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CONSIDERATIONS ABOUT THE RELIABILITY OF TELECOMMUNICATIONS SYSTEMS

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Abstract **– This document discusses the influence of components' reliability on the reliability of telecommunications systems, which by nature of uninterrupted operation without failures, rise problems of safety in operation. These problems are in the attention of equipment manufacturers, and providers of telecommunication services.**

***Keywords*:** *reliability, redundancy, availability, fault rate, running time.*

1. INTRODUCTION

Reliability contains aspects of safety in operation, the availability and performance of maintaining a constant value, attributes that have a major role in carrying out the services provided by systems and telecommunications networks. One of the first tasks of reliability is ensuring continuity of services, particularly for urgent cases. To achieve these objectives, telecommunications operators must ensure secure architectures. Although this represents a significant investment which increases system cost, the need to ensure efficient service, makes providers consider key communication aspects of their systems' reliability.

2. SAFETY IN OPERATION AND AVAILABILITY OF TELECOMMUNICATIONS SYSTEMS

Safety in operation is the probability of a system to fulfill the functions prescribed for a time in certain given conditions. This corresponds to the mission success of telecommunications. Otherwise the mission is not fulfilled, and functionality-wise, the system will fail for a shorter or longer period of time. As such, it is estimated *the likelihood of success at time t, or the probability or operation for a time t.*

In telecommunications and in particular the ground equipment, which are generally recoverable, an important feature is the *availability* of systems.

The availability is defined as the systems' probability to work (to be running) at any time t, whatever the previous state was (faulty or repaired).

Such a telecommunication system is characterized in two ways:

-safety in operation, which is the likelihood of uninterrupted activity up to time t:

-availability, which shows the probability to be active at the time t.

Because availability is usually high, approaching 1 (0.99) and the assessment process is difficult to place in practice, it is used as a parameter the systems' *unavailability* which is the complement of 1 and is expressed as 10^{-x}.

3. FAULT RATE AND THE „BATHTUB CURVE"

Instantaneous faulty rate $\lambda(t)dt$ is the probability of the system that is working correctly at a time t, to fail (to discontinue the range $[t, t + \Delta t]$.

During the operating (living) time of repairable systems there are three periods (fig. 1), consistent with the behavior of failure rate:

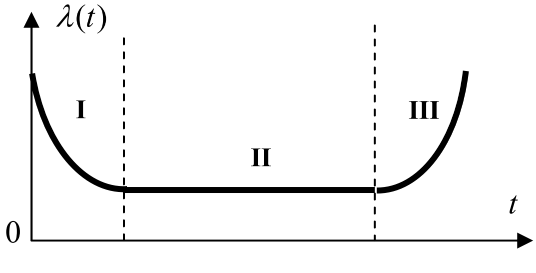

Figure 1: Bathtub curve

I. The period of *early life* is characterized by faults' decrease rate *(λ)* as time passes. It corresponds to the period during which the remaining gaps (hardware and software) that were not detected during the setting up of the system are corrected after system startup.

II. The second period, *the middle* one, is characterized by a roughly constant rate of faults. During this period, the longest life of the system, failures occur (hardware and software) randomly. It is not necessary to identify and correct these residual deficiencies, if the fault rate is negligible.

III. The third period, the *exhaustion period,* is characterized by growth of the fault rate in time; irreversible degradation of the system appears, either because of material degradation of the components, either from lack of proper maintenance for the systems repaired. In what follows we will focus on the middle period, which is called the *in service period*. Because the systems are repairable, we introduce the concept MTBF (Mean Time Between failures). This is the inverse of the constant failure rate λ, of the period of operation.

4. SAFETY IN REPAIRABLE OPERATING SYSTEMS

At the level of a telecommunications system it is considered the state of operation of an equipment E_i, and the defective state $\overline{E_i}$, so that:

$$\overline{E} = \overline{E_1} \bigcup \overline{E_2} \bigcup .... \bigcup \overline{E_i} \bigcup ....$$

Reliability F is defined as the probability of the equipment E_i to be running:

$$F = P(E) = 1 - P(\overline{E})$$

The probability of the equipment E_i to be faulty is:

$$Q = 1 - F = 1 - 1 + P(\overline{E}) = P(\overline{E})$$

5. RELIABILITY OF A SYSTEM WITH SERIAL CONFIGURATION

A system can be regarded as a series of equipments:

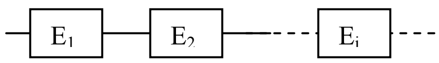

Figure 2: System with serial configuration

Event $\overline{E}$ characterizes the system disorder (faulty system). Formula (1) can be written as:

$$\overline{E} = \overline{E_1 \bigcap E_2 \bigcap ... \bigcap E_i \bigcap ....} \text{ or } E = E_1 \bigcap E_2 \bigcap .. \bigcap E_i \bigcap ...$$

Starting from this formula and considering independent events, we can write:

$$P(E) = \prod_{i=1}^{n} P(E_i)$$

So the reliability of a system with serial configuration of equipment is equal to the reliability of its equipments:

$$F = \prod_{i=1}^{n} F_i$$

If all system components have a fault rate exponentially distributed with the parameter λ_i, the system reliability is:

$$F(t) = e^{-\sum_{i=1}^{n} \lambda_i t}$$

For this system, MTBF is:

$$M = \int_0^\infty F(t)dt \text{ or}$$

$$M = \frac{1}{\sum_{i=1}^{n} \lambda_i}$$

6. EFFECTS OF VARIATION OF RELIABILITY OF SERIAL COMPONENTS

It is considered a reliable series with values below for the reliability of the three equipments

It is considered the reliability of a serial system having the values below for the reliability of the three equipments E1, E2, E3:

$$F_1 = 70\%; \; F_2 = 80\%; \; F_3 = 90\%$$

According to Table 1, one can examine the reliability of each device affecting the reliability of the entire system. First row (I) shows the reliability of each device and the corresponding reliability of the system.

Table 1: The effect of the reliability of serial components

	FE 1	FE 2	FE 3	System
I	0,7	0,8	0,9	0,504
II	0,8	0,8	0,9	0,576
III	0,7	0,9	0,9	0,567
IV	0,7	0,8	0,99	0,554

In the second row of the table (II), the reliability of the first equipment is increased by 10% and the reliability of the other equipments are kept constant. Likewise, regarding other lines one can observe

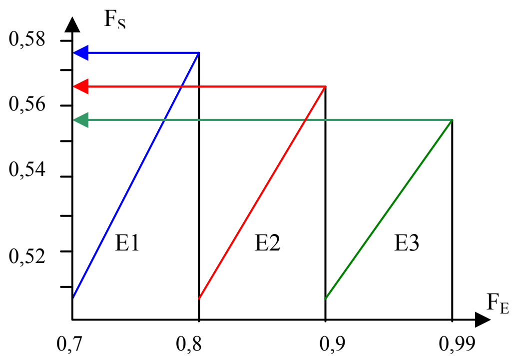

Figure 3: Evolution of the system's reliability *(F_S)* when increasing the reliability of each device *(F_E)*.

Slope difference between the reliabilities of the three components in Figure 3 represents the difference effect of the reliability of each component on the reliability of the entire system. In other words, the rate of changing the system's reliability is a function of changing the reliability of each component.

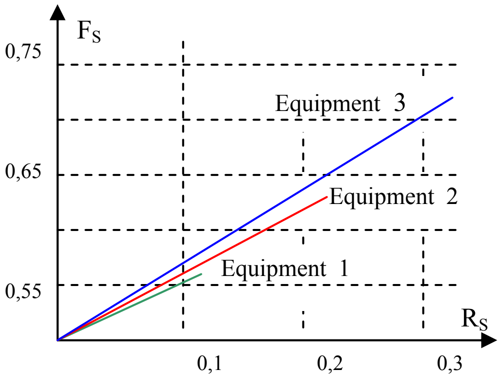

Figure 4: The changing rate of the system's reliability

In Figure 4 slope 1 is the most abrupt, which indicates that system reliability will be influenced most by the reliability's variation of this equipment. So equipment 1 is the most important in terms of reliability. In addition of influencing the reliability of each device within a system, its reliability suffers from increased complexity of the system because of multiplying the number of equipments.

The number of equipments of a serial system has an inversely proportional effect to the operating system reliability. Thus, the more equipment in series, the lower the system reliability. Figure 5 shows a variation of a system's reliability with 3, 4, 5, 10, 15 and 20 components.

Consequently, a system with a serial configuration in which more equipment is present, the components must have good reliability to ensure high reliability of the whole system.

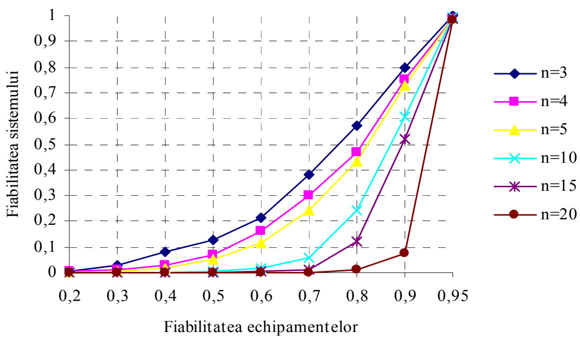

Figure 5:The reliability of a system *(F_S)* with *n* equipments

7. RELIABILITY OF A SYSTEM WITH PARALLEL CONFIGURATION

The system is considered faulty only if all its equipments are faulty.

$$\overline{E} = \overline{E_1} \bigcap \overline{E_2} \bigcap \ldots \bigcap \overline{E_j} \bigcap \ldots$$

$$P(E) = \prod_{j=1}^{n} P(E_j)$$

The probability for the system to be faulty is:

$$D = \prod_{j=1}^{n} D_j \qquad D = 1 - F$$

As such, the reliability (F) of a system with parallel configuration (fig.6) is:

$$F = 1 - \prod_{j=1}^{n} (1 - F_j)$$

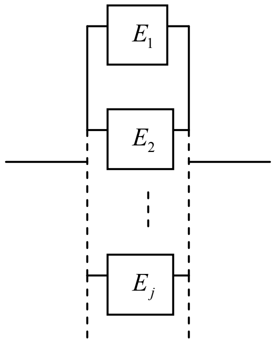

Figure.6: System with parallel configuration

The system works (is running), when at least one of the equipments is running. The fault probability (D) of the system is equal with the composition of the fault probabilities of its equipments.
If all equipments have a fault rate exponentially distributed with the λ_i parameter, the reliability of the system is:

$$F(t) = 1 - \prod_{i=1}^{n} (1 - e^{-\lambda_i t})$$

For 2 parallel equipments, the reliability of the system is:

$$F(t) = F_1(t) + F_2(t) - F_1(t) F_2(t)$$

Or, for elements whose fault rate is distributed exponentially with the parameters λ_1 and λ_2 :

$$F = 1 - \prod_{j=1}^{k} (1 - \prod_{i=1}^{s} F_i)$$

$$F(t) = e^{-\lambda_1 t} + e^{-\lambda_2 t} - e^{-\lambda_1 t} e^{-\lambda_2 t}$$

For this system, MTBF is:

$$M = \int_0^{\infty} F(t) dt$$

and for 2 equipments:

$$M = \frac{1}{\lambda_1} + \frac{1}{\lambda_2} - \frac{1}{\lambda_1 + \lambda_2}$$

8. EFFECTS OF COMPONENTS' RELIABILITY VARIATION OF A PARALLEL SYSTEM

We will take into consideration a system with 3 parallel equipments, having the following reliabilities:

F_1=99,5%; F_2=98,7%; F_3=97,3%

After a running time of 100 hours, the reliability of the system will be:

$$F_S = 1-[(1-0{,}995)(1-0{,}987)(1-0{,}973)]$$

$$F_S = 99{,}9998\%$$

In the parallel configuration, the equipment with the best reliability has the biggest influence over the entire system. So th most reliable component will probably fail last.

În table 2 one can see the influence of each equipment's reliability (F_1=60%; F_2=70%; F_3=80%) over the reliability of the entire system.

Table 2: The effect of the reliability of components that are parallel connected

	FE 1	FE 2	FE 3	System
I	0,6	0,7	0,8	0,976
II	0,7	0,7	0,8	0,982
III	0,6	0,8	0,8	0,984
IV	0,6	0,7	0,9	0,988

First row has the reliabilities of each component and the corresponding reliability of the system. In the second row, the first equipment is increased with 10%, but the rest of the equipments have their reliability unaltered.

Likewise, the same adjustment is performed on the other equipments and one can see the influence of each equipment's reliability over the reliability of the entire system. One can reach the conclusion that the highest reliability of the system is achieved when the value of the reliability of the third device is increased, that device having the highest reliability

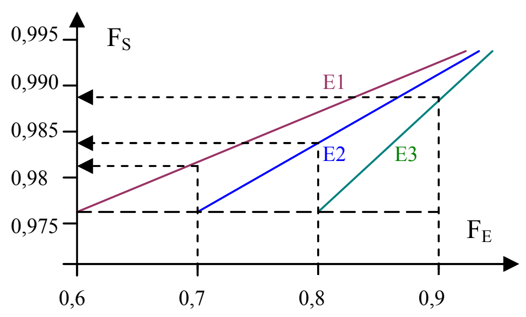

Figure 7: Changes of reliability of the system (F_S) when increasing the reliability of the equipments (F_E)

Even if in a parallel system, the weight of raising the system's reliability falls on the element with the highest reliability, one can increase system reliability by increasing the number of components, even if they have low reliability.

In fig.8 is graphically shown the increase in reliability of a system with n identical components. One can observe the evolution of the reliability, when increasing the number of equipment components.

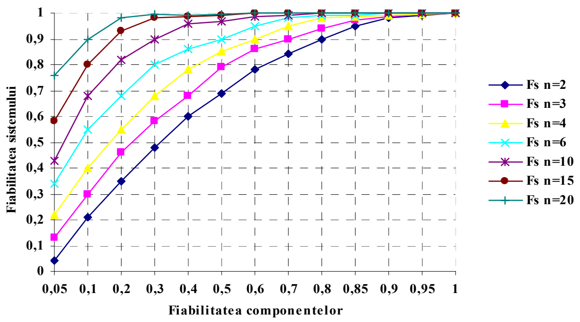

Figure 8: Increased system reliability by increasing the number of components

The conclusion is obvious, namely that adding redundancy improves system reliability. Of course, this is done by raising costs.

9. AVAILABILITY OF VOIP SYSTEMS

Typical for voice communication systems, reliability refers mainly to hardware. Without ensuring the reliability of hardware, the availability of systems decreases. In the field of classical telephony and IP, reliability is evaluated at the "five nines" level, which means that the system is available at least 99.999% of time [3].

Availability is assessed, considering the type and number of the hardware components and considering the average duration of operation (in hours), or in other words calculating MTBF (Mean Time Between Failure). On the flip side, one must consider the repair time for defective components, MTTR (Mean Time To Repair).

For example if an IP switch has an approximately 135000hours MTBF and each fault is an interruption of one hour for MTTR, the availability of the switch would be:

$$D = \frac{MTBF}{MTBF + MTTR} = \frac{135000}{135000 + 1} = 99{,}9993\%$$

This proves that the availability of this switch is „five nines".

Considering the availability of telecommunications equipment, in industrial terms we come to the conclusion that there isn't a system with MTTR = 24 hours that can reach the availability of "five nines" [4].

For that would be necessary that the MTBF to be 2,400,000 hours between faults:

$$D = \frac{2400000}{2400000 + 24} = 99,999\%$$

However, one can build a real-time system whose MTBF should be 400000 hours, and the repair time only 4 hours. In this case, the system's availability is "five nines".

$$D = \frac{400000}{400000 + 4} = 99,999\%$$

10. THE RELIABILITY OF THE NETWORK

In IP telephony implementation, the most difficult problem is raised by the functionality of the existing infrastructure. If your LAN or WAN which is used as the communication infrastructure has low reliability, then it will raise QoS problems which will not allow viable solutions for VoIP. For example LAN's with multiple serial components, have a typical availability of "3 nines or 4 nines", but it is possible to achieve an availability of "5 nines" using aggregate redundant switches with redundant channels. For WANs, the availability is between 99% and 99.9%, and the availability and quality of voice transmissions can be less than 98%. The solution lies in distributing the control of calls in local switches, or in switches with remote control logic, and available database.
A centralized control system is working hulkingly on a WAN connection, and at a network fault, the remote units will not have control, which means that calls will not be made until a system backup is performed.

11. THE RELIABILITY OF APPLICATIONS

A number of VoIP applications such as automatic operator, voice-mail, teleconference, abbreviated numbering and others, are available on the network server. To increase the reliability more than one server can be used. One solution is a *site hierarchy* that requires that each applications server, has access to the configuration database of the central server, starting from the first application of of the users' hierarchy. As such, network reliability increases, with each server having the database configuration, any application is available even if the network fails.

12. CONCLUSIONS

Reliability of telecommunication systems is becoming more present in the applications of telecommunications operators, and they in turn must demonstrate it to the customers. The degree of confidence in networks and telecommunications systems is the criteria by which they choose their operator. From this point of view has emerged the concept of Service Level Agreement (SLA), closely related to the reliability of an operator to provide telecommunications services.
The analysis of the reliability of systems has major implications in the steps of telecommunications operators, in order to increase traffic flow and offer quality services.

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