UCLA-ENG-7429
APRIL 1974

ARPA CONTRACT NO. DAHC-15-73-C-0368

PACKET SWITCHING IN A MULTI-ACCESS BROADCAST CHANNEL WITH APPLICATION TO SATELLITE COMMUNICATION IN A COMPUTER NETWORK

S.S. LAM

COMPUTER SYSTEMS
MODELING AND ANALYSIS GROUP

COMPUTER SCIENCE DEPARTMENT

School of Engineering and Applied Science
University of California
Los Angeles

COMPUTER SYSTEMS MODELING AND ANALYSIS GROUP
REPORT SERIES

Richard R. Muntz, Editor

Turn, R., "Assignment of Inventory of a Variable Structure Computer," January 1963, ENGRG Rept No. 63-5.

Martin, D.F., "The Automatic Assignment and Sequencing of Computations on Parallel Processor Systems," January 1966, UCLA-ENG-6604 (AEC/ONR).

Coffman, E.G. "Stochastic Models of Multiple and Time-Shared Computer Operations," June 1966, UCLA-ENG-6638 (AEC/ARPA/ONR) AD No. 636-976.

Bovet, D.P., "Memory Allocation in Computer Systems," June 1968, UCLA-ENG-6817 (AEC/ARPA/ONR).

Baer, J.L., "Graph Models of Computations in Computer Systems," October 1968, UCLA-ENG-6846 (AEC:UCLA-10P14-51/ARPA/ONR) AD No. 678-753.

Russell, E.C., "Automatic Program Analysis," March 1969, UCLA-ENG-6912 (AEC:UCLA-10P14-72/ARPA/ONR) AD No. 686-401.

Koster, R., 'Low Level Self-Measurement in Computers," December 1969, UCLA-ENG-6957 (AEC:UCLA-10P14-84).

Cerf, V.G., "Measurement of Recursive Programs," May 1970, UCLA-ENG-7043 (AEC:UCLA-10P14-90/ARPA).

Volansky, S.A., "Graph Model Analysis and Implementation of Computational Sequences," June 1970, UCLA-ENG-7048 (AEC:UCLA-10P14-93).

Cole, G.D., "Computer Network Measurements: Techniques and Experiments," October 1971, UCLA-ENG-7165 (ARPA) AD No. 739-344.

Hsu, J., "Analysis of a Continuum of Processor-Sharing Models for Time-Shared Computer Systems," October 1971, UCLA-ENG-7166 (ARPA) AD No. 739-345.

Ziegler, J.F., "Nodal Blocking in Large Networks," October 1971, UCLA-ENG-7167 (ARPA) AD No. 741-647.

Cerf, V.G., E. Fernandez, K. Gostelow and S. Volansky, "Formal Control-Flow Properties of a Model of Computation," December 1971, UCLA-ENG-7178 (AEC:UCLA-10P14-105).

Gostelow, K.P., "Flow Control, Resource Allocation, and the Proper Termination of Programs," December 1971, UCLA-ENG-7179 (AEC:UCLA-10P14-106).

Cerf, V.G., "Multiprocessors, Semaphores, and a Graph Model of Computation," April 1972, UCLA-ENG-7223 (AEC:UCLA-10P14-110).

Fultz, G.L., "Adaptive Routing Techniques for Message Switching Computer Communication Networks," July 1972, UCLA-ENG-7252 (ARPA).

Fernandez, E., "Activity Transformations on Graph Models of Parallel Computations," October 1972, UCLA-ENG-7287 (AEC:UCLA-10P14-116).

Gerla, M., "The Design of Store-and-Forward (A/F) Networks for Computer Communications," January 1973, UCLA-ENG-7319 (ARPA).

Talan, R., "Optimal Control of Tandem Queues," May 1973, UCLA-ENG-7333 (AFOSR).

Postel, Jonathan B., "A Graph Model Analysis of Computer Communications Protocols," January 1974, UCLA-ENG-7410 (ARPA).

Opderbeck, H., "Measurement and Modeling of Program Behavior and its Applications," April 1974, UCLA-ENG-7418 (ONR).

Lam, Simon S., "Packet Switching in a Multi-Access Broadcast Channel with Application to Satellite Communication in a Computer Network," April 1974, UCLA-ENG-7429 (ARPA).

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1 REPORT NUMBER	2 GOVT ACCESSION NO.	3 RECIPIENT'S CATALOG NUMBER
4. TITLE *(and Subtitle)* PACKET SWITCHING IN A MULTI-ACCESS BROADCAST CHANNEL WITH APPLICATION TO SATELLITE COMMUNICATION IN A COMPUTER NETWORK		5. TYPE OF REPORT & PERIOD COVERED
		6. PERFORMING ORG. REPORT NUMBER UCLA-ENG-7429
7. AUTHOR*(s)* Simon S. Lam		8. CONTRACT OR GRANT NUMBER*(s)* Contract No. DAHC-15-73-C-0368
9. PERFORMING ORGANIZATION NAME AND ADDRESS School of Engineering and Applied Science University of California Los Angeles, California 90024		10. PROGRAM ELEMENT, PROJECT TASK AREA & WORK UNIT NUMBERS
11 CONTROLLING OFFICE NAME AND ADDRESS Advanced Research Projects Agency (ARPA) 1400 Wilson Blvd. Arlington, Virginia 22209		12. REPORT DATE April 1974 13. NUMBER OF PAGES 306
14. MONITORING AGENCY NAME & ADDRESS*(if different from Controlling Office)*		15. SECURITY CLASS. *(of this report)* UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT *(of this Report)*

Approved for Public Release; Distribution Unlimited

17. DISTRIBUTION STATEMENT *(of the abstract entered in Block 20, if different from Report)*

18. SUPPLEMENTARY NOTES

Ph.D. Dissertation, March 1974

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

Computer-Communication Networks
Terminal Access Networks
Large Networks
Satellite Packet Communication
Radio Packet Communication

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

This report considers a packet switching technique applicable to packet communication using a satellite or ground radio channel. The objective of this research is to develop analytic models for the evaluation and optimization of the system performance in terms of stability, throughput and delay.

Advantages of packet switched satellite and ground radio systems over conventional wire communications for large computer-communication

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

S/N 0102-014-6601

19. Multi-Access Broadcast Channels
Packet Switching Techniques
Statistical Load Averaging
Slotted ALOHA Random Access
Contention Systems
Probabilistic Models
Fluid Approximation
Equilibrium Throughput-Delay Performance
Stable Channels
Unstable Channels
Channel Saturation
Expected First Exit Time
Stability-Throughput-Delay Tradeoff
Markov Decision Models
Dynamic Channel Control Procedures
Control-Estimation Algorithms
Satellite Reservation Schemes

20. networks are discussed. The emphasis of this research is on a high-speed channel shared by a large population of "small" users. The channel behavior is typical of "contention" systems in which the throughput vanishes to zero as the load on the system increases. This phenomenon is called channel saturation. The channel may go into saturation as a result of (a) time fluctuations, and (b) stochastic fluctuations in the channel input. The channel response to time varying inputs is first studied using a deterministic approximation analysis. The effect of (b) is then studied through probabilistic models. In this case, contributions of this research may be classified into three categories:

(1) a coherent theory of channel behavior in which the key result is the characterization of stable and unstable channels
(2) evaluation of channel performance such as equilibrium throughput-delay tradeoffs for stable channels and stability-throughput-delay tradeoffs for unstable channels
(3) dynamic channel control and estimation procedures for optimal control of unstable channels.

This study has several implications. First, a coherent theory of channel behavior has been developed, system design variables have been identified and operational strategies for the optimization of channel performance have been evaluated. These results suggest a system design methodology. Second, the techniques employed in characterizing the stability behavior and evaluating dynamic channel control schemes may profitably be applied to probabilistic models of other contention systems.