

**Maria Eriksson**

**UNPACKING ONLINE  
STREAMS**

**APRJA Volume 7, Issue 1, 2018  
ISSN 2245-7755**

**CC license: 'Attribution-NonCommercial-ShareAlike'.**

## Introduction

At face value, streaming services have often been associated with smoothness and steady supply. Drawing on metaphors of aquatic flows and currents, streaming evokes an imagery of data as a peaceful and precious natural resource. Yet below the seemingly calm interfaces of platforms, complex data arrangements reside—data arrangements that absorb users into circuits of capital and link together data infrastructures across vast geographic distances. In 2016, it was estimated that mankind produced a staggering 71.3 exabytes of Internet traffic per month (Cisco), and significant part of this data traffic originates from streaming services, who now make up a multi-billion dollar industry with wide-reaching environmental impacts (Greenpeace “Clicking Clean: A Guide to Building the Green Internet”; Avgerinou, Bertoldi and Castellazzi).[1]

Currently, one of the world’s most influential streaming services for music is Spotify—a company that administrates the listening practices of over 70 million paying subscribers, and a total of over 140 million active users around the globe (Plaugic). Spotify exemplifies how streams “are highly capitalized and... [operate] at massive scales under the contemporary conditions of a globalized economy” (Soon 195). In 2016, it was reported that Spotify handles more than 38 terabytes of incoming data per day, while simultaneously storing more than “70 petabytes of... data about songs, playlists etc.” (Sarraf). During 2016, Spotify also declared that its backend system was capable of pushing more than “700 000 events per second halfway across the world,” where an event refers to any action being performed by a user on the Spotify client (Maravić). Given that Spotify’s paying customer base has more than doubled since 2016 (Plaugic;

McIntyre), the scope of these data transmissions are significantly larger today. In short, Spotify exerts great logistical power over global music consumption.

This article reflects on the visible and invisible layers of data traffic that permeate streamed music distribution on Spotify. Drawing from studies of media infrastructures (Blok et al.; Larkin; Parks and Starosielski ed.), it explores the kinds of data transmissions that a single play on Spotify can trigger. In doing so, it seeks to highlight “the extensive, patch-worked, and varied electrical infrastructures that undergrid world processes of mediation” (Parks “Stuff You Can Kick” 364). A focus on data infrastructures—that is, digital environments that are built to handle data logistics and “coordinate, capture, and control the movement of people, finance and things” (Rossiter 4)—involves a move away from studying content and towards investigations of materiality, distribution and territoriality. To borrow from Christian Sandvig, it implies paying attention to how technologies work, rather than what people say with them (90). How might we begin unpack and intervene in Spotify’s streamed data infrastructure? By what means can the nature of streamed network transmissions be explored?

In times of exceeding data growth, I suggest there is value in resisting the push to approach network infrastructures at scale and at the heightened speed at which they operate. Alongside efforts to amplify the scope and pace of our observations, we also need to find strategies of slowing down and zooming in on data traffic. Lisa Parks suggests that one way of unpacking “the physicality of distribution and the dynamism of media infrastructure” could involve “isolating moments in which content is in the process of moving from one site to another” (“Stuff You Can Kick” 359). Inspired by this approach, I suggest we begin infrastructural

investigations in the domain of data packets—that is, the small units of data into which online communication is generally split. This article considers how packets can serve as an entryway for considering the organization of digital streams.

I begin by briefly outlining the theoretical and methodological frameworks that have guided this research. Next, I discuss the technological fundamentals of packet switching and streamed content distribution in order to lay the groundwork for an understanding of how packets are situated within media infrastructures. By drawing from an experiment that involved capturing and analyzing packets with the help of software called Wireshark, the article then introduces two areas where the analysis of packets help to unpack the infrastructural agency of Spotify. On the one hand, I suggest that packets can assist in mapping the multiplicities of actors that are involved in streamed content transmissions. Thereby, the analysis of packets also functions as a corrective to simplistic descriptions of online services, and illustrates the layered nature and environmental effects of services like Spotify. On the other hand, I suggest that packets can serve as an entryway for problematizing the notion of smooth and frictionless streams. Packet analysis points to the redundant and flawed nature of digital content transmissions and thereby help us reach a deeper understanding of the messiness of online communication. Ultimately, I suggest that the small and humble packet can serve as an entryway for critically scrutinizing data infrastructures.

## On packets, streams and data infrastructures

Infrastructures facilitate the movement of goods, people, and ideas. Thereby, they also play a key role in regulating everyday life. In recent years, a large body of scholarly work has inquired into the histories and politics of digital media infrastructures, with a focus on issues such as materiality (Parks and Starosielski), poetics (Larkin), and environmental effects (Rust, Monani, and Cubitt). Building on a tradition of infrastructural studies in the field of media research, social anthropology, and science and technology studies (c.f. Sandvig), this research collectively highlights the importance of paying attention to seemingly mundane infrastructures that undergrid cultures and markets.

A focus on infrastructure directs attention towards issues of distribution, and the processes that support networked communications. It also alerts key questions around “who and what exactly is acting in and on specific environments, often in asymmetrical ways” (Blok et al. 17). Inspired by the practice of “breaking infrastructures down into discrete parts and framing them as objects of curiosity, investigation and/or concern” (Parks “Stuff You Can Kick” 356), this research pauses to consider how clues hidden in packets give insights into larger infrastructural arrangements. It also borrows from scholars like Paul Dourish, whose focus “is not with the physical infrastructure as such—the cables, the servers, the switches, the buildings, and so on—but with the processes at work” in network transmissions (184). I seek to excavate Spotify’s data infrastructure by back-tracking and studying the remains of machine operations that are visible in packets.

Like most online content, music on Spotify is transmitted via the Transmission Control Protocol and Internet Protocol (TCP/IP). TCP/IP ensures that all data that passes to and from an online device is broken down into small sequences of zeros and ones called packets. Originally implemented as part of the Internet predecessor ARPANET in the 1960s (Abbate), this method of splitting online messages into smaller units implies that messages are fragmented as they are shipped through digital networks. In such processes, each packet holds several layers of data. The top layer contains transport oriented information about where packets are bound, while the bottom layers contain the actual cargo of the packets. The bottom layers also come with mechanisms for controlling that packets arrive in one piece, and information concerning how different packets fit together.

According to TCP/IP, packets do not travel along pre-defined roads from point A to B when they are sent across networks. Instead, information is forwarded through several nodes and connections, based on a series of automated micro-decisions (Sprenger). This process is called packet switching and implies that packets take different routes on their journeys through media infrastructures. As Tiziana Terranova once wrote, “the communication of information in computer networks does not start with a sender, a receiver and a line, but with an overall information space, constituted by a tangle of possible directions and routes, where information propagates by autonomously finding the lines of least resistance” (65). “This”, she further argues, “produces a space that is not just a ‘space of passage’ for information, but an informational machine itself—an active and turbulent space” (ibid.). No one knows precisely which path an individual packet will take on its journeys, and an original message is never complete until all

packets have been reassembled at their final destination.

This basic setup was originally deployed to safeguard against enemy disturbances under the threat of the Cold War (Abbate). By transmitting messages in automatized, distributed and unpredictable ways, a network becomes less susceptible to failures along its nodes. Yet while this arrangement has paved way for time- and resource efficient data transmissions, it also implies that content transmissions have an ephemeral existence that makes them challenging to grasp and study.

## Unpacking streams

One way of entering the substrate of streamed content transmissions—and studying data infrastructural arrangements—could involve eavesdropping on network traffic using packet sniffers. A packet sniffer (or network protocol analysis tool) is a software solution that makes visible the plethora of data transmissions that occur below the interface of a service like Spotify. It does so by placing itself between a digital device and the wider Internet, thereby capturing the data that passes to and from a selected device. In this way, packet sniffers can be used as entryways for mapping how content is amassed, packaged and shipped off during streaming sessions and other types of online content transmissions. Packet sniffers are also frequently used for diagnosing network problems, detecting network intrusion attempts, gathering network statistics, and evaluating the effectiveness of security systems like firewalls or spam filters. In some cases, packet sniffers are also deployed to spy on unprotected Internet users since they enable eavesdropping on every computer that is connected to the same WiFi network. [2]

In order to explore Spotify's infrastructural entanglements, a packet sniffer was repurposed as a digital research tool (Rogers; Sandvig and Hargittai; Soon), and used as an entryway for 'listening in' on streamed data traffic. This implied that careful measures were taken to not collect anyone else's private communication details, except for especially assigned Spotify accounts. The packet sniffer used was Wireshark—one of the world's most popular tools for monitoring network traffic. Wireshark is free to use and download and was first created in 1998. At the time of this writing, it has been developed by 1,316 open source contributors (and counting). According to its founders, Wireshark "lets you see what's happening on your network at a microscopic level" (Wireshark). What the program essentially does is to provide detailed live captures of data traffic. Thereby, it also decelerates streams and makes visible packet transmissions that are normally hidden from the user. In the words of Wendy Chun, packet sniffers disclose how "your computer constantly wanders without you" (3). Here, the constant background activities of software become visible.

In the remaining parts of this article, I consider how a close reading of packets and packet transmissions open up for critical considerations of data infrastructures. The packets studied were intercepted from Stockholm, Sweden during two Spotify streaming sessions that lasted for 20 minutes each. During these sessions, a series of five songs were played on one Spotify free account and one Spotify premium account. Meanwhile, packet transmissions were captured using Wireshark. All plays were activated manually and careful measures were taken to make sure that only Spotify's data traffic was monitored.<sup>[3]</sup> The collected data provides a snapshot of what Spotify's data infrastructure looked like at a particular location and point in space and time, and

resulted in a capture of 13,271 different Spotify-related packets which made up about 12 megabytes of data in total.

In what follows, I discuss two areas where such packets invite for considering Spotify's infrastructural connections. These areas include exploring third-party software entanglements, and problematizing the notion of smooth streams. In presenting these topics, my intention is not to suggest that packet sniffing could help us reach an inner essence of truth with regards to the organization of data infrastructures. Packets are seldom fully transparent and their cargo is often encrypted and hidden from view. Packet sniffers can also only access the last (or first) destination of incoming (or outgoing) data. In this way, a study of packets must involve recognizing the limits of what we can see with regards to online data transmissions. Packet sniffing remind us that full knowledge of where and how our data travels remains a challenge. The departure of this research is therefore that a detailed study of packets assists in establishing a starting point for formulating questions and critique about the organization of data infrastructures.

## Third-party supply chains

The first area where packet inspections can be of assistance is in mapping how actors like Spotify are entangled in supply chain capitalism—that is, complex "commodity chains based on subcontracting, outsourcing, and allied arrangements" (Tsing 148). As Anna Tsing argues, supply chain capitalism is central to contemporary modes of capital extraction and relies on the establishment of diverse, fragmented, specialized and interconnected divisions of labor. Hidden in the captured packets were several traces of Spotify's entanglements with third-party

hardware and software businesses such as Tier-1 Backbone Networks (AOL, Level 3), cloud platforms (Fastly, Google), Content Delivery Networks (Akamai, Amazon CloudFront), and programmatic advertising companies (Appnexus, AudienceScience, MediaMath, Turn, Rubicon).[4] This testifies to the hybrid nature of online services. While platforms like Spotify are often described as autonomous vehicles of market growth (Nicolaou), Spotify is neither self-built nor self-maintained and instead relies on a vast network of software providers that aid in maintaining its streams.

For instance, clues in the collected packets revealed Spotify's use of the Ogg Vorbis Codec—an open source-solution for lossy audio compression that is run by the Xiph.org Foundation. Originally founded in the 1990's by the programmer Chris Montgomery, the Ogg Vorbis codec was partly developed as a response to Fraunhofer Society's decision to introduce licensing fees on the MP3 audio format. Currently, the codec is applied by a wide variety of streaming services, websites, online radio stations, and computer games. [5] By using Ogg Vorbis, Spotify gains access to a compression technology without having to pay costly proprietary fees. This cost-saving practice runs as a red thread across the company's data infrastructure. "At Spotify we love open source", Noa Resare, one of Spotify's 'free software mediators' proclaimed in 2014 (Resare). The Spotify client, for example, has been built with the help of more than three hundred different open-source projects.[6] While Spotify gives back to the open source community by making repositories of code available to the public,[7] the fusion of corporate and open-source software systems which became apparent through packet analysis calls for future research. Here, the study of packets allows for considering corporate appropriations of code. It also provides grounds for

reconsidering the identity of online services. What, exactly, is Spotify *itself* if it is mainly made up of a patchwork of other services? How do we understand its role in drawing together and aggregating various types of software solutions?

A reading of packets also encourages considerations of how a mundane task such as listening to streamed music triggers complex entanglements with internet infrastructures. Such infrastructures are tightly linked to controversial debates around environmental damage, digital policymaking, network neutrality, and the freedom of the web. As Nicole Starosielski notes, a simple click on a computer commonly activates vast subterranean and subaquatic infrastructures where information is pushed through routers, local Internet networks, Internet exchange points, long-haul backbone systems, coastal cable stations, undersea cables, and data warehouses at high speeds (54). In the case of Spotify, an initial sense of such data arrangements could be glanced from using Wireshark. For instance, it became visible that the Spotify client had been interacting with two different Content Delivery Networks (or CDNs): Akamai and Amazon CloudFront on nearly 2800 occasions. These packets had travelled across multiple national borders, and their IP-addresses could be tied to locations such as Seattle, Amsterdam, New York, and Stockholm. In Akamai's facilities in Amsterdam, for example, the packets had been channeled through Europe's fourth largest market for data centers (Avgerinou, Bertoldi and Castellazzi 8). The trade organization Dutch Data Center Association estimates that at least 504 000 m<sup>2</sup> of land is now covered with data center facilities in the Netherlands as a whole (DDA 16).

As Stephen Graham and Simon Marvin noted already in 2001, CDNs like Akamai and Amazon CloudFront are network constructions that bypass congested Internet

infrastructures and instead establish parallel traffic routes that allow information to reach its destination at a higher speed against a fee. Such parallel networks have clear political dimensions. They often run between high priority cities across the globe (such as capital cities) and frequently target areas with a high density of corporate activity, thus disfavoring rural regions. In fact, Akamai has been singled out as providing a private network infrastructure that serves to enhance the unequal distribution of global network connectivity (ibid.). Because of how they sell high quality Internet access to selected customers, CDNs are known for sidestepping net neutrality regulations, and thus counteracting the basic and open end-to-end principles of the Internet.

CDNs also form part of a growing cloud computing industry with significant environmental effects. Amazon CloudFront, for example, is part of Amazon Web Services—one of the world's largest cloud computing services, and the collected packets could be tied to several of their facilities in Seattle and Stockholm. The company is currently established in 56 cities across 25 different countries and controls 116 different network nodes across North America, Europe, Asia, Australia and South America.[8] Amazon thus links together several major continents across the globe, yet it mainly does so with support of non-renewable energy sources like coal, nuclear power and natural gas. In a Greenpeace report released in 2017, Amazon Web Services was described as “one of the single biggest obstacles to sector transparency” in the context of online energy use, and the company has been heavily critiqued for concealing detailed information concerning its energy footprints (Greenpeace, “Clicking Clean: Who Is Winning the Race to Build a Green Internet?” 30). While Amazon implemented a clean energy policy in 2017, the company is still ranked as one of the worst

big players in the business. Relatedly, Spotify was also the streaming service for music which had the worst ranking in Greenpeace's comparison of energy use among six different online music platforms (ibid.). Only 56 percent of the company's energy use could be tied to clean energy, as compared to iTunes which ranked highest and utilized 83 percent renewable energy.[9]

By mapping and providing evidence of third-party entanglements, packet sniffing thus highlight how access to streamed music ‘on demand’ always implies connecting to—and relying on—complex systems of water, gas, and electricity infrastructures. In this sense, packet analysis remind us that streaming affects the biophysical world; it is entwined in complex sets of environmental relations, and it leaves behind environmental residues. Streaming—much like Google Earth viewings and other forms of software use—happens as “lands, water, electricity, heavy metals, and other materials are organized to transmit signals” (Parks, “Earth Observation” 157). The analysis of packets, thus point to the extensive material routes through which streamed content is shipped.

As a whole, Spotify's entanglements with open source projects and content delivery networks illustrate how “software systems are always intensely striated and highly hierarchical, comprised of layers that provide fertile ground for archaeological digging” (Solomon 2). Instead of operating as an autonomous platform, Spotify resembles a mixture of third-party software solutions. Here, it becomes evident that Spotify's business is organized as a stack where different software solutions are layered on top of each other (Vonderau; Bratton). To borrow from Michel Callon, Spotify may appear as a coherent, durable and independent entity, but it “enrolls a mass of silent others from which it draws its strength and credibility” (96). Here, packet sniffing may aid in “showing that

what appears to be simple or reified is in fact messy and contingent” (Gehl 37). Embarking on a detective hunt among collected data packets opens up for considering the market appropriation of publicly developed code, as well as the complex ways in which online services involve software dependencies and natural resource extraction.

## Unsmooth streams

Secondly, a close reading of packet transmissions allows for problematizing the notion of smooth streams, and instead highlight the interruptions that mark online content transmissions. While the 13,271 packets that were intercepted during the previously mentioned experiment might sound like a significant amount of data, a majority of these packets contained fairly ingenuous content. Upon close inspection, it turned out that about thirty percent of the intercepted packet transmissions had failed. While such packets did not contain a large amount of data, they were large in number. These failures were never noticed at the interface level during the data collection. For example, the client never froze, and music was played without lags or interruptions. Still, music and its surrounding data was moving in ways that were far from smooth. Erroneous packet transmissions reveal how states of breakdown continuously underlie the seemingly well-functioning interfaces of software programs. Even if Spotify appeared to be running smoothly, hundreds of minor malfunctions were taking place in its network transmissions.

For instance, Spotify made 213 attempts to establish contact with an IP address located in San Francisco and 215 attempts to communicate with an IP address in New York City without any success. In making such ineffective data transmissions known,

packet sniffing opens up for considering how “technology cannot without failure” (Frabetti). Even in cases when Spotify appears to be functioning seamlessly, quasi-failures might still lurk below the surface (ibid.). These failures are not abnormalities, but rather inherent parts of network transmissions. As Florian Sprenger points out, “there is no stream in digital networks” (Sprenger 89). Rather, online traffic is traversed by breaks, ruptures and pauses.

Considering such gaps is not least important since it helps to critique notions of seamless connection. The idea of immediacy is central to the marketing of streaming services, who frequently claim to offer instant access to content. In the context of marketing, real-time streams have been endowed with phantasmatic and messianic qualities (Berry) and are “used to describe media characterized by fresh, dynamic or continuously processed content in opposition to static or archival media” (Weltevrede, Helmond, and Gerlitz 126). As Geert Lovink once put it, “realtime is the new crack” (Lovink), and streaming services are not alone in expressing idealistic notions of untroubled online communication. The notion that global network technologies cause “the annihilation of time” has not least been reified by scholars like Manuel Castells (502).

Yet streaming always involves latencies and obstructions and hence its instantaneousness is a fiction. ‘Real-time’ streams must be therefore understood as mediated constructs that serve to enforce particular technological imaginations (Berry; Sprenger; Soon; Weltevrede, Helmond, and Gerlitz). Failures to recognize the existence of interruptions in streams run the risk of ignoring “the operational modes of digital networks” (Sprenger 107). Here, tools like Wireshark can be used as entryways for studying the troubled communication attempts that take place between computers, as well as the



moments when software breaks down and misbehave. Such elements help show an alternative image of network transmissions that stand in contrast to the metaphor of the smooth, natural and wholesome stream.

In many cases, the packets that were captured with the help of Wireshark also turned out to be simple handshake/“can you read me?”-requests—that is, short messages that allow computers to acknowledge each other’s existence in order to establish if further communication is possible. Resembling what has elsewhere been described as “phatic communication,” these messages are not primarily intended to transmit important content, but rather establish bonds between agents for the purpose of maintaining social ties (c.f. Fiske; Malinowski).[10] In human language, examples of phatic communication include conventional ‘Hello’-greetings and superfluous remarks such as ‘nice day today.’ As John Fiske describes it, phatic communication “refers to acts of communication that contain nothing new, no information, but that use existing channels simply to keep them open and usable” (Fiske 14). Building on the works of Roman Jakobson, Fiske notes that such communicative acts—which are seemingly deprived of meaning and content—are crucial in holding a community or society together. In other words, their repetitive and mundane character is far from meaningless. Generated for the purpose of cultural bonding, phatic communication keeps communication channels on stand-by.

3-way handshake interactions and acknowledgement messages between computers are an embedded ingredient of TCP/IP transmissions, and the prevalence of such messages in the captured packets does thereby not come as a surprise. Yet handshake packet transmissions point to interesting features of digital communication. In particular, wide-ranging handshaking between remote computers illustrate how

humans are not necessarily at the center of communicative acts within online networks. Brian Christian and Tom Griffiths describe excessive handshaking as “the anxiety of all packet-switching protocols” and note that they frequently add up to considerable amounts of data traffic (Christian and Griffiths). Packet-switching implies that computers are programmed to continuously (and somewhat anxiously) connect and reaffirm each other’s existence in anticipation for future communication. The examples of machinic phatic communication that were discovered through packet sniffing thus highlight logics of ongoing machine speech. It also invites investigations into efforts of locating users across remote global distances. Spotify usage involves continuous acts of positioning users and devices in relation to other machines in space and time; it implies becoming territorially ‘known’ to a wide network of computers.

## Conclusion

Brian Larkin notes that infrastructures play a dual role; they are things that “enable the movement of other matter”, while simultaneously also constituting “the relationship between things” (Larkin 329). As both ‘things’ and ‘relations’, then, infrastructures connect, prompt and link together distributed elements in ways that affect their usage, visibility, and reach. Packet sniffing offers an opportunity to freeze and inspect packet transmissions that otherwise move at speeds which surpass human cognition. In this way, it assists in unpacking digital streams and exploring the data transmissions that a simple ‘click’ can trigger. This article has sketched out the possibilities of mapping Spotify’s data infrastructure by intercepting conversations taking place between computers using Wireshark.

It has also discussed how streamed music is fundamentally entangled with the “technical, social, and organizational practices of large-scale computer-enabled information infrastructures” (Blok et al. 7), and proposed that packet sniffing provides a starting point for mapping the politics of distribution, third-party supply chains, failed streams, phatic computer speech, and the environmental effects of streaming services.

In the context of digital media, knowledge of how network transmissions are organized can normally be glanced from reading press releases and information on corporate websites. Yet such information quickly runs out of date and frequently lacks in detail. Though packet sniffing, it becomes possible to extract empirical data concerning the composition of digital infrastructural networks, improve transparency with regards to collaborations between online actors, and gain knowledge about the complex ways in which global data flows are arranged. While this experiment has far from exhausted the kinds of infrastructures that a service like Spotify relies on, it has provided some insight into the lively, complex and sometimes downright failing network transmissions that a simple click can generate.

## Notes

[1] Streamed audiovisual content generates the most data-intensive online traffic, although consumption of streamed music also contribute to the general environmental impact of online streams.

[2] This is done when packet sniffers are set in so-called “promiscuous mode” which can be used to gather sensitive information such as passwords, private email details, credit card numbers, web browsing histories, or saved login credentials from unsuspecting targets (given that the information is not encrypted).

[3] This was ensured by keeping a close eye on the computer’s activity monitor, using a Wi-Fi with no other connected devices, and only monitoring the ports that Spotify uses. The data was first stored in a pcapng format and later exported to Excel and Google spreadsheets for analysis.

[4] These actors and connections were established by resolving IP-addresses through multiple IP address lookup services and crosschecking the results. For more information about Spotify’s involvements with ad-tech businesses see Vonderau.

[5] Such services and games for example include Wikipedia, Minecraft, Grand Theft Auto, and World of Warcraft.

[6] The most updated list of precisely which open source-projects can be found by clicking Help > Third party software in the top menu of any Spotify client.

[7] At the time of this writing (May 2018), Spotify had published 193 different repositories on Github.

[8] See Amazon's webpage, <https://aws.amazon.com/cloudfront/details/> (accessed May 22, 2018).

[9] Notably, Spotify is likely to improve its ranking as it has announced a transition to Google's cloud services which has committed to a 100 percent renewable energy goal.

[10] Thank you Johan Jarlbrink for giving me the advice to explore research on phatic communication.

## Works cited

Abbate, Janet. *Inventing the Internet*. Cambridge & London: MIT Press, 1999. Print.

Avgerinou Maria, Bertoldi Paolo and Castellazzi Luca. "Trends in Data Centre Energy Consumption under the European Code of Conduct for Data Center Energy Efficiency." *Energies*, 10.10 (2017): 1470. Web <<https://doi.org/10.3390/en10101470>>

Berry, David M. "Messianic Media: Notes on the Real-Time Stream." September 12, 2011. Web <[stunlaw.blogspot.se/2011/09/messianic-media-notes-on-real-time.html](http://stunlaw.blogspot.se/2011/09/messianic-media-notes-on-real-time.html)>

Blok, Anders, Moe Nakazora, and Brit Ross Winthereik. "Infrastructuring Environments." *Science as Culture* 25.1(2016): 1–22. Web <<https://www.tandfonline.com/doi/pdf/10.1080/09505431.2015.1081500>>

Bratton, Benjamin. *The Stack*. Cambridge & London: MIT Press, 2015. Print.

Callon, Michel. "Society in the Making: The Study of Technology as a Tool for Sociological Analysis." *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology*. Ed. Weibe E. Bijker, Thomas P. Hughes, and Trevor J. Pinch. Cambridge: MIT Press, 1987. 83–103. Print.

Castells, Manuel. "The Information Age: Economy, Society and Culture." *The Rise of the Network Society*, 2nd ed. Volume I. Wiley-Blackwell, 2010. Web <<https://onlinelibrary.wiley.com/doi/book/10.1002/9781444319514>>

Christian, Brian, and Tom Griffiths. *Algorithms to Live By: The Computer Science of Human Decisions*. Henry Hold and Company, 2016. Print.

Chun, Wendy Hui Kyong. *Control and Freedom: Power and Paranoia in the Age of Fiber Optics*. Cambridge & London: MIT Press, 2006. Print.

Cisco. "Global – 2021 Forecast Highlights." Cisco 2016. Web <[cisco.com/c/dam/m/en\\_us/solutions/service-provider/vni-forecast-highlights/pdf/Global\\_2021\\_Forecast\\_Highlights.pdf](http://cisco.com/c/dam/m/en_us/solutions/service-provider/vni-forecast-highlights/pdf/Global_2021_Forecast_Highlights.pdf)>

DDA. "DDA Annual Report". *Dutch Data Center Association*, 2017. Web <[dutchdatacenters.nl/en/publications/annual-report-2017/](http://dutchdatacenters.nl/en/publications/annual-report-2017/)>

Dourish, Paul. "Protocols, Packets, and Proximity: The Materiality of Internet Routing." *Signal Traffic: Critical Studies of Media Infrastructures*, edited by Lisa Parks and Nicole Starosielski. Urbana, Chicago & Springfield: University of Illinois Press, 2015. 183–204. Print.

- Fiske, John. *Introduction To Communication Studies*, Second Edition. London & New York: Routledge, 2002. Print.
- Frabetti, Federica. “Does It Work?: The Unforseeable Consequences of Quasi-Failing Technology.” *Culture Machine* 11 (2010): 107–135. Web <<http://www.culturemachine.net/index.php/cm/article/view/388/409>>
- Gehl, Robert W. “The Politics of Punctualization and Depunctualization in the Digital Advertising Alliance.” *Communication Review* 19.1(2016): 35–54. Print. Web <<https://www.tandfonline.com/doi/abs/10.1080/10714421.2016.1128187>>
- Greenpeace. “Clicking Clean: A Guide to Building the Green Internet.” *Greenpeace*, 2015. Web <[greenpeace.org/usa/global-warming/click-clean/#top](http://greenpeace.org/usa/global-warming/click-clean/#top)>
- . “Clicking Clean: Who Is Winning the Race to Build a Green Internet?” *Greenpeace*. Web <<http://www.greenpeace.org/usa/global-warming/click-clean/#top>>
- Larkin, Brian. “The Politics and Poetics of Infrastructure.” *Annual Review of Anthropology* 42.September (2013): 327–343. Web.
- Law, John. *Organizing Modernity*. Oxford & Cambridge: Blackwell, 1994. Print.
- Lovink, Geert. *Networks Without a Cause: A Critique of Social Media*. Cambridge & Malden: Polity Press, 2011. Print.
- Malinowski, Bronislaw. “The Problem of Meaning in Primitive Languages.” *The Meaning of Meaning*. Ed. C. K. Ogden and I. A. Richards. London: Kegan Paul, Trench and Trubner, 1923. 296–336. Print.
- Maravić, Igor. “Spotify’s Event Delivery – The Road to the Cloud ( Part I ).” *Spotify* 2016. Web <[labs.spotify.com/2016/02/25/spotify-event-delivery-the-road-to-the-cloud-part-i/](http://labs.spotify.com/2016/02/25/spotify-event-delivery-the-road-to-the-cloud-part-i/)>
- McIntyre, Hugh. “With 30 Million Users, Spotify Is Gaining Subscribers Faster And Faster Music.” *Forbes Mar.* 2016. Web <<https://www.forbes.com/consent/?toURL=https://www.forbes.com/sites/hughmcintyre/2016/03/21/with-30-million-users-spotify-is-gaining-subscribers-faster-and-faster/>>
- Nicolaou, Anna. “How Streaming Saved the Music Industry.” *Financial Times* 16 Jan. 2017. Web <<https://www.ft.com/content/cd99b95e-d8ba-11e6-944b-e7eb37a6aa8e>>
- Parks, Lisa. “Earth Observation and Signal Territories.” *Ecomedia: Key Issues*. Edited by Stephen Rust, Salma Monani, and Sean Cubitt. London & New York: Routledge, 2016. 141–161. Print.
- . “‘Stuff You Can Kick’: Toward a Theory of Media Infrastructures.” *Between Humanities and the Digital*. Edited by Patrik Svensson and David Theo Goldberg. Cambridge & London: MIT Press, 2015. 355–374. Print.
- Parks, Lisa, and Nicole Starosielski, eds. *Signal Traffic: Critical Studies of Media Infrastructures*. Urbana, Chicago & Springfield: University of Illinois Press, 2015. Print.
- Plaugic, Lizzie. “Spotify Now Has 70 Million Subscribers.” *The Verge* Jan. 2018. Web.
- Resare, Noa. “Making Open Source a Priority at Spotify.” 2014. Web <[lccona14.sched.com/event/1ouHhHB/making-open-source-a-priority-at-spotify-noa-resare-spotify](http://lccona14.sched.com/event/1ouHhHB/making-open-source-a-priority-at-spotify-noa-resare-spotify)>

- Rogers, Richard. *Digital Methods*. Cambridge & London: MIT Press, 2013. Print.
- Rossiter, Ned. *Software, Infrastructure, Labor: A Media Theory of Logistical Nightmares*. New York & London: Routledge, 2016. Print.
- Rust, Stephen, Salma Monani, and Sean Cubitt, eds. *Ecomedia: Key Issues*. London & New York: Routledge, 2016. Print.
- Sandvig, Christian. "The Internet as Infrastructure." *The Oxford Handbook of Internet Studies*. Edited by William Dutton. Oxford & New York: Oxford University Press, 2013. 86–106. Print.
- Sandvig, Christian, and Eszter Hargittai. "How to Think About Digital Research." *Digital Research Confidential: The Secrets of Studying Behavior Online*. Cambridge, Massachusetts; London, England: The MIT Press, 2015, pp. 1-28. Print.
- Sarrafi, Ali. "How Data Drives Spotify." Slides presented at the Stockholm School of Entrepreneurship. Aug 10, 2016. Web <[http://slideshare.net/alisarrafi3/how-data-drives-spotify?qid=b7ca7727-0a01-4441-9107-14410ccf0e7d&v=&b=&from\\_search=32](http://slideshare.net/alisarrafi3/how-data-drives-spotify?qid=b7ca7727-0a01-4441-9107-14410ccf0e7d&v=&b=&from_search=32)>
- Solomon, Rory. "Last In, First Out: Network Archaeology Of/as the Stack." *Amodern 2* (2013): n. pag. Web <<http://amodern.net/article/last-in-first-out/>>
- Soon, Winnie. *Executing Liveness: An Examination of the Live Dimension of Code Inter-Actions*. Diss. Aarhus University, 2016. Web <[siouson.net/home/me/doc/soon\\_PhD\\_FINAL.pdf](http://siouson.net/home/me/doc/soon_PhD_FINAL.pdf)>
- Sprenger, Florian. *The Politics of Micro-Decisions: Edward Snowden, Net Neutrality, and the Architectures of the Internet*. Leuphana: Meson Press, 2015. Print.
- Starosielski, Nicole. "Fixed Flow: Undersea Cables as Media Infrastructures." *Signal Traffic: Critical Studies of Media Infrastructures*. Parks, Lisa, and Nicole Starosielski, eds. Springfield: University of Illinois Press, 2015. 53–70. Print.
- Terranova, Tiziana. *Network Culture: Politics in the Information Age*. London & Ann Arbor: Pluto Press, 2004. Print.
- Tsing, Anna. "Supply Chains and the Human Condition." *Rethinking Marxism* 21.2 (2009): 148–176. Web.
- Vonderau, Patrick. "Scaling Up: Music, Capital, and Programmatic Advertising." *Forthcoming in Content Wars*. Ed. D. Mann. New Brunswick: Rutgers University Press, 2018. Print.
- Weltevrede, Esther, Anne Helmond, and Carolin Gerlitz. "The Politics of Real-Time: A Device Perspective on Social Media Platforms and Search Engines." *Theory, Culture & Society* 3 1.6 (2014): 125–150. Web <<http://journals.sagepub.com/doi/abs/10.1177/0263276414537318>>

## Acknowledgements

This research was funded by the Swedish Research Council as part of the ongoing research project "Streaming Cultural Heritage: Following Files in Digital Music Distribution." For more information, visit [www.streamingheritage.se](http://www.streamingheritage.se). A related version of the text will be published in the forthcoming book *Spotify Teardown: Inside the Black Box of Streaming Music*, MIT Press (2018).