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THE MEASUREMENT OF COMPUTER NETWORKS

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ABSTRACT

A survey is given about the monitor systems of computer networks. Three levels of the measurement: diagnostic, performance and analytic methods are summarized.

АННОТАЦИЯ

В статье рассматривается мониторная система сети ЭВМ и суммируются три уровня измерений: диагностические, аналитические измерения и измерения мощности.

KIVONAT

A cikk áttekintést nyujt a számitógépes hálózatok monitorrendszeréről, majd összefoglalja a mérések három szintjét: a diagnosztikus, a teljesitőképesség és analizáló méréseket.

1. INTRODUCTION

The measurement of computer networks can be derived from two rather different fields of measurement techniques:

- the measurement of telecommunication
- the measurement of computer systems.

The measurement of telecommunication has a past of several decades. Nearly all steps of the measurement are determined by wellconsidered recommendations of CCITT and the theoretical fundamentals are clear and obvious.

At first, the measurement of computers was a very simple task and only the development and the complexity of the computers necessitated the production of special measuring sets and the elaboration of suitable measurement methods. The theoretical fundamentals of "compumetrics" are in the process of developing yet and the different "task-oriented" methods of the individual computer manufacturer firms sometimes lead to erroneous conclusions. It is also a fact, however, that computer industry is one of the most dynamically developing ones and this dynamical development moves powerful financial and intellectual capitals.

It is necessary to emphasize in the same way, as no up-to-date packet switching computer network can be produced by simply connecting a telecommunication net and several computers, similarly no up-to-date measurement of computer networks will be identical to the joint application of telecommunication measuring sets and computer monitors and to the joint adoptation of measurement methods of both fields.

The first measurement results took their origin in the same time with the appearance of the first computer networks, and the networks them selves were modified on the basis of the evaluation of these measurements.

Why is it necessary to measure computer networks? The main reasons for this can be arranged in three groups:

a/ diagnostic inquiery

- the control of correct operation
- the exact detection of errors
- the diagnostics of the reason of errors

b/ recognition of performance

- the examination of performance
- the control of the network traffic
- the determination of the utilization of the resources

c/ analysis of relationships

- the analysis of interdependence of different software and hardware elements
- assurance of corresponding statistics for model parameters
- the analysis of operation concerning the essence of computer networks.

2. MONITORS, MONITOR SYSTEMS

The components of measurement systems of the computer networks are the software, hardware and hybrid monitors used for the measurement of computers. Since the measurement of a computer network is rendered more difficult by the fact that, as a rule, the nodes are geographically widely dispersed, it is necessary to distribute the activity of the monitor system along the whole network. One part of the tasks is concentrated in a measurement center (control and coordination of the measurements, analysis of the results) while the other parts of task (collection of data) are distributed along the nodes.

The same is characteristic of the measurement of ARPANET, too.

All IMP-s perform a measurement task, but some host machines composing the Network Measurement Center and the Network Control Center, also play an important part in the control and the evaluation of the measurement.

The geographical and functional distribution of the tasks is shown in Figure 1.

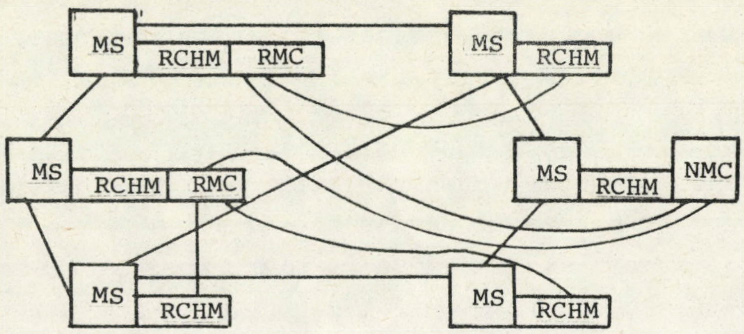

Fig. 1. Network measuring monitor system

The hybrid monitor system [3] has a Measurement Software (MS) distributed along the nodes, and connected directly to the Remote Controlled Hybrid Monitor (RCHM). The Network Measurement Center (NMC) controls these Hybrid Monitors through the Regional Measurement Center (RMC). An up-to-date test facility has be developed by Bell Company for the analysis of store-and-forward message-switching systems [1]. The principle was: "using the system to test the system" namely, the test facility is an existing system configuration: a modified version of the BISCOM (Business Information Systems Communication System).

BISCOM is a large-scale, computer-based, store-and-forward message-switcher, the test set based on BISCOM contains hardware and software monitors, terminal and network simulators, as well as data-reduction and analysis packages. The hardware monitors collect the data on the activity of the hardware components. Their output data are stored on magnetic tape and later these are used as input data of data reduction routines. Software monitors log in statistical reports in a terminal every three minute and collect the significant events on a magnetic tape. BISCOM applies a link control protocol in accordance with ANSI X.3.28.

3. WORKLOAD

The analysis of a system in only under given condition an unambiquous task, therefore a system has to be analysed under a determined workload [4].

Benchmark mixes, traces and synthetic jobs used for measuring computer systems and the traffic samples suggested by CCITT for testing communication lines can form the base of the workload of computer networks, after due consideration [6].

The workload of computer networks is produced by artificial traffic generators. The changeable parameters for these generators are e.g. the proportion of long and short messages [2], the number of messages per time unit the proportion of overhead to real information.

I should mention the test tape library of BISCOM, the tapes of which represent different workloads, message mixes, and test durations. The creation of a test-message tape can be seen in Figure 2. The selection of message workload and message mixes was performed after the forecasting of Bell Laboratory.

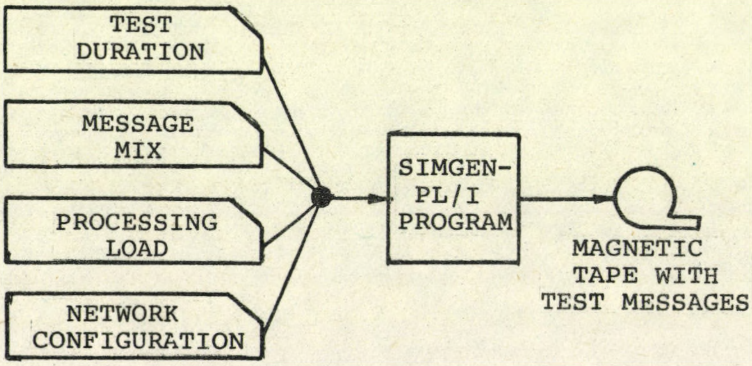

Fig. 2. Creation of a test-message tape

4. THE LEVEL OF MEASUREMENTS

A computer network is characterized by its throughput, delay cost and reliability. To determine these is the direct or indirect aim of measurement. The measurements can be classified according to several points of view, e.g. which parameter is measured, whether the parameters are deterministic or stochastic, which type of monitor is used, whether the user or the Post Administration has a priority.

The comprehensive analysis of the measurement is made easier by considering its hierarchy. The diagnostic test controlling the correst operation of the system represent the bottom level while the performance measurement means the middle level and the analytic measurement constitutes the topmost level. Let us follow this logical structure.

5. DIAGNOSTIC MEASUREMENTS

The purpose of diagnostic measurements is the control of correct operation of computer networks, the detection and diagnostics of errors. The operation of a computer network is characterized by numerous events. An event e_k can be regarded as a logical function defined on subset E_k, where $E_k \in X$. X means the set of possible states of a computer network. An event e_k starts when the network steps from state x_{old} to state x_{new}, supposing that $x_{old} \in E_k$ and $x_{new} \in E_k$. An event e_k terminates in the opposite case (Fig. 3.).

The essence of a diagnostic measurement means observation of the logical functions belonging to the events.

The observed events can be classified in too groups:

- current network configuration
- current operational status.

The current network configuration gives in up-to-the-minute report on the living links, node and host machines.

The current operational status represents the state of network elements, the errors and their causes.

The measurement components are carried by additional parts of standard packets or by special packets. The additional diagnostics of the standard packets can be represented by the acknowledgement of the header of link control protocols and the error control in its trailer. Special packets inform the source if the packet hasn't arrived to its destination (Non-delivery Diagnostics) while packets tell the users the network time (TIME). The special packets indicate the information packets crossing the nodes (TRACE). These special packets are different network by networks.

A rather simplified model of computer communication is considered at the diagnostic measurements. The measurements are time or event controlled. It is difficult to evaluate the extraordinary large number of the data. The results can be surveyed by a hierarchical groupping. E.g. the automatic monitor system of the international network of General Electric [5] makes available the results in three levels:

- the state of all nodes hosts and links is accessable from many nodes

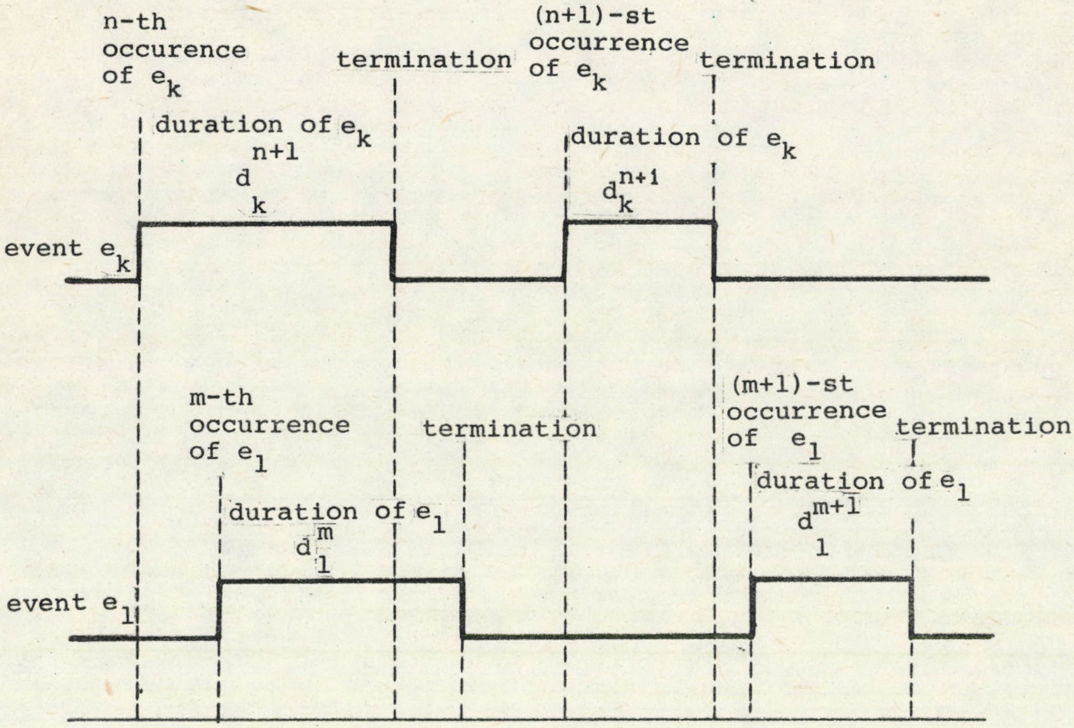

Fig.3. The definition of events.

- the code numbers of the elements near the overload or showing increasing error rate are depicted in displays in some nodes
- the list of erronous components can be read on a single monitor by the central operator.

6. PERFORMANCE MEASUREMENTS

The performance of a computer network means the quality and quantity of services by given workload. The purpose of performance measurements is the analysis of effective operation under dynamically changing conditions. The measures of performance are the functions of events e_k defined in Chapter 5. The countable measures of performance give the occurence of events, the timeable measures the duration of events. The measures of performance are generally conditional probabilities interpreted in a set of workload characteristics [4].

The general form p_k of performance can be described as an integral:

$$p_k(t) = \frac{1}{t-t_o} \int_{t_o}^{t} f_k(t)\, dt$$

where $f_k(t)$ is the density function belonging to event e_k.

The average value of timeable performance measures is

$$p_k^T\,(t) = \frac{t}{t-t_o} \int_{t_o}^{t} e_k(t)\, dt \qquad t \geq t_o$$

where $e_k = 1$ if $x \in E_k$

$e_k = 0$ otherwise

The average value of countable performance measures is

$$p_k^C\,(t) = \frac{1}{t-t_o} \int_{t_o}^{t} i_k\,(t_n - t)\, dt \qquad t \geq t_o$$

where $i_k = 0$ if $t \neq t_n$

undefined for $t = t_n$

and t_n is the time for which $x(t_n)_- \in E_k$ and $x(t_n)_+ \in E_k$

i_k is the impulse function, thus $\int_{t_o}^{t} i_k(t_n - t)\, dt = \sum_n 1$

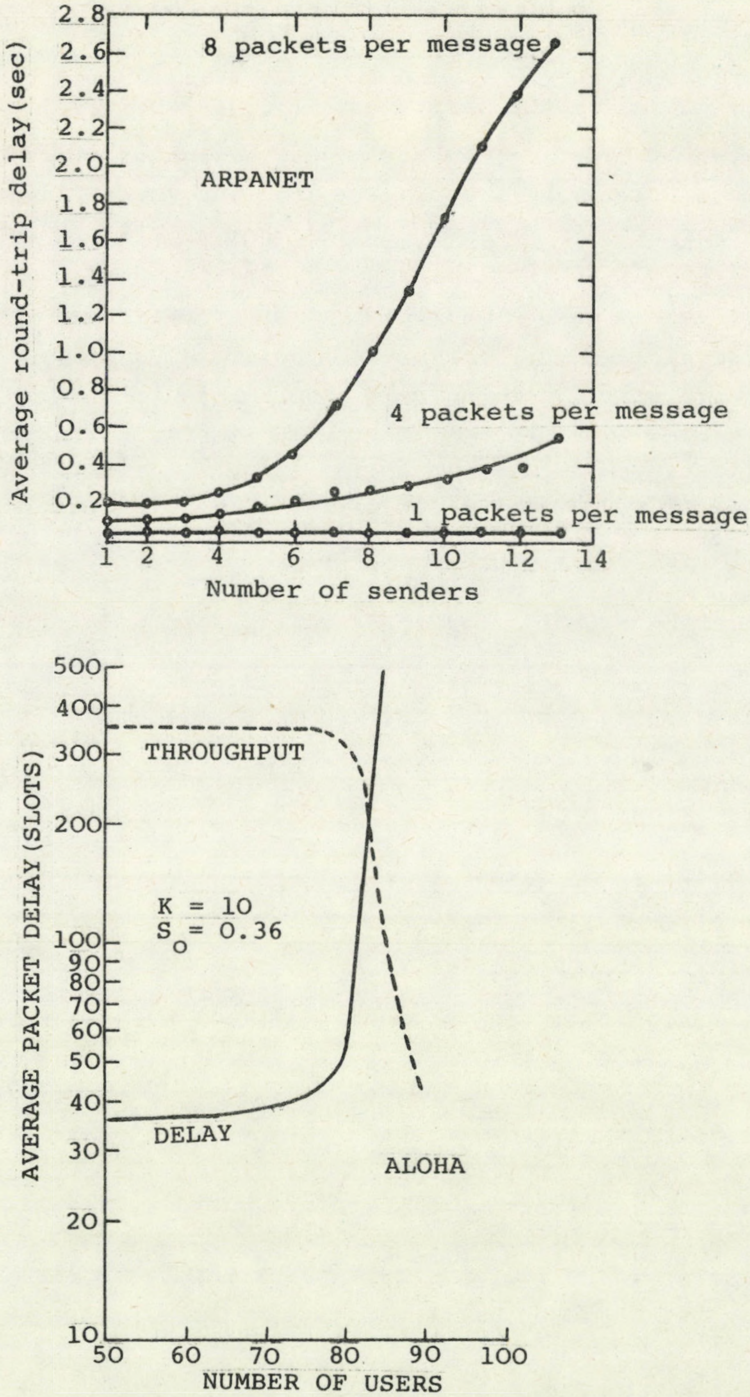

Fig.4. Performance measurement of ARPANET and ALOHA

Two tipical examples can be seen in Figure 4. Figure 4.a shows the average delay of ARPANET, the Figure 4.b the average delay of ALOHA as a function of the user's number [2].

It is worthwhile to mention that CCITT is working on standardization of probabilities characterizing the performance of data networks:

- grade of service (GOS)
- quality of service (QOS)

The computer network models used by performance measurements are essentially more complex than models by diagnostics. The right selection of workload parameters and the correction of errors caused by measurement loss according to the traffic necessitate a hard work and a thorough consideration.

7. ANALYTIC MEASUREMENTS

The analytic measurements represent a higher level as compared with the performance measurements. The goal of analytic measurements is to understand the processes in computer communication and their impact on the performance of the system. The measures of analytic measurements are determined in the most general way by the joint density function of the performance probability variables. The number of joint density functions can be reduces by filtering the independent probability vector variables.

The determination of the average line effectivity of ARPANET is a good example for analytic measurements [2]. The analytic models are based on the probability theory, decision making theory and system theory. It is difficult to imagine a right analysis without the knowledge of measurement theory.

8. CONCLUSIONS

Many computer network measurements were performed, some of them have been published. Most of the publications deals with the measurement of ARPANET. Since the different network measurements have given a lot of unexpected results, further development of the measuring methods and elaboration of the theory have a great importance. Among the problems to be solved the most interesting ones belong to the interdisciplinary area of computer communication and measurement technique.

REFERENCES

[1] W.E. Bracker, E.R Sears: Test facility for a Message-Switching System
The Bell System Technical Journal
1976 Sept No.7 Vol.55 pp. 857-873

[2] L. Kleinrock: Queueing systems Vol. II.
John Wiley & Sons, 1976.

[3] D.E. Morgan, W. Banks, D.P. Goodspeed, R. Kolanko: A computer network monitoring system
IEEE Trans. on Software Engineering
Vol. SE-1 No.3 1975. pp. 299-311

[4] L. Svobodova: Computer performance measurement and evaluation methods
AD-A013 318 1974.

[5] G.H. Wedberg, L.W. Hauschild: The General Electric network monitor system
Information Processing 74. pp. 24-28

[6] CCITT Green book Vol.VIII.
Data transmission
International Telecommunication Union, 1973.

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