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# COMPUTER NETWORK DESIGN PRINCIPLES DERIVED FROM EXPERIENCE AND MEASUREMENTS ON THE ARPA NETWORK

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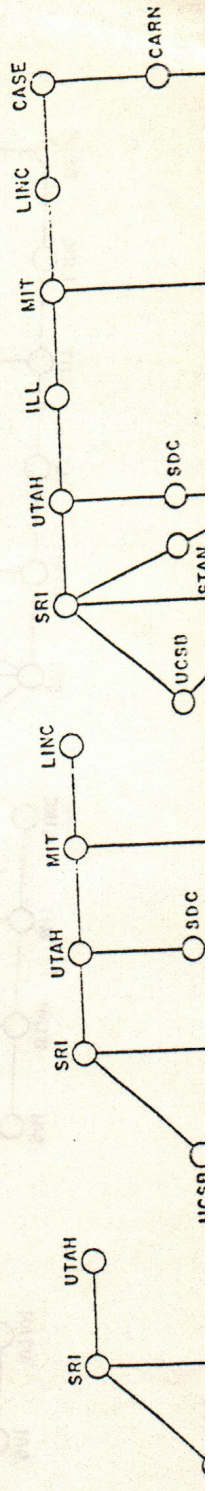
Summary. -The design of the ARPA experimental computer network was a distributed effort which benefited from the talents of many people working both in concert and independently. In this paper we discuss some of the principles of design which have evolved from that effort. The measures, models and analytical results from design are further compared to simulation and measurement of the network itself; this permits us to evaluate the design tools themselves. We find that these principles are applicable to message-switching networks in general, and therefore the scope of this paper goes beyond that of the ARPA network.

The evolution of the ARPA network from a small four-node net in 1969 to the proposed 34-node net later this year is shown in the attached figure.

We discuss some of the modeling techniques which have been found useful in this network design and review those simulation and measurement experiments which by-and-large lend validity to the mathematical models proposed. It is shown that message-switching networks of the ARPA type may be implemented in a rather straightforward fashion and provide an economical message service compared to other current techniques. Furthermore there is a heavy reliance on approximate methods, simulation and actual network measurement which together permit one to gain an understanding of the more complex aspects of network behavior. Heuristics are also necessary in this process for the selection of good topologies and traffic flow assignments. The study of really large networks (thousands of nodes) will undoubtedly require the development of new tools; it is clear that some clever decomposition or partitioning of the network into supernodes and regions (perhaps in a hierarchical structure) will be necessary.

Among the more difficult design problems which remain are: the specification of routing and flow control procedures; the design of optimal topologies; the optimal assignment of capacities with non-linear discrete cost functions; the consideration of large message-switching nodes judiciously placed in the network; and many other related questions. It is fair to say that these questions will occupy us for some time to come.

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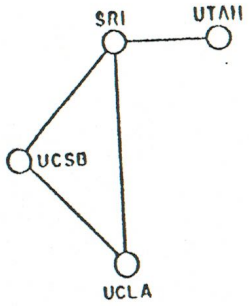
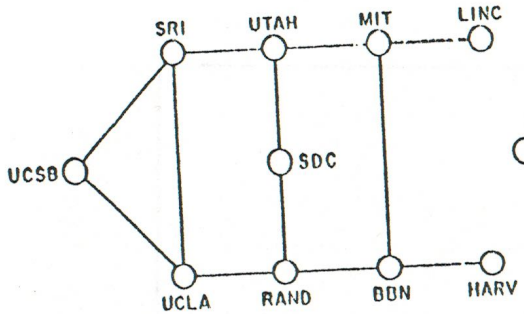


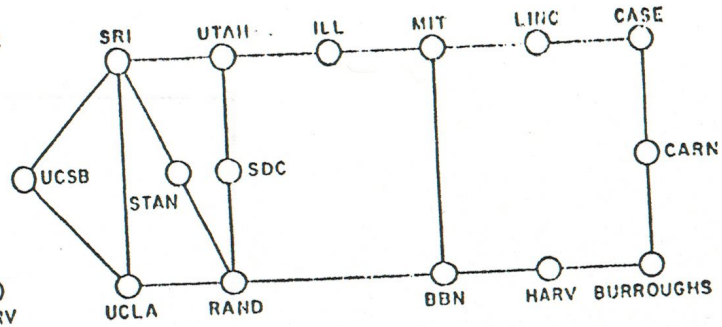

4-IMP NETWORK - 12/1/69

(a)



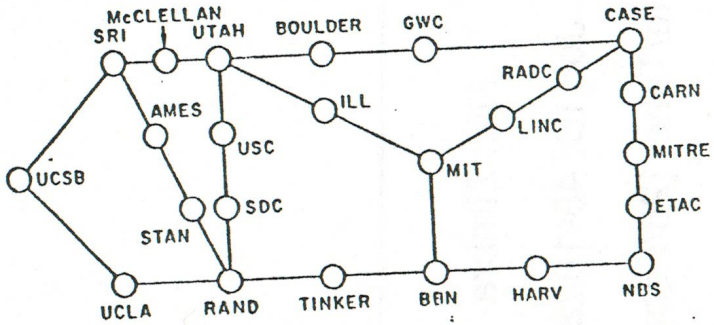

10-NODE NETWORK - 7/1/70

(b)



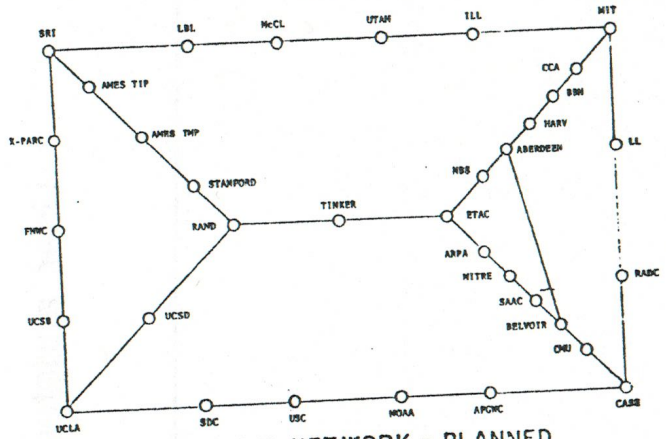

15-IMP NETWORK - 3/1/71

(c)




24-IMP NETWORK - 4/1/72

(d)




-IMP NETWORK - PLANNED

(e)

FIGURE 1