BLE2AV

Bidirectional, Location-aware, Enhanced Bluetooth® Low Energy Audio and Voice Systems

Nowadays wireless audio is used everywhere. Use cases range from the personal (e.g., music streaming to speakers) to the public (e.g., conferencing systems). Many of these applications are realized through Bluetooth® technology, since every wireless speaker or headset sold today incorporates a Bluetooth® chip.
Bluetooth® Audio solutions, however, used to be power-hungry and required custom extensions to support more than one stream. As a solution, in 2020 an extension to Bluetooth® Audio LE audio was announced: LE Audio. It includes a new audio codec (LC3) and provides support for multiple synchronized streams and audio broadcasting (Auracast™).
LE Audio technology is still novel. Therefore proper benchmarking is a must for companies that intend to incorporate LE Audio streaming in their offering. Moreover, complex use cases such as many-to-many or critical low-latency streaming require additional extensions that are beyond the current state-of-the-art. These challenges formed the research ground for the BLE2AV consortium, which looked into both the audio signal processing and

FRAMING THE RESEARCH OBJECTIVE

The BLE2AV consortium worked to gain an in-depth understanding of LE Audio. They gathered detailed insights on its performance and hardware limitations. The researchers studied the achievable audio quality under various codec settings, stream configurations and link conditions, and they established the maximum achievable concurrent audio streams.

As the project aimed to transcend the current state-of-the-art, it tackled complex use cases. Use cases that require many-to-many and critical low-latency streaming, as well as efficient acoustic source localization and distributed microphone audio capture, using lossy LC3-encoded signals.

THREE MAIN OUTCOMES

The three main outcomes of the BLE2AV project concern benchmarking, wireless connectivity, and audio signal processing.

1. **BENCHMARKING**
   The consortium collaborated on implementing a multi-disciplinary simulation model that can simulate Auracast™ behavior. The tool can mimic how a listener would experience an incoming stream from a single broadcaster, under various LC3 settings, stream configurations, and link conditions.

   The insights gained from this model show the impact of packet loss on the audio quality. They also illustrate how retransmissions and channel blacklisting can limit the packet loss. In addition, calculations indicate that streaming high-quality music imposes a limit on the maximum achievable number of concurrent audio streams. This limit is half of the number of streams that is achievable in the case of voice streaming.

2. **WIRELESS CONNECTIVITY**
   The project partners have validated the outcomes of the simulation model on a testbed. They did so while emulating realistic network conditions by means of a variable attenuator and injecting BLE interference into the testbed. Moreover, Auracast™ has been successfully demonstrated in a Televic Conference setup, achieving a large set of concurrent language streams by combining multiple transmitters.

   Particularly of interest during live events is low-latency streaming to ear buds or hearing aids. During those events, audio is simultaneously played through the speakers. So it is critical to minimize the annoyance associated with the delayed reception of two sound sources. Regarding this challenge, Cochlear has

achieved low-latency streaming by changing the way data is handled in LE Audio, building on top of the Bluetooth® core specification. More research into low-latency audio codecs is needed to show how to benefit from additional retransmissions.

3. **AUDIO SIGNAL PROCESSING**
   Further, the project examined the impact of using LC3-encoded audio signals for complex audio signal processing. Two techniques were considered: acoustic source localization and distributed microphone capture. Acoustic source localization consists of combining microphone signals to calculate an estimate for the direction of audio arrival. Distributed microphone capture attempts to perform efficient speech audio separation from multiple human speakers whose voice is captured through multiple, ad hoc distributed microphones in a room. In both cases, the captured audio needs to be transmitted to a central node for further processing. The associated algorithms were improved during the project, especially concerning the ability to cope with lossy LC3 signals.

   Next to this, to improve the listening experience on an edge device, the distortions introduced by LC3 were minimized via a novel bitrate-informed deep learning framework. The enhanced audio signals consistently deliver high audio quality even at the lowest bitrates, indicating a significant improvement compared to native LC3.

NEXT STEPS

The outcomes of the BEL2AV project will allow the companies involved to further incorporate LE Audio in their product offering. The research partners in their turn have gained additional expertise in end-to-end wireless LE audio streaming, bolstering their standing in the associated research domains.

During the course of the project, multiple research tracks have been identified that require additional investigation. Therefore, a number of partners within the current consortium are looking to establish a follow-up research collaboration. They want to tackle challenges related to the development of large-scale end-to-end wireless audio streaming systems. They are particularly interested in optimizing solutions to operate on constrained devices and incorporating context awareness.

BLE2AV project partners:

The BLE2AV project was co-funded by imec, with project support from Agentschap Innoveren & Ondernemen

FACTS

NAME	**BLE2AV**
OBJECTIVE	Next-generation audio and voice systems based on LE Audio
TECHNOLOGIES USED	wireless audio, simulation, testbed, Bluetooth® Low Energy, LE Audio, Auracast™, LC3, deep learning, Python, Zephyr RTOS, Packetcraft
TYPE	imec.icon project
DURATION	01/07/2021 – 31/12/2023
PROJECT PARTNERS	Televic Conference, Cochlear Technology Centre Belgium, Qorvo Belgium
RESEARCH GROUPS	imec – IDLab – UGent
BUDGET	2.517.300 euro
PROJECT PARTNERS	Theo Technologies, Citymesh, EMG Belgium, and Telenet
RESEARCH PARTNERS	-
RESEARCH GROUPS	imec – IDLab – UGent

WHAT IS AN
IMEC.ICON PROJECT?

The imec.icon research program equals demand-driven, cooperative research. The driving force behind imec.icon projects are multidisciplinary teams of imec researchers, industry partners and/or social-profit organizations. Together, they lay the foundation of digital solutions which find their way into the product portfolios of the participating partners.

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