Reliability Engineering & System Safety
Volume 99, March 2012, Pages 114 – 122

Generic metrics and quantitative approaches for system resilience as a function of time

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http://dx.doi.org/10.1016/j.ress.2011.09.002, How to Cite or Link Using DOI

Abstract

Resilience is generally understood as the ability of an entity to recover from an external disruptive event. In the system domain, a formal definition and quantification of the concept of resilience has been elusive. This paper proposes generic metrics and formulae for quantifying system resilience. The discussions and graphical examples illustrate that the quantitative model is aligned with the fundamental concept of resilience. Based on the approach presented it is possible to analyze resilience as a time dependent function in the context of systems. The paper describes the metrics of network and system resilience, time for resilience and total cost of resilience. Also the paper describes the key parameters necessary to analyze system resilience such as the following: disruptive events, component restoration and overall resilience strategy. A road network example is used to demonstrate the applicability of the proposed resilience metrics and how these analyses form the basis for developing effective resilience design strategies. The metrics described are generic enough to be implemented in a variety of applications as long as appropriate figures-of-merit and the necessary system parameters, system decomposition and component parameters are defined.

Highlights

► Propose a graphical model for the understanding of the resilience process. ► Mathematical description of resilience as a function of time. ► Identification of necessary concepts to define and evaluate network resilience. ► Development of cost and time to recovery metrics based on resilience formulation.

Keywords

Network analysis; System resilience; Quantitative methods; Restoration

Figures and tables from this article:

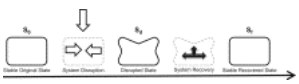

Fig. 1. System state transition in resilience.

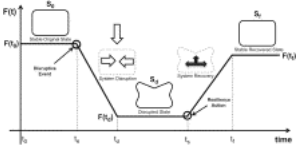

Fig. 2. Delivery function transition in resilience.

Figure options

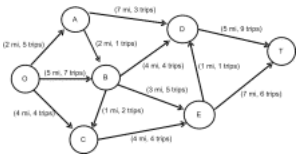

Fig. 3. Seervada park problem.

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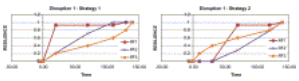

Fig. 4. Resilience analysis for Disruption 1.

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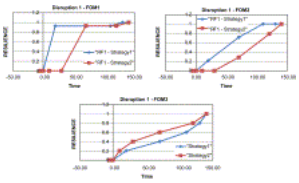

Fig. 5. Comparing strategies for Disruption 1.

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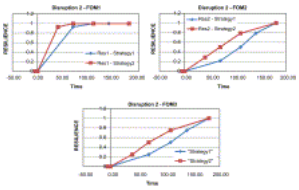

Fig. 6. Comparing strategies for Disruption 2.

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Table 1. Network Behavior under Disruption 1—Strategy 1.

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Table 2. Resilience computations for Disruption 1—Strategy 1.

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