David Lennox Mills

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1. Personal Data

Born 3 June 1938, Oakland, CA; married, two children.

2. Education

B.S.E. (Engineering Science), University of Michigan), 1960.
B.S.E. (Engineering Mathematics), University of Michigan, 1961.
M.S.E. (Electrical Engineering), University of Michigan, 1962.
M.S. (Communication Sciences), University of Michigan, 1964.
Ph.D. (Computer and Communication Sciences), University of Michigan, 1971.

3. Employment Summary

University of Delaware (1986 - present), Newark, DE: Professor of Electrical Engineering

Dr. Mills presently leads projects in high speed networks and internetworking research sponsored by the Defense Research Projects Agency and National Science Foundation. He is Principal Investigator for the Highball Project, which is studying high speed routing, switching and synchronization technology. His research activities are concentrated in the areas of network architecture, protocol engineering and experimental studies involving the DARPA/NSF Internet system.

He is a member of the Internet Research Steering Group, End-to-End Research Group and AT&T Network Architecture Advisory Panel, and formerly chaired the DARPA Internet Architecture Task Force and Gateway Algorithms and Data Structures Task Force. He served on the National Academy of Sciences Committee on Survivable Telecommunications Networks, DARPA Internet Activities Board and NSF Network Technical Advisory Group, as well as several other groups involved with internetworking research coordination.

Dr. Mills was the advisor and principal architect for the NSFNET Phase I backbone network, which interconnected six supercomputer sites and later evolved into the present national backbone. Software and network routing protocols he developed for use in the DARPA Internet research program and commonly called the “Fuzzball” was used in the packet routers and gateways of that system.

He has for many years been an active contributor to the field of computer network time synchronization. Protocols he developed, prototyped and deployed evolved to the Network Time Protocol, which is now in widespread use in the Internet from the Pacific Rim to Eastern Europe to South Africa. One of his current interests is in extending the accuracy, stability and robustness of this technology to the submillisecond regime on desktop workstations.

Linkabit Corporation (1982 - 1986), Vienna, VA: Director, Networks

Dr. Mills directed and participated in internetworking research projects sponsored by DARPA and other government agencies. One of these involved research on network and internetwork architectures, protocol design and implementation, performance measurement and evaluation. He designed, prototyped and wrote the specification of the Exterior Gateway Protocol, which is still in use throughout much of the Internet community to exchange routing information between campus, regional and backbone networks.

Another project involved research on multi-media message systems, including image, speech and text mail, local networks and satellite systems. A third involved research on network vulnerability and robustness, especially in the area of protocol threats and countermeasures. In addition, he directed and participated in a number of contracted studies for DoD customers, including a link-level protocol design for a reliable high-frequency radio system and several protocol-standards projects.

COMSAT Corporation (1977 - 1982), Washington, DC: Senior Research Scientist, Communication Sciences Laboratory

Dr. Mills directed and participated in the analysis, design and implementation of communication protocols and systems for the DARPA Internet Project, including a demonstration local network (DCNET) and internetwork hosts and gateways. He actively participated in the evolution of TCP, TELNET, FTP, SMTP and related protocols which are now widely used. He also participated in many experiments and demonstrations with several networks, including DCNET and ARPANET, and consulted on and participated in the transfer of this technology to the INTELPOST electronic mail system then run by COMSAT and the U.S. Postal Service.

He also worked on the analysis, design and implementation of SATNET, a state-of-the art satellite communications system sponsored by DARPA, and participated in the experimental program for the measurement of satellite channel characteristics with respect to delay, stability, fairness and robustness. He also supervised and participated in the implementation of experiment control and data reduction software. He conducted tests and measurements of the network, including overseas and domestic earth stations and a special experimental earth station at COMSAT Laboratories.

During this period Dr. Mills was appointed Visiting Lecturer at the University of Maryland and taught graduate-level seminar courses in Computer Networks and Protocols. He also performed analytical and experimental studies on a number of algorithms for real-time detection and decoding of manual Morse code signals sent by radiotelegraphy.

University of Maryland (1972 - 1977), College Park, MD: Assistant Professor of Computer Science

Dr. Mills participated in the analysis, design and implementation of the Distributed Computer Network (DCNET), which employs concepts of virtual operating systems, portable processes and novel communication protocols for the DEC PDP11 and Univac 1100-series computers. In addition, he developed a compact structured-programming language and compiler designed to produce object programs for a number of computers and microcomputers, including the IBM System/370, Univac 1100, DEC PDP8 and PDP11, Intel 8080 and Toshiba TLCS-12. This compiler was used by Ford in the production of code for the first onboard automobile computer.

In addition, he developed and taught a number of undergraduate courses in systems programming, programming languages, data communications and networks, as well as graduate courses in operating systems theory, systems architecture and seminars on advanced operating systems,

advanced data communications and networks, analytical models of operating systems and distributed computer networks.

University of Edinburgh (1971 - 1972), Edinburgh, Scotland: Lecturer in Computer Science

Dr. Mills worked on the development of a front-end processor for the ICL 4-75 computer and on digital filtering and ionospheric modeling. He also taught a third-year course on systems architecture and operating systems.

University of Michigan (1964 - 1971), Ann Arbor, MI: Research Associate, Computing Center

Dr. Mills worked on the specification and implementation of MAD/1 for the System/370, a follow-on version of a popular programming language for the IBM 7090. In addition, he was project leader on the development of the Data Concentrator, a special-purpose device for the attachment of interactive terminals to the System/360 Model 67 and supported by ARPA. He also designed and supervised construction of a computer-controlled electronic audio switch for use by the University of Michigan Language Laboratory and assisted in several sections of beginning and intermediate programming courses.

University of Michigan (1959 - 1964), Ann Arbor, MI: Research Assistant, Electrical Engineering Department

Dr. Mills worked on sponsored projects involving radio direction finding, secure-speech transmission, frequency synthesis, and digital communication.

Other Employment

Dr. Mills worked one summer (1975) at the Defense Communication Electronics Center in Reston, VA, on studies involving satellite channel modelling and distributed resource management. He also worked one summer (1963) at Beckman Instruments in Richmond, CA, on a microwave frequency synthesizer involving exotic materials. In addition, he moonlighted part-time for some years (1957 - 1963) for local broadcast stations as announcer and engineer to supplement income. He currently holds FCC operator licenses for commercial radiotelephone, marine radiotelegraph and amateur stations.

He has designed and taught many tutorials and continuing-education courses on internetworking, data communications, minicomputers, systems architecture, microprocessors and distributed computer networks for several universities, professional societies and meetings since 1966. He has served as a consultant on internetworking, operating systems, programming languages, communications and engineering design for several government and industrial research and development organizations.

4. Membership in Honorary and Professional Societies

Honoraries: Sigma Xi, Tau Beta Pi, Eta Kappa Nu.

Member of: Association for Computing Machinery SIGOPS, SIGPLAN, SIGCOMM, SIGCAPH (since 1963), Institute of Electrical and Electronic Engineers Computer Society and Communications Society (since 1988), American Radio Relay League (since 1953), Radio Society of Great Britain (since 1971), American Association for the Advancement of Science (since 1960).

Appointed ACM National Lecturer in the U.S. (1970 - 1976) and Europe (1971 - 1972).

5. Courses Taught (number of times)

University of Maryland: CMSC415 Systems Programming (2), CMSC440 Structure of Programming Languages (3), CMSC498 Seminar on Teleprocessing (1), CMSC600 Operating @INDENT = ystems (3), CMSC610 Hardware Architecture (3), CMSC818 Seminar on Data Communications Systems and Networks (6), CMSC818 Seminar on Analytical Models and Advanced Operating Systems (2).

University of Delaware: ELEG202 Introduction to Digital Systems (1), ELEG225 Logical Design of Digital Circuits (1), ELEG312 Circuit Analysis II (3), ELEG323 Digital System Design I (3), ELEG422 Digital System Design II (2), ELEG667/867 Seminar on Computer Networks (6).

6. Contracts and Grants

1. Co-Principal Investigator: "Appraisal of a Distributed Operating System for Network Control," University of Maryland, Department of Computer Science, for Office of Naval Research contract N00014-67-A-0239-0032 (June 1973 - May 1975, $74K total).

2. Principal Investigator: "Distributed Computer Network Project," University of Maryland, Department of Computer Science, for Office of Naval Research contract N00014-75-C-0872 (June 1975 - May 1977).

3. Co-Principal Investigator: "Research Equipment to Support Interactive Pattern Analysis System," University of Maryland, Department of Computer Science, for NSF Division of Control and Automation Engineering grant (May 1974 - October 1975, $70K).

4. Co-Principal Investigator: "Interactive Pattern Analysis and Classification Systems," University of Maryland, Department of Computer Science, for NSF Division of Control and Automation Engineering grant GK-41602 (February 1974 - January 1976, $94K).

5. Senior Scientist: "Research on the Internet System," COMSAT Laboratories (Clarksburg, MD), for DARPA Information Processing Technology Office contract MDA-903-80-C-0534-P0003 (January 1980 - June 1982, approx $300K).

6. Project Director and Manager: "High-Frequency Radio Communication Protocol Design and Implementation," M/A-COM Linkabit Eastern Operations (Vienna, VA) for U.S. Government agency contract (June 1982 - January 1983, approx $675K).

7. Principal Investigator, Project Director and Manager: "Experimental Test and Evaluation of the Internet Architecture," M/A-COM Government Systems Division (Vienna, VA) for DARPA Information Processing Technology Office contract MDA903-83-C-0024 (January 1983 - December 1983, approx $300K; January 1984 - December 1986, $1.34M).

8. Project Director and Manager: "Support for STC Fuzzball," M/A-COM Linkabit Eastern Operations (Vienna, VA) for SHAPE Technology Centre (den Hague, Holland) contract 640020 (January 1984 - July 1984, approx $40K).

9. Project Director and Manager: "Support for DCEC SETA on Internet Development," M/A-COM Linkabit Eastern Operations (Vienna, VA) for Systems Development Corporation (Santa Monica, CA) and Defense Communications Engineering Center (Reston, VA) subcontract 640000 (January 1984 - January 1985, approx $270K).

10. Project Director and Manager: "NSC HYPERchannel Driver for Fuzzball," M/A-COM Linkabit Eastern Operations (Vienna, VA) for Systems Development Corporation (McLean VA) and Defense Communications Engineering Center (Reston, VA) subcontract 6803 (January 1984 - February 1984, approx $20K).

11. Principal Investigator: "Support of the National Science Foundation Supercomputer Network Program," University of Delaware, Electrical Engineering Department, for NSF Division of Network and Communications Research and Infrastructure grant NCR-86-12015 (September 1986 - September 1989, $29K).

12. Principal Investigator: "Research in Internet Architectures and Protocols," University of Delaware, Electrical Engineering Department, for DARPA Information Processing Technology Office contract N00140-87-C-8901 (June 1987 - May 1989, $282K).

13. Principal Investigator: "Support of the National Science Foundation Networking Program," University of Delaware, Electrical Engineering Department, for NSF Division of Network and Communications Research and Infrastructure grant NCR-89-13623 (October 1989 - February 1992, $72K).

14. Principal Investigator: "Performance and Policy Dimensions in Internet Routing," University of Delaware, Electrical Engineering Department, for DARPA Information System Technology Office contract NAG-2-638 (February 1990 - January 1993, $849K).

15. Principal Investigator: "SAFENET Time Management," University of Delaware, Electrical Engineering Department, for Southeastern Center for Electrical Engineering Education contract N609 21-87-D-A315 (January 1991 - January 1992, $40K).

7. Journal and Symposium Publications

1. Mills, D.L. A random-access multiple-program system for the University of Michigan Language Laboratory. *Foreign Language Courier*, University of Michigan Press, June 1969. Also published as a technical report by: Language Laboratory, University of Michigan, April 1965.

2. Mills, D.L. Preliminary design specifications for a solid-state computer-controlled RAMP system. *Foreign Language Courier*, University of Michigan Press, June 1969.

3. Mills, D.L. Preprocessors in a data communication computer environment. *Proc. ACM Symposium on the Optimization of Data Communications Systems* (Pine Mountain, Georgia, October 1969), 112-109.

4. Mills, D.L. Multiprogramming in a small-systems environment. *Proc. ACM Second Symposium on Operating Systems Principles* (Princeton, New Jersey, October 1969), 286-310. Also published as: CONCOMP Project Technical Report 19, University of Michigan, May 1969.

5. Mills, D.L. Communications software. *Proc. IEEE 60, 11* (November 1972), 1333-1341. Also in: Green, P.E., and R.W. Lucky, (Eds.). Computer Communications. IEEE Press, New York, New York, 1975. Also in: Abrams, M., R.P. Blanc, and I.W. Cotton, (Eds.). Computer Networks: a Tutorial (Revised 1975). IEEE Press, New York, New York, 1975.

6. Lay, W.M., D.L. Mills, and M.V. Zelkowitz. Design of a distributed computer network for resource sharing. *AIAA Computer Network Systems* Conference (Huntsville, Alabama, April 1973).

7. Mills, D.L. Executive systems and program development for minicomputers. *Proc. IEEE 61, 11* (November 1973), 1556-1562.

8. Lay, W.M., D.L. Mills, and M.V. Zelkowitz. Operating systems architecture for a distributed computer network. *Proc. NBS IEEE Conference on Trends and Applications of Minicomputer Networks* (Gaithersburg, Maryland, April 1974).

9. Mills, D.L. Structured programming and compiling in a minicomputer environment. *Proc. IFIP TC-2 Working Conference on Software for Minicomputers* (Lake Balaton, Hungary, September 1975). Also published as: Computer Science Technical Report TR-339, University of Maryland, October 1974.

10. Mills, D.L. An overview of the Distributed Computer Network. *Proc. AFIPS National Computer Conference* (New York, New York, June 1976). Also published as: Computer Science Technical Report TR-413, University of Maryland, October 1975.

11. Mills, D.L. Transient fault recovery in a distributed computer network. *Proc. NBS/IEEE Trends and Applications Symposium* (Gaithersburg, Maryland, May 1976). Also published as: Computer Science Technical Report TR-414, University of Maryland, January 1976.

12. Mills, D.L. A new algorithm to determine the Levenshtein distance between two strings. *Proc. Workshop on String Matching* (University of Montreal, May 1979).

13. Kirstein, P., D.L. Mills, et al. SATNET application activities. *Proc. National Telecommunications Conference* (Washington, D.C., November 1979), 45.5.1-45.5.7.

14. Chu, W.W., D.L. Mills, et al. Experimental results on the packet satellite network. *Proc. National Telecommunications Conference* (Washington, D.C., November 1979), 45.4.1-45.4.12.

15. Mills, D.L. Internetworking and the Atlantic SATNET. *Proc. National Electronics Conference* (Chicago, Illinois, October 1981), 378-383.

16. Cudhea, P.W., D.A. McNeill and D.L. Mills. SATNET operations. *Proc. AIAA Ninth Communications Satellite Systems Conference* (March 1982).

17. Palmer, L., J. Kaiser, S. Rothschild and D. Mills. SATNET packet data transmission. *COMSAT Technical Review 12, 1* (Spring 1982), 181-212.

18. Leiner, B., J. Postel, R. Cole and D. Mills. The DARPA Internet protocol suite. In: P.E. Green (Ed.), *Network Interconnection and Protocol Conversion*, IEEE Press, New York, NY, 1988. Also in: *IEEE Communications 23, 3* (March 1985), 29-34.

19. Mills, D.L., and H.-W. Braun. The NSFNET Backbone Network. *Proc. ACM SIGCOMM 87 Symposium* (Stoweflake Vermont, August 1987), 191-196.

20. Mills, D.L. The Fuzzball. *Proc. ACM SIGCOMM 88 Symposium* (Palo Alto, California, August 1988), 115-122.

21. Mills, D.L. Wiretap: an experimental multiple-path routing algorithm. *ACM Computer Communication Review 19, 1* (January 1989), 85-98.

22. Mills, D.L. On the accuracy and stability of clocks synchronized by the Network Time Protocol in the Internet system. *ACM Computer Communication Review 20, 1* (January 1990), 65-75.

23. Mills, D.L., P. Schragger and M. Davis. Internet architecture workshop: future of the internet system architecture and TCP/IP protocols. *ACM Computer Communication Review 20, 1* (January 1990), 6-17.

24. Mills, D.L. Internet time synchronization: the Network Time Protocol. *IEEE Trans. Communications 39, 10* (October 1991), 1482-1493.

25. Mills, D.L. On the chronology and metrology of computer network timescales and their application to the Network Time Protocol. *ACM Computer Communications Review 21, 5* (October 1991), 8-17.

8. Technical Reports

1. Aupperle, E.M., T.W. Butler, and D.L. Mills. A remotely controlled tactical direction finder. Cooley Electronics Laboratory Technical Report 124, University of Michigan, July 1961.

2. Mills, D.L. Magnetically tunable discrete-frequency generator. Engineering Report RD-63-5. Berkeley Division, Beckman Instruments, Inc., August 1963.

3. Mills, D.L. The Michigan Automatic Direction Finder. Cooley Electronics Laboratory Technical Report 137, University of Michigan, February 1964.

4. Mills, D.L. Considerations in LORAN C/D receiver design. Cooley Electronics Laboratory Technical Report 155, University of Michigan, October 1964.

5. Mills, D.L. A proposal for a computer-supervised RAMP system. Language Laboratory, University of Michigan, May 1965.

6. Mills, D.L. RAMP: a multiprogramming system for real-time device control. CONCOMP Project Memorandum 5, University of Michigan, May 1967.

7. Mills, D.L. I/O extensions to RAMP. CONCOMP Project Memorandum 11, University of Michigan, February 1968.

8. Mills, D.L. and V.M. Powers, PDP-8 program relocation: concepts and facilities. CONCOMP Project Memorandum 17, University of Michigan, February 1968.

9. Mills, D.L. System/360 interface engineering report. CONCOMP Project Memorandum 13, University of Michigan, March 1968.

10. Mills, D.L. The Data Concentrator. CONCOMP Project Technical Report 8, University of Michigan, May 1968.

11. Mills, D.L. The syntactic structure of MAD/I. CONCOMP Project Technical Report 7, University of Michigan, May 1968.

12. Mills, D.L., V.M. Powers, and N. Laurance. An assembly language system for DEC mini-computers. CONCOMP Project Memorandum 20, University of Michigan, May 1969.

13. Mills, D.L. RAMP architecture in a utility calculator system. CONCOMP Project Memorandum 24, University of Michigan, May 1969.

14. Mills, D.L. Topics in computer communications systems. CONCOMP Project Technical Report 20, University of Michigan, May 1969.

15. Mills, D.L., J.L. Di Guiseppe, and W.S. Gerstenberger. Data Concentrator user's guide. CONCOMP Project Technical Report 28, University of Michigan, April 1970.

16. Mills, D.L. The basic operating system for the Distributed Computer Network. Computer Science Technical Report TR-416, University of Maryland, October 1975.

17. Mills, D.L. Dynamic file access in a distributed computer network. Computer Science Technical Report TR-415, University of Maryland, October 1975.

18. Mills, D.L. User's Guide to the ULP language for the PDP11. Computer Science Technical Report TR-536, University of Maryland, May 1977.

19. Mills, D.L. The ULP language and compiler. Computer Science Technical Report TR-537, University of Maryland, May 1977.

20. Mills, D.L. Final report on the Distributed Computer Network project. Computer Science Technical Report TR-555, University of Maryland, July 1977.

21. Mills, D.L. Real-time recognition of manual Morse telegraphy using nonlinear estimation and Viterbi decoding. Computer Science Technical Report TR-554, University of Maryland, July 1977.

22. Palmer, L., and D.L. Mills. COMSAT participation in ARPA packet satellite program - final report. COMSAT Laboratories, October 1979.

23. Mills, D.L. Analytical and experimental investigation of the Ratio-Weighted Estimation algorithm. Computer Science Technical Report TR-889, University of Maryland, March 1980.

24. Mills, D.L. Time synchronization in DCNET hosts. DARPA Internet Project Report IEN-173, COMSAT Laboratories, February 1981.

25. Mills, D.L. DCNET internet clock service. DARPA Network Working Group Report RFC-778, COMSAT Laboratories, April 1981.

26. Mills, D.L., and M.J. O'Connor. DCNET mail plan. DARPA Internet Project Report IEN-194, COMSAT Laboratories, July 1981.

27. Mills, D.L. Internet name domains. DARPA Network Working Group Report RFC-799, COMSAT Laboratories, September 1981.

28. Agarwal, A., M.J. O'Connor and D.L. Mills. Dacom 450/500 facsimile data transcoding. DARPA Network Working Group Report RFC-803, COMSAT Laboratories, November 1981.

29. Mills, D.L. Internet delay experiments. DARPA Network Working Group Report RFC-889, M/A-COM Linkabit, December 1983.

30. Mills, D.L. DCN local-network protocols. DARPA Network Working Group Report RFC-891, M/A-COM Linkabit, December 1983.

31. Mills, D.L. Exterior gateway protocol formal specification. DARPA Network Working Group Report RFC-904, M/A-COM Linkabit, April 1984.

32. Mills, D.L. Experiments in network clock synchronization. DARPA Network Working Group Report RFC-956, M/A-COM Linkabit, September 1985.

33. Mills, D.L. Algorithms for synchronizing network clocks. DARPA Network Working Group Report RFC-957, M/A-COM Linkabit, September 1985.

34. Mills, D.L. Network Time Protocol (NTP). DARPA Network Working Group Report RFC-958, M/A-COM Linkabit, September 1985.

35. Mills, D.L. Autonomous confederations. DARPA Network Working Group Report RFC-975, M/A-COM Linkabit, February 1986.

36. Mills, D.L. An experimental multiple-path routing algorithm. DARPA Network Working Group Report RFC-981. M/A-COM Linkabit, March 1986.

37. Mills, D.L. (Ed.). Requirements for internet gateways. DARPA Network Working Group Report RFC-985. NSF Network Technical Advisory Group, May 1986.

38. Mills, D.L. Statistics server. DARPA Network Working Group Report RFC-996. University of Delaware, February 1987.

39. Mills, D.L. A distributed-protocol authentication scheme. DARPA Network Working Group Report RFC-1004. University of Delaware, April 1987.

40. Mills, D.L. Network Time Protocol (Version 1) specification and implementation. DARPA Network Working Group Report RFC-1059, University of Delaware, July 1988. Also published as: Electrical Engineering Department Report 88-4-1, University of Delaware, May 1988.

41. Mills, D.L. Internet time synchronization: the Network Time Protocol. Electrical Engineering Department Report 89-9-1, University of Delaware, September 1989.

42. Mills, D.L. Network Time Protocol (Version 2) specification and implementation. DARPA Network Working Group Report RFC-1119, University of Delaware, September 1989. Also published as: Electrical Engineering Department Report 89-9-2, University of Delaware, September 1989.

43. Mills, D.L. Measured performance of the Network Time Protocol in the Internet system. DARPA Network Working Group Report RFC-1128, University of Delaware, October 1989. Also published as: Electrical Engineering Department Report 89-9-3, University of Delaware, September 1989.

44. Mills, D.L. Internet time synchronization: the Network Time Protocol. DARPA Network Working Group Report RFC-1129, University of Delaware, October 1989. Also published as: Electrical Engineering Department Report 89-9-1, University of Delaware, September 1989.

45. Mills, D.L. Network Time Protocol (Version 3) specification, implementation and analysis. Electrical Engineering Department Report 90-6-1, University of Delaware, June 1990.

46. Mills, D.L. Final report on NSF/DNCRI grant NCR-86-12015: Support of the National Science Foundation Supercomputer Network Program. Electrical Engineering Department Report 90-7-1, University of Delaware, July 1990.

47. Mills, D.L. Final report on DARPA/IPTO Contract N00140-87-C-8901: Research on Internet architectures and protocols. Electrical Engineering Department Report 90-7-2, University of Delaware, July 1990.

48. Mills, D.L., C.G. Boncelet, J.G. Elias, P.A. Schragger and A.W. Jackson. Highball: a high speed, reserved-access, wide-area network. Electrical Engineering Department Report 90-9-3, University of Delaware, September 1990.

49. Mills, D.L. A computer-controlled LORAN-C receiver for precision timekeeping. Electrical Engineering Department Report 92-3-1, University of Delaware, March 1992.

50. Mills, D.L. Network Time Protocol (Version 3) specification, implementation and analysis. DARPA Network Working Group Report RFC-xxxx, University of Delaware, March 1992. Previous draft published as: Electrical Engineering Department Report 90-6-1, University of Delaware, June 1990.

9. Other Publications

1. Mills, D.L. Practical parsing algorithms for deterministic context-free languages. Ph.D. dissertation, Department of Computer and Communications Sciences, University of Michigan, August 1971.