There and Back Again

Composing for Networked Reverberation Chamber and Live Orchestra

Austin Franklin
Mälardalen University
Västerås, Sweden
austin.franklin@mdu.se

Rikard Lindell
Mälardalen University
Västerås, Sweden
rli@du.se

Henrik Frisk
The Royal College of Music
Stockholm, Sweden
henrik.frisk@kmh.se

ABSTRACT

This paper documents the deployment of a mobile, web-based, real-time distributed reverberation chamber named the Auxtrument designed for a live concert setting. Rather than presenting a technical case study, the project is framed as an artistic and collaborative investigation into how networked audio systems can inform and transform musical composition and performance. In close collaboration with a contemporary orchestra, we composed two (2) site-specific works that utilise the inherent latency and uncertainty of WebRTC media streams over a mobile network as musical parameters. Through this process, we explored new aesthetic possibilities afforded by the system, foregrounding temporal instability and environment as integral compositional tools.

CCS Concepts

•**Applied computing** → **Sound and music computing;** •**Human-centered computing** → *Auditory feedback;* •**Software and its engineering** → Software prototyping;

Keywords

WebRTC, Distributed Systems, Network Music Performance, Music Composition

1. INTRODUCTION

In the evolving field of Networked Music Performance (NMP), latency and uncertainty are often treated as adversarial to traditional musical values such as synchronicity and consistency. However, Rebekah Wilson's work proposes a critical reframing of these perceived limitations as aesthetic opportunities. In *Aesthetic and Technical Strategies for Networked Music Performance*, Wilson argues that network-induced conditions can serve as compositional material, transforming the network from a conduit into a collaborator [28]. Drawing from her background in experimental and electroacoustic music, Wilson articulates a practice in which the network itself becomes an "instrument" whose behavior can be learned, shaped, and responded to in performance contexts.

Licensed under a Creative Commons Attribution 4.0 International License (CC BY 4.0). **Attribution**: owner/author(s).

Web Audio Conference WAC-2025, November 19–21, 2025, Paris, France.

© 2025 Copyright held by the owner/author(s).

This paper builds on Wilson's arguments, documenting the creation of a mobile, web-based, real-time distributed reverberation system named *Auxtrument* developed for a concert with a live orchestra. Rather than requiring a near perfect latency and stability solution, the system embraces the anomalies of WebRTC and mobile networks as expressive parameters. This approach aligns with the aesthetics of artists such as Pauline Oliveros, whose Deep Listening practice emphasises attentiveness to space and environment as integral to sound-making [22], and John Cage, whose indeterminate strategies foreground the role of systems and environments in shaping composition and performance [5].

Wilson's ideas resonate with a lineage of thinkers who argue for an aesthetic, rather than purely technical, framing of networked audio. Michael Dessen describes networked improvisation as a model for distributed authorship, challenging centralised roles like the composer or conductor [9]. Similarly, Miriam Iorwerth expands on these themes in *Networked Music Performance*, arguing that artists must co-develop technical and aesthetic strategies in tandem [17].[1] The compositions described in this paper adopt this multifaceted perspective and explore how latency and uncertainty can shape musical gesture and form.

2. BACKGROUND

The field of NMP is both expansive and relatively young, shaped by ongoing advances in low-latency audio transmission protocols and real-time data sharing. Though its conceptual roots date back to the 1970s [12], NMPs have only recently matured into a practical domain, largely due to the proliferation of high-speed networks like Internet2 in the United States and GEANT in Europe.

NMP systems pose a number of technical challenges. These include minimising latency during the full signal path as well as overcoming bandwidth bottlenecks, synchronising distributed streams, and maintaining resilience against data loss. Perhaps the most significant constraint is the Ensemble Performance Threshold (EPT), the maximum delay between performers that still allows for tight musical coordination. While video conferencing systems can tolerate end-to-end delays of 150 milliseconds or more [26], NMP demands sub-25 millisecond latency to maintain real-time ensemble cohesion [7]. Meeting this threshold requires ultra-low-latency solutions at every stage–recording, encoding, transmission, reception, decoding, and playback–all of which are complex in their own right.

[1] See [1] for similar reasoning.

Modern research is addressing these limitations, such as adapting audio processing in streaming applications to overcome jitter [19]. However, these solutions are often context-specific, technically demanding, and not easily scalable. They tend to rely on specialised infrastructure, such as Software-Defined Networking (SDN) or dedicated low-latency audio codecs, which limits their applicability to broader, more heterogeneous network environments [16]. Moreover, such approaches frequently assume stable topologies and controllable network conditions–assumptions that break down in mobile, Peer-to-Peer (P2P), or public internet scenarios between disparate service providers–precisely the kinds of conditions where more democratic and accessible forms of networked music performance might occur.

Dedicated software such as JackTrip [4], SonoBus [2], Jamulus [10], and Aretousa [25], among many others, exists to address some of these technical demands, offering means for monitoring and configuration. However, these systems are limited by constraints inherent to the networks themselves–many of which are difficult or impossible to overcome. For example, issues like Carrier-Grade Network Address Translation (CGNAT) and mobile roaming introduce significant challenges to reliable connectivity, P2P networking, and consistent identity persistence across sessions. Most of these applications, such as JackTrip, Jamulus, and Aretousa, are not available on mobile devices. SonoBus does provide a mobile app, but its reliability across mobile networks is limited, and successful connections often require port forwarding–a step that may not be possible in many real-world scenarios, preventing peers from connecting altogether. Some tools have targeted narrower domains–for example, choir-specific platforms like the one described by Cychnerski and Bartłomiej–but these are often tailored to a particular ensemble or musical style [8].

Most recently, NMP systems have taken advantage of the ubiquity of modern web technologies. Browser-native platforms–powered by tools such as WebRTC, Web Audio API, and WebMIDI API–have enabled musicians to collaborate remotely with minimal setup, no proprietary software, and greater device accessibility. These systems not only lower the barrier to entry but also support dynamic, distributed topologies that were previously impractical outside of research institutions or custom-built infrastructure. However, this accessibility comes with trade-offs. Performance is still constrained by browser inconsistencies that make scalability and distribution across Internet of Things (IoT) devices difficult [27]. Despite these hurdles, the browser has become an increasingly viable platform for networked music–transforming NMPs from an institutional concern into a widespread, participatory, and flexible creative practice.

Altogether, the diverse projects and systems surveyed in this section demonstrate both the richness and the fragmentation of the NMP landscape. Each approach offers valuable workarounds, but all are shaped by persistent infrastructural challenges: latency, jitter, NAT traversal, inconsistent connectivity, and the "black box" nature of Internet Service Providers (ISPs). These limitations are structural conditions of the contemporary internet. In this light, Rebekah Wilson's aesthetic approach is not just a novel reframing but a practical necessity. By treating the network as an active and expressive component of musical practice, Wilson offers a way forward that does not rely on elusive infrastructural fixes. Instead, her work invites artists to co-create with the network's peculiarities, cultivating a practice that is attuned to the realities of distributed performance.

3. INSTRUMENT DESIGN

The *Auxtrument* is a web-based instrument designed to act as a distributed, real-time reverberation chamber that transmits the acoustic qualities of remote physical spaces. It works by sending a live signal from a concert hall to several geographically dispersed locations via a mobile network. At each site, the signal is played through loudspeakers, recorded via stereo or ambisonic microphones, and sent back to the concert venue. The returned signal, now transformed by the spatial characteristics and ambient noise of the remote environment, is rendered in surround sound for the live audience. The system enables multiple environments to be layered in the same listening space, creating a composite acoustic experience.

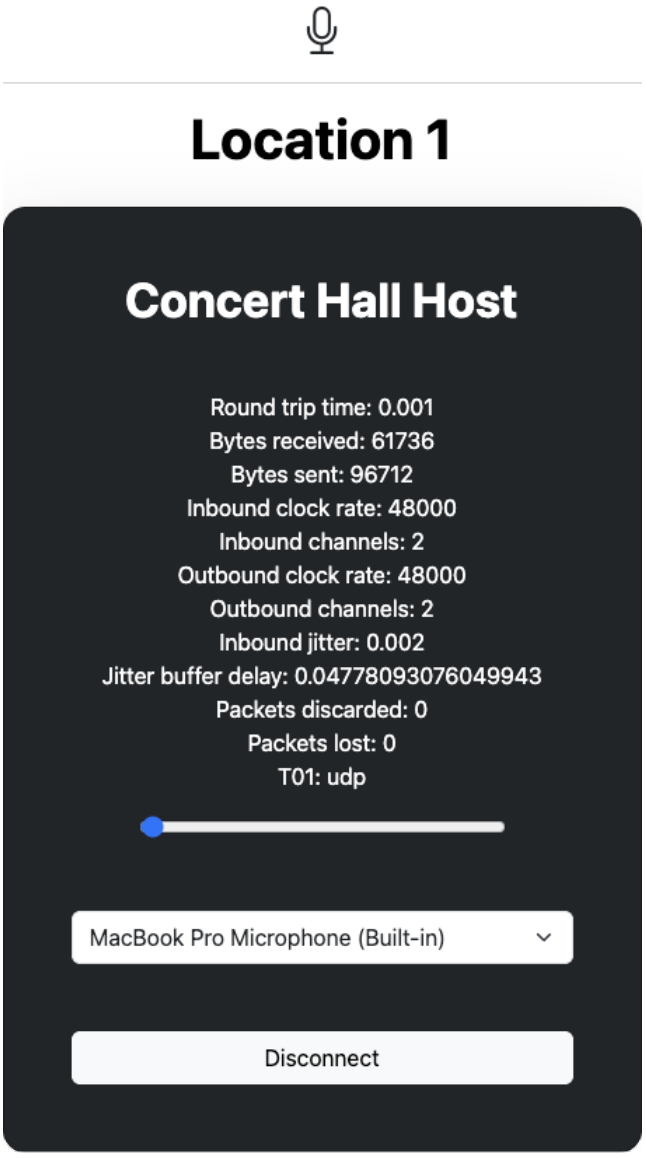

Figure 1: Remote node graphical user interface

To use the *Auxtrument*, users navigate to the URL, se-

lect their role (whether they are the concert hall or remote nodes), and select their input device for the browser. The interface for each location monitors network status information such as round trip latency, jitter buffer delay, and bit transfer rate (Figure 1). Users can adjust volume levels on either the location or concert hall side via a slider to prevent clipping. Currently, the *Auxtrument* supports up to three (3) remote locations and one (1) concert hall host, but can be expanded for different use cases. More information is detailed in a recent paper presented at the Quality of Media Experience conference 2025 [14].

3.1 Technology Stack

The stack includes node.js, express.js, WebSockets, WebRTC, and the WebAudio API. P2P connections are established using peer.js, with Interactive Connectivity Establishment (ICE), Session Traversal Utilities for NAT (STUN), and Traversal Using Relays around NAT (TURN) protocols employed to overcome Network Address Translation (NAT) and firewall restrictions. WebRTC is a standard for real-time communication on the web with a specific focus on audio and video. The peer.js library simplifies WebRTC setup, and the *Auxtrument* adopts the Opus codec at a 48 kHz sampling rate to ensure browser compatibility and prevent resampling at any stage of the transmission.

ICE uses the STUN server to probe various ways to connect to the clients from the outside, a process often called hole punching [13]. The results are transmitted back to the peers to establish a direct connection. However, if the network is explicitly configured to block P2P connections, WebRTC falls back on TURN servers that externally relay communication between peers. For peers to connect, peer identifiers must be exchanged in a process known as signaling [23]. Our deployment uses a lightweight Node.js/Express signaling server hosted by the authors which initiates the connection before peer.js handles the P2P negotiation.

Audio capture is initiated with the Media Capture and Streams API, which grants access to the device's microphone in the browser. In order to go beyond WebRTCs default mono configuration, Session Description Protocol (SDP) munging is used to manipulate the session description protocol. The SDP negotiates the specifics of a real-time communication session between two devices, such as the codecs, formats, and network parameters. On the concert hall side, the audio streams from multiple locations are merged into a single multi-channel output stream, using `ChannelSplitterNode` to split the stereo stream from each location and `ChannelMergerNode` to merge all channels into a single 6-channel stream. This multi-channel stream is then rendered to the audience using a multi-channel speaker array.

3.2 Spatial Thinking and the Network

Each remote node, by virtue of its unique acoustic environment, contributes distinct reverberant modifications to the performance. These environments might include stairwells, bathrooms, resonant halls, or small, acoustically "dry" rooms–all of which color the sound differently. When multiple nodes are active simultaneously, the *Auxtrument* enables the superposition of different environments in real time. For instance, a resonant stairwell might be layered with the reflections and artifacts from the forest, resulting in a hybrid reverberation that is impossible to realise in any single physical environment. The merger of impulse responses acts as a form of cross-space convolution, dynamically combining the spatial character of each site into a composite sonic image. A performer might shift weight from one room to another over time, or move between groupings as a piece unfolds.

4. COMPOSITION TASKS

Wilson identifies several defining characteristics of networked music performance [28]. Foremost among the primary characteristics are latency and uncertainty, which are inherent to networked systems and cannot be entirely eliminated due to the speed of light constraint. Another essential aspect is the presence of at least two participants–a transmitter and a receiver. Wilson also emphasises the digital mediation of presence, where performers are co-located not physically but through technological infrastructure.

In contrast, secondary characteristics–including rhythm, harmony, and timbre–are musical elements traditionally shaped by the composer or performer. In the context of networked performance, however, these are contingent on how the composer engages with the primary characteristics. The negotiation between these two layers defines the aesthetic and structural parameters of the work. Finally, Wilson's tertiary characteristics are consequences of how certain rules are applied to these parameters. For example, using a variable jitter buffer to reduce latency might create unexpected rhythms between the original and network signals. These characteristics are emergent and not explicitly defined by either the composer or in the system.

In this section, we present two (2) original compositions for symphony orchestra and smaller performer subsets, written specifically for live performance using the *Auxtrument*. Rather than imposing rigid constraints, we embraced a practice-based approach, using network latency and uncertainty as creative prompts [6]. The following subsections detail the motivations and compositional strategies behind each work, using Wilson's characteristics as a framework, and illustrate how technological constraints can become musical opportunities.

4.1 Locations and Concert Setup

For the performance, we chose three (3) acoustically and environmentally unique locations: a forest, an underground tunnel beneath a city street, and a large stairwell (Figure 2). These sites were selected for their distinct sonic properties–reverberation time, spatial depth, and background noise. The forest included open-air diffusion and absorptive surfaces, lending an organic unpredictability that sometimes included wind, birds, and leaves crunching as people walked by. The tunnel, located below central Västerås, introduced low-frequency resonance cloaked in the dull roar of vehicles passing above. The stairwell, with hard concrete surfaces and vertical geometry, produced long reverberations.

Table 1 summarizes the approximate reverberation times and notable environmental features observed during the concert. It should be noted that the reverberation times are approximated based on recordings taken from the performance, since more quantitative measurements, such as the RT60, don't account for network latency or other transmission artifacts that affect the perception of resonance.

To present these spatial layers in the concert space, we used a 6-channel spatialisation setup. Odd numbered channels lined the left side of the hall and even channels lined the

Figure 2: Remote locations: forest (top left), tunnel (bottom left), and stairwell (right)

Table 1: Characteristics of remote locations

Location	Approximate RT	Environmental Features
Forest	< 0.5 s	Wind, bird calls, leaves
Tunnel	$\sim$2.0 s	Traffic noise
Stairwell	$>$3.5 s	Vertical concrete walls

right side. The orchestra was positioned at the front of the hall while the *Auxtrument* signal was projected across the sides of the hall. This allowed the streamed signals from the remote sites to envelop the audience. The intention was to contrast the stable, grounded presence of the local performers with the dislocated sound of distant acoustic spaces.

4.2 Composition 1: Murk

"Murk" expresses the alienation that immigrants experience in a foreign land. The composer, Austin Franklin, who is himself a recent immigrant to Sweden, chose to pair his composition with the sounds of the Swedish forest via the *Auxtrument* to capture the immersive experience of a foreign landscape. Here are the program notes for the piece:

> Since moving to Sweden in August 2023, my life has overflowed with new experiences. Murk is an exploration of these experiences, a journey through the conflicting emotions that have shaped my time here. The piece unfolds as a meandering stream of energy—at times foreboding, at times buoyant and promising. There is the exhilaration of immersing myself in a new culture and language; there is also the weight of Swedish winters, cultural isolation, and alienation. Through Murk, I hope to convey the complexities, depths, and polarity of this period of adapting to a land where light and darkness have played such a profound role in daily life.

Light and darkness are key themes of the piece, often expressed through extremes of musical parameters such as dynamics, register, and timbre. Other parameters such as harmony, rhythm, and style are intentionally ambiguous. This contrast represents the polar feelings of moving to a new land and understanding oneself in a new context.

4.2.1 *Latency and Uncertainty*

Most of the piece revolves around large chords that are repeated many times, where entrances between players are staggered. This is designed to create variation in the orchestra with each repetition while contributing to a blurring effect with the *Auxtrument*, whose latency was expected to extend across barlines. Further aiding this effect is a textual instruction given to performers in the performance notes for the piece: "The ensemble should be instructed to observe small changes in tempo from the conductor to help create a blurring effect." The tempo for the piece is in a near constant state of flux, changing gradually from one tempo to another between sections. This varies the distance between the notes in each chord and ensures that the expected overall sound is a blend of the concert hall and remote locations.

4.2.2 *Harmonic*

Throughout most of the piece, a single collection of pitches are used. The pitch material contains all pitches from an A melodic minor (ascending) scale, with the inclusion of the

lowered 6th scale degree that is designed to create dissonance: A, B, C, D, E, both F and F#, and G#. When notes from this scale are shuffled and orchestrated, many different chords and chord types can emerge. This helps contribute to the absence of a tonal center, as the predominant gesture at any given time becomes more helpful in establishing the harmony than the notes on the page themselves.

4.2.3 Textural

The piece uses latency from the *Auxtrument* to blend textures, as shown in Figure 3. When performing at extremely soft dynamics, sound fills the concert hall evenly when used with a location with long reverberation times, such as the stairwell. Moments such as these relied on the stairwell for this effect over the other locations which contained environmental sounds and shorter reverberation times.

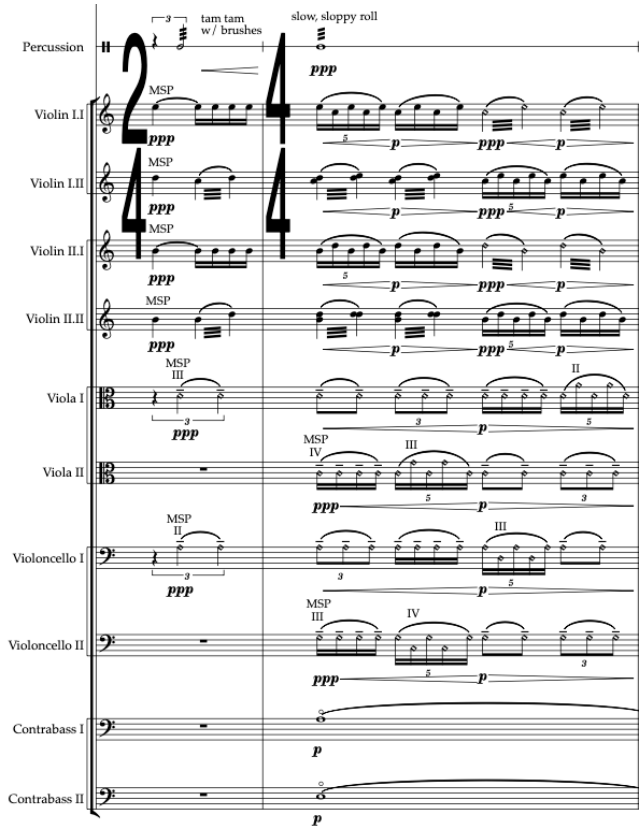

Figure 3: Textural Ambiguity in the string parts

4.2.4 Stylistic

"Murk" stylistically draws from features of Swedish folk music. One such example is the kulning, traditionally a herding call for livestock, which is presented in the high winds in the piece [24]. These sections use the forest location to include sounds from a Swedish forest, such as bird calls, wind, and the crunching of leaves from nearby passersby. Figure 4 shows bird calls imitated using the orchestra by employing the upper winds.

Other features of Swedish folk music include improvisation and ornamentation. Several moments throughout the score instruct performers to play short melodic lines freely,

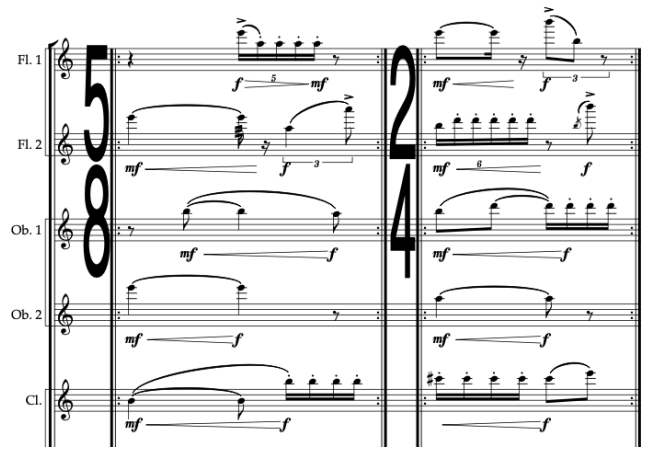

Figure 4: Bird imitation in the upper wind parts

marked "not in strict time" in the score (Figure 5). This occurs in the upper winds alongside strictly notated music in the brass, percussion, and strings. Ornamentation includes grace notes, trills, and tremolos.

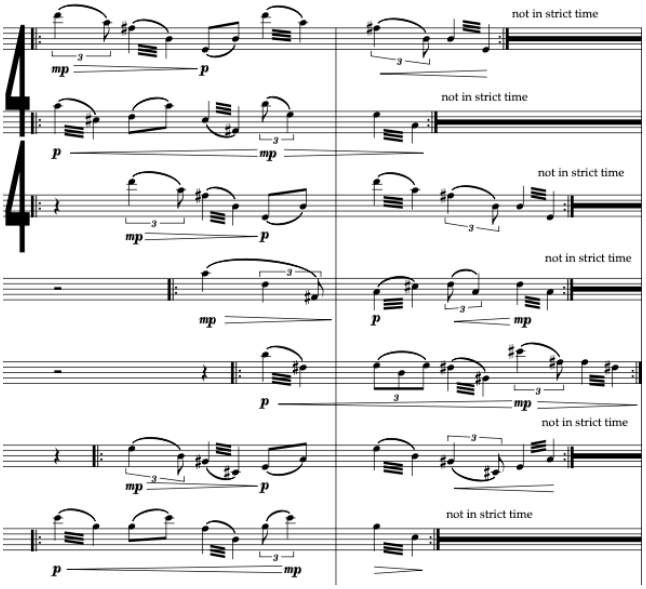

Figure 5: Improvisation inspired by Swedish folk music in the wind parts

4.3 Composition 2: Miss Saeki

"Miss Saeki", composed by Rikard Lindell, takes its name and narrative arc from a character in Haruki Murakami's novel *Kafka on the Shore*. The novel was analysed using grounded theory [15], an inductive method shaped by pragmatic and hermeneutic principles. Rather than producing a formal model, the method was used to generate aesthetic material: intuitive interpretations from the novel were coded and compared, forming the conceptual basis for the composition.

The plot of the novel *Kafka on the Shore* alternates between the interwoven storylines of many characters. The

Figure 6: An excerpt from "Miss Saeki" demonstrating a crossfade between two locations

piece "Miss Saeki" is principally inspired by the stories of the characters Kafka Tamura, a boy who flees an Oedipal-like fate, and Miss Saeki, a librarian who underwent a metaphysical transformation in her youth. The composition represents the arc of Miss Saeki's life; it begins with brightness and sensuality but is later overtaken by a quiet withdrawal. The composition reflects the suspension between dream and memory, between outer calm and inner intensity.

The original piece was written for modular synthesiser, clarinet, and cello and then transcribed for the orchestra. In the modular synthesis version, granular delays were used to create chord-like textures from monophonic ostinatos. The orchestration of "Miss Saeki" focused on recreating these ostinatos played as if a multi-tap delay or a granular delay had been used on acoustic instruments. For example, the violas and cellos play an ostinato that is delayed three (3) and five (5) sixteenth notes respectively from what the first cello part plays (Figure 7).

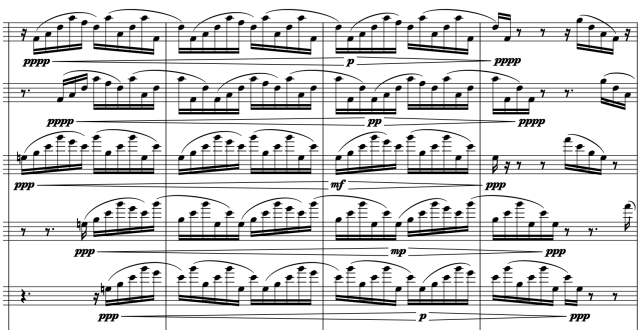

Figure 7: Four bars of Vla. 1, 2, Vc. 1–3, where the Vc. 1 is the main stem and the others plays the ostinato in canon.

4.3.1 Places

During the analysis of the novel, it became clear that three particular settings of the story play a decisive role in Miss Saeki's life: the primeval forest, the clearing resembling the bottom of a well, and the big city. These settings are embedded into the score via a dedicated *Auxtrument* part that instructs the performer when and how they should move between locations during the performance (Figure 6). The opening section of the piece represents Miss Saeki's early life of contentment while the rustling of leaves in the forest reverberate through the concert hall. Then comes Miss Saeki's break from reality, which echoes in the enclosed stairwell. The final section of the piece details the journey home. The crossfade from the forest to the city (tunnel) corresponds to this journey, and the piece concludes with the sound of rain produced by woodwind key clicks.

4.3.2 Harmonic

In the novel, Miss Saeki composes a song titled "Kafka on the Shore" many years before she meets the boy Kafka. "Kafka on the Shore" uses a melancholic, falling melody over the chords A/E and Am7/E. Other structural elements of the song represent Miss Saeki's metaphysical journey, where she experiences a split in her identity and reality. Miss Saeki describes it as such: "At the chorus two strange chords make their appearance. The first time I listened to them I was confused. To put it bluntly, I felt betrayed. Those sudden dissonances shook me and made me feel insecure" [21, p. 258]. This structure, among others, is drawn upon in the composition as chords build up in increasing dissonance to represent this journey.

4.3.3 Latency and Uncertainty

The latency and uncertainty of the *Auxtrument* is an integral part of the latter section of the piece, which represents Miss Saeki's death in the novel. The clarinet and oboe parts play the same arpeggio as the cello, viola, and bassoon parts, but are transposed upwards by a fifth and in canon by a dotted fourth. Meanwhile, the strings play in canon. The instruments are blended by the *Auxtrument*, whose latency helps disguise note entrances and highlight the swelling gesture achieved by the ensemble. Additionally, the *Auxtrument*'s latency contributes to a flowing effect between chords, like waves on the shore.

4.3.4 Rhythmic

In the novel, Murakami expresses the feelings of characters through the way they perceive the sound of their own heartbeat in different situations. This symbolism appears in "Miss Saeki" with a pizzicato double bass paired with a muted bass drum. In cardiology, heart sounds are described by the verbalisation "lub-dub" to refer to the contracting of heart valves [20]. The deeper and louder "dub" sound is on the downbeat of each bar and the "lub" is on the sixth and last eighth-note of each bar. The heartbeat changes throughout the piece in relation to how the heart sounds are described in the book. Functionally, this rhythm creates a strong pulse that helps performers synchronise the delayed sixteenth-notes.

5. REFLECTIONS

Central to both works is an ecological sensibility: environments are not solely musical artifacts but also sites of emotional and narrative resonance. Despite this, the two pieces diverge significantly in expressive intent and construction. "Murk" is affectively assembled from diaristic fragments and field recordings taken from live environments in Sweden, while "Miss Saeki" operates as a musical essay on a fictional character where the locations themselves are abstracted and used thematically.

Primarily, "Murk" uses temporal elasticity to evoke natural phenomena and unpredictability, while "Miss Saeki" associates rhythm more directly with embodied sensation (e.g., heartbeat), deploying it narratively and symbolically. "Miss

Saeki" relies on a steady pulse to provide a reference for all voices in the phase-shifted canon. Nevertheless, both compositions employ the latency of the *Auxtrument* to intentionally obscure the acoustic musics own perception. As a central strategy, they explore the fluidity of time and gesture through staggered entrances and layered textures.

Each composition approached the secondary characteristics narratively. The loss of rhythmic synchronisation with the *Auxtrument* for "Murk" lead to the formulation of feelings of ambiguity in an new culture. Likewise, the importance of location in "Miss Saeki" was a compositional asset that informed decisions such as key clicks to imitate rain and dynamic swelling to imitate waves on a beach. In different ways, each piece tests the boundaries between internal perception and external environment, proposing that time, place, and identity are shifting fields through which the listener moves.

It is important to acknowledge that the aesthetic analysis presented here is subjective. This subjectivity is not a weakness but an inherent feature of practice-based research methodologies, in which artistic practice itself becomes a mode of inquiry [6]. Through this lens, the works are understood as experiments in composing with latency, space, and environment. The subjective reflections of the composers are therefore integral to the research process, offering insights that cannot be fully captured by a purely technical evaluation.

6. FURTHER DIRECTIONS

While these two works demonstrate coherent compositional and aesthetic strategies, several areas remain open for further exploration. First, the embodied experience of performers could be documented through rehearsal notes, interviews, or autoethnographic accounts. Second, the reception and perception of NMPs–particularly when mediated through multichannel speaker systems or mobile devices–invite deeper study. After the concert, we invited audience members to write about their listening experience. We gathered approximately fifty (50) responses, which ranged from detailed written reflections to brief comments. While the data has not yet been analysed, initial impressions suggest that many listeners perceived the spatial layering of environments as immersive and at times disorienting. Future work will more rigorously analyse this audience feedback in order to better understand how perception can inform compositional strategy. Finally, future development could benefit from broader aesthetic contextualisation. Concepts such as hauntology [11], mediated intimacy [3], and ecological composition [18] may provide useful theoretical frames for understanding the affective and structural strategies deployed here. The blending of environmental sound, fictional reference, and temporal displacement positions these works within a growing lineage of contemporary music that may be better understood outside of traditional taxonomies.

7. CONCLUSIONS

This paper presents two (2) original works for live orchestra and a networked reverberation chamber instrument, focusing on the compositional strategies developed for Networked Music Performance (NMP). Drawing on Rebekah Wilson's characterisation of NMPs as both compositional and analytical frameworks, we document the creative process alongside our WebRTC and Web Audio API–based prototype named Auxtrument. Rather than treating network limitations as deficits, we approach them as creative prompts. This paper aims to contribute to the discourse on NMPs by foregrounding the aesthetic and structural affordances of contemporary web technologies in live musical settings.

8. ACKNOWLEDGMENTS

Information Retrieval in Embedded Systems for Audiovisual Artistic Processes (IRESAP) is supported by The Knowledge Foundation (KKS).

9. REFERENCES

[1] *Musical Transformations: Networked Performance in Intercultural Music Creation*. PGVIS, 2020.

[2] SonoBus, Feb. 2024.

[3] F. Attwood, J. Hakim, and A. Winch. Mediated intimacies: Bodies, technologies and relationships, 2017.

[4] J.-P. Cáceres and C. Chafe. Jacktrip: Under the hood of an engine for network audio. *Journal of New Music Research*, 39(3):183–187, 2010.

[5] J. Cage and E. Jandl. *Silence*. Wesleyan University Press Middletown, CT, 1961.

[6] L. Candy. Practice Based Research: A Guide. Technical Report V1.0, Creativity & Cognition Studios, Nov. 2006.

[7] C. Chafe, M. Gurevich, G. Leslie, and S. Tyan. Effect of time delay on ensemble accuracy. In *Proceedings of the international symposium on musical acoustics*, volume 31, page 46. Nara, 2004.

[8] J. Cychnerski and B. Mróz. Architecture design of a networked music performance platform for a chamber choir. In *European Conference on Advances in Databases and Information Systems*, pages 437–449. Springer, 2022.

[9] M. Dessen. New polyphonies: Score streams, improvisation and telepresence. *Leonardo Music Journal*, 20:21–23, 2010.

[10] V. Fischer. Case study: Performing band rehearsals on the internet with jamulus. *URL: https://jamulus.io/PerformingBandRehearsalsontheInternetWithJamulus.pdf*, 2015.

[11] M. Fisher. What is hauntology? *Film quarterly*, 66(1):16–24, 2012.

[12] G. Föllmer. Electronic, aesthetic and social factors in net music. *Organised Sound*, 10(3):185–192, 2005.

[13] B. Ford, P. Srisuresh, and D. Kegel. Peer-to-peer communication across network address translators. In *USENIX Annual Technical Conference, General Track*, pages 179–192, 2005.

[14] A. Franklin, D. Hedin, R. Lindell, and H. Frisk. Merging places: A real-time distributed live reverberation chamber. In *2024 16th International Conference on Quality of Multimedia Experience (QoMEX)*, pages 54–57. IEEE, 2024.

[15] B. Glaser and A. Strauss. *The Discovery of Grounded Theory: Strategies for Qualitative Research*. Mill Valley, Sociology Press, 1967.

[16] P. K. D. S. S. J. M. D. Haleplidis, E. and O. Koufopavlou. Software-defined networking (sdn): Layers and architecture terminology. Technical Report No. rfc7426, Internet Research Task Force (IRTF), 2015.

[17] M. Iorwerth. *Networked music performance: Theory and applications*. Focal Press, 2023.

[18] D. Keller and A. Capasso. New concepts and techniques in eco-composition. *Organised Sound*, 11(1):55–62, 2006.

[19] E. Lakiotakis, C. Liaskos, and X. Dimitropoulos. Improving networked music performance systems using application-network collaboration. *Concurrency and Computation: Practice and Experience*, 31(24):e4730, 2019.

[20] A. M. Media. Heart sounds and heart murmurs. retrieved 2025-06-11.

[21] H. Murakami. *Kafka on the Shore*. Nordstedts, 2005.

[22] P. Oliveros. *Deep listening: A composer's sound practice*. IUniverse, 2005.

[23] D. Rodríguez Baquero. Analysis of webrtc signaling. 2021.

[24] S. Rosenberg. Kulning–an ornamentation of the surrounding emptiness: about the unique scandinavian herding calls. *Voice and Speech Review*, 8(1):100–105, 2014.

[25] K. Tsioutas, G. Xylomenos, and I. Doumanis. Aretousa: A competitive audio streaming software for network music performance. In *Audio Engineering Society Convention*, volume 146, 2019.

[26] I. T. Union. Objective quality measurement of telephone-band (300-3400 hz) speech codecs. *ITU-T Recommendation*, 861, 1998.

[27] G. Weinberg. Interconnected musical networks: Toward a theoretical framework. *Computer Music Journal*, 29(2):23–39, 2005.

[28] R. Wilson. Aesthetic and technical strategies for networked music performance. *AI & society*, 38(5):1871–1884, 2023.