Prototyping Self-Managed Interdependent Networks - Self-Healing Synergies against Cascading Failures

Submitted by aekwall on Mon, 03/25/2019 - 9:54am

Title	Prototyping Self-Managed Interdependent Networks - Self-Healing Synergies against Cascading Failures
Publication Type	Conference Paper
Year of Publication	2018
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Conference Name	2018 IEEE/ACM 13th International Symposium on Software Engineering for Adaptive and Self-Managing Systems (SEAMS)
Date Published	may
Keywords	Adaptation models, cascading failure, catastrophic instabilities, complex networks, composability, Computational modeling, digital society, distributed system, failure analysis, general prototyping approach, healer network, interdependent networks, interdependent power networks, interdisciplinary scope, Load flow, Load modeling, Modeling, modular design solution, multiplex networks, network interconnection, open source software extension, organizational constraints, power cascading failures, power engineering computing, power flow exchanges, power grids, power system faults, power system interconnection, Power system protection, power system reliability, pubcrawl, public domain software, real-world interdependent networks, resilience, self-healing, self-healing mechanism, self-healing networks, self-healing synergies, self-managed interdependent networks, self-management, self-management software systems, SFINA, simulation, simulation framework for intelligent network adaptations, Smart grid, socio-economic effects, Software, software artifact, techno-socio-economic sectors, Unified modeling language

Abstract The interconnection of networks between several techno-socio-economic sectors such as energy, transport, and communication, questions the manageability and resilience of the digital society. System interdependencies alter the fundamental dynamics that govern isolated systems, which can unexpectedly trigger catastrophic instabilities such as cascading failures. This paper envisions a general-purpose, yet simple prototyping of self-management software systems that can turn system interdependencies from a cause of instability to an opportunity for higher resilience. Such prototyping proves to be challenging given the highly interdisciplinary scope of interdependent networks. Different system dynamics and organizational constraints such as the distributed nature of interdependent networks or the autonomy and authority of system operators over their controlled infrastructure perplex the design for a general prototyping approach, which earlier work has not yet addressed. This paper contributes such a modular design solution implemented as an open source software extension of SFINA, the Simulation Framework for Intelligent Network Adaptations. The applicability of the software artifact is demonstrated with the introduction of a novel self-healing mechanism for interdependent power networks, which optimizes power flow exchanges between a damaged and a healer network to mitigate power cascading failures. Results show a significant decrease in the damage spread by self-healing synergies, while the degree of interconnectivity between the power networks indicates a tradeoff between links survivability and load served. The contributions of this paper aspire to bring closer several research communities working on modeling and simulation of different domains with an economic and societal impact on the resilience of real-world interdependent networks.

Citation Key pournaras_prototyping_2018

Adaptation models cascading failure catastrophic instabilities complex networks composability Computational modeling digital society distributed system failure analysis general prototyping approach healer network interdependent networks interdependent power networks interdisciplinary scope Load flow Load modeling modeling modular design solution multiplex networks network interconnection open source software extension organizational constraints power cascading failures power engineering computing power flow exchanges power grids power system faults power system interconnection Power system protection power system reliability pubcrawl public domain software real-world interdependent networks resilience self-healing self-healing mechanism self-healing networks self-healing synergies self-managed interdependent networks self-management self-management software systems SFINA simulation simulation framework for intelligent network adaptations Smart Grid socio-economic effects Software software artifact techno-socio-economic sectors Unified modeling language