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A SURVEY ON AVAILABILITY CALCULATION AND DEFINITION FOR INFORMATION TECHNOLOGY SERVICES

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Abstract

Nowadays companies outsource a lot of their IT resources and capabilities by contracting them with external IT providers. The agreements between providers and customers concerning different quality aspects of the contracted services such as availability, maintainability, security and continuity are formalized through Server Level Agreements (SLAs). One of the most important quality aspects and, at the same time, most difficult to agree is the availability level to be reached. Indeed, the process, methods and types of inputs used by providers and customers to calculate this level are still very informal and in many cases the resulting availability target is not suited to the customer requirements and the provider capabilities. In this boarder, this work presents a survey aimed at identifying and analysing the research literature to analyse what are the most used inputs and methods for availability calculation and prediction as wells as to analyse their applicability in the industry.

Keywords: Service Level Agreement, SLA, Availability, Definition, Literature Review.

1 INTRODUCTION

Over the past decade there has been an increasing tendency for outsourcing of IT services. Thus companies' IT resources and capabilities are being contracted to external IT providers following a service orientation. By using this approach, Service Level Agreements (SLAs) are very important tools for defining responsibilities of providers and consumers. The Service Level Targets (SLTs), documented into the SLAs, constitute an agreement between providers and consumers in reference to different quality aspects of the service such as availability, maintainability, security and continuity. SLTs are defined through negotiation on Service Level Requirements (SLRs) between the two parts.

Even though the availability is the most crucial quality aspect to IT service customers (Franke et al., 2014), it is at the same time one of the most difficult to be defined. Indeed, the measurement used to agree the SLT related to availability is commonly defined in terms of a percentage to be reached by the provider. One important characteristic of IT service availability is that it does not only depend on the service infrastructure (software, hardware, network, etc). Indeed, an IT service is a complex and abstract concept that involves IT, processes and people. In this way there are important organizational elements apart from infrastructure that providers and customer need to consider when defining availability SLTs. For instance, the availability of an IT service in case of fail depends on the reactivity mechanisms of the IT organization to resolve incidents. These mechanisms may include processes such as incident management and resources such as management tools and people.

Despite the importance of availability and the complexity of its definition, process, methods and types of inputs used by providers and customers to calculate or defining the availability SLTs are still very informal. In fact, as inputs they use mainly the history of reached service levels (when it exists) as well as the SLTs documented in existing underpinning contracts (UCs) with third parties and Operating Level Agreements (OLAs) between internal IT areas from which the service availability depends. As calculation method the main one used is the expert judgment. The lack of a formal definition of inputs and methods is leading to erroneous definitions of availability SLTs what in turn leads to fail in meeting customer service requirements because they were defined below the optimal level or incur in expensive and unnecessary acquisitions of IT resources and capabilities because they were defined above the optimal level.

In this boarder, our main objective is to carry out a systematic review of the literature in order to identify and analyse the main methods that could help practitioners to define optimal availability SLTs as well as to evaluate their applicability to the industry. In addition, we consider in the review the research works addressing reliability prediction as it measures how long an IT service or system can perform its agreed function without interruption and therefore availability directly depends on it.

This paper is organized as follows: Section 2 presents the related work in terms of previous surveys, Section 3 describes the method used in the literature review process and its results and finally Section 4 presents the discussion and concludes the paper.

2 RELATED WORKS

Although literature reviews on availability and reliability prediction already exist (Bosse et al., 2014; Immonen & Niemelä, 2008; Goševa-Popstojanova & Trivedi, 2003), they only present the description of different approaches and do not analyse the aspects previously mentioned.

Bosse et al., (2014) performed a literature review in the area of IT service availability prediction, specifically in the design phase of a service. The authors evidenced that the area is growing their publications numbers and the works were published with the following distribution: Conference (22%), Book (23%) Journal (35%) and Symposium (19%). The authors concluded about the analysis that the field of IT Service Availability prediction is still heavily discussed and current research still lacks of approaches approved by scientists and practitioners.

Goševa-Popstojanova and Trivedi (2003) made a survey to identify the common approaches that address the quantification of the software reliability based on black-box models. The authors give an overview about quantitative methods to assess the reliability of software systems based on architecture-based approaches. They distinguish state-based, path-based and additive approaches and present examples from literature for each category. State-based approaches model all possible states of the system. Path-based approaches focus on execution paths. Additive models consider the system reliability as a random variable and try to map it to stochastic processes.

Immonen and Niemelä, (2008) provide a survey of reliability and availability prediction methods in Software Architecture. They develop a framework to compare different methods. The framework includes criteria from the context, the users, the contents and the validation of the models. The Context is related with the goal, the scope of applicability, the architecture specificity, the platform implementation technology independency, the component specificity and the application domain independency. The Users are related to the target group, the expected benefits, the needed skills and the required resources. The Contents are associated to the language, the analysis model, the system usage, the variability, the tool support, the analysis process, the limitations and the architectural viewpoints. Finally, the Validation relates the maturity of the method, the precision of the prediction and the traceability of R&A requirements. With these criteria six different works were compared. According to the authors the most common shortcomings were a lack of support for tools and variability, weak reliability analysis of software components, and weak validation of the methods and their results. The final conclusion of the paper is that none of the investigated methods satisfies all defined criteria.

3 SURVEY METHOD AND RESULTS

The structured literature review process consists of four steps: *Planning, Conducting and Material Collection, Summarizing and Reporting* (Bosse et al., 2014; Seuring & Müller, 2008). The *Planning* consist in the definition of the criteria to conduct the search and validate the selected works. It aims to identify the relevant contributions in the research fields. The *Conducting and Material Collection* step is related to perform a comprehensive, exhaustive search for primary approaches by using the criteria previously defined as well as validation and assessment of found approaches with respect to the research questions. In this phase the formal aspects of the identified papers are analysed in order to characterize the result set. In order to evaluate the material content related categories are identified and selected in this step. The *Summarizing* is related with extract for each selected work the most relevant information to answer the research questions. Finally, the *Reporting* phase present a synthesis of the answers for the research questions and a review analysis and interpretation of the material.

3.1 Planning

The review goal is to find out the main elements used in the research literature to define the availability of IT services**.** The availability of IT services does not only depend on the IT infrastructure. In fact, it also depends on other IT resources and capabilities such as IT processes and teams. Thus the review concentrates on approaches related to IT processes, IT capabilities, IT infrastructures and Computer Systems. To perform the review three evaluation elements are defined: (1) Context, related with the domain, goal and scope of the approach. (2) Method, related with the necessary inputs, the techniques used to calculate availability and reliability and the output of the solution. (3) Application, related to usability of the approach which can give us hints about its potential applicability in the industry. Each element contains criteria that answer a review question. The revaluation element and criteria are presented in Table 1.

Category	Criteria	Question
Context	Domain	What is the main area of the work?
	Goal	What is the goal of the approach?
	Scope	What applications have the approach?

Method	Input	What are the inputs needed to perform the prediction?
	Technique	What are the methods and techniques used in the solution?
	Output	What are the solution's output and metrics?
Application	Tools	Are there any tools that support the method?
	Precision of prediction	How close are the predicted values to the actual values when the method has been used?
	Limitations	What are the assumptions and limitations when using the method?

Table 1. Categories, criteria and questions to resolve with the survey.

3.2 Conducting and Material Collection

In order to search for primary approaches, we use the Scopus Database by introducing the following criteria:

- ***Searching terms:*** (Availability or Reliability) and (Software or Information Technology or IT or System or IT processes or IT capabilities) and (Prediction or Estimation or Forecast).
- ***Search area:*** Computer Science.
- ***Document type:*** Conference paper or Journal paper.
- ***Search field type:*** abstract, title and keywords.
- ***Language:*** English.

Given these criteria, the Scopus searching engine gave as a result of 2249 candidate articles. To limit the number of papers to be included in the review, firstly, we limited the articles by reading the title and keywords. This filter reduced the number of works to 140. Then we read the abstract of the works to filter those ones that do not have hint to answer the review questions. This filter limited the number of work to 16. Finally, a full reading of the paper was performed to select the final set of works. A group of 9 papers were identified and included in this review. In this set of papers, a relevant survey on Availability was included.

3.3 Summarizing

In this phase, data was identified, extracted and summarized for selected approaches. A description and classification of them is given below.

According to Benlarbi (2006) there are two modelling approaches to evaluate networking systems availability: discrete-event simulation and analytical modelling. A discrete-event simulation model dynamically mimics detailed system behaviour to evaluate specific measures such as rerouting delays or resources utilization. An analytical modelling uses a set of mathematical equations to describe the system behaviour. The measures, e.g. the system availability, reliability and Mean Time Between Failure (MTBF), are obtained from solving these equations. The author proposes to represent the two modelling approaches by using the Reliability Block Diagram (RBD) in conjunction with a Markov Chain. In this work, each node of the network represents a state of the Markov Chain, and the availability prediction is performed by the estimation of possible change state of the Node using the RBD Logic.

According to Rahman et al. (2010), exploiting the unused resources in the enterprise Grid environments across the Internet can deliver massive computer power to investigate complex problems in different scientific fields (biology, physics, astronomy, business intelligence, etc.). Thus, the prediction of a machine availability in an enterprise Grid (that goes until it restarts) is useful to perform an effective resource allocation and application scheduling. To this end, the authors propose a Jaccard Index based prediction approach in conjunction with a lazy learning algorithm that dynamically searches for a best match of a sequence pattern in the historical or training data to predict the availability. To test the approach, the author used two datasets: (i) Microsoft Corporate Network (51.662 Pc's) and (ii) PlanetLab (321 nodes). They used two week of the traces as training data and evaluate the prediction for the following three weeks. They compare the accuracy with two existing predictive algorithms (K-NN and Naive Bayes) obtaining an improvement of 0.0265 and 0.2248 respectively.

Toktam and Deldari (2010) propose two prediction systems for task execution availability of resources in desktop grid platform by using binary data of availability (available and unavailable).The first system is based on cellular automats that consist of a set of cells that interact between them. The state of each cell represent a resource availability and it is updated in discrete time depending on its current state and the neighbours' states by using the Von Neumann neighbourhood. The second system is based on Bayesian networks that use a feature vector of four characteristics: (i) the hour of the day and (ii, iii and iv) the availability history of the resource in the last three time steps. The accuracy of proposed prediction systems were evaluated in four real desktop grids. The comparison between the two prediction systems indicates that cellular automata have a better behaviour than Bayesian network.

Rodrigues et al. (2005) propose to calculate the prediction of software system reliability by adding two attributes to software systems functional scenarios (Uchitel et al., 2004). These attributes are: (i) the probability of component failure, and (ii) the probability of transition between scenarios from an operational profile of the system which consists in a quantitative representation of how the system will be used. The extended scenario specification is then combined with probabilistic behaviour models for each component to represent the reliability of a component. Specifically, the model uses the relative frequency of the failure probability resulted from system usage and the transition probability from one scenario to another. Finally, the authors use the Cheung model for software reliability to compute a reliability prediction from the system behaviour model.

Gokhale and Trivedi (2006) propose a unified framework to synthesize state-based approaches that calculate independently the reliability of software components in order to predict the whole reliability of a software. This framework uses as inputs: (i) a method of solution (Hierarchical or Composite), (ii) the system architectural model and (iii) the system failure model. From the inputs the framework relies on a classification scheme of the state-based approaches in order to assist practitioners in the selection of one of them to calculate the reliability. As the approach selected is based on either Continuous Time Markov Chain or Discrete Time Markov Chain, the inputs to calculate the probability of reliability are: transition probabilities among the software components, historical execution time and failure behaviour.

According to Koutras et al. (2008), software usually presents memory leaks, fragmentation and numerical round-off errors that can cause software aging and unavailability. In this context, software rejuvenation has been proposed in the literature to perform preventive maintenance consisting in periodically stopping a running software, cleaning its internal state and then restarting it. In the rejuvenation process some errors could arise that directly impact the machine availability and cause a failed rejuvenation. Consequently, one step before to the rejuvenation is to determine what policies must be used to ensure the success of the process. Thus, the authors propose a method that uses rejuvenation policies, maximum likelihood estimators and Markov chains to predict the availability level during the rejuvenation process. Specifically, the method predicts in which of the following states the machine will be during the process: (i) robust; (ii) resource degradation; (iii) failure probable; (iv) failure may occur.

Bartsch et al. (2009) propose a Petri-net based approach for modelling and simulating service processes in terms of availability levels to foster a priori estimations in design time of a service, based on the need to perform a good estimation service level agreements (SLA) between stakeholders. Petri-nets are a formal graphical process description language that combines the advantages of the graphical representation of processes with a formal definition. The authors use service downtimes and the corresponding Time to Restore Service as input parameters to simulate the availability of the service. Then, petri-nets are used to represent each state of the availability by using the duration of the service. Finally, the simulation predicts period of times when the service could be unavailable and the possible causes.

According to Bosse S. (2013), ensuring high availability in IT services is crucial for IT service provider. The author argues that operator errors account a high number of service downtimes, however in current prediction systems these errors are not being considered as an important factor to predict quantitatively the availability. In this way, the author proposes a new model for availability prediction of IT services, based on flexible petri-nets' simulation that includes operator errors and mechanisms to face them. The

approach uses models of the service components that are extended to include operators, tasks, errors and mechanisms to face errors. Within this, petri-nets are used to simulate the behaviour of the service and predict its availability. This approach requires a detailed knowledge of the system and the parameterization with real data could be difficult due to the knowledge of unknown components.

Franke et al., (2014) present an architecture framework for modelling IT services in order to assess availability. This approach combines and integrate the qualitative methods, such as maturity models, with quantitative methods, such as fault trees. The framework is composed of models, meta-models, relationships and attributes suitable to represent availability. It has also features to represent a computational model with the probabilistic version of the Object Constraint Language. The model of the framework is based on fourteen systemic factors that impact software availability and integrates the structural features of the service architecture. The framework was tested empirically with nine enterprise information systems case studies, based on the availability baseline and the annual evolution of the model's factors. The outcome of the tests were availability predictions that were compared with actual outcomes, the SLA reports and System Logs.

3.4 Reporting

The contributions of the ten selected approaches related to the three evaluation elements are summarised as follows: Table 2 present the Context element, Table 3 shows the Method element and Table 4 summarises the Application element. These tables allow the understanding of how availability prediction is achieved from different perspectives.

Author	Context		
	Domain	**Goal**	**Scope**
Benlarbi (2006)	Networks	To predict the availability of a node in a network	Network Communications
Rahman et al. (2010)	Grid Computing	To predict the availability of a machine	Enterprise Grids
Toktam and Deldari (2010)	Grid Computing	To predict the availability of a machine	Enterprise Grids
Rodrigues et al. (2005)	Software Engineering	To predict software system reliability	Software systems
Gokhale and Trivedi, (2006)	Software Engineering	To predict software system reliability	Software systems
Koutras et al. (2008)	Software Engineering	To predict the availability of a machine	Systems' Components
Bartsch et al. (2009)	IT Services	To predict the service's availability	Infrastructure Services
Bosse S. (2013)	IT Services	To predict the service's availability	Infrastructure Services
Franke et al. (2014)	IT Services	To predict the service's availability	Infrastructure Services

Table 2. Evidence related to the Context category of the survey

Summarizing from the Table 2, it can be concluded the following with respect to each research question of the Context:

- **What is the main area of the work?** The domain areas are mainly divided in three: Software architecture and engineering, IT (infrastructure) services and networks, grid and cloud computing. As a consequence, the research literature is mainly focused on the IT infrastructure aspects and we do not find works dealing with organizational aspects such as IT support process when defining availability.
- **What is the goal of the approach?** The goal of each approach is related to its context and consists in predicting a quantitatively measure, e.g., percentage or time, of availability or reliability for a machine, node, etc. The latter is directly involved with the former as reliability is a measure of how long an IT service or other IT configuration item can perform its agreed function without interruption.

- **What applications have the approach?** The approaches show that the applications are related commonly to full systems and services, in some cases, by aggregating the availability of single components. Most of the approaches are aimed to enterprise applications.

Author	Method		
	Inputs	**Process**	**Output**
Benlarbi (2006)	Current Node State	Markov Chains and RBD	Prediction of node state
Rahman et al. (2010)	Historical Data of Availability	Lazy algorithm that use the Jaccard Index	The availability prediction of each machine
Toktam and Deldari (2010)	The three last states of a machine	Cellular automats and Bayesian Networks	The availability of the machine
Rodrigues et al. (2005)	Annotated message sequence charts, labelled transition systems	Markov model	System reliability estimation.
Gokhale and Trivedi, (2006)	Transition probabilities, execution time and failure behaviour	Continuous and Discrete Time Markov Chains	Probability of component reliability
Koutras et al. (2008)	Rejuvenation Policies	Maximum likelihood estimators, Markov Chain	Availability state of a machine
Bartsch et al. (2009)	Service downtimes and time to restore	Simulation on High-level Petri Nets	Service availability
Bosse S. (2013)	Model of each service	Petri Nets and availability estimation model	Service availability
Franke et al., (2014)	Availability baseline of 14 factors	Probabilistic prediction through a framework	Service availability

Table 3. Evidence related to the Method category of the survey.

Summarizing from the Table 3, it can be concluded the following with respect to each research question of the method:

- **What are the inputs needed to perform the prediction?** The inputs commonly used in the methods are historical data or states, system and service representations and probabilities of failures.
- **What are the methods and techniques used in the solution?** The techniques are variable between them, however the most used are the Markov chains and probabilistic methods.
- **What are the solution's output and metrics?** The methods mainly present as an output the forecast of availability or reliability in terms of percentages, nodes states or time.

Author	Application		
	Tools	**Precision of prediction**	**Limitations**
Benlarbi (2006)	The calculation algorithm is automated	Not compared with actual values	A high knowledge about Markov Chains
Rahman et al. (2010)	The calculation algorithm is automated	98.31% of accuracy	The historical Data
Toktam and Deldari (2010)	There exists commercial tools	95.22% of accuracy	Variability on the learning phase
Rodrigues et al. (2005)	Tool for synthesis of LTS models	Not compared with actual values	Component reliability must be available
Gokhale and Trivedi, (2006)	There no exists a tool that supports the approach	Not compared with actual values	A high knowledge about Markov Chains
Koutras et al. (2008)	There no exists a tool that supports the approach	Not compared with actual values	A high knowledge about Markov Chains
Bartsch et al. (2009)	The calculation algorithm is automated	Not compared with actual values	Computational resource intensive
Bosse S. (2013)	The calculation algorithm is automated	The prediction differs in 1% of reference values	A high knowledge about the system

Franke et al., (2014)	EA2T tool for implementing the model	The Root Mean Squared Error is 25% smaller	No to be used with detailed arch. models

Table 4. Evidence related to the Application category of the survey.

Summarizing from the Table 4, it can be concluded the following with respect to each research question of the Application:

- **Are there any tools that support the method?** Only Toktam and Deldari (2010) proposes a commercial tool that can support practitioners. However, most the calculation algorithms are automated so that it could be easy to build tools from them.
- **How close are the predicted values to the actual values when the method has been used?** The approaches that perform quantitative evaluation show a high precision in terms of accuracy. However, datasets used are smaller than real world applications and in most of the cases the authors propose as future work an exhaustive evaluation of the methods to be applicable in real context.
- **What are the assumptions and limitations of the method?** The limitations of the methods are related, in most of cases, to the availability of the inputs parameters. Also, most of the approaches were tested within controlled scenarios, cases studies and were rarely used by practitioners.

4 DISCUSSION AND CONCLUSION

This paper presents a survey that identifies and analyses research works for availability and reliability prediction by using three evaluation categories: context, method and application. Each category contains criteria that answer a review question. The first category, context, is related with the domain, goal and scope of the reviewed approaches. The second category, method, analyses inputs, techniques used to calculate availability and reliability and outputs of the research works. The last, application, is intended to evaluate the usability of the reviewed approaches in the industrial context. Concerning the analysis of the context, as a result we obtained that most of the research works focus on IT infrastructure aspects which is confirmed by the fact that the main research domains concern Networks, Grid Computing, Software Engineering and IT Services. Therefore, there is a lack of research works addressing the organizational aspects involved in the definition of IT service availability such as, for example, IT support process and IT skills.

Regarding the method analysis category, the inputs used in the reviewed approaches are rarely available in enterprises and real scenarios. In addition, these inputs are mainly related to the technical capabilities of the IT providers, e.g., historical availability or failure probability of technical components and communication infrastructures. However, in the SLT definition process, other inputs, that are not necessarily technical and depend on the customer, need to be included, such as the customer available budget and the criticity of the business process to be supported. Indeed, these inputs can determine the level of the technical capabilities to be delivered by the provider. Furthermore, on the provider side, inputs such as the SLT documented in existing UCs and OLAs on which the service availability can depend, need to be included as well. Respecting the calculation methods, they were not validated or used in the industry so that there is no proof of the maturity of such methods. This is because most of the works concentrate the discussion on the modelling aspect and how the method could be used. With respect to the analysis of the last evaluation category, i.e. application, the low use of the approaches by practitioners may be influenced by the low number of commercial tools and the need for expert knowledge to apply the methods. Last, the lack of a quantitative application of the approaches in real world scenarios or using datasets that relates availability of services over a long period of time results in that the accuracy of the predictions presented is not reliable.

In summary, future work is needed to develop frameworks that help in the prediction of IT service availability facilitating the agreement between customers and providers. These frameworks should include other organisational factors on which IT service availability directly depend such as IT support process, skills, budget, business process criticity, among others.

References

Bartsch, C., Mevius, M., and Oberweis, A. (2009). Simulation of IT Service Processes with Petri-Nets. Service-Oriented Computing–ICSOC 2008 Workshops (pp. 53-65). Berlin: Springer Berlin Heidelberg.

Benlarbi, S. (2006). Estimating SLAs availability/reliability in multi-services IP networks. Third International Service Availability Symposium (pp. 30-42). Helsinki: Lecture Notes in Computer Science.

Bosse, S. (2013). Predicting an IT Service's Availability with Respect to Operator Errors. Proceedings of the Nineteenth Americas Conference on Information Systems (pp. 1-11). Chicago: AIS.

Bosse, S., Splieth, M., and Turowski, K. (2014). Model-Based Prediction of IT Service Availability - A Literature Review. Proceedings of the 13th International Conference on Modeling and Applied Simulation. Bordeaux: Curran Associates.

Franke, U., Pontus, J., and König, J. (2014). An architecture framework for enterprise IT service availability analysis. Software and Systems Modeling, 13(4), 1417-1445.

Gokhale, S. S., and Trivedi, K. S. (2006). Analytical Models for Architecture-Based Software Reliability Prediction: A Unification Framework. IEEE Transactions on Reliability, 55(4), 578-590.

Goševa-Popstojanova, K., and Trivedi, K. S. (2003). Architecture-based approaches to software reliability prediction. Computers and Mathematics with Applications, 46(7), 1023-1036.

Hunnebeck, L., Rudd, C., Lacy, S., and Hanna, A. (2011). ITIL service design. London: The Stationery Office.

Immonen, A., and Niemelä, E. (2008). Survey of reliability and availability prediction methods from the viewpoint of software architecture. Software and Systems Modeling, 7(1), 49-65.

Koutras, V. P., Platis, A. N., and Limnios, N. (2008). Availability and reliability estimation for a system undergoing minimal, perfect and failed rejuvenation. International Conference on Software Reliability Engineering Workshops (pp. 1-6). Raleigh: IEEE.

Rahman, M., Hassan, M. R., and Buyya, R. (2010). Jaccard index based availability prediction in enterprise grids. Procedia Computer Science, 1(1), 2707-2716.

Rodrigues, G., Rosenblum, D., and Uchitel, S. (2005). Using scenarios to predict the reliability of concurrent component-based software systems. Fundamental Approaches to Software Engineering (pp. 111-126). Edinburgh: Springer Berlin Heidelberg.

Seuring, S., and Müller, M. (2008). From a literature review to a conceptual framework for sustainable supply chain management. Journa of cleaner production , 16(15), 1699-1710.

Toktam, G.-M., and Deldari, H. (2010). Task execution availability prediction in the enterprise desktop grid. Proceedings of the 9th Parallel and Distributed computing and networks Conferences (pp. 16-23). Innsbruck: IASTED.

Uchitel, S., Kramer, J., and Magee, J. (2004). Incremental elaboration of scenario-based specifications and behavior models using implied scenarios. ACM Transactions on Software Engineering and Methodology (TOSEM), 13(1), 37-85.