PROBLEMS IN THE DESIGN OF DATA COMMUNICATIONS NETWORKS

WUSHOW CHOU

NETWORK ANALYSIS CORPORATION
GLEN COVE, N. Y. 11542

I. INTRODUCTION [1]

The worldwide trend in computers in the 1970's has been the growing integration of computing and communications. As a result, communications systems are becoming increasingly larger, more complex and more intelligent. In addition, innovations in system design concepts, hardware features and transmission services have accelerated. To cope with the complexity and the innovations, a data communication manager, or designer, must seek solutions for the following problems.

How should he conduct the planning or upgrading of a modern data communication network? What are the parameters he should use to measure system's performance? What are network users' requirements and design constraints? How can he select, for his system, the best cost/performance communication devices? How can he select the best cost/performance transmission services? Are there design and analysis tools available to assist him make his decision? How can he evaluate the best system concept and design strategy for his system?

II. MANAGEMENT AND PLANNING [1], [2]

In most large communications networks currently in operation, costs can easily be reduced by fifteen percent or more with only minor alterations in the network. The cost savings can often reach thirty percent or more if reoptimization of the whole network is allowed. Furthermore, the cost reductions can be realized without degradation in performance. Indeed, both cost and performance can often be improved simultaneously.

The implication of the above statement is that the existing networks are not properly planned and designed. Why is this so? The single most significant factor is the underestimation of the complexity of data communications by top management. Many causes that contribute to the inefficient design are the direct consequences of this factor.

III. REQUIREMENT ANALYSIS AND DESIGN CONSTRAINTS

Successful implementation of a data communications system depends to a great extent on the thoroughness of the data traffic analysis and the user requirement analysis.

Gathering traffic information is the most tedious part of the planning. It should be collected from every user by means of current measurements and future projections. It is often helpful if the planner visits the users to assist them and to validate the information supplied by them. [3]

Even more uncertain than the traffic statistics and projections are the users' requirements on network performance. In general, users do not know exactly what they want. Sometimes they may demand a performance level which is practically impossible. Other times, they demand a performance level that they may not need but must pay a high price to attain. It is the designer's responsibility to show them the relationship between cost and performance, and thereby assist them in determining their performance requirements. The traffic information and the users' performance requirements thus form the constraints for the design.

IV. PERFORMANCE CRITERIA AND CONSIDERATIONS

A general goal in designing a data communications network is "to design a minimum cost network satisfying performance requirements or criteria." What is performance? It means different things to different people. For a well designed system, the performance should be measured by the following criteria:

A. BLOCKING PROBABILITY

This criterion is used to measure the promptness with which a data communications system responds to calls from dial-up terminals.

B. MESSAGE RESPONSE TIME

This criterion is used to measure the promptness with which a system responds to terminals connected to the system by leased or private lines.

C. SYSTEM CAPACITY OR THROUGHPUT

Capacity in its most liberal interpretation is often taken to mean the maximum amount of traffic, in terms of transactions per second, etc., that a system can carry. More practically, it is defined as the maximum traffic that a system can carry, while satisfying the blocking probability criteria and/or response time requirements.

D. NETWORK RELIABILITY

While the failure rates, MTTF, and MTTR of the equipment and lines are often beyond the control of network planners, the network's reliability can usually be strengthened with proper network structures.

E. SENSITIVITY AND FLEXIBILITY

A good planner should be concerned with the effects that the system would experience if the actual traffic volume and operating environment deviate from the projection.

F. TRANSMISSION ERROR RATE

The transmission error rate is a function of message size, line conditioning, line speed, and hardware characteristics.

V. SELECTION OF COMMUNICATION DEVICES [4], [5], [6], [7], [8], [9], [10]

With the advancement of solid state electronics, communications devices become ever more versatile and generous with options. There are numerous possible combinations available for improving performance, reducing communications cost and satisfying special requirements. However, these goals are not easily achievable. One must know what a vendor has "not" said, what devices are most effective for specific network structures or performance requirement, and how many of each particular device should be used.

VI. SELECTION OF TRANSMISSION FACILITIES [11], [12], [5], [6] [13], [14], [15], [16], [17]

All data communications network need transmission lines. The planner must choose between dial-up and dedicated lines, choose the right line speed, and calculate and compare line costs among various different line tariffs.

It used to be relatively easy to select and interface a specific line type and to calculate line costs. Now, with existing and forthcoming special common carriers of various types, numerous new line tariffs and modifications to old tariffs (AT&T's Hi/Lo Density, Digital Data Service, etc.), and the addition of domestic satellite communications service and digital transmission service, the determination of line costs and optimal network topologies is harder than before. In many situations, computer programs with special algorithms are necessary to calculate and determine a least cost connection.

VII. NETWORK STRUCTURES

Network costs and performance depend greatly on the structure the planner chooses. The following are the most commonly used network structures:

1. Point to point connection via dial-up.
2. Point to point connection with leased lines.
3. Multipoint tree-structured connection.
4. Multipoint ring-structured connection. [18]
5. Multiplexed structure.
6. Hierarchical ring structure. [18]
7. Hierarchical structure (without rings).

VIII. DESIGN TOOLS [19]

Due to the complexity of many data communications networks, hand analysis and design becomes almost impossible. Computer programs for various analysis and design functions are essential. The usefulness of such programs relies heavily on how convenient it is to repetitively run the programs. Thus efficiency in size and running time is as important as accuracy. The following is a list of important design tools:

A. Contention Simulation Program: Determining Blocking Probability.

B. Central Processor System Configuration Program: Verifying Performance for Specified CPU Configurations.

C. Network Simulation Program: Simulation of the Whole Data Communications System [20], [21].

D. Network Design Program: Concentrator and Multiplexer Allocation, Terminal Clustering, Multidrop Line Topological Design and Economical Analysis [22], [23].

E. Network Reliability/Availability Program: Calculation of Network Reliability [24], [25].

IX. DESIGN STRATEGIES AND COST/PERFORMANCE TRADEOFFS [1]

It is the network planner's responsibility to assist users in defining their requirements and to design a least cost network while satisfying the requirements. To do a good job for a large network, one needs to develop a set of curves to weigh and compare the tradeoffs for cost/performance and for design alternatives. Design tools described in Section VIII are extremely useful for this purpose.

A. EVALUATION OF DESIGN ALTERNATIVES

By choosing some of the network structures given in Section VII, and by using different line speeds, one can develop several sets of curves showing cost/throughput relationship constraints, and showing cost/response time relationship requirements. From these curves, one can determine the most cost-effective network structure.

B. EVALUATION OF COST-THROUGHPUT TRADEOFFS

From curves showing relationship between cost and throughput for fixed response time requirement, the network designer can help users to decide how much they are willing to, or must, pay for throughput in the network.

C. EVALUATION OF COST-RESPONSE TIME TRADEOFFS

From curves representing the cost-response relationship for specified throughput requirement, the user can determine how much he is willing to pay for the response time that he will get.

D. EVALUATION OF COST-RELIABILITY TRADEOFFS

There are many schemes for improving network reliability. To evaluate them, one must develop a curve to show the incremental cost one must pay for improved network reliability.

REFERENCES

1. Chou, W., "Planning and Design of Data Communications Networks," Proc. of 1974 NCC, May 1974.

2. Hopewell, L., "Management Planning in the Data Communications Environment," Proc. of 1974 NCC&E.

3. Gourley, D., "Data Communications: Initial Planning," Datamation, October 1972.

4. McGregor, P., "Effective Use of Data Communications Hardware," Proc. of 1974 NCC&E.

5. Martin, J., Systems Analysis for Data Transmission, Prentice Hall, 1972.

6. Datapro 70, Datapro Research Corporation, 1974.

7. Davey, J. R., "Modems," Proc. of the IEEE, Vol. 60, No. 11, November 1972, pp. 1284-1292.

8. Newport, C. B. and J. Ryzlak, "Communication Processors," Proc. of the IEEE, Vol. 60, No. 11, November 1972, pp. 1321-1332.

9. Doll, D. R., "Multiplexing and Concentration," Proc. of the IEEE, Vol. 60, No. 11, November 1972, pp. 1313-1321.

10. Frank, H., L. Hopewell, A. Kershenbaum and W. Chou, "Providing Reliable Computer Networks from Unreliable Components," to appear in Datamation.

11. Gerla, M., "Line Tariffs and Their Impack on Network Design," Proc. of 1974 NCC&E.

12. Gaines, E., "Specialized Common Carriers - Competition and Alternative," Telecommunications, 1973.

13. "A Major Rate Restructuring in Making," Center for Communications Management, 1973.

14. "Planning Guide: Digital Data Communication Services," Center for Communications Management, 1973.

15. Auerbach Data Communications Equipment Digest, 1974.

16. Gerla, M., W. Chou and H. Frank, "Cost Throughput Trends in Computer Networks Using Satellite Communications," Proc. of 1974 ICCC.

17. Chou, W. and H. Frank, "Communications Cost Reductions Using Domestic Satellites," Symp. on Trends and Applications in Computer Networks, Washington, D.C., May 1974.

18. Hayes, J. F. and D. N. Sherman, "Traffic Analysis of a Ring Switched Data Transmission System," BSTJ, Vol. 50, No. 9, November 1971.

19. Kershenbaum, A., "Tools for Planning and Designing Data Communications Networks," Proc. of 1974 NCC&E.

20. Chou, W., H. Frank and R. Van Slyke, "Simulation of Centralized Computer Communications Systems," Data Networks: Analysis and Design, Third Data Communications Symposium, November 13-15, 1973, pp. 121-130, to appear in IEEE Trans. on Communications.

21. Van Slyke, R., W. Chou and H. Frank, "Avoiding Simulation in Simulation Computer Communication Networks," Proc. of National Computer Conference, June 4-8, 1973, pp. 165-169.

22. Chou, W. and A. Kershenbaum, "Unified Algorithm for Designing Multidrop Teleprocessing Networks," Data Networks: Analysis and Design, Third Data Communications Symposium, November 13-15, 1973, to appear in IEEE Trans. on Communications.

23. Woo, L. S. and D. T. Tang, "Optimization of Teleprocessing Networks with Concentrators," National Telecommunications Conference, Atlanta, Georgia, November 26-28, 1973.

24. Kershenbaum, A. and R. Van Slyke, "Recursive Analysis of Network Reliability," Networks, Vol. 3, No. 1, 1973, pp. 81-94.

25. Van Slyke, R. and H. Frank, "Network Reliability Analysis," Networks, January 1972.