DEPARTMENT: ANECDOTES

Bell Labs’ Portrayal of Switching as Computing (or Not)

Kim W. Tracy, *Rose-Hulman Institute of Technology, Terre Haute, IN, 47803, USA*

Bell Labs was eager to apply evolving computing technologies and electronics to the Bell System, particularly for enabling the Bell System to be able to handle the rapidly increasing demands on the telephone network. By the mid-1940s and into the 1950s, Bell Labs had begun multiple efforts to develop electronic switching. In the late 1940s, the Switching Research group led by Deming Lewis was investigating the use of pulse code modulation (PCM) as a way of digitizing speech and building systems to leverage electronics not only for the control systems but for the switching fabric as well, particularly in the Experimental Solid State Exchange (ESSEX) [6], [23]. With the transistor’s invention in 1947, there was an eagerness to apply this technology once it became reliable enough to replace vacuum tubes, which were considered less reliable and more power hungry than relays.

Other Bell efforts to apply electronics to telephone switching came from Bell Labs Systems Engineering group, which was led by Ken McKay. These systems engineering efforts were realized with the installation of the No. 1 Electronic Switching System (ESS) in Morris, Illinois, in 1960 [3], [7], [10]. External pressures were also coming to bear with the 1956 Consent Decree effectively barring AT&T from competing in the computer business. So, there was a need to make sure that telephone switching was not perceived as a computer business.

Bell Labs produced a number of histories related to is contributions to computing. A recently rediscovered history from 1961 [15] had an extensive history of switching compared to later histories, such as [4] and [5]. The rest of this 1961 history was very similar in content to later efforts. As a result, this discrepancy with how telephone switching was included (or not) in Bell Labs’ computing history stimulated me to investigate the shift in how telephone switching was portrayed from computing to being termed *stored-program control*.

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BELL LABS COMPUTING HISTORIES

The earliest document that describes the contributions of Bell Laboratories to computing is a 71-page internal Bell Labs report from 1961 [15]. This document has an extensive section on telephone switching (five pages including references) as well as sections on computing that remained in later Bell Labs histories. This unpublished document appears to be a report prepared for Ken G. McKay (vice president for systems engineering from 1959 to 1962) and William O. Baker (then vice president of Bell Labs research and, later, president of Bell Labs) [18]. “The Bell System is not in the commercial computer business,” it declared, but

> It does have a growing interest in electronic switching, data transmission, and digital techniques for voice and television transmission. It also must continue to assume military tasks for which it is especially qualified. For these reasons, it will continue to be a major contributor to the digital computing and information processing fields. [15, p. 2]

The 1961 report was edited by W. Deming Lewis, who was leading switching research, with sections authored by those with primary roles in the technologies they describe. At the time, Baker supported computing research as a vice president. This document was found by a Nokia Bell Labs archivist at this author’s request in Baker’s papers remaining at Murray Hill. Bill Baker went on to heavily support computing research during his tenure as Bell Labs president (1973–1979).

Later histories to commemorate the 50th anniversary of Bell Labs were created in the early 1980s. These included an internal document on Bell Labs’ role in computing [4] that was later expanded for external audiences [5]. This latter document was also revised as well for the 1984 *A History of Engineering and Science in the Bell System, Communications Sciences*. These documents say almost nothing about telephone switching when compared to the 1961 history [15].

Additionally, Amos Joel Jr. (whom we called the father of electronic switching within Bell Labs) edited the 1982 switching history volume of *A History of Engineering and Science in the Bell System*. Joel was influential in transitioning telephone switching to use electronics, particularly in the creation of the Morris electronic central office (ECO) and the follow-on No. 1 ESS. Oral histories of Joel detail the breadth of Joel's work [8], [9]. The Bell Labs' telephone switching history presented to the public became completely separate from the computing history in these externally published books and even in the internal folklore within Bell Labs.

ELECTRONIC SWITCHING AT BELL LABS

Bell Labs began considering how to integrate electronics into switching in the late 1940s. At the time, step-by-step and crossbar systems were the prominent electromechanical telephone switching platforms. In the 1940s, Bell began to consider using electronics to automate switching. After 1947, the transistor was viewed as having even greater promise than vacuum tubes in the future.

One of the primary decisions was whether or not to *fully* automate the switching network with electronics. Automating the switching network would require moving to something like time-division multiplexing (TDM) and so abandoning the use of end-to-end physical connections (then called "space-division switching") using electromechanical switches. Using TDM would be more easily enabled by encoding the signals in something like PCM, which used sampling to translate analog voice calls into binary streams of data.

Figure 1 provides a rough timeline of early electronic switching efforts at Bell Labs. This timeline is separated into efforts made by the switching research unit (noted in green and above the timeline) and the production switching efforts led by the systems engineering unit (noted in blue and below the timeline). Beginning in 1947, the earliest effort was the Electronically Controlled Automatic Switching System (ECASS) that used thermionic (vacuum) tubes, dry-reed relays, and cold cathode gas diodes to replace human operators [17]. The ECASS continued to use end-to-end physical connections rather than replacing them using TDM and PCM.

An automatic telephone system employing magnetic drum memory, the Drum Information Assembler and Dispatcher (DIAD), in 1949 began to closely resemble a computing system by using a separate memory and electronic control [16]. DIAD "may be considered a kind of computer." DIAD used about 1,100 vacuum tubes and 2,200 germanium diodes. The switching research unit was also involved with developing PCM [19], [20] and saw it as the key to TDM [19]. The switching research's ESSEX implemented PCM in an all-solid-state systems, which included the switching elements [23], [6]. ESSEX demonstrated that such all-electronic systems were feasible and could be considered a specialized form of computer. Lewis [15] notes that a systems engineer, Chester E. Brooks, proposed an all-electronic switch in 1951 but gives only a reference to a 1958 *Fortune* article [1] that predicted the Bell System would be using solid-state switching based on PCM and TDM by 1980. (This turned out to be about right.[1])

[1]Chester E. Brooks was the author of a number of U.S. patents, including 3,120,581 for an "Electronic Automatic Telephone Switching System" filed November 19, 1956. This describes the operations of the system, including the use of binary for control circuits. A preliminary search of Bell Labs' internal documents by Brooks around 1951 has yet to yield those documents, but this author is convinced they existed.

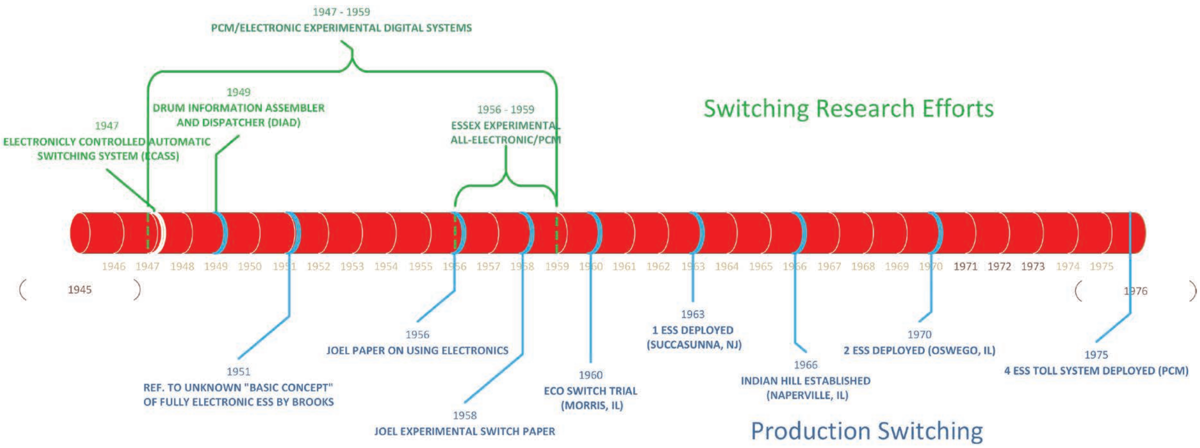

FIGURE 1. Timeline of early electronic switching efforts at Bell Labs (this author's analysis). DOC: document; REF.: reference.

On the production switching side of Bell Labs, Joel documented the possible uses of electronics to control the switching network in 1956 [7]. He went on to propose an experimental switch that implemented those ideas in a practical system [11] concurrent with research work on the ESSEX. Joel built on that idea for a successful field trial in 1960 in Morris, Illinois (sometimes called the Morris switch or, alternatively, the ECO) [13]. By this time, the embedded base of crossbar and other switching technologies made the evolution of the network challenging and impossible to digitize all at once. This successful 1960 trial led to a production version that became the No. 1 ESS system [3], [12], [2]. This deployment of changes to the Bell System's production switching network became the accepted public history of switching [10] as well as that shared within Bell Labs [2].[2] It would not be until the 4ESS toll switch and then the 5ESS local switch in the late 1970s and 1980s that all-electronic and digital switching networks would be deployed in the Bell System. [20]

EVOLUTION OF SWITCHING FROM COMPUTING TO STORED-PROGRAM CONTROL

In 1953, Deming Lewis [14] tied electronic computers directly to telephone switching and detailed the relationships between them. A 1949 article [21] by Claude Shannon detailed the memory requirements for a telephone exchange in terms of John Tukey's recently coined "bits." Much of Shannon's work in the late 1940s and early 1950s was tied to switching. Even work such as Shannon's famous Theseus mouse (which could "learn" how to traverse a maze) was justified as being related to switching [22].

In an article where he looked back on his role in switching history, John Pierce linked the efforts to develop and promote PCM as a way to make fully electronic switching possible [20]. PCM work was done not only with Pierce but also with Shannon and Oliver, as noted in [19], where they hinted that PCM would enable fully electronic telephone switching. Early ESSs made a direct comparison to a computer, particularly the 1949 DIAD, whose description contains a figure that equates the system to a computer, with the only difference that the arithmetic logic unit (ALU) was replaced by the "connecting network" or switching fabric (Figure 2) [17, p. 1341].

In [14], Lewis made direct comparisons between ESSs and computers, especially for the DIAD as well as the 1947 ECASS [17]. He made direct comparisons to the Harvard Mark I and II as well as the Bell relay computers that showed their strong functional resemblance to these ESSs. Lewis went on to say that the contributions between computing and switching go both ways, with switching likely to contribute to computing "devices, to reliability and to systems employing two or more computers." These examples demonstrate that the thinking, particularly within Lewis's research team, was that computing and switching were complementary and overlapping technologies. Lewis made general and particular arguments of the strong tie to computing:

> But the similarity between a digital computer and a "common control" switching system extends beyond the machinery. It is functional as well. [14, p. 1242]

and

> In a common control switching system, central units are used to process information about all calls and control all the switches. Here there is a particularly close resemblance to the modern large digital computer. [14, p. 1242]

Lewis also predicted the future of computer networking in 1953:

> Applying this [referring to multiple central offices handling a call] to computers there emerges the possibility of joint action of two or more computers to solve problems which are too big for any one alone. [14, p. 1244]

and

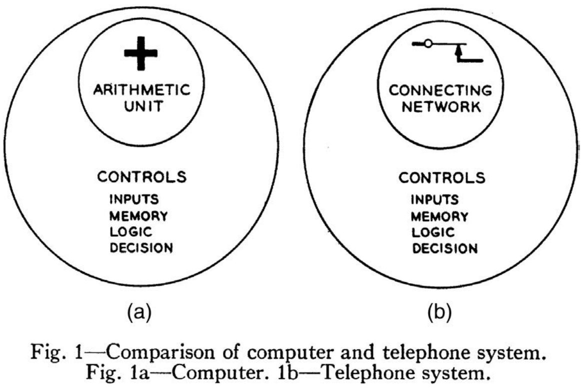

FIGURE 2. Figure from the DIAD 1952 paper [14] comparing switching to computing, where the only difference is that the ALU is replaced by the "connecting network."

[2]The *Engineering and Operations in the Bell System* book [2] was primarily intended as a training document and issued to every new engineer at Bell Labs.

> Since big computers are likely to be separated geographically, this would call for means for high-speed transmission and reception of digital information. [14, p. 1244]

Joel's system engineering group within Bell Laboratories provided practical switching systems that could expand with the rapidly growing telephone network. Joel had proposed using electronic components as in [7] as well as a system that did not digitize the switching network but, rather, only for control, much like the architecture the DIAD had used. He went on to use this same architecture for the ECO [11], [13] and in the No. 1 ESS [2], [3], [12]. AT&T seemed to have already decided to postpone digitizing the switching network until 1980 [1], using PCM as the Bell Labs switching research group proposed in the ESSEX [23], [6] in the late 1950s.

Joel's systems engineers appear to have settled on a stored-program control model of switching that would last until the mid-1970s deployment of the 4ESS toll switch using PCM. It makes sense that stored-program control would differentiate Joel's approach from the fully digital model that the switching research group saw as the future. This terminology of "stored-program control" continued even after the switching system became fully electronic and digital with the 4ESS and 5ESS in the late 1970s and 1980s. By then, and the 1984 divestiture, the terminology of "stored-program control" was ingrained in the switching system engineering culture, and there was little need to change it to be a "specialized computer" or similar explicit terms.

CONCLUSION

Early in the development of electronic switching at Bell Labs, telephone switching was viewed as a specialized form of computing. With the competing efforts within the Labs to develop an all-electronic versus a partially ESS, it made sense to call the version that didn't replace the switching network "stored-program control," as it was for controlling the switching network. The partially electronic version won out, largely for practical reasons of reliability and cost. The situation was complicated by the 1956 Consent Decree requiring that AT&T not enter the computing business, which explains why the histories for telephone switching and computing were portrayed separately to the world outside Bell Labs. By the time that Bell began deploying ESSs in the 1970s, "stored-program control" was so ingrained in Bell Labs culture that it made no sense to change.

ACKNOWLEDGMENTS

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KIM W. TRACY teaches computer science and software engineering at the Rose-Hulman Institute of Technology, Terre Haute, IN, 47803, USA, and previously worked at Bell Labs. Contact him at tracy@rose-hulman.edu.