

Wojciech Zamojski · Jacek Mazurkiewicz  
Jarosław Sugier · Tomasz Walkowiak  
Janusz Kacprzyk *Editors*

Proceedings of the Ninth  
International Conference on  
Dependability and Complex  
Systems DepCoS-RELCOMEX.  
June 30 – July 4, 2014,  
Brunów, Poland

# **Advances in Intelligent Systems and Computing**

Volume 286

*Series editor*

Janusz Kacprzyk, Polish Academy of Sciences, Warsaw, Poland  
e-mail: kacprzyk@ibspan.waw.pl

For further volumes:

<http://www.springer.com/series/11156>

## *About this Series*

The series “Advances in Intelligent Systems and Computing” contains publications on theory, applications, and design methods of Intelligent Systems and Intelligent Computing. Virtually all disciplines such as engineering, natural sciences, computer and information science, ICT, economics, business, e-commerce, environment, healthcare, life science are covered. The list of topics spans all the areas of modern intelligent systems and computing.

The publications within “Advances in Intelligent Systems and Computing” are primarily textbooks and proceedings of important conferences, symposia and congresses. They cover significant recent developments in the field, both of a foundational and applicable character. An important characteristic feature of the series is the short publication time and world-wide distribution. This permits a rapid and broad dissemination of research results.

## *Advisory Board*

### Chairman

Nikhil R. Pal, Indian Statistical Institute, Kolkata, India  
e-mail: [nikhil@isical.ac.in](mailto:nikhil@isical.ac.in)

### Members

Rafael Bello, Universidad Central “Marta Abreu” de Las Villas, Santa Clara, Cuba  
e-mail: [rbellop@uclv.edu.cu](mailto:rbellop@uclv.edu.cu)

Emilio S. Corchado, University of Salamanca, Salamanca, Spain  
e-mail: [escorchado@usal.es](mailto:escorchado@usal.es)

Hani Hagrass, University of Essex, Colchester, UK  
e-mail: [hani@essex.ac.uk](mailto:hani@essex.ac.uk)

László T. Kóczy, Széchenyi István University, Győr, Hungary  
e-mail: [koczy@sze.hu](mailto:koczy@sze.hu)

Vladik Kreinovich, University of Texas at El Paso, El Paso, USA  
e-mail: [vladik@utep.edu](mailto:vladik@utep.edu)

Chin-Teng Lin, National Chiao Tung University, Hsinchu, Taiwan  
e-mail: [ctlm@mail.nctu.edu.tw](mailto:ctlm@mail.nctu.edu.tw)

Jie Lu, University of Technology, Sydney, Australia  
e-mail: [Jie.Lu@uts.edu.au](mailto:Jie.Lu@uts.edu.au)

Patricia Melin, Tijuana Institute of Technology, Tijuana, Mexico  
e-mail: [epmelin@hafsamx.org](mailto:epmelin@hafsamx.org)

Nadia Nedjah, State University of Rio de Janeiro, Rio de Janeiro, Brazil  
e-mail: [nadia@eng.uerj.br](mailto:nadia@eng.uerj.br)

Ngoc Thanh Nguyen, Wroclaw University of Technology, Wroclaw, Poland  
e-mail: [Ngoc-Thanh.Nguyen@pwr.edu.pl](mailto:Ngoc-Thanh.Nguyen@pwr.edu.pl)

Jun Wang, The Chinese University of Hong Kong, Shatin, Hong Kong  
e-mail: [jwang@mae.cuhk.edu.hk](mailto:jwang@mae.cuhk.edu.hk)

Wojciech Zamojski · Jacek Mazurkiewicz  
Jarosław Sugier · Tomasz Walkowiak  
Janusz Kacprzyk  
Editors

Proceedings of the Ninth  
International Conference  
on Dependability and  
Complex Systems  
DepCoS-RELCOMEX.  
June 30 – July 4, 2014,  
Brunów, Poland

### *Editors*

Wojciech Zamojski  
Institute of Computer Engineering, Control  
and Robotics  
Wrocław University of Technology  
Wrocław  
Poland

Tomasz Walkowiak  
Institute of Computer Engineering, Control  
and Robotics  
Wrocław University of Technology  
Wrocław  
Poland

Jacek Mazurkiewicz  
Institute of Computer Engineering, Control  
and Robotics  
Wrocław University of Technology  
Wrocław  
Poland

Janusz Kacprzyk  
Polish Academy of Sciences  
Systems Research Institute  
Warsaw  
Poland

Jarosław Sugier  
Institute of Computer Engineering, Control  
and Robotics  
Wrocław University of Technology  
Wrocław  
Poland

ISSN 2194-5357

ISSN 2194-5365 (electronic)

ISBN 978-3-319-07012-4

ISBN 978-3-319-07013-1 (eBook)

DOI 10.1007/978-3-319-07013-1

Springer Cham Heidelberg New York Dordrecht London

Library of Congress Control Number: 2014939038

© Springer International Publishing Switzerland 2014

This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed. Exempted from this legal reservation are brief excerpts in connection with reviews or scholarly analysis or material supplied specifically for the purpose of being entered and executed on a computer system, for exclusive use by the purchaser of the work. Duplication of this publication or parts thereof is permitted only under the provisions of the Copyright Law of the Publisher's location, in its current version, and permission for use must always be obtained from Springer. Permissions for use may be obtained through RightsLink at the Copyright Clearance Center. Violations are liable to prosecution under the respective Copyright Law.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

While the advice and information in this book are believed to be true and accurate at the date of publication, neither the authors nor the editors nor the publisher can accept any legal responsibility for any errors or omissions that may be made. The publisher makes no warranty, express or implied, with respect to the material contained herein.

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

# Preface

We are pleased to present the proceedings of the Ninth International Conference on Dependability and Complex Systems DepCoS-RELCOMEX, which took place in a beautiful Brunów Palace, Poland, from 30<sup>th</sup> June to 4<sup>th</sup> July, 2014.

Started in 2006, DepCoS – RELCOMEX is a conference organized annually by the Institute of Computer Engineering, Control and Robotics (CECR) from Wrocław University of Technology. Its roots go nearly 40 years back to the heritage of the other two cycles of events: RELCOMEX (1977 – 89) and Microcomputer Schools (1985 – 95) which were organized by the Institute of Engineering Cybernetics (the previous name of CECR) under the leadership of prof. Wojciech Zamojski, now also the DepCoS chairman. In this volume of “Advances in Intelligent and Soft Computing” we would like to present results of research on selected problems of complex systems and their dependability. Effects of the previous DepCoS events were published in volumes 97, 170 and 224 of this series.

Today’s complex systems are integrated unities of technical, information, organization, software and human (users, administrators and management) resources. Complexity of such systems comes not only from their involved technical and organizational structures built on hardware and software resources but mainly from complexity of information processes (processing, monitoring, management, etc.) realized in their specific environment. In operation of such wide-ranging and diverse systems their resources are dynamically allocated to ongoing tasks and the rhythm of system events (incoming and/or ongoing tasks, decisions of a management subsystem, system faults, “defense” system reactions, etc.) may be considered as deterministic or/and probabilistic event stream. Security and confidentiality of information processing introduce further complications into the modelling and evaluation methods. Diversity of the processes being realized, their concurrency and their reliance on in-system intelligence often significantly impedes construction of strict mathematical models and calls for application of intelligent and soft computing methods.

Dependability is the modern approach to reliability problems of contemporary complex systems. It is worth to underline the difference between the two terms: system dependability and system reliability. Dependability of systems, especially

computer systems and networks, is based on multi-disciplinary approach to theory, technology, and maintenance of the systems working in a real (and very often unfriendly) environment. Dependability concentrates on efficient realization of tasks, services and jobs by a system considered as a unity of technical, information and human assets, while “classical” reliability is more restrained to analysis of technical system resources (components and structures built from them).

Presenting our conference proceedings to the broader audience we would like to express the sincerest thanks to all the authors who have chosen to describe their research here. It is our hope that the communicated results will help in further developments in complex systems design and analysis aimed at improving their dependability. We believe that the selected contributions will be interesting to all scientists, researchers, practitioners and students who work in these fields of science.

Concluding this brief introduction we must emphasize the role of all reviewers who took part in the evaluation process and whose contribution helped to refine the contents of this volume. Our thanks go to, in alphabetic order, Salem Abdel-Badeeh, Andrzej Białas, Frank Coolen, Manuel Gil Perez, Zbigniew Huzar, Jacek Jarnicki, Vyacheslav Kharchenko, Mieczysław M. Kokar, Alexey Lastovetsky, Marek Litwin, Jan Magott, István Majzik, Jacek Mazurkiewicz, Katarzyna M. Nowak, Yiannis Papadopoulos, Oksana Pomorova, Krzysztof Sacha, Ruslan Smeliansky, Janusz Sosnowski, Jarosław Sugier, Victor Toporkov, Carsten Trinitis, Tomasz Walkowiak, Max Walter, Bernd E. Wolfinger, Marina Yashina, Irina Yatskiv, Wojciech Zamojski, and Włodzimierz Zuberek.

The Editors

# Ninth International Conference on Dependability and Complex Systems DepCoS-RELCOMEX

organized by

Institute of Computer Engineering, Control and Robotics,  
Wrocław University of Technology  
under the auspices of prof. Tadeusz Więckowski, Rector

**Brunów Palace, Poland, June 30 – July 4, 2014**

## Programme Committee

Wojciech Zamojski (Chairman)	Wrocław University of Technology, Poland
Salem Abdel-Badeeh	Ain Shams University Abbasia, Cairo, Egypt
Ali Al-Dahoud	Al-Zaytoonah University, Amman, Jordan
George Anders	University of Toronto, Canada
Artem Adzhemov	Technical University of Communications and Informatics, Moscow, Russia
Włodzimierz M. Barański	Wrocław University of Technology, Poland
Andrzej Białas	Institute of Innovative Technologies EMAG, Katowice, Poland
Dariusz Caban	Wrocław University of Technology, Poland
Krzysztof Cios	Virginia Commonwealth University, Richmond, USA
Frank Coolen	Durham University, UK
Antonio Ferrari	University of Aveiro, Portugal
Francesco Flammini	University of Naples “Federico II”, Napoli, Italy
Manuel Gill Perez	University of Murcia, Spain
Janusz Górski	Gdansk University of Technology, Poland
Zbigniew Huzar	Wrocław University of Technology, Poland
Igor Kabashkin	Transport and Telecommunication Institute, Riga, Latvia
Janusz Kacprzyk	Polish Academy of Sciences, Warsaw, Poland
Andrzej Kasprzak	Wrocław University of Technology, Poland
Vyacheslav S. Kharchenko	National Aerospace University “KhAI”, Kharkov, Ukraine
Mieczysław M. Kokar	Northeastern University, Boston, USA
Krzysztof Kołowrocki	Gdynia Maritime University, Poland
Leszek Kotulski	AGH University of Science and Technology, Krakow, Poland
Henryk Krawczyk	Gdansk University of Technology, Poland



Alexey Lastovetsky	University College Dublin, Ireland
Marek Litwin	ITS Polska, Warsaw, Poland
Jan Magott	Wrocław University of Technology, Poland
Istvan Majzik	Budapest University of Technology and Economics, Hungary
Jacek Mazurkiewicz	Wrocław University of Technology, Poland
Katarzyna M. Nowak	Objectivity Bespoke Software Specialists Sp. z o.o., Wrocław, Poland
Yiannis Papadopoulos	Hull University, UK
Oksana Pomorova	Khmeltsky National University, Ukraine
Ewaryst Rafajłowicz	Wrocław University of Technology, Poland
Nikolay Rogalev	Moscow Power Engineering Institute (Technical University), Russia
Krzysztof Sacha	Warsaw University of Technology, Poland
Mirosław Siergiejczyk	Warsaw University of Technology, Poland
Ruslan Smeliansky	Moscow State University, Russia
Czesław Smutnicki	Wrocław University of Technology, Poland
Janusz Sosnowski	Warsaw University of Technology, Poland
Jarosław Sugier	Wrocław University of Technology, Poland
Ryszard Tadeusiewicz	AGH University of Science and Technology, Krakow, Poland
Victor Toporkov	Moscow Power Engineering Institute (Technical University), Russia
Casten Trinitis	Technische Universität München, Germany
Tomasz Walkowiak	Wrocław University of Technology, Poland
Max Walter	Siemens, Germany
Bernd E. Wolfinger	University of Hamburg, Germany
Marina Yashina	Moscow Technical University of Communication and Informatics, Russia
Irina Yatskiv	Transport and Telecommunication Institute, Riga, Latvia
Jan Zarzycki	Wrocław University of Technology, Poland
Włodzimierz Zuberek	Memorial University, St. John's, Canada

## Organizing Committee

Wojciech Zamojski (Chairman)  
Włodzimierz M. Barański  
Monika Bobnis  
Jacek Mazurkiewicz  
Jarosław Sugier  
Tomasz Walkowiak

# Contents

<b>Framework for the Distributed Computing of the Application Components</b> .....	1
<i>Razvan-Mihai Aciu, Horia Ciocarlie</i>	
<b>Analysis of Statistical Characteristics of User Arrival Process to the Testing Service</b> .....	13
<i>Artem Adzhemov, Nikolay Albov, Irina Sineva</i>	
<b>The Role of Enterprise Social Networking (ESN) on Business: Five Effective Recommendations for ESN</b> .....	23
<i>Saeed M. Alqahtani, Sultan Alanazi, Derek McAuley</i>	
<b>Dependability and Safety Analysis of ETCS Communication for ERTMS Level 3 Using Performance Statecharts and Analytic Estimation</b> .....	37
<i>Tomasz Babczyński, Jan Magott</i>	
<b>Entropy-Based Internet Traffic Anomaly Detection: A Case Study</b> .....	47
<i>Przemysław Bereziński, Józef Pawelec, Marek Małowidzki, Rafał Piotrowski</i>	
<b>A Formal Approach for Preventive Maintenance Workload Balancing</b> .....	59
<i>Ammar Bessam</i>	
<b>Computer Support for the Railway Safety Management System – Requirements Analysis</b> .....	69
<i>Andrzej Białas</i>	
<b>Computer Support for the Railway Safety Management System – First Validation Results</b> .....	81
<i>Andrzej Białas</i>	

<b>Reductions of Operators in Java Mutation Testing</b> .....	93
<i>Ilona Bluemke, Karol Kulesza</i>	
<b>An Approach for Planning and Analysis of the Sewage Sanitary Networks Using Some Calculation Formulas and Computer Simulation</b> .....	103
<i>Lucyna Bogdan, Grażyna Petriczek, Jan Studziński</i>	
<b>Mathematical Model of Task Scheduling in Educational Cloud</b> .....	115
<i>Agata Brzozowska, Jerzy Greblicki</i>	
<b>Optimization and Control of Transport Processes in the Distributed Systems</b> .....	123
<i>Alexander Buslaev, Mikhail Volkov</i>	
<b>On Some Resources Placement Schemes in the 4-Dimensional Soft Degradable Hypercube Processors Network</b> .....	133
<i>Jan Chudzikiewicz, Zbigniew Zieliński</i>	
<b>Efficient Training of Context-Dependent Neural Nets with Conjugate Gradient Algorithms</b> .....	145
<i>Piotr Ciskowski</i>	
<b>Analysis of Mutation Operators for the Python Language</b> .....	155
<i>Anna Derezińska, Konrad Hałas</i>	
<b>Deterministic Schedule of Task in Multiprocessor Computer Systems with Higher Degree of Dependability</b> .....	165
<i>Mieczysław Drabowski, Edward Wantuch</i>	
<b>Using Simulation to Evaluate Dynamic Systems with Weibull or Lognormal Distributions</b> .....	177
<i>Ernest Edifor, Neil Gordon, Martin Walker, Yiannis Papadopoulos</i>	
<b>FSM Simulation of Cryptographic Protocols Using Algebraic Processor</b> .....	189
<i>Alexander Frolov, Alexander Vinnikov</i>	
<b>Disturbance Injection in Dependability Assessment of Android Applications</b> .....	199
<i>Piotr Gawkowski, Maciej Sulek</i>	
<b>Approximate Algorithm for Fast Capacity Provisioning in WANs with Trade-Off between Performance and Cost under Budget Constraint</b> .....	211
<i>Mariusz Gola, Adam Czubak</i>	

<b>Evolution of Software Quality Models in Context of the Standard ISO 25010</b> .....	223
<i>Oleksandr Gordienko, Vyacheslav Kharchenko, Nataliia Fominykh, Vladimir Sklyar</i>	
<b>Model Checking of UML Activity Diagrams in Logic Controllers Design</b> .....	233
<i>Iwona Grobelna, Michał Grobelny, Marian Adamski</i>	
<b>Impact of Selected Java Idioms on Source Code Maintainability – Empirical Study</b> .....	243
<i>Bogumiła Hnatkowska, Anna Jaszczyk</i>	
<b>Quantification of Temporal Fault Trees Based on Fuzzy Set Theory</b> .....	255
<i>Sohag Kabir, Ernest Edifor, Martin Walker, Neil Gordon</i>	
<b>Analysis of Physical Layer Model of WLAN 802.11g Data Transmission Protocol in Wireless Networks Used by Telematic Systems</b> .....	265
<i>Zbigniew Kasprzyk, Mariusz Rychlicki</i>	
<b>Web Systems Availability Assessment Considering Attacks on Service Configuration Vulnerabilities</b> .....	275
<i>Vyacheslav Kharchenko, Alaa Mohammed Abdul-Hadi, Artem Boyarchuk, Yuriy Ponochozny</i>	
<b>A Recommender System Based on Content Clustering Used to Propose Forum Articles</b> .....	285
<i>Urszula Kuźlewska, Ewa Guziejko</i>	
<b>Simple Measure of Network Reliability Using the Variance of the Degree Distribution</b> .....	293
<i>Ho Tat Lam, Kwok Yip Szeto</i>	
<b>CDM: A Prototype Implementation of the Data Mining JDM Standard</b> .....	303
<i>Piotr Lasek</i>	
<b>Confidential Transportation of Data on the Technical State of Facilities</b> .....	313
<i>Dariusz Laskowski, Piotr Lubkowski</i>	
<b>Test of the Multimedia Services Implementation in Information and Communication Networks</b> .....	325
<i>Piotr Lubkowski, Dariusz Laskowski</i>	
<b>Unified Approach to Network Systems Multicriterial Analysis</b> ...	333
<i>Jacek Mazurkiewicz</i>	

<b>A Comparison of Forecasting Methods for Ro-Ro Traffic: A Case Study in the Strait of Gibraltar</b> .....	345
<i>José Antonio Moscoso López, J.J. Ruiz-Aguilar, I. Turias, M. Cerbán, M.J. Jiménez-Come</i>	
<b>Partial Blur: Model, Detection, Deblurring</b> .....	355
<i>Dmytro Peleshko, Mariya Rashkevych, Andriy Klyuvak, Yuriy Ivanov</i>	
<b>Software Support for Common Criteria Security Development Process on the Example of a Data Diode</b> .....	363
<i>Dariusz Rogowski</i>	
<b>Increasing Performance of SMS Based Information Systems</b> ....	373
<i>Mariusz Rychlicki, Zbigniew Kasprzyk</i>	
<b>Internet-Based Production Monitoring and Reporting</b> .....	383
<i>Krzysztof Sacha, Wojciech Pikulski</i>	
<b>Reliability Analysis of a Two-Stage Goel-Okumoto and Yamada S-shaped Model</b> .....	393
<i>Ioannis G. Sideratos, Agapios N. Platis, Vasilis P. Koutras, Nicholas Ampazis</i>	
<b>Reliability Assessment of Cooperation and Replacement of Surveillance Systems in Air Traffic</b> .....	403
<i>Miroslaw Siegiejczyk, Karolina Krzykowska, Adam Rosiński</i>	
<b>Swarm Intelligence Metaheuristics Application in the Diagnosis of Transformer Oil</b> .....	413
<i>Anis Smara, M'hana Bouktit, Ahmed Boubakeur</i>	
<b>Performance Aspect of SaaS Application Based on Tenant-Based Allocation Model in a Public Cloud</b> .....	423
<i>Wojciech Stolarz, Marek Woda</i>	
<b>Low Cost FPGA Devices in High Speed Implementations of Keccak-f Hash Algorithm</b> .....	433
<i>Jarosław Sugier</i>	
<b>Distributed Time Management in Wireless Sensor Networks</b> ....	443
<i>Tomasz Surmacz, Bartosz Wojciechowski, Maciej Nikodem, Mariusz Ślabicki</i>	
<b>Heuristic Cycle-Based Scheduling with Backfilling for Large-Scale Distributed Environments</b> .....	455
<i>Victor Toporkov, Anna Toporkova, Alexey Tselishchev, Dmitry Yemelyanov, Petr Potekhin</i>	

<b>Behavior of Web Servers in Stress Tests</b> .....	467
<i>Tomasz Walkowiak</i>	
<b>The Impact of Reconfiguration Time on the Dependability of Complex Web Based Systems</b> .....	477
<i>Tomasz Walkowiak, Dariusz Caban</i>	
<b>Propagation Losses in Urban Areas</b> .....	489
<i>Marian Wnuk, Leszek Nowosielski</i>	
<b>Web Service for Data Extraction from Semi-structured Data Sources</b> .....	499
<i>Marina V. Yashina, Ivan I. Nakonechnyy</i>	
<b>Investigation of System Reliability Depending on Some System Components States</b> .....	511
<i>Elena Zaitseva, Vitaly Levashenko, Miroslav Kvassay</i>	
<b>Model Fusion for the Compatibility Verification of Software Components</b> .....	521
<i>W.M. Zuberek</i>	
 <b>Erratum</b>	
<b>CDM: A Prototype Implementation of the Data Mining JDM Standard</b> .....	E1
<i>Piotr Lasek</i>	
<b>Author Index</b> .....	531

# Web Systems Availability Assessment Considering Attacks on Service Configuration Vulnerabilities

Vyacheslav Kharchenko<sup>1,2</sup>, Alaa Mohammed Abdul-Hadi<sup>1</sup>, Artem Boyarchuk<sup>1</sup>,  
and Yuriy Ponochovny<sup>3</sup>

<sup>1</sup> National Aerospace University KhAI, Kharkiv, Ukraine

<sup>2</sup> Centre of Safety Infrastructure-Oriented Research and Analysis, Kharkiv, Ukraine  
V.Kharchenko@khai.edu

<sup>3</sup> Poltava National Technical University named after Yuriy Kondratyuk, Poltava, Ukraine  
pnch1@rambler.ru

**Abstract.** The paper examines the issues of web systems assessment availability. It is defined that unavailability of web services may be caused by internal and external factors in particular server side vulnerability attacks. Three Markov's models of web system availability are developed; these models consider influence of software defects and vulnerability attacks for DNS, DHCP and Route services. Elimination of configuration vulnerabilities during system operation is considered. Conclusions about the impact of the probability of detection and elimination of vulnerabilities and the recovery rate on the web systems availability function are proposed.

**Keywords:** web system availability, Markov's models, attacks on vulnerability services.

## 1 Introduction

The successful beginning and operation of web systems is only possible in case of payback on their functioning and positive profit earning. The break-even point is reached after the start of system exploitation, and it might not be achieved at all if risk assessment was wrong. This leads to the importance of modeling the functioning of web systems based on actual cyber security risks [1-3].

Nowadays, most web services experienced the attacks of various kinds. With regard to commercial Web services, they certainly are the most attractive target for attacks [1, 4]. In such circumstances, modeling of web attacks as events that lead to their inaccessibility is in high demand. However, today the majority of the models of attacks, threats and incidents have probabilistic nature of risk assessment. Only some sources refer to the possibility of web system modeling using semi-Markov processes and Petri nets [5].

The modern web system is a complex multileveled and distributed system. It can be presented by the charts with various hierarchy levels. This paper discusses the three-component reliability block diagram of the web system (RBD). It describes the interaction of basic services: IP-address assignment (DHCP), IP routing (Route) and support the direct and inverse transformation of text URLs to IP-addresses (DNS).

This decision is due to the fact that vulnerability subsets of mentioned services might be distinguished in line with CVE classifiers [6,7]. This allows getting estimates of the intensity of attacks and their criticality [8].

Unavailability of any of these services entails the refusal in customer service. On this basis, the RBD will include three consecutive elements, each of which corresponds the up-states of three services (fig.1).



**Fig. 1.** Reliability block diagram of web system

While assessing web systems availability the focus is given on Markov's models based on hardware and software failures (caused by physical and design faults correspondingly) and recoveries [9, 10]. Researches [11, 12] analyze the concept of an integrated approach of dependability as a property which combine in particular reliability, availability and information security. In [13] the possibility of the development of mathematical models that consider the unavailability of web systems in context security is proposed. Unavailability is caused by not only by software faults, but by attacks on their components as well.

The objective of this paper is to develop Markov models of web systems availability considering attacks, and to investigate the impact of input parameters of the model to the availability function. First of all, we research behavior of web systems in non-stationary modes taking into account various kinds of attacks and recovery procedures. The paper is structured as follows: the second section describes the simple Markov models of web-services without attacks (MA1) and with mechanism for restart after attack (MA2). The third section describes the MA3 model used for assessment of web-service availability considering consequent fixing of vulnerabilities after attacks. Verification results and case study of developed models are presented in the fourth and fifth sections. The last section includes the conclusions and directions of future work.

## 2 Availability Models of Web Systems without Attacks and with System Restart after Attack

### 2.1 Model MA1

We consider an ideal web system model without attacks as a basic model in which there are processes of software failures and recoveries of related network services (MA1). Resulting characteristics of such model often are used by hosting providers as the availability and uptime rate of hosting platforms.

Marked graph of states and transitions of such model is shown at the fig.2,a. It includes initial up-state  $S_0$  and down-states  $S_1$ ,  $S_2$  and  $S_3$ . The transitions into down-states are marked with the corresponding failure rates ( $\lambda_{dns}$ ,  $\lambda_{dhcp}$  and  $\lambda_{route}$ ). System returns into up-state after service recovery with corresponding rates  $\mu_{dns}$ ,  $\mu_{dhcp}$  and  $\mu_{route}$ .



# Author Index

- Abdul-Hadi, Alaa Mohammed 275  
Aciu, Razvan-Mihai 1  
Adamski, Marian 233  
Adzhemov, Artem 13  
Alanazi, Sultan 23  
Albov, Nikolay 13  
Alqahtani, Saeed M. 23  
Ampazis, Nicholas 393
- Babczyński, Tomasz 37  
Bereziński, Przemysław 47  
Bessam, Ammar 59  
Białas, Andrzej 69, 81  
Bluemke, Ilona 93  
Bogdan, Lucyna 103  
Boubakeur, Ahmed 413  
Bouktit, M'hana 413  
Boyarchuk, Artem 275  
Brzozowska, Agata 115  
Buslaev, Alexander 123
- Caban, Dariusz 477  
Cerbán, M. 345  
Chudzikiewicz, Jan 133  
Ciocarlie, Horia 1  
Ciskowski, Piotr 145  
Czubak, Adam 211
- Derezińska, Anna 155  
Drabowski, Mieczysław 165
- Edifor, Ernest 177, 255
- Fominykh, Nataliia 223  
Frolov, Alexander 189
- Gawkowski, Piotr 199  
Gola, Mariusz 211  
Gordieiev, Oleksandr 223  
Gordon, Neil 177, 255  
Greblicki, Jerzy 115  
Grobelna, Iwona 233  
Grobelny, Michał 233  
Guziejko, Ewa 285
- Hałas, Konrad 155  
Hnatkowska, Bogumiła 243
- Ivanov, Yuriy 355
- Jaszczak, Anna 243  
Jiménez-Come, M.J. 345
- Kabir, Sohag 255  
Kasprzyk, Zbigniew 265, 373  
Kharchenko, Vyacheslav 223, 275  
Klyuvak, Andriy 355  
Koutras, Vasilis P. 393  
Krzykowska, Karolina 403  
Kulesza, Karol 93  
Kuźelewska, Urszula 285  
Kvassay, Miroslav 511
- Lam, Ho Tat 293  
Lasek, Piotr 303  
Laskowski, Dariusz 313, 325  
Levashenko, Vitaly 511  
López, José Antonio Moscoso 345  
Lubkowski, Piotr 313, 325

Magott, Jan 37  
 Małowidzki, Marek 47  
 Mazurkiewicz, Jacek 333  
 McAuley, Derek 23

Nakonechnyy, Ivan I. 499  
 Nikodem, Maciej 443  
 Nowosielski, Leszek 489

Papadopoulos, Yiannis 177  
 Pawelec, Józef 47  
 Peleshko, Dmytro 355  
 Petriczek, Grażyna 103  
 Pikulski, Wojciech 383  
 Piotrowski, Rafał 47  
 Platis, Agapios N. 393  
 Ponochovny, Yuriy 275  
 Potekhin, Petr 455

Rashkevych, Mariya 355  
 Rogowski, Dariusz 363  
 Rosiński, Adam 403  
 Ruiz-Aguilar, J.J. 345  
 Rychlicki, Mariusz 265, 373

Sacha, Krzysztof 383  
 Sideratos, Ioannis G. 393  
 Siergiejczyk, Mirosław 403  
 Sineva, Irina 13  
 Sklyar, Vladimir 223

Ślabicki, Mariusz 443  
 Smara, Anis 413  
 Stolarz, Wojciech 423  
 Studziński, Jan 103  
 Sugier, Jarosław 433  
 Sułek, Maciej 199  
 Surmacz, Tomasz 443  
 Szeto, Kwok Yip 293

Toporkov, Victor 455  
 Toporkova, Anna 455  
 Tselishchev, Alexey 455  
 Turias, I. 345

Vinnikov, Alexander 189  
 Volkov, Mikhail 123

Walker, Martin 177, 255  
 Walkowiak, Tomasz 467, 477  
 Wantuch, Edward 165  
 Wnuk, Marian 489  
 Woda, Marek 423  
 Wojciechowski, Bartosz 443

Yashina, Marina V. 499  
 Yemelyanov, Dmitry 455

Zaitseva, Elena 511  
 Zieliński, Zbigniew 133  
 Zuberek, W.M. 521