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UNES : A VERSATILE ENVIRONMENT SIMULATOR FOR LOAD TESTS OF SWITCHING SYSTEM SOFTWARE

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ABSTRACT

Opposite to the model oriented and queueing system oriented performance investigation methods with different degrees of abstraction and complexity, the environment simulation technique provides the most realistic test technique for telecommunication systems. This paper discusses the concept, the implementation and field experiences of the universal environment simulator (UNES), by means of which realistic customer behaviour as well as subscriber-system interaction are considered. UNES provides a tool to investigate switching system performance, e.g. call handling capacity under designed load as well as under overload, or the effectivity of overload control strategies. The simulator is designed to simulate more than one thousand connected subscribers or trunks for telephone switching systems. The interconnection and the communication to an arbitrary switching system to be tested is realized by an interface which is independent of the target system.

1. INTRODUCTION

In accordance with advances in hardware and software methodologies, the architectural complexity of the new switching system generation increases rapidly. This tendency can also be recognized in current developments of private automatic branch exchanges (PABX's) as well as in public networks. As a consequence, more powerful performance investigation methods are required in order to support the system design and to ensure a proper system performance. Beside of the two model oriented and queueing system oriented simulation levels with different degrees of abstraction and complexity, the environment simulation provides the most realistic test technique for telecommunication systems.

A number of environment simulation approaches can be found in the literature. Most of them are designed for specific systems to be tested [5]. Thus they are system dependent and can only be applied to the dedicated systems. Other approaches deal with more system-independent concepts; they are designed for use in simulations of a relatively small number of subscriber lines [4]. Most of known environment simulators do not take into consideration the dependency of the subscriber behaviour on system reactions (feedback effects, e.g. repeated attempts, subscriber impatience, etc.) as well as their subscriber system interactions.

In this paper the concept, the implementation and the first field experience aspects of the universal environment simulator UNES will be presented [1, 3]. This environment simulator has been developed at the Institute of Communications Switching and Data Technics, University of Stuttgart (Federal Rep. of Germany) as a cooperation project with Philips Kommunikation Industrie, Nuremberg.

The simulator UNES is implemented by means of a multiprocessor structure operating in a function sharing mode according to a distributed control strategy. UNES provides a tool to investigate switching system performance, e.g. call handling capacity under designed load as well as under overload or the effectivity of overload control strategies. Using the simulator realistic customer behaviour and subscriber system interaction can be implemented for test purposes; the simulator is designed for telephone switching systems for up to one thousand connected subscriber lines or trunks. The interconnection and the communication to an arbitrary switching system is realized by an interface which is independent of the target system (see Fig. 1). The random subscriber behaviour is described in terms of arbitrarily chosen distribution functions and includes also real time system reactions. Therefore, realistic system loads which model stationary as well as nonstationary overload conditions can be generated and offered to the

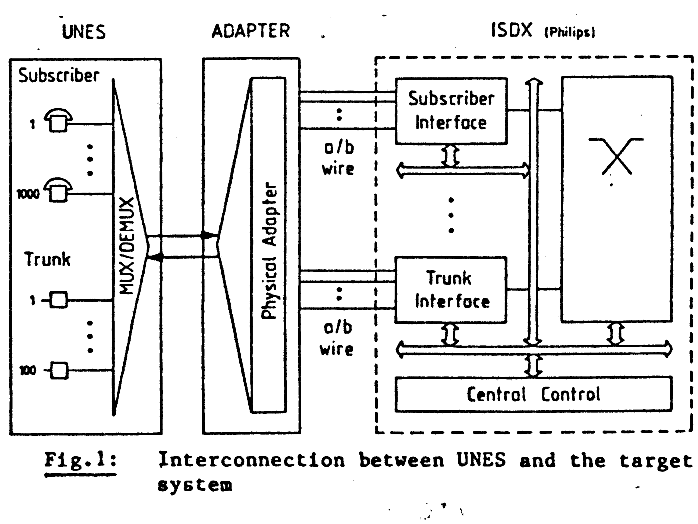

Fig.1: Interconnection between UNES and the target system

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system for test purposes. In order to characterize and to simulate overload traffic streams, e.g. for performance investigations of overload control mechanisms the offered traffic can be realized by means of short term nonstationary load patterns, whereby realistic effects like repeated attempt phenomena can be taken into account.

The main features of the developed universal environment simulator will be briefly outlined. The subscriber behaviour is modelled and specified in the form of SDL (SDL: CCITT Functional Specification and Description Language) and is embedded in a multiprocessor structure environment. Thus the subscriber behaviour model is programmable depending on the desired application. The interface to the target system - i.e. the switching system to be tested - is designed in a system independent manner represented by a set of telephonic events in conjunction with a messageing system. In order to generate the random subscriber reactions, e.g. to simulate effects like dialling before dial tone conditions, incompleted dialling, call abandonments, subscriber impatience, etc., a large number of programmable distribution function types by means of a hardware random number generator are provided.

2. SYSTEM DESCRIPTION AND PERFORMANCE ASPECTS

The functional- and hardware-structure of the universal environment simulator UNES is illustrated in Fig. 2. The simulator is subdivided into five functional modules:

- System Control Module (SCM)
- Subscriber Behaviour Module (SBM)
- Random Number Generator (RNG)
- Timer Handler (THD)
- Target System Interface (TSI).

The System Control Module includes the man machine interface, the simulation control, the trace file generator and the statistic evaluation. The man machine interface can be choosen between standard operating systems, e.g. OS9 or UNIX. This enables the user to access UNES as a standalone test equipment independent of the support of a host computer. The configuration data and test sequences of UNES can be either developed and stored direct on the mass storage of UNES or on an external host computer and is entered interactively through a specific custom oriented software via a terminal. The interconntecting between UNES and the host computer is done via a serial terminal interface and a support software which presents the simulator as a VT 220 terminal to a VAX 11/7xx computer. The System Control Module is based on a readily available CPU board with a terminal interface and a floppy-disk interface onboard.

The Subscriber Behaviour Module includes the message handler for the dispatching of the intermodule messages during a simulation run and the firmware for the designed number of subscriber-lines and trunks connected to the system to be simulated. The desired subscriber type behaviour can be programmed in terms of state transition diagrams which consist of behaviour dependent branching probabilities and random variables for timer periods in conjunction with programmable distribution functions. The Subscriber Behaviour Module is based on a readily available CPU board with a serial interface onboard. Via the serial interface an online trace of the module internal activities can be enabled and output to a terminal or printer. Due to the fact, that the firmware for the subscriber model can be changed easily by the user the whole firmware for the SBM is loaded by the System Control Module from the mass storage into the SBM program area in front of every simulation run.

The Timer Handler and the Target System Interface are based on CPU boards with dual ported RAM for system messageing and local memory for program and data. The program code for these modules can be stored resident or can be loaded during the configuration phase from mass storage into the local memory. In the case of software testing under load conditions a software timer is allocated to each simulated subscriber process controlled by the Timer Handler. The message passing between the Timer Handler and the Subscriber Behaviour Module is done via bidirectional message buffers allocated in the dual ported RAM area of the Timer Handler. The special functions of the Timer Handler for controlling the software timers are supported by five 16 bit hardware timers. The simulation time is relocated by the Timer Handler and can be accessed simultaneously by the Subscriber Behaviour Module without any interference to the local activities of the Timer Handler control unit. The software and the data area is set up for up to 1000 active subscriber processes and will be adapted automatically to the actual number of active subscriber processes during a simulation run. The Target System Interface Module consists functionally of a Message Transformer which translates the message alphabets (e.g. coding and numbering of subscribers, digits) used internally in the simulator and in the test sys-

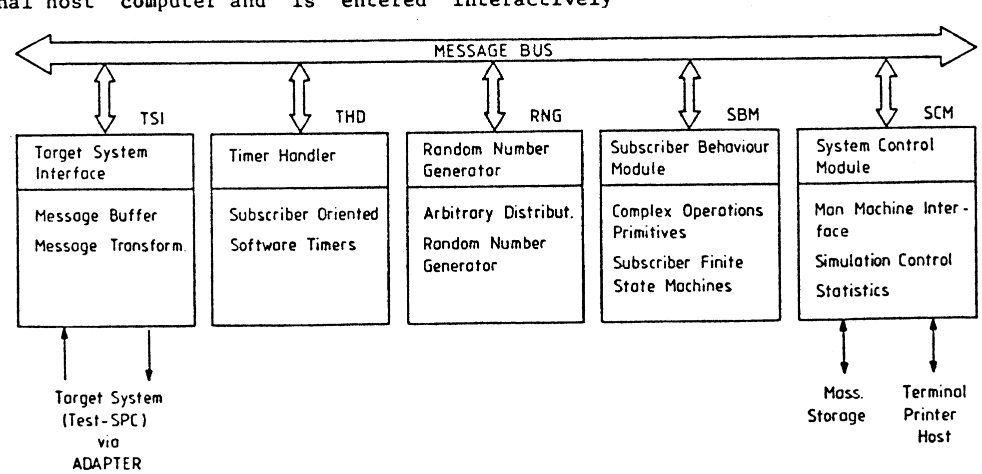

Fig.2: Functional and Hardware Structure of UNES

tem. On the other hand, the Target System Interface performs the flow control function based on an intermediate message buffer. In order to enable more accurate measurements of message delay and system reaction times the Target System Interface is able to report the sending and receiving instants of messages to the System Control Module and to the Subscriber Behaviour Module. Furthermore, the Target System Interface can be set up into a mode which enables the user to load the software of the target system direct from UNES, thus taken into consideration the same data bases for the configuration data for the target system and the simulator itself.

The Random Number Generator (RNG) relocates random numbers based on arbitrary distribution functions to the Subscriber Behaviour Module; it is implemented by means of a multiplicative congruential random number generator providing uniformly distributed random variates in the interval (0,1] in conjunction with a tabledriven Distribution Function Decoder (DFD).

Based on the functional- and hardware structure described above, the operating scheduling of the environment simulator, can be distinguished between the four phases :

- the installation and configuration phase
- the simulation administration phase
- the simulation phase
- the result interpretation phase.

During the installation and configuration phase the user is able to program and modify the behaviour of the simulated subscribers and the firmware of the TSI- and THD-module. During the simulation administration phase the initialisation data and test patterns for a simulation run are defined. During these phases the operating control units of SBM, THD and TSI are deactivated. This enables the System Control to take control over the whole system and to address the local program/data storage areas of the modules SBM, TSI and THD.

By starting a simulation run all control units get activated and all interlevel communication has to be executed via message interchanging. The System Control Module deactivates its overall system control, activates its simulation control and statistic evaluation tasks and transfers the control over the system and messageing processes to the Subscriber Behaviour Module (SBM). Additionally the SBM will supervise the individual subscriber processes realized as Finite State Machines (FSM) in accordance with their appropriate data and program areas.

In order to estimate the performance and the maximum call throughput capacity of the environment simulator UNES, a detailed queueing model is developed which will be investigated by means of computer simulations. In the model the call level and the message level (subcalls, telephonic events) are taken into account. The detailed data flow structure of UNES is depicted in Fig.3 in the form of a queueing network.

The server stations correspond to the functional units as already mentioned. The Timer Handler control unit is modelled by the server station TM (Timer Manager) which is connected to the multiserver group of subscriber processes. This server group consisting of n_S servers stands for the subscriber individual software timers. The departure process of this server group forms the timeout message traffic which initiates subscriber activities. The server station SB represents the message handling activities corresponding to the state transitions of the subscriber behaviour in the FSM. The server IC models the control unit of the TSI module, which supervises the transfer protocol of telephonic messages to the target system as well as the intermodule communication towards the SBM (cf. Fig.2). The reaction time of the test system is approximately described by means of a multi-server group. This server group consisting of n_T servers stands for the subscriber-individual processes inside the target system. Since the queueing system is a closed queueing network there exist no external traffic sources. However, due to the splitting of messages after being served in the subscriber behaviour module, message generation in the sense of a branching process is taken into account.

At the message splitting node a message coming from queue 2 will generate three messages, one towards SIC, one to queue 3 and 4 each. A message coming from queue 7 will generate three messages, one towards SIC and two messages towards queue 3. After being processed in the switching system, a system reaction upon a message will be created and an additional message with a probability q_1 is sent back to the simulator. This is due to the internal message flow between UNES and ADAPTER.

The server stations operate according to the following schedules :

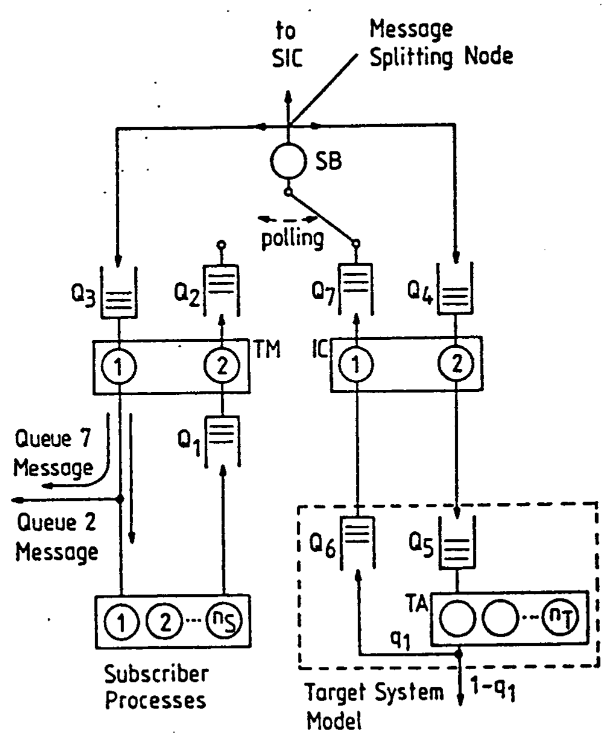

Fig.3: Queueing Model for UNES

- Server TM
  While queue 1 is served exhaustively in a first in, first-out order a non-exhaustive service is implemented for queue 3.
- Server SB
  A cyclic non-exhaustive service in conjunction with a polling mechanism is applied.
- Server IC
  Non-exhaustive service is implemented for incoming messages (queue 6) and exhaustive service is designed for outgoing messages (queue 4).

Some typical performance measures which are of interrest [3] were (see Fig.4) :

- Input delay : Receiving and recognizing delay of input messages
- Output delay : Sending delay for sending messages
- Circulation delay : Reaction time of UNES on target system signalling.

Input, output and circulation delays are shown here for a worst case estimation over the subscriber traffic intensity. Normally average message interarrival time per subscriber in telephone systems is greater than 4 sec. As shown in Fig.4 for this traffic intensity the delays considered are in a reasonable range for up to one thousand simulated subscriber lines or trunks. This indicates that for the designed number of simulated subscribers, the delay caused by the simulator is neglectible comparing with intermessage times.

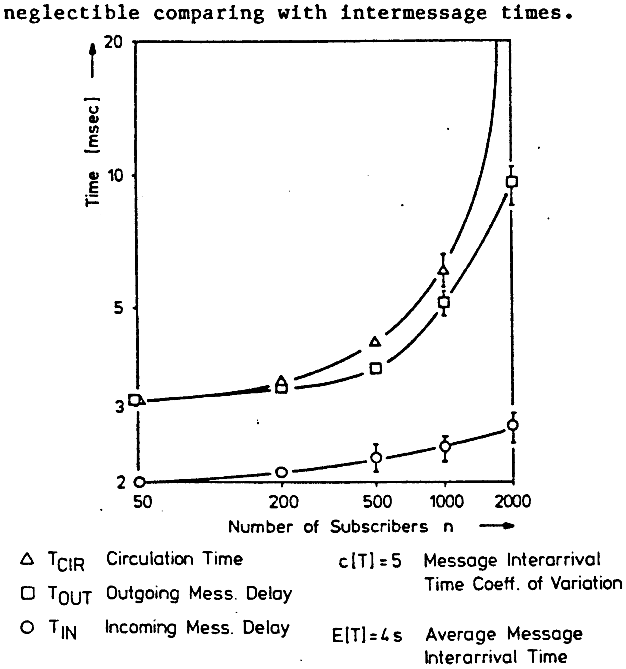

Fig.4: Mean Delays vs Number of Simulated Subscribers

3. LOAD TESTING USING THE SIMULATOR

The aim of testing under load conditions is to evaluate the performance of the target system under a given subscriber load and a given subscriber behaviour. Moreover, the influence of the systems reaction to the subscribers behaviour can be determined by the user. The software structure of the simulator is depicted in Fig.5 where also the embedding of the modules into a hierarchical structure is shown as already described in chapter 2. Starting a simluation run by the user at the man machine interface, the operating system deactivates its overall system control and activates the measurement and statistics software inside the System Control Module. After an internal initialisation phase this task transfers the control via the system and messageing processes to the Subscriber Behaviour Module, thus activating the control units of the THD and TSI. Subsequent the interlevel communication is executed via message interchanging. This message interchanging is done by a dispatcher inside the Subscriber Behaviour Module.

The tasks of the System Control Module during a simulation run are to monitor the whole system activities and to gather messages from the Subscriber Behaviour Module for measurement and statistics purposes.

The main function of the Subscriber Behaviour Module is to model the designed number of subscriber lines and trunks connected to UNES via ADAPTER. It generates telephonic events (e.g., off-hook, onhook, digits, trunk seizure, trunk realize etc.) for the simulated subscriber lines or trunk groups according to the subscriber line or trunk behaviour models and reactions of the target system. The subscriber or trunk processes which define the behaviour of subscribers or trunk groups, are described by means of finite state machines (FSM). In order to model a subscriber line or trunk in conjunction with its individual behavioural timing properties (impatience interval, wait for reattempt event, interdigit intervals, etc.), a software timer is allocated to each simulated subscriber line or trunk process. This timer is controlled by the Timer Handler. Messages generated by a simulated subscriber line or trunk are transmitted to the Target System Interface and messages received from the Target System Interface are rooted to the addressed subscriber, i.e. the appropriate FSM. Inside the FSM each subscriber is represented by an individual random driven process. The actual state of a process is located in the individual data area of the simulated subscriber line or trunk associated to this process where references to the specific data for this type of subscriber (e.g. behaviour oriented time periods, probabilities for actions/reactions, facilities, etc.) are stored.

The behaviour of subscribers is modelled by a SDL diagram. The Subscriber Behaviour Module reports all activities of its FSMs to the System Control Module which in turn describes all activities between UNES and the target system. This enables the user to observe in detail the target system's reactions under a given traffic load or to do performance evaluations for specific time intervals or events.

Based on the hardware configuration currently used, run-time measurements of the software executed in the modules of UNES and performance investigations of the message transport delays between the Subscriber Behaviour Module and the interface

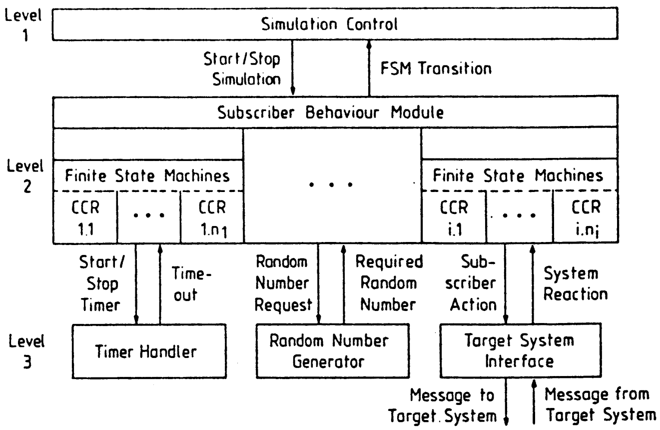

Fig.5: Software Structure of UNES

o ADAPTER resulted in acceptable delay figues for up to 1000 simulated subscribers.

4. FIELD EXPERIENCE

In the current application of UNES, there exists two test configurations dedicated to functional and load tests of switching systems. The first configuration aiming system tests under load and overload conditions is embedded in research projects at the Institute of Communications Switching and Data Technics, University of Stuttgart, where the environment simulator UNES has been developed. A complete second test configuration, consisting of UNES, ADAPTER and a target system (c.f. Fig.1), is installed in the development environment of Philips Kommunikation Industrie (PKI), Nuremberg, used for functional tests of conventional and new ISDN-featured PABX's.

Several tests have been done for the target system of type EBX-180 (PKI, Nuremberg). These tests show the designed performance and the advantageous features of the environment simulator UNES using in witching system tests. In parallel, the overload performance (e.g. dial-tone delay, ring-tone delay, internal blocking, call completion characteristics, etc.) of such a system was investigated for a offered subscriber load of up to a factor of 10 comparing to the designed load of the system.

Currently UNES is used for testing ISDN-featured PABXs during the development phase, thus giving assistance to the development department by testing the program modules. Due to the fact that an automatic functional and load test for the subscriber- and trunk lines could be executed repeatively, the stable phases for the different program modules can be achieved before the original schedule.

5. CONCLUSIONS AND OUTLOOK

In this paper the concept, the implementation, performance aspects and some field experience of the universal environment simulator UNES have been presented which is developed as a test tool for telephone switching systems. The simulator provides a universal performance evaluation tool for switching systems where realistic phenomena which strongly affect the switching system performance like subscriber impatience or repeated attempts can be considered and investigated.

The performance of the simulator is investigated by means of a queueing model. By means of which performance measures like the limiting load generation capability under a given message traffic characteristic and message delays are obtained.

The use of the environment simulator results in some major improvements. Tests can be repeated exactly based on detailed predefined test scenarios. The environment simulator allows the investigation of process interference inside the software of a switching system under designed load and overload conditions. Furthermore,it can be applied to evaluate the effectivity of overload control strategies in switching systems whereby detailed modelling of subscriber behaviour including considerations of the system feedback is arbitrarily programmable and adaptable. The concept will be extended to model subscribers operating with new services which will be provided in current and future system software developments, e.g. in ISDN-featured systems.

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