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PROBLEMS OF CRITICAL SITUATION SETS IN NETWORK SYSTEMS

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The paper describes the analysis and discussion about the critical situation that happens during ordinary work of the network systems. We propose the formal model – based on the two types of real sophisticated network systems – with the approach to its modelling based on the system behaviour observation. The defined critical situation sets are caused by reliability, functional and human reasons. No restriction on the system structure and on a kind of distribution describing the system functional and reliability parameters is the main advantage of the approach. The proposed solution seems to be essential for the owner and administrator of the transportation systems.

Keywords: network systems, critical sets, reliability, dependability modelling

1. Introduction

Contemporary network systems are very often considered as a set of services realised in well-defined environment created by the necessary hardware and software utensils. The system dependability can be described by such attributes as *availability* (readiness for correct service), *reliability* (continuity of correct service), *safety* (absence of catastrophic consequences on the users and the environment), *security* (availability of the system only for authorized users), *confidentiality* (absence of unauthorized disclosure of information), *integrity* (absence of improper system state alterations) and *maintainability* (ability to undergo repairs and modifications) [1, 3, 8, 13].

The system realises some tasks and it is assumed that the main system goal, taken into consideration during design and operation, is to fulfil the user requirements. The system functionalities (services) and the technical resources are engaged for task realisation. Each task needs a fixed list of services which are processed based on the system technological infrastructure. The different services may be realised using the same technical resources and the same services may be realised involving different sets of the technical resources. It is easy to understand that the different values of performance and reliability parameters should be taken into account. The last statement is essential when tasks are realised in the real system surrounded by unfriendly environment that may be a source of threads and even intentional attacks.

Moreover, the real systems are built on the base of unreliable technical infrastructures and components. The modern systems are equipped with suitable measures and probes, which minimise the negative effects of these inefficiencies (a check-diagnostic complex, fault recovery, information renewal, time and hardware redundancy, reconfiguration or graceful degradation, restart etc). The contemporary network systems are created as very sophisticated products of human idea characterized by the complex structure. This way the critical situations observable during its exploitation are not always predictable for system owners and managers, but could be very costly for a company and sometimes even damaging.

The aim of this paper is to point the problems of the critical situations in unified network system – product of essential elements and features taken from two kind of real systems: ***Discrete Transport System (DTS)*** and ***Computer Information System (CIS)***. Each part of the system is characterised by unique set of features and can caused the critical situation of whole system if it starts to work in unusual way or the fault or error of it is noticed. It is hard for an administrator, manager or an owner to understand the system behaviour and to combine the large scale of variant states of it in single – easily observable and controlled global metric as a pointer to make the proper decision in short time period. To overcome this problem we propose a functional approach. The system is analysed from the functional point of view, focusing on business service realized by a system [14]. The analysis is following a classical [15]: modelling and simulation approach. It allows calculating different system measures, which could be a base for decisions related to administration of the transportation systems.

The results of the system observation – understand as the set of data collected during the simulation process are the basis to define the critical situations and they allow providing proper solution to lift-up the systems in effective way if the critical situation occurs. This is the only sensible way, because the critical situations are the real and not removable part of the system life. The organization of this paper is as follow. We start with description of the abstract service network model (section 2). Base in it we define the normal conditions of the system work (section 3). In section 4 we provide the most adequate – in case of the level of detail - the well-established description of the critical situation.

2. Abstract Service Network Model

The paper describes approach based on functional-dependability models understood as a concept of specifying dependability aspect for two perspectives: secure and dependable system as much as service-related operational system. In our research, we focus on two types of service models, that where close to our interest area: ***Discrete Transport System*** (***DTS***) [13, 14, 15, 16, 17] and ***Computer Information System*** (***CIS***) [8, 10, 11, 12]. Both systems can be analysed separately, but because of their specific goal, some common mechanisms can be seen. Taking into consideration more generic perspective, we decided to focus on a common view on the system model we call - ***Abstract Service Network Model***.

As mentioned, both systems have the same aim – to provide a service in a sense of user request accomplishment. For this reasons, the key point to analyse the systems is a *Task* (*T*) given to the systems. Task is defined by the user and parameters related with time (user patience time, delivery take, etc.) but also it is strongly and inextricably connected with some service scenario. In fact, when we analyse logically the way the service is provided, we can see that the scenario conditions define specific choreography (graph of various components) within a service.

The choreography must be defined and known. Since task is realized as an input to the *Business Service* (*BS*), therefore its choreography is based on predefined service components located in network nodes (reconfigurable components). Moreover, network nodes base on *Technical Infrastructure* (*TI*) – resources used as elements for providing dependable service seen as a hardware and software linked within a network. Various functional define each element of the Technical Infrastructure (routes and central points in *Discrete Transport System*, computers or network devices in *Complex Information Systems*) and dependability parameters, not to mention about some time functions. Time related with the technical resources is as much important as time on a service level, therefore we speak about – *Chronicle of the System* (*K)*.

Taking into consideration these common features an abstract model can be proposed as follows:

$$ANS =< T, BS, TI, M, K >, \tag{1}$$

where
ANS – Abstract Network Services,
T – Task,
BS – Business Service,
TI – Technical Infrastructure,
M – User,
K – Chronicle of the System.

The unified description can guarantee the required level of abstraction for the analysis we are going to provide.

3. Network Service Definition

3.1. System and Tasks

The problems of the contemporary systems reliability certainly need to be extended to cover the envisaged fact that the main object (system) of its studies is a tightly connected complex of hardware resources, information resources (algorithms and procedures of operations and system management) and human-factor (managers, administrators and users).

The studied systems realize complex functions and are capable of substituting tasks on detecting faults (functional redundancy). The systems operate in a changing environment, often antagonistic to

them. Users generate tasks which are being realised by the system. The task to be realised requires some services (functionalities) available in the system. A realisation of the service needs a defined set of technical resources. In a case when any resource component of this set is in a state "out of order" or "busy", the task may wait until a moment when the resource component returns to a state "available" or the service may try to create other configuration based on available technical infrastructure [2, 3, 4].

A technological infrastructure is considered as a set of hardware resources (devices and communication channels) which are described by sets of their technological, reliability and maintenance parameters. The information resources are understood in the same way. The human-factor's functions are defined little bit different: she or he can be defined as: a system operator, a service person, a system manager (administrator) etc. [21, 22]. The system management allocates the resources to the task realisation, checks the efficient states of the system, performs the suitable actions to locate faults, attacks or viruses and to minimise their negative effects. In many situations the system staff and the management system have to cooperate in looking for adequate decisions (for instance to fight with a heavy attack or when a new virus is disclosed). The system events corresponds to: tasks realisation, occurrence of incidents (faults, viruses, attacks) and system reactions to them (technological and information renewals). Task configurations change when the tasks are being processed. The software management, reacting with the system users, determines the changes. Some changes may be the result of detecting system faults and reacting to them. This is called system reconfiguration [18, 20]. The subsets of resources used by the tasks do not need to be disjoint. A resource that can be allocated to more than one configuration at the same time is called sharable, whereas one that cannot is non-sharable. Some resources, for example the central processors in computer systems, are "time-sharable". This is a technique that allows sharing of resources that are essentially non-sharable, by very fast switching of the allocation in time [1, 10, 11].

3.2. Incidents

The system incidents may be classified as unintentional damages generated by faults of the hardware, software or human-factor and intentional events aimed at harming the information resources and system processes. Very often incident is a result of a broadcast attack that is not addressed to a fixed entity (device, machine, truck, lathe, computer, and network) but to all anonymous entities (systems, computers or networks). This kind of attack is called virus. An incident may be "insignificant" if its consequences are easily removed from the system. Sometimes an incident may have a more serious impact on the system's behaviour: it may escalate to a security incident, a crisis or a catastrophe. If a fault appears during the task execution then the system – based on the decision of its managing system and/or its operators – starts the renewal processes. Time of the technological renewal activities and the time of informational renewals are added to the nominal time of the task so a real time of the task duration is longer (Figure 1). The real duration time of the executed tasks depends on kind of faults; hardware failures need both renewals; technological and information but removing of consequences of human errors or software ones is very often limited only to the information renewal process [3, 4, 5, 20].

3.3. Maintenance Problems

The modern systems are equipped with suitable measures, which minimise the negative effects of these inefficiencies (a check-diagnostic complex, fault recovery, information renewal, time and hardware redundancy, reconfiguration or graceful degradation, restart etc). The special services resources (service persons, different redundancy devices, etc.) supported by the so-called maintenance policies (procedures of the service resources using in purpose to minimise negative consequences of faults that are prepared before or created ad hoc by the system manager) are build in every real system [3, 4, 17, 20]. The maintenance policy is based on two main concepts: detection of unfriendly events and system responses to them. Detection mechanisms should ensure detection of incidents based on observation of a combination of seemingly unrelated events, or on an abnormal behaviour of the system. Response provides a framework for counter-measure initiatives to respond in a quick and appropriate way to detected incidents. In general, the system responses incorporate the following procedures:

- detection of incidents and identification of them,
- isolation of damaged resources in order to limit proliferation of incident consequences,
- renewal of damaged processes and resources.

Relations among the incidents and the reactions of the system are shown on Figure 1.

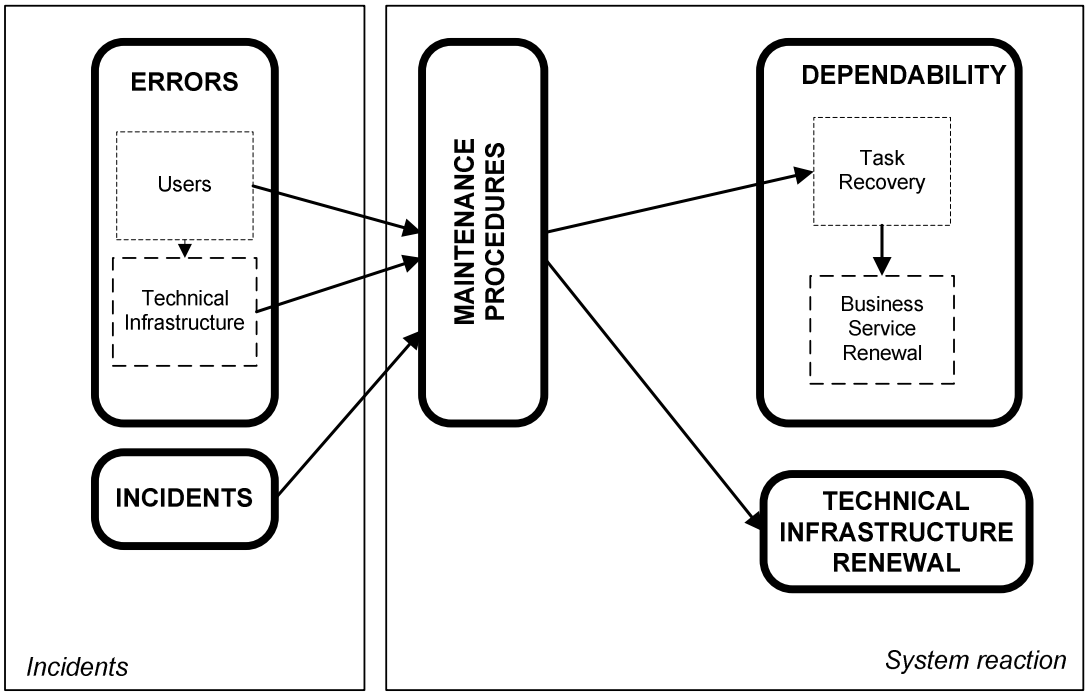

Figure 1. Incidents and reactions of the system

3.4. Network Service Dependability

The term dependability is well known in the literature and commonly used by fault tolerant and dependable computing community, but has been assigned many different meanings. For example, there is more than one definition of dependability [3, 4, 6, 7, 9].

The dependability of the system can be defined as the ability to execute the functions (tasks, jobs) correctly, in the anticipated time, in the assumed work conditions, and in the presence of threats, technological resources failures, information resources and human faults (mainly malfunctions) [5]. Dependability is the most comprehensive concept for modelling complex systems taking a top-down approach [1].

It is evolving into a distinct discipline attempting to subsume the preceding concepts of reliability, and fault-tolerance. There is no universally accepted definition of dependability; the term has been accepted for use in a generic sense as an umbrella concept [2, 3].

Users of the system realise some tasks using it – for example: send a parcel in the transport system or buy a ticket in the internet ticket office. It is assumed that the main goal, taken into consideration during design and operation, is to fulfil the user's requirements. We can easy find some quantitative and qualitative parameters of user's tasks [2, 20].

The system functionalities (services) and the technical resources are engaged for task realisation. Each task needs a fixed list of services, which are processed based on the system technological infrastructure or the part of it. The different services may be realised using the same technical resources and the same services may be realised involving different sets of the technical resources. It is easy to understand that the different values of performance and reliability parameters are taking into account.

The last statement is essential when tasks are realised in the real system surrounded by unfriendly environment that may be a source of threads and even intentional attacks. Moreover, the real systems are built of unreliable software and hardware components as well.

Therefore, it should take into consideration following aspects:

- specification of the user requirements described by task demands,
- functional and performance properties of the system and theirs components,
- reliable properties of the system technological infrastructure that means reliable properties of the system structure and its components considered as a source of failures and faults which influence the task processing,
- process of faults management,
- threads in the system environment,

- measures and methods which are planned or build-in to eliminate or reduce the faults, failures and attacks consequences,
- applied maintenance policies (together with their costs) in the considered system.

It is hard to predict all incidents in the system; especially, it is not possible to envision all possible attacks, so system reactions are very often "improvised" by the system, by the administrator staff or even by expert panels specially created to find a solution for the existing situation. The time, needed for the renewal, depends on the incident that has occurred, the system resources that are available and the renewal policy that is applied. The renewal policy should be formulated on the basis of the required levels of system dependability (and safety) and on the economic conditions (first of all, the cost of downtime and lost processing/computations) [2].

As a consequence, a system is considered as a dynamic structure with many streams of events generated by realised tasks, used services and resources, applied maintenance policies, manager decisions etc. Some network events are independent but other can be found as direct consequences of previously history of the network life. Generally, event streams created by a real network are a mix of deterministic and stochastic streams, which are strongly tied together by network choreography. Modelling of this kind of systems is a hard problem for system designers, constructors and maintenance organisers, as well as for mathematicians. It is worth to point out some achievements in the computer science area such as Service Oriented Architecture [3, 4, 19] or Business Oriented Architecture [19, 22], and a lot of languages for network description on a system choreography level, for example *WS-CDL* [11], or a technical infrastructure level, for example *SDL* [11, 20]. The approach seems to be useful for analysis of a network from the designer point of view. The description languages are supported by the simulation tools, for example modified *SSF Net* simulator [14, 15]. Still it is difficult to find the computer tools which are combination of model languages and Monte Carlo simulators [12, 16, 17].

4. Critical Situations

The **working point** of a unified network system is defined by specific values of functional parameters (resulting from the existing infrastructure – load capacity of commodity carriers and the available number of carriers, passing transfer limits, connection quality, availability and quality of handling equipment, route selection, etc.) and reliability (mean time to elements failures, the number of repair crews, the frequency and duration of traffic jams and other problems, machine renewal time, etc.). In practice, only some elements of the system model may be treated as decision variables. For example, a system designer may adjust carrier capacities to the actual needs of the task but very often, he or she has no possibility to choose the elements base on their reliability features. For example, it is possible to choose a better throughput of the connection, but it is no chance to change the parameters of this part of the network. The appropriate operating point of the network system may be achieved thankfully to the dispatching mechanisms and the actions of organizational nature as: choosing the number of carriers and/or the number of repair crews, bypassing a blocked (overload) by traffic connections, rescheduling, etc. Dispatching decisions concerning allocation of services (functionalities) and resources can define the system reconfiguration necessary to accomplish the planned tasks. The **dependability analysis** of network systems is carried out to assess the degree of risk associated with the implementation of task agreements. Note that in this case, the risk is defined and assessed as likely to ensure the system performance under certain conditions. Another important issue is the evaluation of the impact of various system parameters on defined measures of performance (performability, dependability). **Dependability synthesis** of network systems is based primarily on proper selection of services and resources to fulfil the functional requirements defined by users' tasks (the so-called. input tasks) – see functional – reliable models [14, 15, 20]. Optimisation of system synthesis is carried out based on the minimization of potential losses resulting from breach of contract. Since the parameters and decision variables of the process of network system synthesis are determined by nominal values contained in the intervals of tolerance, though unlikely, is a scenario corresponding an operation point defined by the worst of circumstances (for example, the simultaneous maximum demand of tasks, the maximum number of long-term traffic jams, outbreaks caused by different matters, etc.). The decision variables and the parameters are very often treated as random variables within appropriate tolerance ranges. The operation point of the system may be defined together with a multidimensional solid of tolerance that is created at the appropriate confidence level. The tolerance solid of the network system may be used as a basis for estimating the risk of system faults. It is worth noting the difference between the intended ("built-in") redundancy (functional, reliable) and pseudo-redundancies as a result of random variables distributions,

and therefore both the system constructor and the dispatching mechanisms should exercise adequate caution in these situations. The set of system operation points forms a **system efficient operation area** defined in n-dimensional hyperspace of system parameters and decision variables. The task of synthesis of the network system can be formulated as to ensure the global task performance for a specified number of carriers, choosing the appropriate delivery route and the costs do not exceed a fixed value. Figure 2 illustrates the problem of selecting the operation point of the network system taking into account the number of carriers and repair utensils. The actual system quality is measured by the availability parameter.

The boundaries of the efficient operation area shall be determined on the basis of the acceptable costs of tasks, the maximum allowable repair time, and cost of used infrastructure. The boundaries can be set for the expected values – the hyper-planes of maximum costs of working system and the hyper-plane of the minimum, but still acceptable, system availability. It is easy to notice that the efficient operation area may consist of many operating points, which are associated with different operating costs or risk of incorrect operation of the system. It is introduced a concept of **a critical operation point** of the system, i.e., such an operation point within the efficient operation area that the occurrence of a single hostile incident (e.g. damage of single system element) causes a transient exit (e.g. for renewal time) beyond the area of efficiency and an additional hostile event that appears during the renewal time (e.g. a traffic jam on one of the used routes) leads to system crush (e.g. interruption of the supply chain in a just at time operating system). A subset of the critical operation points constitutes the so-called **critical efficient operation area** of the system (Figure 2) corresponds to **critical system operation states**. The critical system state can be a simple consequence of change of "process parameters", such as raising the intensity of damage of the systems elements as a result of their use or the result of unfavourable combination of circumstances (adverse realization of random variables). For example, without necessarily changing the intensity parameter, too many carriers would be damaged at the same time, and repair crews would be overwhelmed. In extreme cases, it may lead to an avalanche of hostile events, or even to crash the system.

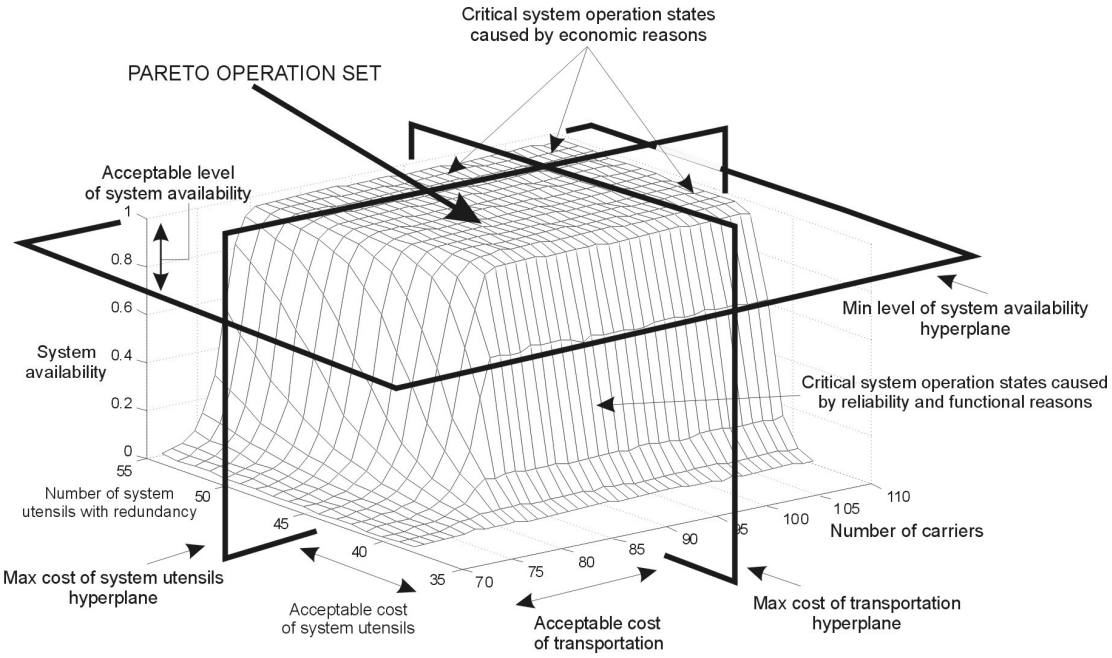

Figure 2. General idea of critical sets for network system

5. Conclusions

We have presented a formal model of sophisticated network system including reliability, functional parameters as well as the human factor component at the necessary level of detail. The model is based on the essential elements and features extracted from the ***Discrete Transport System (DTS)*** and the ***Computer Information System (CIS)***. We pointed the crucial conditions of the normal work of the system. The critical situation is described and discussed to create the Pareto set – guarantying the possible safety operating points for actual network system.

The proposed approach allows performing reliability and functional analysis of the different types of network systems – for example:

- determine what will cause a ”local” change in the system,
- make experiments in case of increasing volume of the commodity incoming to system,
- identify weak point of the system by comparing few its configuration,
- better understand how the system behaves.

Based on the results of simulation it is possible to create different metrics to analyse the system in case of reliability, functional and economic case. The metric could be analysed as a function of different essential functional and reliability parameters of network services system. Also the system could be analyse in case of some critical situation (like for example a few day tie-up [17]).

The presented approach – based on two streams of data: dependability factors and the features defined by the type of business service realized – makes a starting point for practical tool for defining an organization of network systems maintenance. It is possible to operate with large and complex networks described by various – not only classic – distributions and set of parameters. The model can be used as a source to create different measures – also for the economic quality of the network systems. The presented problem is practically essential for defining and organization of network services exploitation.

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