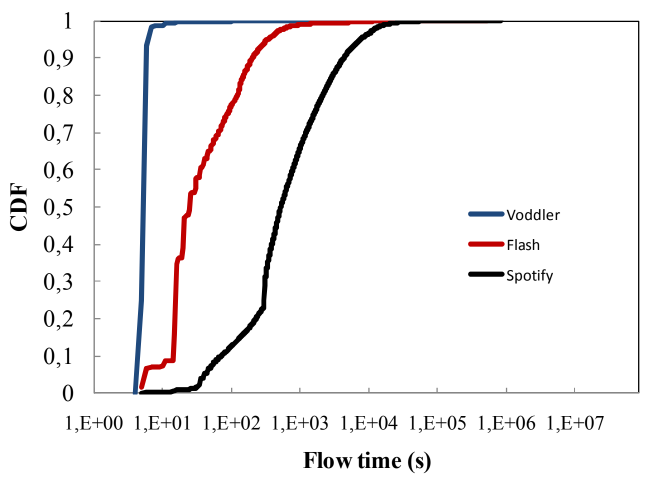


Fig. 8. Flow duration for, from left to right, Voddler (blue), Flash video (red) and Spotify (black).

Looking at the bytes per flow, we note that 97 % of the Voddler flows contain between 500 and 1000 bytes. This is shown in Fig. 9, where the cumulative distribution functions for Voddler (inbound bytes and outbound bytes), Spotify (in and out) and Flash video (only in) are displayed. This emphasizes the fact stated earlier, that Voddler uses many, short flows, and shows that they are also small looking at the byte count. In the Spotify case, we note that the flows are significantly larger and that 80 % of the flows are between 7 kB and 600 kB in the inbound direction. In the outbound direction, there is more traffic transmitted, which is in line with the results shown in Fig. 4. The Flash video flows are larger, with 70% larger than 1 MB and almost 30 % more than 5 MB.

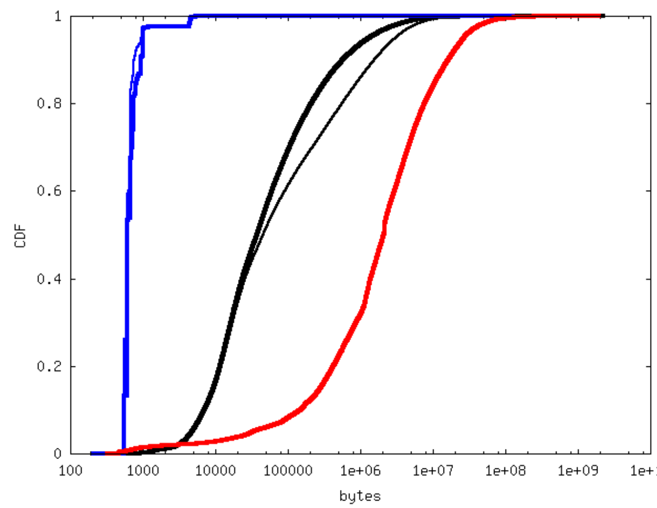


Fig. 9. Cumulative distribution function of bytes per flow. The colors are the same as in Fig. 8. Thick lines denote inbound bytes, thin lines denote outbound bytes. So, from left to right, we see Voddler (inbound and outbound), Spotify (inbound and outbound) and Flash video (only inbound).

## VI. Relevant Work

Several studies have been performed, analyzing IP traffic and application usage in access and core networks. Fraleigh [1] studied traffic in high speed links in the Sprint IP backbone, looking at traffic workload, but also flow and packet characteristics. Fukuda [5] presented analysis of month-long traffic logs in major Japanese ISPs. In [6], measurements of 20,000 residential DSL customers in an urban area were presented. Fiber-to-the-home (FTTH) customer activities were characterized in [7], whereas [8] showed comparisons of end user application usage depending on access type. Several papers have noticed that streaming traffic represents a significant share of the overall traffic mix, see e.g. [12][13]. These papers also show that TCP is mainly used for streaming. The performance issues regarding TCP streaming are analyzed in [9] - [11]. Looking more at application specific studies, [14] [25] and [26] studied IPTV usage including channel switching and channel popularity. User behavior in a large VoD system was analyzed in [23], regarding popularity and access patterns. These features were also analyzed in [24], but in this case it was YouTube media that was studied. Measurements from P2P based multimedia systems have been explored in [16]-[21]. A measurement based study of Spotify was performed in [22]. Performance of a P2P based live TV streaming system is studied in [15].

## VII. Conclusion

In this paper, we have characterized streaming media services and protocols. The data that was analyzed came from a live access network in Sweden, with more than 2000 residential fiber-to-the-home customers. The data was analyzed on the application level, and hence the actual services were identified. Data was analyzed on flow and byte level. We conclude that the streaming services made up 24 % of the incoming bytes and 9 % of the incoming connections. Looking at the streaming services, the flow count is totally dominated by a Swedish P2P video service, Voddler, with almost 98 % of all streaming flows. This, even though only 20 % of the local IPs were using the service. We also found that Spotify, a Swedish P2P music service, is used by 65 % of the local IPs. The flow characteristics of these two services are quite different. Voddler generates many short flows (98 % shorter than 7 seconds) whereas Spotify generates fewer and longer flows (50 % longer than 8 minutes. The longest over nine days). Also Flash video over HTTP was investigated, and there we could see that 50 % of the flows are shorter than 25 seconds. The number of bytes per flow are quite different between these services. In the Voddler case, 97 % of the flows are between 500 and 1000 B. For Spotify, 80 % of the inbound flows contain between 7 kB and 600 kB, slightly larger in the outbound. A lot larger are the Flash video flows, where 70 % contain more than 1 MB and 30 % of the flows contain more than 5 MB.

In general, the inbound traffic is significantly larger than the outbound traffic, but in the case of Voddler and Spotify, the opposite applies. Here, the outbound traffic dominates, due to the many flows initiated by remote hosts. These remote hosts were mainly located in Sweden, but also the other Nordic countries and the United States. We suspect that the high percentage of US based destination addresses may be biased by American companies based in Europe, classified as US locations.

The widespread use of P2P for multimedia delivery may have impact on several aspects of network design. For instance, the possibilities of finding local peers may be affected by the design choices in the local access network. One conclusion may be that in order to better support the P2P content delivery, a meshed network would be appropriate. Another issue which is of great interest at the moment is energy efficiency. This is something that we intend to look into in further studies, regarding e.g. efficiency of P2P delivery vs client-server, and locality aspects of traffic.

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