FROM SPRAWL TO MËSH: NETWORKED MUSIC SYSTEMS FOR TOURING AND STAGE INTEGRATION

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ABSTRACT

MËSH is a wireless, networked system for music performances and installations. The next development of the SPRAWL system, it consists of a set of interaction nodes that are wirelessly dispersed throughout a space. The system distributes sound generation, control, and interaction across compact, self-contained nodes, each capable of operating independently while remaining networked through OSC-based communication. Designed for use as a performance instrument and for interactive installations, the MËSH system is portable and can be set up quickly. The design is motivated by prior experience with SPRAWL, a wired distributed ensemble system, and reflects a shift toward lightweight, decentralized infrastructure. This paper outlines the system's hardware and software architecture and documents its use across domestic and international performances, installations, and workshops. This evaluation contributes a practical and scalable approach to networked music performance, emphasizing portability, reduced technical overhead, and adaptability to diverse venues.

1. INTRODUCTION

Distributed music systems expand the possibilities for contemporary electroacoustic ensembles rethinking how sound, control, and interaction are organized across performers and spaces. The initial advantage is physical; distributed ensembles are malleable to the space and create ensemble configurations that are impossible with a classic PA. This architecture increases the range and richness of interaction between musicians, allowing for more dynamic, responsive, and spatially nuanced collaboration. At the same time, distributed systems support the flexible dissemination of scores and performance instructions in real time, enabling adaptive and algorithmically driven compositions. They also open new avenues for audience participation, transforming listeners into active contributors who can influence musical outcomes. Together, these affordances position distributed ensemble systems as a powerful paradigm for extending the scope of electroacoustic performance.

While these systems enable rich modes of interaction and control, they often require complex technical infrastructure, including centralized servers, multichannel audio routing, and extensive networking between performers. As a result, deploying such systems in real-world performance contexts can be challenging. Setup time is frequently substantial, and the need to transport and configure specialized equipment can limit opportunities for rehearsal, touring, and performance in diverse venues. A particular constraint in many existing systems is the reliance on wired networking. Ethernet-based architectures provide reliable, low-latency communication, but introduce significant practical challenges. Cabling complexity increases with ensemble size, constrains the physical placement of performers, and can complicate setup in unfamiliar or temporary venues.



Figure 1. A SPRAWL V2 access point.

This paper presents MËSH, a portable networked ensemble system designed to support rapid deployment in diverse performance environments. [1] The system introduces a wireless local area network architecture that replaces portions of the wired infrastructure with flexible, cable-free connectivity. In addition, a streamlined setup workflow enables fast system initialization and configuration, reducing the time to deploy the system in new venues. Together, these features support a more flexible and portable approach to networked ensemble performance.

Section 2 will outline the foundational and recent work in this domain. Next, sections 3 and 4 will discuss the pathway from SPRAWL [1] to MËSH, highlighting the technological similarities and differences between the systems and case studies where each system was used. A timeline

[1] https://github.com/L42i/MËSH

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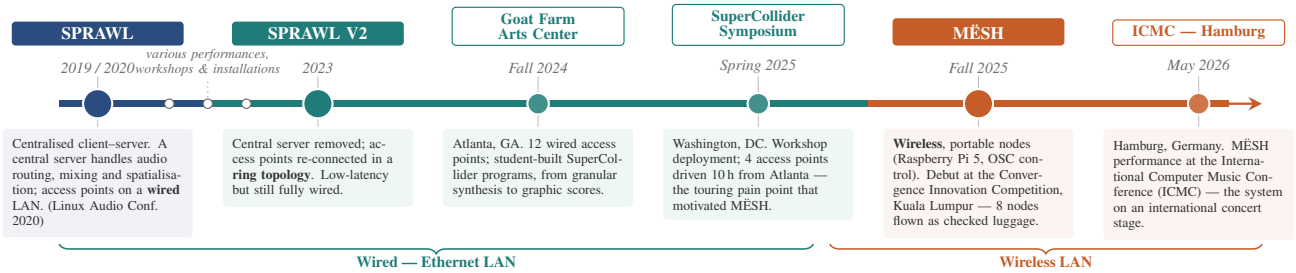

Figure 2. Evolution from SPRAWL to SPRAWL V2 to MËSH: a move from a wired, server-centric architecture toward a wireless, decentralised one, punctuated by the field deployments that exposed the touring overhead.

for this development is shown in Figure 2. Finally, section 5 will examine the key takeaways from MËSH system development and use.

2. RELATED WORK

Networked and laptop-based musical ensembles have a long history of exploring distributed interaction through digital systems. One of the earliest and most influential examples is The Hub [2], a pioneering computer network ensemble active from the 1980s to the 1990s. The Hub introduced the concept of interconnected performers exchanging control data in real time, establishing a foundation for network-based musical interaction and collaborative composition.

Building on these ideas, laptop orchestras have emerged as a prominent paradigm for ensemble performance with networked computers. The Princeton Laptop Orchestra (PLOrk) [3, 4] established a model based on standardized "meta-instruments," where each performer uses a laptop paired with a dedicated loudspeaker and controller. This approach emphasizes both individual agency and collective interaction, supported by network communication and shared software environments. Following this model, the Stanford Laptop Orchestra (SLOrk) [5] further developed the concept with a focus on spatialized sound and distributed performance practice.

The Linux Laptop Orchestra (L2Ork) [6] extends the laptop orchestra paradigm through the use of open-source software and flexible system configurations. By prioritizing accessibility and adaptability, L2Ork supports a wide range of hardware and software setups, enabling broader participation and experimentation in networked ensemble performance.

In contrast to the standardized approach of PLOrk and SLOrk, the Huddersfield Experimental Laptop Orchestra (HELO) [7] emphasizes diversity in both hardware and software. HELO brings together diverse systems within a single ensemble, reducing technical constraints and encouraging creative exploration, while still relying on networked communication for coordination and interaction.

Other recent work in networked and distributed music systems has expanded beyond co-located ensembles toward telematic and hybrid performance environments. Networked Music Performance (NMP) is now an established research area focused on enabling musicians to interact over communication networks under strict latency and audio quality constraints [8, 9]. Contemporary studies emphasize that even small delays can significantly impact synchronization, motivating ongoing research into low-latency transmission protocols and perceptual thresholds [10].

A growing ecosystem of software platforms has emerged to support these practices. In particular, JackTrip [11] has been widely adopted in both research and performance contexts due to its support for uncompressed, bidirectional audio streaming and its ability to achieve latency below perceptually critical thresholds under appropriate network conditions.

In parallel, recent artistic and theoretical work has emphasized the aesthetic implications of networked performance. Rather than treating latency and network artifacts solely as technical limitations, some approaches incorporate these constraints into compositional practice, framing telematic performance as a distinct medium with its own experimental qualities [12].

Finally, there has been increasing interest in decentralized and embedded approaches to distributed music systems. Research into wireless distributed sound installations and Internet of Musical Things frameworks highlights the potential of low-cost, networked devices to support flexible, scalable, and site-specific performance configurations [13].

These developments align closely with the design philosophy of MËSH, which emphasizes portability, minimal infrastructure, and adaptable deployment across diverse performance contexts.

3. SPRAWL V2: THE WIRED PREDECESSOR

Launched in 2019/2020, the original SPRAWL system [1] was based on a centralized client–server architecture designed to support networked ensemble performance. A central server was responsible for audio routing, mixing, and spatialization, acting as the core processing unit for the entire system. Performers interacted with the system through distributed access points, each of which is connected to the server via a wired local area network.

Audio from each access point is transmitted to the server, where it is processed and redistributed to other performers and to the spatialization system. In addition to audio streaming, control communication is handled through Open Sound Control (OSC) [14], allowing performers to

adjust parameters such as levels, routing, and spatialization in real time.

In 2023, SPRAWL V2 updated original SPRAWL hardware and removed the centralized server. Access points now connected in a ring topology.

This architecture provides a stable and low-latency environment for ensemble interaction, but relies on wired network connections between all components, contributing to the overall complexity of system deployment.

3.1 The Goat Farm Arts Center - Atlanta, Georgia

In fall 2024 SPRAWL V2 was utilized at The Goat Farm Arts Center in Atlanta Georgia. 12 access points were set up at the space, each featuring a musician playing their chosen instrument into the system. The concert consisted of a set of student created programs for SPRAWL V2, ranging from real-time spatialized granular synthesis to displaying a graphic score visible to audience and musicians. Figure 1 shows an access point at the concert. At this access point, the drum was captured by a microphone connected to the audio interface and then fed into the system. Other access points were designed for the audience to play and participate with the ensemble.

3.2 SuperCollider Symposium - Washington DC

Having been taught in the classroom in fall 2024, spring 2025 brought Sprawl V2 to Washington DC for a workshop at the SuperCollider Symposium. The workshop focused on successful techniques for working with SPRAWL V2 and generalizable techniques for working with distributed performance systems. As well as demoing past uses for SPRAWL V2, the system was connected in a ring topology and attendees designed the audio processing for their access point. A picture from the workshop is shown in Figure 3.



Figure 3. Workshop at the Supercollider Symposium.

Four SPRAWL V2 access points were transported in a midsize vehicle over a ten-hour drive from Atlanta to Washington, DC.

4. THE MËSH SYSTEM

In response to traveling with SPRAWL V2, the MËSH system is designed as a distributed performance infrastructure that prioritizes portability, efficiency, and flexibility without sacrificing expressive capability. At its core, the system rethinks traditional electroacoustic setups by minimizing physical and logistical overhead while maximizing spatial and interactive possibilities.

A primary design goal is portability, achieved through the use of compact, self-contained nodes that can be easily transported and deployed in a wide range of venues. Each node integrates computation, audio I/O, and control into a single unit, resulting in a minimal hardware footprint that reduces the need for bulky racks or centralized equipment.

The system also emphasizes a wireless network architecture. Instead of extensive analog or digital audio runs, MËSH relies on network-based communication between nodes. This significantly decreases setup complexity and improves reliability in dynamic environments. As a result, nodes can be placed with a high degree of flexibility, enabling unconventional stage layouts, distributed audience configurations, or site-specific installations where traditional infrastructure would be impractical.

From an architectural perspective, MËSH operates over a dedicated wireless network, with each node acting as both an independent sound source and a participant in a larger, coordinated system. Control data, such as timing, parameter changes, and interaction events, is transmitted using OSC, allowing for low-latency, high-resolution communication. This structure supports a wide range of performance paradigms, from tightly synchronized ensemble playing to more decentralized, emergent behaviors.

The current implementation of MËSH does not support audio streaming between nodes; instead, each node generates and processes sound locally while sharing control data via OSC. This design choice reduces bandwidth requirements, simplifies network configuration, and improves system robustness in wireless environments, where maintaining low-latency, high-quality audio streams can be challenging. Future iterations of MËSH will explore integrating audio streaming capabilities to expand possibilities for more tightly coupled ensemble interaction.

4.1 Hardware

As illustrated in Figure 4, each node is centered around a Raspberry Pi 5. The system integrates a 10.1-inch ROADOM touchscreen for local control and visualization, along with a Focusrite Scarlett 2i2 audio interface to support high-quality input and output. All nodes are networked through a dedicated router, enabling low-latency communication and coordinated behavior across the ensemble. Typically supplied by the venue, a powered loudspeaker is located with each node. Past MËSH installations have featured EMEET C960 webcams at each node to facilitate audience interaction.

Video nodes extend this architecture by incorporating Beelink S12 Mini PCs running Ubuntu 24.04 LTS. Connected to the same network as the audio nodes, these units receive OSC messages and translate them into generative



Figure 4. Hardware for one MËSH node.

visual outputs, often implemented in Processing. They are also used to display graphic scores. This integration of synchronized audio and visual nodes supports a cohesive, multimodal performance environment.

4.2 Software

All nodes run a Linux-based operating system (Debian 13 "Trixie"), providing a stable and flexible environment for real-time audio processing and network communication.

Sound synthesis, processing, and control logic are implemented in SuperCollider. Each node runs SuperCollider independently, allowing for localized audio generation while also responding to networked control messages. Communication between nodes is handled via OSC, which facilitates the exchange of musical data such as timing information, parameter changes, and performer interactions. This architecture enables both tightly synchronized behaviors and more decentralized, emergent performance structures.

For visual processing and audience interaction, OpenCV [15] is used in conjunction with webcams to capture and analyze video data in real time. This information can be mapped to musical parameters or used to influence generative visuals on video nodes. Together, these software components form a cohesive ecosystem that supports scalable, interactive, and spatially distributed performance.

To streamline deployment and maintenance, the MËSH workflow incorporates automation through Ansible [16]. This enables centralized configuration, software updates, and system management across all nodes simultaneously. Furthermore, Ansible scripts are key to deploying MËSH in performance contexts. Pieces and installations become Ansible playbooks that configure all audio and video nodes at the click of a button. This ensures consistency throughout the system and significantly reduces setup time, making it possible to quickly replicate or reconfigure the network for different performance contexts.

4.3 Convergence Innovation Competition - Kuala Lumpur, Malaysia

In Fall 2025, MËSH was deployed internationally for the Convergence Innovation Competition Asia, where it was presented in Kuala Lumpur, Malaysia. This deployment served as a practical evaluation of the system's portability, ease of setup, and flexibility across different use cases. An eight node version of the system transported internationally as standard checked luggage, with all node and networking equipment packed into three Gator road cases, as shown in Figure 5. All required gear fit into the cases, except for a speaker for each node (which were supplied by the venue).



Figure 5. The complete system in cases.

This demonstrated a significant reduction in logistical overhead compared to the previous SPRAWL systems.

Upon arrival, the system was set up in a new venue with minimal outside infrastructure requirements. The wireless LAN architecture eliminated the need for extensive Ethernet cabling, allowing access points to be distributed freely throughout the space as shown in Figure 6. The setup process involved powering the router and nodes, establishing the wireless network, and initializing the audio routing and control systems. This process was entirely automated with Ansible scripts. Altogether, it took two people two hours to setup and soundcheck the system.

The system was used in two distinct modes: as an interactive installation and as a live performance tool.

4.3.1 Installation

In the installation setting, audience members were able to engage with the system through a camera at each node. Using an OpenCV python script, the cameras tracked total pixel movement as a proxy for the movement of audience members through the space. The data from each node was shared across the network via OSC and used as con-

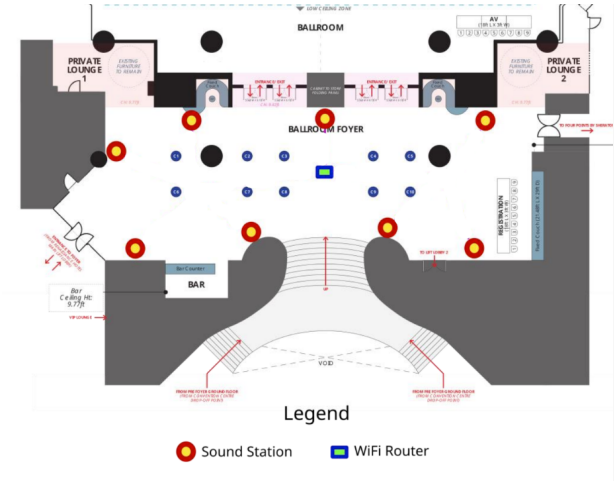

Figure 6. Installation of MËSH in Kuala Lumpur.

trol data for a SuperCollider sound field. The touchscreen at each node featured a visualization that showed the direction each pixel traveled between frames. This visual feedback system, shown in Figure 7, invited the audience to interact with the system and discover how their active and passive movements affect the sound field's state.

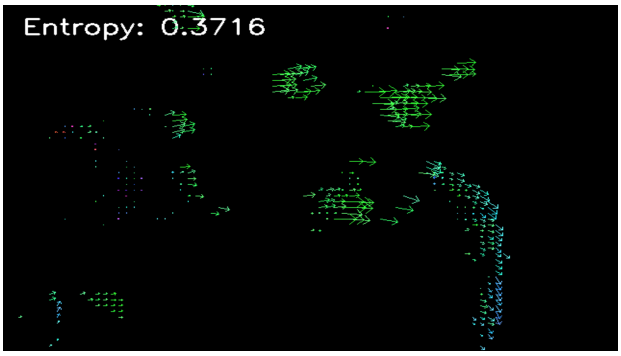

Figure 7. Visualization of the entropy in the PI's screen.

4.3.2 Performance

In the performance context, MËSH supported a networked ensemble configuration, enabling performers to control their individual audio streams. Using Ansible, the graphic score DISCOUNT [2] was synchronously deployed across all nodes. Musicians viewed the score from the touchscreen at their node. Simultaneously, the video nodes displayed the score for the audience. A musician playing the graphic score is shown in Figure 8. The wireless connectivity facilitated flexible placement of performers within the space, allowing performers and sound alike to fill the room.

4.4 International Computer Music Conference - Hamburg, Germany

Spring 2026 saw the deployment of MËSH to the International Computer Music Conference. Similar to the previous deployment, the system traveled in 3 road cases and

[2] https://hvc.berlin/discount/



Figure 8. Dr. Ahmad Daudzi Musib performing with the MËSH system

speakers were provided by the conference. Using the process described in the previous section, it took two people two hours to setup and soundcheck the system in an unfamiliar venue. In Hamburg, the system was used to run a workshop and as an installation.

4.4.1 Workshop

The one hour workshop introduced participants to the MËSH platform through a highly interactive, hands-on learning experience designed to build both conceptual understanding and introduce techniques for distributed music performance systems. Attendees explored the platform's capabilities through four guided demonstrations that showcased key workflows, features, and real-world applications of MËSH. Each demonstration was paired with structured prediction activities, facilitated discussion, and exercises that encouraged participants to actively analyze system behavior, identify potential use cases, and evaluate tradeoffs. The session concluded with a discussion that enabled participants to identify opportunities for integrating MËSH (or MËSH type systems) into their own workflows and organizational contexts.

4.4.2 Installation

The installation featured a reworked version of the installation displayed in Kuala Lumpur. The sound design was completely redone and the visual component was tooled to be computationally more efficient. The installation ran autonomously for 8 hours and was attended by roughly 100 people from the ICMC community. The installation in action is shown in Figure 9.

5. CONCLUSION

As a portable, wireless alternative to traditional networked ensemble systems, MËSH addresses key limitations in setup complexity and deployment flexibility observed in prior systems such as SPRAWL V2. By distributing computation, sound generation, and control across self-contained nodes, MËSH enables a scalable and spatially flexible performance environment without reliance on centralized infrastructure or extensive wired networking.



Figure 9. Installation with MËSH at ICMC 2026.

Overall, the international deployment demonstrated the viability of MËSH as a portable and adaptable system for networked musical performance. The ability to transport, set up, and operate the system in a new environment with minimal infrastructure highlights its potential for touring ensembles, temporary installations, and other applications requiring rapid and flexible deployment.

Through its integration of wireless communication, OSC-based control, and automated deployment via Ansible, the system significantly reduces setup time while maintaining the expressive capabilities of distributed electroacoustic performance. The case studies in Kuala Lumpur and Hamburg demonstrate that MËSH can be transported, configured, and operated in a new environment with minimal logistical overhead, supporting both interactive installations and ensemble performance contexts.

Future MËSH iterations will explore the options for wireless audio streaming between nodes. Furthermore, we will also examine the benefits of switching from Raspberry Pi nodes to laptop nodes, generalizing the MËSH hardware overhead.

Ultimately, MËSH contributes to ongoing work in networked music performance by prioritizing portability, accessibility, and adaptability. These qualities make it well-suited for a wide range of applications, including touring ensembles, site-specific works, and participatory installations, and suggest a broader shift toward lightweight, decentralized approaches in electroacoustic music systems.

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