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Supporting the monitoring services reliability in transportation systems – antropo-technical approach

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ABSTRACT

Process of ensuring the security of citizens, objects and material goods requires access to the information from sensors located in different points of monitoring and data acquisition systems. They are a widely used in administration of car fleet or the visualization of selected functions of transport processes. However, transmission of data from multiple video sensors may lead to the degradation of video quality and even to lack of identification capabilities. As a result, the overall service reliability can be decreased. The process of the system exploitation can determine the reliability of the video monitoring 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 components elaborated for maintenance of reliable video monitoring services as well as the results of selected tests showing its efficiency. Proposition of comprehensive metrics for assessing the reliability of exploitation of video monitoring system, which takes into account antropo-technical approach is presented as well.

Keywords: monitoring and data acquisition systems, service reliability, system exploitation

1. Introduction

Video surveillance systems for many years are used to enhance the safety of citizens and the protected objects. These systems can be meet both in public and national utility facilities, in places publicly available and in the areas with limited access. Monitoring systems are a combination of video recording (sensors), transmitting, storing and reproducing devices in one integral unit. They enable the observation of people or objects in real time as well as the event recording for later analysis. A characteristic feature of the video monitoring systems is also their performance on an ongoing basis. 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 sensor (machine) 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 (ST), antropo-technical technical (SA-T) and social engineering (SS-T) (Fig. 1). This process is accompanied by anomalies related to the time-varying:

1. The state of technical system and its functionality.
2. Destructive behaviour of people or/and environmental factors (exposure).

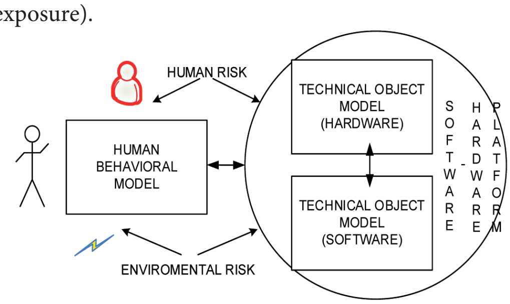

Fig. 1. Antropo-technical (human-machine) system model [own study]

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.

Modern transport systems use highly developed technology to perform the functions of monitoring, supervisory and management of transport processes. In each of the mentioned applications, the reliability and quality of the supervision and monitoring processes is an important issue. Requirements for video surveillance systems are de-fined in the area of functional and quality constraints. Quality assurance at the network level (QoS - Quality of Service) is extremely important because it allows prediction of the size of the available bandwidth and the level of losses at the application layer. However, this information will only allow a fair distribution of bandwidth between the cameras and does not reflect the user's requirements on service severability. Thus in the case of video surveillance systems it is important to consider also the quality at the application layer. It determines the possibility of obtaining on demand services in the specified range and under certain conditions, and to continue it for the required period. Provision of QoS for such systems is a great challenge and requires appropriate QoS platform with traffic control mechanisms to handle video traffic transferred through such systems. Although in the literature many QoS-enabled architectures and protocols have been proposed to solve the problem of end-to-end quality of real-time video services ([1, 2, 3, 4]) they are not well suited to the large variation of maximum available data rate of video monitoring systems. The influence of system administrator "bad" decisions is also not reflected.

In this paper, the QoS platform is presented with ability to negotiate the traffic contract parameters for preserving service accessibility and reliability. It uses a Cross-Layer Data Base (CLDB) and cross-layer signalling (CLS) to share information's between LINK and APP layers [5]. Suitable testing scenarios were selected in order to present an effect of functioning of these components in the QoS-supporting video monitoring network.

The analysis and synthesis of the selected aspects of the SA-T operation in which inability state of essential components of the system or destructive interactions of user can cause interruptions in transmission or losses of information are also presented.

2. Platform for service quality supporting

the platform for provisioning of reliable video surveillance service is based on the layer independent from the techniques as well as network mechanisms applied in the administrative domains of video monitoring network. It consists of the QoS-aware client application and the QoS Streaming Server with the functionality of Resource Broker modules (Fig. 2) [6]. The modules, named respectively "user" and "admin", were implemented in the form of executable programs written in C++ and configured to operate under Windows. They accelerates the video encoding and decoding as well as floating point operations, so it is possible to use the full power of x86 computing.

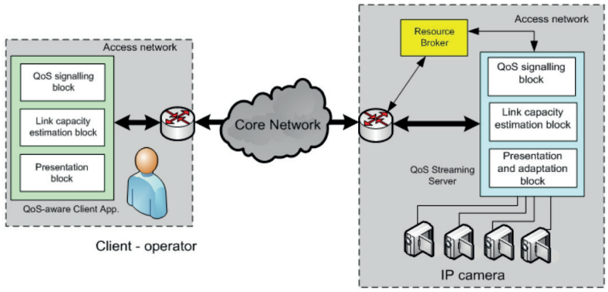

Fig. 2. Functional diagram of QoS platform [own study]

Streaming server (Qo3S) and RB module ("admin") retrieves images from surveillance cameras and provides it on demand to the Client application ("user"). The Qo3S cooperates simultaneously with eight cameras of monitoring system. For each video stream Qo3S performs the procedure of video rate adaptation according to the throughput estimated by RB. Throughput estimation and video rate adaptation procedures have been described in detail in [7]. Additionally, RB executes also resource reservation for the selected video stream according to the QoS requirements coming from "user" application. The RB manages and estimates its known resources and decides about resources allocation for each selected video stream. The "user" application provides a possibility of communication with "admin" module and reception of video sequences from cameras supported by the server Qo3S. As it was already mentioned the customer of "user" application has the ability to manually select the best image quality and the priority of video stream in each of maintained class of services (Fig. 3).

The division of the system into components – elements of a TO – will facilitate its subsequent analysis in terms of reliable and airworthiness exploitation [8].

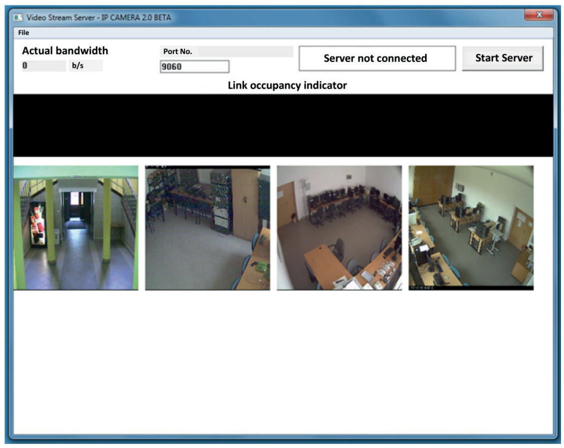

Fig. 3. The "admin" application window [own study]

3. The results of qualitative tests

Verification tests were performed in a demonstrator environment established in the MUT (Military University of Technology) laboratory (Fig. 4).The demonstrator consists of three access domains, which are connected by a backbone network. Two domains are a source of information from video monitoring and one of them represents a monitoring centre. The domains are connected over backbone network where tunnels of predefined bandwidth are established. Only under this condition we can use our mechanism for available bandwidth evaluation. Reasoning about the correctness of network components specification as regards data transmission reflecting information from the monitoring system is based on a statistical estimation of reliability of the software and hardware platform forming the service chain [9]. Products of renowned suppliers of hardware and software for both the systems and applications are the components of the QoS supporting platform. Therefore, it appears reasonable to conclude that the specified measuring system is a correct and highly reliable testing environment [10].

During the tests the video from the IP Axis cameras operating at a resolution of 640x480 was used. The server performs additional video compression using bilinear interpolation based on the designated bandwidth. Throughput restriction is performed by the client application. It reduces the bandwidth of the client interface to the value declared in the application window. The results showing the impact of the applied-implementation on achieved video stream quality are discussed below.

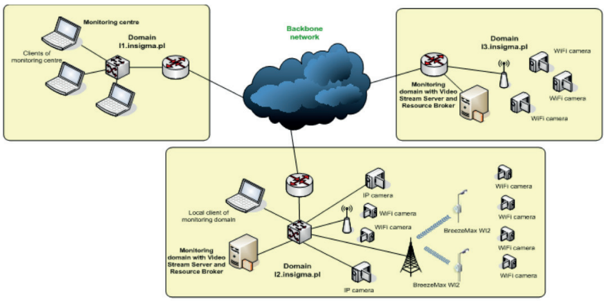

Fig. 4. Architecture of demonstrator environment [own study]

The first experiment selected for discussion in this paper is based on a video streams transmitted to client application with different quality and priority. It represents the behaviour of QoS supporting mechanism caused by changes of throughput given in the transmission channel. The "admin" application handled five video cameras. Five video streams were sent to the "user", of which the last three are as-signed the highest class of service and different priorities (high, medium and lowest). During the experiment a reduction of the available bandwidth was carried out from the maximum value (approximately 10 Mbps) to 100 kbps.

Figure 5 show a picture of the main application window once all cameras are plugged. With respect to the supported cameras (marked with colour squares) information concerning percentage occupancy of the available bandwidth is presented. The figures show also the colour indicator which represents actual link occupancy by each of the handled cameras. Cameras marked with red, magenta and dark blue are serviced with highest class of service. The others (green, blue) are not supported with developed QoS mechanisms. In the first part of the experiment, all cameras share the bandwidth according to the approved resolution of video stream. The overall bandwidth occupancy is equal to 4.08% of available link capacity.

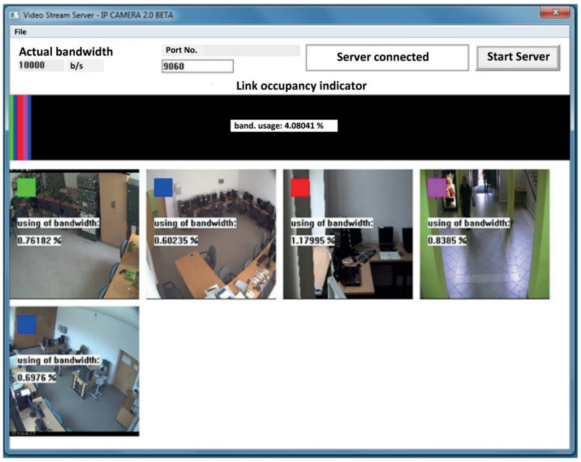

Fig. 5. The "admin" application window during the experiment [own study]

Next, the available bandwidth was restricted. As a result the quality of the video streams of the first two cameras was also restricted (reduction of available bandwidth) while the throughput for other cameras were maintained according to the values declared for the supported class of service (Fig. 6).

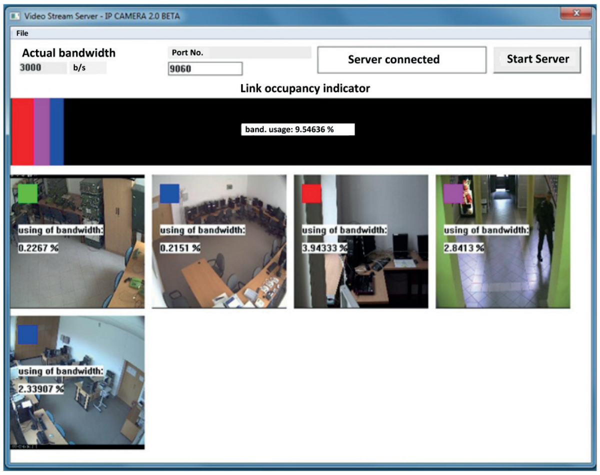

Fig. 6. The effect of available bandwidth reduction – only throughput for cameras supporting QoS mechanisms is maintained (red, magenta, dark blue squares) [own study]

We can also observe only three colour bars presented in the link occupancy indicator due to the fact that with respect to the other two streams (without QoS support) a significant reduction of the resources was made.

The results obtained confirm the effective functioning of the proposed QoS mechanisms in the presence of changes in the available bandwidth.

4. Antropo-technical system reliability

The process of assessment the reliability of video monitoring system exploitation is a fundamental operation for validation of overall system services functionality. The measurable properties of a system reliability, respectively interpreted in a certain unit of time (t), are expressed with [11]:

3. The required potentiality ($E_{p-wym}(t)$) – determined by the number of services that starts and continues on demands of system users.
4. The required potential ($F_{p-wym}(\Delta T)$) – a measure of utility needs addressed by the S. This measure characterize the users' expectations regarding the number and type of services provided over a certain period of time.
5. The predisposed potentiality ($E_{p-dys}(t)$) – 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 expressed by the following formula:

$$E_{p-dys\_S}(t,e_i) = f\left[P_{Pf\_S}(t,e_i)\right] = \begin{cases} f\left[P_{Pf\_ST}(t,e_i)\right] & for \quad ST \\ f\left[P_{Pf\_SA-T}(t,e_i)\right] & for \quad SA-T \\ f\left[P_{Pf\_SS-T}(t,n,\pi,e_i)\right] & for \quad SS-T \end{cases} \tag{1}$$

where:
$P_{Pf\_S}(t,e_i)$ – the probability of abilities of the system (ST, SA-T and SS-T) or its components (e_i) taking into account the internal properties.

For purposes of this paper we assume that the S represents the classical data transportation system. Then, in the analysed model of the system, we took into account also the impact of human machine and environmental factors. So the final model of the system consists of three elements.

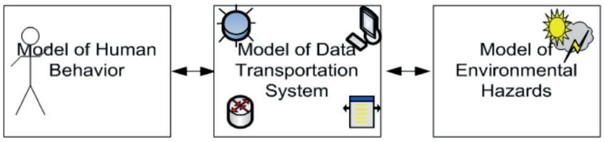

Fig. 7. The final model of the data transportation system [own study]

Based on the assumptions given in [11] we propose to define the SA-T reliability in the following way: „The reliability of a anthropo-technical system is defined as the capability to perform a system services for a defined user in the environmental exposure conditions and to adaptation of the system components in order to restore its correctness of operation".

Considering the size and the complexity of factors that could be grouped into meaningful sets of conditions in the form of the intrinsic properties of the system, the properties of the operator and the harmful effects of the environment, one can derive a formula for the probability of the system airworthy. Such a formula was derived and was presented in [8]. We use it for formulation of the SA-T reliability indicator which is as follows:

$$E_{p-dys\_S}(t,e_i) = f\left[P_{Pf\_S}(t,e_i)\right] = f\left[P_{wW}(t,e_i), P_{bOp\_HCR}(t,e_i), P_{e_i}(t,e_i,U_k^{xh})\right] \tag{2}$$

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*)
$P_{ei}(U_k^{xh})$ – 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*.

The presented formula includes hardware and software properties of the internal components, the operator proper operation in the presence of environmental hazards.

A set of experiments were conducted for verification of the derived formula in a test environment similar to that presented in Fig. 4. The test plan included the verification of the reliability of the monitoring system exploitation under conditions of varying the available bandwidth, constant exposure to damage of its elements and changes in the level of operator knowledge. Research methodology assumes the correctness of the architecture of the SA-T in the context of its operation.

The results of experiments are summarized in the table 1 and shown in figures (Fig. 8 – Fig. 11). The resulting trajectories of potentiality are taking into account the following indicators:

1. Determinants:
   - base of stationary relations system and random occurrence of exposure,
   - detailed: change in the level of knowledge.
2. The result, values for charts:
   - Trajectory of ST (E_{p-dys}_*ST*), SA-T (E_{p-dys}_*SA-T*) and SS-T (E_{p-dys}_*SS-T*) in the scope of knowledge of the Expert (Fig. 8) and Advanced (Fig. 10) users,
   - Differences in the probabilities of trajectories:
     - ST (E_{p-dys}_*ST*) - SA-T (E_{p-dys}_*SA-T*),
     - ST (E_{p-dys}_*ST*) - SS-T (E_{p-dys}_*SS-T*),
     - SA-T (E_{p-dys}_*SA-T*) - SS-T (E_{p-dys}_*SS-T*)

   in the scope of knowledge of the Expert (Fig. 9) and Advanced (Fig. 11) user.

On the trajectory (Fig. 8), depending on the requirements of the operator, determining a required critical value ($E_{p-dys-requirment}$), below which it is believed that OT is no longer fit for operation. For example, the value may be 0.6, and the probability of $E_{p-dys-requirment}$ is reached after 7 months.

Tab. 1. Results of conducted experiments [own study]

No.	Parameter	Value		
		minimum	maximum	average
		[%]	[%]	[%]
Scenario 1 Expert knowledge (Figure 10)				
	E_{p-dys_ST}	99,334735	99,7877975	99,56105
	E_{p-dys_SA-T}	29,160907	89,8280945	54,16555

No.	Parameter	Value		
		minimum	maximum	average
		[%]	[%]	[%]
1	E_{p-dys_SS-T}	20,827015	80,8401576	44,53682
Scenario 1 Expert knowledge_difference (Figure 11)				
2	E_{p-dys_ST} - E_{p-dys_SA-T}	9,9597030	70,173827	45,39550
3	E_{p-dys_ST} - E_{p-dys_SS-T}	18,947639	78,507719	55,02423
4	E_{p-dys_SA-T} - E_{p-dys_SS-T}	8,3338924	10,300253	9,628727
Scenario A1 Advanced knowledge (Figure 12)				
5	E_{p-dys_SA-T}	25,55337	78,7153405	47,46465
6	E_{p-dys_SS-T}	18,250477	70,8393134	39,02711
Scenario A1 Advanced knowledge _ difference (Figure 13)				
7	E_{p-dys_ST} - E_{p-dys_SA-T}	21,072457	73,7813622	52,09639
8	E_{p-dys_ST} - E_{p-dys_SS-T}	28,948484	81,0842576	60,53394
9	E_{p-dys_SA-T} - E_{p-dys_SS-T}	7,3028954	9,0259953	8,437544

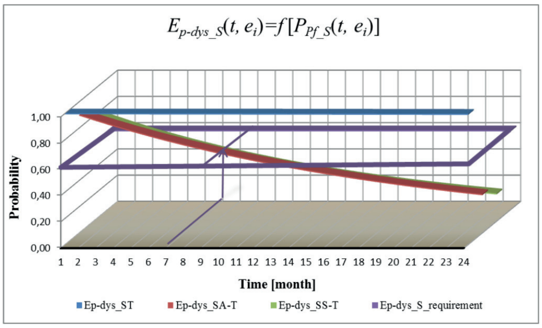

Fig. 8. Scenario 1_The knowledge of the expert [own study]

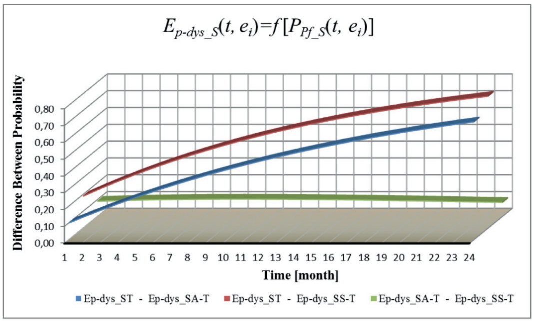

Fig. 9. Scenarios A1_The knowledge of the expert difference [own study]

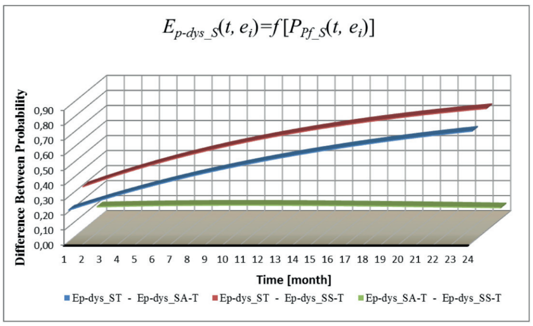

Fig. 10. Scenarios A1_Advanced knowledge [own study]

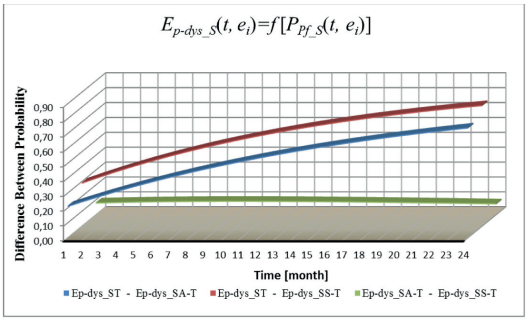

Fig. 11. Scenarios A1_Advanced knowledge_difference [own study]

Trajectories E_{p-dys}_*ST*, E_{p-dys}_*SA-T*, E_{p-dys}_*SS-T* can be divided into several major sets that are characterized by similar shapes depending on:

- E_{p-dys}_*ST* – network traffic – "slightly" linearly decreases (this phenomenon is due to the proper functioning and high reliability of hardware and software),
- E_{p-dys}_*SA-T* – knowledge of the operator – "significantly" exponentially descending, value of traffic volume – "significantly" smaller than the impact of the human factor,
- E_{p-dys}_*SS-T* – knowledge of the operator, environmental exposures and human factor – "significantly" exponentially descending; values of traffic volume are smaller and oscillate at about 1%.

The variability of the differences between the trajectories E_{p-dys}_*ST*, E_{p-dys}_*SA-T*, E_{p-dys}_*SS-T* can be divided into two basic sets of relationships:

- E_{p-dys}_*ST* – E_{p-dys}_*SA-T* and E_{p-dys}_*ST* – E_{p-dys}_*SS-T* – "significantly" logarithmic growing,
- E_{p-dys}_*SA-T* – E_{p-dys}_*SS-T* – close to constant in time.

The data obtained on the basis of the proposed concept, confirmed the need to consider many factors component in case of reliability of exploitation identification. These factors determine the suitability of the technical SA-T (also ST, SS-T) and the correctness of the network services implementation.

6. Conclusion

Testing results presented here confirm that the elaborated QoS mechanisms work correctly in conditions of changing the throughput of the transmission channel. The results obtained show also that the provision of video stream classification preserves the continuity of service without significant deterioration of image quality. This enables the support of end-to-end QoS in terms of service accessibility and reliability.

It is worth to notice, that is possible to determine the value of E_{p-dys}_*ST*, E_{p-dys}_*SA-T*, E_{p-dys}_*SS-T* for a properly-specified baseline data that identify the properties of hardware and software platform, the operator and environmental exposures. The accuracy of the trajectory change and shape of it depends on the number and variety of events occurring in the system environment. The presented method 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.

Acknowledgement

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