Dependency-Aware Resilience through Link Addition and Higher-Order Rewiring in Multiplex Networks

Abstract

Network Resilience is increasingly shaped by the need to reconcile performance with evidence quality, resource limits, and transfer across settings. This technical review examines link interventions that improve robustness without hiding cross-layer dependencies or rewiring cost. It synthesizes 3 focal papers with 11 independently retrieved publications whose authorship and venue fields were independently checked. The analysis is organized around attack model, interlayer coupling, rewiring cost, restoration sequence, and critical services. Rather than treating reported outcomes as directly interchangeable, the review compares problem formulation, design assumptions, and transfer boundary. Across the literature, the central lesson is that advances in network resilience become credible when workload, dependency, and recovery policy are evaluated together and when uncertainty about observability is reported explicitly. The resulting framework links method selection to decision consequence and recurring validity threats, and proposes a research agenda centered on traceable baselines, scenario testing, and reusable evidence.

Keywords

Network Resilience; Attack Model; Interlayer Coupling; Rewiring Cost; Restoration Sequence; Critical Services

1. Introduction

Research on network resilience sits at an interface between scientific ambition and practical constraint. The field seeks not only stronger nominal performance but also explanations that reveal why an approach works in one setting. That challenge is especially visible in link interventions that improve robustness without hiding cross-layer dependencies or rewiring cost. A result that is compelling in a particular material, corpus, cohort, geography, or load profile can diminish when the evaluation environment moves. Consequently, synthesis must preserve the unit of analysis and the decision context. It must also distinguish a mechanism from a correlation, a benchmark advantage from a deployment advantage, and an interpretable diagnostic from a causal explanation.

This review uses five analytical lenses: attack model, interlayer coupling, rewiring cost, restoration sequence, critical services. The lenses were selected because they jointly cover method construction, evidence collection, and the conditions needed for generalization. The organizing principle is workload, dependency, and recovery policy. Under that principle, methodological novelty is necessary but insufficient; the comparison also asks whether baselines are aligned, whether uncertainty is visible, and whether resource or safety constraints are represented. The article is a literature synthesis and is not presented as a new experiment and supplies no synthetic performance claim.

2. System Context and Failure Model

A useful conceptual decomposition begins with the input evidence, the transformation applied to it, the output used for evaluation, and the decision that follows. In network resilience, these stages are often optimized separately even though errors propagate across them. Model expressiveness can propagate bias that enters with the observations; an apparently accurate output can still be poorly calibrated for the final decision. For that reason, failure semantics should accompany aggregate performance. A strong comparison states its controlled factors and permitted variation, then selects metrics that correspond to the intended use rather than to convenience alone.

The second foundation is boundary awareness. Attack model defines the local design problem, while critical services determines whether the design can survive outside that boundary. Intermediate lenses such as interlayer coupling and rewiring cost connect those ends by exposing trade-offs that a single score conceals. This is where negative results and robustness analysis identifies the envelope that supports the interpretation. For applied work, documentation of operational constraints is therefore part of the scientific result, not an administrative afterthought.

3. Comparative Evidence

The target study X0-01, A modified connectivity link addition strategy to improve the resilience of multiplex networks against attacks [1], addresses a concrete part of network resilience through targeted connectivity-link addition to strengthen multiplex-network resilience. It identifies a representation, mechanism, or evaluation boundary needed to compare claims. Against the focus on link interventions that improve robustness without hiding cross-layer dependencies or rewiring cost, the paper is positioned as a context-dependent design instance: transfer may depend on its sensing regime, preparation, workload, population, or benchmark. The synthesis keeps the original envelope visible and contrasts it with nearby evidence.

The target study X0-02, Higher-order rewiring strategy for enhancing robustness of multiplex aviation networks [2], addresses a concrete part of network resilience through higher-order rewiring of multiplex aviation networks. It identifies a representation, mechanism, or evaluation boundary needed to compare claims. Against the focus on link interventions that improve robustness without hiding cross-layer dependencies or rewiring cost, the paper is positioned as a context-dependent design instance: transfer may depend on its sensing regime, preparation, workload, population, or benchmark. The synthesis keeps the original envelope visible and contrasts it with nearby evidence.

Across the focal studies, attack model should be interpreted jointly with interlayer coupling. A design can improve one while shifting cost or uncertainty into the other. The practical comparison is a matrix whose rows are operating conditions and whose columns are evidence quality, computation or process cost, robustness, and consequence of failure. Such a matrix prevents an attractive mechanism from being detached from the circumstances that support it. It also clarifies which ablations are informative: ablation design should target causal attribution instead of numerical proliferation.

Rewiring cost provides the bridge from method to decision. At minimum, evaluation should evaluate baseline and stress regimes separately and expose result dispersion, and test plausible alternative explanations. Where observability is central, calibration or sensitivity is as important as ranking. Where costs or hazards are asymmetric, utility-weighted assessment is more revealing than undifferentiated accuracy. These choices do not make studies identical; they make the reasons for their differences auditable.

4. Design and Optimization

The design space is broadened by A Coordinated Restoration Method of Hybrid AC/DC Distribution Network for Resilience Enhancement [3]; Resilience-Oriented Critical Load Restoration Using Microgrids in Distribution Systems [4]; Leveraging Network Topology Optimization to Strengthen Power Grid Resilience Against Cyber-Physical Atta... [5]. These publications were retrieved and verified through DOI or publisher metadata, and their titles directly intersect the problem boundary of network resilience. Together they illuminate attack model: some emphasize representations or mechanisms, whereas others foreground validation and application conditions. The useful comparison is not a leaderboard across incompatible settings, but a structured reading of what each study controls, leaves variable, and treats as a meaningful outcome. Divergence can then reveal a change in scale, data process, endpoint, or operating constraint.

A first comparison set connects Distribution Network Restoration in a Multiagent Framework Using a Convex OPF Model [6]; Enhancing Distribution System Resilience With Proactive Islanding and RCS-Based Fast Fault Isolation and... [7]; Enhancing Resilience of Power Distribution Systems Under Cyber-Physical Hybrid Attacks: A Coordinated Lo... [8]. These publications were retrieved and verified through DOI or publisher metadata, and their titles directly intersect the problem boundary of network resilience. Together they illuminate interlayer coupling: some emphasize representations or mechanisms, whereas others foreground validation and application conditions. The useful comparison is not a leaderboard across incompatible settings, but a structured reading of what each study controls, leaves variable, and treats as a meaningful outcome. Divergence can then reveal a change in scale, data process, endpoint, or operating constraint.

The neighboring evidence base brings together Risk-Limiting Load Restoration for Resilience Enhancement With Intermittent Energy Resources [9]; Resilience-Motivated Distribution System Restoration Considering Electricity-Water-Gas Interdependency [10]; Online Coordination of LNG Tube Trailer Dispatch and Resilience Restoration of Integrated Power-Gas Dist... [11]. These publications were retrieved and verified through DOI or publisher metadata, and their titles directly intersect the problem boundary of network resilience. Together they illuminate rewiring cost: some emphasize representations or mechanisms, whereas others foreground validation and application conditions. The useful comparison is not a leaderboard across incompatible settings, but a structured reading of what each study controls, leaves variable, and treats as a meaningful outcome. Divergence can then reveal a change in scale, data process, endpoint, or operating constraint.

A complementary strand is visible in Coordinating Multiple Sources for Service Restoration to Enhance Resilience of Distribution Systems [12]; Resilience Enhancement Strategies for Power Distribution Network Coupled With Urban Transportation System [13]. These publications were retrieved and verified through DOI or publisher metadata, and their titles directly intersect the problem boundary of network resilience. Together they illuminate restoration sequence: some emphasize representations or mechanisms, whereas others foreground validation and application conditions. The useful comparison is not a leaderboard across incompatible settings, but a structured reading of what each study controls, leaves variable, and treats as a meaningful outcome. Divergence can then reveal a change in scale, data process, endpoint, or operating constraint.

5. Operational Implications

For implementation, the review suggests a staged workflow. First, define the decision and its failure cost. Second, specify the evidence and operating envelope. Third, choose a method whose inductive assumptions match that evidence. Fourth, test restoration sequence and critical services under controlled perturbations. Finally, retain provenance so that an unexpected outcome can be traced to data, configuration, material batch, environmental condition, or user interaction. This sequence keeps link interventions that improve robustness without hiding cross-layer dependencies or rewiring cost connected to observable requirements.

The broader implication is that responsible progress in network resilience depends on interfaces as much as components. Interfaces determine how uncertainty moves between measurement and inference, between algorithm and operator, or between microscopic design and system behavior. Teams should establish beforehand both success criteria and evidence for correction. When those agreements are explicit, optimization remains accountable to validity, hazard control, and interpretability.

6. Limitations and Future Directions

This synthesis is limited by inconsistent terminology, research designs, and reporting detail. Metadata verification establishes that a publication and its bibliographic fields are real; it does not by itself reproduce the study or certify every empirical claim. In addition, fast-moving work may change venue or version. The supplied focal strings remain preserved while questionable normalization is shown only as a candidate.

Future work should preregister comparison protocols where feasible, provide structured configuration records and assess a realistic transfer condition in operational constraints. Research should also classify failures by causal mechanism as well as prevalence. For network resilience, a valuable shared benchmark would combine routine performance, deployment demand, calibration, and robustness after disruption. Such a benchmark would reward designs that remain useful when evidence is incomplete or conditions change.

7. Conclusion

The literature on network resilience is best understood as a connected evidence system rather than a collection of isolated scores. The focal studies show how link interventions that improve robustness without hiding cross-layer dependencies or rewiring cost; the additional literature reveals the assumptions required to interpret those contributions. Across attack model, interlayer coupling, rewiring cost, restoration sequence, and critical services, the most durable principle is alignment: the representation or mechanism must match the problem, the decision needs a fitting evaluation and deployment a demonstrated operating range. Aligned evidence produces work that can be repeated, transferred cautiously, and learned from when unsuccessful.

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