Music Streaming Services: A Comparison of Data Usage & User Preferences

Erika Rumbold

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Contents

1 Introduction

Over the past several years, streaming services have become the main means of consuming media, whether it be movies, TV, or music. And over those years, more and more streaming services have emerged in competition with each other to gain our usership. Streaming services for film and TV often feature exclusive content (e.g., Netflix Original Series) that isn't available on any other platform. This makes it seem worthwhile for an individual to subscribe to multiple streaming services at a time. On the other hand, users of music streaming services don't feel the need to subscribe to more than one. As consumers, we want to make informed decisions with our money, but it can be difficult to choose one music streaming service when there are so many options.

There are numerous articles that highlight and compare the different music streaming services. In their efforts to appeal to a wide audience, however, these articles take a very generalized approach - recommending each existing streaming service to a certain type of user. For example, CNET recommends Tidal for rock and urban fans, but YouTube Music for Android users [15]. Recommendations like this can be confusing and unhelpful if a reader falls into more than one of these classifications.

1.1 Project Overview

For this project, I sought to compare music streaming services with a more targeted approach; this was done in two parts. First, I conducted an experiment to observe the data usage of each streaming service. Data usage is the amount of data downloaded and uploaded while streaming music. This is affected by the duration of the song(s) streamed, how the song was encoded, how the song was recorded, and data rate settings determined by the streaming services. I will discuss these factors in more depth in Section 2.

The second component of this project is a user study, in which I asked participants about their favorite music streaming services, how important audio quality is for their listening

experience, and how much they care about a streaming service's data usage.

The rest of this report is structured as follows: In Section 2, I give an overview of the streaming services observed in the experiment and user study. In Section 3, I describe the setup, procedure, and results of the data usage experiment. In Section 4, I discuss the user study and the results from the responses. And in Section 5, I summarize the findings from the project and identify future work that could be derived from this project.

2 Music Streaming Services

There are dozens are music streaming services available to the public. For this project, I chose five of the most well-known streaming services to observe.

2.1 Spotify

Spotify was founded in 2006 in Stockholm, Sweden and later launched in the United States in July 2011. By August 2012, *Time* reported 15 million active users, four million being paying subscribers [16]. Today, Spotify serves 574 million users, including 226 million subscribers worldwide. In addition to the over 100 million songs available on the platform, Spotify also hosts 5 million podcasts and 350,000 audiobooks [20]. Spotify offers a Free and Premium tier. Spotify Free is ad-supported with shuffle-only listening and fewer audio quality options [22].

Songs on Spotify can be streamed at five different quality levels: Low, Normal, High, Very High, and Automatic, which adjusts the quality according to your network capabilities [21]. Each quality setting determines both the encoding method and data rate of the streamed audio, as shown in Table 1. HE-AAC, or High Efficiency Advanced Audio Coding, and Vorbis are both lossy data compression methods, with HE-AAC being specifically optimized for low-bitrate applications. In 2021, Spotify announced plans to introduce a HiFi subscription that will offer lossless sound. This tier has yet to be released [24].

Name	Encoding Format	Data Rate (kbit/s)
Low	HE-AAC v2	24
Normal	Vorbis	96
High	Vorbis	160
Very High	Vorbis	320

Table 1: Spotify audio quality settings

2.2 Apple Music

Apple Music was launched on June 30, 2015, and reached 10 million users in its first six months [1]. As of 2022, Apple Music has grown to 88 million subscribers [5]. The Apple Music Radio service is free for all users, with all other features requiring a subscription. In addition to music, Apple Music hosts a variety of exclusive video content, including the music video for *Hotline Bling* by Drake [19] and a documentary for Taylor Swift's 1989 World Tour [6].

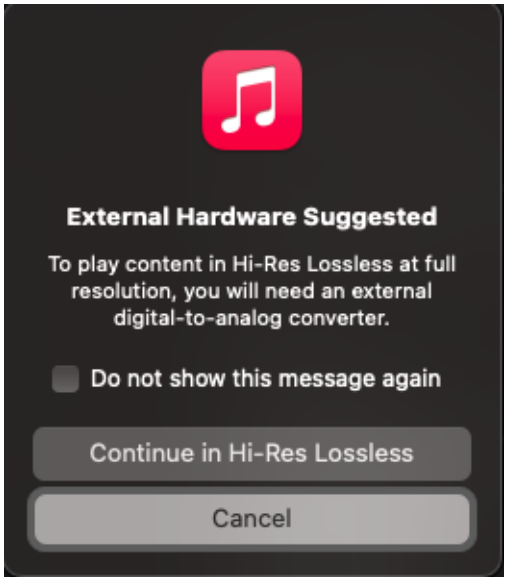


Figure 1: Apple Music recommends external hardware to play Hi-Res Lossless content [3].

Apple Music offers four audio quality options: High Efficiency, High Quality, Lossless, and Hi-Res Lossless, as shown in Table 2. The lossless options use the Apple Lossless Audio Codec, or ALAC, and were made available in June 2021 along with support for spatial audio and Dolby Atmos [4].

2.3 YouTube Music

YouTube Music was released in November 2015 as a part of YouTube Premium (formerly called YouTube Red), a subscription service for the entirety of the YouTube platform [12].

Name	Encoding Format	Audio Quality/Data Rate
High Efficiency	HE-AAC	Variable data rate
High Quality	AAC	256 kbit/s
Lossless	ALAC	16-bit/44.1 kHz to 24-bit/48 kHz
Hi-Res Lossless	ALAC	16-bit or 24-bit/88.2 kHz to 192 kHz

Table 2: Apple Music audio quality settings

In May 2018, YouTube announced a new version of YouTube Music that would be available with or without YouTube Premium. This revamp included a web-based desktop player and redesigned mobile app, more dynamic recommendations, and search enhancements based on Google[1] artificial technology [14]. YouTube Music offers a free, ad-supported tier with limited audio quality options.

YouTube Music offers audio at Low, Medium, High, and Always High settings, as shown in Table 3. Always High maintains high quality even when connection is poor [11]. Opus is a lossy format designed for efficient coding of speech and general audio that replaced Vorbis for new applications [9].

Name	Encoding Format	Data Rate (kbit/s)
Low	HE-AAC and Opus	32 and 48
Normal	Opus	64 and 128
	AAC	128
High	AAC	256

Table 3: YouTube Music audio quality settings

2.4 Amazon Music

Amazon Music originated in 2007 as an online music store named Amazon MP3, and released as a full streaming service in October 2016 [18]. Amazon Music offers digital purchases in addition to three streaming tiers:

- Free - ad-supported access to select playlists and stations, with limited skips and shuffle-only playback [2]

[1] YouTube is a subsidiary of Google.

- Prime - unlimited streaming of a limited music catalog, available to Amazon Prime subscribers at no additional cost [8]
- Unlimited - a full-catalog streaming service, available as an add-on to an Amazon Prime subscription or as a standalone subscription [18]

Name	Encoding Format	Audio Quality/Data Rate
Standard	Opus	Up to 320 kbit/s
HD	FLAC	16-bit/44.1 kHz at 850 kbit/s
Ultra HD	FLAC	24-bit/44.1 to 192 kHz at 3730 kbit/s

Table 4: Amazon Music audio quality settings

Amazon Music offers both lossy (Standard) and lossless audio (HD/Ultra HD), as shown in Table 4. FLAC is a lossless format that has support for metadata tagging, album cover art, and fast seeking. It was developed by the Xiph.Org Foundation, the same organization that created Vorbis and Opus [10].

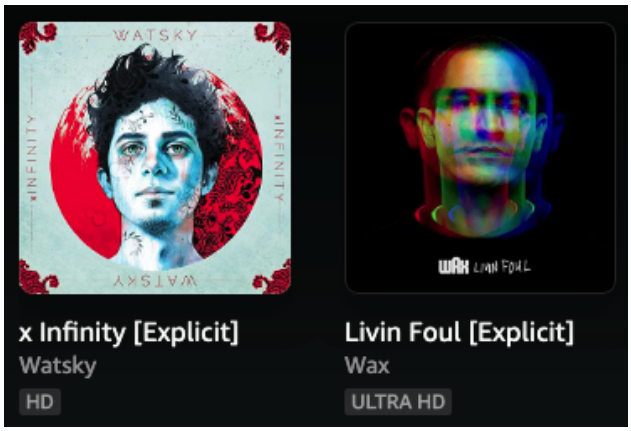


Figure 2: HD and Ultra HD tags on albums in Amazon Music.

When playing lossless music, Amazon Music will stream the best quality available. For example, the album *x Infinity* by Watsky was recorded at 16-bit/44.1 kHz, so it's streamed at the HD level. The album *Livin Foul* by Wax was recorded at 24-bit/44.1 kHz, which makes it playable at the Ultra HD level. As in Figure 2, Amazon Music shows tags on songs and albums to indicate whether they are played at HD or Ultra HD.

2.5 Tidal

Tidal is a Norwegian-American streaming service that was launched in 2014 by Swedish company Aspiro. In 2015, Aspiro was purchased by Project Panther Bidco Ltd., controlled by American rapper and businessman Jay-Z [17]. As a streaming service, Tidal focuses on delivering the highest sound quality "exactly as the artist intended" [25]. Tidal has two subscription tiers: HiFi and HiFi Plus, which are differentiated by the level of audio quality offered. Tidal also has a free tier that is currently only available in the United States.

The audio quality settings are labeled Low, High, and Max, as shown in Table 5. In January 2017, Tidal announced a partnership with Master Quality Authenticated (MQA), making it the only streaming service to offer MQA audio. MQA claimed to deliver master-quality recordings at 24-bit/96 kHz. However, the validity of these claims have been disputed. And in April 2023, MQA Ltd., the owner of the MQA license announced that it had entered bankruptcy protection [13]. Soon after, Tidal's CEO Jesse Dorogusker stated that high-resolution FLAC streaming would be available either concurrently or as a replacement for MQA content on the platform [7].

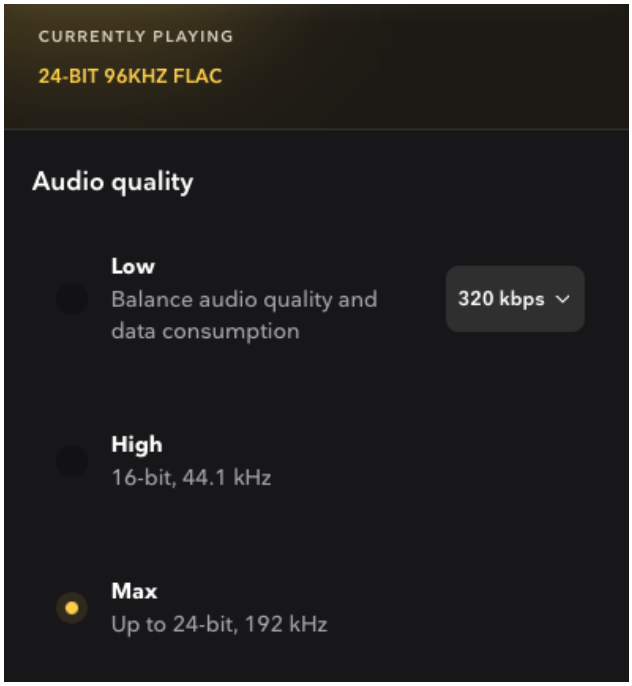


Figure 3: Tidal's audio quality display

Name	Encoding Format	Audio Quality/Data Rate
Low	AAC	96 or 320 kbit/s
High	FLAC, ALAC (iOS)	16-bit/44.1 kHz at 1411 kbit/s
Max	FLAC, MQA, ALAC (iOS)	24-bit/44.1 to 192 kHz at 9216 kbit/s

Table 5: Tidal audio quality settings

As with Amazon Music's Ultra HD, some content is not available at the Max quality. If the streaming setting is at Max quality but the content was only recorded at 16-bit/44.1 kHz, it will be streamed as if it were set to High quality. Unlike Amazon Music, Tidal gives the option of streaming premium quality content at a lower quality setting. For example, if a song was recorded at 24-bit/96 kHz but the quality is set to High, the song would be streamed at 16-bit/44.1 kHz. Tidal displays `High` and `Max` tags to indicate the highest streaming option for a given song or album. And the media player displays the audio quality that is currently being streamed, as shown in Figure 3.

3 Data Usage Experiment

In order to make an empirical comparison between these five streaming services, I measured the amount of data downloaded and uploaded while streaming music on each service. Table 6 shows the quality settings that I tested in this experiment. For the sake of time, I omitted some of the lower quality options.

Streaming Service	**Audio Quality Options**
Amazon Music	Standard, HD/Ultra HD
Apple Music	High Efficiency, High Quality, Lossless, Hi-Res Lossless
Spotify	Normal, High, Very High
Tidal	High, Max
YouTube Music	Normal, High

Table 6: Audio quality options observed in this data usage experiment

3.1 Experiment Setup & Procedure

I conducted each trial on the same Mac computer with the same WiFi network connection. Using the `scapy` library for Python, I wrote a script[2] to log the network traffic from a specified process (i.e., streaming service desktop app) for a given amount of time. Unlike

[2]Adapted from "How to Make a Network Usage Monitor in Python": `https://thepythoncode.com/article/make-a-network-usage-monitor-in-python`

the other streaming services, YouTube Music does not have a desktop app. Instead, I logged the traffic from Google Chrome with only YouTube Music active and no other tabs open.

In each trial, I streamed the album *x Infinity* by Watsky, which is an album that's available on all five streaming services. The network traffic was logged for the full duration of the album, 75 minutes.

Since *x Infinity* was recorded at 16-bit/44.1 kHz, streaming the album would not be possible at Amazon Music's Ultra HD or Tidal's Max settings. To show the full extent of these premium settings, I ran additional trials using different albums that are available at those high quality levels. On Amazon Music, I streamed the album *Livin Foul* by Wax with Standard and Ultra HD quality settings. On Tidal, I streamed the album *RENAISSANCE* by Beyoncé with High and Max quality settings. Both albums were recorded at 24-bit/44.1 kHz quality.

3.2 Results

Charts with the results of this data usage experiment can be found in Appendix A.

By a significant margin, Spotify uploaded and downloaded the least data with less than 10 KB transmitted in either direction. It is also the only streaming service that uploaded more data than it downloaded, and the amount of data transmitted was roughly the same regardless of quality setting. I'm unsure why Spotify was the only streaming service to have results like this. Since Spotify is the service I regularly use, I made sure that I did not have *x Infinity* downloaded or saved to my library; I even ran the Spotify trials a second time, which yielded similar results. Apple Music's High Efficiency option was close to Spotify, uploading 11.2 KB and downloading 19.4 KB. But there was a significant increase with Apple Music's next highest setting, High Quality, downloading 702 KB of data.

Of the *x Infinity* trials, the largest amount of downloaded data was with Amazon Music at HD quality and Tidal set to High quality. Both of these options downloaded approximately 21.51 MB of data for the 18-song album. This makes sense since both are encoded with

FLAC at 16-bit/44.1 kHz.

For the additional trials, there were clear differences in data usage between Amazon Music and Tidal's audio quality options. Amazon Music downloaded 14.4 MB for *Livin Foul* at Standard quality, and 46.2 MB at Ultra HD. This is approximately a 221.3% increase in the amount of data downloaded for the same album. This is most likely due to the difference in encoding format. Standard quality uses Opus, a lossy method, while Ultra HD uses the lossless method FLAC.

The difference in data usage between Tidal's High and Max settings was not as drastic but still notable. Tidal downloaded 19.5 MB for *RENAISSANCE* at High quality and 37.7 MB at Max quality. This is approximately a 93.6% increase. I presume this change is smaller than that of Amazon Music because both High and Max quality on Tidal use FLAC encoding.

For this experiment, I omitted the lower quality settings from Tidal, YouTube Music, and Spotify. However, I suspect they may perform similarly to Spotify or Apple Music High Efficiency, given these lower quality options are all AAC-encoded with a data rate of 320 kbit/s or less.

4 User Preferences Study

4.1 Survey

The purpose of the user study component of this project was to discern what matters to users - what they prioritize and what aspects they may pass over when choosing a streaming service. I sent out an anonymous survey to classmates and personal friends. The survey questions were presented as follows:

1. What type(s) of phone do you have? (iPhone, Samsung, Google, etc.)

2. What type(s) of computer do you have? (Mac, Windows, Linux)

3. Which of the following music streaming services have you used at least once? Amazon Music, Apple Music, Spotify, Tidal, YouTube Music

4. Which of the above music streaming services is your favorite and why?

5. On a 1-5 scale, how important is audio quality for your music listening experience?

6. On a 1-5 scale, how much does a music streaming service's data usage affect your choice of preferred service?

4.2 Results

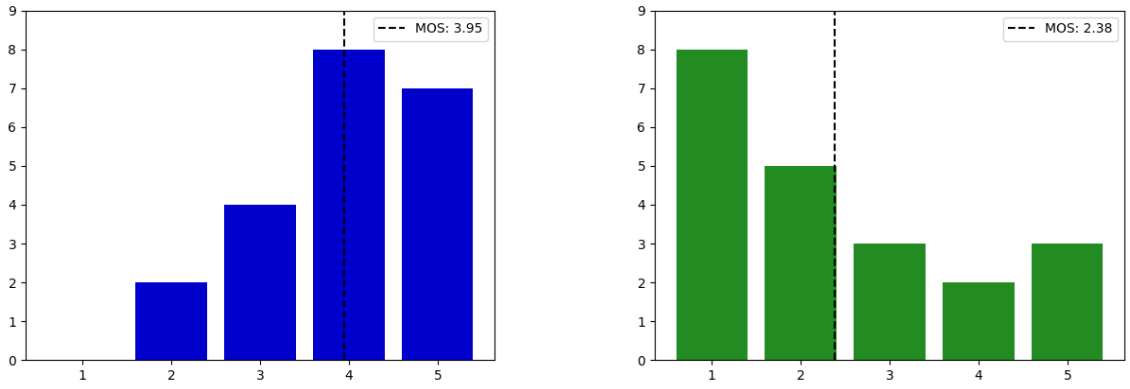
I collected 21 survey responses in all, which I acknowledge is not enough to make any strong claims. However, the results can still provide a general idea of what users may be looking for in a streaming service. All response data can be found in Appendix B.

4.2.1 Most popular streaming service

Of the five streaming services, Spotify was both the most commonly used (18 out of 21 participants) and the most favored streaming service (15 out of 21). However, nine of the participants who chose Spotify as their favorite have not tried any other service; Spotify is their favorite by default. If we disregard these responses, Spotify still takes half of the votes for favorite streaming service (6 out of 12).

Four participants chose YouTube Music as their favorite streaming service. Each of these participants noted that they preferred YouTube Music because its free tier offers the most control compared to other free streaming service options. Apple Music was chosen as two people's favorite streaming service for its compatibility with their Apple devices, the user interface, and the size of the library.

Amazon Music has been tried by five of the participants, but not favored by any. Instead, two preferred Spotify, two preferred YouTube Music, and one preferred Apple Music. None of the study participants has tried Tidal.



(a) Audio Quality

(b) Data Usage

Figure 4: Importance of (a) audio quality and (b) data usage in a music streaming service

4.2.2 Importance of audio quality and data usage

Survey participants were asked to rate on a 1-5 scale: 1) How important is audio quality for your listening experience? and 2) How much does a music streaming service's data usage affect your choice of preferred service? It was clarified on the survey that a 1 meant "Not Important" and 5 meant "Very Important." The ratings for these questions can be seen in Figure 4.

In regard to audio quality, most participants rated its importance for their listening experience as a 4 or 5. The average level of importance of audio quality was 3.95. In contrast, the effect of data usage on these participants' choice of music streaming service was lower, with most responses being 1 or 2 and an average level of importance of 2.38. From these responses, we can see that the survey participants consider audio quality more important to their choice of music streaming service than data usage.

4.3 Discussion

I will re-emphasize that these survey results are not comprehensive enough to make definite claims about music streaming service users as a whole; 21 responses cannot be representative of user bases in the hundred millions. Furthermore, the demographics of the participants

were limited. Although the survey was anonymous, I was only able to get responses from classmates and friends, who mostly fall into the 18-25 age group and all have some amount of higher education.

Let's consider the results in isolation. Nine of 21 participants have only used one of the five streaming services, Spotify. I presume this is because Spotify is the oldest, so users who have been using Spotify for a while had no interest or need to try any of the new services as they came about. One participant who had only used Spotify noted that they "have not had any need to try another service as Spotify does what [they] want it to do very well." Another said they were a long-time Spotify user and had gotten "used to using it."

Among the participants who have tried other streaming services and still preferred Spotify, the responses gave insight to why Spotify was chosen over the others as their favorite. Some mentioned Spotify's wide variety of music and extensive podcast catalog, but the comments I found more interesting were made about the various extra features that Spotify offers. Features mentioned include ways to interact with friends (Blend, Jam Sessions), personalized music curation (made-for-you playlists, AI DJ [23]), and subscription bonuses (Hulu access).

5 Conclusion

In this project, I compared five of the most popular music streaming services for their data usage at the various quality settings they each offer. I found that Amazon Music and Tidal use the most data, and Spotify the least, when streaming the same content. I found that premium audio quality options offered by Amazon Music and Tidal come with significant increases to data usage.

I also compared these streaming services based on user preferences. I found that most of the survey participants prefer Spotify over any other streaming service. Being the oldest of the streaming services in this study, Spotify has a longstanding user base that are satisfied

with the service. Several of the Spotify users surveyed have only used Spotify and don't feel the need to try another streaming service.

5.1 Future Work

Among the reasons why Spotify is their preferred service, participants noted a lot of features that Spotify provides beyond the catalog of audio. Good recommendations and music curation, interactivity with friends, and subscription bonuses were specifically called out. Other streaming services also provide some or all of these features, namely Apple Music. With that in mind, it's unsurprising that Apple Music is considered Spotify's closest competition. It would be interesting to investigate this rivalry to see how many former Spotify users have changed over to Apple Music, why a user may choose one over the other when they have so many similarities, and how many users would choose one over the other if used an equal amount before deciding.

Most music listening is done on a mobile device; it would be great to expand the data usage experiment to track the data usage of music streaming services on a smartphone. This would be interesting data on its own as well as in comparison with the data collected from this desktop app experiment.

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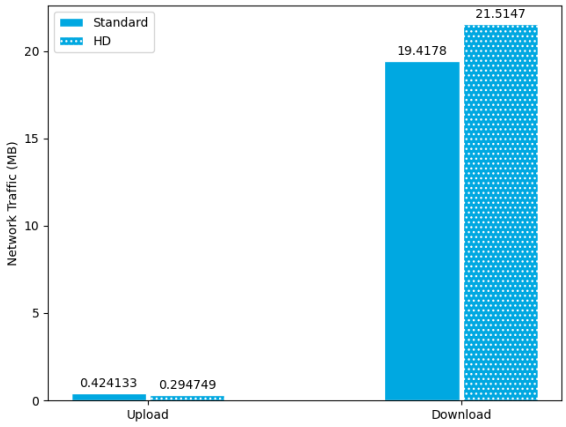
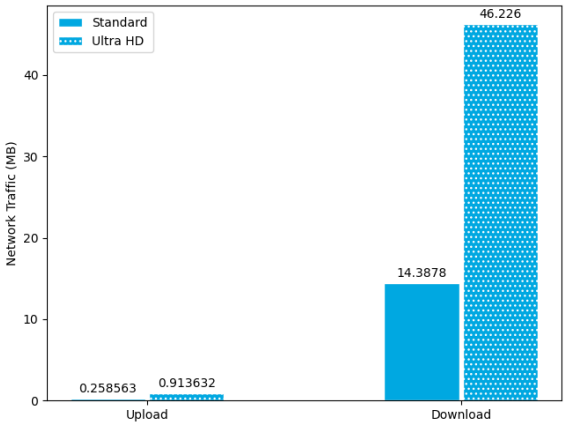
A Data Usage Experiment Results

This appendix includes visualizations of the results from the data usage experiment. Each bar chart shows the uploaded and downloaded data from a given streaming service at the different audio quality options tested. Instead of a data rate (i.e., KB/s), I chose to show the total amount of traffic at the end of the trial (i.e., MB). I find the former to be more understandable from a user perspective.

When looking at these charts, make sure to note the scale on the y-axis; each chart was scaled differently for legibility. Also note that the chart for Spotify is scaled to KB instead of MB like the rest.

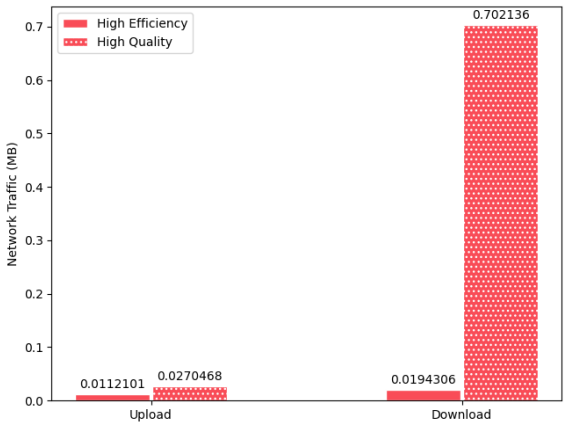


(a) Standard vs. HD (*x Infinity* - Watsky)

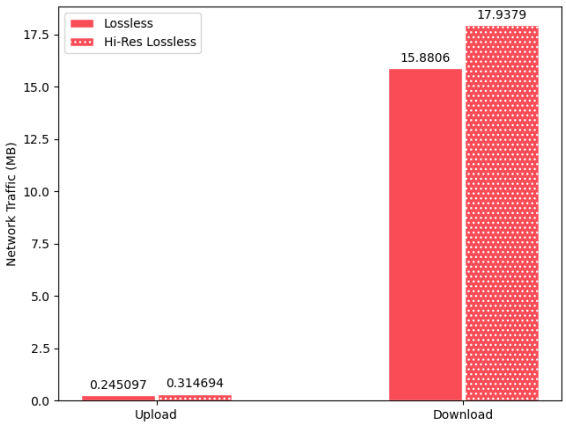


(b) Standard vs. Ultra HD (*Livin Foul* - Wax)

Figure 5: Amazon Music

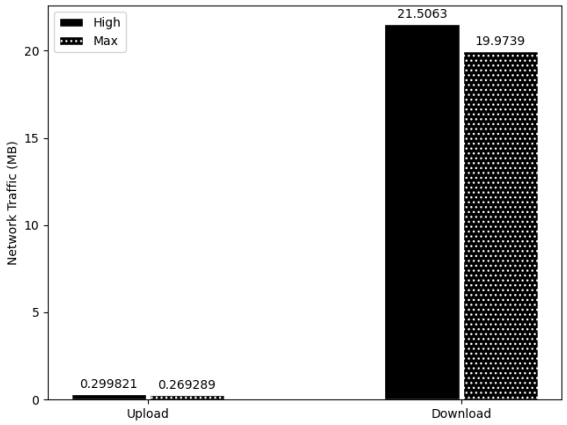


(a) Lossy: High Efficiency vs. High Quality

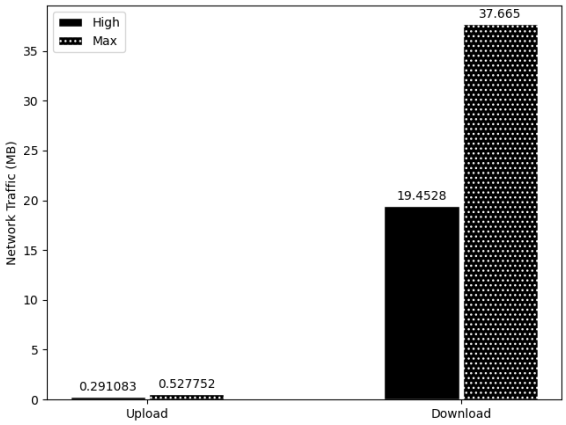


(b) Lossless: Lossless vs. Hi-Res Lossless

Figure 6: Apple Music

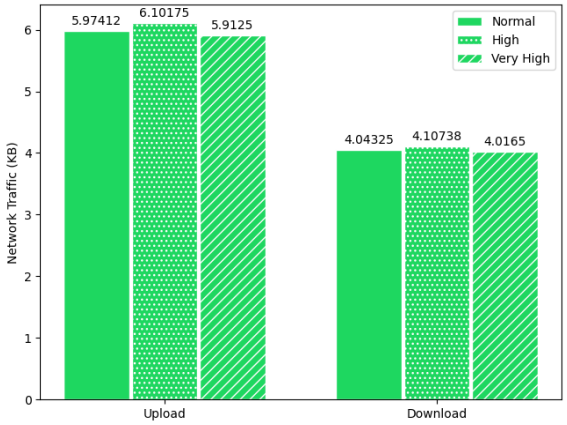


(a) *x Infinity* - Watsky

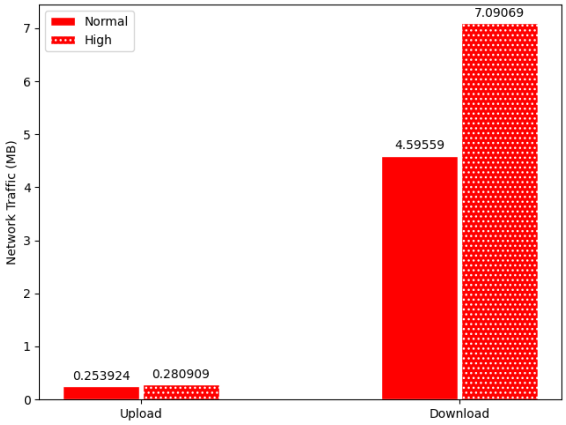


(b) *RENAISSANCE* - Beyoncé

Figure 7: Tidal



(a) Spotify (in KB)



(b) YouTube Music (in MB)

Figure 8: Spotify and YouTube Music

B User Preference Study Results

This appendix contains all of the responses from the user survey. Under the column **4. Favorite**, reasons for the participants' choices of favorite have been summarized or for legibility, but the intent remains consistent with their responses.

1. Phone	2. Computer	3. Tried	4. Favorite	5. Audio	6. Data
Samsung	Windows	Spotify	Spotify	4	1
Google	Windows	Spotify	Spotify	3	2
iPhone	Windows	Apple Music Spotify	Spotify - Has vast majority of music I like - Blend and Party options - Habit from when it was free with ads - College discount	5	1
iPhone	Windows	Amazon Music Apple Music Spotify YouTube Music	YouTube Music - Wider variety of songs	4	2
Sony	Linux	YouTube Music	YouTube Music - Free membership	4	1
Google	Windows	Spotify	Spotify	5	1
iPhone	Mac Windows	Apple Music Spotify	Spotify - Suggested playlists	3	5
Google	Mac Windows Linux	Apple Music Spotify YouTube Music	Spotify - Comfortable with UI - Widest range of genres I listen to	5	3
Samsung	Windows	Amazon Music Spotify YouTube Music	YouTube Music - Free membership - Most control over compared to other free options - Existing insights from Google history	3	1

1. Phone	2. Computer	3. Tried	4. Favorite	5. Audio	6. Data
iPhone	Mac	Apple Music	Apple Music - iPhone integration	5	5
Google, Xiaomi	Windows Linux	Apple Music YouTube Music	YouTube Music - Free membership	5	1
iPhone	Windows	Spotify	Spotify - Haven't had any need to try another service	4	1
iPhone	Windows	Spotify	Spotify	4	2
Google	Windows Linux	Spotify	Spotify	5	2
Samsung	Windows	Amazon Music Spotify YouTube Music	Spotify - Reasonable price, - Music/podcast catalog - Spotify DJ	2	4
Samsung	Mac Windows	Amazon Music Apple Music Spotify YouTube Music	Apple Music - User interface - Size of library	3	1
iPhone	Windows Linux	Spotify	Spotify - Best UI and recommendations	4	2
Google	Windows	Spotify	Spotify	2	4
Google	Windows	Spotify	Spotify - Amount of playlists - Song radio	4	5
iPhone	Mac Windows	Amazon Music Spotify	Spotify - Made-for-you playlists - Interaction with friends	4	3
iPhone	Windows	Apple Music Spotify	Spotify - Easy to use - Includes Hulu access	5	3