



The Future of Sound: Envisioning the Ecosystem of Bluetooth LE Audio

The introduction of LE Audio in Bluetooth 5.2 enables low-power audio in connected and connectionless formats, creating audio applications that were previously impossible. In this white paper we look at the features that define this new protocol and imagine some of the possibilities that it brings in public and private spaces.

Introduction

Bluetooth technology is so ubiquitous today in electronic devices that it can be easy to forget its humble origins. But in 1999, the first consumer-available Bluetooth device was a headset for mobile phones, an application that became itself ubiquitous by the mid-2000s. Audio is deep in the DNA of Bluetooth, even as applications for the protocol exploded into HID devices, file transfer, and the entirety of the personal area network. For decades, while Bluetooth audio improved with regular updates to the Bluetooth specification, it remained at its core the same protocol serviced by the Headset Profile (HSP) and Advanced Audio Distribution Profile (A2DP).

Bluetooth audio over this time was relatively power-hungry by comparison to other Bluetooth profiles. When the Bluetooth 4.0 specification was released, Bluetooth Smart (now Bluetooth Low Energy (LE)) was introduced with central and peripheral roles to support low-power, intermittent communications for sensor devices. This did not include a low power alternative for audio – at least not until 2020, when the Bluetooth 5.2 specification announced inclusion of an exciting new feature: LE Audio.

By comparison to previous Bluetooth Classic audio, LE Audio significantly decreases the power consumption of Bluetooth audio via the LC3 codec and enables new use cases that were impossible with HSP and A2DP. An example: Bluetooth-enabled hearing aids, which are tiny by nature and cannot support a large battery to feed a power-hungry audio receiver. LE Audio introduced not just lower power consumption, but new broadcast options that support multi-channel for stereo, one-to-many broadcasting for multiple receivers, the Enhanced Attribute Protocol (EATT), Isochronous Channels, and more.

Bluetooth audio is widely understood and appreciated for its consumer applications: headsets, earbuds, and speaker audio are often the public face of Bluetooth and its most recognizable use cases. But there are many possible use cases for Bluetooth audio, especially LE Audio, which take advantage of these new broadcast features and power consumption to enable completely new applications that are only now being devised. Much like the Bluetooth-enabled hearing aid, these new feature sets make possible applications that were previously out of reach.

In this white paper, we'll look at the core features and high-level overview

of what's new with LE Audio, some applications that make compelling and innovative use of LE Audio, and explore the roadmap to broad LE Audio adoption and availability.

Showstopping Features: EATT, Isochronous Channels, and More

As always, new top-level feature functionality (such as LE Audio) is the product of several underlying changes that enable something entirely new. In Bluetooth 5.2, LE Audio is built on new protocols, codecs, and power management schemes that combine to form a completely innovative Bluetooth audio solution.

One such feature is the **Enhanced Attribute (EATT) Protocol**, which improves overall latency of Bluetooth LE clients connecting to a gateway device. Previous implementations of the attribute layer operated sequentially, meaning if one client's transaction with the attribute layer was particularly large, other simultaneously connected clients



were forced to wait until that transaction completed before they could begin their own transaction. This means clients with smaller transactions would experience worse latency, causing some devices to lag while others occupy huge portions of the L2CAP layer's processing time. The EATT protocol solves this problem by dividing large ATT layer transactions into portions and processing them in sequence, weaving in the ATT transactions of multiple clients into frames. By dividing this time, clients with smaller ATT transactions enjoy the same latency as those with larger ATT requests, distributing processing time across all connected clients and creating a more uniform device experience.

On the transmit/receive side, Bluetooth 5.2 manages an optimal connection and efficient power consumption with the introduction of **LE Power Control (LEPC)**, which allows either end of the connection to request a modification to the other end's transmit power. If transmit power is too high, the signal is noisy, indistinct, and difficult to parse; too low, and the signal arrives incomplete or unclear. Using the received signal strength indicator, either end of the connection can determine that the other's transmit power is too high or too low and request a change accordingly. Allowing this to happen dynamically and bidirectionally means faster, more responsive, and more thorough network adjustments that happen quietly and on-the-fly.

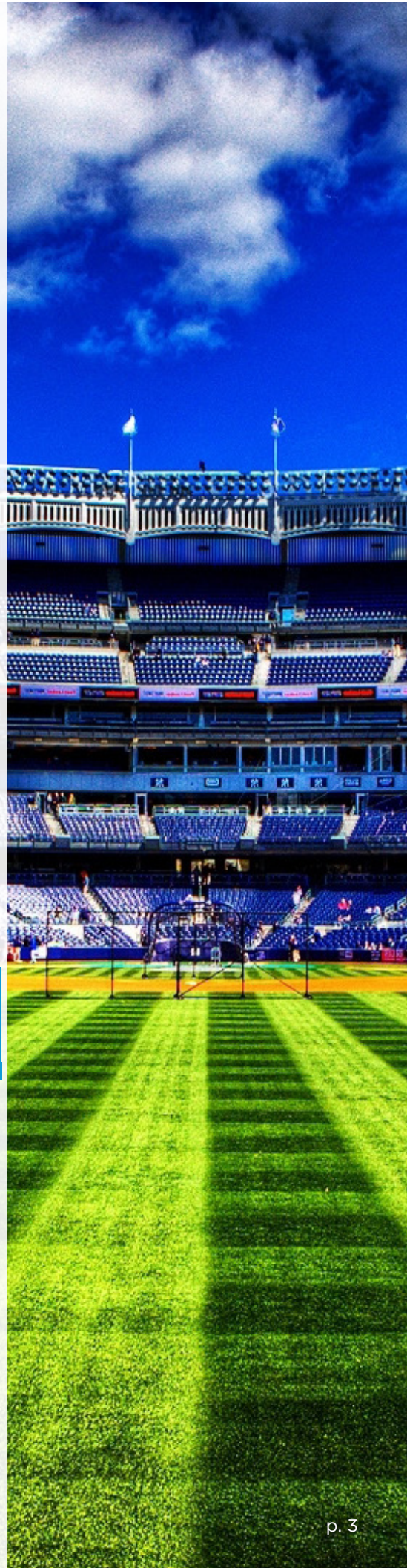
Of specific interest to LE Audio, the introduction of **LE Isochronous Channels** enables an entirely new functionality with no parallel in previous Bluetooth Classic audio. The purpose of this new channel type is to bundle audio streams into groups which are synchronized: the link can be connected or connectionless, meaning the link can support either a direct connection to a receiver or a one-to-many broadcast that can be joined agnostic to the host by multiple receivers. There can also be multiple simultaneous broadcasts, meaning that multiple synchronized audio streams, in stereo, can all be managed from a single broadcaster. The applications for this, as we'll explore later, go well beyond personal audio: synchronized multi-language streams, concurrent information systems in public transit, and many

more can all be enabled by these groups of simultaneous and time-sensitive audio streams.

Finally, encoding the actual audio stream for Bluetooth LE is the **Low Complexity Communication Codec (LC3)**, the successor to the SBC codec used for A2DP in previous Bluetooth specifications. The LC3 codec provides comparable or better perceived audio quality, even at bitrates as low as half that as required by the SBC codec. Evaluating perceived audio quality can be difficult and subjective, but the Bluetooth SIG provides an especially illustrative demonstration on their website that shows the differences between unencoded, SBC-encoded, and LC3-encoded audio at various bitrates. It bears out the claim that, for many listeners, LC3 accomplishes near indistinguishable audio fidelity at half or less the bitrate of SBC (and merely 8% of the bitrate of unencoded audio). This increased quality with lower data volume is largely responsible for LE Audio's ability to provide comparable audio with much lower power consumption.

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These sub-features all add up to a dramatically improved audio product from a performance and power consumption perspective. As previously mentioned, Bluetooth audio immediately calls to mind a handful of scenarios for which Bluetooth has become synonymous: Headphones, speakers, and other personal audio among them. But as we'll explore in the next section, LE Audio doesn't just improve existing go-to use cases, it also creates totally new opportunities as well. In particular, there are new uses for public spaces and larger venues where LE Isochronous Channels can serve exciting, innovative applications.



LE Audio – Moving from Personal to Public

Some of the most broadly discussed new applications for LE Audio are primarily personal uses and typically in the standard personal area audio network. Personal Audio Sharing, for example, has the potential to shift wireless audio into a highly social experience, where users can broadcast their audio to nearby audio sinks, enabling many users to listen to synchronized audio as a group with the broadcasting feature of LE Isochronous Channels.

However, just as compelling is the expansion of Bluetooth from the personal to the public, especially in venues, public transit terminals, theaters, and other spaces. The use cases even now are still being formulated, and many of them have yet to be realized, but the potential is truly massive. Anywhere that a large group has an interest in receiving the same information, or synchronized information, or information translated into various languages, there are a wide array of use cases for connectionless broadcast audio.

Consider the following examples:

Theaters and auditoriums

Theaters and auditoriums: In large venues where a presentation or a film is being delivered to an audience, there are currently untapped ways that the same information could be presented in synchronization in different ways to different audiences. For example, multi-lingual concurrent broadcasts: a speaker's audio and the audio of multiple translators can be broadcast on several concurrent audio streams in the same space, enabling users to listen personally to the same material in their native languages. A central Bluetooth-enabled broadcasting gateway can serve all these streams simultaneously, a simplified means to provide this audio with the nearly universal receiver: Bluetooth

headphones or earbuds. The same can be said for movie theaters, where multiple audio tracks can simultaneously accompany the same film in the same space, opening a new opportunity for studios to sell more tickets in the same theater with a more accessible film experience.

Public Transit Terminals

In places like bus depots and airports, travelers all need access to the same kinds of information (arrivals, departures, delays, and more), but are segmented into different groups (by terminal, destination, airline, and others). Broadcasting all of this information over speakers introduces a relevance problem, where the vast majority of information and announcements are irrelevant to any particular traveler. Simultaneous broadcasting of tailored, specific information allows travelers access to the information they need, when they need it, filtering out the general chatter of a bustling transit depot. Additional specialization can limit these broadcasts to zones or areas, further simplifying the process for travelers seeking information relevant to their trip.

Industrial Environments

In factories, power stations, mills, and other challenging environments, a combination of factors often necessitates greater-than-average attention to operational requirements like temperature, vibration, dust and water ingress, and more. In many of these environments, hearing protection is a necessity, making it difficult to communicate while protecting operators from dangerously loud machinery. Bluetooth-equipped hearing protection could provide a key advantage for operators in these environments, allowing the broadcast of safety alerts, machine status, or other important information to workers in an otherwise impossible manner. Using the hearing protector as an audio receiver could enable entirely new means of communication on the shop floor and even localize alerts and information to just what's relevant to specific groups of workers and management.



LE Audio's Isochronous Channels feature helps people share a physical space without the problems inherent in playing multiple audio sources over one another.

Convention centers, karaoke bars, and more

Anywhere that there are multiple sources of audio that threaten to overwhelm each other, LE Audio provides a compelling solution to help listeners focus on just what they want. For example, a convention center is full of vendor booths where individual presentations are physically adjacent, and separate LE Audio streams can help those in attendance listen to just the presentation they want. The same goes in the entertainment space, such as a karaoke bar, where groups of patrons intend to focus on just their music and experience. A group of LE streams can support both the backing audio track and the singer's track, and each group can tune specifically to the booth or stage of their choice. LE Audio's Isochronous Channels feature helps people share a physical space without the problems inherent in playing multiple audio sources over one another.

The Road to LE Audio

Even in ordinary times, without supply shortages and delays affecting timelines an availability, the road to market for an emerging wireless standard is flexible and uncertain. With the current chip shortages and other supply chain issues that define today's global economy, it's even harder to be certain when Bluetooth 5.3 will reach the mass market. It's largely an estimate, but an important one for manufacturers, including for those on the broadcast side of the use cases. The most brilliant audio broadcasting solution has no utility without devices on the receiving end.



Using the past as a reference and accounting for current conditions, it's fair to say broad adoption of LE Audio won't begin to reach the market until 2022 or 2023, a window best thought of in terms of many quarters away. And while that might seem like quite a while away, it presents a generous design window for OEMs to begin innovating and designing applications for this exciting new architecture.

OEMs can either design with a bring-your-own-receiver approach (planning for users to use their own listening devices, such as earbuds) or design the complete broadcast-to-receiver solution, based on whether proprietary functionality is needed in the final design. Public spaces like transportation hubs can greatly leverage personal devices to get needed audio information to travelers. An industrial machine-monitoring

and hearing protection system, on the other hand, will require custom hardware to meet its requirements.

The time to begin exploring these design possibilities is now, with ample time to identify more new use cases and create new opportunities.



New: LE Audio Evaluation Kit from Laird Connectivity and Packetcraft

Laird Connectivity's upcoming LE Audio evaluation kit, the EK-B02-BL5340 Evaluation Kit, leverages our BL5340 module with industry-leading LE Audio software by Packetcraft. Packetcraft's mission is to apply their decades of Bluetooth and embedded protocol expertise to enable their customers with leading-edge protocol stacks and create faster, better, and easier stacks for all.

Our kit is pre-configured out of the box. Simply plug in power, audio input, and audio output, follow our one-page quick start guide to select your demo, and you're off testing LE Audio applications with Packetcraft's industry-best LE Audio software.

To learn more, visit our website at www.lairdconnect.com/le-audio-evk

About Laird Connectivity

Laird Connectivity simplifies the enablement of wireless technologies with market-leading wireless modules and antennas, integrated sensor and gateway platforms, and customer-specific wireless solutions. Our best-in-class support and comprehensive engineering services help reduce risk and improve time-to-market. When you need unmatched wireless performance to connect electronics with security and confidence, Laird Connectivity delivers — no matter what.

Learn more at www.lairdconnect.com.

