COMMUNICATION NETWORK DESIGN USING MESSAGE FLOW SIMULATION

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SUMMARY

The determination of a near optimum cost-effective design for a large military communication network is a complex task. The detailed methods used in solving a particular network design problem will depend on the system requirements, the projected operational time frame, and on the time, money, and technical means available for its solution. Computer simulations of the operation of various possible networks under anticipated critical traffic loads and the determination thereby of the resulting message delay times and subsystem utilizations can be used to predict the performance of proposed designs and also to show how to modify them in order to maximize the cost-effectiveness of the ultimately realized operational network.

TRAFFIC ANALYSIS

The system operational requirements usually indicate the communicants and their geographic locations. A traffic analysis based on this information may be made in order to establish the different types of messages and their corresponding sources, destinations, importance, perishability, and security requirements. The message lengths, especially for voice messages, will often be found, or realistically assumed, to be close to exponentially distributed. The message input rates during the time or times when the network will become most heavily loaded must also be estimated. If a complete traffic analysis cannot be made immediately, due to cost or time limitations, it may be practical to assume that the amount of traffic between locations is proportional to the numbers of communicants at each location and inversely proportional to the distance between the locations.

The traffic analysis will usually show that the arrival of messages for input into the network is random for very short time periods and can, therefore, be mathematically described as a Poisson process. The arrival rate may be a function of the time of day or the time since the beginning of an intense phase of a most rapidly developing hostile military engagement or some other system operation. The maximum arrival rate may last sufficiently long for a given network to come to quasiequilibrium, i.e. become a stationary stochastic process, with time-invariant probability distributions describing the system state and performance parameters. Or, the maximum input rate may not continue long enough for this to happen and the worst loading and performance of the network may depend on the preceding and varying input rate history.

PRIORITIES

Each message type can be assigned a priority on the basis of its importance and perishability. Human operator and or computer program procedures, including queueing disciplines, can also be tentatively established in conjunction with these priority assignments.

MEASURES OF EFFECTIVENESS

The practical measure of effectiveness for each message priority class will be either the mean delay time or the delay time which is not exceeded by, say, 95% of the messages. The entire message delay time distributions and their mean values for each priority can be tabulated and output by a computer simulation program. Requirements can be set establishing the acceptable delay times in either of these ways for each priority. This type of requirement is more directly related to system effectiveness than any of the grade of service criteria commonly used for comm systems.

SUBSYSTEM CAPACITIES

The subsystems of the comm network (phone terminals, teletype machines, other input and/or output devices, patch panels, switchboards, computers, buffers, crypto units, modems, multiplexers, transmitters, receivers, transceivers, antennas, satellite ground terminals, wirelines, submarine cables, relays, satellites, etc.) may be existing hardware, hardware in development, or what is considered producible within the advancing state of the art by the time the comm system is to be operational. Their initial and operating costs, spectrum utilizations, and performance capacities are needed for optimizing the comm network cost-effectiveness and may be known or projected. The subsystem capacities which can be taken into account in simulating a comm network are the numbers of channels in voice links, voice link qualities (factors which multiply the message transmission time), the bit rates (roughly bandwidths) of data links, switching capacities at nodes, bit storage capacities of buffers or computers at nodes, the bandwidths of satellite repeaters, the bandwidths of satellite ground terminals, and bit rates of computer input-output terminals.

TENTATIVE NETWORK AND DEGRADATION STATES

From a knowledge of the communicants, their locations, the traffic analysis estimates, and the reliable propagation distances of the subsystems, a tentative network structure can be formulated. And, from a consideration of the threat of destruction by the enemy, the ECM threat, subsystem availability, and propagation reliability, the most important degraded network states and their probabilities may be evaluated.

NETWORK SIMULATION

The simulation of the full-up and major degraded network states with the traffic input(s) which load the network most heavily will yield the message delay time distributions, the individual mean and maximum queue lengths, and the subsystem mean and maximum utilizations. The overall network effectiveness may be evaluated by combining the delay distributions, weighted by the network state probabilities, for each priority and applying the criteria or requirements obtained from the traffic analysis. The costs, both monetary and radio spectrum usage, of the networks can be estimated from the numbers and capacities and corresponding costs of the various subsystems comprising the network. In general, there is no simple, automatic way of optimizing the network topology. In many network design problems there will be constraints on the subsystem design parameters that will limit the choices available to the design engineer. However, an iterative pragmatic approach can be used by the design engineer in modifying the topology and capacities to increase cost-effectiveness. The subsystem utilizations will often show how subsystem capacities and the corresponding costs can be reduced. Long queue lengths may reveal isolated bottlenecks, which can be eliminated.

In addition, network simulation may be used to evaluate and aid in the optimum choice of alternative priority schemes, queueing disciplines, and routing procedures.

VOICE NETWORK SIMULATION

A voice communication network simulation program has been written in the General Purpose Simulation System (GPSS)/360 language. Message interarrival times, sources, destinations, lengths, and priorities can be generated deterministically or pseudorandomly with prescribed probability distributions and dependencies. Operator terminals are assigned to network nodes. Each node has a maximum circuit switching capacity and each link between nodes has a specified number of voice channels. Any network topology can be simulated, including tree and distributed networks. The program simulates the flow of messages into and thru the network and contains an algorithm for finding for each message an available route having the minimum number of links. The program output includes message queue delay time distributions, mean and maximum queue lengths, and the mean and maximum utilization of terminals, nodes, and links, both individually and collectively for each class of entities.

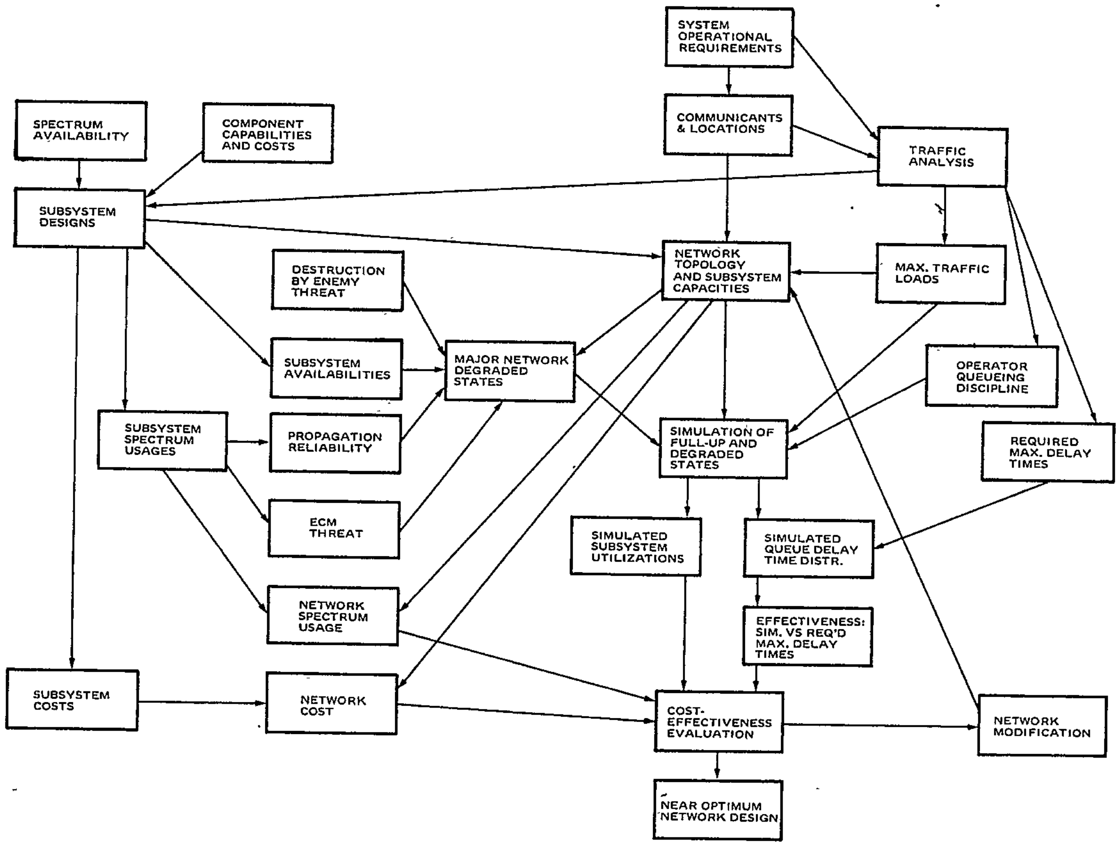

Figure 1: Comm Network Design Using Simulation

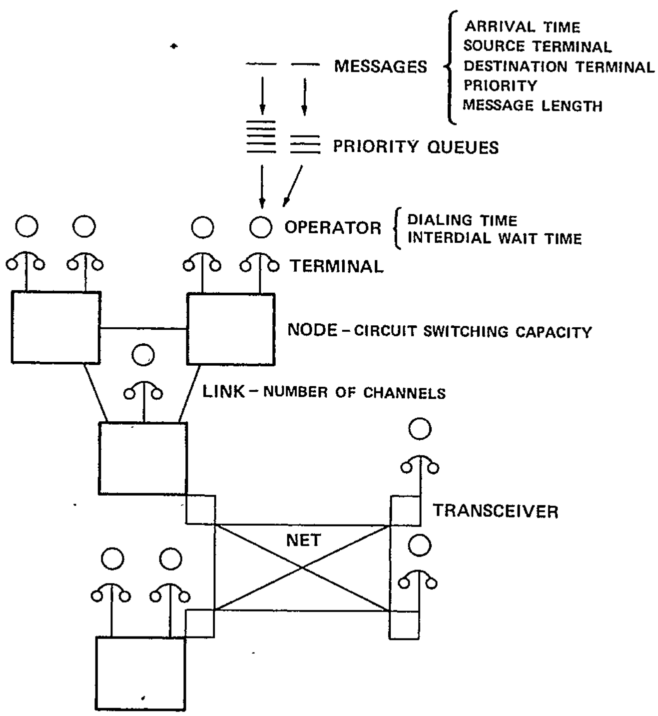

Figure 2: Voice Network Simulation Model

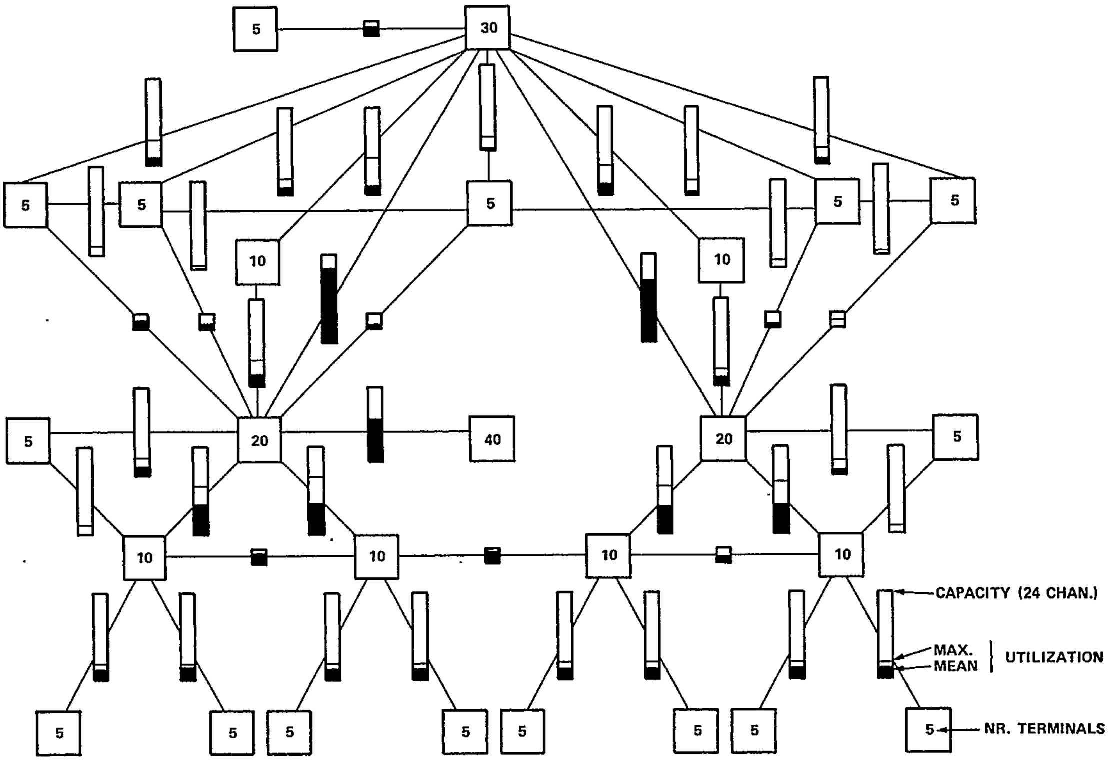

Figure 3: Link Utilizations in Voice Network Simulation

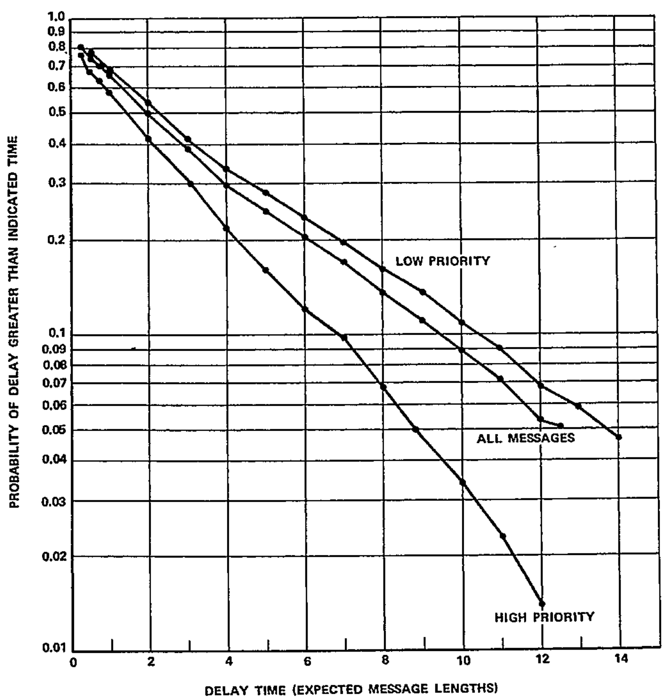

Figure 4: Time Series From Voice Network Simulation

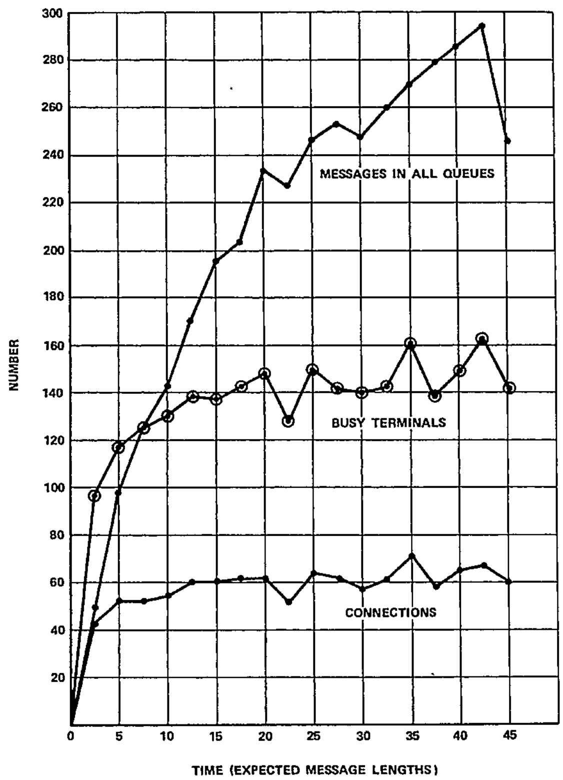

Figure 5: Queue Delay Times in Voice Network Simulation