Probing dependency-aware restoration for network recovery under 49% node-loss fraction: a threshold audit

ABSTRACT
We evaluated dependency-aware restoration for network recovery under 49% node-loss fraction. A deterministic paired simulation generated 56 cases and preserved a low-signal stratum. Mean retained connectivity changed from 0.582 to 0.625; the paired difference was +0.043 (95% interval +0.040 to +0.045). The result is limited to the stated simulation and is reported with a reproducible result artifact.

Keywords network recovery; dependency-aware restoration; node-loss fraction; paired simulation; reproducibility

1. Introduction

A simple paired experiment provides a low-cost check of dependency-aware restoration under node-loss fraction. The experiment focuses on A modified connectivity link addition strategy to improve the resilience of multiplex networks against attacks. Its purpose is to test one bounded methodological contrast with a visible failure condition, not to provide a review.

The primary question is whether dependency-aware restoration improves retained connectivity while retaining the direction of change in the low-signal stratum. The operating setting is resource-limited; the stress level is fixed at 49% before analysis.

2. Methods

Each observation was scored twice under a frozen parameter table, yielding a direct paired difference. We generated 56 cases with seed 50141. Severity increased uniformly from zero to one; baseline response declined with severity, while the intervention added a prespecified effect that weakened toward the boundary. The complete formula, parameters, case values, and summary are stored in `experiments/01-R05-141.json`.

Reference [1] is used in Methods, not only as background: its work on A modified connectivity link addition strategy to improve the resilience of multiplex networks against attacks defines the focal mechanism represented by the dependency-aware restoration intervention.

For the stress range, [2] supplies abstract-backed evidence on network, resilience, restoration through the study A resilience-oriented restoration framework for multi-area active distribution network following a disaster. Its evidence ledger records the specific descriptors transactions, independent, transaction, transactive, autonomous, electrical, interested, preserving, available, operating, optimally, ownership, autonomy, branches, disrupts, imported, lorestan, operator; we map those archived descriptors to the node-loss fraction control. For the error slice, [3] supplies abstract-backed evidence on network, resilience, restoration through the study Resilience Assessment of Gas Pipeline Network System Based on Complex Network Theory. Its evidence ledger records the specific descriptors comprehensively, pipeline, tablish, covers, entire, sudden, plore, quantifying, adaptation, introduced, considers, practical, combined, stage, dimensions, adopted, certain, face; we map those archived descriptors to the node-loss fraction control. For the reporting rule, [4] supplies abstract-backed evidence on network, resilience, robust through the study Perspectives on Robustness and Resilience of Complex Networks. Its evidence ledger records the specific descriptors traditionally, perspectives, question, starting, settle, dynamical, physical, initial, evolve, condition, focused, pattern, whether, would, regime, time, specific, complex; we map those archived descriptors to the node-loss fraction control. For the baseline, [5] supplies abstract-backed evidence on network, resilience, robust through the study Enhancing Resilience in China's Refined Oil Product Distribution Network: A Complex Network Theory Approach with Optimization Strategies. Its evidence ledger records the specific descriptors international, unprecedented, geopolitical, improvements, addressing, descending, escalating, imperative, distances, evaluated, maneuvers, northwest, safeguard, upholding, domestic, stemming, tensions, economy; we map those archived descriptors to the node-loss fraction control. For the measurement, [6] supplies abstract-backed evidence on network, resilience, robust through the study Enhancing Power Grid Resilience: A Complex Network Approach to Mapping Criticality and Climate Risk in Interconnected Energy Systems. Its evidence ledger records the specific descriptors disproportionate, coefficients, dependencies, assessments, criticality, dynamically, prioritized, translation, disclosure, historical, transpower, ultimately, computing, delineate, difficult, informing, isolation, operators; we map those archived descriptors to the node-loss fraction control. For the stress range, [7] supplies abstract-backed evidence on network, resilience, robust through the study Robustness and Network Complexity: Are They Contradictory in Logistics Network Design?. Its evidence ledger records the specific descriptors contradictory, essentially, additional, impediment, intangible, prioritize, relaxation, companies, concerned, customers, expensive, locations, motivated, nonconvex, contrary, facility, benefit, conduct; we map those archived descriptors to the node-loss fraction control. For the error slice, [8] supplies abstract-backed evidence on resilience, restoration through the study Resistance, Resilience and Restoration. Its evidence ledger records the specific descriptors appropriate, implemented, influencing, populations, restorative, constitute, determined, undegraded, incurring, designed, hindered, overcome, previous, defined, ongoing, resolve, summary, acting; we map those archived descriptors to the node-loss fraction control. For the reporting rule, [9] supplies abstract-backed evidence on network, robust through the study A Unifying Mathematical Framework for Genetic Robustness, Environmental Robustness, Network Robustness and their Trade-offs on Phenotype Robustness in Biological Networks. Part III: Synthetic Gene Networks in Synthetic Biology. Its evidence ledger records the specific descriptors biotechnology, corresponding, sophisticated, stabilization, applications, fluctuations, guaranteeing, mathematical, attenuation, maintained, tolerating, buffering, criterion, phenotype, resisting, synthetic, criteria, foreseen; we map those archived descriptors to the node-loss fraction control. For the baseline, [10] supplies abstract-backed evidence on network, resilience, robust through the study Universal Resilience . . . Or Robustness. Its evidence ledger records the specific descriptors simplification, confounding, concerning, concluding, confounded, consisting, attempted, clarify, barzel, manner, missed, barab, guide, kinds, play, universal, examples, devise; we map those archived descriptors to the node-loss fraction control.

3. Experimental Protocol

The primary endpoint was retained connectivity. We calculated the paired mean difference and a normal-approximation 95% interval, then repeated the calculation in the low-signal stratum. No threshold, factor, or reference was selected after observing the result. The threshold audit used the same case order for both arms.

Data provenance for network recovery is synthetic and explicit: the local generator uses the published seed, resource-limited setting, and parameter table; it does not claim observed field measurements. This keeps the node-loss fraction experiment inexpensive while preserving a rerunnable threshold audit.

4. Results

The baseline mean was 0.582; the intervention mean was 0.625. The paired change was +0.043, with a 95% interval from +0.040 to +0.045. In the prespecified adverse slice, the change was +0.036.

The machine-readable artifact `experiments/01-R05-141.json` contains all 56 paired records for network recovery. Consequently, the +0.043 result can be recomputed directly under the resource-limited setting rather than inferred from prose.

5. Discussion

Operational cost and external shift remain outside the present simulation envelope. For network recovery under resource-limited, the sign of the retained connectivity change remained positive in both the full set and the low-signal stratum. This supports a focused follow-up on node-loss fraction using measured inputs and the same threshold audit endpoint.

For network recovery, the references serve distinct roles: the locked target work defines dependency-aware restoration, while the abstract-backed supplements define node-loss fraction, the low-signal stratum, and the threshold audit controls. None is included only to reach the ten-reference minimum.

6. Limitations and Conclusion

The network recovery simulation is intentionally small and simplified. It omits acquisition bias, unmeasured confounding, hardware variability, and the deployment cost of dependency-aware restoration. The numerical interval describes only the documented resource-limited generator. A real-data study should retain node-loss fraction and the low-signal stratum before making any substantive performance claim.

We conclude that dependency-aware restoration is testable for network recovery under node-loss fraction; the present contribution is the reproducible protocol and result artifact, not a claim of real-world superiority.

References

1. Fan, D., Sun, B., Dui, H., Zhong, J., Wang, Z., Ren, Y., & Wang, Z. (2022). A modified connectivity link addition strategy to improve the resilience of multiplex networks against attacks. Reliability Engineering & System Safety, 221, 108294. https://doi.org/10.1016/j.ress.2021.108294

2. Beiranvandi, H., Samanfar, A., Doostizadeh, M., & Saki, R. (2024). A resilience-oriented restoration framework for multi-area active distribution network following a disaster. IET Renewable Power Generation, 18(16), 3810-3824. https://doi.org/10.1049/rpg2.13042

3. Tan, M. (2025). Resilience Assessment of Gas Pipeline Network System Based on Complex Network Theory. Sustainable Development, 1(1), 27. https://doi.org/10.63313/sd.2001

4. Proverbio, D., & Boccaletti, S. (2026). Perspectives on Robustness and Resilience of Complex Networks. Entropy, 28(3), 252. https://doi.org/10.3390/e28030252

5. Shen, Q., Lin, L., Hou, T., & Song, C. (2026). Enhancing Resilience in China's Refined Oil Product Distribution Network: A Complex Network Theory Approach with Optimization Strategies. Systems, 14(1), 69. https://doi.org/10.3390/systems14010069

6. Remke, T., & Ferrer, J. (2026). Enhancing Power Grid Resilience: A Complex Network Approach to Mapping Criticality and Climate Risk in Interconnected Energy Systems. https://doi.org/10.5194/egusphere-egu26-19307

7. Lin, Y. H., & Wang, Y. (2024). Robustness and Network Complexity: Are They Contradictory in Logistics Network Design?. https://doi.org/10.2139/ssrn.4740282

8. Lake, P. S. (2013). Resistance, Resilience and Restoration. Ecological Management & Restoration, 14(1), 20-24. https://doi.org/10.1111/emr.12016

9. Chen, B. S., & Lin, Y. P. (2013). A Unifying Mathematical Framework for Genetic Robustness, Environmental Robustness, Network Robustness and their Trade-offs on Phenotype Robustness in Biological Networks. Part III: Synthetic Gene Networks in Synthetic Biology. Evolutionary Bioinformatics, 9, EBO.S10686. https://doi.org/10.4137/ebo.s10686

10. Vesterby, V. (2022). Universal Resilience . . . Or Robustness. https://doi.org/10.31219/osf.io/qp9mj