Remembering the LFK Network

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1 Introduction

The well known ARPANET was the first operational packet switching network.[1] Almost completely unknown is what we believe (claim) was the second operational packet switching network — the LFK Network — although, admittedly it was a fairly minimal network.

Work on the LFK Network began in the fall of 1970, and it was installed and accepted by the fall of 1972. It was used as part of a logistics system relating to the Norwegian Air Force and NATO. It was developed for the Norwegian Air Force Supply Command[2] by two companies: Siemens Norway (which held the formal contract with LFK) and Norsk Data or ND (which was technically subcontractor to Siemens but did most of the technical work).[3] The relevant offices of both companies were based a little east of downtown Oslo, near the Linderud stop of Oslo's subway system. The people in LFK supervising this project were located near the Norwegian

[1]The ARPANET history has been described in many places — in contemporary technical papers and in popular and historical accounts of the history of the Internet. Two easily accessible books describing ARPANET's history are by Abate [1] and Hafner [3].

[2]The *Luftforsvarets forsyningskommando* in Norwegian, hence the initials LFK, pronounced in Norwegian as an English reader might say "el ef koh".

[3]Norsk Data was *the* Norwegian computer company, started in 1967 and growing into a legendary Norwegian success story [5] by the mid 1980s. Unfortunately, by the late 1980s, ND's minicomputer-with-ND-proprietary-operating-system products began to suffer significantly from competition from personal computers with the Windows, MAC, or UNIX/LINUX operating systems; this business problem was exacerbated by the severe stock market decline of 1987 ("black Monday" and what followed).

government's research complex in Kjeller, about 30 kilometers northeast of Oslo.

2 The relationship between the LFK Network and ARPANET

In 1970, having participated in the development of the ARPANET and the installation of the first several ARPANET packet switches as part of the BBN "IMP Guys" team, Dave Walden[4] and his family were trying to find a place Dave could work in Europe so they could experience living in Europe for a while. By happenstance, Dave sent a resume to ND. He was interviewed by ND co-founder Rolf Skår who happened to be spending a term at MIT as a visiting engineer,[5] and he was offered a job by ND. In September of 1970, Dave and his family moved to Oslo where Dave begin work for ND.

When he got to Oslo, Dave was informed that ND had a contract to participate in the development of the LFK Network, and he was asked to work on that project. Still excited about participating in the accomplishment of developing the first packet switch, Dave encouraged use of many of the techniques used in the ARPANET IMP, although the scale of the LFK Network didn't really require the generality present in the ARPANET IMP.[6]

3 System design overview

The LFK Network was basically a fancy teletype front-end for a Control Data 1700 and had both the ARPANET IMP and TIP functions.[7]

[4]Second author of this paper.

[5]Bolt Beranek and Newman Inc. (BBN), which developed the IMP packet-switch under contract to ARPA, was located in Cambridge, a few miles from MIT.

[6]However, since the LFK Network was done as a relatively modest commercial contract, bidding to do this job as a *network* probably wouldn't have been possible for ND without the "pre-solution" available from the ARPANET design. Without the ARPANET design input, the LFK Network probably would have been implemented as a terminal concentrator.

[7]The Interface Message Processor (IMP) was the ARPANET packet switch [4], and the Terminal IMP (TIP) was the ARPANET terminal-server host [8] that resided in the same

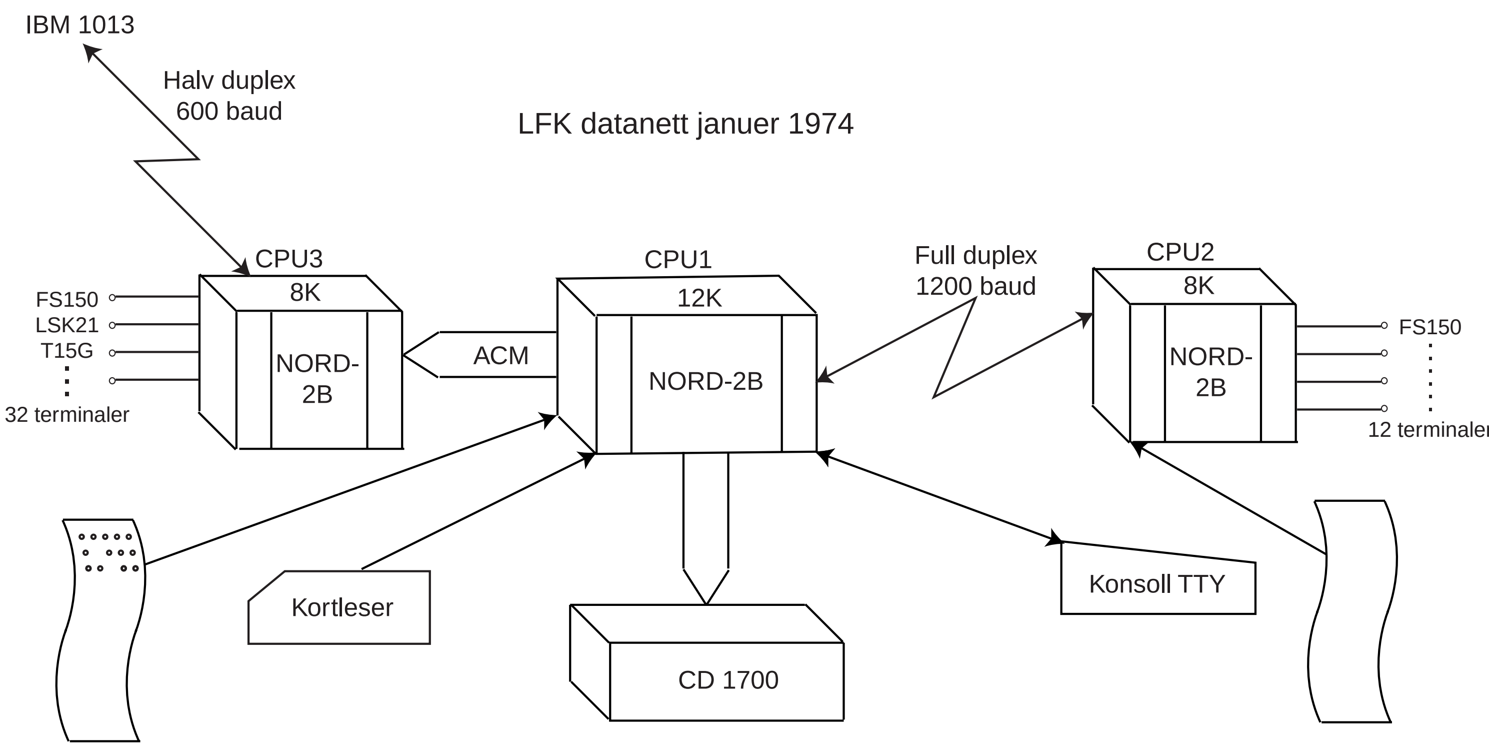

Figure 1: LFK Network Configuration

Figure 1 is a reillustration (so it prints well in this paper) of the configuration of the LFK Network in 1974, at the time Nils Liaaen[8] was leaving the project and, thus, doing some wrap-up documentation.[9] The NORD-2B machines were packet-switches with built-in TIP functionality.

The LFK Network copied aspects of the ARPANET implementation, for instance, positive acknowledgements and time-outs between packet switches, source-to-destination Ready-for-next-message (RFNM) signals, and a simple dynamic routing mechanism. The LFK packet switches also had built-in remote debugging capabilities modeled after the ARPANET IMPs. The LFK packet switches also only used single packet-messages, rather than the combination of single- and eight-packet messages used in the ARPANET.

The end-to-end RFNM-like mechanism controlled message flow. Also in place was a form of priority traffic messages to prevent deadlocks.[10]

The LFK Network topology was no routing challenge, to say the least. However, we did implement a general mechanism that counted distance (hops) between nodes and selected the shortest route.[11] The dynamic routing algorithm was not strictly necessary in the actual network configuration except for adapting to node ups and downs and to allow future expansion (which was not anticipated).

The system software was designed to have a maximum of eight nodes and 128 (teletype) terminals on each node. There were also 30 "canned" communication formats ("forms") in support of the network's logistics function. The teletype drivers also had some built-in formatting and format checking software used to fill in military forms. A small, special purpose interpretive programming language was designed to handle this.

box as the IMP.

[8]First author of this paper.

[9]The labels in the figure should be reasonably self-explanatory, albeit in Norwegian. *Kortleser* means card reader. The component in labeled ACM between the left and middle NORD-2B computers is a direct accumulator-to-core-memory channel. The similar shaped component going downward from the middle NORD-2B computer is also a direct memory channel, in this case into the CD 1700 computer.

[10]See [4] for a description of RFNMs. While RFMMs sort of worked in the very simple LFK Network, they did not adequately control congestion in the larger ARPANET [6] and had to be replaced with a better mechanism [7]. With the transition to TCP/IP for the Internet, much of the problem of end-to-end flow control was passed to the host level.

[11]Like ARPANET's distance-vector routing before ARPANET switched to link-state routing.

TELEX-like e-mail was also supported by the system; it was not part of the contract but was added as a bonus to the customer because it was easy to add because of the generality of the system design.[12]

The packet switch labeled CPU2 was located in Bodø in northern Norway, where it served as a terminal interface for 12 teletype-like terminals (mostly 50 and 100 baud, 5 bit Baudot code) serving northern Norway all the way up and around to the Russian border. CPU3 was connected to a pair of NORD-2Bs (CPU1 and CPU2 in the LFK computer room at Kjeller outside Oslo) via 1200 baud full duplex leased telephone lines (an almost unheard of extravagance in Norway in those days).[13]

The logical connection between the pair of NORD-2B packet switches in Kjeller (CPU1 and CPU3) was a packet-switch to packet-switch connection just like that over the CPU1-to-CPU2 modem line; however, the physical connection was a register-to-memory channel, involving a straight forward semaphore algorithm to synchronize transmissions between the two machines. The packet switch labeled CPU3 handled 32 teletype-like terminals (mostly 50 and 100 baud, 5 bit Baudot code) in southern Norway. The packet switch labeled CPU1 managed communication with the CD 1700 and also had various other peripherals, such as a 80-column card reader, a console teletype and a special IBM 1013 card transmission terminal emulator. The connection of the card reader and the 1013 were also additions to the system not in the original contract, made easy because of the generality of the underlying communication system.

The IBM 1013 was part of a dial-up connection between Norway and the AUTODIN II network, which served the U.S. military and NATO countries. The normal operation of this IBM 1013 was transmitting (and receiving) punched card images from an AUTODIN II node in West Germany. The LFK Network concept was that the CD 1700 should be able to treat the German 1013 as a local card reader / card punch through the network. We got it to work towards the local 1013, but never in Germany. We gave up, blaming the German PTT for having poor modems. Nils Liaaen remembers the 1013 as a fun part of the system to work on. Among other memorable things, he used a field telephone listening to the modem traffic

[12]We can't resist noting the parallel with ARPANET where e-mail was also a simple, natural addition once the underlying system was in place.

[13]Incidentially, Kjeller was also the destination of the first international ARPANET connection — to the NORSAR seismic array and the Norwegian Defense Research Establishment (and the group led by Yngvar Lund).

while debugging the 600 baud, half duplex, 4-of-8 coded IBM protocol.

The 1200 baud synchronous line used a homemade protocol and recovery mechanism. It was slow and very conservative when synchronizing. When retransmission counts where exceeded, a long delay was introduced to make sure that both ends would declare the line dead and be reset to the same state before restarting the synchronization process and finally achieving normal communication again. As already mentioned, we used only positive acknowledgements and time-outs (no negative acknowledgements). The protocol was influenced by the ECMA-24 standard, which supported binary transparency using DLE-doubling.

The LFK Nework ran "forever" (more than 10 years) with very little, if any, problems or maintenance. In some ways the LFK Network was an early internet as it consolidated several protocols and codes into a pretty unified and consistent communication system.

4 Project team

Dave Walden was system architect and ND's project leader from the time he arrived at Norsk Data until he returned to BBN and the ARPANET project in September 1971.

Nils Liaaen soon joined ND as a control systems engineer fresh out of the Norwegian Technical University in Trondheim. He was the programmer for the project and collaborated with Dave Walden in thinking out the system architecture. When Dave returned to BBN, Nils took over as system architect and project leader.

Dag Spilde of ND took over responsibility for the LFK Network when Nils Liaaen left ND.[14]

Jack Jensrud of ND designed the NORD-2B minicomputer used for the system, the LFK Network being the first application for the 2B. The 2B was a significantly down scaled version of ND's main product, the NORD-1. It had the same instruction set as the NORD-1, but without the multiply and divide instructions and floating point capability. The 2B had two identical register banks for fast interrupt servicing (the NORD-1 had 1 register set, but automatic context switching to memory and 16 priority levels[15]).

[14] He was leaving to go to BBN — see section 5.

[15] Partially resulting from the experience using the 2B in the LFK Network, the later and very successful NORD-10 had 16 register sets.

Jan Bjerke of ND designed the CD 1700 interface. The network interface accessed the 1700 through its disc IO-channel, reading and writing directly to the 1700 memory.

Bård Sørbye of ND designed the special teletype interfaces to the exsisting military teletype equipment, as well as somewhat unusual *lochstreifen karte* readers (a punched paper-tape / card combination).

Leif Riisnes and Rolf Andersen were the Siemens people involved in the project. As mentioned earlier, Siemens had the formal contract with the Norwegian Air Force since ND was a relatively new and unproven entity. However, most of the actual work was done at ND.

Major Nils Michelsen was LFK project manager and the primary CD 1700 programmer.

5 Other connections with the future Internet

Nils Liaaen at BBN. During development of the LFK Network, the authors of this paper became good friends. After Dave returned to BBN, he encouraged BBN's management to offer Nils an opportunity to work at BBN and, thus, to live in the United States for a couple of years. In 1974, Nils left ND and joined the ARPANET team at BBN, where he worked on the Satellite IMP system that was used in some of the earliest experiments with actual networking among networks. Nils's U.S. stay was cut short when circumstances required him to return to Ålesund, Norway, to help manage Liaaen A / S, the ship building business of his family.

Bo Lewendal at ND. In 1971, Bo Lewendal, a Swede who had spent much of his youth and his college years in San Francisco Bay Area and wanted to return to Scandinavia, came to work at ND. Bo had been at the Berkeley Computer Company (BCC), which had been founded by the team of people (mostly out of UC Berkeley) who, as part of Berkeley's Project Genie (which had ARPA funding), had modified an SDS-930 computer and added a time-sharing system software that became the prototype for the SDS-940.

The BCC team included Peter Deutsch, Butler Lampson, Charles Simonyi, Chuck Thacker, etc., many of whom later became a core part of Xerox PARC. One of this group of people was Ed Fiala who had previously worked at BBN where he knew Dave Walden. At BBN, Ed was involved with the BBN team that drew on its experience with the SDS-940 system in the development of the ARPA-funded TENEX time-sharing system that later evolved into the TOPS-20 system from Digital.

Knowing of Bo's desire to return to Scandinavia, Ed asked Dave (by that time at ND) if there might be an opportunity for Bo at ND. Dave passed word of Bo's interest on to Rolf Skår and helped Rolf calibrate what should be inferred when someone like Peter Deutsch or Butler Lampson answered reference checks saying that Bo was a "good" programmer.

Bo was hired by ND and brought with him insights from the ARPA world of time-sharing system development. A marvelous programmer, Bo was key to implementation of a time-sharing system for ND's computers that was much better than what was available at the time from most ND's competitors in Europe (mostly U.S. companies). This time-sharing system helped ND win a contract to deliver computer systems to CERN in Switzerland.[16] According to Gillies and Cailliau [2], these ND computer systems played a small role in the development of the World Wide Web.

References

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[2] James Billies and Robert Cailliau. *How the Web was Born*. Oxford University Press, Oxford, UK, 2000.

[3] Katie Hafner and Matthew Lyon. *Where Wizards Stay Up Late*. Touchstone imprint of Simon & Schuster Inc., New York, paperback edition, 1998.

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[5] Per Oyvind Heradstveit. *Enentyret Norsk Data*. J. M. Steenersens Forlag A/S, Oslo, Norway, 1985.

[16] At one time or another, Nils Liaaen, Rolf Skår, and Bo Lewendahl all spent time in Geneva working on installing the ND computer system at CERN.

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