COLLABORA

PipeWire and Bluetooth®

The road to LE Audio

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- Author & maintainer of WirePlumber
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- New to BlueZ !

Bluetooth® audio

Core & Profile specifications

- Core Specification
  - Basic building blocks
  - Low-level protocols, layers, features
- Profile Specifications (“Profiles”)
  - Specific use cases
  - Higher level protocols & procedures (on top of Core)
  - Follow their own versioning scheme

Bluetooth® history

- **Bluetooth 1.0** (1999): initial version, no audio
- Idea from the late 80’s
  - A wireless replacement for RS-232 (serial) data cables
- Development started in 1994 by Ericsson
  - Focus on mobile phone use cases

Bluetooth® audio: history

- **Bluetooth 1.1** (2001): audio for phone calls
  - Headset & Hands-Free profiles (HSP, HFP)
  - Synchronous Connection Oriented (SCO) transport

Headset / Hands-Free Profiles (HSP, HFP)

- Bi-directional audio for headsets & hands-free units
- Intended for phone calls / voice data
- SCO link for audio
  - Steady transmission rate with reserved TX time slots / capped bandwidth
- RFCOMM for control (with AT commands!)
  - *RFCOMM*: Serial over Bluetooth
  - *Hayes AT command set*: Dial-up modem commands (Hayes Smartmodem, 1981)
- Roles: Headset / Hands-Free (HS, HF), Audio Gateway (AG)

HSP vs HFP: differences

	HSP	HFP
Audio Quality	Narrow Band (8 kHz, CVSD codec)	Narrow Band (8 kHz, *CVSD*) Wide Band (16 kHz, *mSBC*, since v1.6 - **2013**) Super Wide Band (32 kHz, *LC3-SWB*, since v1.9 - **2023**)
Control Features	**Basic** (answer, hangup, volume ctl)	**Advanced** (dial, hold, 3-way calls, voice activation, …)
Use Case	Basic headset functionality	Hands-free in cars or advanced headsets
Audio Transmission	SCO	SCO or eSCO
Compatibility	Older devices	Modern devices, replacing HSP

Bluetooth® audio: history

- **Bluetooth 1.2** (2003)
  - Advanced Audio Distribution Profile (A2DP)
  - Extended Synchronous Connections (eSCO)
- **Bluetooth 2.0** (2004)
  - Audio/Video Remote Control Profile (AVRCP)

Advanced Audio Distribution Profile (A2DP)

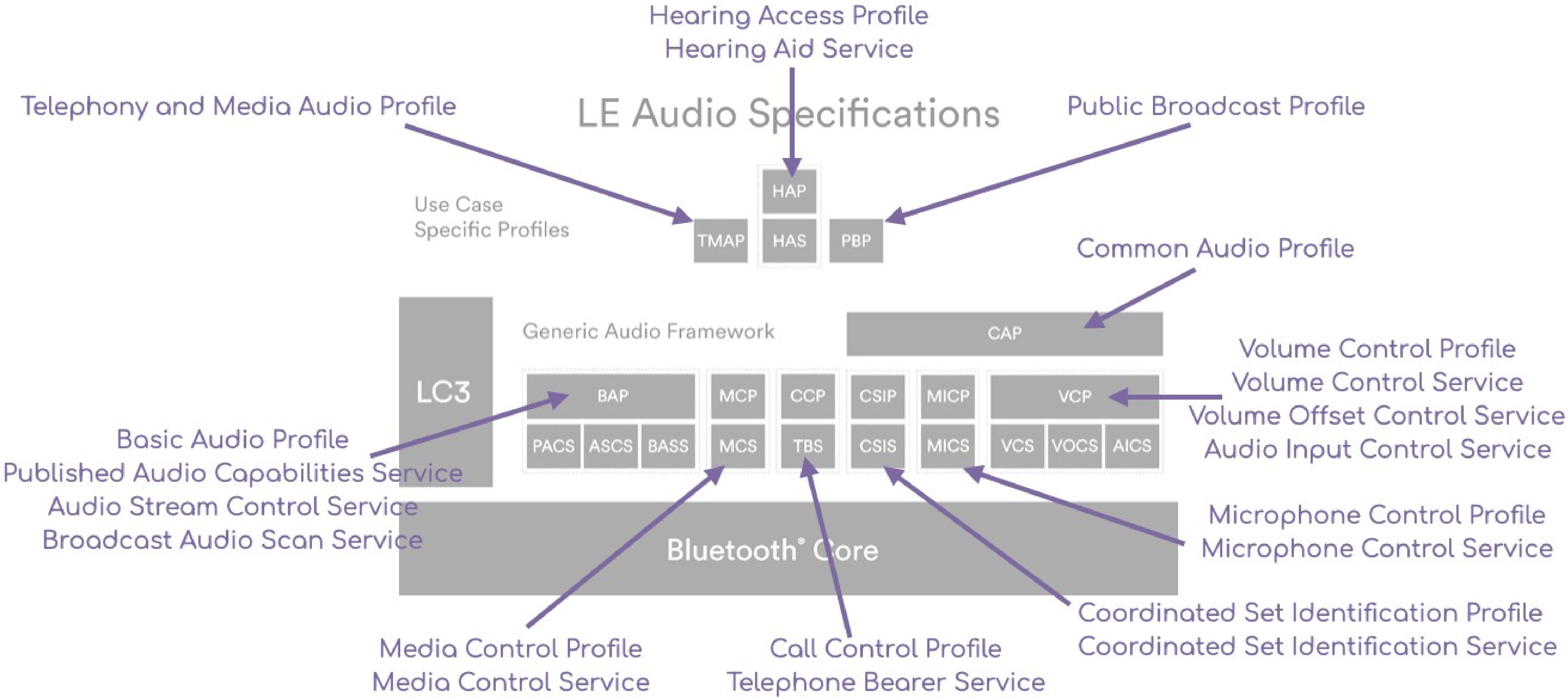
- High quality audio streaming – **one direction**
- Media playback to headphones/speakers
- Uses AVDTP (A/V Distribution Transport Protocol – i.e. RTP)
- Codecs: SBC (Sub-Band Codec), AAC, aptX, LDAC, Opus, …
- Roles: Source (SRC), Sink (SNK)
- Combined with Audio/Video Remote Control Profile (AVRCP)

Notice any problems?

- High quality audio (A2DP) is uni-directional only
  - Non-standard solutions exist, few implement them
  - Devices switch to HFP when mic is in use
  - Sounds terrible (but also due to speech-optimized DSPs)
- High latency
- High energy consumption
- Outdated tech not keeping up to modern use cases
  - Co-ordinated devices (earbuds), hearing aids, spatial audio, audio sharing, voice assistants, much more…

Bluetooth® LE Audio: the future of wireless audio!

- **Bluetooth 5.2** (2020), based on Bluetooth LE stack
- Collection of profiles for next-gen audio communication
- Generic audio framework, modular design
- Combines all modern use cases & allows for expansion
- Lower latency (down to 20ms) & enhanced range
- Low Complexity Communication Codec (LC3)



Hearing Access Profile
Hearing Aid Service

Telephony and Media Audio Profile

Public Broadcast Profile

Common Audio Profile

Volume Control Profile
Volume Control Service
Volume Offset Control Service
Audio Input Control Service

Basic Audio Profile
Published Audio Capabilities Service
Audio Stream Control Service
Broadcast Audio Scan Service

Microphone Control Profile
Microphone Control Service

Coordinated Set Identification Profile
Coordinated Set Identification Service

Media Control Profile
Media Control Service

Call Control Profile
Telephone Bearer Service

LE Audio: Features

- Unified telephony & media use cases
- Modern call control, voice activation, etc (no more 80s tech)
- Hearing aids are first class citizens
- Multi-stream audio for True Wireless Earbuds
- Audio broadcasting (“Auracast”)
  - Discover and join sources via phone app

Bluetooth® on Linux

Bluetooth® on Linux

- BlueZ: the default Linux Bluetooth stack
  - Kernel drivers & userspace daemons/tools
- PipeWire: multimedia IPC
  - Default **audio server** nowadays across all distributions
  - BlueZ plugin to enable access to Bluetooth audio devices
  - Implements A2DP, HSP, HFP, ASHA, LE MIDI & LE Audio !

PipeWire & Bluetooth: A2DP

Codec	Mandatory	Req. License	Library	Library Licence	Bi-directional
SBC (XQ)	✓		libsbc	LGPL 2.1+	
AAC		✓	fdk_aac	Fraunhofer	
AptX (HD)		✓	libfreeaptx	LGPL 2.1+	
LDAC		✓	ldacBT-enc ldacBT-abr	Apache 2	
Opus			libopus	BSD	
LC3 Plus		✓	liblc3plus	Fraunhofer	
FastStream			libsbc	LGPL 2.1+	✓
AptX LL		✓	libfreeaptx	LGPL 2.1+	✓

PipeWire & Bluetooth: HSP/HFP

- HS/HF and AG roles supported
- Codecs: CVSD, mSBC (wide band) & LC3-SWB
- Backends:
  - Native (the best)
  - oFono
  - hsphfpd (deprecated)

HSP/HFP native vs oFono

- oFono: focus is on telephony & modem abstractions
  - Was the only way to use HFP telephony commands until late 2024 !
- PipeWire’s native HFP
  - Original focus on headsets and BT speakers
  - Added telephony support in 2024 (in HF role) – controlled via D-Bus
  - Integrates with ModemManager in AG role – expose local modem to HF units
  - Integrates with uPower – local battery status available remotely

PipeWire & Bluetooth: ASHA

- Audio Streaming for Hearing Aids (by Google)
- Based on Bluetooth LE, but not LE Audio
- G.722 codec
- Supported since early 2025 in PipeWire, “central” role
- For compatibility with existing devices
  - Don’t use for new things, use LE Audio instead

PipeWire & Bluetooth: BLE MIDI

- MIDI (Musical Instrument Digital Interface) messages over Bluetooth Low Energy (BLE)
- Server & client support
- Connect (or implement!) BLE MIDI controllers and musical instruments

PipeWire & Bluetooth: LE Audio

- Handling BAP (basic audio) & VCP (volume control)
- Uses liblc3 from Google – Apache2.0
- Co-ordinated device sets supported via WirePlumber
  - Each device is an independent node; combine-sink used to group them
- Broadcast audio (Auracast) supported
  - If you know how to configure it…

LE Audio known issues

- Format negotiation problematic & reconfiguration missing
- Presentation delays are not accurate
  - Missing in the Bluetooth spec ?
- Devices that support both A2DP and LE Audio prefer A2DP
  - Need to configure `ControllerMode = le` in the BlueZ config file, disabling classic

What’s next?

- Workshop tomorrow (join us!)
  - https://gitlab.freedesktop.org/pipewire/pipewire/-/wikis/Embedded-Recipes-Workshop-in-Nice---May-2025
- Potentially move HFP control to BlueZ ?
  - Easier qualification
- Improve LE Audio & Auracast support
  - Usability, microphone control, voice control, call control, …
- Desktop UI integration
  - Call/telephony UI, Auracast control
- Tidy up codebase
- Potentially oxidize where possible
- There’s more coming to the LE Audio spec soon… !

Thank you!