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NETWORK TRAFFIC ANALYSIS MODEL.(U)
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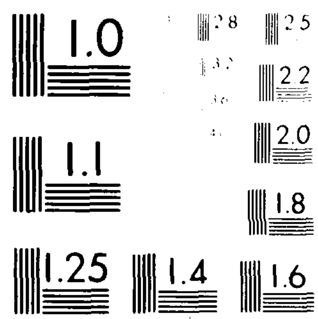

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NETWORK TRAFFIC ANALYSIS MODEL (U)

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DAVID H. KELSO, MR.
US ARMY ELECTRONIC PROVING GROUND
FT HUACHUCA, ARIZONA 85613

JOHN J. MARLEY, MR.
HQ US ARMY TEST AND EVALUATION COMMAND
ABERDEEN PROVING GROUND, MD 21005

I. INTRODUCTION

The Network Traffic Analysis Model is a fully documented time and event oriented dynamic model which simulates the actions of individual equipment at the macro decision level. All multichannel related equipment in a communications system and their interactions are simulated so as to arrive at an analysis tailored to each individual problem.

The basic program is titled the "Simulation Model for Interference Analysis of Nodal Systems" (SIMIANS). SIMIANS consists of many programs which simulate a "black box" or group of "black boxes" for each general type of equipment, (for example, a message switch). The black boxes are defined with specific equipment characteristics, such as delays, capacities, and other parameters. It is in this manner that specific equipment are simulated, (such as an AN/TYC-39 using step 2 software[1]).

[1]SIMIANS does not emulate software when modeling a communications system. The software and hardware of a system is assumed to work as intended by the designer unless empirical data is avilable.

Simulated tactical equipment is modeled in a simulated tactical scenario which includes both friendly and enemy communication-electronic emitters. The deployment currently used is a Scenario-Oriented Recurring Evaluation System (SCORES).(2) With a SCORES simulated deployment, SIMIANS can simulate communications systems up to and including the size normally used for the support of a US Army Corps actively engaged with the enemy. This simulation includes the effects of electromagnetic compatibility and vulnerability.

Traffic Loading of the Network Traffic Analysis Model is accomplished by modifying data from the Communications Support Requirements Studies (COMSR) supplied to the US Army Electronic Proving Ground (USAEPG) by the US Army Signal School.(3) COMSR data (which is based upon input from all US Army Service Schools) contains the average times per day and lengths of conversations and messages between any two or more individuals in a deployment, as well as other relevant data such as precedence, and information content. The times and lengths are then modified by statistical processes to provide unique traffic (calls & messages) between individual subscribers in the simulation.

II. SIMULATION METHODOLOGY

a. General

SIMIANS is a dynamic discrete time event oriented model written in an extension of FORTRAN called "the Simulation Language for the Analysis of Communications Systems," (SLACS).(4,5,6) SLACS, (which has been designed to provide efficient, simplified coding for dynamic simulation modeling an extensive electromagnetic environment), simulates dynamic interaction using a general methodology similar to GPSS and SIMSCRIPT II.5 in that it utilizes external and internal event files as well as a driver program.(7,8) (See Figure.) The SIMIANS program, written in SLACS, diverges from other tactical communication simulations in the level of detail, the size of the modeling effort, and the consideration of the effects of the electromagnetic environment.(9,10,11,12,13)

b. Creation of External Events

External events are stored in a computer file before the simulation begins. The computer file is then used to drive the simulation by providing distinct calls and messages with their respective phone numbers and routing indicators as input to the simulation. These telephone calls and messages are derived from real-time tactical communications requirements which in turn have been derived from COMSR needlines[2] to be simulated by the model. In addition to communication requirements, the file may contain event data on attritions, failures, and repairs which have been derived from DA statistics. An individual external event identifies the time, origin, destination of call or message, precedence, information content, and length of the call or message.

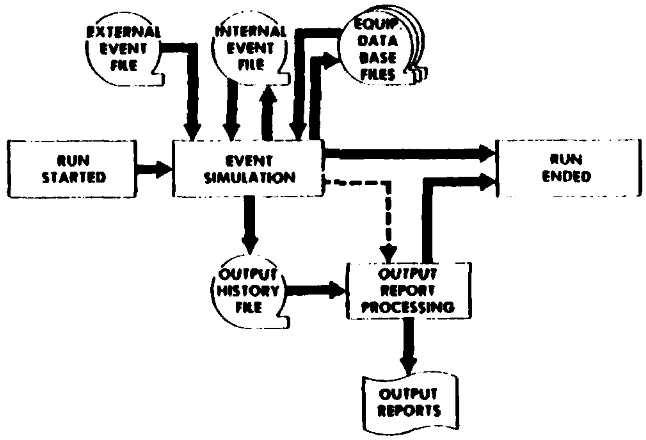

Figure. SLACS Simulation Methodology.

COMSR data contains the message or call originator and destination, the average number of communications per 24-hour period, and the average message length as well as the other information pertaining to messages and calls discussed in the previous paragraph. SIMIANS assumes that the COMSR needline traffic can be represented by a non-homogeneous stochastic process. Needline data described by COMSR data is in terms of 24-hour intervals. SIMIANS considers each needline in terms of a nonuniform arrival rate throughout a given 24-hour period (described in more detail, next para). Each period is considered a unique increment statistically independent of other increments, in

[2]A needline is defined as the requirement of two individuals to transfer information for a specific purpose by a specific mode. In COMSR, each interunit COMSR record and intraunit COMSR record is a needline.

(381)

that the calls or messages generated during one 24-hour period are not influenced in any manner by traffic generated in a previous period. Arrival rates as defined by COMSR remain constant, and will remain so in the generation of external events with the exception of a change of combat posture to an other than normal condition. The arrival rate is defined as the frequency with which a message or call is attempted.

It has been assumed in the writing of SIMIANS, that the average number of calls or messages per 24-hour period reflected in COMSR data has been derived from traffic which follows a Poisson Distribution. The traffic is then assumed to be uniformly placed throughout a 24-hour period at the average rate supplied by COMSR. A random number is generated between zero and one, and converted to a time scale between 0.00 and 86,400.00 seconds (86,400 sec = 1 day). Thus, the unique time of each call and message attempted is derived.

Next the length of each call and message is defined. Each message and telephone call simulated in SIMIANS assumes that a telephone call or message can be broken into two parts, an identification, or preamble section of fixed length and the text which is of variable length. The variable length is assumed to be exponential defined with a mean (u) minus the length of the fixed portion l. (The value u+l is equal to the average length found in COMSR.) A random number from 0.00 to 1.00 is used to vary the length of the text and thus, the entire message length. The message length is determined in SIMIANS by the following equation:

$$L = l - (u-l)\ln R$$

Where L = message length, l = fixed portion of length, u = the mean of the text length, R = the random number generated from 0.00 to 1.00.

The calculation of unique messages and calls is performed for each unit in the simulated tactical deployment. Then, using Army doctrine, telephone numbers and message routing indicators are assigned to each telephone call or message.

Although not part of the current effort, equipment-oriented events can be calculated in a manner similar to traffic events. Instead of using COMSR data as the basis for calculating equipment events, DA statistics, studies, test results, and equipment specifications are used. Thus, mean time between failure data is used to calculate the time of equipment failures and the mean downtime is used to calculate unique lengths of equipment downtime. In addition, attrition due to the simulated combat can be injected either on a one to one basis or on a statistical basis dependent upon a unit's combat posture.(14) Equipment events are calculated for each communication device in the deployment. Then each equipment event is associated with the pertinent routing indicator(s) or telephone numbers they would affect.

Once the equipment oriented events have been produced, they are combined with the traffic events and then sorted by time. This time ordered sequence of events is then loaded into the external event file.

c. Details of Simulation

All known and future multichannel communications can be essentially broken down into three main categories, common user voice traffic, dedicated circuit traffic, and message traffic. SIMIANS handles each of these three systems as independent systems sharing the same and/or different radio-equipment cable link resources. Should a system be designed where one or more of these categories are no longer independent, SIMIANS will be modified.

(1) Common User Voice Traffic Simulation. SIMIANS breaks the common user telephone call down into a series of events at which delays and decisions are calculated. The simulation process for each call starts when the telephone is lifted up and placed in an off-hook condition (at a time determined by an external event). The status of equipment is then checked, and depending upon circuit wiring, a delay is incurred in the dialing of the phone or ringing of the operator. The equipment added (switch or switchboard) has its status checked. If the status is operational, the call is connected to the first switch or switchboard. Here at the switchboard, delays are incurred for the routing and alt-routing of the call, (the decision as to the routing and alt-routing of the call is based solely upon information available at that piece of equipment), decision as to preemption, and the addition of cryptographic equipment if the call is secure. This process continues until the telephone call either reaches its destination and/or fails due to excess dB loss, equipment nonavailability, preemption, or failure of the called party to answer. (Note: The telephone call may fail for any of these reasons after it reaches its destination before it is completed.) If the call is interrupted or never connected, a decision is made whether or not the call will be reinitiated based upon a probability dependent upon the failed call's precedence times a random number from 0.00 to 1.00, drawn from a

uniform distribution. The time of reinitiation is generated statistically, based upon the call precedence, by generating an exponentially distributed random number with a mean value equal to the average delay assumed for the precedence of that call. The length of the reinitiated call will remain the same as the original if never connected or will be calculated as follows if it was interrupted before completion. First, the percentage of call lengths remaining is calculated. Then the time to reinitiate the conversation is the time to identify oneself and re-start the discussion, added to the unfinished length. This reinitiation time is based upon 10% of the original telephone conversation. For example, a telephone conversation is interrupted when it is 30% complete; 70% remains to be completed. Thus, the new call length is (0.7 + 0.1) L, where L is the length of the original call. In the manual switching system (and possibly some automatic switches) it is possible that the initiator of a high precedence telephone call may desire to wait at a particular switching node for a circuit to become available. SIMIANS evaluates this possibility by assuming that the higher the call precedence and the more nodes already connected, the more willing the caller will be to hold rather than to place the call at a later time. However, the longer the caller has been on hold, the less likely he is to be willing to remain on hold. The formula used by SIMIANS in calculating this probability is:

$$P(\text{hold}) = \frac{((15P) + (5N))}{100} \quad \text{where } 0 \leq P(\text{hold}) \leq 1.$$

P = call precedence
1 = Routine
2 = Priority
3 = Immediate
4 = Flash
5 = Flash Override
N = Numer of nodes already connected.

If the caller had been on hold previously, the probability of remaining on hold is decreased by 0.1. This computed probability (P(hold)) is compared to a uniformly distributed random number between the interval of 0.00 and 1.00 to decide whether the caller will hang up or hold. (The decision to hold is made if P(hold) is less than the generated number.) If the caller hangs up, the probability of reinitiation is calculated as described previously.

In the manual system a process called ring-off occurs. Ring-off is the process which allows the caller to notify his local operator that he has completed his conversation. This notifies the operator that the caller's circuit is free. Should this not be done, depending upon operator availability, false indications as to trunk and circuit availability are used in the calculation of routings, preemptions, and alt-routings. Failure to comply with this procedure could thus noticeably affect the performance of a node or switchboard. SIMIANS calculates the probability that ring-off will occur at the end of all telephone calls and compares it with a random number from 0 to 1. If the number generated is less than the calculated probability, a ring-off will occur. Should a ring-off not occur, the availability of a circuit would be discovered in SIMIANS the same as it would be in reality.

Although much of the discussion above is addressed toward the manual switching process, the same basic decisions occur in the automatic switch. However, unlike the manual system each automatic switch has its decisions based upon its hardware and software rather than just hardware capacity. Delays and probabilities will have to be reevaluated for each type of automatic software/hardware combination, which may result in additional specific algorithms for a certain type of equipment. Thus, an average delay (T) for an AN/TTC-39 circuit switch will step 0 software is expected to be different when compared with an AN/TTC-39 circuit switch with step 2 software.

(2) Dedicated Circuit Traffic Simulation. Dedicated circuits unlike common user circuits are not connected through an active switching process. In a manual system, through circuits are connected only through a patching panel and are routed via appropriate communication links. In an automatic system the dedicated circuit call may be routed only through a patch panel, but more than likely will also be routed over a preprogrammed route by a circuit switch. This type of call is called an essential user bypass call. In both the automatic and manual systems, preemption, routing, busy circuits, and other related problems of the common user system do not impact upon the dedicated circuit. However, the automated system has direct access service (hotline) which does not exist in the manual system. SIMIANS treats this type of call as a pre-dialed common user call because normal precedence and preemption procedures are followed.

The dedicated circuit call simulation by SIMIANS starts when the phone is picked up. (This time like the common user is determined by an external event.) A check is made to determine if the circuit

385

is operational. If it is, a check then follows to determine if the circuit is "busy." (Note: Busy here refers to the probability of another person in the same office as the person originating the call already using the phone. For example, the S-3 is talking to a G-3 when the assistant S-3 desires to talk to the assistant G-3.) Should this "busy" condition exist, then it is assumed by SIMIANS that the call in question will immediately follow the call in progress by some small delay. The caller then signals the called party and, after a delay, the called party answers and the call continues until completion or until the circuit fails. If the dedicated circuit fails, the conversation will be reiniated over the common user system in the same manner as a reinitiated common user call.

(3) Message Circuit Traffic Simulation. The essential differences between the telephone system and message system are, for the purposes at hand, that the former may require a number of links all in use simultneously, and that call preemption and alt-routing can occur frequently; the latter may involve a number of one-link circuits used in sequence and queing is used to resolve most circuit contention conflicts.

The major difference between message and voice traffic is that many messages contain multiple addresses, thus, one external event may initiate many different addressed messages of different precedences over different circuits.

An external event starts the simulation of a message. (SIMIANS assumes that the message is ready for transmission at this time, i.e., already typed, etc.) The operational status of the circuit to the next node is checked. If the circuit is not available, then the message is placed in a queue. The message is then sent to the next node with an appropriate transmission delay added. If the next node is an automatic switch, the format is checked for correctness. If it is in error, then the message is re-initiated. (The probability of error is determined differently for each item of equipment.) This process continues until the message is received by the address node when an acknowledgement is sent to the sender (if required). When messages are awaiting transmission, a que will build up in SIMIANS, based upon order of precedence and first in/first out. Although the probability of human error is determined on an individual basis (if determined at all), the probability of bit errors being injected by the transmission media is very real. (This injection of bit error rates is addressed by SIMIANS as described in paragraph IIc(4).)

The above discussion is pertinent to both automatic and manual message switching, however, manual switching delays can be readily defined where the automatic delay is dependent upon the software/hardware combination. Thus, a particular hardware/software combination may have more or less macro decisions resulting in different delays than the manual system. SIMIANS will address this difference by the addition and modification of algorithms as necessary.

(4) Simulation of Electromagnetic Effects. The simulation of electromagnetic effects within SIMIANS is based upon Environmental Interference Effects Model, which itself is a combination of programs used to predict the electromagnetic compatibility and vulnerability of communications-electronics systems operating in a tactical environment.(15)

At the run initialization, SIMIANS evaluates all radio-links of interest, their present status and status change times are calculated. This process is repeated every 0.1 second (real time). Link status is recalculated for all lines when jamming events occur. A determination of jamming effectiveness is made as a function of jammer azimuth and frequency when it is turned on.

SIMIANS performs this analysis as follows: Based upon the assigned frequency or frequency band of each link transmitter, a sort is made of all potential interference generators to determine which of these can possibly cause interference on each link based upon frequency compatibility. Those interference generators with compatible frequencies are further scanned to determine which of them are close enough to the link to interfere with the signal of interest. For each potential interferer a detailed test is made to determine the signal to interference ratio (S/I) when the potential interferer is emitting. (Signal strengths are calculated based upon the Longley-Rice propagation model as modified by the Electromagnetic Environmental Test Facility.(16,17)) The list of links interfered with for a given jammer are compiled in a computer file for that jammer. Thus, when that jammer is turned on, appropriate internal events are generated, (internal events are simulated events generated as a result of other internal and external events). The turn-on cycle or duty cycle of a jammer is supplied as input to the model which is determined from available threat data. Once the S/I ratio has been calculated, the bit error rate and other rates are calculated based upon test data which has been inputted into the model. This data is then used to determine the effects of electromagnetic emitters on the system.

d. Output from the Simulation

Details of each event process will be saved in an output history file. The output history file contains a complete record of each call and message processed. However, for most purposes, such bulk data is useless, therefore, several reports have been devised.(18) (Others are possible and may be added as part of specific projects.) The first report available is a call status report which will provide a detailed listing of each unique communication message that was attempted by the model, for each completed call the average delay is computed. The second report is a call failure report which describes failed attempts, consisting of a detailed listing and a statistical summary by time period. A third report provides a statistical summary by time received and a distribution of call attempts throughout a given block of time. A fourth, and the last currently available report, is the delay summary. It is the accumulation of delays as determined for each of the Δt's accumulated. These delays reflect the real-world delay patterns of network operations.

In addition to the reports produced after the simulation, reports can be generated by external events during the simulation to provide such data as the current use of all internodal channels in the system, or the current contents of all store and forward queues.

III. VALIDATION AND VERIFICATION

The SIMIANS program is continually being assessed to determine how well it faithfully represents actual tactical communications equipment working as a system.(19,20) This is being done four different ways; using sensitivity analysis, comparison of model output with historical records, comparison of model output with data collected explicitly for the validation, and finally, from the comparison of model output with the experiences of experienced tactical Army communicators.

The sensitivity analyses are conducted to determine how much the model output varied with small changes in delay parameters. When a parameter can be changed considerably without any noticeable change in output, its probability based calculation is replaced by a constant. Where the model has proved to be sensitive to a parameter, the most accurate data is used, and the method of delay calculation reexamined to insure that the calculation was correct.

The history of past field exercises by tactical Army units when available is compared to the output of SIMIANS when possible. Where large differences occur, the model is examined to determine if a basic process is correctly modeled.

Since the accuracy of data from past exercises is not known, it was decided to conduct a simple field exercise using three manual switchboards to compare the model's design logic with that of the real world. This was done by comparing the number of telephone calls attempted, completed, lost, interrupted, and preempted. No attempt was made at this time to obtain information or call delays, due to the time and cost involved.

In addition, all of the model's outputs are reviewed by experienced Army tactical communicators to determine if correct procedures and expected results are obtained. When the model deviates from experience, the cause of this difference is extensively investigated. When the fault is with the model, the logic is corrected.

IV. CONCLUSIONS

The Network Traffic Analysis program, SIMIANS, can be used to compare magnitudes of delays for different equipments and networks to determine a doctrine of optimal efficiency and stability through a series of trade-off sensitivity studies. This type of analysis can be used to determine how to best deploy a type of equipment in a given theater by using a simulated tactical deployment and various levels of expected traffic loading. Additionally, the results of trade-off sensitivity studies may be used as input to cost effectiveness studies.

Although SIMIANS is extremely valuable during the various phases of equipment developmental testing, the use of SIMIANS could be of as great or greater value in determining the efficiency of proposed equipment specifications at the beginning of the developmental life cycle.

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