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Cloud Video System Availability Assessment Using Markov and Semi-Markov Models

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***Abstract*— Comparative analysis of Markovian and Semi-Markovian modelling for cloud video system availability is performed considering its architecture and dependability characteristics of various components. Initial data for modelling is based on review of research and operation data of cloud systems. The results of modelling provide decision making related to choice of technique of modelling and availability assessment. Besides, they contributes to ensuring the high availability of cloud systems and can be used by developers in order to address the issues into DevOps engineering area.**

Keywords—cloud systems, availability, Markov Modelling Processes, Semi-Markov Modelling Processes

I. Introduction

The cloud services and systems are customer attractive due ability to deploy power and isolated virtual resources. At the same times, different great enterprise facilities and companies concern the possible disasters of clouds systems caused by components failures, cyberattacks [1, 2] and uncertainty of response time [3, 4]. They are reason of serious damages and heavy losses. In particular, such failures can contribute accidents and disasters with the severe consequences for critical infrastructures (CI) based on cloud technology. To minimize risks of failures the researchers and developers should work together advancing the DevOps methodology for cloud systems and CI [5, 6].

Nowadays typical scheme to provide the cloud resources is based on attractive and advanced possibilities of Cloud Service Providers (CSPs) [7]. Among the CSPs, leading places have Amazon Web Services, Microsoft and Google. Therefore, researchers need to carry out availability control different resources of these CSPs during whole cloud systems' lifecycle. Accordingly, any user needs to pay attention to availability level for the cloud services delivered by provider. This requirement is one of the most important for the CSP.

In this regard, it is noteworthy different hardware and software faults and vulnerabilities can be considered by developers and researchers using of various modeling procedures. Consequently, any developers claim need be proofed by modelling negative events according to a concrete scenario using diverse availability models. This suggests that it would be appropriate to leverage relevant modeling lineup. Currently, many researchers estimate availability of the cloud systems using analytical and stochastic models such as, Markov and Semi-Markov models [8-10]. These models are generally applied together with Reliability Block Diagrams (RBD) method. However, there is no detailed analysis of the possibilities and limits of application of these models.

We suggest to perform the comparing analysis of availability models of a cloud video system (CVS) using Markov (MMPs) and Semi-Markov Modelling Processes (SMMPs) considering CVS architecture and components failures for different phases for the lifecycle. CVS service personnel could use the modelling results to better conduct procedures of DevOps engineering.

The rest of this paper is built as follows. Related works analysis of the MMPs, SMMPs, RBD methods implementations for service models of cloud systems are described in Section II. The appropriate modelling methods of availability changes for CVS based on MMPs and SMMPs are presented in Section III. Numerical modelling results for the comparative analysis of pertinent CVS are outlined in Section IV. Section V concludes and discusses results and further research directions.

II. Related Works

Service personnel and scientists have to take more attention the problem pertaining to assurance of high availability of different cloud's systems and technologies. Those requirements must be justified and reflected to Service Level Agreement (SLA). In fact, the requirements for a cloud SLA relating to availability need to estimate according to modelling results. We set out to answer the question 'how can researchers conjunction utilize the MMPs and SMMPs in order to estimate availability level of a concrete cloud infrastructure that is CVS?'

MMPs could be used by researchers in order to describe some significant phases of availability estimation for the cloud systems and infrastructures, study finds. Input data to modelling the availability level of CVS can be taken by researchers from the relevant sources. In particular, Continuous Time Markov Chains have been applied by researchers in order to determine availability assessments of a cloud mobile system [8].

Another group of researchers has proposed a modeling framework in order to assess performance and availability for the virtualized environment according to concrete scenarios of them behavior [9]. The availability and performance assessments for appropriate cloud data centers and different technical systems have been received by using of Stochastic

Reward Nets [10] and queueing models [11]. In [12] the authors demonstrated how can use Markov reward models in order to compute availability metrics of an application server. Note that this type of servers are used by service personnel of cloud data centers as one of the most significant architectural component.

A substantial part of researches deals with the coupled application of some techniques and approaches. The studies finds that RBD method may be applied with FTA (Fault Tree Analysis) method and Continuous Time Markov Chains in order to determine availability of complex systems. Authors of the [13,14] discussed issues pertaining to availability determining of various technical and cloud systems using the methods noted above. Some scientists have regarded how to utilize different approaches based on MMPs in order to estimate availability level of various systems.

As it turns out, the MMPs have been successful in estimation of clouds systems availability. In the meantime, one must accept that MMPs can restrict some possibilities for researchers, since these types of models base on the use of Markovian property. In addition, using Markov models the researchers can only apply exponential distribution for modelling of quite wide spectrum of negative events. Nevertheless, really it does not, since different by the nature processes cannot be shaped just using of the one exponential distribution.

At any rate, negative effect of natural events and other influences cannot be assessed by utilizing of the exponential distribution. In this situation, scientists can use a familiar modelling pattern for availability assess of clouds systems based on SMMPs. Therefore, some researchers found that Semi-Markov availability models are more accurate then Markov models since they allow considering greater number of influence factors for the system study.

We consider the use of SMMPs as a possibility to improve assess accuracy of availability for the cloud systems considering component failures. To use SMMPs researchers can leverage a deep scientific studies, as set out in papers [15, 16]. These excellent works describe main aspects of constructing and applying both MMPs and SMMPs.

In [17] authors describe the approach based on the use of SMMP to assess availability of a cloud infrastructure with multiple pools. Unlike MMPs, the SMMPs are utilized by researchers when the system operated at diverse modes on different intervals in time.

Therefore, we propose to conduct comparative analysis of CVS availability modelling possibilities and results by using the MMPs and SMMPs.

III. Architecture, Markovian and Semi-Markovian Availability Models CVS

The essential architecture of CVS that developed based on the use of Microsoft Azure resources have been applied for implementation of the offered models. Fig. 1 shows the basic architecture of CVS. In accordance with main Markovian Modelling Theory [16] provisions, the realization of the proposed Markov availability model for CVS must starts with building of a finite graph.

The graph for this Markovian model that unfolded in a form of Continuous Time Markov Chain is shown on Fig. 2. Using the graph for appropriate CTMC (Fig. 2), the system of differential Chapman-Kolmogorov equations [16] can be written as

$$\begin{cases}
\frac{dP_{AVL}(t)}{d(t)} = W_{AVL}(t) - \alpha P_{AVL}(t); \\
\frac{dP_{DSM}(t)}{d(t)} = \lambda_{DSM} P_{AVL}(t) - \mu_{DSM} P_{DSM}(t); \\
\frac{dP_{CDN}(t)}{d(t)} = \lambda_{CDN} P_{AVL}(t) - \mu_{CDN} P_{CDN}(t); \\
\frac{dP_{Wi-Fi}(t)}{d(t)} = W_{Wi-Fi}(t) - \beta P_{Wi-Fi}(t); \\
\frac{dP_{UAWM}(t)}{d(t)} = W_{UAWM}(t) - \gamma P_{UAWM}(t); \\
\frac{dP_{MNT}(t)}{d(t)} = W_{MNT}(t) - \delta P_{MNT}(t); \\
\frac{dP_{APS1}(t)}{d(t)} = \lambda_{APS1} P_{AVL}(t) - \mu_{APS1} P_{APS1}(t); \\
\frac{dP_{QS}(t)}{d(t)} = \lambda_{QS} P_{AVL}(t) - \mu_{QS} P_{QS}(t); \\
\frac{dP_{LB}(t)}{d(t)} = \lambda_{LB} P_{AVL}(t) - \mu_{LB} P_{LB}(t); \\
\frac{dP_{SGR}(t)}{d(t)} = W_{SGR}(t) - \varepsilon P_{SGR}(t); \\
\frac{dP_{UAVS}(t)}{d(t)} = W_{UAVS}(t) - \varsigma P_{UAVS}(t); \\
\frac{dP_{VPN}(t)}{d(t)} = W_{VPN}(t) - \eta P_{VPN}(t); \\
\frac{dP_{APS2}(t)}{d(t)} = \lambda_{APS2} P_{AVL}(t) - \mu_{APS2} P_{APS2}(t),
\end{cases} \tag{1}$$

The initial conditions for the system of differential Chapman-Kolmogorov equations in this case [9] are $P_0(0) = P_{AVL}(0) = 1$, $\forall\ P_i(0) = 0$, where $i = 1,2,...,12$. The following notations are utilized in the system of differential Chapman-Kolmogorov equations (1):

$$W_{AVL}(t) = \mu_{DSM} P_{DSM}(t) + \mu_{CDN} P_{CDN}(t) +$$
$$+ \mu_{Wi-Fi_1} P_{Wi-Fi}(t) + \mu_{MNT_1} P_{MNT}(t) + \mu_{APS1} P_{APS1}(t) +$$
$$+ \mu_{QS} P_{QS}(t) + \mu_{LB} P_{LB}(t) + \mu_{SGR_1} P_{SGR}(t) +$$
$$+ \mu_{VPN_1} P_{VPN}(t) + \mu_{APS2} P_{APS2}(t),$$
$$W_{Wi-Fi}(t) = \lambda_{Wi-Fi_1} P_{AVL}(t) + \mu_{Wi-Fi_2} P_{UAWM}(t),$$
$$W_{UAVM}(t) = \lambda_{Wi-Fi_2} P_{Wi-Fi}(t) + \lambda_{MNT_2} P_{MNT}(t),$$
$$W_{MNT}(t) = \lambda_{MNT_1} P_{AVL}(t) + \mu_{MNT_2} P_{UAWM}(t),$$
$$W_{SGR}(t) = \lambda_{SGR_1} P_{AVL}(t) + \mu_{SGR_2} P_{UAVS}(t),$$
$$W_{UAVS}(t) = \lambda_{SGR_2} P_{SGR}(t) + \lambda_{VPN_2} P_{VPN}(t),$$
$$W_{VPN}(t) = \lambda_{VPN_1} P_{AVL}(t) + \mu_{VPN_2} P_{UAVS}(t),$$
$$\alpha = \lambda_{DSM} + \lambda_{CDN} + \lambda_{Wi-Fi_1} + \lambda_{MNT_1} + \lambda_{APS1} + \lambda_{QS} +$$
$$+ \lambda_{LB} + \lambda_{SGR_1} + \lambda_{VPN_1} + \lambda_{APS2},$$
$$\beta = \mu_{Wi-Fi_1} + \lambda_{Wi-Fi_2},\ \gamma = \mu_{Wi-Fi_2} + \mu_{MNT_2},$$
$$\delta = \mu_{MNT_1} + \lambda_{MNT_2},\ \delta = \mu_{MNT_1} + \lambda_{MNT_2},$$
$$\varepsilon = \mu_{SGR_1} + \lambda_{SGR_2},\ \varsigma = \mu_{SGR_2} + \mu_{VPN_2},$$
$$\eta = \mu_{VPN_1} + \lambda_{VPN_2}.$$

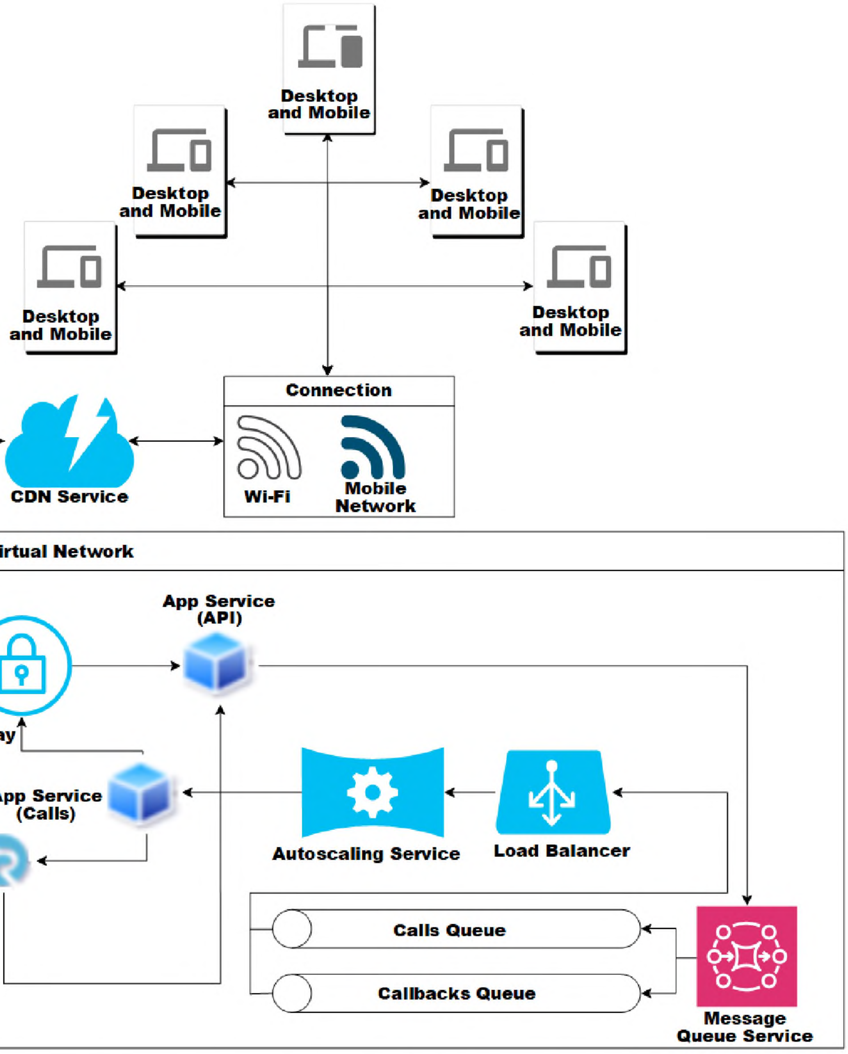

Fig. 1. The essential architecture of CVS based on the use of Microsoft Azure resources

The states' characteristics and values of the parameters of CTMC and Semi-Markovian availability models for the CVS are summarized in Table 1 taking into account data of research

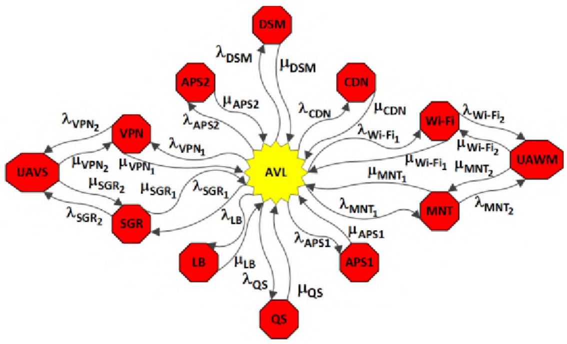

Fig. 2. Finite graph of CTMC availability model of the CVS

[17-20] and operation of similar systems [21, 22]. Solution for the system of differential equations (1) can be received by investigating a limit behavior of the Markov Modelling Process when $t \to \infty$ [9]. Then, researchers can write the solution, which satisfies the system of linear equations [16]:

$$\sum_{i \in S} \lambda_{ij} P_i \pm \sum_{j \in S} \mu_{ji} P_j = 0, \quad \sum_{i \in S} P_i = 1. \tag{2}$$

The solution of the system (1) using the equations (2) has been written by us as

$$P_{AVL} = \frac{1}{1 + c_1 + c_3 + c_4 + c_5 + c_6 + c_7 + c_8 + c_9 + U_1}, \tag{3}$$

where

$$U_1 = c_{10} + k_7 + k_{10} + c_1 k_{11} + c_2\left[c_3 + c_4 + k_{11}(c_3 + c_4)\right] + Z,$$

$$Z = \frac{1}{k_1}\left[k_2 + k_3 k_7\right] + \frac{1}{k_4}\left[k_5 + k_6 k_7\right], \quad c_1 = \frac{k_9 k_{10}}{\varsigma - k_9 k_{11}},$$

$$c_2 = \frac{k_8}{\varsigma - k_9 k_{11}}, \quad c_3 = \frac{\lambda_{SGR1}}{\varepsilon - c_2 \mu_{SGR2}}, \quad c_4 = \frac{c_1 \mu_{SGR2}}{\varepsilon - c_2 \mu_{SGR2}},$$

$$c_5 = \frac{\lambda_{DSM}}{\mu_{DSM}}, \quad c_6 = \frac{\lambda_{CDN}}{\mu_{CDN}}, \quad c_7 = \frac{\lambda_{APS1}}{\mu_{APS1}}, \quad c_8 = \frac{\lambda_{QS}}{\mu_{QS}},$$

$$c_9 = \frac{\lambda_{LB}}{\mu_{LB}}, \quad c_{10} = \frac{\lambda_{APS2}}{\mu_{APS2}}, \quad k_1 = \gamma^2 \delta - \lambda_{MNT_2} \mu_{MNT_2},$$

$$k_2 = \gamma \lambda_{MNT_1} \lambda_{MNT_2}, \quad k_3 = \gamma \delta \lambda_{Wi-Fi_2},$$

$$k_4 = \gamma \delta - \lambda_{MNT_2} \mu_{MNT_2}, \quad k_5 = \gamma \lambda_{MNT_1}, \quad k_6 = \lambda_{Wi-Fi_2} \mu_{MNT_2},$$

$$k_7 = \frac{\lambda_{Wi-Fi_1} k_1 + \mu_{Wi-Fi_2} k_2}{\beta k_1 - \mu_{Wi-Fi_2} k_3}, \quad k_8 = \frac{\lambda_{SGR_2}}{\varsigma}, \quad k_9 = \frac{\lambda_{VPN_2}}{\varsigma},$$

$$k_{10} = \frac{\lambda_{VPN_1}}{\eta}, \; k_9 = \frac{\mu_{VPN_2}}{\eta}.$$

In equation (3) the value of probability P_{AVL} corresponds an availability level of the CVS, when the Markovian property is true. However, either way, developers and researchers will be forced to utilize other stochastic distributions in order to describe the cloud's systems behavior accordingly various emerging situations.

We propose to get the solution of a similar task, in the interest of DevOps Engineering considering Non-Markovian distributions of both time to failures and time to repairs of the CVS components. The next stage of the availability assess for CVS is implemented using the SMMPs. Assume that the Semi-Markov Modeling Process is carried out in accordance with a concrete scenario. The Wi-Fi communication known for its quite low reliability, since its available for different intruders. Therefore SMMP can be implemented by us when failure rate of Wi-Fi component increases.

TABLE I. INPUT PARAMETERS MARKOVIAN AND SEMI-MARKOVIAN MODELS OF CLOUD VIDEO SYSTEM

Systems Name	Parameters			
	Failure rate	*Value (1/h)*	*Repair Rate*	*Value (1/h)*
Desktop and Mobile (DSN)	λ_{DSM}	0,0053	μ_{DSM}	2,00
Content Delivery Network Service (CDN)	λ_{CDN}	0,001	μ_{CDN}	1,00
Wi-Fi	λ_{Wi-Fi_1}	0,00016 … 0,00050	μ_{Wi-Fi_1}	0,01 … 0,60
		0,000003… 0,003000		
	λ_{Wi-Fi_2}	0,00008 … 0,00025	μ_{Wi-Fi_2}	0,01 … 0,60
		0,0000015… 0,0015000		
Mobile Network (MNT)	λ_{MNT_1}	0,0001	μ_{MNT_1}	0,60
	λ_{MNT_2}	0,00005	μ_{MNT_2}	0,60
App Service (API)	λ_{APS1}	0,004	μ_{APS1}	0,90
Queue Service (QS)	λ_{QS}	0,0037	μ_{QS}	1,14
Load Balancer (LB)	λ_{LB}	0,0001	μ_{LB}	1,00
SignalR Socket Service (SGR)	λ_{SGR_1}	0,001	μ_{SGR_1}	1,00
	λ_{SGR_2}	0,0005	μ_{SGR_2}	1,00
VPN Gateway	λ_{VPN_1}	0,0005	μ_{VPN_1}	1,00
	λ_{VPN_2}	0,00025	μ_{VPN_2}	1,00
App Service (Calls)	λ_{APS2}	0,004	μ_{APS2}	0,45

The proposed Semi-Markov Availability Model (SMM) is described by using the graph (Fig. 3). According to Fig. 3 the SMM of cloud video system describes set of its states $S = \{0,1,2,...,12\}$, and S_0 – the state of cloud video system availability (up-state), $\forall \; S_i$, $i = 1,2,...,12$ – the states of unavailable CVS (down states) caused by component failures. For comparative analysis, it is proposed to perform modeling of CVS behavior in accordance with a scenario, when failure rate of Wi-Fi is changed into the appropriate range. The SMMP for the cloud video system considering established stochastic distributions was been addressed during the time interval $t \in [0,T]$.

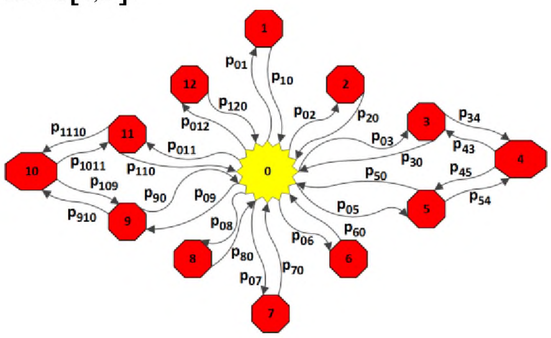

Fig. 3. Finite graph of SMM availability model of the CVS

The transient probabilitiy matrix $P = [p_{ij}]$ is written in accordance with finite graph of the SMM availability model (Fig. 3). Furthermore, the initial distribution $P = [P_i(0) : i \in S]$, $P_0(0) = 1$, $\forall \; P_i(0) = 0$, $i = 1,2,...,12$ and the kernel $Q(t) = [Q_{ij}(t) : i,j \in S]$, $t \geq 0$ [9] are added to the described SMMP.

It would be relevant to get the assessments of probability matrix components, in order to move to the next phase of availability estimation of the CVS. The separate component of the probability matrix for SMMP implementation is given by:

$$p_{ij} = P_{ij}(t) = \int_0^t \prod_{r \neq j} (1 - Q_{ir}(u)) \, dQ_{ij}(u). \qquad (4)$$

Considering the modelling scenario, the authors determined p_{ij} in accordance with the equation (4) based on the use of cumulative distribution function $Q_{ij}(t)$ (CDF), which describes a transition from S_i to S_j [23]. In particular, they leveraged three well-known distributions, such as exponential, Weibull and Erlang distributions [5].

The needed to use equations can written as

$$Q_{ij}(t) = 1 - e^{-\lambda_i t} = Exp(\lambda_i), \qquad (5)$$

$$Q_{03}(t) = 1 - e^{-(\beta t)^{\alpha}} = Weibull(\beta, \alpha), \qquad (6)$$

$$Q_{ji}(t) = 1 - (1 + \mu_j t) e^{-\mu_j t} = Erlang(2, \mu_j), \qquad (7)$$

where λ_i – failure rate for all CVS component except for the Wi-Fi component;

$\lambda_{Wi-Fi} = \alpha\beta(\beta t)^{\alpha - 1}$ – failure rate of Wi-Fi component;

μ_j – repair rate for all CVS components.

Using equations (4)–(7) and some theoretical provisions of SMMPs [5,12,16,23] can be solved the system linear equations in shape $\nu = \nu P$. The solution of this system is

$$\nu_0 = \frac{1}{1 + p_{01} + p_{02} + p_{06} + p_{07} + p_{08} + p_{012} + U_2}, \qquad (8)$$

where

$$U_2 = \rho_3 + \rho_4 + \rho_5 + \rho_9 + \rho_{10} + \rho_{11},$$

$$\rho_3 = p_{03} + w_1 p_{43}, \; \rho_4 = w_1, \; \rho_5 = p_{05} + w_1 p_{45},$$

$$\rho_9 = p_{09} + w_2 p_{109}, \; \rho_{10} = w_2, \; \rho_{11} = p_{011} + w_2 p_{1011},$$

$$w_1 = \frac{p_{03} p_{34} + p_{05} p_{54}}{1 - p_{34} p_{43} - p_{45} p_{54}}, \; w_2 = \frac{p_{03} p_{34} + p_{05} p_{54}}{1 - p_{34} p_{43} - p_{45} p_{54}}.$$

Note that a significant timing parameter for the Semi-Markovian availability assess procedure is a mean sojourn time h_i at i state.

The researchers can estimate this characteristic using a technique depicted in [24]. Then, the equation in order to determine the steady-state availability of CVS for SMMP (Fig. 3) is given by

$$A_{CVS} = \frac{h_0}{h_0 + h_1^* + h_2^*}, \tag{9}$$

where

$$h_1^* = p_{01}h_1 + p_{02}h_2 + p_{06}h_6 + p_{07}h_7 + p_{08}h_8 + p_{012}h_{12},$$

$$h_2^* = \rho_3 h_3 + \rho_4 h_4 + \rho_5 h_5 + \rho_9 h_9 + \rho_{10} h_{10} + \rho_{11} h_{11}.$$

Let us look to assess availability level of the CVS applying equations (2)–(9), which paint behavior of the system considering implementations' features of MMPs and SMMPs.

IV. Numerical Modelling and Assessing CVS Availability

Availability of the CVS has been assessed by means modelling the behavior of system employing RBD, Markovian and Semi-Markovian techniques. Fig. 4 is shown RBD of the CVS. The overall availability of the system is given by

$$A_{CVS} = A_{DSM} \times A_{CDN} \times A_{WM} \times A_{APS1} \times \times A_{QS} \times A_{LB} \times A_{VS} \times A_{APS2}, \tag{11}$$

where

$$A_{WM} = 1-(1-A_{Wi-Fi})(1-A_{MNT}),$$

$$A_{VS} = 1-(1-A_{VPN})(1-A_{SGR}).$$

In equation (11) every component is computed using the formula $\mu_i / (\mu_i + \lambda_i)$, where values μ_i and λ_i are asked according to Table 1.

In this regard, it is recalled that the authors have tried to model the situation in accordance with the scenario above mentioned. The proposed scenario was implemented with as follows: 1) the RBD model (Fig. 4) was being calculated using equations (5) (10), (11); 2) the model based on MMP (Fig. 2) was being calculated using equations (1)–(3), (5); 3) the model based on SMMP (Fig. 3) was being calculated using equations (4)–(9). Note that in order to simplify Semi-Markovian calculations equation (12) instead of equation (4) is utilized. It allowed to conduct the transition from not steady-state to steady-state mode.

Thus, the estimations of components of transient probability matrix for the SMMP implementation are computed by:

$$p_{ij} = P_{ij}(t) = \int_0^{\infty} \prod_{r \neq j} \left(1 - Q_{ir}(u)\right) dQ_{ij}(u). \tag{12}$$

Table 2 is shown overall characteristics for the implemented modelling scenario. Modelling was being conducted in full compliance with the provisions RBD, Markovian and Semi-Markovian methods taking into consideration the characteristics presented in Table 2.

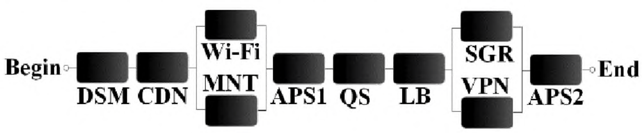

Fig. 4. RBD of the CVS

TABLE II. Overall Characteristics of Implemented Scenario

Title	Input Data for Concrete Models		
	RBD	*MMP*	*SMMP*
CDF	$Exp(\lambda_i)$, $Exp(\mu_i)$	$Exp(\lambda_i)$, $Exp(\mu_i)$	$Exp(\lambda_i)$, $Erlang(2, \mu_j)$, $Weibull(\beta_{Wi-Fi}, 0,5)$, $Weibull(\beta_{Wi-Fi}, 3)$
Finite graphs and schemes	Fig, 4,	Fig. 2	Fig. 3
Calculation formulas	(5), (10), (11)	(1)–(3), (5)	(4)–(9), (12)

Fig. 5 and Fig. 6 are shown availability assessments of the CVS in accordance with the described scenario.

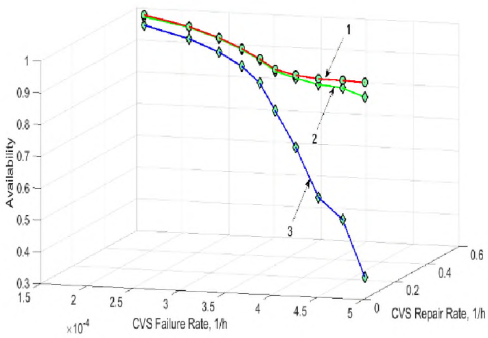

Fig. 5. Availability assessments of the CVS: 1 – for RBD method; 2 – for MMP; 3 – for SMMP with CDF $Weibull(\beta_{Wi-Fi}, 0,5)$

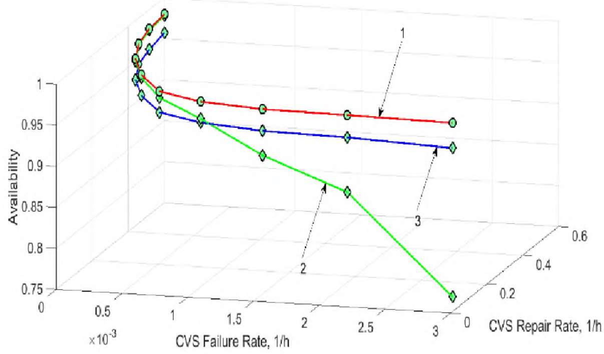

Fig. 6. Availability assessments of the CVS: 1 – for RBD method; 2 – for MMP; 3 – for SMMP with CDF $Weibull(\beta_{Wi-Fi}, 3)$

The presented in Fig. 5 and Fig. 6 numerical modeling results have been the` results ambiguous. Let us try to analyze received results by estimating the following value:

$$\Delta_{CVS} = \left| A_{CVS_i}^{RBD} - A_{CVS_i}^{MMP} \right|, \tag{13}$$

where $A_{CVS_i}^{RBD}$ – actual value of the SSA for RBD method; $A_{CVS_i}^{MMP} \left(A_{CVS_i}^{SMMP} \right)$ – actual value of the SSA for method based on the use of MMP or SMMP.

Table 3 contains the results of SSA computations for two above mentioned methods using the formula (13). These numerical modelling results were received for two values of failure rates $\lambda_{Wi-Fi} = 0,5\beta(\beta t)^{-0,5}$ and $\lambda_{Wi-Fi} = 3\beta(\beta t)^2$.

TABLE III. RESULTS OF COMPUTATIONS OF SSA

Number	Results of Computations using formula (13)	
	RBD–MMP	*RBD–SMMP*
1	0,0018	0,0381
	0,00163	0,0252
2	0,0024	0,0557
	0,0021	0,0252
3	0,0051	0,1297
	0,0077	0,0253
4	0,0181	0,3725
	0,0563	0,0264
5	0,0465	0,6130
	0.2117	0,0306

In accordance with Table 1 the Markovian and Semi-Markovian modelling results are significantly different. Choice of the model is influenced on the assess accuracy. The modelling results that completed in Table 3 prove (as researchers extend to employ non-exponential distributions) the adequacy of availability models is improved. At the same time, modelling results are becoming less optimistic.

V. CONCLUSIONS

In this scientific paper, the authors presented modelling results of the CVS behavior considering a concrete scenario for negative events development that influence on availability of the system. The comparative analysis of the MMPs and SMMPs was performed to assess availability of the CVS. The received modelling results allowed to establish that the SSA availability is varied in range from 0,00163 to 0,6130. This quite wide range of SSA assessment results is derived from the fact that they have been computed using different stochastic distributions. Therefore choice of a model strongly influences on assess accuracy of the CVS availability level. In particular, wrong choice of the model my lead to serious mistakes, which is the developers or researchers can both overestimate and underestimate availability level of the system. These situations create additional risks and open the door to cause great damages. The presented results can be used by both developers and DevOps engineers to ensure effective functioning of the high available CVS. Future research directions can be connected with analysis of cloud multi-version architectures by use of DevOps tools.

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