Selected issues of vibration effects on IT network devices reliability

Piotr Łubkowski[1], Rafał Burdzik[2], Dariusz Laskowski[3], Łukasz Konieczny[4], Polak Rafał[5]
[1, 3]Military University of Technology, Warsaw, Poland
[2, 4]Silesian University of Technology, Katowice, Poland
[5]Transbit Sp. z.o.o, Warszawa, Poland
[1]Corresponding author
E-mail: [1]*piotr.lubkowski@wat.edu.pl*, [2]*rafal.burdzik@polsl.pl*, [3]*dariusz.laskowski@wat.edu.pl*, [4]*lukasz.konieczny@polsl.pl*, [5]*rafal.polak@wat.edu.pl*

(Accepted 2 October 2015)

Abstract. Process of provision the multimedia services which are characterized by a selected level of reliability is an important challenge in nowadays multimedia systems. Ensuring the specific level of reliability requires the use of dedicated network devices (i.e. routers) characterized by the set of technical and functional properties. However, mentioned devices are very often exploited in highly mobile environment which is exposed to a number of external factors, among which there are also vibrations. An example would be transport systems in a wide range utilizing IT solutions. As a result, the overall service reliability can be decreased. Hence the process of the system exploitation can determine the reliability of the services as well. This process includes the technical object (hardware and software) and the man (operator) who exploits the system under certain environmental conditions (external and internal) and represents so called antropo-technical approach in which the operating requirements are taken into consideration (particularly related to reliability). The paper presents results of research conducted to assess the impact of vibration on reliability of technical object (TO) represent by IT network devices. The research carried out on the basis of the proposed scenarios has become a source of data that allows developing a comprehensive measure of TO reliability.

Keywords: vibration, IT device, reliability, technical object.

1. Problem description

Network environment includes commonly operated information and communication networks which are part of a telecommunication network. It constitutes a framework for a platform generally used for provision of various multimedia services. These services are characterized by a selected level of quality of services (QoS). Provision of QoS is an important challenge as far as parameters related to the establishing, disconnecting and call-blocking of connection are considered [1]. Within this group of parameters, service accessibility and service reliability are particularly relevant [2]. They determine the possibility of obtaining on demand services in the specified range and under certain conditions, as well to continue it for the required period. Ensuring the specific values of those parameters requires the use of dedicated network devices (i.e. routers) operating in a very differentiated often a mobile environment. Modern transport systems use highly developed network devices to perform the functions of monitoring, supervisory and management of transport processes [3]. In each of the mentioned applications, the reliability and quality of the supervision and monitoring processes is an important issue. Taking this into account, it can be concluded that such a system represents a Technical Object (TO) which is exploited by the man. Transmission of information between the network devices (machines) and the operator is connected with the flow of data through interfaces in stationary and mobile, simple and complex architectures of system that can be divided into classical (TS) and antropo-technical (A-T S) (Fig. 1). This process is accompanied by anomalies related to the time-varying:

1) The state of technical system and its functionality.
2) Destructive behavior of environmental factors (exposure).

The anomalies of various types may have a negative effect on the transport of data in the form of its degradation or losing. As a consequence this leads to reduction of the service availability and reliability as well as can cause serious financial losses.

One frequently occurring anomalies, whose influence is often overlooked in the set of representative parameters identifying TO reliability, are vibrations. However, this is important to have a simple and comprehensive measure for estimation the influence of vibrations on TO reliability. The analysis and synthesis of the selected aspects of the vibration influence on reliability of operation on IT network devices working in highly mobile environment are discussed in paper.

The remaining part of the paper is organized as follows: Section II describes the characteristics of network devices from TO point of view. In section III a specification of environmental exposures is presented. Results of studies of selected types of vibrations are given in section IV. Section V presents the conclusions including proposed measure of TO reliability.

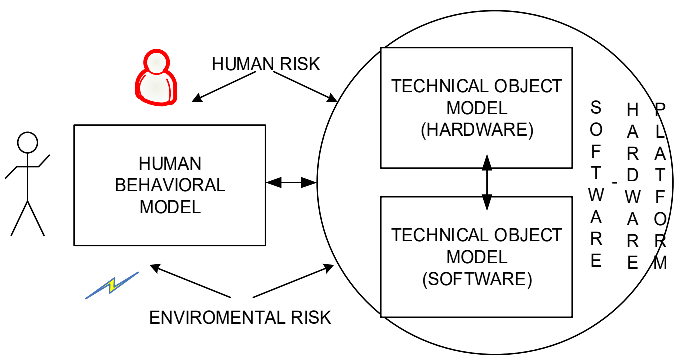

Fig. 1. Antropo-technical (human-machine) system model [own studies]

2. Technical object identification

The IP routers are network layer devices designed for connecting the segments of local area network (LAN) to a backbone WAN (Wide Area Network). The basic function of these network devices is to provide the end-to-end communication. In order to perform such a function for the third layer of the ISO layered model the routers have to be equipped with the following network mechanisms:

– addressing, which allows clear identification of network interfaces and create a list of available networks;

– routing, which is responsible for the selection of the output network interface to send traffic to the destination network;

– forwarding which executes the connection of input to the output port.

Network layer devices, such as routers, are characterized with the use of functional as well as performance requirements. The functional requirements are described in [4]. Among a number of important requirements the most significant are: verification of IP packet headers checksums, monitoring of the TTL (Time to Live) along with resolution of the destination address. The performance requirements include interface baud rate, system throughput and packet transfer rate. The set of functional and performance requirements determines the architecture of the network device. In the real implementations the input and output ports exist in the form of a single interface [5]. Each port of the router is equipped with mechanisms of first and second layers. The network layer of input port is responsible for IP packets forwarding. It also participates in the process of packet classification, which is extremely important when considering issues related to supporting QoS.

It should be noted, however, that the correct functioning of all elements mentioned is associated with the IT device operation environment. As it was already mentioned in many cases IT network elements are exploited on mobile transportation platforms where are commonly associated with exposure of vibrations (i.e. cars, trucks, planes, ships).

As far as the problem of environmental exposure is considered the predisposed potentiality ($E_{p-dys}(t)$) of the system should also be take into account [6]. This is identified by a number of services possible to provide ordered by the user or the probability of an airworthy condition (properly functioning) for their realization and expressed by the following formula referenced to the A-T S:

$$E_{p-dys_S}(t,e_i) = f\left[P_{Pf_S}(t,e_i)\right] = f\left[P_{wW}(t,e_i), P_{bOp_{HCR}}(t,e_i), P_{e_i}\left(t,e_i,U_k^{xh}\right)\right], \tag{1}$$

where: P_{wW} – probability of proper operation of the TO; $P_{bOp_{HCR}}$ – the probability of correct operation of the TO operator with regard to knowledge and experience in project implementation in time regimes determined on the basis of the method of HCR (Human Cognitive Reliability); P_{ei} – the probability of remaining the system in the state of airworthiness e_i after the occurrence at the object of U_k factors of multiplicity h.

It is obvious that from the point of view of TO expose to the effects of vibration significant are P_{wW} and P_{ei}. The probability of proper operation of TO taking into account its internal properties is represented by formula:

$$P_{wWi}(t,e_i) \cong f\left(\frac{K_{gi}}{R_N}, P_{sri}, P_{sni}\right), \tag{2}$$

where: K_{gi} – non-stationary index of readiness (including damage intensity λ and repairing μ); P_{sri} – the probability of blockages in the ith component taking into account service model; P_{sni} – the probability of loss data stream in the ith element as a result of incorrectly functioning synchronization (signalling).

The element representing the impact of environmental factors in the P_{wW} formula is non-stationary index of readiness given by the formula:

$$K_G(t) = \frac{\mu_i}{\lambda_i + \mu_i} + \frac{\lambda_i}{\lambda_i + \mu_i} e^{-(\lambda_i+\mu_i)t}. \tag{3}$$

The K_{gi} index represents the relations of environmental factors with the model of TO (Fig. 2). But much important, as far as vibration effects on TO be considered, seems to be the probability of remaining the system in the state of airworthiness $P_{e_i}\left(U_k^{\times h}\right)$:

$$P_{e_i}\left(U_k^{\times h}\right) = 1 - P_{de_i}^{\times h}\left(U_k^{\times h}\right) = \prod_{k=1}^{h} \left[1 - P_{de_i}^{U_k}(r_n^k)\right], \tag{4}$$

where: $P_{dei}^{Uk}(r_n^k)$ – the probability of destruction of e_i element being in the nth radius of U_k factor impact; r_n^k – the radius of interaction of nth exposure belong to the πth set of types of exposures.

The presented formulas reflect hardware and software properties of the IT network router as well as the environmental hazards in form of vibrations and can considered as a comprehensive measure of TO reliability.

3. Environmental exposures

Noise and vibrations from road and rail traffic through residential areas are ones of major concern, because nearby buildings and residential areas need to be protected from them. For example vehicle contact with irregularities of the road and rail surface induce dynamic loads that generate stress waves, which propagate in the soil, eventually reaching the foundations of adjacent buildings and causing them to vibrate.

The group of technical objects most considerably exposed to the impact of vibrations includes railway transport lines, vehicle transport roads, airfields and ports. The vibrations generated by means of transport, analyzed from the perspective of their environmental impact, are to be classified as elastic foundation vibrations generating paraseismic waves. With regard to the impact surface, one can distinguish between surface waves and body waves. Surface waves propagate on boundaries of two media, e.g. on the ground surface. Body waves propagate in all directions. Depending on the propagation direction, paraseismic waves can be divided into primary and secondary waves. The propagation velocity of longitudinal waves is about two times higher than that of transverse waves. Having reached the medium boundary, e.g. the ground surface, these waves keep propagating as surface waves of either the Rayleigh or the Love type. The energy dissipation of surface waves is far smaller than that of body waves. Moreover, surface waves are characterized by a lower frequency and higher amplitude. For all these reasons, they constitute a greater hazard to the environment and the infrastructure [7, 8].

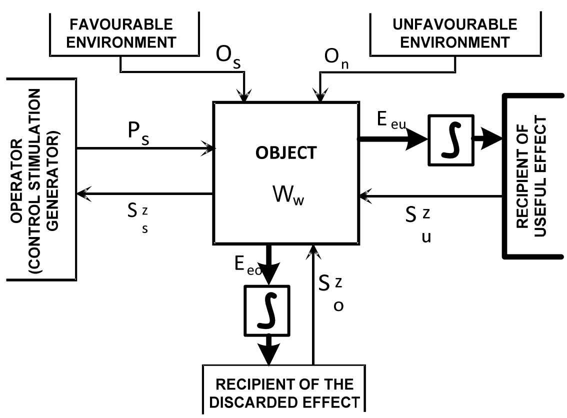

Fig. 2. Model of the object and its relations with environment (where: E_{eu} – useful (utility or maintenance) effectivity, E_{eo} – discarded effectivity (utility or maintenance), S_{zu} – response effect to the object of the useful effect recipient, S_{zo} – response effect to the object of the discarded effect recipient) [6]

4. Results of studies

A set of experiments were conducted for estimation of vibration effect on the TO in the form of IT device. The test plan included the verification of the reliability of services provisioning under conditions of constant exposure of TO elements to vibration from transportation node (i.e. truck or car). Research methodology assumes the correctness of the architecture of the A-T S in the context of its operation.

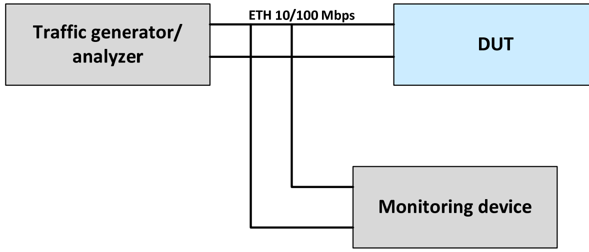

Fig. 3. Model of the testing configuration [own studies]

We assume that the device under test (DUT) is a so called black box. It was tested in predefined configuration that consists of traffic generator and monitoring device with “iperf” and “ping” applications (Fig. 3). The DUT was tested in the vibration system TIRA 17/01 type TV56263/LS according to the testing methodology. The tests were conducted with the following assumptions: the total number of vibrations – 6600, the pulse duration of 10 ms, acceleration – 200 mps. During the test the ETH interfaces and cables of DUT were also examined.

The characteristic of strength and resistance on vibration impact of DUT is presented in Fig. 4. It was observed that device worked correctly.

There have been no any interruptions during DUT operation. All services were available during the testing procedure.

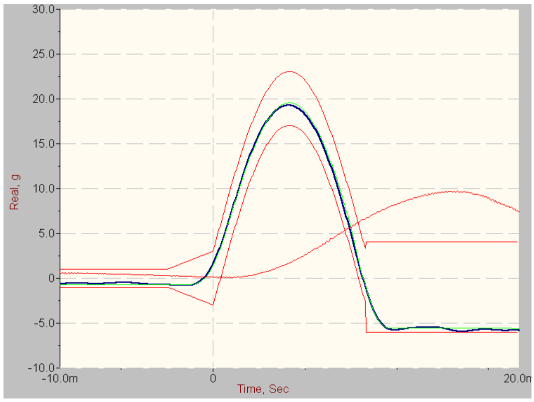

Fig. 4. Characteristics of strength and resistance on vibration impact

5. Conclusions

Testing results presented here confirm that vibrations have an effect on reliability of IT devices. However, the reliability of A-TS was preserved despite the presence of vibration. It is worth to notice, that is possible to determine the value of predisposed potentiality ($E_{p-dys}(t)$) for a properly-specified baseline data that identify the properties of hardware and software platform and environmental exposures. The presented method of comprehensive estimation of TO reliability is universal and can be used to evaluate the reliability of the exploitation of the system, by estimating selected parameters of current and future networking technologies and techniques used in the system.

References

[1] End-User Multimedia QoS Categories Series G: Trans-mission Systems and Media, Digital Systems and Networks Quality of Service and Performance-Study. ITU-T Recommendation G.1010, 2001.

[2] **Lubkowski P., Laskowski D., Pawlak E.** Provision of the reliable video surveillance services in heterogeneous networks. Safety and Reliability: Methodology and Applications, Proceedings of the European Safety and Reliability Conference, Poland, 2014, p. 883-885.

[3] **Lubkowski P., Laskowski D.** Selected Issues of Reliable Identification of Object in Transport Systems Using Video Monitoring Services, Telematics. Support for Transport Book Series: Communications in Computer and Information Science, 2014, Vol. 471, p. 59-68.

[4] **Baker F.** Requirements for IP Version 4 Routers, RFC 1812, 1995.

[5] Optimizing Converged Cisco Networks – Student Guide. Cisco Systems Inc., Vols. 1-2, 2006.

[6] **Laskowski D., Lubkowski P., Pawlak E., Stanczyk P.** Anthropo-technical systems reliability. Safety and Reliability: Methodology and Applications, Proceedings of the European Safety and Reliability Conference, 2014, p. 399-407.

[7] **Burdzik R.** Identification of Sources, Propagation and Structure of Vibrations Affecting Humans in Means of Transport Based on the Example of Automotive Vehicles. JVE Book Series on Vibroengineering, Vol. 1, JVE International Ltd., Kaunas, Lithuania, 2014.

[8] **Burdzik R.** Research on structure and directional distribution of vibration generated by engine in the location where vibrations penetrate the human organism. Diagnostyka, Vol. 14, Issue 2, 2013, p. 57-61.