Bluetooth Latency Testing

AnyTune Pro Beta 4.3.0 (2019062800)

Ken Koran - July 9, 2019

Introduction

The purpose of this test is to determine if it is feasible to utilize a wireless Bluetooth connection between an iOS device running AnyTune with LiveMix and an audio output device such as wireless headphones or speakers. The primary detriment to this approach is the latency introduced into the signal path by current Bluetooth technology. This latency results in a lag or delay between the time a user physically plays a note and the time that he/she actually hears the note being played. Even wired connections have latency due to processing time and conversion between analog and digital. However, this is typically on the order of a few milliseconds, which is imperceivable to the human ear. Bluetooth latency is considerably larger and can range from tens of milliseconds to hundreds of milliseconds.

Previous versions of AnyTune disabled LiveMix when output was directed to a Bluetooth device. The current Beta version now has it enabled for testing purposes.

Unfortunately, on the iPad I have no way to determine for certain which Bluetooth version or Codec is being used at any point in time by iOS. I can only make assumptions based upon what *should* be used based upon the hardware in each test case.

The test plan is designed to isolate, as much as possible, where the issue is relative to the excessive latency in the Bluetooth connection when used with AnyTune & LiveMix. To this end, the first two tests employ using true wireless ear buds as the Bluetooth receiver. In one of those cases, the transmitter is the Apple Bluetooth protocol stack within the iPad Air. In the other, the Apple stack is replaced with the TaoTronics device.

The next two tests switch over to the ATH-M50x headphones with the Fiio Bluetooth interface. In the first of these tests, the Bluetooth connection comes directly from the iPad, whereas in the second test uses the TT-BA08 device in place of the Apple protocol stack in the iPad.

The following equipment was used in the testing.

Apple iPad Air 3rd generation with 256 GB storage. This is the latest version of the iPad Air. It supports Bluetooth 5 as well as SBC and AAC Codecs. *Apple does not support any flavor of AptX on iOS devices, so AAC is the only viable Codec.*

iRig HD guitar / bass interface to connect into AnyTune for use with LiveMix. It has a ¼" input for guitar / bass and a lightning connector for the iPad.

TaoTronics TT-BA08 Bluetooth transmitter. The TT-BA08 supports Bluetooth 5 as well as SBC, AAC, and aptX Low Latency Codecs. It connects to the headphone jack on the iPad.

The following Bluetooth headsets were used in the testing.

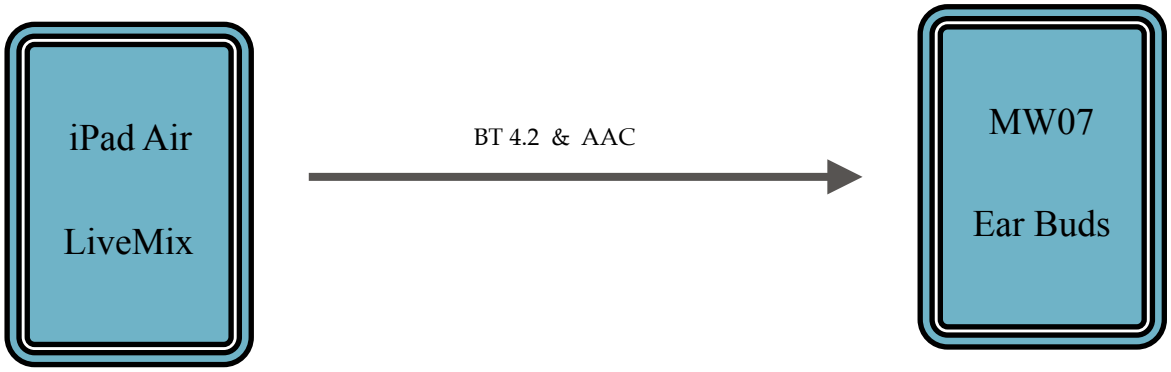
Audio Technica ATH-M50x headphones with a Fiio BTA-10 Bluetooth receiver specific to these headphones. The BTA-10 supports Bluetooth 5 as well as SBC, AAC, aptX, and aptX Low Latency Codecs.

Master & Dynamic MW07 true wireless ear buds. The MW07 supports Bluetooth 4.2 as well as SBC, AAC, and aptX Codecs. It does not support aptX Low Latency.

Apple Powerbeats Pro true wireless ear buds. The Pro supports Bluetooth 5 as well as SBC and AAC Codecs. It uses the latest Apple “H1” chip and is the most advanced headset within the Apple eco system.

Test Case #1

This test case utilizes Bluetooth direct from the iPad to the MW07 ear buds. This connection should negotiate use of the AAC Codec since that is the highest quality common to both ends of the connection. While the iPad supports Bluetooth 5, the MW07 only supports version 4.2 of the protocol, so 4.2 would be used.



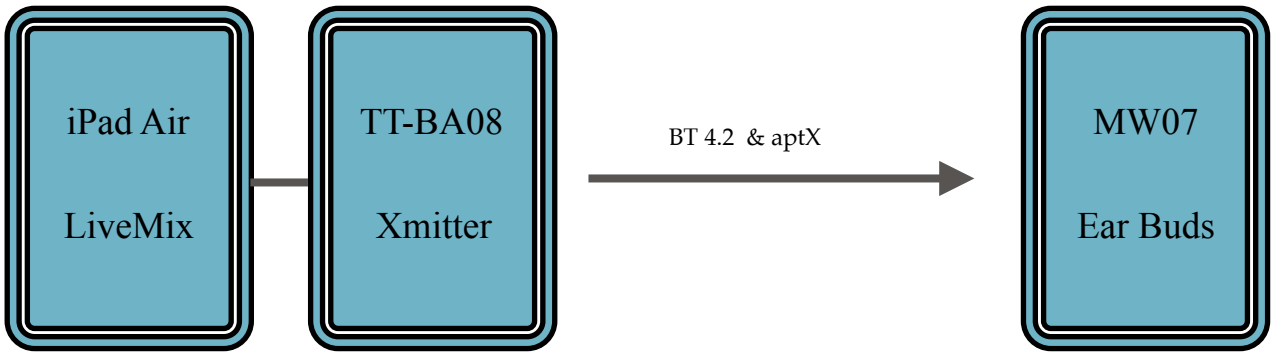
Results

This scenario exhibits a significant amount of latency, approaching half a second. Of note is that the first note struck has a large delay, but when playing continuously the delay shortens somewhat. The delay encountered here is unacceptable.

This test establishes a baseline for the remainder of the test cases to be compared against as it is the most “plain vanilla” test.

Test Case #2

This test case incorporates an additional piece of hardware to replace the Bluetooth transmitter and Codec in the iPad. The TaoTronics TT-BA08 device connects to the 3.5mm headphone jack on the iPad and transmits directly to the Master & Dynamic MW07 ear buds. This connection should negotiate use of the aptX Codec since that is the highest quality Codec common to both ends of the connection. While the iPad supports Bluetooth 5, the MW07 only supports version 4.2 of the protocol, so 4.2 would be used.



Results

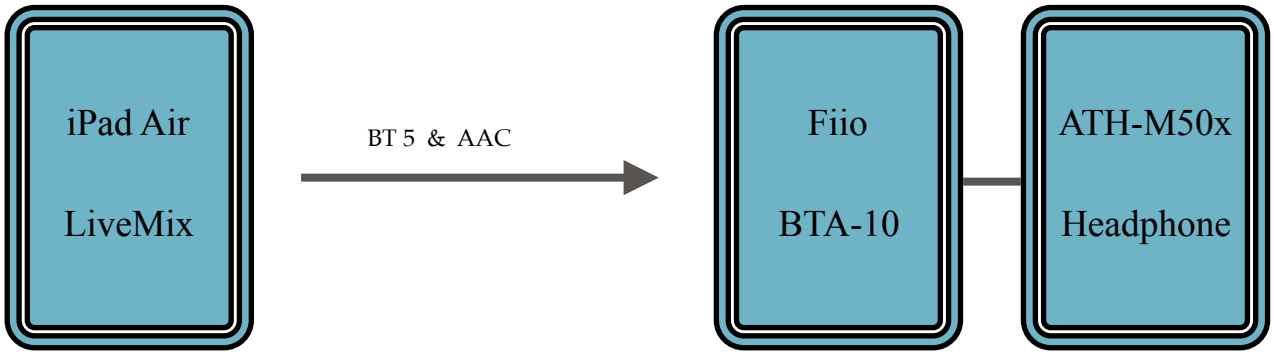
This scenario exhibits latency, but noticeably less than test case #1. Better, but still not really usable. The key points with this case are:

- Not using the Apple iPad protocol stack.
- Using aptX instead of AAC Codec.
- D->A and A->D conversions are necessary in the iPad and TT_BA08, respectively.

This demonstrates that the aptX Codec may have a slight advantage in latency as compared to the AAC Codec.

Test Case #3

This test case utilizes Bluetooth direct from the iPad to the Fiio BTA-10 Bluetooth receiver in the ATH-M50x headphones. This connection should negotiate use of the AAC Codec since that is the highest quality Codec common to both ends of the connection. Both ends of the connection support Bluetooth 5.



Results

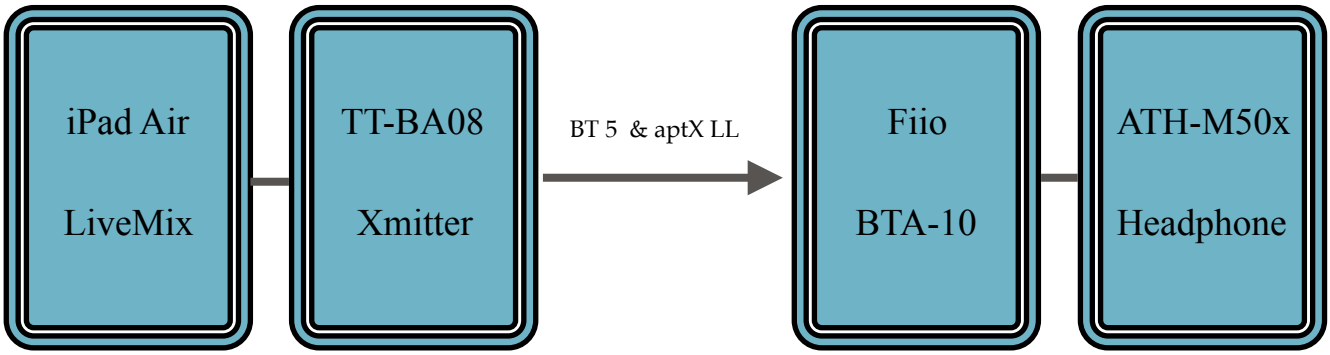
This scenario exhibits a significant amount of latency, very similar to test case #1 at about half a second. The key points with this case are:

- Using the Apple iPad protocol stack.
- Using the AAC Codec.
- Using Bluetooth 5.

This demonstrates that even though Bluetooth 5 is used, with its potentially higher throughput, it does not improve the latency. This points to the AAC Codec and/or the protocol stack in the iPad.

Test Case #4

This test case incorporates an additional piece of hardware to replace the Bluetooth transmitter and Codec in the iPad with the TaoTronics TT-BA08 device. It connects to the 3.5mm headphone jack on the iPad and transmits directly to the Bluetooth receiver in the headphones (in this case the Fiio device on the ATH-M50x). This connection should negotiate use of the aptX Low Latency (aptX LL) Codec since both ends of the connection support it. Both ends also support Bluetooth 5, so this is as fast as we can get with the current state of the technology.



Results

This scenario exhibits very little latency. It is just barely noticeable (at least to my ears). The combination of Bluetooth 5 and the aptX Low Latency Codec appears to significantly reduce the delay between physically plucking the string and hearing the note play. This would likely be an acceptable level to most people. The downside is that it requires the additional hardware at the iPad side since the iPad does not support aptX LL.

Test Case #5

This test case involves using Apple Powerbeats Pro ear buds that contain the "H1" chip. These are the very latest, high performance earbuds from Apple along with the second generation AirPods. The "H1" chip is purported to improve the performance of the AAC Codec that Apple uses on iOS devices. Also, both ends of the connection support Bluetooth 5, so performance wise this may be the fastest setup that utilizes the AAC Codec.

Results

I had high hopes for this setup since staying completely within the Apple ecosystem usually results in the best performance. That proved to not be the case in this instance. While there may have been a slight improvement over tests #1 - #3, it was nowhere close to real-time and would not be usable with an instrument. Very disappointing.

Conclusions and Recommendation

The short answer is that, in its current state, enabling Bluetooth for use with LiveMix would likely not work well for the majority of users, if any at all. I concur with your testing that LiveMix over Bluetooth is not feasible at this time. That being said, we have shown that with the correct hardware and software configuration, it can be done. Below is an analysis of the test results.

Bluetooth Version vs. Codec Type

1. Based upon the results of the tests #1 and #3, which had very similar outcomes, we can conclude that as long as the Codec is AAC, the Bluetooth version (4.2 or 5.0) makes little to no apparent difference.
2. Based upon the results of test #2, as well as #1 and #3, we can conclude that aptX is just slightly faster than AAC regardless of the Bluetooth version.
3. Based upon the results of test #4, we can conclude that the use of the aptX LL Codec is the key to lowering latency (since we have previously proved that the Bluetooth version does not make a significant difference).

Additional Observations

Based upon the observed difference in latency between the first note played and subsequent notes (from tests #1 - #3), this suggests that the Bluetooth protocol stacks and/or Codecs connect when there is data to send and then disconnect when there is not. *This is not to be confused with Bluetooth pairing.* Or it could mean that the first note has to wait to fill a buffer before being transmitted. Codecs typically need to "look ahead" at data to perform the compression. This implies that the Codec must wait until it has enough data to start compressing. Then it needs to fill the buffer and transmit the data. While that packet is being sent, the compression of the next packet can proceed in parallel. This parallel operation continues as long as there is constant data to send. So buffer / packet size has an impact on latency since it takes longer to fill a larger buffer, especially the first one.

Test #5 demonstrates that using Apple's latest equipment (2019 iPad Air, Powerbeats Pro ear buds) is still not sufficient to remove enough latency to be usable for LiveMix. The only viable path is to use aptX LL, preferably with Bluetooth 5. Apple has thus far resisted using any aptX Codec on its iOS devices. So unless they change course this basically kills any chance of reducing the latency unless they are able to significantly rework its AAC Codec.

The results of test #4 proves that Bluetooth technology is sufficiently far along to support the needs of LiveMix with the right combination of underlying hardware and software. Unfortunately, the iPad & iPhone do not have this on their own and require an external device to be connected to the headphone jack. Of course this means that AnyTune is not using Bluetooth directly in the iPad and, therefore does not need to enable its use.

AAC Codec Configuration

So the question is: what (if anything) can be configured in the Apple protocol stack today that will reduce latency to an acceptable level such that additional hardware is not required? If configuration changes, such as smaller buffer size, sample rate, etc. can be made, then it may be feasible to use it with LiveMix.

The iPad as currently configured appears to have a less than optimal buffering scheme for real-time use with applications such as AnyTune plus LiveMix. This may be due to a design choice since there is a trade off between using more small buffers (which yields less latency and thus better responsiveness) and using fewer larger buffers (which takes less CPU utilization which opens Bluetooth up to older, slower platforms). There are other concerns as well, such as larger packets having a greater chance of RF interference thus causing retransmissions which adds to the latency.

Recommendations

It is obvious that we are in a transitional phase between wired and wireless connections for things like headphones, speakers, etc. and Bluetooth is the prime mover of this shift. The technology is improving but it is not yet perfect. As is shown in test #4, it is possible to get near enough to real time using Bluetooth that LiveMix can successfully be used. Depending upon how much effort you want to put into this, the first course of action could be to look at what can be configured in iOS relative to Bluetooth and the AAC Codec. If a few tweaks could be made, such as buffering, that may be enough to lower the latency to a tolerable level. If that can be achieved, then I would suggest that LiveMix over Bluetooth be a configurable option in AnyTune with the default being OFF. This provides users with the same "out of box" experience but gives those with appropriate hardware an opportunity to enable Bluetooth. Otherwise, if configuration does not work out, then it makes sense to stay the course and keep Bluetooth out of the picture for LiveMix.

My Comments

I really like the freedom of not being tethered to the iPad with wired headphones when I practice with AnyTune. That is why I volunteered to do this testing. However, I suspect that in all likelihood Bluetooth will not be enabled in AnyTune and LiveMix in the near term. So, I use the same setup as in test case #4.

This works pretty well, the only real downside is that I have the two extra battery powered devices (TaoTronics & Fiio) that need to have constant care and feeding to keep them charged up. But it's worth the effort since AnyTune is an excellent product and a tool I would not want to be without. If you decide to pursue configuration changes, I will happy to perform further testing.