High-Fidelity Audio Streaming In 2006

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Contents

Summary

While many music streaming services in 2023 offer hi-fidelity audio streaming, the first one, the French Qobuz, didn't start until 2008. In this project, I evaluated the potential of implementing a FLAC-based lossless audio streaming in 2006, as this is likely to have been around when development would have started for Qobuz. The findings showed average 2006/2007 internet speeds are sufficient to stream the lossless CD (16bit 44.1kHz) audio in real-time. The addition of a buffer would allow withstanding any speed fluctuations or network congestion without stuttering. A lower quality 320kbps MP3 option would be offered alongside 44.1kHz FLAC streaming for users with data limits or speed issues.

As the hardware requirements are low enough, there shouldn't be any issues with user's PC hardware bottlenecking playback. Future testing using various network speeds with hardware from the era would verify that there isn't any unforeseen issues with lossless streaming.

Introduction

Currently, to listen to music on a PC, you must download or rip the music you want to listen to beforehand, or stream a lossy and heavily compressed version from the web. This excludes the segment of the market who care about getting the highest quality audio, as they will want the option to listen to songs at or near CD quality, but without the storage space and time needed to have local copies of their music.

Background

To listen to music locally, you must load the CD into your disk drive, rip the disc into music files, download the music from an online music store like iTunes, or stream the music from a music streaming service. While many music streaming services in 2023 offer hi-fidelity audio streaming [1] [2] [3] [4], the first one, Qobuz, didn't start until 2008 [5] and the more well-known Tidal started out as WiMP in 2009 [6].

Playing Music Locally

Playback Directly from CD

While listening to the music directly from the CD is the simplest option, you are restricted to listening to only the music on the disk, and requires you to eject and swap disks to listen to other songs. As a result, you are unable to create playlists or randomize playback order for several albums or artists. While this is not an issue for me as I usually just listen to music by album, many people, especially those used to portable music players, will want the flexibility.

Ripping CDs

Ripping the contents of your CDs to digital audio files will allow the flexibility to seamlessly swap between albums or songs without changing disks. While this solves issues with playlists and randomized playback, the audio files for even a few dozen CDs stored as lossless FLAC may take up a significant percentage of an user's few hundred GB hard drive [7] [8], especially if listening to music on a laptop with the much smaller capacity of 2.5 inch drives [9].

This issues is even more of an issue if the playback software or computer hardware cannot handle FLAC, and the user uses uncompressed WAV. While the space issue could potentially be solved by converting the FLAC or WAV files to MP3, the maximum bitrate of the MP3 specifications is only 320Kbit/s [10] compared to the 1141.2 Kbit/s of CDs [11], resulting is significant quality loss.

Online Downloads

While there is nothing that prevents someone from having a mix of digital music purchased from an online store like iTunes and downloaded and existing music streamed or ripped from CDs, the music downloaded from most online stores in 2006 is likely to be MP3s, so much lower quality compared to CDs. As I am trying to create an option for people who want the highest quality audio, this is not a good alternative.

Existing Music Streaming Services

Although several music streaming services existed in 2006 [12], they did not offer lossless audio for their streaming. In addition, most offered audio bitrates not near the MP3 standard's max bitrate of 320kbit/sec [10] and instead offer bitrates in the 24-160kbit/s [13] [14] range, making the quality significantly lower than that of a CD [11].

Research

While I had initially planned to research internet speeds in US, Canada, and at least a few European countries to give a overall idea of the speeds a potential user may have. With the issues I had in finding creditable sources for US internet speeds for on or near 2006, I decided to just get internet speeds for the US.

US Internet Speeds

In order to see if it was viable for the average person to even stream uncompressed audio in 2006, I first needed to find the average residential internet speed in that era.

CWA

I was able to track down a 2009 Communications Workers of America (CWA) news report looking into US internet speeds compared to other countries [15]; while the report focuses on the current (2009) internet speeds in various US states, they state a 2007 internet speed of 3.5 Mbps [15]. While CWA do not cite a source for this figure, as they are a major labour union, it is likely that this figure is from themselves or a legitimate source.

FCC

The Federal Communications Commission (FCC) released their *OBI Technical Paper No. 4* in 2009 looking into residential broadband usage and performance [16]. While the report was based on results from 2009 [16], on page 12, they included a chart of the median advertised consumer broadband download speeds from 1994 through 2009 [16]. The FCC chart lists a median internet speed in 2006 of 4Mbps for broadband and 3Mbps if dial-up is included [16]; this lines up with what was reported by CWA [15], suggesting the accuracy of their claim, or that the FCC was their source.

Conclusion

Since the figures from both the FCC and CWA line up, I feel safe in assuming the 3Mbps figure for 2006/2007 US internet speeds to be accurate, or at least close to the true figure. As the CWA news report claims the US to have lower internet speeds than other advanced nations [15], it is likely that other countries will have similar or higher internet speeds, meaning the 3Mbps figure should be sufficient to base an analysis on.

FLAC Audio Bitrate

In order to verify the widely claimed figure of 1411.2 Kbit/s for CD-A [17], I decide to check the updated 1999 ‘Red Book’ standard (IEC 60908:1999) that replaced the original and 1987 specifications.

While I was unable to find a place where the bitrate was listed, the *Recorded parameters – General* section lists the sample frequency of 44.1 kHz and a linear encoding at a depth of 16 bits [11]. As the bitrate is equal to *bit depth * sample frequency*, and CD-A has stereo audio, the claimed 1411.2 Kbit/s is accurate.

Comparison of Broadband and Audio Bitrate

In order to directly compare the internet speeds, I first had to convert the Kbit/s to Mbps; this was simple, as both are in bits, so 1Mbit/s = 10^3 Kbit/s or 1000 Kbps, giving a converted speed of 1.4112Mbps. As this is less than half the 3Mbps given by CWA's 2006 internet speed average and FCC's advertised speed if dial-up is included; this gives good overhead for below-average internet speeds and any connection speed issues.

Additional Research From Peer Feedback

Variations in Internet Connectivity & Network Congestion

Jiayi Yang asked me how I was planning to "factor in the variations in internet connectivity and the potential for network congestion in your assessment of the feasibility of streaming lossless CD-quality audio during that period".

As the average length of a song is around 3 minutes, [18] [19] [20] if a 30 second buffer was utilized and filled before playback, as long as the internet stays at or above ~1.21Mbps, the buffer would not be depleted before the song finishes. As a result of this and the over 2x average speed, I feel it to be safe to assume the buffer would accommodate any congestion or speed variations.

Hardware-based Limitations & Handheld Devices

It was suggested by Carson Todd to look into any hardware-based limitations and “if the average handheld device back then also possessed the hardware to output 44.1 kHz FLAC audio quality”.

Since FLAC audio decoding is software-based, there shouldn’t be any hardware issues with the decoding of the file itself. As for required hardware needed to decode the audio in real-time, the RAM usage is likely to be similar to lossy audio [21]. As there is a forum post where the OP was comparing CPU usage of audio files on a Nokia N79 cellphone [22], it is unlikely that any PC capable of accessing the site will be unable to handle decoding. Finally, as CDs have been around since the 1980s, all modern sound cards should be capable of outputting audio from a 16bit 44.1kHz audio source.

For a handheld device to work with lossless streaming, it would need to be able to connect to the internet, eliminating all the iPods, excluding the iPod Touch, and the commonplace MP3 players. Apple did not support FLAC files natively on mobile until iOS 10 [23], so iPods Touch and iPhones would be unable to decode a FLAC file. Android did not add support until Android 3.1 Honeycomb in 2011 [24] [25], so any smart phone using Android would also not been able to decode FLAC data. With this research and too many flip phones existing in 2006 to check their support, I decided to just focus on Desktop/Laptop PCs for the audio streaming.

Transmission Compression Algorithms

Kieran Smith inquired as to if there was any tricks I could use to compress the data. AS the idea of utilizing FLAC for the music instead of WAV, there is not much more I can do to compress the data further. I decided to look into whether the data could be compressed during transmission, but was unable to find any algorithm or format to losslessly compress a audio transmission.

Lightly Compressed Audio Option

Myles Peterson suggested I offer a lightly compressed audio "that is still a higher bitrate than typical MP3". As many MP3 files already are at the bitrate limit of the MP3 specification of 320Kbps [10], I would not be able to offer a anything higher than that without using a separate audio format, which might create further compatibility issues.

The obvious option would be to resample the CD audio to have a bitrate between that of a MP3 (32-320Kbps) and that of the lossless FLACs (1411.2Kbps) and store the result as another FLAC file. While this would solve the bitrate issues, the file size is likely to be closer in size to the source FLAC than a lossy audio file of similar quality, requiring more storage space for the hosting server.

As most music streaming services in 2006 offer bitrates in the 24-160kbit/s [13] [14] range, offering a 320Kbps MP3 streaming option would still offer higher quality than competing music services while still offering a much lower bandwidth requirement compared to FLAC.

Although TIDAL did not start until 2009 [6], they still offer this option in 2023 [1]. This is the option I would choose.

Discussion

My findings suggest that the average internet speeds of 2006/2007 would be sufficient to stream lossless CD quality (16bit 44.1kHz) audio over the internet. With the addition of a buffer, the audio stream should be able to withstand any speed fluctuations or network congestion without stuttering. As there may be users who don't have the necessary internet speeds, or has a data limit, the addition of a lower quality 320kbps MP3 option would be a beneficial addition to the lossless FLAC streaming.

As many handheld and portable devices do not have the required network connectivity and/or the capability to decode FLAC audio, I would ignore the part of the market wanting to stream music with their cell phones and portable audio players, and instead aim the internet-based lossless audio streaming exclusively at desktop and laptop PCs. Additionally, as the hardware requirements for decoding FLAC files is low enough that someone has successfully used a Nokia N70, a cell phone from 2008, to decode FLAC files, there shouldn't be the need to specify minimum system requirements for a PC to stream lossless audio.

Although my research indicated that the speed and hardware is sufficient for audio streaming, it would be a good next step to try real-life prototyping using era PC hardware and an artificial network bottleneck to simulate the equipment of the day. While the network speed could be tweaked to simulate different speeds, congestion, and fluctuations, it wouldn't be effective to test all potential hardware configurations, and should instead focus on a handful of configurations. While this would not account for all users, this should be sufficient to test the real-life feasibility.

Conclusion

In this project, I evaluated the potential of implementing a FLAC-based lossless audio streaming in 2006. My findings showed the average internet speeds of the era would be sufficient to stream the lossless 16bit 44.1kHz audio over the internet in real-time. The addition of a buffer allows the audio stream to withstand any speed fluctuations or network congestion without audio stuttering. I would also offer a lower quality 320kbps MP3 option alongside 44.1kHz FLAC streaming for any users with data caps or speed issues.

As the hardware requirements are low enough to decode successfully on even a 2008 cell phone, there shouldn't be any issues with user's PC hardware bottlenecking playback. Future testing using various network speeds with hardware from the era would verify that there isn't any unforeseen issues with lossless streaming.

Overall, this project provided great insight into the feasibility of lossless streaming in the era when Qobuz and other early high fidelity streaming services debuted. While the theoretical information I collected is insightful, the next step would be to do real-time testing, which would verify my research.

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