The Future of Bluetooth is Faster, More Flexible, and Sounds Great:

An Introduction to Bluetooth 5.1 and 5.2

Laird™ CONNECTIVITY

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If it feels like time is spinning faster and faster than ever before, you may be right – especially when it comes to new advancements with the Bluetooth wireless protocol. Even though the specification for Bluetooth 5.0 hit the market not that long ago, there are two new updates to the specification that have important features that will impact the future of wireless design: Bluetooth 5.1 and 5.2.

Based on the conversations I have with engineers and customers nearly every day, the wireless engineering community is pleased with the technical advancements included in the Bluetooth 5.0 specification. It delivered major steps forward in Bluetooth Low Energy's (LE) speed and range as well as key capabilities like advertising extensions, which collectively support a wider range of use cases and provide a more powerful radio to work with in their design projects. An overview of those features is included in this post on the Laird Connectivity blog for anyone who wants a primer on the key takeaways from version 5.0.

With many engineering teams just beginning to work regularly with Bluetooth 5.0, it may be intimidating to think about also getting up to speed on 5.1 and 5.2. This white paper is designed to make that process simple by providing an overview of the key features you should know about Bluetooth 5.1 and 5.2. This paper also provides the most important recommendations to keep in mind as you plan ahead for these latest specs.

Before I dive into that discussion, I should tell you that this is the latest in a series of Laird Connectivity white papers with practical advice for engineers working with Bluetooth LE:

- Top Challenges of Getting Bluetooth IoT Sensor Data to the Cloud – Provides guidance on successfully linking Bluetooth IoT sensors to the cloud.
- Four Approaches for Expanding the Range of Bluetooth – Walks engineers through options for dramatically increasing the range of Bluetooth using four methodologies.
- Making LE Mesh Simple – Provides a roadmap for how to simplify the complexity of LE Mesh in a way that makes it a practical option for any engineering team.
- Bluetooth Deployment in Hospital Settings – Does a deep dive into the specific use cases of Bluetooth in hospital settings.

I should also mention that we have a parallel series of white papers focusing on cellular IoT, which can often involve the pairing of cellular technology with Bluetooth.

- Choosing the Right Route to Low Power-Cellular IoT: A User Guide to Simplifying LTE-M/NB-IoT Design Projects was the first in this series. My colleague Paul Elvikis and I teamed up to give a rundown on these technologies, as well as provide recommended practices to follow when starting a cellular IoT design project.
- Combining Bluetooth and Low Power Cellular for IoT: Practical Design Consideration and Innovative Use Cases is another white paper in that series that is worth reviewing. It discusses how to combine Bluetooth with LTE-M and NB-IoT to support a broad range of use cases.

Key Takeaways About Bluetooth 5.1

The announcement of the Bluetooth 5.1 specification was dominated by headlines about the inclusion of Angle of Arrival (AoA) and Angle of Departure (AoD) functionality, but there is much more to this release. The following is an overview of the key things you should know about Bluetooth 5.1. This list includes important functionality that provides for more efficient device operation which lowers the overall power consumption of the system.

- **New Direction-Finding Capabilities**

  The features that have generated the most excitement in the industry are the enhanced direction-finding features, AoA and AoD included in Bluetooth 5.1. AoA and AoD methods enable the ability to locate a signal's relevant position, especially when coupled with other methods like RSSI strength. AoA and AoD leverage multiple antenna arrays from a network of 5.1 devices to triangulate position with a precision that was previously not possible. The swiftness with which the SIG rolled out this feature in 5.1 is a great sign of how responsive the group is to industry feedback and this is a significant upgrade to Bluetooth despite being part of a point release.

  In order to get the high accuracy advertised for Bluetooth 5.1 AoA and AoD features, it is necessary to utilize arrays with multiple antennas. Form factor issues can quickly become significant with a large number of co-located antennas, but embedded antenna technology allows engineers to take advantage of AoA and AoD without running into issues with the collective size of the antenna array.

  To many engineers, the new direction-finding capabilities represent a major step toward what many wireless engineers consider a Holy Grail for wireless devices: Real Time Location Services (RTLS). There has been a lot of industry discussion on this topic and the hype is justified – RTLS unlocks very exciting use cases that have been predicted for the future of wireless. I should be clear that Bluetooth 5.1 does not make RTLS a reality today. But it does enable engineers to make major strides in that direction, especially when AoA and AoD are combined with more powerful chipsets and other technologies that collectively provide more precise, more timely data about relative location, movement, and more. I anticipate that the Bluetooth SIG will continue to make strides in this direction. In the interim, we have a set of features that move us closer to that goal by giving us tools we can use for use cases such as asset tracking in warehouses, wayfinding for visitors in large facilities such as hospitals and museums, limited contact tracing, and more.

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- **GATT Caching Enhancements**

  This feature in Bluetooth 5.1 is another that may not be relevant for every design project an engineering team is tackling, but it is significant for those where speed of connection is critical. GATT (Generic Attribute) caching makes it possible for Bluetooth devices to store the GATT table of generic attribute handles when connected to a GATT server. This expedites future connections with GATT servers of the same type and saves energy in the process. The prior versions of Bluetooth Low Energy performed "service discovery" each time a device sought to connect with another device. Service Discovery requires processing power and time to perform which adds up significantly as the number of connections increases. By caching the GATT

table, that process is expedited with known devices, just like skipping a lengthy personal introduction when you see an old friend. You know each other, so you can skip the pleasantries. GATT caching accomplishes the same thing, saving time and energy for devices where speed and battery power are key priorities.

- **Randomized Advertising Channel Indexing**

  The last feature of Bluetooth 5.1 that I will highlight is Random Advertising Channel Indexing. This feature allows the devices to randomly choose advert channels to use, as opposed to previously going in strict order. This allows for fewer collisions and can lead to more efficient connection establishment. Going with the theme so far, fewer collisions and quicker connection establishment lead to more efficient battery usage and better reliability.

  The Bluetooth SIG designed this enhancement to respond to feedback from the wireless engineering community that the prior methodology of channel selection and data transfer was overly rigid, making it inefficient for many applications. In response to that feedback, they built more flexibility into LE. This allows engineering teams to give devices the ability to randomly select between the advertising channels, rather than rigidly following a pre-established order (which is predictable and prone to collisions with other similarly timed advertisers in the area causing slow connections and high power consumption). This feature helps to randomize transmissions from a device, which decreases the likelihood of colliding with nearby advertisers. As a result, advertising signals are more likely to successfully be heard and connections are likely to happen more quickly.

Each of these features, individually and collectively, help make LE faster, more efficient, and more battery-smart by giving engineers the flexibility to fine-tune their designs and their network implementations to align with the use case they are supporting.

There is a long list of other enhancements for those of you who want to do a closer examination of the specification, but the three I have discussed are key as you chart the future of your Bluetooth strategy. For a deeper dive into these three features, please listen to this recent podcast featuring members of the Laird Connectivity engineering team.

Key Takeaways about Bluetooth 5.2

Bluetooth 5.2 also has some important enhancements to the specification that might be under the radar because they are included in a point release.

- **LE Audio**

  LE Audio, in particular the LC3 (Low Complexity Communication Codec) codec, is a feature of 5.2 that is generating a lot of early excitement since the original announcement from the Bluetooth SIG. It enables engineers to utilize Bluetooth LE for stereo and other audio applications without a drop in the quality of the audio data.

  Up until Bluetooth 5.2, applications requiring quality audio were limited to using Classic Bluetooth which puts a bigger drain on batteries and has a higher than desired latency. This made Bluetooth undesirable for some real-time audio applications. Another drawback was the power required to stream Classic Bluetooth audio which limited how long consumer devices like ear buds, wireless headphones, headsets, hearing aids, and wireless speakers could operate between charges. LE Audio gives engineering teams the option to utilize LE for high quality audio applications which will be impactful for devices where achieving lower latency and a longer battery life or a smaller form factor (thanks to a smaller battery) is a top priority.

  LE Audio also includes multi-streaming connectivity, which enables new features for consumer devices. Audio-related devices using Bluetooth 5.2 will be able to maintain synchronized audio streams, both incoming and outgoing. For incoming audio, devices with the LE Audio feature can maintain simultaneous connections with audio streams from

multiple devices, allowing a single audio-receiving device (such as ear buds) to do far more than previously possible. Wireless headphones are a great example, given how a user might want to use the same headphones to be able to switch seamlessly across audio signals from multiple devices such as a tablet, a smartphone, a stereo, a friend's phone, etc. It also enables the reverse: allowing a single device to broadcast audio to many others via synchronized audio streams. If you envision a group of teens listening to the same song from a single person's phone playing Spotify, you can start to see the possibilities of this functionality. This opens up the possibility for exciting new audio features that consumers will see as reasons to upgrade.

Before moving on to other features, I should note that as of the writing of this white paper, the full LE audio specification has not yet been released by the SIG. The building blocks of LE Audio are included in Bluetooth 5.2 and the SIG will build on that foundation with additional guidance that enables engineers to activate those building blocks to achieve interoperable LE Audio.

- **Other Features**

  These LE Audio capabilities are thanks in large part to three underlying aspects of the specification that will also have an impact beyond audio features in consumer devices: the Enhanced Attribute Protocol, LE Power Control, and LE Isochronous Channels. You will likely hear those three technologies associated primarily with the audio capabilities covered in the prior section, but engineers can also leverage them for other design benefits and novel use cases where lower latency and multi-casting/multi-stream functionality is beneficial. For example, the Enhanced Attribute Protocol (abbreviated as EATT), which enables the multi-stream functionality for incoming audio in LE Audio also can be utilized for other types of data.

  Engineers can use EATT to allow multiple applications to simultaneously use the LE stack while minimizing the interference that each data flow causes the others. One of the key benefits of this is lower latency for each of the data streams which will be valuable for a number of use cases beyond audio. LE Power Control plays a major role in extending the battery life of audio applications, but it can also have the same impact on other applications by dynamically optimizing the transmit power used based on signal quality when two devices are communicating. The intelligence built into this feature enables the device to identify ways to reduce power consumption in real-time while also ensuring the quality of the signal strength and factoring in the coexistence of other nearby wireless devices. LE Isochronous Channels enable the broadcasting functionality discussed in the LE Audio section but have the potential to be used for other applications where the time-synchronized broadcasting of data from one device to many may be impactful.

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The Laird Connectivity team will follow up this introduction to Bluetooth 5.1 and 5.2 with another white paper that includes a discussion of design best practices and other engineering advice for organizations that are on the path to incorporating the new specification into their product development roadmap. Until then, additional resources about Bluetooth design will continue to be posted on the Laird Connectivity website's Resources page.

Laird Connectivity's Bluetooth Modules:

Laird Connectivity provides a full suite of Bluetooth modules that deliver robust performance, easy global certification, and simple implementation to accelerate your entire new product development cycle.

Laird Connectivity's Bluetooth 5.1 and Bluetooth 5.2 modules include the BL5340, BL653 Series, and BL654 Series. Carefully designed and tested, these modules maximize the performance from Nordic Semiconductor silicon, delivering all the recent Bluetooth features of higher data throughput, longer range, increased broadcasting capacity, direction finding, increased temperature range, and more – all in one tiny footprint of your choice.

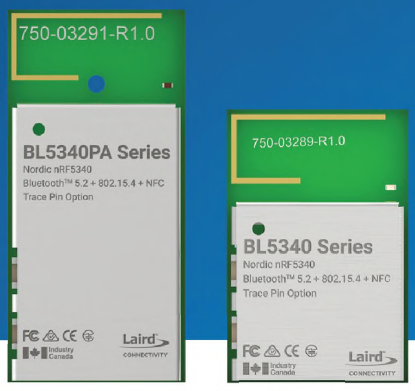
These modules deliver a complete multi-protocol embedded wireless offering with exceptional processing capabilities, all at a micro power budget. Leverage maximum development flexibility with programming options for the Nordic SDK, a simple intuitive AT command set, Zephyr RTOS, as well as Laird Connectivity's own smartBASIC environment.

And complete regulatory certifications enable faster time to market and reduce development risk, simplifying your Bluetooth design.

A full range of solutions that combine the capabilities of Bluetooth with other wireless technologies such as Wi-Fi and LoRaWAN are also available from Laird Connectivity.

For more information, visit: www.lairdconnect.com/wireless-modules/bluetooth-modules

BL654 Series



BL5340 Series

BL653 Series

About the Author:

Jennifer Gibbs is a Field Applications Engineer for Laird Connectivity, with a focus on Bluetooth, Cellular, and ISM embedded wireless modules and solutions. Jennifer is an Electrical Engineer specializing in Communications Systems and Digital Signal Processing and has 16 years of experience supporting and designing wireless embedded systems. Jennifer's previous experience includes positions at Sprint and Garmin before joining Laird 10 years ago.

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.

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