REALTIME SONIFICATION AND VISUALISATION OF NETWORK METADATA (The *NetSon* Project)

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ABSTRACT

The development of the *NetSon* project is described, from its exploratory origins in a polymedia work for an art and technology event, to real-time continuous sonifications of network metadata. The project currently exists in two forms: bespoke multichannel installations and a centrally-configured live video version streamed to the internet. These sonifications are accompanied by realtime visualizations that have been developed to assist in the immediate recognition of the dynamically configurable sonification mappings. A review of related work and a detailed discussion of the sonification mapping models are outside the scope of this paper.

1. INTRODUCTION

NetSon is a network data sonification project that has been developed to sonically reveal aspects of the temporal structure of computer network data flows in a relatively large-scale organization. It grew out of a 2014 Art and Technology project at Fraunhofer Institute for Integrated Circuits IIS (IIS hereafter), entitled *Corpo Real*.

The title is a play on the idea of revealing of a (corpor)ation's corporeal (bodily) existence through the connective neural "tissue" of its digital networks. While the aesthetic impulse of *Corpo Real* is more transcendental (after Baumgarten [1] and Kant [2]) and *NetSon* more pragmatist (after Dewey [3] and Merleau-Ponty [4]), the distinction is not considered categorically significant for, to paraphrase Dewey, the important question is not "is it music?" but "when is music?"

This artistic-exploration-first approach to sonification design proved useful as it provided an opportunity to build software tools to explore wider potential scenerios in the early development stages than a more goal-directed utilitarian approach would have. For example, in one of the *Corpo Real* pieces, *net-flow-path*, pitch and time are used to represent the flow rate through the whole network by employing a mapping of inter-event time differences to pitch class: The pitch rises and falls as the duration between network flow events decreases and increases. Its melodic nature thus helps the listener hear (remember, mentally compose) the structure of the temporal flow, which is being sonified at 100 times slower than real-time. A further motivation was that the nature of this load fluctuation was unknown to the network administrators and it was thought, following earlier work [5], that such a tool might enable those monitoring the network to learn to detect network malfunctions earlier that might otherwise be possible. The *Corpo Real* animations can be viewed online [6] and other material associated with the exhibition are available on the IIS website [7].

The remainder of this paper discusses the major components of *NetSon*, followed by some preliminary conclusions and some possible future developments. The discussion follows the order of numerical labels in the schematic of Figure 1.

2. NETWORK METADATA

Two major issues in capturing something of the character of modern institutional networks are the sheer volume of the data and security risks involved in accessing it.

2.1. Volume of data

There is not an accurate account of how many gigabytes of data flow thorough the IIS network every second during a 24 1
hour period; even just to count and categorize them would place such unacceptable load on the network's operation as to render it unviable. Furthermore, the numbers of sub-networks that operate in such an environment, some private, some virtual as well as various kinds of connections (cable, WIFI, Bluetooth etc) another means of monitoring network traffic is required.

The tool that IIS network administrators use is *sflow* which employs a sampling technique: a data packet or small group of data packets are 'plucked' from the stream at a known sampling rate as they pass through a switch. This random collection of packets is 'wrapped' with a meta-packet that identifies such things as the time of creation, source and destination of the packets [8]. Because the sampling rate is fixed (but configurable), the time difference between *sflow* metadata packets is the amount of time (in microseconds) between successive samples, thus providing information of the network flow-rate (i.e the load on the system); a feature explored in *net-flow-path*, mentioned earlier.

2.2. Data handling

Exposing any aspect of an organization's data network to scrutiny is a potential security threat and needs to be 2
undertaken with a great deal of caution, especially in circumstances where the organization derives significant commercial benefit from its intellectual property. The following procedures were thus applied: (a) All data is transferred through secure networks and portals (e.g. encrypted VPN) and, where possible, between fixed IP addresses. (b) Only metadata (*sflow* packet data) is sonified. (c) All source and destination IP addresses are stripped of their least significant byte before being made available to the sonification software. While anonymizing data impacts on the ability to identify and thus sonify for specific locations, it has the benefit of reassuring individuals that their activity are not being under surveillance.

Filtered data is backed-up into a 24-hour round-robin 3 repository for off-line (non-realtime) use as required for such operations as further analysis, adjustments to the mapping model, sound mixing adjustments and the exploring the sonification of newly identified features.

The data is then made available to the sonification 4 software via a FIFO that it reads and clears as part of each reads a configuration file provided by the network engineers in order to organizationally identify the IP addresses being received. The sonification software *Sonipy* [9], reads a file provided by the network engineers in order to organizationally identify the IP addresses being received. While this leads to another layer of abstraction, the advantage is that NetSon can automatically adjust to any changes in the network configuration that are inevitable from time to time.

Which particular IP address streams are sonified is under the control of a user interface that has graphic selection, 5 syntactic and logical components. The computer code is modularized to enable routines to be dynamically generated if necessary.

3. SONIFICATION MAPPING MODELS

6 Flow rates of the various network streams vary considerably during 24-hour-workday-holiday cycles, it was decided to make a sonification that reveals a combination of interesting features (such as printer server activity) and load-balancing through the identification of the source and destination of the packets passing through the *sflow* switch. Such addresses are in two categories: known (mostly within the organization's network) and unknown (arriving from or being delivered to locations outside the network. For unknown addresses a glissando was applied, the destination frequency of which was derived from the (virtual) distance of the unknown IP address and that of the organization.

Given that some versions of *NetSon* are run in public places, the sound field needs to be able to support a diversity of distinguishable event types while not being "overtly annoying or distracting" [10] i.e. able to be heard, listened to when necessary with a minimum of fatigue. One might observe, somewhat wryly perhaps, that this aim was shared by Muzak [11] and pre-empted by Eric Satie's *musique d'ameublement.*

For this reason, in contradistinction to much parameter-mapping sonification, 'melodic' pitch structures are used very sparingly in favour of a diverse *klangfarben* (timbral) palette.

Simple one-to-one mapping results in the servers completely dominating the displays. To date, various techniques have been used to rebalance this effect of such features however a detailed discussion of these these features is outside the scope of this paper, as is a more general discussion of the techniques employed to produce coherent sound scenes with minimum inter-field interferences.

4. PERCEPTUALISATION

4.1. Sound

7 The sound output format is varied according to the intended installation. For public spaces, the sound can be rendered in multichannel ambisonic format. For the online version it is rendered in stereo.

4.2. Visualization

A dynamically configurable realtime graphical plot has been developed to assist in the identification of the information 8 being sonified. The visualization software receives sound-rendering parameters from sonification software in real-time in a simple UDP format.

By providing a visual representation of recently past events, it also assists the user to identify patterns and features that might otherwise be missed: There is a subtle balance between the ears leading the eyes and the eyes supporting short-term aural memory.

4.3. Internet Streaming

A public version of *NetSon* is available via a live video 9 stream from the IIS website [7].

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6. REFERENCES

[1] A. G. Baumgarten, *Metaphysics. A Critical Translation with Kant's Elucidations, Selected Notes, and Related Materials* translated and edited by Courtney D. Fugate and John Hymers, London, New York: Bloomsbury Publishing, 2013.

[2] I. Kant, *Critique of Judgement*, Translated by James Creed Meredith, Oxford: Oxford University Press, 2007 (orig. 1952).

[3] J. Dewey *Art as Experience* New York: Penguin, 2005 (orig. 1934.)

[4] M. Merleau-Ponty, Trans: Colin Smith. *Phenomenology of Perception*, London: Routledge, 2005. (Orig. in French 1945.)

[5] W. W. Gaver, R. B. Smith and T. O'Shea. "Effective sounds in complex systems: The arkola simulation", In S. Robertson, G. Olson, and J Olson, editors, *CHI '91 Conference on Human Factors in Computing Systems*, pages 85–90, New Orleans, 1991. ACM Press/Addison-Wesley.

[6] https://www.youtube.com/channel/UCDm-NuvqwRkUudUH4Azy7ng

[7] http://www.iis.fraunhofer.de/

[8] http://www.sflow.org/about/

[9] D. Worrall, M. Bylstra, S. Barrass, and R. Dean. SoniPy: The Design of an Extendable Software Framework for Sonification Research and Auditory Display. In *Proc. Int Conf. on Auditory Display (ICAD)*, Montreal, Canada, 2007.

[10] P. Vickers. "Sonification for Process Monitoring" in T. Hermann, A. Hunt, and J. G. Neuhoff (Eds.) *The Sonification Handbook*, Berlin, Germany: Logos Publishing House, 2011, ch. 18 pp. 455-491.

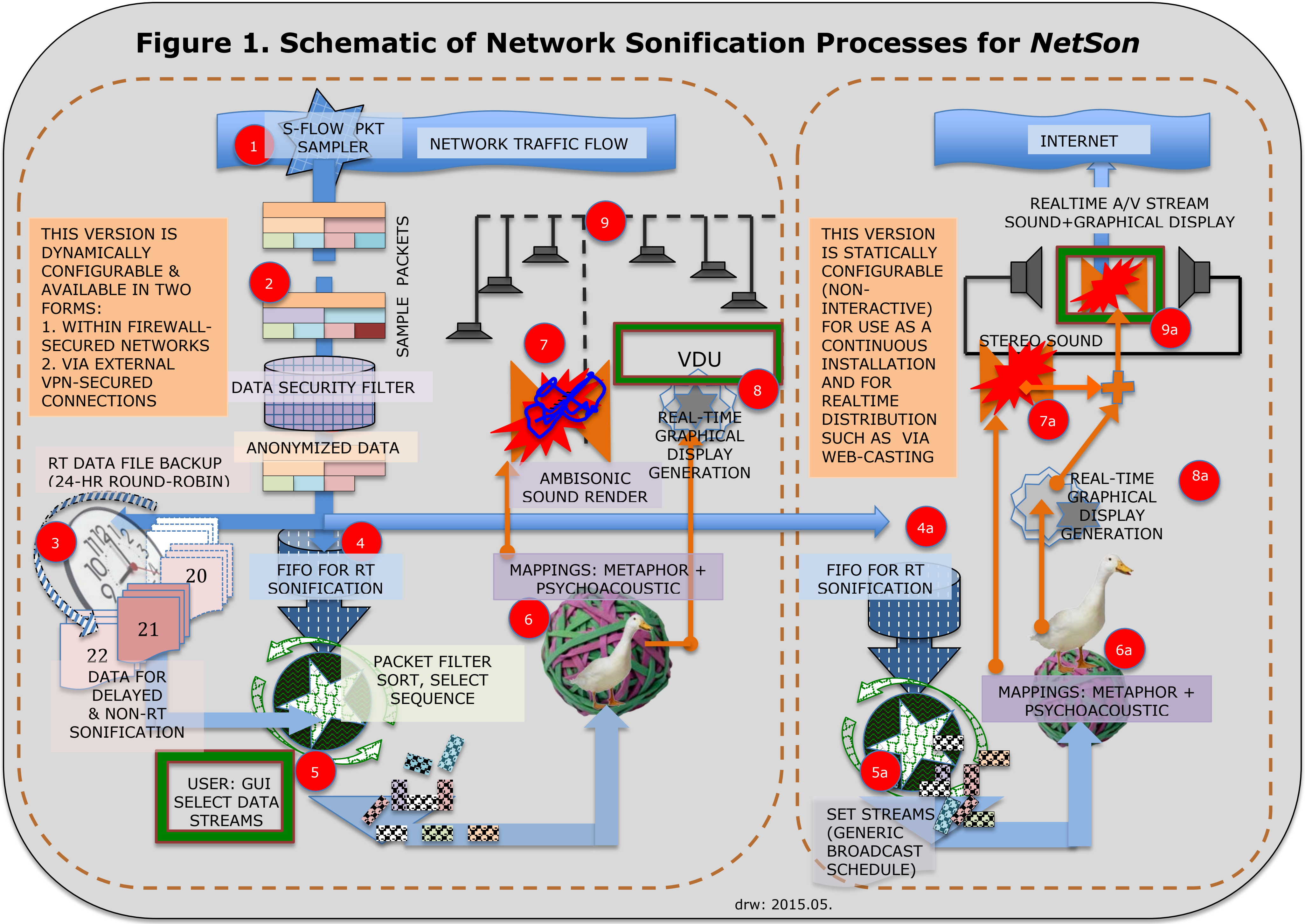

Figure 1. Schematic of Network Sonification Processes for *NetSon*