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A Q-GERT NETWORK SIMULATION MODEL FOR A VOICE-DATA COMMUNICATION SYSTEM

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A generalizable Q-GERT network simulation model for a hypothetical voice-data communication system with infinite buffer system, two transmission channels, and random server interruptions is provided in this paper. Simulation results of various traffic intensities and interruption processes are provided to demonstrate the flexibility of this simulation model. Experiments have been conducted under following conditions: 1) Poisson arrivals, 2) constant data transmission rate, 3) geometric talkspurts, 4) two geometric silence gaps (short and long), and 5) three discrete probability distributions of having a short silence gap. The results have indicated a dramatic increase in buffer storage requirement when there are more frequent data arrivals and more short silence gaps.

1. INTRODUCTION

The buffer behavior of a communication system has been studied extensively in the past. Recently, research attention has been focused on buffer systems subject to random interruption. For example, an infinite buffer system with uniform arrival rate and random server interruptions was studied by Sherman (1971). A similar system with Poisson arrivals was analyzed by Hsu (1973a, 1974b). Multiple output channels were included in a study by Georganas (1976). Moreover, Kekre and Sexena (1978) analyzed the finite buffer behavior with Poisson arrivals and random server interruptions. A further extension to include a mixed arrival patterns was made in a study by Kekre, Sexena, and Khalid (1980).

A brief scan of these past studies reveals clearly a research trend of altering the characteristics of the basic communication system. With almost no exception, queueing theory has been used to analyze the system's performance. While analytical results do provide the best prediction of the buffer behavior, it may become extremely time consuming or even impossible to derive theoritical results when the system under study becomes increasingly complicated. The purpose of this paper is to propose a generalizable network simulation model in which changes to the original voice-data communication system can be incorporated easily. Thus, it will provide researchers with more flexibility to extend their studies. A simple voice-data communication system will be modeled to illustrate the usage of such a network simulation model.

2. A VOICE-DATA COMMUNICATION SYSTEM

A basic voice-data communication system is depicted in Figure 1. It has been recognized in many studies, e. g. (Brady 1965a, 1969b), that voice messages normally contain silence gaps which can be utilized for transmitting data. Therefore, when a silence gap in a conversation is detected, the switch will be closed so that the data waiting in the buffer can be transmitted through the output channels. On the other hand, since the switch is open during the talkspurt, data can not be transmitted and therefore has to be held in buffer storage.

3. THE Q-GERT NETWORK MODEL

The above voice-data communication system is modeled using a network simulation language, Q-GERT (Queueing Graphic Evaluation and Review Technique) (Pritsker 1979). The modeling procedure in Q-GERT first requires a translation of the actual operating system into a network diagram. Figure 2 displays such a network diagram for the above voice-data system. The node number is indicated on the right hand side of each mode. The branches on this network

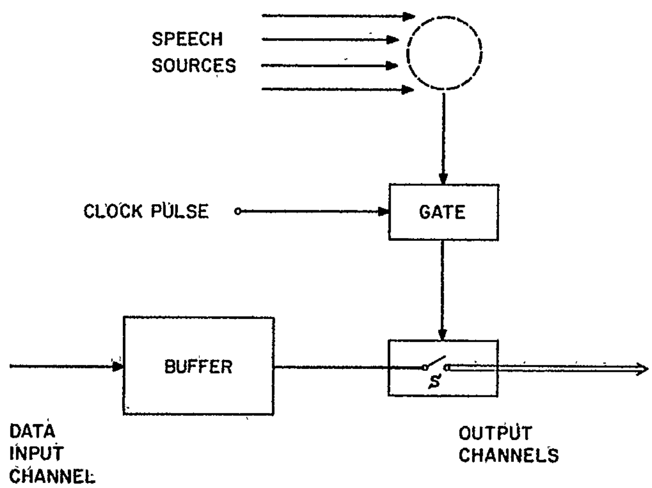

Figure 1. Configuration of a Voice-Data System

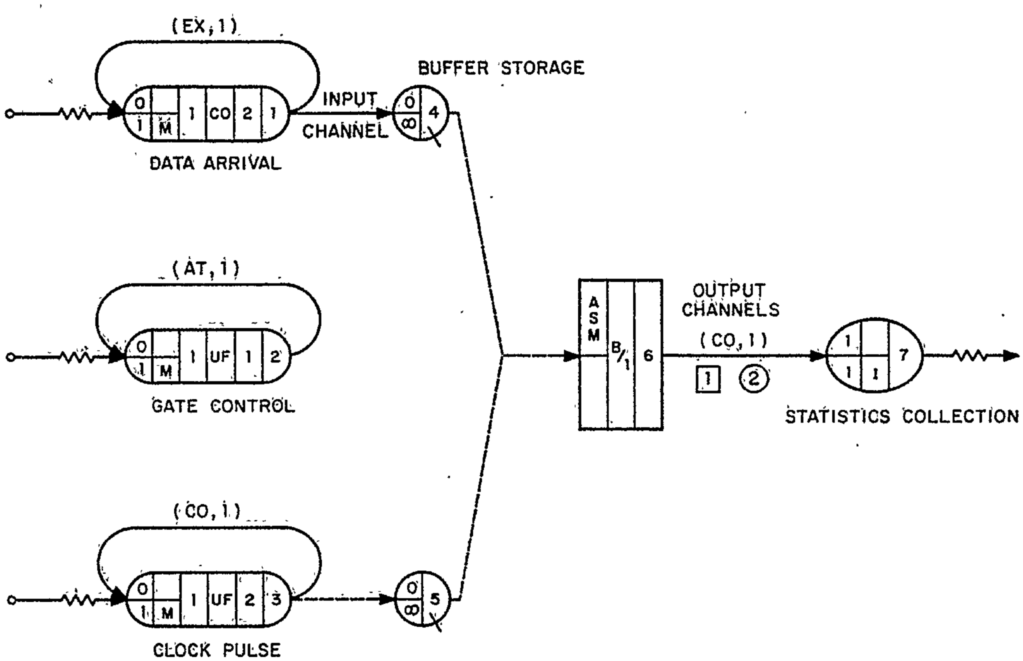

Figure 2. A Q-GERT Network Simulation Model

diagram represents various activities. For example, the branch connecting node 6 and node 7 symbolizes the service provided by the transmission channels. The notation (CO,1) above the branch describes the fact that the duration of the service activity is a constant of one time unit. The '2' in the circle beneath the branch indicates that there are two identical transmission channels available.

The branch connecting node 1 and node 4 portrays the activity of transmitting the arrived data from its source to the buffer. A rather unique set of branches in Q-GERT is the backward loops such as the branch eminating from node 1 and then loops back to itself. This branch is used to model the creation of a new piece of data. The notation (EX,1) above the branch shows that the time until the next arriving data is a random variable whose distribution is exponential with parameters defined in the parameter set number 1. Consequently, the data arrival pattern follows a Poisson distribution.

Node 4 is a symbol for the buffer storage where data can be held when the switch is open. Whenever the switch is closed, data waiting in the buffer will be selected and transmitted through output channels according to the First-Come-First-Served criterion. For a finite buffer system, the only change required is to replace the infinity notation in the lower left corner of node 4 by the appropriate buffer capacity.

Nodes 2, 3 and 5 provide the necessary elements to model the clock pulse and two different 'states' of the transmission channels: 1) blocked, or 2) available. Node 2 serves as a gate control. As a transaction is released from this node, a user function which basically is a set of FORTRAN statements written by the modeler, will be called to determine the status of the gate. In this paper, two types of silence gaps which allows the gate to be closed and data to be transmitted through a channel are modeled in user function 1. The duration of each type of silence gaps as well as the length of the talkspurt are represented by random varietes generated from three independent geometric distributions

Node 3 functions as clock pulse. Every one time unit, node 3 generates a transaction which represents the beginning of a new time unit. In the process of generating one 'clock pulse', user function 2 will be called to check the current 'state' of the output channels. If the current 'state' indicates that the switch is closed, a subroutine PTIN provided by Q-GERT Simulation and Analysis Program can be called to insert a transaction to node 5 indicating that the data currently waiting in the buffer can be selected and transmitted through one of the output channels. Node 6, a select node, is employed to model this selection process. The symbol 'ASM' in the upper left corner of node 6 shows that in order to transmit a piece of data through the output channel, at least one transaction must be available from both node 4 and node 5. In a practical sense, this is a representation of the actual transmission process of a voice-data communication system in which the output channels can transmit data only if there is at least one piece of data waiting in the buffer and that the switch is closed.

For studies on buffer behavior of a voice-data communication system, the average time data spent waiting in the buffer, the average and the maximum number of data waiting in the buffer, and the average time data spent in the system are frequently used as measures of system performance. Node 7, a statistic node, is used to collect one or more statistics for output analysis.

The basic network model in Figure 2 can be translated into data inputs to Q-GERT Simulation and Analysis Program. After the modelers determined the appropriate length of one simulation run and the number of replications, the network simulation model can be simulated to provide sampling results of the system performance. Moreover, varying the characteristics of the basic voice-data communication system requires only limited changes in the Q-GERT network model. Therefore, complicated voice-data system can be modeled and studied with limited efforts.

4. EXPERIMENTAL CONDITIONS

To study the buffer behavior of a voice-data communication system under various traffic intensities and random interruption processes, following simulation condition have been incorporated into the Q-GERT network simulation model:

1) The length of the talkspurt is geometrically distributed with a mean of 50 milliseconds (ms).

2) The length of the short silence gap and the length of the long silence gap are also geometrically distributed with mean of 10 ms and 1000 ms.

3) Data arrival follows a Poisson distribution.

4) Two transmission channels are available for transmitting either a voice message or a piece of data. The time required to transmit a piece of data is a constant of 1 ms.

5) Buffer storage has infinite capacity.

6) The clock pulse is set to 1 ms.

Moreover, two major factors, with three levels each, are included in this study:

1) Traffic intensity (mean arrival rates):
- 0.10 (unit/ms)
- 0.20 (unit/ms)
- 0.33 (unit/ms)

2) Interruption process (frequency ratio of short vs. long gap):
- 0.93
- 0.95
- 0.97

Since the primary purpose of this paper is to report a network simulation approach for a voice-data communication system, the simulation run length is arbitrarily selected as 100,000 time units. To reduce the autocorrelation problem, each simulation condition is replicated 10 times.

5. PRELIMINARY RESULTS

The most important measure of a voice-data communication system is the maximum buffer capacity required. The results of the maximum queue length for various simulation conditions are presented in Table 1.

Table 1. The maximum queue length in various simulation conditions

Gap Ratio, or Prob (Short Gap)	Mean arrival rate (unit/ms) 0.10	0.20	0.33
0.93	55	145	416
0.95	51	163	463
0.97	57	139	982

As the traffic intensity increases, Table 1 indicates clearly that the buffer system needs a larger capacity to absorb the additional data. This buffer storage problem has been aggrivated when the interruption process involves more short silence gaps.

The average queue length and the average queueing time per piece of data are reported in Tables 2 and 3. Similar interpretations can be given to results in these tables.

Table 2. The average queue length in various simulation conditions

Gap Ratio, or Prob (Short Gap)	Mean arrival rate (unit/ms) 0.10	0.20	0.33
0.93	2.78	8.38	30.25
0.95	3.16	9.91	38.74
0.97	3.83	11.92	62.63

Table 3. The average waiting time in various simulation conditions

Gap Ratio, or Prob (Short Gap)	Mean arrival rate (unit/ms) 0.10	0.20	0.33
0.93	27.75	41.84	90.34
0.95	31.58	49.47	115.73
0.97	38.20	59.52	187.06

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