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What is Bluetooth and Is It Secure?

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Editor's note: *Marshall Chasin of CanadianAudiologist.ca caught up with Steve Armstrong of SoundsGoodLabs to talk about Bluetooth.*

Bluetooth is a "standards-based" wireless protocol. The advantage of being standards-based is that Bluetooth earbuds and Bluetooth-enabled hearing aids can communicate with cellphones and a whole range of other devices that use this standard. Not everything has to come from the same manufacturer. One of the things that came with Bluetooth from the get-go were security concerns. It was initially designed to replace the serial connections (RS232) between various devices so "credentials" are required to ensure data security once provided by the physical cable. "Credentials" are a series of steps that includes some method of verifying ID when sensitive information is being shared- there can be a fair amount of overhead in this. Bluetooth uses a transmission frequency of 2.4 GHz, one of the internationally created ISM (Industrial, Scientific, and Medical) bands you don't need a license to transmit in. As you can imagine, there can be a lot of congestion in the 2.4 GHz band, which is why it is necessary to use "burst mode" transmission to share the airwaves.

What is "Burst Mode"?

The reality is that digital radios, and many other devices, are not continuously transmitting- they transmit in a short burst of activity, then go to sleep, and then wake up … the benefit of burst mode is quite high because when they are asleep, other Bluetooth transmissions can occupy the airwaves, as can WIFI and a few other proprietary 2.4 GHz systems.

The original "Classic" Bluetooth, since it was so concerned with security, would ask you for ID – metaphorically asking for your VISA card, your passport, and boating license information, for each burst. Then, each time it is confident that it is speaking to just you–the conversation goes something like "Now I will send the data, and I will go back to sleep, BUT I will need to see your VISA card, your passport, and boating license again when I wake up before I send you anything more." So, obviously, a fair amount of overhead gets added to the audio data payload, especially if you want low latency where you are sending a lot of small data packets out of necessity.

That doesn’t sound very efficient. Does Bluetooth still ask for all ID credentials each time it comes out of its sleep mode?

Excellent question! When Low Energy (LE) Bluetooth was developed, one focus area was reducing the overhead-to-payload ratio. So the first burst asks you for all of your ID, but from then on, only a simple 4-digit PIN is required for each successive burst (I’m playing loose with this analogy). This doesn’t compromise security since much of the data is encrypted, and the frequency-hopping nature of the radio itself provides a measure of privacy.

Related to all of this is a requirement of the Bluetooth Classic standard that when it sends a packet of information to the receiver, the receiver has to send back an acknowledgment packet saying that the packet has successfully been received, much like fax machines do. If the original data is corrupted, the packet will be sent again. This “handshaking” means that the receiver must also be a transmitter for everything to work. Since both signals are traveling through the same RF space, and conditions, both the transmitter and receiver need to have similar RF power capabilities if they are to hear each other. Given the power constraints within a hearing aid this aspect quickly limits the distance you can send audio data wirelessly. In contrast, if you were driving in your car listening to an FM broadcast, you are receiving the signal, but your car radio doesn’t need to acknowledge the FM reception- it’s a broadcast-only mode, and there is no checking of the data to see if it is corrupted. This enables asymmetric power consumption and much greater distances.

One of the great things provided in the latest LE Bluetooth audio specification is the availability of a more efficient broadcast mode called Auracast™ . This allows for several things- it breaks the symmetry in the power consumption (transmitter to receiver power = receiver power to transmitter) which saves power, and this also allows for multiple listeners

Can you give me some examples of “low-level data”? And also “high-level data”?

With wireless transmission, one may get into many situations where only a few bits of data (low bit rate data) are sent, such as sending the measured temperature from a wireless outdoor thermometer to your smart-watch. Another example of low bit rate data from a hearing aid would be when you wanted to use your Smartphone or a remote to change your hearing aid volume control or program- this does not require a lot of bits of information.

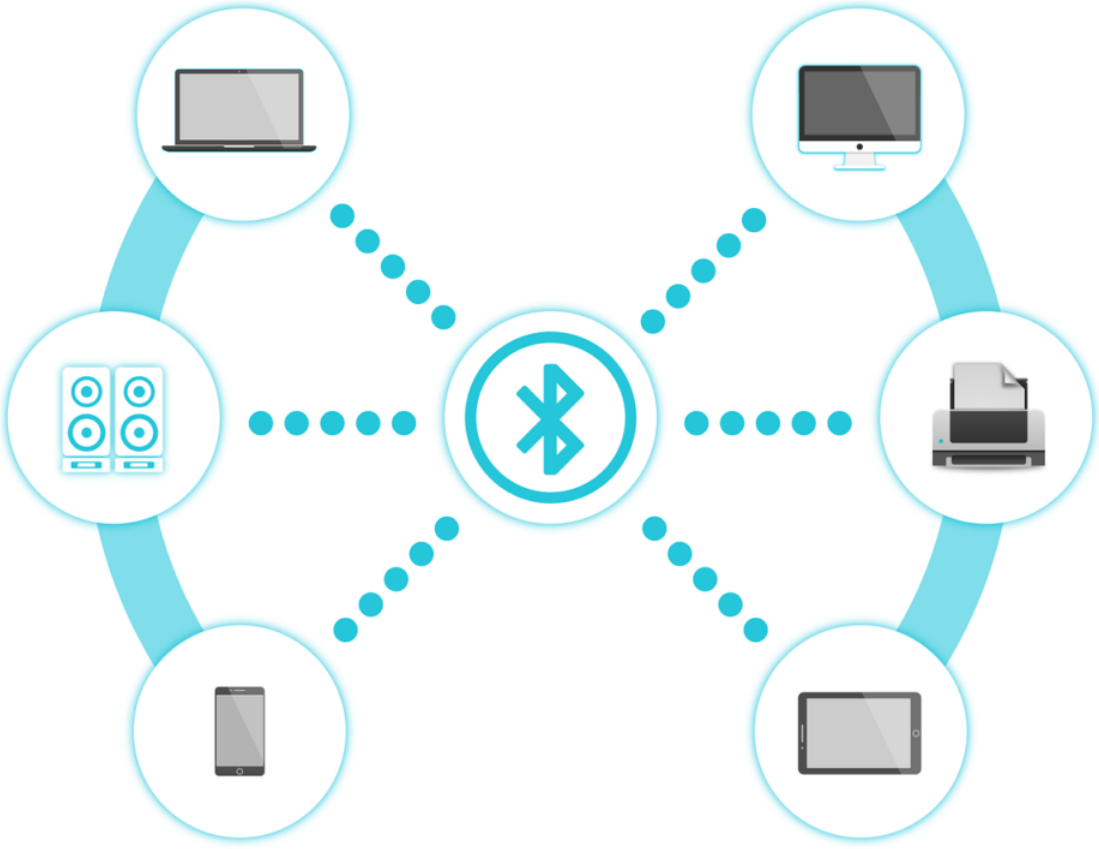
Where it gets more challenging is when you want to transmit high-quality audio, then your data rate goes up dramatically. For example, if you are sampling at 32 kHz (for a 16 kHz bandwidth) and sending 16-bit samples then, the transmission can increase to the Megabits/second levels. In contrast, by changing your volume control setting we may only need a few bits sent once. The power consumed is proportional to the number of bits transmitted/second. So, if you want to send a high number of bits/second such as in high-quality audio, LE Bluetooth becomes quite attractive. Unlike Bluetooth Classic, Bluetooth LE shortens the overhead significantly, as well as reduces the size of the audio payload.

MP3 files for audio and music use quite a bit of compression. Does Bluetooth do this to help with the overhead?

Yes, with Bluetooth LE you never transmit uncompressed audio – you would love to, but the power consumption would make that prohibitively expensive in terms of battery life. The other thing that happened during the development of LE audio is the development of a new audio CODEC (COding DECoding) – an example of a compressed format is mp3 audio. The CODEC compresses the audio into an mp3 file and then later has to decompress it. Since we're talking about all of this in the context of hearing aids, I think it's worth mentioning that the word "compression" has two meanings. We aren't talking about WDRC-type compression, where we alter the audio signal envelope. Rather we are talking about reducing the number of bits of information required for good-sounding audio.

The challenge of an mp3 (despite being around since the mid-1990s) is the amount of latency associated with it. One can experience 100 msec of latency just by the COding and the DECoding process, in addition to the delay of sending that data over the air wirelessly. A new CODEC was created called LC3 (Low Complexity Communication Codec), which greatly reduces the latency compared to an MP3 CODEC. LC3 also provides improved sound quality, at a reduced data rate, compared to the popular SBC CODEC. We can look forward to latencies dropping from Classic audio SBC's 100 msec down to less than 10 msec for an LE audio LC3 system.

Lossy audio CODECs extensively use the psychoacoustic phenomena of masking - if you can't hear what you can't hear, there is no point in coding this inaudible audio data. This is the main method used to maintain a high sound quality at a fraction of the power required for an uncompressed transmission. "Let's take all of the things you can't hear and stop trying to move them to the end of the communication channel–it doesn't make any sense." LC3 is very effective at doing this. The interested reader can find more information, and audio demos at https://www.bluetooth.com/learn-about-bluetooth/recent-enhancements/le-audio/#lc3



When I fit hearing aids, I mention to my patients that Bluetooth is only for up to 10 meters (and worse if someone walks between the transmitter and the receiver). Yet my new wireless headphones are good for 20-30 meters. What is it about Bluetooth that mandates this 10-meter limit?

I am not sure which earphones you are using but many earphones use a lower transmission frequency such as 900 MHz (vs. 2.4 GHz) and a feature of the lower transmission carrier frequency is that for the same RF power, they go farther. The antenna, of course, needs to be larger with a 900 MHz transmission range but headphones generally have enough physical space in them to be able to encase the antenna. Some readers may remember the earlier days of wireless audio being sent to hearings aids. In some of those designs proprietary radios were implemented at 900 MHz resulting in longer distances, but the lack of a global ISM band at that frequency resulted in poor economic outcomes for the manufacturer.

Would those still be called Bluetooth?

It can't be called Bluetooth if it is a proprietary wireless protocol. But remember, Bluetooth is only at 2.4 GHz, so that also gives us a pretty big hint.

Is Bluetooth transmission mono or stereo?

Bluetooth can be either, but this does touch on another issue. Bluetooth Classic audio only allows one connection (receiver) at a time. This poses a big problem since most hearing aid fittings are made up of two separate hearing aids, and we don't like to have them necessarily wired together. So technically, one can't receive the Bluetooth Classic audio transmission at the right and the left hearing aids. Some manufacturers used the workaround to receive at only one ear, then use ear-to-ear communication to send the other audio stream to the opposite ear. The new Bluetooth LE audio standard supports having two separate receivers/hearing aids with streams that go directly to each ear. While this potentially reduces the need for ear-to-ear communication to reproduce stereo audio, other features will probably continue to rely on this data stream.

Another capability LE audio allows is the use case of multiple listeners enjoying streaming audio from a single source, perhaps a Smartphone. This seems a little retro when considering the original Sony Walkman from the 1980s. Sony's President insisted that the Walkman have two headphone jacks allowing a listener to share their music with someone else. Sony felt strongly that music listening was to be a shared experience.

Multi-listener capability also provides a pathway for an alternative to larger loop systems that may be implemented in some facilities where the "broadcast to many" may be useful as long as the listener has the appropriate receiver such as an enabled Smartphone, or they use hearing aids

Are there any drawbacks to the selection of the 2.4 GHz band for Bluetooth audio transmission? Are there other 2.4 GHz transmitters that may interfere with LE Bluetooth?

Microwave ovens also use the 2.4 GHz band. Water and fat molecules like to resonate at 2.4 GHz,

making microwaves quite efficient at cooking food or boiling water. Since humans have a similar molecular makeup, if someone walks between a 2.4 GHz transmitter and a receiver, the signal may be absorbed by the person walking past, thereby causing intermittencies in the transmission.

WIFI signals can also occupy the 2.4 GHz spectrum, but being focused on sending digital data around reliably in packets, like Bluetooth does, burst transmissions and frequency hopping, each of those bursts helps ensure minimal airwave contention.

While we are talking about power consumption, with rechargeable hearing aids being able to obtain a fresh charge in only 3-4 hours (with 15-18 hours of use including streaming), is the power consumption really a big issue anymore?

If you wanted your rechargeable hearing aids to last 18 hours, one needs to ask at what point in the life of the rechargeable hearing aid battery we are talking about. It may easily last 18 hours between charges when new, but perhaps only 80% of that after one or two years. Rechargeable batteries do wear out–not only is this true of hearing aids but also true of electric vehicles, Smartphones, etc. We're all familiar with the shortening battery life on our phones as the years progress. Likewise, an older Tesla has less driving range life than when first purchased.

There is no question that developments such as LE audio and the LC3 CODEC will enable lower overall power consumption. Hopefully this leads to greater initial runtime between hearing aid recharges, which in turn means that a couple of years down the road a user can still get in a full 16-hour day!