COLLABORA

PipeWire and Bluetooth[®]

The road to LE Audio

George Kiagiadakis Principal Software Engineer



Open First



- Linux Systems Engineer focus on <u>multimedia</u>
- Principal Software Engineer @ Collabora
- GStreamer, PipeWire
- Author & maintainer of WirePlumber
- Automotive Grade Linux contributor
- 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	SP 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...





11



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)





Open First

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)	\checkmark		libsbc	LGPL 2.1+	
AAC		\checkmark	fdk_aac	Fraunhofer	
AptX (HD)		\checkmark	libfreeaptx	LGPL 2.1+	
LDAC		✓	ldacBT-enc ldacBT-abr	Apache 2	
Opus			libopus	BSD	
LC3 Plus		✓	liblc3plus	Fraunhofer	
FastStream			libsbc	LGPL 2.1+	\checkmark
AptX LL		✓	libfreeaptx	LGPL 2.1+	✓



Open First

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!



