Mezcal: A Collaborative Transmission Art Instrument

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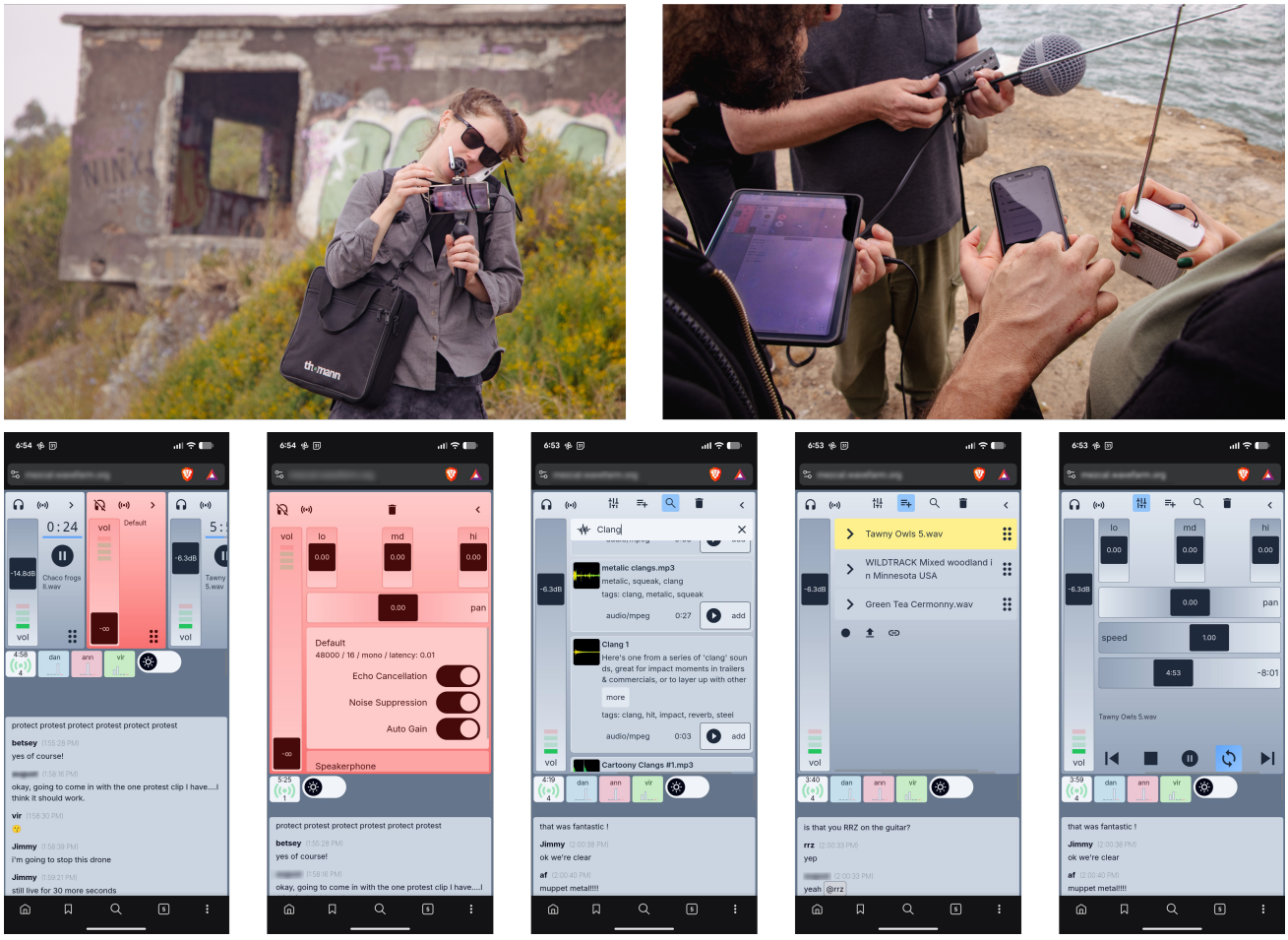

Figure 1: Top: Florencia Curci and Rodrigo Ríos Zunino making live radio with Mezcal in Festival Toda la Teoría del Universo, Región del Biobío, Southern Chile. Bottom: Screenshots of Mezcal in mobile mode showing left-to-right main view, mic input, search, playlist, and playback controls.

Abstract

Mezcal is a browser-based instrument for real-time acoustic interchange that is mobile, accessible, and lives on the web as a 24/7 WebRTC service. Each participant that visits the URL for the server is automatically connected together in a horizontal improvisational audio context; no one controls the mix. The interface presents each participant with an uncluttered audio mixing interface that allows one to play sound from various sources (archives, files, streams) along with input from multiple virtual and connected sound devices (mic, external devices, Jack/Blackhole, etc.). Altogether, when combined with broadcasting strategies, Mezcal allows multiple remote participants to collaborate with sub-second latency and affords a more ambulant and discursive style of radio that is often cross-border, archive-driven, and environmentally engaged. This paper discusses the history, motivation, and genesis of this work while also discussing its technical makeup, current status, future directions, and aesthetic and creative use in various cultural and activist domains.

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Keywords

software, transmission, connected musics

1 Introduction

Mezcal[1] is a novel browser-based instrument that allows multiple constituents to fluidly participate in broadcast-like scenarios through their desktops and mobile devices at the swipe of their trackpads and the flick of their thumbs. Unlike conventional teleconferencing and streaming applications such as Zoom, Discord, Jacktrip, Sonobus, and Jamulus, which emphasize minimizing latency and tight musical timing over scale of participation and accessibility, Mezcal lives more as a web service for variable live configurations than an application solely for audio transport. Mezcal leans into the sloppy latency of networks and emphasizes long-form radiophonic modes of musical expression.

Mezcal works in a browser and is designed with accessibility and mobile-first principles. The design of the system tries to strike a balance between being frictionless, quick, and flexible for various kinds of media makers (newcomers to advanced), while also being conscious in how it shapes group interaction and audio aesthetics. Browser development is a very messy space, and what Mezcal gains in accessibility and easy on-boarding by being browser-based, it loses in control over many potentially critical areas.

While resembling a mixing interface on the surface, it presents a new kind of live telematic situation where the lines between listener and producer can be blurred in new ways. It also presents a new interface for live re-sampling that I call "recreational aesthetics": the re-creation of audio from existing archives for the purpose of aesthetic recreation a la Negativland[2], Matmos, People Like Us and others. The overall set of design criteria and constraints lends itself well to a form of live audio that is biased towards improvisation, ambient noise, and emergent structures.

Beyond and around this instrument, the project facilitates a larger research agenda that aims to catalyze new forms of live interactive radio for the purpose of growing communities, making experimental acoustic and artistic situations, and enabling grassroots initiatives through immediate real-time telecommunication that can simultaneously be discursive and long-form, lightweight and free-form, hyper-local and border-crossing, participatory and autonomous. While this research does present novel assemblages of instrumentation and design, the main contribution is more centered on the shift "...from interfaces to interfacing to create arenas for action rather than tools for purposes."[42]

Specifically, Mezcal addresses a gap in online telecommunication software by focusing on live collaborative dynamics in the aggregate, at scale, and on the move. In combination with broadcast formats, the development explores whether it's possible to "rewild" the radio sphere beyond standard genres of talk and music playback, particularly through playful collaborative infrastructure and new formats of environmental reporting.

2 Related Work

This research draws inspiration from multiple domains. Theoretically and artistically, the project connects to formative 20th-century movements including Italian Futurism, 1960s media art and activism, and tactical net-art of the 1990s. Practically, it builds upon point-to-point audio streaming protocols, WebRTC developments, and bespoke infrastructural projects that sculpt telematic infrastructure or reanimate archives.

[1]The Spanish word "mezclar" means "to mix" or "to mingle". I named the software Mezcal as a potentially more "potent" bastardization of mezclar, but with hope to keep the same connotation of mixing signals and mingling participants.

[2]It is not surprising or unrelated that as early as 1988 Negativland was interested in transmitting their sample based collage aesthetic to radio stations via Teletours[41]

The theoretical foundation examines McLuhan's concepts of liveness and simultaneity, while the practical analysis covers software precedents in audio transport and bespoke transmission infrastructure. Given Mezcal's archival integration, the research also explores sample-driven aesthetic practices and their potential for live collaborative application.

2.1 Liveness and Simultaneity

Marshal McLuhan is a seminal figure in media theory with an interesting set of conjectures around the liveness of media.[3] Among other things, he was fascinated with the replay feature of live sports broadcasting and how it changed our perception and experience of the game, both for players and spectators. He saw the replay as emblematic of the new electronic world and its properties of simultaneity/instantaneity, and as representative of the coming return to what he called "acoustic space". His conjecture claimed that we once lived in an ancient oral culture of spoken words; we entered "visual space" with the invention of the phonetic alphabet; the immediacy of electronic media will deliver us back to an "acoustic" state where images are so hyperactive and omnipresent that they acquire the acoustic property of ambient mixability.[4]

Mezcal aims to develop concepts of live broadcast in the same vein as the instant replay. In fact, live sports is an interesting (albeit unusual) way to think about the liveness of broadcast. It is one thing to watch the World Cup at the moment it is being played. It is an *entirely* other thing to watch the day after. The research in this project seeks to develop instrumentation and infrastructure for the purpose of exploring the field of live performance for broadcast and streaming.[5]

Just as "acoustic space" is about instantaneity and immediacy, Mezcal is about having your hand on the dial, and sits in contrast to much automation software in the streaming domain such as Streaaam[35] and Liquidsoap[17]. Mezcal's necessity of "presence" is situated in the blurry bounds between senders and receivers, something Alex McLean et al. have called "...a semi-official space between personal and public sphere" in reference to live coding. McLean et al. go on to say that "These early live coding initiatives replace the focus on the audience with a focus on collective exploration, often referred to as public thought."[12] I see the research focusing on various geometries of liveness (and perhaps even "togetherness") that are implied by our networks and social relations, but are (still) under-explored.

2.2 Audio Streaming

There are, generally speaking, three types of configurations when considering audio streaming and transport on the internet: broadcast one to many, interactive many to many, and some atypical mixture of those two. These configurations also include innovations at the levels of protocols, formats, encodings, and applications in various combinations. Mezcal is of the third open-ended type that attempts to encourage some interchange between broadcast and interactive configurations while dealing with the very real constraints of latency and participant on-boarding.

[3]It's no coincidence that McLuhan's popularity expanded in the 1960s and 1990s, correlating directly with the invention of the portable video camera and the internet, respectively.

[4]The way the younger generation uses memes and emojis in place of oral speech is perhaps small evidence to this claim.

[5]A recent live TV broadcast of Alex Honnold free-soloing the Taipei tower with 101 floors is a maybe an extreme but relevant notion.

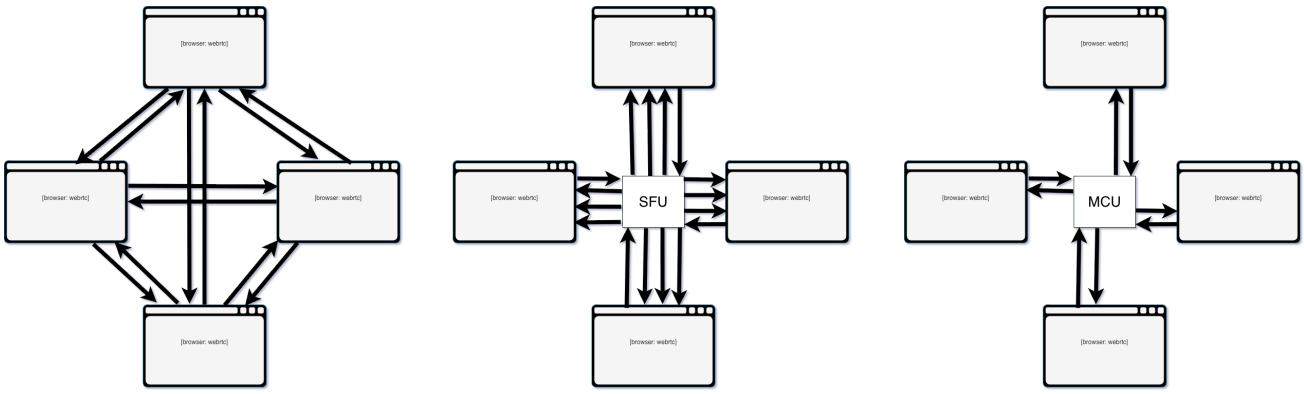

Figure 2: Three different WebRTC topologies: P2P Mesh, Selective Forwarding Unit (SFU), and Multi-point Control Unit (MCU). Peer-to-peer mesh networks can achieve the least possible latency and require no central audio server, but are entirely unscalable. In a 10 participant situation, each participant is sending 9 and receiving 9 streams. SFU's are what most telecom software, such as Zoom or Discord, use. They collect and forward packets at a central location so that in a situation of 10 participants, each participant is sending 1 and receiving 9 streams. The later MCU type mixes the audio on the server so that in a situation of 10, each participant is only sending 1 and receiving 1 stream.

Broadcast one-to-many configurations typically use TCP transmission to centralized servers, delivering content to listeners with large buffers and deliberate delay. Their primary goal involves compensating for network inconsistency and jitter while delivering clear, consistent signals. These configurations handle most audio streaming needs, using tools like OBS, Butt, Mixx, and Izicast for transmission, with Icecast and Nginx handling server-side distribution.[6] Because of the large buffer, these systems are impractical for collaborative live acoustic interchange.

Interactive formats prioritize real-time sub-second latency to accommodate verbal and musical exchange within acceptable thresholds. Most utilize RTC protocols where latency becomes the primary technical challenge. If latency exceeds 1-3 seconds, conversation becomes difficult and musical interaction nearly impossible. Consistent latency under 30ms is unlikely at scale due to physical and real-world constraints.[18]

Of the real-time interactive formats, network topology proves crucial, offering three primary options: mesh, SFU (Selective Forwarding Unit), and MCU (Multi-point Control Unit). See Fig.2. For audio-only applications in first-world contexts of bandwidth ubiquity and only a few participants, any topology suffices. However, Mezcal's goal of supporting potentially hundreds of participants in low-bandwidth situations (mobile LTE networks, jungles, deserts etc.) necessitates an MCU topology.[7]

Two major players in this real-time interactive domain are Jacktrip[3, 23] and Sonobus[10]. Each allow for point to point networking and come with a downloadable app to install and configure. Jacktrip allows for building a mesh network topology.

Jamulus[28] and Ninjam[30] represent significant MCU-style approaches. Jamulus uses a home-brewed opus-over-UDP protocol for server-side mixing but returns the full downmix to all participants, causing problematic delayed self-monitoring. Ninjam employs a unique MCU approach that synchronizes musical intervals between participants using intentional delay, with each participant monitoring their sound at the delayed interval.

Other WebRTC libraries and frameworks in this domain are Mediasoup[6], Pion[9], Antmedia[1], Jitsi[5], Aoo[47], and Janus[4, 15]. Mezcal was first built on top of Mediasoup in an SFU configuration, before switching to Janus's MCU. Of the above, only Janus and Antmedia have a fully fledged MCU option.

While robust server-client software such as Jacktrip, Sonobus, Jamulus exist, none are browser based or share Mezcal's experimental vision. Why is the browser so important? It is the only piece of software that is basically guaranteed to exist on all devices, mobile included. It provides the mobility and accessibility for experimental telematic situations that include people on-the-go and in wild terrain, while also allowing children and septuagenarians easy access to production. Anything outside of the browser at this moment in time is simply non-negotiable for this research.[8]

2.3 Atypical/Prototypical Infrastructure

Many prototypical and atypical NIMEs serve as prior art for this work, especially in the realm of experimental interfaces for collective improvisation, mobile participatory networks, or web-based distributed performance. Group-based mobile instruments such as Auracle, Aural, Jamspace, Echobo, Wijam, *12*, and Simone[13, 25, 31, 33, 38, 44, 45] allow for collaborative and remote participation through mobile devices. Some, like Nexus or Esmeril [14, 27], have a live mixing interface whereby clients send control signals to each other through a central server. Others, like Simone or Pulse Memorial[53], focus on distributed but co-located sounding. Lolc[39] is relatable for its text-based collaborative improvisation with pre-recorded material. Many Mezcal users operate the internal chat in a similar way, allowing participants to send out-of-band communication in a free-form manner to guide the audio.

As users often return and replay the feedback of their output stream, there is formal relevancy in projects such as GroupLoop, Fields, Squidback, and others [26, 46, 51, 54] that invite audience participation in constrained environments with fun, noisy output. Exquisite Score[40] is also relevant in how it prompts and formalises collaborative composition. Experimental transmission

[6]YouTube and Twitch exist in the commercial domain. Newer formats such as HLS or DASH have better features such as bit-rate peeling, but still lack server and browser support.

[7]Because the audio is mixed at a central location, not only does it require bandwidth at that location, it also adds latency proportional to the mixing buffer size, time of decompression and recompression, and any input-output delay.

[8]Users as young as 11 and as old as 78 have participated without assistance in Mezcal-driven telematic events.

Figure 3: Mezcal v2 screenshots on the desktop.

software that creates collective "sound dialogues", such as HearHere[20] and Open Band [52] are especially inspirational. These projects have similar intentions to open public space on FM or develop collective sonic "agoras".

2.4 Mixing Interfaces

Another critical element of this research project is the interface for making audio in live contexts. In this case, our main visual and functional inspiration comes from the lowly sound console or audio mixer. Prior art in this area comes in many forms on the commercial level and a little less so in the area of research and independent media making. I'd like to focus on the later where innovative interfaces for mixing audio, such as Mixx, Mmmmm, and Control, have informed some of the design decisions in Mezcal.[16, 48–50].

One of the early and most influential references for this work is Scott Manley's Ncurses based Icecast streamer from the 1990's, called Liveice. Liveice was a command line application for Linux that allowed one to mix two tracks of audio files with one line or mic input and stream it live to an Icecast server (version 1). It had basic features for playback that allowed one to pause, loop, change playrate. I used this for weekly radio shows where my partner and I streamed live to FM on Radio FRO in Upper Austria. This also inspired me to build two other early mixing interfaces, MuSE and Userradio[19].

In 1999, I started working on a Linux application, called MuSE[9] that, like Liveice, allowed one to mix multiple tracks of audio with a line-in/mic channel and stream it live. Our goal was to build similar functionality as Liveice, but expanding the number of playback tracks and developing a point-and-click user interface for a more performative dimension.[10] Around that time in 2002, I started developing a server-client system called Userradio that consisted of a browser-based frontend in in Macromedia Flash and a java/puredata backend that mixed sound on the server. The frontend was collaborative and only sent control signals to the server via a TCP socket; flash being the only viable tech at the time to do so on the web. Userradio was also meant to be connected to an FM broadcast so that latency was near-zero and a locality of operation was defined by proximity to the radio. Mezcal is a more contemporary attempt, two decades later, to mix networks with broadcasting in a context where bandwidth is more ubiquitous and where nearly everyone is carrying a portable networked microphone with them at all times.

[9]Made in collaboration with Denis Roio

[10]We built the UI first in Tcl/Tk and then later in FLTK. The current version was taken over by other developers in GTK

2.5 Recreational Aesthetics

Since Mezcal's interface includes well-integrated access to various kinds of audio archives, a subsection of this related work occurs in the domain of ludic archival reinterpretation. Sampling audio for musical repurposing is, of course, as old as electronic recording technology. Hip-Hop of the late 70s and 80s turned it into a supreme art form. Where music meets the semantic space of broadcast talk and news, there is vast poetic territory to explore that I think is well-illustrated by works such as Brian Foo's Citizen DJ project[29] and the many projects based on the Freesound archive listed as part of Freesound Labs[2].

The term I have started using for this is Recreational Aesthetics, a play on the concept of "Relational Aesthetics"[11] The archival gateways of Mezcal allow for users to re-create and re-ambiguate the archive into more questioning, utopian, playful possibilities; in a recreational manner.[21]

3 Description

Mezcal is web-based instrument that allows multiple geographically dispersed participants to collaboratively mix real-time audio for live radio events in high-quality and low-latency in a fluid call and response style. As a system made of many moving parts, it currently consists of both client-side and server-side components.

3.1 Client-side

The client-side of the software is a single-page web application written in Typescript using React, Xstate, and Tailwind CSS. Users visiting the Mezcal URL enter their user name in a modal window and encounter a layout with a mixing console on top, a chat window on the bottom-left, and an info window on the bottom-right (see Fig. 3). Like old-school IRC, there is no real authentication in the system. You type your name and go.[12]

The chat allows participants to communicate with one another in various ways. My experience shows that participants use the chat mainly to cheer each other (e.g. nice whistles, more cowbell, etc.) and coordinate and queue audio (e.g. "cutting out in 10 seconds" or "everyone come in with car honks"). The info window shows a button for the main incoming audio and one each for every participant. These buttons light up with a green underscore when any participant is sounding. They also show roughly the channel count and mix of each participant in a mini-view. Clicking on the info button for the participant opens a modal

[11]This is a term put forth by French art critic Nicolas Bourriaud centered on situational and social practice in contemporary art.[22]

[12]There is an admin password for any Mezcal instance that allows one to record on the server, stream to Icecast, and mute participants. The muting of participants is the only protection against would-be trolls or bad-actors.

window with a larger view that shows all tracks that that participant has open. This allows each participant to observe others in some small detail. This view also allows an administrator with password to mute the participant.

The mixing interface currently allows the user to add two types of tracks: input (red-pink) and playback (gray). The red-pink input tracks allow the user to bring in internal mics, external audio interfaces, or even virtual sound cards such as Jack and Blackhole. The latter virtual devices allow one to hookup Ableton LIVE, Max/MSP, Puredata, etc. to the live Mezcal mix. The grey playback tracks allow users to play files from their own devices, streams from the net, or to use the built-in search to play audio files from a number of archives: currently Archive.org, FreeSound (field recordings), or Wave Farm experimental radio archive[11].[13] This built-in archival search is a central feature that biases the practice of mixing inside Mezcal towards collaborative improvised sound collage.[14] Each input channel on the mixer, whether input or playback, includes controls for volume, panning, and EQ.

One notable design element of the browser interface is the humble vertical fader. The web has grown in ad hoc fashion over the past three decades from a more-or-less static hypertext environment into a fully dynamic space of interaction and multimedia. However, it still does not have basic widgets like a fader. Current standards provide a range slider, but not in a way that can be easily styled, set vertical, and is multi-touch aware. I spent a perverse amount of time making a vertical fader that could have a more performative nature within multi-touch mobile devices. The current Mezcal has an animated lazy follow feature that prevents jerky fading (for newcomers). It also allows one to click on the track and have the fader animate and fade towards that mark instead of jumping to it directly. This is especially important on the desktop where the user cannot use multiple fingers to fade one channel in while fading another out.

Figure 4: Headphone and Broadcast toggle buttons (left) allows one to turn on/off local and remote audio sending.

The Mezcal client connects with the server-side using a single WebRTC connection. It mixes all audio from the client's activated tracks and sends a single stream of opus encoded stereo at 48000 Hz to the server. Each participant receives an N-1 signal (all other participants except for themselves) in return. The top of each track includes a button for muting the audio that the user hears as well as the audio that gets sent to broadcast. This acts as a pre-fade listen or solo button that one normally finds on a mixing console. (see Fig. 4)

3.2 Server-side

Mezcal sits on the web as a ready-to-go service. From the participants perspective, there are no desktop applications to install, no walled-garden app gateways to navigate, and no software to maintain over time.

Technically speaking, one can mainly think of Mezcal in its current form as an interface on top the Janus WebRTC gateway, but with other multiple interlinked components. Nginx is the main entry point of the backend application, providing TLS protection, logging, and proxying to the other services involved: Janus, a TURN server[15], and a Node.js side-car application for miscellaneous processing (see Fig. 5).

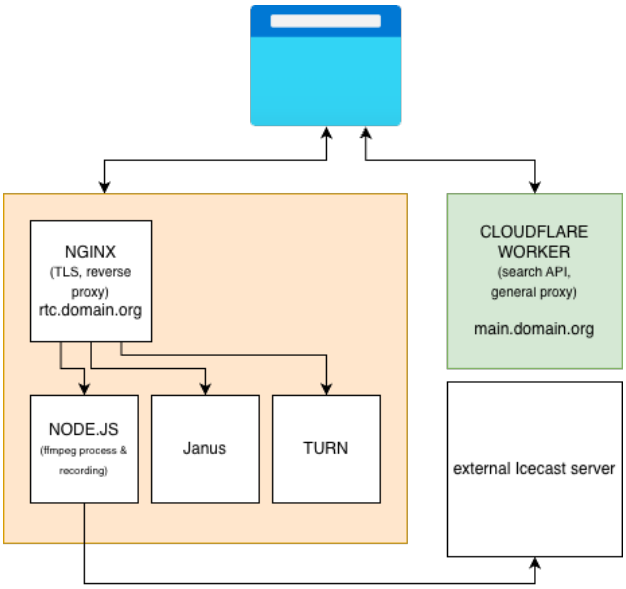

Figure 5: Diagram of Mezcal services.

Janus provides the main Multi-point Control Unit (MCU) architecture managing WebRTC connections, performing server-side audio mixing, and returning single streams to participants. This approach dramatically reduces bandwidth requirements at scale while implementing a crucial feature: mixing audio from incoming participants so each receives signals including all others except their own audio. Unlike Jamulus and other server based mixing, this N-1 prevents speech jamming: where you hear your own signal returned with a slight delay. It is also one of the strangest parts that makes it unlike a normal mixing console. In Mezcal, you monitor your own audio signal as it gets sent to the server, not as it exists within the audio of others.

Additionally, the Janus service allows one to export a plain RTP down-mix of all participants to a parallel node.js process that spanws FFmpeg to convert the local RTP downmix signal and stream it to Icecast (either re-encoding as MP3 or forwarding and re-encapsulating the opus packets without re-encoding). This allows one to take the full mix of all participants and convert it to a more broadcast-ready signal for syndication and scaling an event for listeners. Also, since you can't "link" to a WebRTC stream directly, it provides a format for embedding a simple audio element in a web page.

Beyond audio transport, Mezcal provides a separate Cloudflare worker (CF) that interfaces with external archival API's (YouTube, Freesound, Archive.org, and Wave Farm) and does three main things. It provides a uniform search interface, encapsulates any needed authorization keys, and circumvents secure-origin and cross-origin restrictions.

This proxy service for secure-origin and cross-origin restrictions is a small but very crucial element to this research. It allows

[13] I am currently working with Kunstradio[8] on integrating their entire archive into the interface.

[14] It should be noted that copyright is ultimately the responsibility of the end-user, but that many radio stations have licensing agreements that allow for audio playback on air and that many sampling techniques fall under fair-use rights.

[15] This is allows one to proxy RTC data in situations where the end user is behind a hefty firewall.

Mezcal to ingest external media that would otherwise be off limits in the browser. Because secure origin policies of browsers require HTTPS encryption for WebRTC, all other data such as audio from URL or live Icecast streams must also be HTTPS protected. Furthermore, new cross-origin (CORS) restrictions[16] force web administrators to manually apply special headers to their outgoing media content, something that is poorly understood, fragile, and rarely done.[17] This proxy service is something that I believe is unique to Mezcal, allowing for fluid resampling of archival and live material. It's also potentially a costly service, and something that limits Mezcal's scope as pure (or free) software project.

3.3 Development Timeline and Strategy

I started the development of Mezcal in 2020 as way to seed pluralistic research around contemporary streaming protocols with a vague desire to build a Swiss army knife style instrument for live interaction. At the time, I observed a lot of development for a sedentary and passive style of net-casting that followed the traditional distinction between producer and audience, or band "jamming". While live streaming transport existed, there was little infrastructure for a more gonzo style of ambulant audio technique that I thought (and still think) was needed. Not only have networks changed a lot in the last few decades since the Web became the main interface for the Internet, a new form-factor of mobile devices also provided an interesting context for a more nimble style of mixing on-the-go. The six year journey until today took many turns.

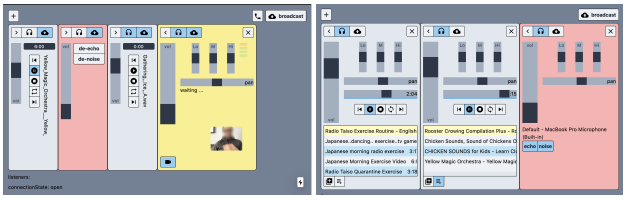

Figure 6: An early version of Mezcal with playlist, "call-in" track with optional video, and mic input. One of the hardest things to consider is what options are desirable and ergonomic at the same time.

The initial theory driving the first design focus was mobility. I called this early development "Radio for your Thumbs" and it shares some affinity with projects, like ThumbTec[55], that focus on small thumb-sized activity with expressive output. Eventually, the overall vision became more aligned with Tetsuo Kogawa's micro-radio[7, 37] and polymorphous radio[36] endeavors that sought to induce a more convivial style of live radio. Simultaneously, it found inspiration in the cross-cultural and cross-border poetic antics of Guillermo Gomez-Peña on radio and television[32, 34], or the nomadic CB interventions of Red Asphalt Nomads[56].

[16] Incidentally, the CORS restrictions come from the same 2004 era Web Hypertext Application Technology Working Group (WHATWG) - part of a larger take-over by Google and Apple of the W3C - and the implementation of the xmlhttprequest feature of javascript. It is debatable whether the CORS restrictions are solely based on security concerns.

[17] Cross-origin and secure-origin are only restricted in browsers. Desktop applications do not have this restriction. In developing Mezcal, I also communicated directly with the engineers at freesound.org and archive.org to attach the proper CORS headers in their respective servers so that their search API services could (theoretically) work without a proxy in the future.

Figure 7: A pre-beta 2020 version of Mezcal with an extra yellow "call-in" track where producers have access to the mixing interface and listeners can only call in. Listeners and other producers could call in directly to one specific user if desired. This allowed ad-hoc configurations to be formed. The right shows a rudimentary search interface.

On a pragmatic level, after settling on Janus's MCU as the backbone of the audio transport, development focused on the instrumental capacity of the mixing console. There was (and still is) a lot to work out in developing an ergonomic design. Initial prototypes explored the idea of point-to-point call-in configurations in two ways. First, I thought it important to develop a dedicated listening interface that would allow listeners to call-in and end up as a track on the producers mixing console (with optional video, see Fig.6). Simultaneously, this would allow producers at different Mezcal servers to link. While interesting on some level, designing an interface where that was easily understood proved to be difficult and ultimately unnecessary in the short run. The next version abandoned that for a more simplified architecture where everyone is a producer-listener in a horizontal fashion.

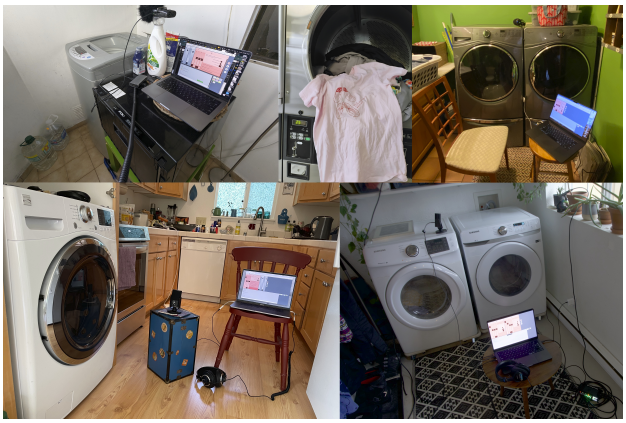

Figure 8: The Conduction Series "White Washing" show from April 2025: Live FM broadcast on WGXC, CiTR, Radio Tsonami, Radio CaSO, and Radio MonteAudio of the hypnotic and rhythmic dissonance and harmony of multiple washing machines from across the Americas (Vancouver, Canada · Boulder/Denver, Colorado · Kingston, NY · Santa Cruz, CA · Valdivia, Chile).

At the same time in 2021, I contacted the director of Wave Farm[11] to help guide the development. We formed a beta group that met once a week for a few months in order to test and

give feedback on iterations of the design and its features and bugs.[18] In late 2021, we also convened a group of artists, activists, and radio makers to develop a monthly live broadcast with the software, called The Conduction Series[21], that has made over 50 broadcasts since and provides a grounded test-bed in which to "dogfood"[19] the on-going development (see Fig.8 for an example). This slow simmer co-evolution of the design with the practice of live collaborative audio making is, I think, one very key element of this development.

4 Discussion

Mezcal represents a plurality of motives and outcomes. On the surface, the browser GUI provides a playful interstitial layer of expressive sonic activity. At the level of infrastructure, Mezcal acts more like a service for cross-border and cross-media operation (e.g. from network to broadcast and back). More deeply, however, there are theoretical and critical underpinnings.

In this sense, the word critical is pertinent in at least two forms. I see this research as critical in that it is vital and alive (e.g. critical infrastructure). It provides a kind of foundational infrastructure for live collaborative radio; an infrastructure that is often quiet, unnoticed, un-cited, and unrewarded. This part of the research should indeed recede to the background at some point so that the human relationships it allows and the content it carries, affords, and delivers is foregrounded. This research is also critical in the sense that it can and should critique the existing media context, including the one that it creates. It asks the questions: Does radio have to be so loud, with mostly talk and music playback? Can we discover new forms and formats of live radio that "rewild" the terrestrial broadcast with global networking in local capacities? Could we look to broadcast and streaming formats as socially engaged practices that require different kinds of criticality? [20]

In evaluating the results of this research, I'd like to speak briefly about the mobility, accessibility, and always-readiness of Mezcal before discussing the "transmissive" and technologically intersectional nature of the project. I'd then like to end with a consideration of various radiophonic and telematic events that have been supported and enabled by Mezcal. I believe these can serve as a kind of evidence for the project as a whole.

4.1 Mobile, Accessible, and Always-Ready

One of the main features of this research that sets it apart from prior art is the fact that it lives on the web as a service and operates within a browser. It's not a desktop app that one downloads and requires installation, setup, and maintenance. This has advantages and disadvantages. The main disadvantage is that one cannot as easily control the graphics, protocols, or latency as well as in a desktop application (e.g. written in C or Rust). Mezcal has to work around many browser restrictions such as CORS and security policies just to do basic transport and playback. It also has to develop its own lower-level widgets that usually come in desktop GUI toolkits. Also, while Mezcal can achieve sub-second latency, it has much less control over the lower-level transport as would a desktop app such as Jacktrip. All considered, Mezcal might not be the best for band practice, but the trade-off strikes a nice balance for most audio needs related to a new form of participatory radio where incoming guests are not necessarily known in advance.

Figure 9: If setup with a stream or FM connection 24/7, Mezcal can be used in an ambulant hop-on, hop-off manner where the sonic output might sound disjointed like in citizen band radio or an acoustic snapchat. Photos by Hethre Contant and Jon Panther (Diffusion FM, Sydney).

The most salient advantage of the browser is that it affords at least two kinds of accessibility. First, as opposed to device-specific applications, browser-based apps work across all devices and allow easy on-boarding. Second, the web has guidelines and standards for accessibility in the traditional sense where HTML standards are meant to allow interaction for those without full sight or hearing. Desktop applications have more control, but less pre-built standards in this regard. In another sense, the browser is an accessible space of media in that all devices come pre-installed with a browser.

Altogether, the browser-based and mobile-first design allows for an accessible, low-friction, and discursive style of audio among multiple geographically dispersed members. I like to think of this techno-aesthetic combination as a kind of collage-across-borders that reanimates archival material within a live context of open mics and connected musical apparatuses from participants that are massively dispersed around the globe. It's subtle, but I can testify from my own activity with The Conduction Series that the on-going monthly interaction through this interface is enabling an ultra-long-form geopolitically intertwined musical conversation (now going on six years). Anecdotal and qualitative reports from others also hint at this (see below).

As a whole, this always-ready, mobile-first design creates a form-factor that allows one to think of musical interaction for radio on a smaller, more adept scale, allowing one to bring transmission to the beach, to the park, in your purse, while waiting to take off, or having your breakfast, etc. (see Fig.9) The potential points to a nimble and discursive space for varied aesthetics, where voice, samples, and sound operate in symbolic and representational, but also harmonic, musical, and contextual ways. Where global networking meets territorial boundaries, a new kind of transmissive geography forms.

4.2 Technical Transmissive Intersectionality

"Transmissive" describes something capable of passing, conveying, or transmitting (e.g., light, energy, or characteristics) through a medium. It is commonly used in physics for materials that allow light to pass through or in technical contexts to describe components that transmit signals. That we as humans are constantly signalling to each other and our environments (also known as memetics) is not unrelated to this research. This research meets

[18] This is incidentally a practice that I learned as an engineer for Cycling '74. In smaller production teams where full user studies and test-driven development is not possible, developing a dialogue with practitioners is a vital way to set priorities and guide a software through stages of development.

[19] Dogfood is an industry term meaning to use one's own products or services internally.

[20] See "Be Water My Friend" for an insightful overview of non-oppositional criticality in art engagement in contemporary China.[24].

at the intersection of art, music, activism, technology, and geopolitics.

Without re-hashing the utopian dream and emancipatory rhetoric of the 1990s, the research behind Mezcal views transmission as more than transport. Given our turbulent times of techno-capital and neo-authoritarian political movements world-wide that are receding from former globalist strategies and concentrating power around nationalist tendencies that fear immigration and cross-border activity[21], it would be prudent to spend a few words on the overlap of communication technology and techno-political expression.

One way to look at electronic communication technology is to see it as the very material of globalisation. It is what allows us to transmit not only entertainment, but also economic, cultural, ethnic, etc. value of all kinds. It would be a sad thought if the broadcasts from 1930's Nazi Germany are the first ones that make it through outer space and into alien minds. My (albeit inflated) hope is that the "posture" of this project can work toward a cross-border globalized consciousness, developing kinds of "togetherness" and empathy. While Mezcal permits a kind of transmission practice by the author that is underscored by a collage musical aesthetic, it also aids and abets other forms of critical expression that are more about mobility in the public sphere and the creation of kinds of "publics". I outline a few below.

4.3 Events with Mezcal

Since starting this project in 2020, I have slowly built personal connections with other radio makers around the world, developing alliances and shared practices that overlap in the software-driven audio space of Mezcal. Of the many compelling radio projects that have been supported by Mezcal - everything from live magic rituals between Uruguay and Sumida Mukojima EXPO 2024 in Tokyo to youth workshops at Project 107 in Sydney by Diffusion FM to live broadcasts on Deutschland Radio, Croatian Radio, SWR, and ORF with over 30 participants - I've selected three below that I feel illustrate the colorful kind of radio that can exist; not exactly created only by Mezcal, but somehow afforded by its special characteristics.

Figure 10: Live-to-air broadcast while circling the Aurora and Otay Mesa migrant detention centers. (photo courtesy of Eliseo Ortiz)

[21] Except maybe where cross-border activity is economic and transactional.

Migrant Detention Radio (2021), by Eliseo Ortiz and Jessica Ordaz, (see Fig. 10) was one of the first projects supported by this research. In this live-to-FM broadcast, presented on WGXC, two participants walked the perimeters of the migrant detention centers at Otay Mesa in San Diego and Aurora ICE facility near Denver, respectively. Each participant reported short snippets about the carceral scenery mixed with vocal histories focusing on the impact of privatized migrant detention and its long history of oppression.

Figure 11: Terraformaciones Radiales: community radio activity in Argentina (photo courtesy of Gabriela Munguía)

Terraformaciones Radiales was a project led by Gabriela Munguía (Mx) and Patricia Bernal (Co) that proposed an open radio space for community-based artistic research and training. (see Fig. 11) Through the use of new technologies and territorial and radio experimentation, the project aimed to cultivate other forms of social and civic participation that support the care of people and the environment. The project has been developed with the collaboration and support of Buenos Aires Museum of Modern Art, the community garden "Las Yungas", and the Bachillerato Popular "Casa Abierta", Contemporary Art Espace of Montevideo (Ur) y Fondo Metropolitano para la Cultura y el Arte (Ar). The project has taken shape as a training and sound production program, together with a series of community work sessions and activations of an experimental, nomadic, communitarian radio.

Prof. Munguía says: "Using Mezcal within Terraformaciones Radiales was key to sustaining a telematic, collective radio practice: a lightweight infrastructure that allowed us to broadcast from multiple locations while, at the same time, composing a shared mode of listening. More than an "app," it worked as a device for sovereignty—enabling concrete exercises in social democracy, where the broadcast became a real-time neighborhood assembly, valuing and amplifying the spoken word and the memory of the neighborhoods."

Radio TSONAMI has been a long time active participant in the development of Mezcal since 2023 when they started Transmisiones Periféricas, a series of radio shows put together by A.R.E. (Asociación de Radios Experimentales), a group comprised of Radio Tsonami, Chercan Radio and Radio Granizo. This series of shows featured the three radio hosts having live conversations with different labels and artists, listening to albums and new releases, field recordings, upcoming cultural events in various parts of the Valparaíso region of Chile.

One performance in particular by Radio TSONAMI was "Señales que llegan del cielo" in September 2025. (see Fig. 12) This experimental radio piece was performed live from four different locations in Mexico City, which aired live on Radio Educación (96.5 FM) on most of the country. The project consisted of installing four temporary radio stations in four different spaces: Casa del

Lago UNAM, Ex Teresa, Fonoteca Nacional, and Radio Nopal. At each of these stations, duos of sound artists from Chile and Mexico gathered to perform a score specially designed for the XV International Radio Bienal of Mexico. The piece was inspired by atmospheric phenomena, exploring different ways of relating to the sky from anthropological, affective, meteorological, and cosmic perspectives. A listening point was also set up at CENART (Centro Nacional de las Artes), allowing the work to be experienced both by tuning in to the radio anywhere in the city and by listening collectively in the public space.

Figure 12: Radio TSONAMI (Chile) and Radio Nopal (Mexico) in Mexico City 2025 (photo courtesy of Radio Nopal)

Ríos Zunino says: "The four broadcasts converged in a realtime mix thanks to Mezcal. In this sense the tool was indispensable for the realization of this project, because of many of the features that it natively hosts, mainly: "Realtime" monitoring of one's signals and the other stations', allowing for in-sync improvisation."

Figure 13: Mort Drew (Soundcamp) setting up for *Spree Channelsea* with Mezcal, a live environmental broadcast between Berlin and London 2023. (photo by Ruth Keating) see: https://acousticommons.net/~/#

5 Future Work

Future work of Mezcal is already underway. Some of it is to address deficiencies or shortcomings in the current iteration. Some of it is to explore new ideas and endless features.

The current design of Mezcal still needs some treatment. A lot of time and energy went into finding an ergonomic form-factor the allows various faders, search modals, controls and more to fit within tiny mobile devices. I've been stubborn about having full sized faders and the current layout is pretty cramped. A new layout is exploring the use of dial knobs in place of faders. I am also removing playlists. There are also minor features that could improve the performance aspect. Being able to group tracks would allow one to control volume for many sounding elements at once. Better handling of default settings and being able to save settings for various input devices could improve user experience. Currently, Mezcal sets all input to "echo-cancellation" on as a default.

Besides layout and usability improvements, I am exploring some new infrastructural ideas. One current prototype has abandoned the use of Janus entirely and has a built-in MCU that acts as an audio server in the browser itself. This is an interesting development for many reasons. First, it can allow operators to do main downmix by hand, potentially on site. I am looking to explore pulling live inputs from mobile devices into theatrical ambisonic settings. Second, it allows Mezcal to be deployed as a slim service that only passes initial handshaking signals. The bandwidth can be offloaded to the participants in a way that allows Mezcal to more easily be handed out without cost. The current Mezcal is more of a service than a software. It needs multiple living components at once. This new MCU-in-browser could be a nice way to give participants/operators of Mezcal some responsibility and freedom in how they carve their bandwidth usage.[22]

6 Conclusion

The biggest difference between Mezcal and other telematic software is in its vision. I don't see this research as a tool for industry or even for band practice (not that these things are bad); I see Mezcal as an expressive instrument for diverse sound, music, and transmission practices, for participatory and open-ended artistic performance, for growing social movements, and for live environmental reporting, all under expanded musical pretexts.

Grant Smith, a design partner from SoundCamp, sums it up in a lovely manner as follows.

"Mezcal is particularly suited to making this kind of radio because it has potential to: (1) enable flat, non-hierarchical associations of streamers, mixers and producers. (2) distribute authorship and agency among people in different places. (3) support a range of sources, especially in our case open microphones, allowing a complex, plural sound world to be developed, which can (4) begin to do justice to more-than-human worlds. (5) allow a mix to move with the timezones, so that, as with the Reveil broadcast, the mix travels west with the sunrise, from London to Valparaiso to Sunshine Coast to Crete.. creating a radio event that is both situated and errant (Edouard Glissant) (6) in these ways, to be part of experimental infrastructures connecting the hyper-local and the planetary, in support of acoustic justice and acoustic commons. (7) support the formation of transmission communities (Anna Friz[43]) through qualities of interaction that are different from those prioritised by mainstream / commercial platforms. (8) support the increased interest among emerging transmission artists in sound and radio as relational practice, both among practitioners and with places and situations we are in. "

[22]Incidentally, one can also run this mcu-in-browser on a headless chrome browser on virtual machine in the cloud.

7 Ethical Standards

Research presented in this paper is the result of my own ideation and development in open collaboration with others. I have done my best to cite all known inspirations for this work as well as any prior software. Audio projects examined and developed in this research sample and use pre-recorded audio from external databases under fair use rules. The software developed in this research is neither free software nor for commercial licensing. It is an art project with an aim to develop and support communities of practice.

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