Anecdotes

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Remembering the LFK Network

The well-known Arpanet was the first operational packet-switching network.[1] Almost completely unknown is what we 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 fall 1970, and it was installed and accepted by fall 1972. It was used as part of a logistics system relating to the Norwegian Air Force and North Atlantic Treaty Organization (NATO). It was developed for the Norwegian Air Force Supply Command (the *Luftforsvarets forsyningskommando* [LFK] in Norwegian) by two companies: Siemens Norway, which held the formal contract with LFK, and Norsk Data (ND),[2] which was a subcontractor to Siemens, but did most of the technical work. The relevant offices of both companies were based a little east of downtown Oslo. The people in LFK supervising this project were located near the Norwegian government's research complex in Kjeller, about 30 km northeast of Oslo.

The LFK Network and Arpanet

In 1970, having participated in Arpanet's development and the installation of the first several Arpanet packet switches as part of the Bolt Beranek and Newman (BBN) Interface Message Processor ("IMP Guys") team, Dave Walden and his family were trying to find a place he could work in Europe so they could experience living there for a while. By happenstance, Walden sent a resume to ND. He was interviewed by ND cofounder Rolf Skår who happened to be spending a term at MIT as a visiting engineer,[3] and ND offered him a job. Walden, with his family, moved to Oslo in September 1970 to begin work for ND.

When he got to Oslo, Walden 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, Walden encouraged following techniques used in the Arpanet IMP, although the scale of the LFK Network didn't require the generality in the Arpanet IMP. However, because 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 established Arpanet design. Instead, it probably would have been implemented as a terminal concentrator.

System design overview

The LFK Network was a fancy teletype front-end for a Control Data 1700 and had both the Arpanet IMP and terminal IMP (TIP) functions. (The IMP was the Arpanet packet switch,[4] and the TIP was the Arpanet terminal-server host[5] that resided in the same box as the IMP.)

Figure 1 illustrates the LFK Network's configuration in 1974, at the time Nils Liaaen was leaving the project and, thus, doing some wrap-up documentation. The NORD-

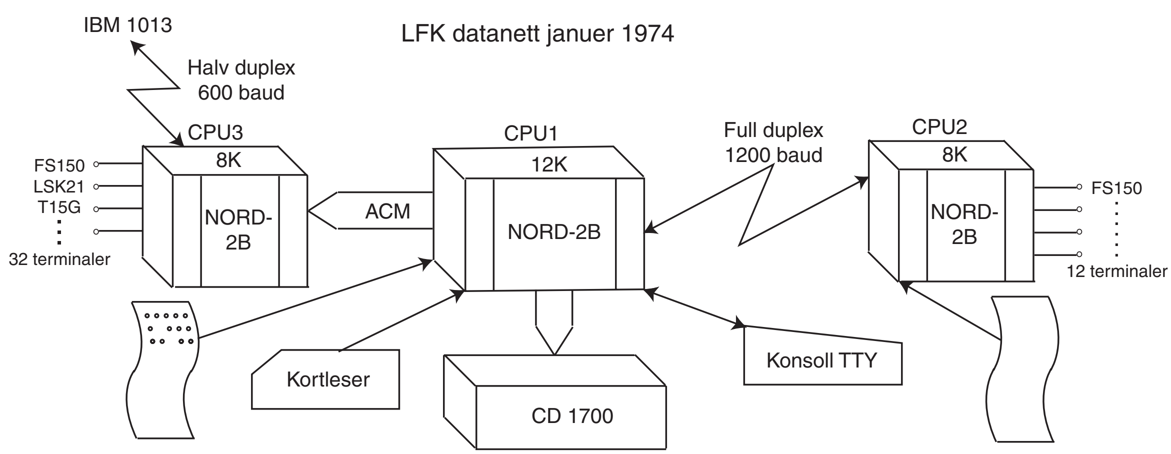

Figure 1. LFK Network configuration, as documented in January 1974. Kortleser means card reader, Halv means half, Konsoll means console, and terminaler means terminals.

2B machines were packet switches with built-in TIP functionality. The component labeled ACM between the left and middle NORD-2B computers is a direct accumulator-to-core-memory channel. The similarly shaped component going downward from the middle NORD-2B computer is also a direct memory channel, in this case into the CD 1700 computer.

The LFK Network copied aspects of the Arpanet implementation—for instance, positive acknowledgments 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 only used single-packet messages, rather than the combination of single- and eight-packet messages used in the Arpanet.

An end-to-end RFNM-like mechanism controlled message flow. Also in place was a form of priority traffic messages to prevent deadlocks. (See Heart et al.[4] for a description of RFNMs. Although RFNMs sort of worked in the simple LFK Network, they did not adequately control congestion in the larger Arpanet and had to be replaced with a better mechanism.)

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—like Arpanet's distance– vector routing before Arpanet switched to link-state routing. The dynamic routing algorithm was unnecessary 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) to support 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. The system also supported Telex-like email; it was not part of the contract but was added as a bonus to the customer because the system design's generality made it easy to add.

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 were 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).

The logical connection between the pair of NORD-2B packet switches in Kjeller (CPU1 and CPU3) was a packet-switch to packet-switch connection over the CPU1-to-CPU2 modem line. However, the physical connection was a register-to-memory channel, involving a straightforward 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 had various other peripherals, such as an 80-column card reader, a console teletype, and a special IBM 1013 card transmission terminal emulator. The connection between the card reader and the 1013 was also an addition to the system not in the original contract, made easy because of the underlying communication system's generality.

The IBM 1013 was part of a dial-up connection between Norway and the Autodin II network, which served the US 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 and card punch through the network. We got it to work toward the local 1013 but never in Germany. We gave up, blaming the German telephone company 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 to listen to the modem traffic 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 conservative when synchronizing. When retransmission counts were exceeded, a long delay was introduced to ensure that both ends would declare the line dead and reset it to the same state before restarting the synchronization process, finally achieving normal communication again. As already mentioned, we used only positive acknowledgments and time-outs (no negative acknowledgments). The protocol was influenced by the ECMA-24 standard, which supported binary transparency using the DLE escape character.

The LFK Nework ran more than 10 years with little, if any, problems or maintenance. In some ways, the LFK Network was an early Internet because it consolidated several protocols and codes into a unified and consistent communication system.

Other connections with the future Internet

During the LFK Network's development, the authors of this anecdote became good friends. After Walden returned to BBN, he encouraged BBN's management to offer Liaaen an opportunity to work at BBN and, thus, to live in the US for a couple of years. In 1974, Liaaen 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. Liaaen's US stay was cut short when circumstances required him to return to Ålesund, Norway, to help manage Liaaen A/S, his family's ship-building business.

In 1971, Bo Lewendal came to work at ND. Lewendal 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, and others, many of whom later became a core part of Xerox PARC. One member of this group was Ed Fiala, who had previously worked at BBN, where he knew Walden. At BBN, Fiala was involved with the 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 Lewendal's desire to return to Scandinavia, Fiala asked Walden (by that time at ND) if there might be an opportunity for Lewendal at ND. Lewendal was hired at ND, and he brought with him insights from the ARPA world of time-sharing system development. Lewendal 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 of ND's competitors in Europe (mostly US companies). This time-sharing system helped ND win a contract to deliver computer systems to CERN in Switzerland. According to Gillies and Cailliau,[6] these ND computer systems played a small role in the development of the World Wide Web.

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References and notes

1. The Arpanet history has been described in many places—in contemporary technical papers and in popular and historical accounts of the Internet's history. Two easily accessible books describing Arpanet's history are by J. Abbate, *Inventing the Internet*, MIT Press, Cambridge, Mass., 1999, and K. Hafner and M. Lyon, *Where Wizards Stay Up Late*, Simon & Schuster, New York, 1996.
2. Norsk Data was the Norwegian computer company, started in 1967 and growing into a legendary Norwegian success story by the mid 1980s. (See P. O. Heradstveit, *Eventyret Norsk Data*, J.M. Steenersens Forlag A/S, Oslo, Norway, 1985.) Unfortunately, by the late 1980s, ND's minicomputer with ND proprietary operating system products began to suffer significantly from competition from PCs with the Windows, Macintosh, or Unix/Linux operating systems; this business problem was exacerbated by the 1987 stock market decline (black Monday) and what followed.
3. Bolt Beranek and Newman (BBN), which developed the IMP packet-switch under contract to ARPA, was located in Cambridge, a few miles from MIT.
4. F.E. Heart et al., "The Interface Message Processor for the ARPA Computer Network," *Am. Federation of Information Processing Soc. (AFIPS) Conf. Proc.*, vol. 36, AFIPS Press, Montvale, N.J., 1970, pp. 551-567.
5. S.M. Ornstein et al., "The Terminal IMP for the ARPA Computer Network," *Am. Federation of Information Processing Soc. (AFIPS) Conf. Proc.*, vol. 40, AFIPS Press, Montvale, N.J., 1972, pp. 243-254.
6. 2. J. Gillies and R. Cailliau, *How the Web Was Born*," Oxford Univ. Press, Oxford, UK, 2000.