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NEIGHBORHOOD SOUNDING

AN ARCHAEOLOGY OF DYNAMIC MEDIA NETWORKS 1960–1980 | 2010

ABSTRACT

According to the French collective of mathematicians which published under the pseudonym Nicolas Bourbaki, neighborhood as a term used in topology is defined as an expression for "sufficiently near" or "as near as we please."[1] In the monograph *Micromotives and Macrobehavior* by sociologist Thomas C. Schelling the concept of neighborhood plays an important role for analyzing the dynamics of separation and segregation of ethnic groups.[2] And the jargon of telecommunications uses the term *neighbor* inter alia for describing the closest switching computers in *packet switching* – a technical term for the media technology of early Internet.

This contribution is a media archaeological inquiry into the past of dynamic media networks such as the Internet and a close reading of some early historical publications describing early computer networks. Concentrating on the programming of routing procedures it outlines *neighborhood sounding* as a key moment of packet switching, an early form of distributed and dynamic networks, where each agent or node was defined by the lively exchanges of its neighboring nodes. It finally discusses whether the assemblage[3] or agencement of *ARPAnet* can be regarded as a complex system,[4] showing emergent behavior or not and whether packet switching can be perceived as an early implementation of principles embodied in more advanced neighborhood technologies of the 21st century.

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[1] Nicolas Bourbaki, *Elements of Mathematics. General Topology. Chapters 1–4 [Éléments de Mathématique. Topologie Générale, Paris: Diffusion C.C.L.S. 1971]* (Berlin: Springer, 1989), p. 19.

[2] Thomas C. Schelling, *Micromotives and Macrobehavior. With a New Preface and the Nobel Lecture,* 1st Ed. 1978 (New York/London: W. W. Norton & Company, 2006), p. 145.

[3] Manuel DeLanda, *New Philosophy of Society: Assemblage Theory and Social Complexity* (London/New York: Continuum, 2006).

[4] Melanie Mitchell, *Complexity. A Guided Tour* (Oxford/New York: Oxford University Press, 2009).

1. NEIGHBORHOODS, MEDIA AND NETWORKS

By analyzing the quantitative dynamics of residential segregation in the early 1970s, Thomas C. Schelling defined neighborhood as a spatial arrangement of households, where each neighbor is defined in reference to their own location.[5] According to Schelling, segregation is a dynamic process where "small incentives, almost imperceptible differentials, can lead to strikingly polarized results."[6] The principle that small changes in the micro-behavior of a neighborhood relate to the macro-behavior of the whole system is also relevant for dynamic media networks. Paul Baran (1926–2011), who worked at the department for Computer Science and Mathematics at RAND Corporation since 1959, wrote and conducted a study on distributed communication. It was presented in 1961 and finally published in 1964.[7] It is notable in this context that also Schelling's research was funded by the RAND Corporation, but ten years later than Baran's study.

Baran conceptualized and simulated a network of computers with locally implemented neighborhood dependent switching rules, which he called a distributed adaptive message-block network.[8] The primary aim of this project was to inquire into the technical implications of building a communication network which could survive a major hostile military attack.[9] The layout of Baran's network was sketched out as a mixture of telephone lines – that is, to be more precise, of pulse-code-modulated multiplexing systems developed by the Bell Labs –, and of microwave stations and satellites networks.[10]

2. SOUNDING ITS NEIGHBORHOOD

Distributed networks are effectuated by the specific interplay of two instances: The node and the packet. The packet is the smallest unit of transmission (in terms of time) and the node is the smallest unit of the network (in terms of space). A packet, as conceptual-

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[5] Thomas C. Schelling, "Dynamic Models of Segregation," *Journal of Mathematical Sociology* Vol. 1 (Gordon and Breach Science, 1971), p. 147–148.

[6] Schelling, "Dynamic Models of Segregation," p. 146.

[7] Paul Baran, *On Distributed Communications: I. Introduction to Distributed Communication Networks (Memorandum, RM-3420-PR, August 1964)* (Santa Monica, CA: The RAND Corporation, 1964): p. iii.

[8] Baran, *On Distributed Communication*: p. iii.

[9] Baran, *On Distributed Communication*, p. 1.

[10] Baran, *On Distributed Communication*, p. 18–19.

ized by Baran, has a standardized and fixed sequence of sections containing data such as (1) start of message, (2) address, (3) sender, (4) handover number, (5) content and (6) end of message. These sequences thus were quite similar to the structure of machine code instructions used in early mainframe computing, albeit slightly more complicated.[11] A constitutive condition for the working of such a network is the timing, flow control or the algorhythmics[12] of the procedure how the small data packets will get forwarded by the nodes and arrive at their point of destination. In this context, Baran proposed an algorithm or method called *store-forward*, based on the metaphor of a postman:

> "A postman sits at each switching node. Messages arrive simultaneously from all links. The postman records bulletins describing the traffic loading status for each of the outgoing links. With proper status information, the postman is able to determine the best direction to send out any letters. […] [T]he postman can infer 'best' paths to transmit mail by merely looking at the cancellation time or equivalent hand over number tag. […] Each letter carries an implicit indication of the length of transmission path."[13]

While the metaphor of an intelligent and skilled ultra-fast human postman is easy to understand, I would like to argue that another description gets significantly closer to the non-human technological workings of distributed networks: It is the model of *neighborhood sounding,* namely of a machine sending signals to and listening to signals from its neighborhood according to a fixed, algorithmically defined ruleset. Etymologically, sounding in its conventional meaning derives from the French term *sonde* (in English: *probe*) and refers to the mechanism of probing the environment – most often distances – by sending out an object and observing the physical responses it caused during its trajectory. Sometimes the object would get reflected and returns back, sometimes it is tied to a string or thread that will act as a medium and sometimes not an object, but a signal is sent out. The last practice is connected to a more unconventional meaning of sounding, which pertains to sending out a sound, not a probe, thus sounding derived from sound, not *sonde* and therefore the performative act of playing a signal and listening for its responses. The medium of sounding changed from being object-based

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[11] Baran, *On Distributed Communication*, p. 22.

[12] Shintaro Miyazaki, "Algorhythmics: Understanding Micro-Temporality in Computational Cultures," *Computational Cultures. A Journal of Software Studies* 2 (2012), http://computationalculture.net/article/algorhythmics-understanding-micro-temporality-in-computational-cultures (January 2014).

[13] Baran, *On Distributed Communication*, p. 25.

to operating signal-based. An early manifestation of this shift, for instance, has been the measurement of distances underwater.[14] On this basis *neighborhood sounding* describes a software-programmed mode of *sounding, that is, measuring with signals,* within a network of multiple communication channels such as computer networks. Furthermore, *neighborhood sounding* refers to a general principle of listening, sensing, reacting and acting implemented in animal echolocation as well as in human sonar operator skills. Physicians practiced percussive diagnosis by sounding out the body[15] before the dawn of medical ultrasonography and other imaging technology. Other sounding practices were applied in classical archaeology for inquiring into the conditions of the ground to excavate. And in a surprisingly similar way, the delays and transmission times in telegraphy networks were measured by sending out electrical impulses, thus sounding out the network. Later, comparable techniques were applied to telephone networks. While the informed reader might remark that acoustic and electromagnetic signals are not the same, he or she might remember that these can easily get transduced[16] into each other as acoustic-couplers the first modems for digital networks showed from early on. Acoustics is one of the first sciences where the practice of modeling general principles by equivalence circuits got established.[17]

3. SIGNALS AND RHYTHMS OF ARPANET

Activated in the late 1960s, the ARPAnet was the first "large-scale demonstration of the feasibility of packet-switching".[18] ARPAnet's major difference to later forms of distributed networks – which were based on the TCP/IP-Protocol after its establishment in the early 1980s – consisted of its *Interface Message Processors* (IMPs). These mediated the handling of

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[14] John Shiga, "Sonar: Empire, Media, and the Politics of Underwater Sound," *Canadian Journal of Communication* 38, no. 3 (September 2013), p. 357–77; Willem Hackmann, *Seek and Strike. Sonar, Anti-submarine Warfare and the Royal Navy 1914–54* (London: Stationery Office Books, 1984).

[15] Axel Volmar, "Listening to the Body Electric. Electrophysiology and the Telephone in the Late 19th Century," *The Virtual Laboratory* (Berlin: Max-Planck-Institute for the History of Science, 2010). Http://vlp.mpiwg-berlin.mpg.de/essays/data/art76.

[16] Adrian Mackenzie, *Transductions. Bodies and Machines at Speed* (London/New York: Continuum, 2002).

[17] Roland Wittje, "The Electrical Imagination: Sound Analogies, Equivalent Circuits, and the Rise of Electroacoustics, 1863–1939," *Osiris* 28, no. 1 (January 1, 2013): p. 40–63.

[18] Janet Abbate, *Inventing the Internet* (Cambridge, MA: MIT Press, 1999), p. 7.

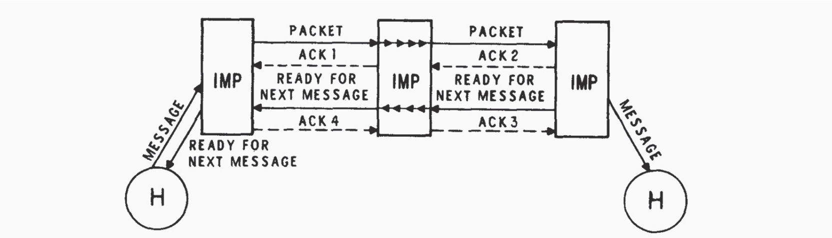

Fig. 1: RFNMs and acknowledgments, Fig. 4 in F. E. Heart, R. E. Kahn, and S. M. Ornstein, "The Interface Message Processor for the ARPA Computer Network," in *AFIPS '70 (Spring) Proceedings of the May 5–7 1970, Spring Joint Computer Conference* (New York: ACM, 1970), 554.

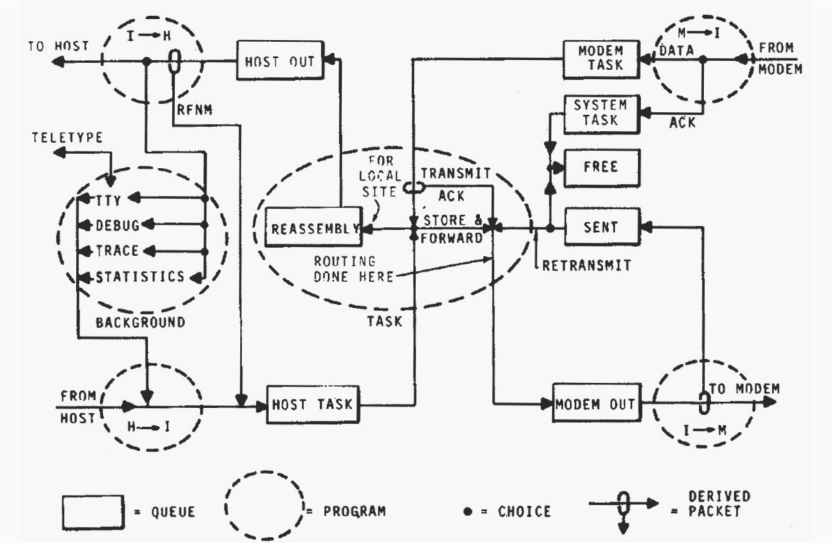

Fig. 2: Internal packet flow, Fig. 9 in ibid., 561.

the messages and packets between two host computers.[19] IMPs were small computers – such as a Honeywell DDP-516 – installed only for packet switching. As shown in Fig. 1, the timing of a packet transmission consists of multiple layers. A message of digital data gets divided into smaller packets, which are individually transmitted over the network towards their final destination. When the topology – that is, the structure – of the

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[19] F. E. Heart, R. E. Kahn and S. M. Ornstein, "The Interface Message Processor for the ARPA Computer Network," *AFIPS '70 (Spring) Proceedings of the May 5–7 1970, Spring Joint Computer Conference* (New York: ACM, 1970): p. 551–567.

network changes due to a failure or an interruption somewhere on their way, the packets can take alternative and different routes. After arriving at the final destination, they are assembled into the right order again. Infrastructural signals for ensuring an error-free transmission such as the *Ready for Next Message* (RFNM) and the acknowledgment (ACK) signals were most important for enabling the *sounding*. Fig. 2 shows an abstract diagram of the data packet flow inside such an IMP, which operates as a medium between a host computer and the modem (acoustic coupler). The packet processing is organized in sub-routines and programs notably as well the background functions such as trace, debug and statistics, which would become important for understanding unexpected breakdowns and failures.

The adaptive routing algorithm implemented in the IMP defined the procedure of packet switching. It tries to estimate the path with the shortest transit time to the final destination. The main principle of such an algorithm is that it uses data tables about the condition of the neighboring network, its connectivity, or signs of traffic congestions. This data gets updated every half second.

> "Each IMP estimates the delay it expects a packet to encounter in reaching every possible destination over each of its output lines. It selects the minimum delay estimate for each destination and periodically (about twice a second) passes these estimates to its immediate neighbors. Each IMP then constructs its own routing table by combining its neighbors' estimates with its own estimates of the delay to that neighbor. The estimated delay to each neighbor is based upon both queue length and the recent performance of the connecting communication circuit."[20]

The timing of each operation in each IMP is consequently highly relevant.[21] Even in the absence of packets to transmit an IMP sends its neighbors a "hello" packet and expects a "I heard you" packet within a period of 0.5 seconds. A dead line is defined by a sustained absence of about 2.5 seconds of such messages.[22]

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[20] Heart et al., "The Interface Message Processor for the ARPA Computer Network," p. 555.

[21] J.M. McQuillan, G. Falk and I. Richer, "A Review of the Development and Performance of the ARPANET Routing Algorithm," IEEE *Transactions on Communications* 26, no. 12 (December 1978).

[22] Heart et al., "The Interface Message Processor for the ARPA Computer Network," p. 555.

4. BREAKDOWNS AND COMPLEX SYSTEMS

The rigidly programmed neighborhood relations and operativity of one IMP, or, in other words, its micro-behavior, affects the overall macro-behavior of the network and its communication processes: "A local failure can have global consequences."[23] Consequently, the early ARPAnet is a complex system as defined by Schelling. It "exhibits nontrivial emergent and self-organizing behaviors."[24] This especially becomes apparent in case of unexpected breakdowns and disturbances. While emergence is usually reserved to living organisms and other ecological assemblages, a reading of the early descriptions of the ARPAnet pioneers reveals that this attribution might as well apply to the nonorganic media ecologies they were confronted with on a daily basis.

Right from the start, Leonard Kleinrock of University of California was one of the researchers who had to deal with the complexity of distributed networking. In a *Proceedings of the* IEEE paper, published in 1978 in a special issue on packet switching, he noted: "Not only was the demand process bursty, it was also highly unpredictable in the sense that the instants when the demands arose and the duration for the demands were unknown ahead of time."[25] Kleinrock recognized that the probabilistic complexities of distributed networks are "extremely difficult" and that an effective "flow control" within the network was one of the important needs, which first was underestimated and ignored.[26] Such flow control mechanism could have prevented many deadlock phenomena such as "reassembly lockup," "store and forward deadlock," "Christmas lockup" and "piggyhack lockup."[27]

Such system deadlocks had been discussed, researched and prevented already in the era of time-sharing during the 1960s,[28] but in case of the ARPAnet the media-ecological environment was less optimal than before. The new network worked with less bandwidth and was geographically distributed over the whole North-American continent, where as the earlier time-sharing, multi-user and multi-programming networks such

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[23] McQuillan et al.,"A Review of the Development and Performance of the ARPANET Routing Algorithm," *IEEE Transactions on Communications*, Vol. *26* , Nr. 12, Dec., p. 1805.

[24] Mitchell, *Complexity. A Guided Tour*, p. 13.

[25] Leonard Kleinrock, "Principles and Lessons in Packet Communications," *Proceedings of the IEEE. Special Issue on Packet Communications*, Vol. *66*, No. 11, Nov., ed. Robert E. Kahn (New York: IEEE, 1978), p. 1321.

[26] Kleinrock, "Principles and Lessons in Packet Communications," p. 1322.

[27] Kleinrock, "Principles and Lessons in Packet Communications," p. 1324.

[28] E. G. Coffman, M. Elphick and A. Shoshani, "System Deadlocks," *ACM Comput. Surv.* 3, no. 2 (June 1971), p. 67–78.

as the famous *Compatible Time-Sharing System* developed at Massachusetts Institute of Technology or *Programmed Logic for Automatic Teaching Operations* a system designed and built by the University of Illinois used more bandwidth and less concrete physical space, thus were in general more controllable.[29] As an effect, Bolt, Beranek and Newman, an East coast-based company which produced the IMPs, implemented measurement tools – sounding tools – to detect the network behavior from the outset.[30] Without these observation media the control, research and optimization of the network would never have been possible in the first place. The ARPAnet was an *experimental system* much in the sense of German historian of science Hans-Jörg Rheinberger.[31] It was not a static system, but was adjusted continuously and optimized according to knowledge gained from measuring and observing unpredicted failures and not by sophisticated prediction. Furthermore the network was not only working with adaptation on the algorithmic level in the IMPs, but also on the level of the many man-made adaptations these algorithmic control mechanisms would need to make the system more stable.[32] Kleinrock described this recursive entanglement as “philosophical”:

> “It is ironic that flow control procedures by their very nature present *constraints* on the flow of data (e.g., the requirement for proper sequencing), and if the situation ever arises whereby the constraint cannot be met, then, by definition, the flow will stop, and we will have a deadlock! This is the philosophical reason why flow control procedures have a natural tendency to introduce deadlocks.”[33]

This epistemological reasoning is extendable to digitized computer-based communication in general. The introduction of complicated *algorhythmics* to control the data flow in complex media networks require careful programming and measurement methods. Otherwise, the system will stop processing. Adaptation and revision of the important concepts and the measurement procedures due to unpredictable failures is thus a core

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[29] Kleinrock, “Principles and Lessons in Packet Communications,” p. 1322.

[30] G. Cole, “Performance Measurements on the ARPA Computer Network,” *IEEE Transactions on Communications* 20, No. 3 (June 1972), p. 630 – 636.

[31] Hans-Jörg Rheinberger, *Toward a History of Epistemic Things: Synthesizing Proteins in the Test Tube* (Stanford, CA: Stanford University Press, 1997).

[32] See for an overview of some of these adaptation processes, McQuillan et al., “A Review of the Development and Performance of the ARPANET Routing Algorithm”.

[33] Kleinrock, “Principles and Lessons in Packet Communications,” p. 1324.

agent in the historical transformation and optimization processes of such *algorhythmic networks* as the ARPAnet.

Thinking about the role of non-human agency in dynamic media networks the philosopher of complex assemblages and former software programmer Manuel DeLanda remarked: "[W]hile computers were originally seen as the medium for getting men out of the loop, network decentralization introduces a new kind of independent will, the independent software objects (or demons), which might prove as difficult to enslave as their human counterparts."[34]

With the network decentralization introduced by the ARPAnet failures and breakdowns such as those deadlocks described above provoke the interpretation that they exhibit emergent and self-organizing behaviors. It seems that with the dawn of distributed networking a new epistemic metaphor began to evolve. It was the model of media networks as complex non-human media ecologies. This shift towards ecologies provokes new theoretical concepts for their historical inquiry.

5. GOING BEYOND ARCHAEOLOGIES

N*eighborhood sounding* implies not only an intensified focus on the timing, delays and rhythms of dynamic media networks, but calls as well for a heterogeneous, multi-scalar analysis of their immanent processes, interdependencies and topological structures. This means that the metaphor of an *archaeologist* who works on the material conditions of past cultures influenced by Michel Foucault[35] and advocated by recent media theorists such as Wolfgang Ernst, Siegfried Zielinski, Erkki Huhtamo or Jussi Parikka[36] needs an extension towards the metaphor of an *ecologist* who reaches present complex systems using specific media-based observation methods: "Ecologists focus rather more on dynamic systems in which any or one part is always multiply connected, acting by

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[34] Manuel DeLanda, *War in the Age of Intelligent Machines*, First Edition 1991 (New York: Zone Books, 2003), p. 121.

[35] Michel Foucault, *The Archaeology of Knowledge and The Discourse on Language* (translated from French by A. M. Sheridan Smith) (New York: Pantheon Books, 1972), p. 135–140.

[36] Erkki Huhtamo and Jussi Parikka, eds., "Introduction: An Archaeology of Media Archaeology," in *Media Archaeology. Approaches, Applications, and Implications* (Berkeley, CA: University of California Press, 2011), p. 1–25.

virtue of those connections, and always variable, such that it can be regarded as a pattern rather than simply as an object."[37]

Emphasizing the rhythmic and dynamic aspects of both past and present complex networks might help to understand their complexity a little more than just looking at their topological or *objective* properties. Under such assumptions, *neighborhood sounding* implies methods for understanding media in quite an active and invasive way. It requires an engagement with the neighborhood in question. N*eighborhood sounding* is not only a principle that is constitutive and pivotal for the inner working of distributed and complex networks. It is also an important methodology in order to inquire them. While trying to understand the certain dynamics of present communication networks and ecologies such as Twitter, Facebook, Instagram, Flickr, processes in the World Wide Web in general or of the past such as the ARPAnet the critical researcher needs to select different nodes of such networks both real or simulated, conduct an analysis of the incoming and outgoing data signals and inquire these rhythms and their timing under his or her specific research question. In doing that he or she might need to go beyond the own disciplinary boundaries of humanities or sociology, acclimate oneself to emerging and long-forgotten neighborhoods, and build his or her own information-aesthetical devices and systems of exploration, experiments and sounding by incorporating current methods of network analysis and measurements both in the study of software and, if possible, even of hardware.

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[37] Matthew Fuller, *Media Ecologies. Materialist Energies in Art and Technoculture* (Cambridge, MA: MIT Press, 2005), p. 4.