PUBLIC SAFETY COMMUNICATIONS SYSTEMS SIMULATION

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Abstract

Multi-media communication systems in a large organization devoted to public safety require an in-depth systems analysis throughout their design process. The complex interactions that occur in emergent communications must be understood prior to the implementation of a system which might easily require a multi-million dollar initial investment.

Police communication systems today often involve voice/digital radio channels, remote data terminals linked to centralized information systems, telephone and telex etc. During the systems design process, a man-machine operational optimum should be sought. The use of computer simulation techniques provides a means of predicting the operational characteristics of various alternate communication system configurations as an aid to further decision making.

This paper describes the philosophy of and problems encountered in the development of a computer simulation model of the Ontario Provincial Police Communication System. The GPSS V model developed is currently being used to test possible alternate solutions to a forseen system redesign. The communication "link" concept employed is regarded as being applicable to other emergency organizations such as the ambulance and fire services.

Introduction

Police forces all over North America rely heavily on the efficiency of their radio communication systems, both for regular and emergency operations. The efficiency and adequacy of such a system, as measured in terms of accessibility of message destinations without delay, appropriateness of message content and length capacity to the information transfer intent, minimal effects of internally and externally generated interference and the capacity of message transmission codes to permit priority and privacy restrictions needs to be assessed from time to time. This is a function of the system design and the related message traffic volume which, in itself, is a function of the area covered, population density and the policing function involved.

The population of the Province of Ontario is expected to increase on an average by 8% by 1984, with a slightly greater increase in the South than in the North [1]. More significantly, records maintained on the national Canadian Police Information Centre (CPIC) are expected to increase in diversity and accessibility. This would mean an increase in occurrences, the number of calls for service, and demand for augmented call handling capabilities both in terms of equipment and trained manpower, etc.

With a view to enhancing the efficiency of the Ontario Provincial Police (O.P.P.) and to meet the anticipated future demands a study is being made to examine the present system and to identify the requirements to which the O.P.P. radio system should be capable of responding.

The objectives of this study are to assess the adequacy of the present system, evaluate its present capabilities and recommend changes required to ensure that the effectiveness of the Force is not compromised.

The existing O.P.P. communication system has been studied with the aid of a computer simulation model written in GPSS V and implemented at the University of Waterloo.

Communication Model

The analysis of the present system proceeds from a simplified model concept in the form of a communications "pipe" along which the communications traffic flows [2]. This concept is particularly relevant in estimating personnel loading and selection criteria (Fig. 1).

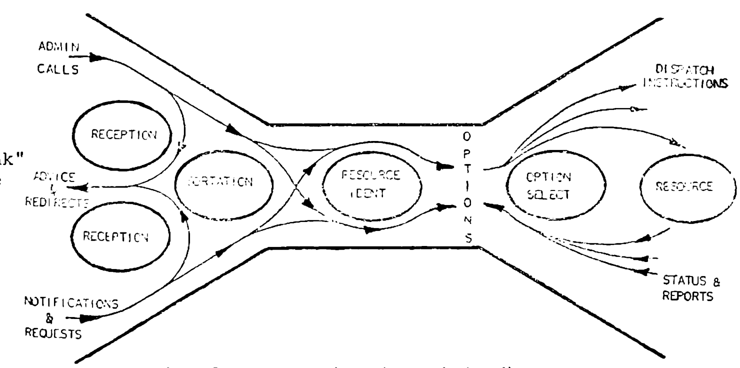

Fig. 1: Communications "Pipe" Model

Calls are received and sorted, and corresponding resources are identified and appropriately allocated. A second less simplified but more recognizable model concept is in the form of communication "links" [2]. Information exchange between O.P.P. personnel, other agencies and the public may take place over a variety of communication links as shown in Fig. 2.

The two-way transmission links may be simplex or duplex and, as transmission media, may utilize radio channels, remote data terminals linked to centralized information systems, e.g. CPIC, telephone, telex, mail, face-to-face or any other signalling technique. These multi-media facilities require conceptual integration into an efficient format during the design process.

Of the 13 links identified (A, B, ... M; Fig. 2) some, principally public-related, will use voice only. Others, such as office-to-office will communicate through voice and/or data. Only minimal link messages may be required when activities are simple (e.g., a building check without incident). However, some simple activities can become more complicated (e.g., insecure building requiring owner notification) necessitating additional link messages. Further complications can arise (e.g. break and enter in

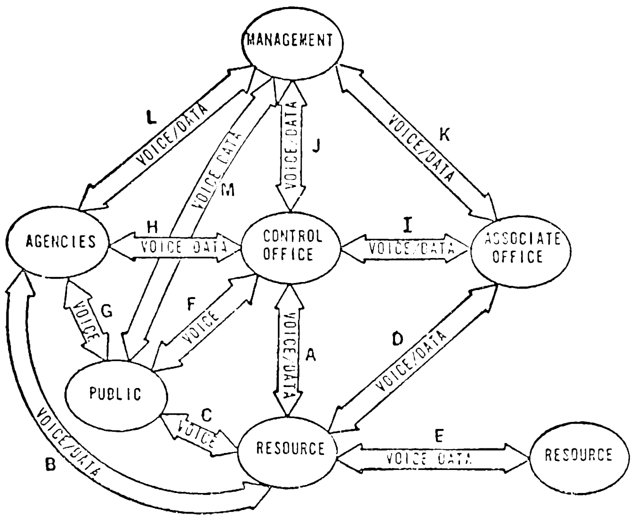

Fig. 2: Communications 'Link' Model

progress requiring assistance) causing more additional link messages. In the present study, ten of these links (all except B,G,M) have been modelled with a view to studying flow patterns and message load distributions. Present and projected volumes are set against the communications 'link' model to examine operational delays and facility utilization problems which may be encountered in the design of a communication system.

Most communication systems presently in operation have been designed to adequately handle message traffic volumes somewhat in excess of the projected average demand [3]. However, emergency situations e.g., an air crash, a train crash or a multi-vehicle fatality which, though not covering an extensive area, may nevertheless create a considerable communications capacity overload to the detriment of more normal operations. Such situations are common. Although the rare extreme cases are handled through a special emergency standby system, a properly designed communication system should be able to handle the periodic variations in message volumes.

In examining the present system so as to assess the anticipated requirements several questions may be asked. Will multi-voice radio channels be all that is needed or should dedicated digital record query channels be included? How many dispatchers, data terminals, complaint takers, etc. might be needed in a communication centre? Indeed, is a communication centre linking several offices really a good idea? These and other related questions have been examined with the help of a computer simulation model.

Simulation Model

The computer program described was written in GPSS V, an IBM software product. A communication system is particularly suited to discrete event simulation as messages may be considered as being discrete events subject to passage through a complex chain.

Model Description

The model is divided into two major sections. The first section deals with the occurence generations (e.g. minor crime, motor-vehicle collision, CPIC query) and the ensuing activity sequencing (e.g. officer is dispatched, officer arrives on scene, radios for additional help, etc.). The second section models the communication links themselves. The two are related in that each step in an activity sequence requires a message block to pass through a link. The link utilization sequencing is determined by the activity sequencing. These are discussed in the following section.

Activity Sequences

An occurrence would lead to a series of activities, each of which places a different type of leading upon the communication systems as a whole. Each occurrence is represented by a transaction which moves through a particular activity sequence. For purposes of this simulation study, five major occurrence types have been utilized. These are CPIC checks, minor crimes, minor violations, motor vehicle collisions and building checks.

Each step of the sequence involves the simulated transmission of a block of messages over a communication link. At each step the transaction is transferred to, and returned from a link section. (Fig. 3).

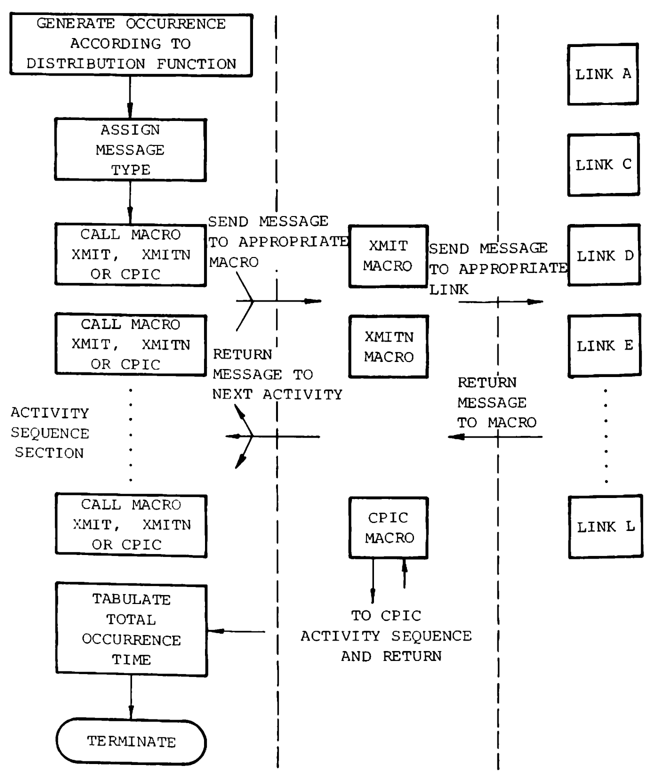

Fig. 3: General Message Handling: Minor Crime, Minor Violations, Motor Vehicle Collisions, Building Checks

The length of time for which the message block occupies a link is stored as a transaction parameter. This time is a random variable determined on the basis of an exponential distribution. Upon leaving a link section, the transaction returns to the sequence at a location determined by a return address, also saved as a transaction parameter. In most cases, there is a waiting period after the transmission of a message block to allow for such contingencies as the dispatcher completing other tasks, or until reply from an outside agency arrives. This is modelled by a uniformly distributed random variable with a given mean and spread.

Every step in the sequence involves similar processing, the assignment of parameters, and transfer to the appropriate link. For this reason GPSS MACROS were utilized.

A number of similar occurrences may be simultaneously processed, each at a different stage of completion. Occurrences can operate in parallel, giving rise to competition for a limited number of communications resources on the various links. Associated with each link are queues in which message blocks wait to be transmitted on a first come, first served basis.

The occurrences are entered into the simulation on a uniformly distributed random basis. The simulation period of one twenty four hour day is divided into 6-four hour periods. An average number of each type of occurrence per period is used to generate the events.

Another general class of occurences is used to model all "other" occurrence types that are an important part of policing activity but are of less specific interest, (e.g. cat up a tree, traffic control). Data were gathered which indicated the rate at which messages in this general category originated and the associated probabilities of
The manner in which these messages are handled is shown in Figure 4.

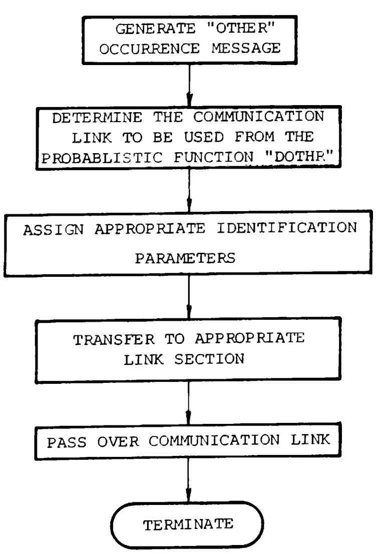

Fig. 4: Message Handling of 'Other' Occurrence Types

As can be seen, no activity sequencing is associated with this model segment.

Communication Links

There are ten communicatin links included in the model (all except B, G, M). Called LINK A, LINK C, ... etc., they correspond to the links identified in Fig. 2 earlier. Each link is modelled in the same fashion (Fig. 5), the only difference between them being their message capacity and their individual statistics.

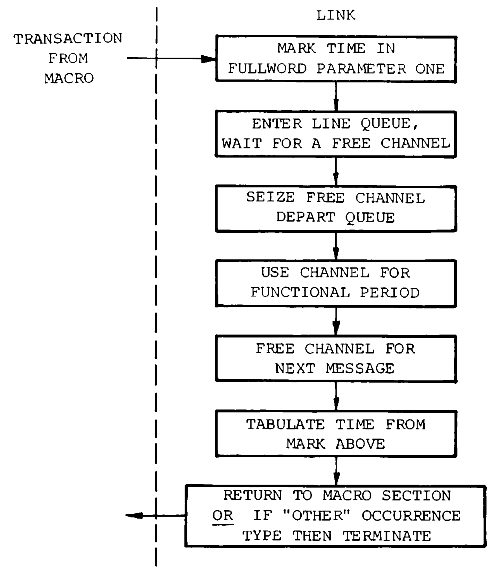

Fig. 5: Message Handling of Communication Link

The actual link is modelled with a GPSS STORAGE whose capacity equals the number of messages the link may simultaneously transmit. For example the capacity of a duplex radio channel is 2.

The links simulate the transmission of message blocks over available channels. The time taken for each transmission is calculated using values stored in the message block transaction's parameters, and is evaluated on the basis of an exponential distribution.

The steps in a message block transaction's passage through a link are outlined below:

1. Record the time of the transaction's arrival at the link.
2. The transaction enters a queue - used for collecting statistics on the length of time the transaction waits to be transmitted.
3. The transaction attempts to enter a storage representing the actual link. If the storage is full, representing a link being used to capacity, the transaction is placed in a "LINE" for the link on a user chain.
4. If the message block transaction succeeds in entering the storage then it is removed from the queue for the link, updating the waiting time for the link. The time needed for transmission is calculated and the transmission waits in the storage for that period.

5. When the transmission time expires, the transaction leaves the storage. The statistics concerning the total time taken for each message to be transmitted are updated. The first transaction on the user chain, representing the waiting line of transactions, is allowed to enter the storage.

6. The transaction is then transferred to the next step in the occurrence sequence that it came from, using the parameter stored return address.

Statistics

Statistics on the following were gathered:

a) Channel capacities and utilizations

b) Message queues and associated waiting times

c) Total air time taken by each occurrence type

d) Time to occurrence completion

e) Personnel utilization

f) Data terminal utilizations

Unfortunately, these cannot be detailed here due to confidentiality of the data.

Discussion

Two major problems arose in the development of the activity sequences. The first of these problems was the establishment of what activities are actually carried out in a given occurrence. In some cases, such as a records query on a person or vehicle, there is a well defined set of activities. However, in other cases, such as a building check, the set of activities is less well defined. If the building is locked and there is no sign of an intruder, little, if any, communication is required. On the other hand, if the building is unlicked, the keyholder must be contacted. This is usually accomplished by the patrolling officer radioing his dispatcher who then telephones the keyholder. The occurrence can escalate communication volumes tremendously if a break-and-enter is actually in progress. Backup patrol cars may be summoned, car to car radio transmission may be used and record queries may be made. Many activity combinations are possible arising from the seriousness or complexity of the occurrence.

The approach taken in the establishment of the activity sequences was to have experienced policemen draw up a set of activity flowcharts. These flowcharts showed the various paths an activity sequence might follow. Weighting factors were assigned to each of the flowchart branches according to the probability of the particular activity path being executed. These flowcharts were then incorporated into the simulation model.

The second problem was the estimation of message times. Accurate time period ranges have been determined for records queries and status change activities. Times for other message types were again established through the knowledge of experienced policemen. An extensive measurements program is now in progress to resolve many of the message timing questions that still exist.

Some of the communication system models currently in use predict channel or facility utilization and queueing under a given message input loading [4,5,6]. Although the same information is being sought in this computer simulation model, additional benefits may be realized.

An important feature of modelling a communication "link" concept is that macro system reconfigurations may be examined. We could, for instance model a single office with its own radio base station, or a multi-office configuration operating through a common radio dispatch/records query system.

The simulation program outlined in this paper is being used as a tool in the redesign of a police communication system. The environment of this system is not limited only to equipment and manpower, but also encompasses operational procedures. The importance of the latter consideration on system performance may be evidenced in the growing use of the ten code (e.g. 10-4: message understood). This operational modification from uncoded messages has shortened the air time on radio channels thereby reducing channel congestion. Further operational improvements may be found through changing message formatting, routing or even deletion in certain instances. The occurrence activity sequences incorporated into this simulation account for the important bulk of messages that are currently being handled in the O.P.P. system. Simple modification of these sequences may be used to investigate the implications of proposed operational changes.

Acknowledgement

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