

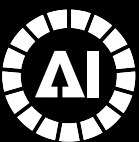
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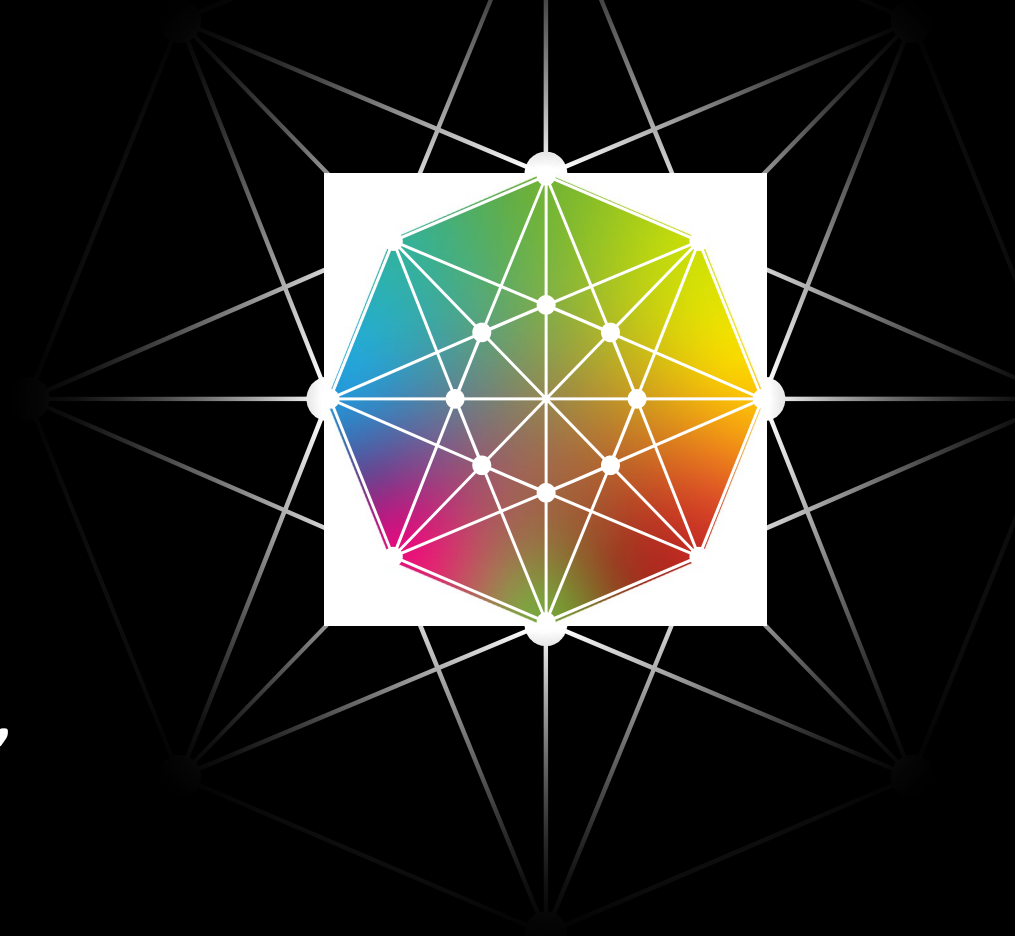
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AI-Native Closed-Loop Self-Healing for Rural and Edge Telecom Networks in NS-3; Randomized Fault Injection, Explainable Detection, and Policy-Grounded Orchestration

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The Problem

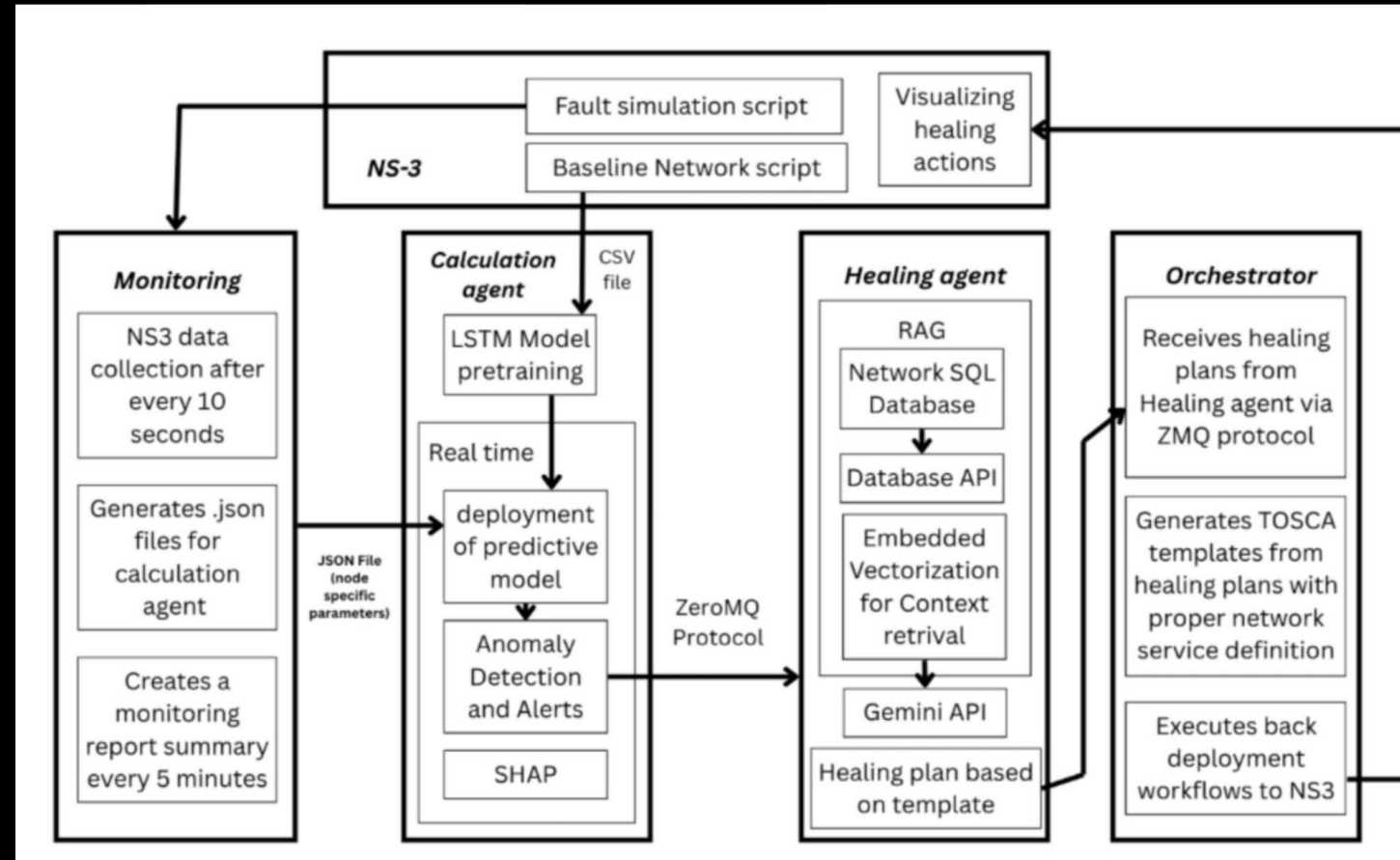
- Fiber cuts, unstable power, and transient equipment degradation disrupt rural/edge connectivity.
- Manual triage is delayed by limited observability and limited on-site support.
- A self-healing system must not only detect faults, but explain, plan, execute, and verify recovery.

So, what do we propose to do about it?

We build a reproducible AI-native closed loop in NS-3.

Monitor → Detect → Explain → Plan → Execute → Verify

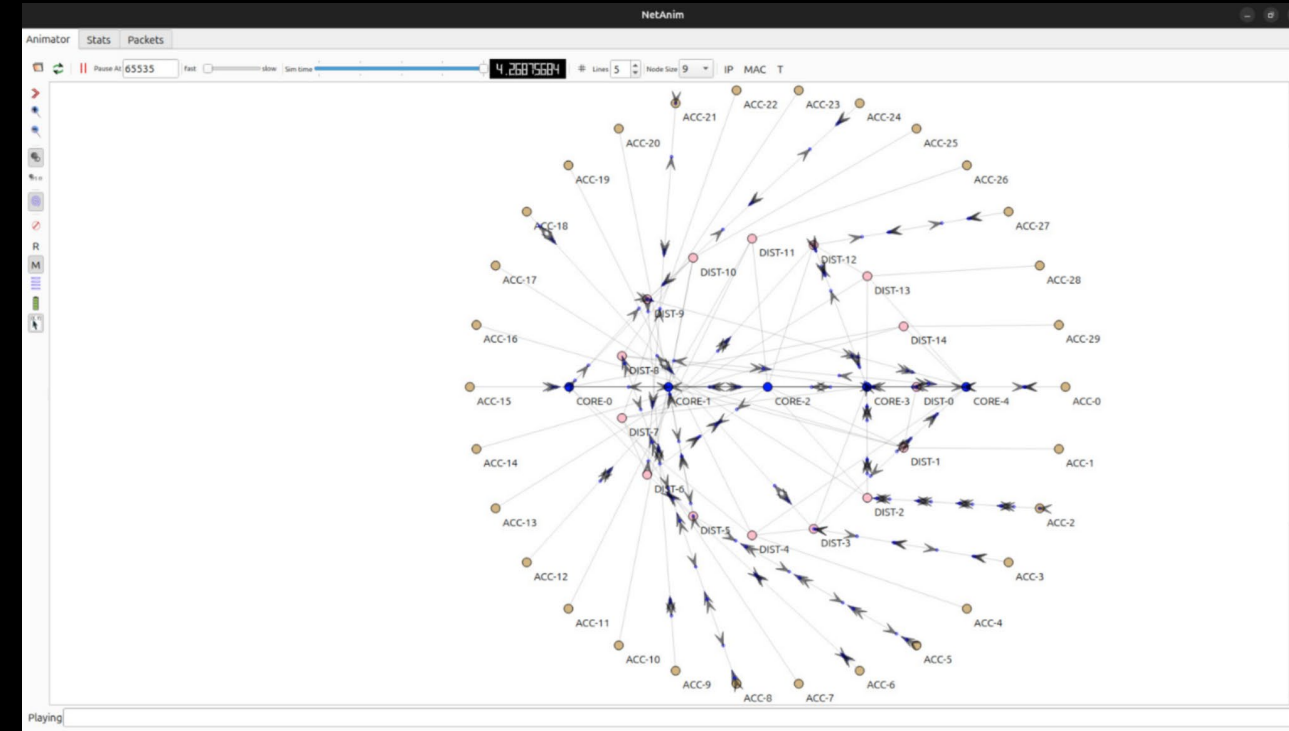
- Randomized fault injection with ground-truth logging.
- LSTM-based anomaly detection over periodic KPI snapshots.
- SHAP explanations for root-cause evidence.
- Policy-grounded healing using SQL/RAG/templates.
- Simulator-side orchestration with auditable artifacts.



Experimental Setup

50-node rural topology with controlled fault injection.

- Three-tier topology: core, distribution, and access nodes.
- Fault classes: fiber cuts and power fluctuations.
- NS-3 provides canonical simulation time, telemetry, and ground-truth events.
- Evaluation tracks detection, planning, deployment, and recovery.



Detection Results

The detector trades raw speed for confirmation, explainability, and zero false alarms.

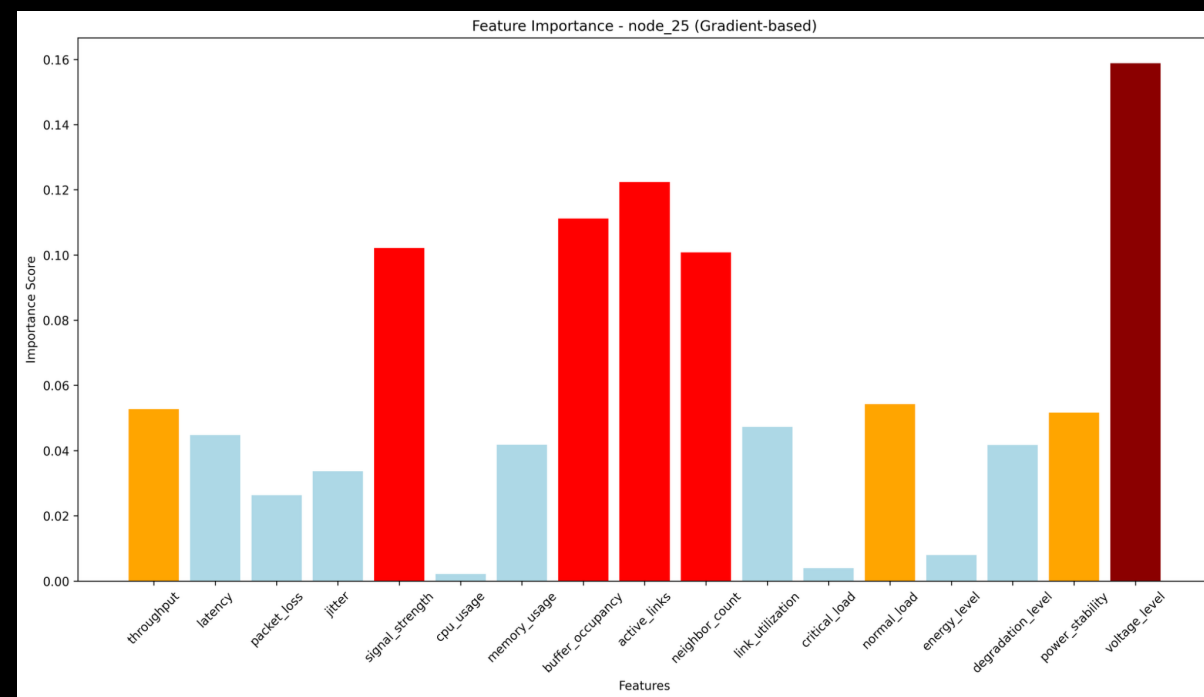
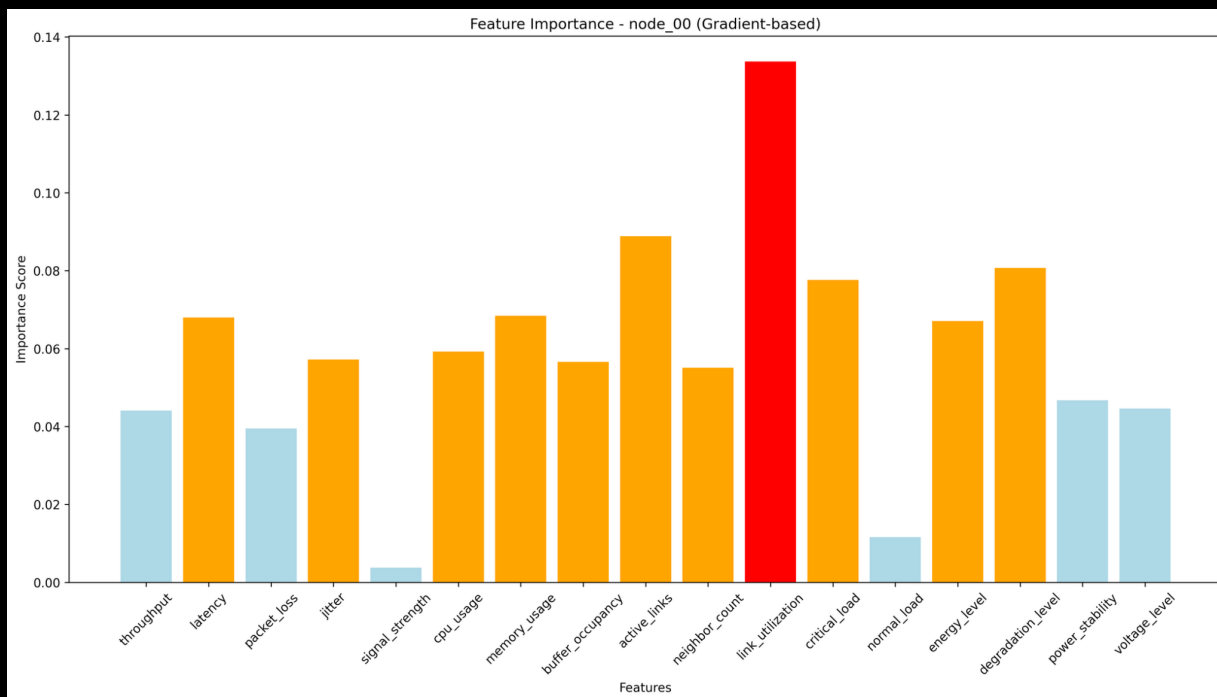
- LSTM+SHAP achieved **Precision 1.000, Recall 1.000, F1 1.000** in the evaluated run.
- Isolation Forest was strong on clean traces, but lacks temporal explanation and healing evidence.
- LSTM+SHAP provides feature-level explanations for downstream orchestration.
- Robustness tests show stability under missing and noisy telemetry in this pipeline.

Method	Precision	Recall	F1	Latency	Expl.	F1 at 30% missing	F1 at $\sigma = 0.20$ noise	Note
Statistical threshold	0.444	0.869	0.587	~0 ms	None	0.192	0.405	brittle
Isolation Forest	0.989	0.989	0.989	0.03 ms	None	0.877	0.864	robust baseline
Autoencoder	0.856	0.856	0.856	0.69 ms	None	0.183	0.135	degrades sharply
LSTM+SHAP	1.000	1.000	1.000	77 s	SHAP	1.000	1.000	buffered confirmation

Explainability and Healing Logic

The system explains why it acts before orchestration.

- Fiber-cut faults are driven by traffic/connectivity degradation.
- Power-fluctuation faults are driven by power, voltage, and resource-stability features.
- SHAP evidence reduces black-box actuation risk.
- Healing plans are constrained by policies, templates, and approval gate



Why This Matters

A standards-compatible testbed for explainable, auditable self-healing.

- Makes AI-native closed-loop stages concrete and measurable.
- Aligns with ZSM/ENI-style monitoring, analytics, decision, execution, and verification.
- Provides audit trail: fault events, KPI snapshots, alerts, healing plans, deployment artifacts, recovery status.
- Future work: field traces, larger topologies, concurrent faults, and constrained optimization.

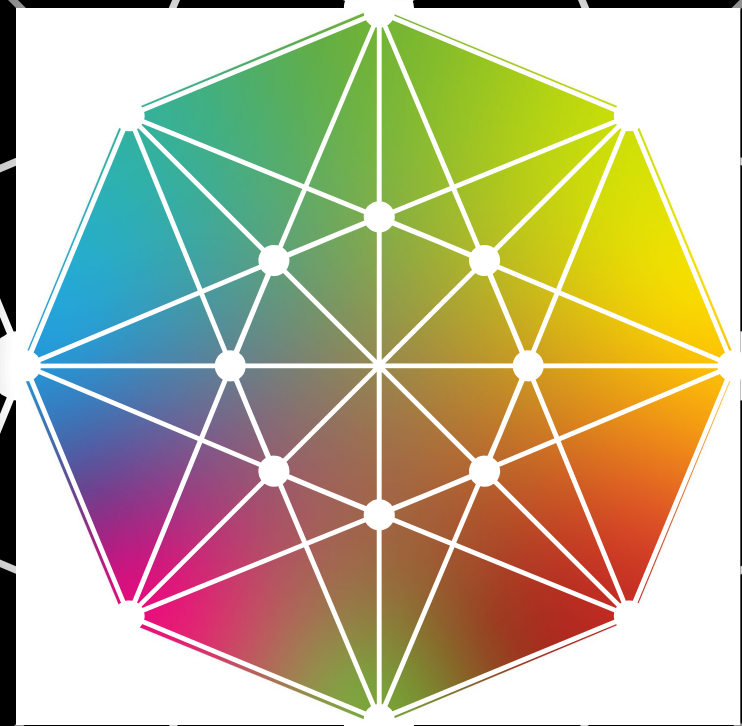


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Session S6.5 — AI-Native networks,
5G/6G, and telecom architectures





Thank You.