Postmodern Resilience and International Collaboration in GpENI

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Where is Kansas?
Geography Lesson

Resilience and Heterogeneity
Outline

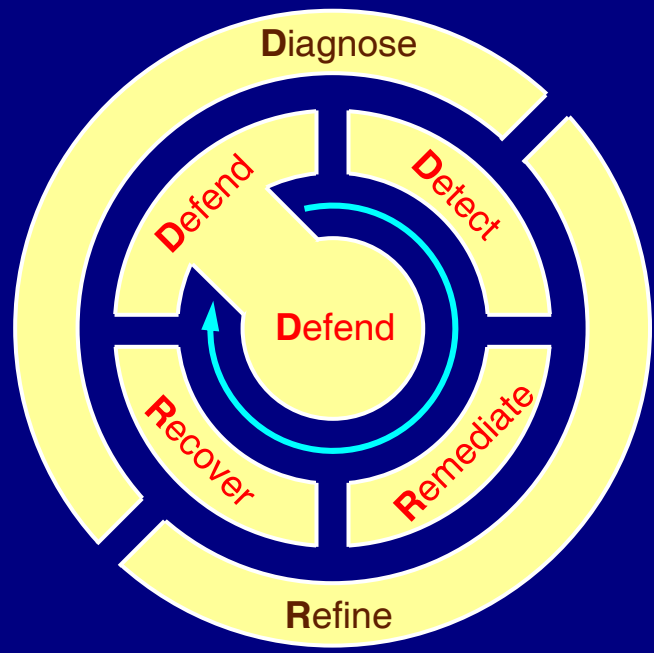
- Resilience and heterogeneity
- Example realms
  - WDTN
  - highly mobile airborne ad-hoc networking
- Evaluation methodology
  - simulation
  - experimentation

Resilience and Heterogeneity
Introduction and Motivation

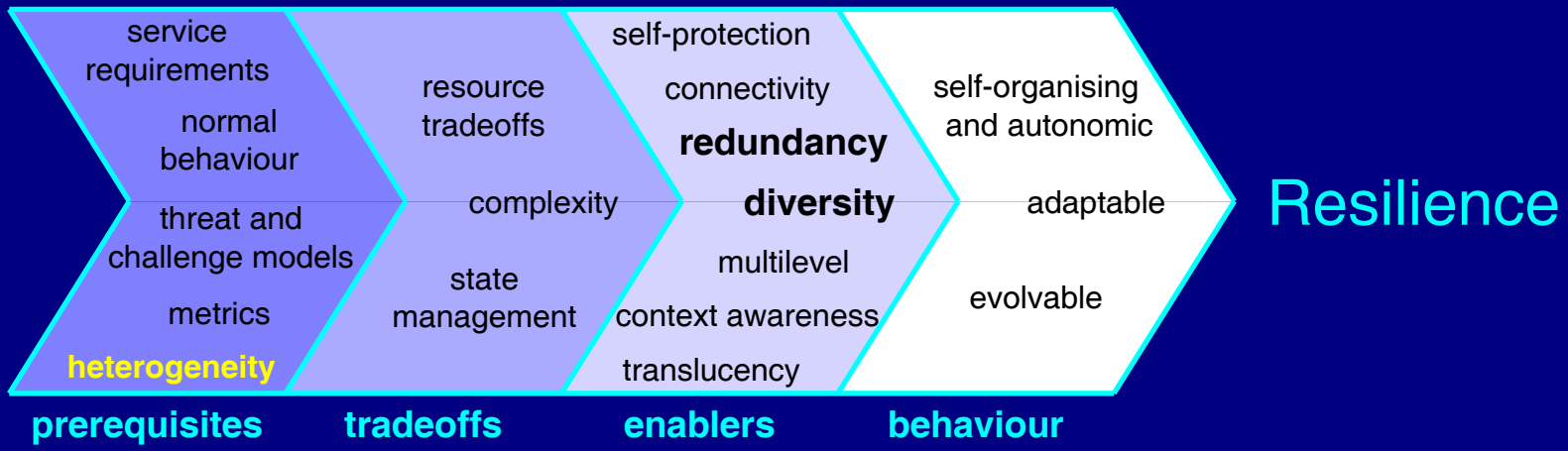
- Network resilience increasingly important
  - as we increasingly rely on the Global Internet
  - increasingly a target of attack
- Heterogeneity
  - new application domains (mobility, sensors, etc.)
  - new network technologies (wireless, etc.)
- Internet architecture strained by both

ResiliNets Strategy
D^2R^2 + DR

- Real time control loop: D^2R^2
  - **defend**
    - passive
    - active
  - detect
  - **remediate**
  - recover
- Background loop: DR
  - diagnose
  - refine



ResiliNets Principles
High Level Grouping

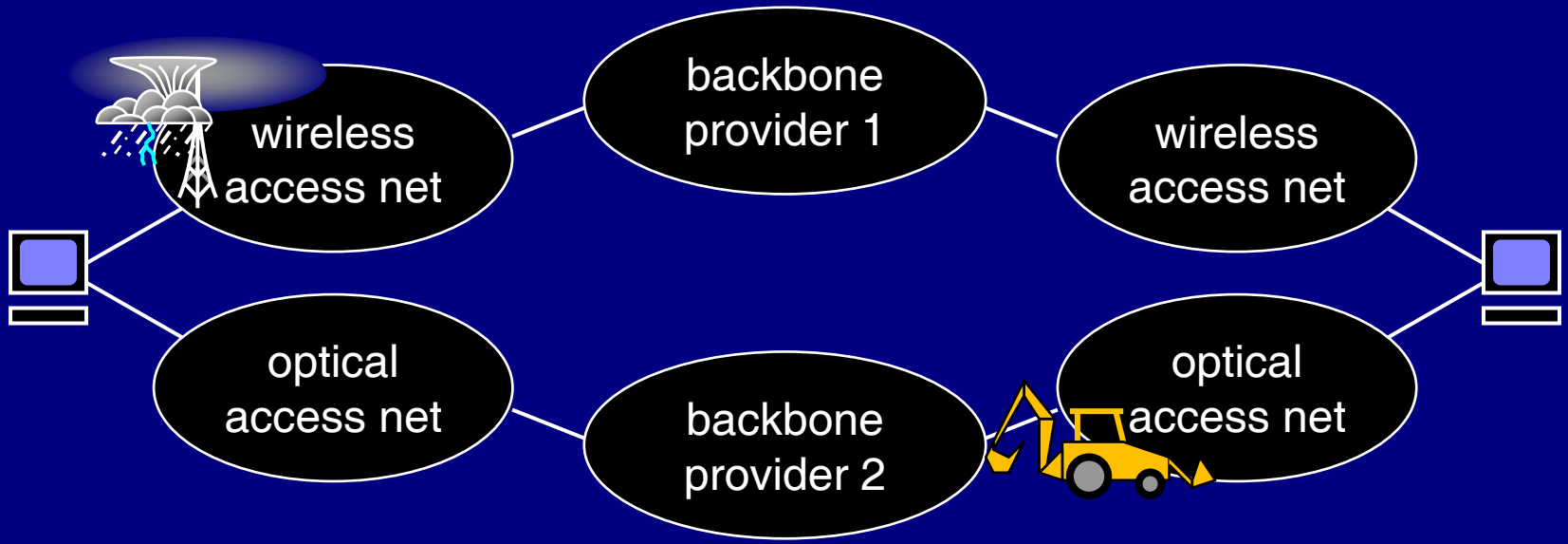


- Prerequisites: to understand and define resilience
- Tradeoffs: recognise and organise complexity
- Enablers: architecture and mechanisms for resilience
- Behaviour: require significant complexity to operate

End-to-End Communication
Redundancy and Diversity

- E2E transport over multiple diverse paths
  - that have minimal (if any) shared fate
- Diversity in
  - service provider: resilience to contract and peering disputes (e.g. Cogent vs. Level3)
  - underlying technology: resilience to medium challenge
    - e.g weather disruption of wireless mesh links
  - path geography: resilience to natural disaster and attacks
    - e.g. Baltimore tunnel fire, Hinsdale central office fire
    - fault tolerance necessary but not sufficient for survivability
- Diversity at *all layers*

End-to-End Communication
Example Scenario



- Realm path choices explicitly available to end user
  - spreading (e.g. erasure coding) or hot standby
  - service tradeoffs: optical when available, fail-over to wireless
  - cheapest path under dynamic pricing

End-to-End Communication
Knobs and Dials

Knobs ↓	Layer	Dials ↑
service class reliability mode	application	service characteristics
	E2E transport	
PoMo knobs, FD, motiv.	PoMo internetwork	path char., geography
realm oper. parameters	network realm	realm characteristics
link type and coding error control type/strength	HBH link	link characteristics

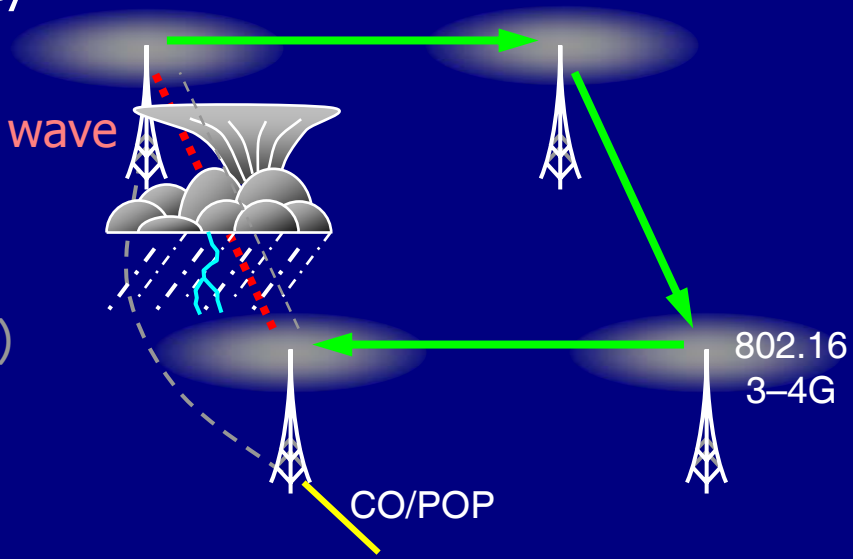
- Knobs and dials between upper layers and PoMo
  - support heterogeneous subnetworks
    - e.g. lossy wireless vs. reliable wired
  - explicit signalling of path diversity and multipath
    - geographic location of realms, nodes, channels

Resilience and Heterogeneity
Weather Disruption-Tolerant Networking

- Resilience strategy and principles
- Postmodern Internet Heterogeneity
- Example realms
  - WDTN
  - highly mobile airborne ad-hoc networking
- Evaluation Methodology
  - simulation
  - experimentation

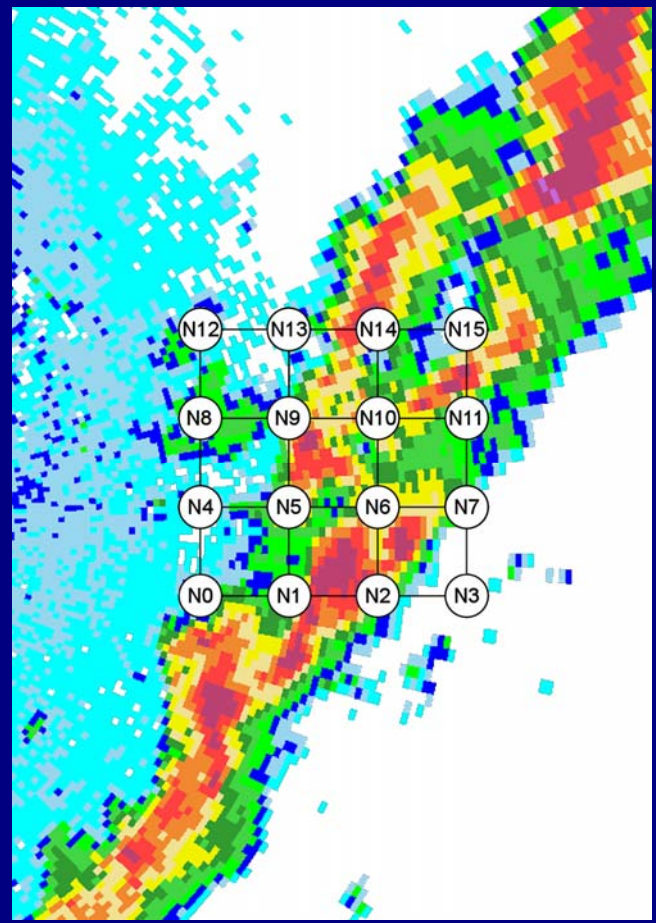
Millimeter-Wave Mesh Networks
Architecture

- Mesh architecture
  - high degree of connectivity
  - alternate diverse paths
    - severely attenuated mm wave
    - alternate mm links
    - alternate lower-freq. RF
    - fiber bypass (competitor)
- Approach
  - route around failures
    - *before* they occur
  - avoid high error links
  - P-WARP and XL-OSPF routing algorithms



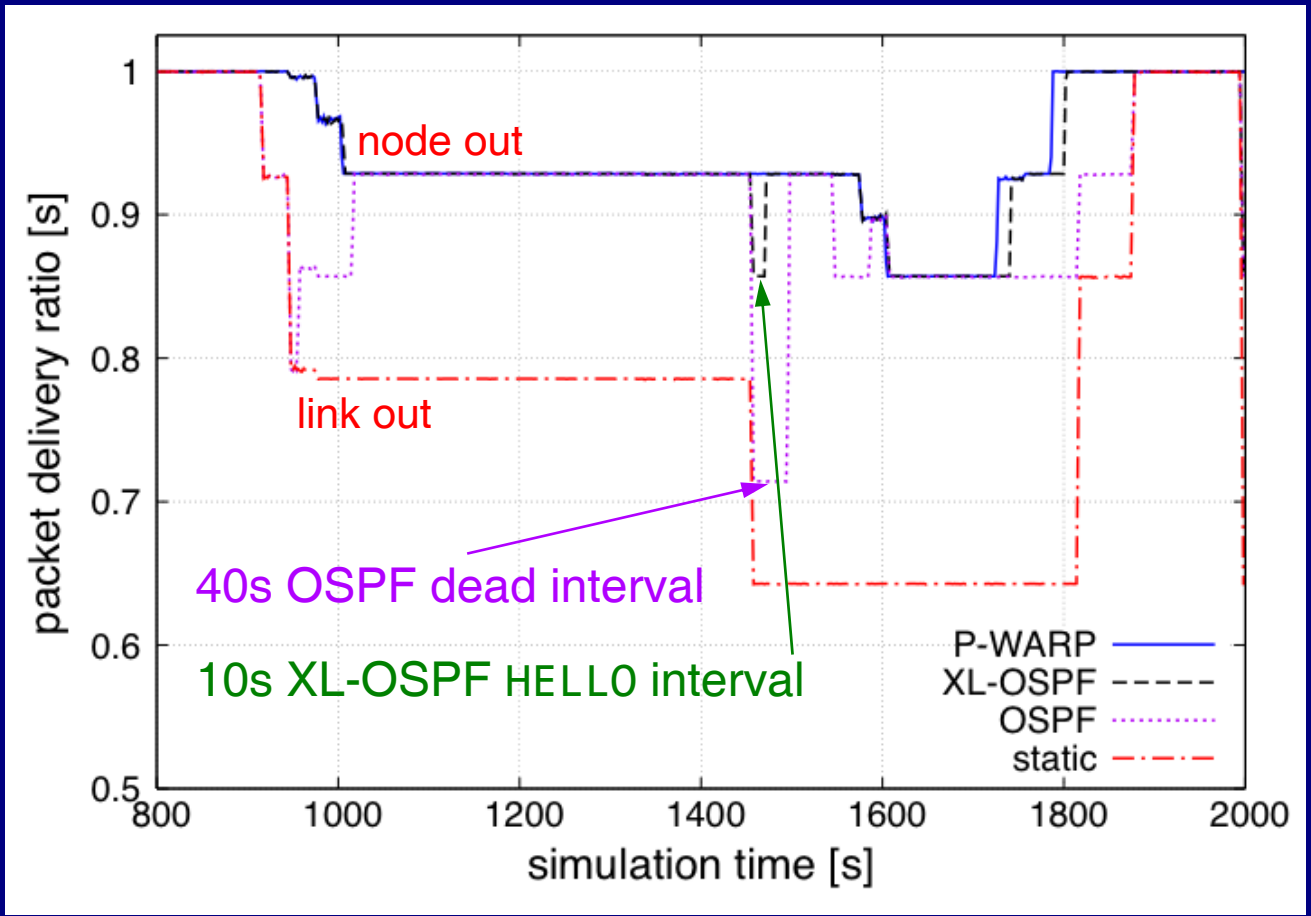
Simulations
Observed Storm in Northeast Kansas

- Millimeter-wave grid location
  - 38.8621N, 95.3793W
- Storm observed at:
  - 20:39:26Z 30 Sep 2008



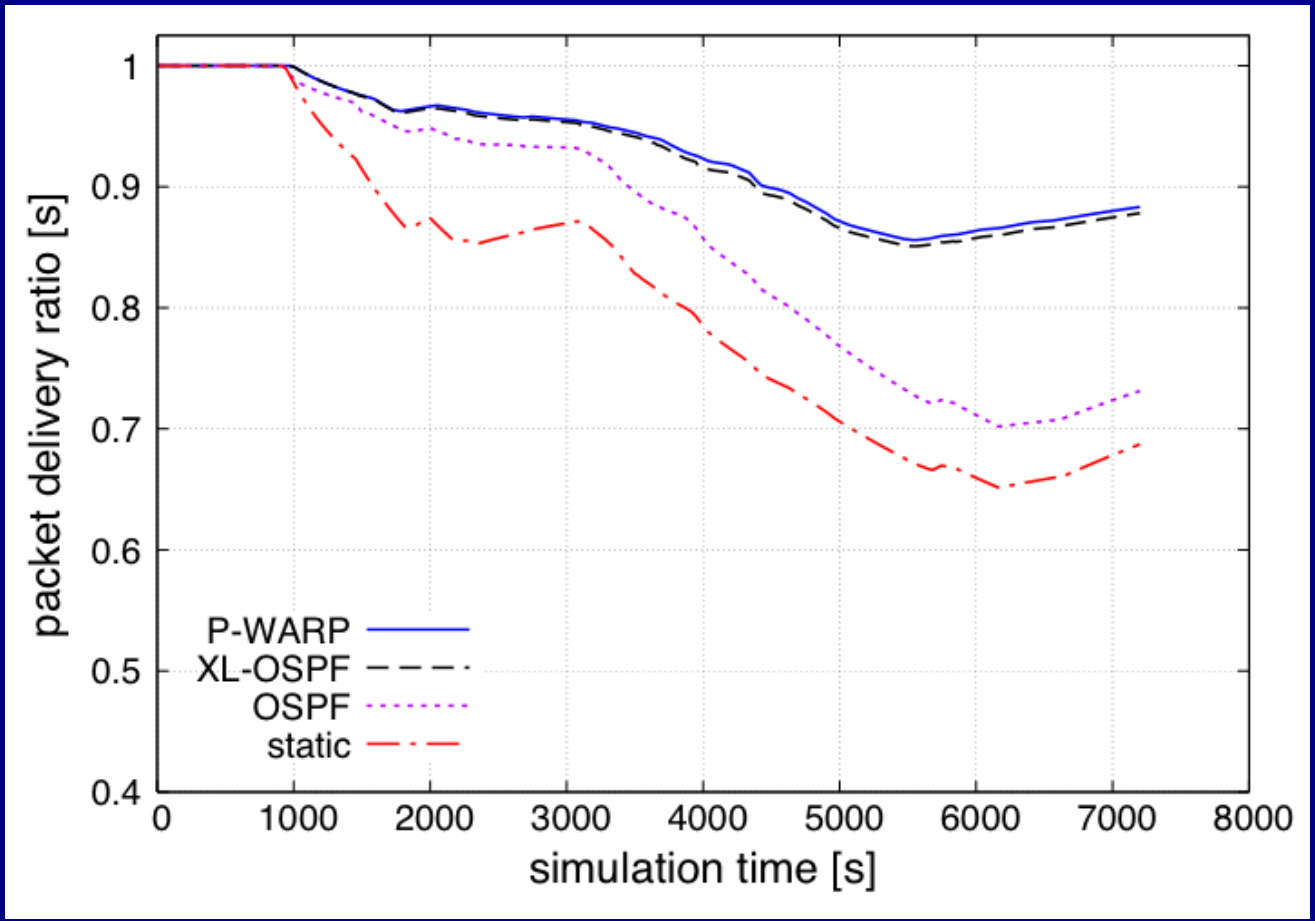
Observed Storm

Performance Analysis: Packet Loss



Observed Storm

Performance Analysis: Cumulative Loss



Resilience and Heterogeneity
Highly-Mobile Airborne Ad Hoc Networking

- Resilience strategy and principles
- Postmodern Internet Heterogeneity
- Example realms
  - WDTN
  - highly-mobile airborne ad hoc networking
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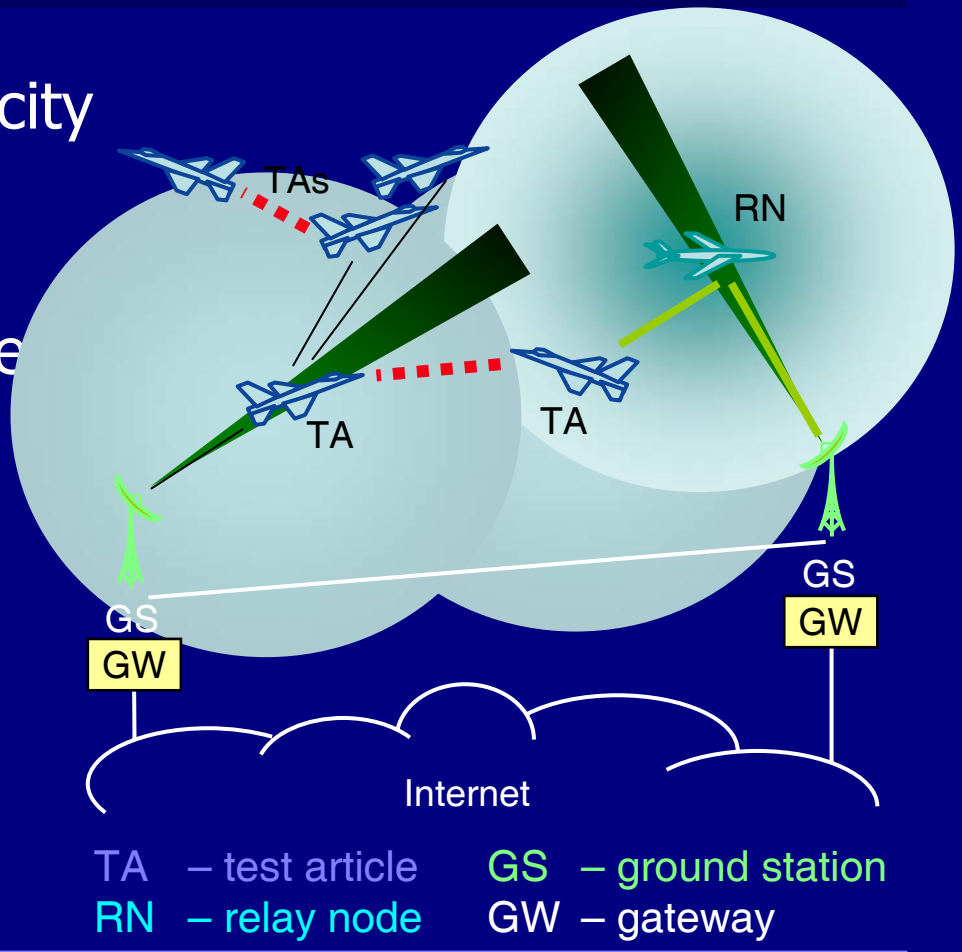
Airborne Telemetry Networking

Scenario and Environment

- Very high relative velocity
  - Mach 7 ≈ 10 s contact
  - dynamic topology
- Communication channe
  - limited spectrum
  - asymmetric links
    - data down omni
    - C&C up directional
- Multihop
  - among TAs
  - through relay nodes

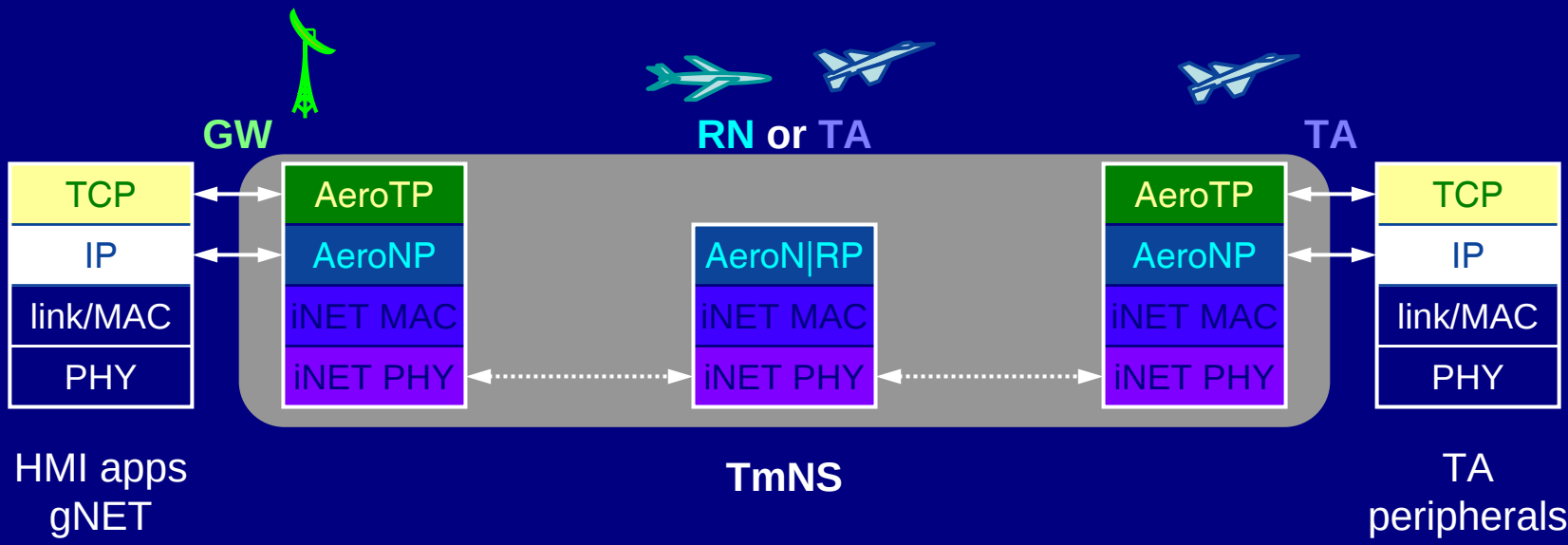


Airborne Telemetry Networking
Link Stability and Contact Durations

Scenario	Transmit Range [nmi]	Relative Velocity	Contact Duration [sec]
Single-Hop Best Case			
GS – TA	140	400 knots	2520
TA – TA	15	800 knots	135
Single-Hop Worst Case			
GS – TA	100	Mach 3.5	300
TA – TA	10	Mach 7.0	15

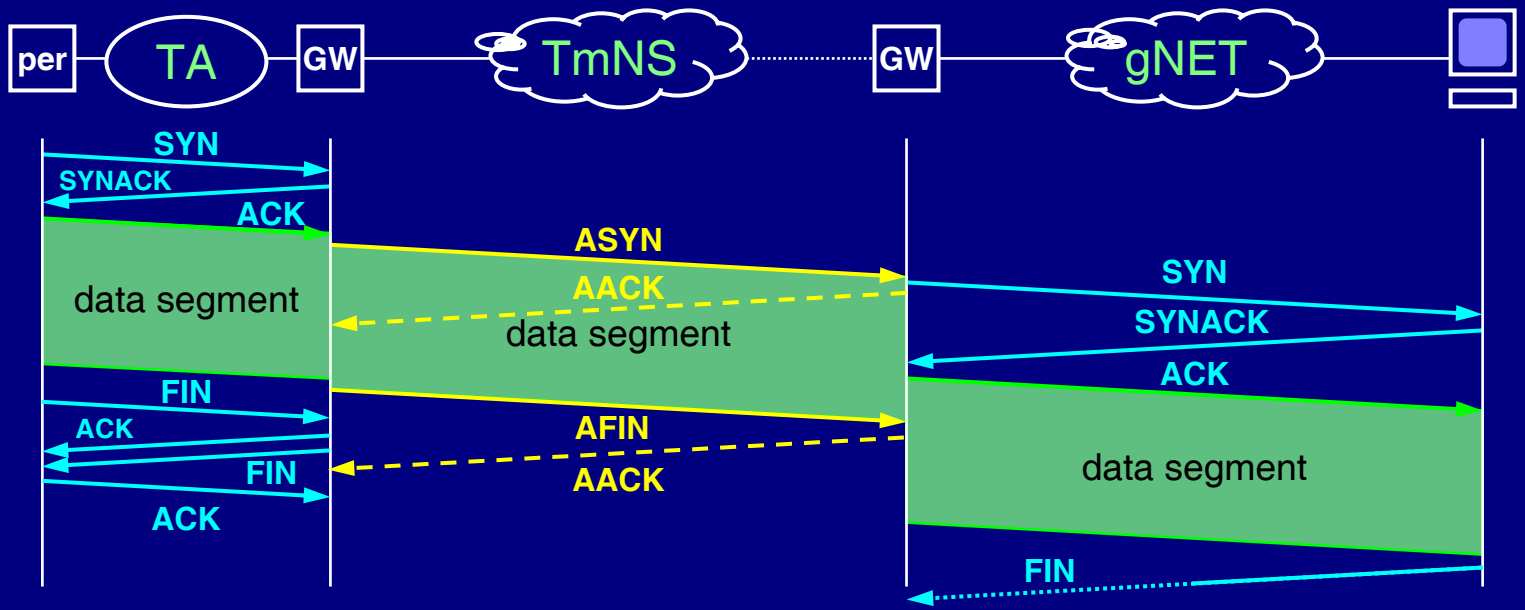
- Multihop case significantly harder
  - probability of stable end-to-end path very low

Airborne Network Protocol Suite
Protocol Stack and Interoperability



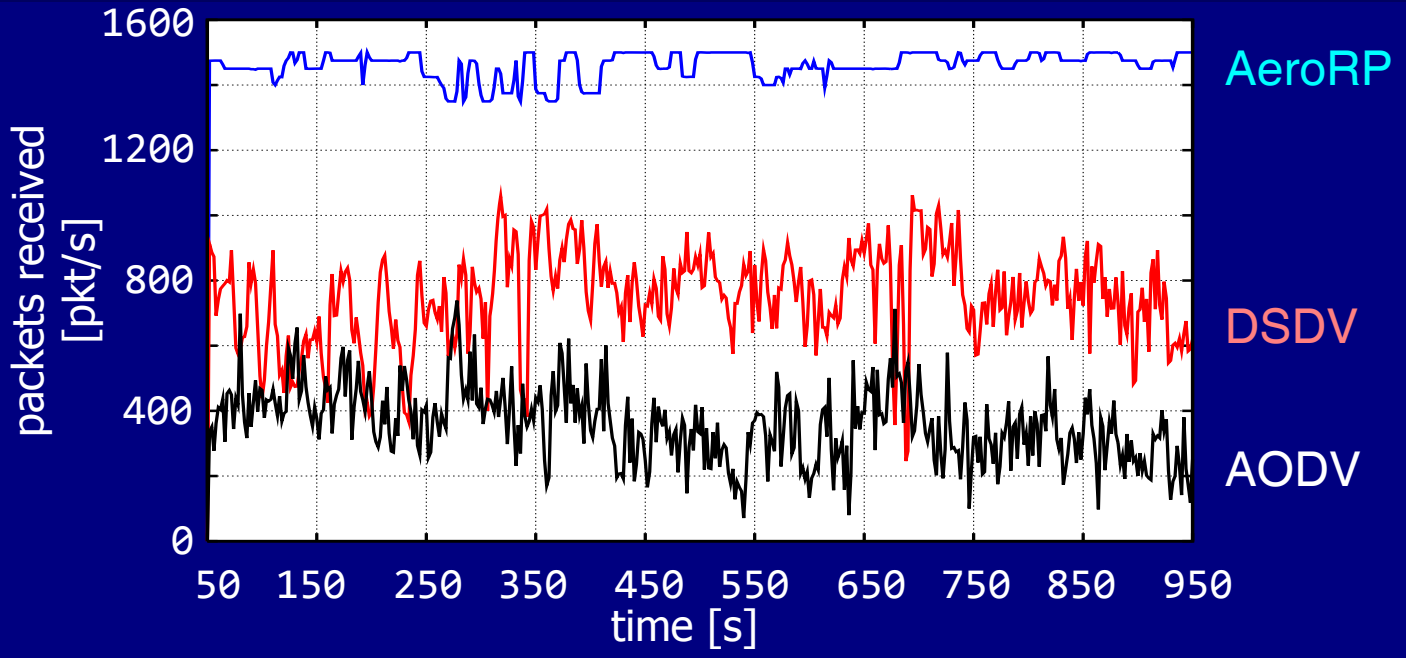
- AeroTP: TCP-friendly transport
- AeroNP: IP-compatible forwarding
- AeroRP: routing

AeroTP
Connection and Flow Management



- AeroTP is *opportunistic*: data overlaps control
  - final ACK of TCP 3WH at GW initiates AeroTP ASYN
  - data follows immediately without 3-way handshake in TmNS
  - optional AACK depending on mode; loss may retrigger ASYN

AeroRP
Performance Comparison (preliminary)



- 60-node ns-2 simulation in 150×150 km² test range
- TA tx range = 15 nmi; v = [200 knot, Mach 3.5]
- CBR traffic = 200 kb/s per TA [MILCOM 2008]

Resilience and Heterogeneity
Evaluation Methodology: Simulation

- Resilience strategy and principles
- Postmodern Internet Heterogeneity
- Example realms
  - WDTN
  - highly mobile airborne ad-hoc networking
- Evaluation methodology
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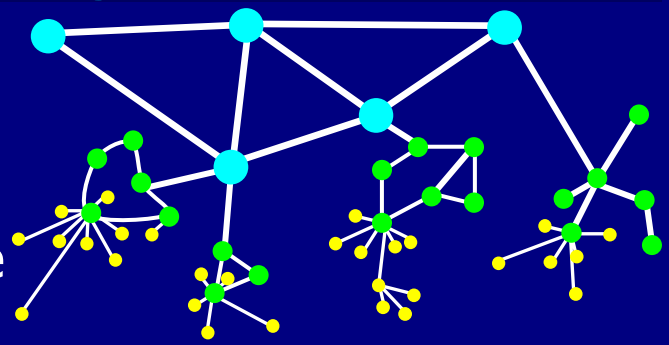
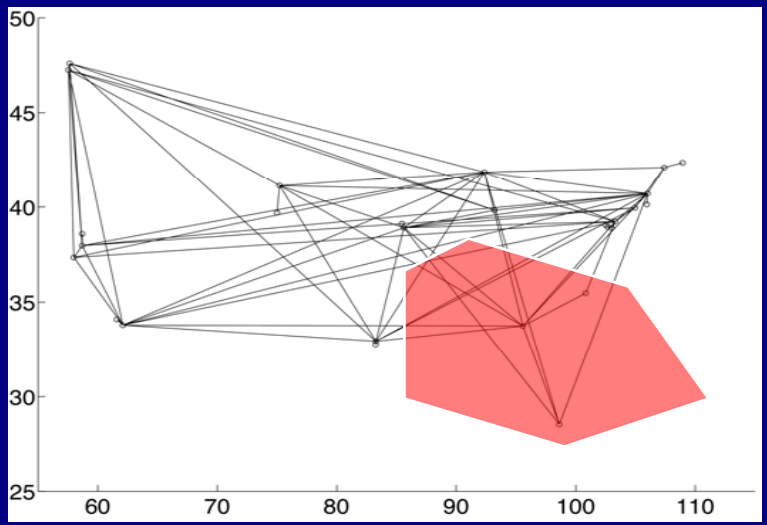
Evaluation Methodology
Flexible and Realistic Topology Generation

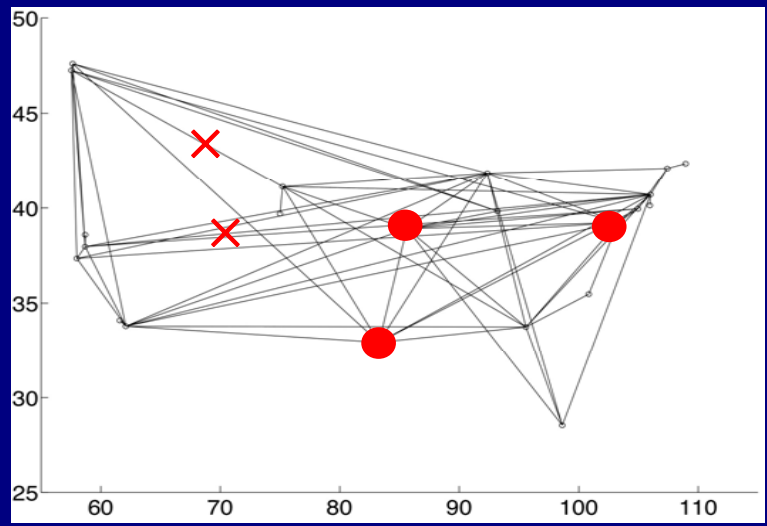


- KU-LoCGen
  - evaluation of PoMo mechanisms
  - network engineering for resilience
- Level 1: backbone realms
  - nodes distributed based on location constraints
  - links generated using various models under cost constraints
- Level 2: access network realms
  - distributed around backbone nodes
  - access network connectivity: ring, star, mesh
- Level 3: subscribers
  - distributed around access network node

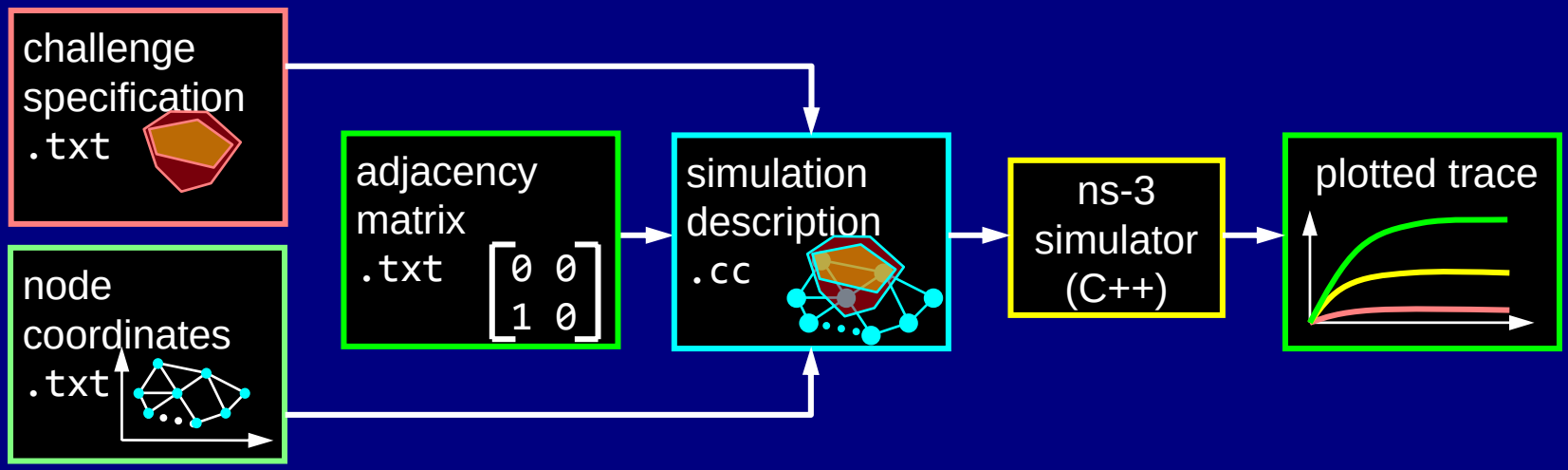
Evaluation Methodology
Challenge Simulation Module

- Separate challenge from network simulation
- Simulate challenges to any network over time interval
  - natural disaster: polygon destroys network infrastructure
  - attack: {node|link} down, wireless link attenuated





Evaluation Methodology
Challenge Simulation Module

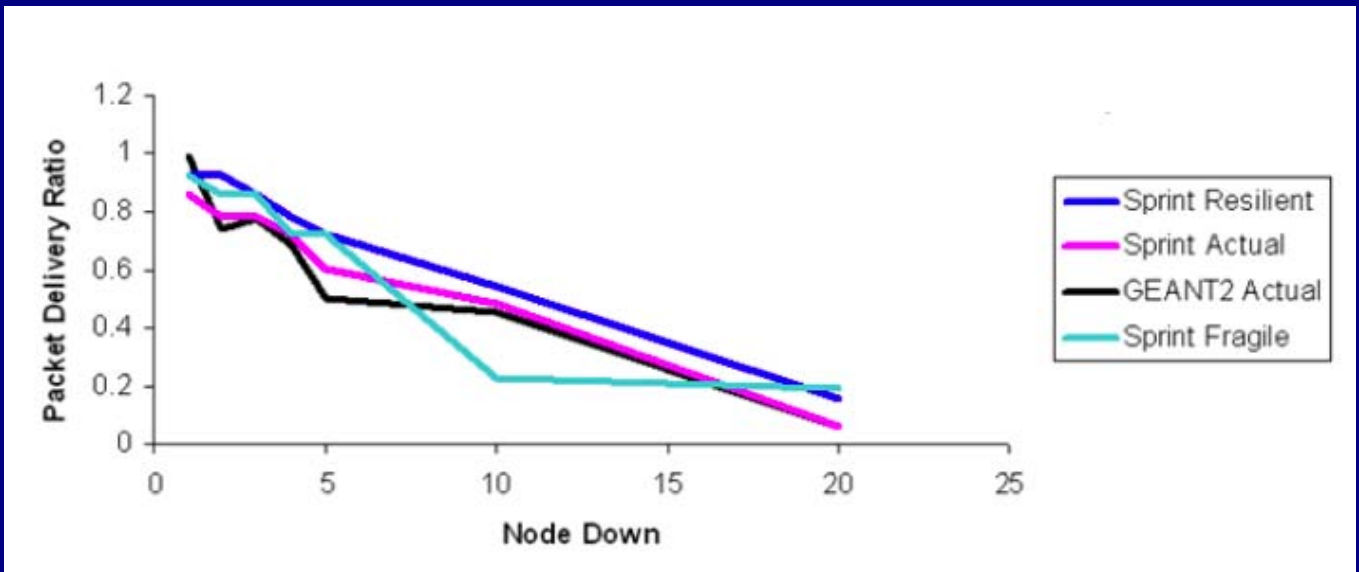


- KU-CSM Challenge Simulation Module
  - challenge specification describes challenge scenario
  - network coordinates provide node geo-locations
  - adjacency matrix specifies link connectivity
  - input to conventional ns-3 simulation run
  - generates trace to plot results

KU-LoCGen

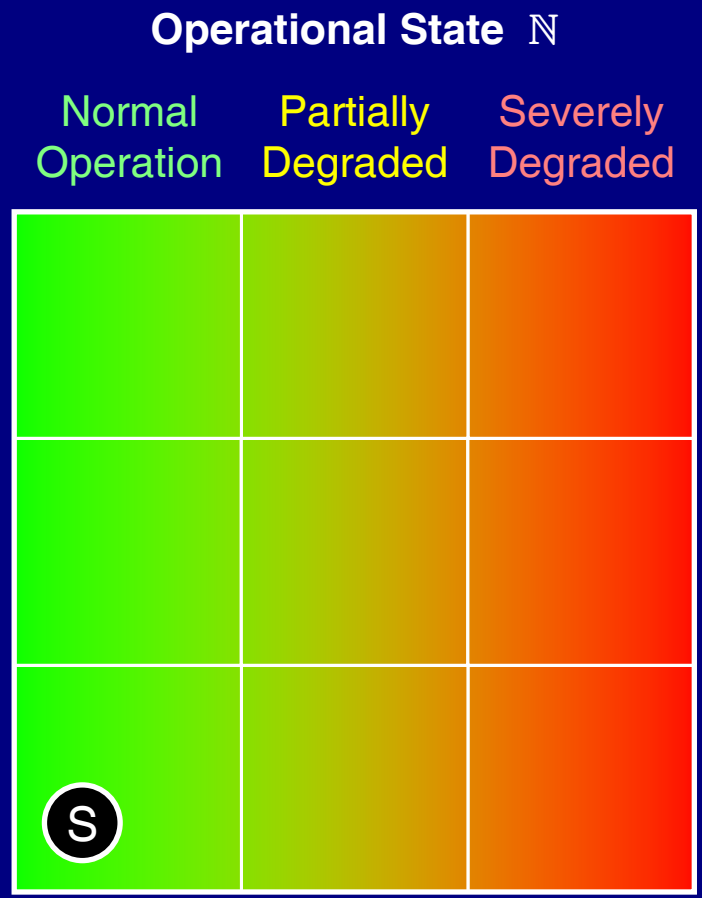
Evaluation Methodology
Example: Resilience to Multiple Node Failures

- Example (and *very preliminary* results)
  - relationship of packet delivery ratio to multiple node failures
  - synthetic Sprint topologies generated by KU-LoCGen



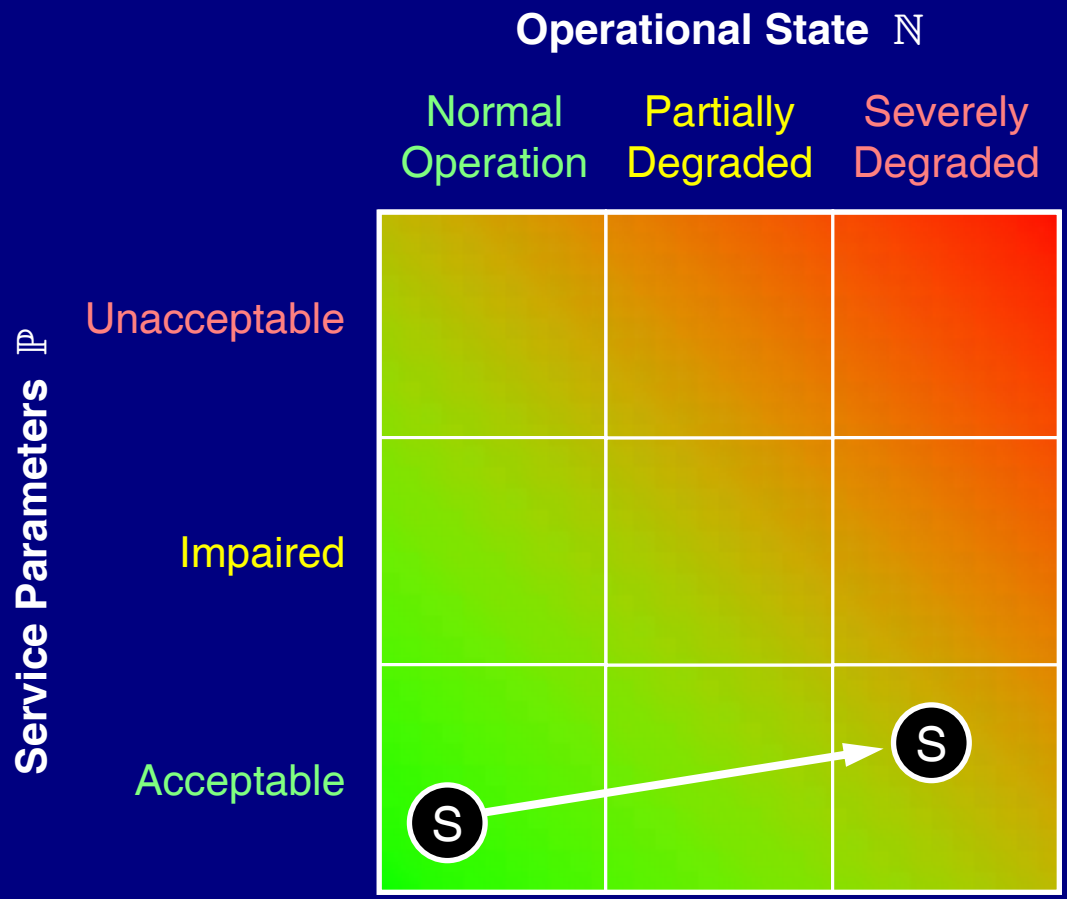
Resilience State Space
Operational Resilience

- Operational resilience
  - minimal degradation
  - in the face of challenges
- Resilience state
  - remains in normal operation



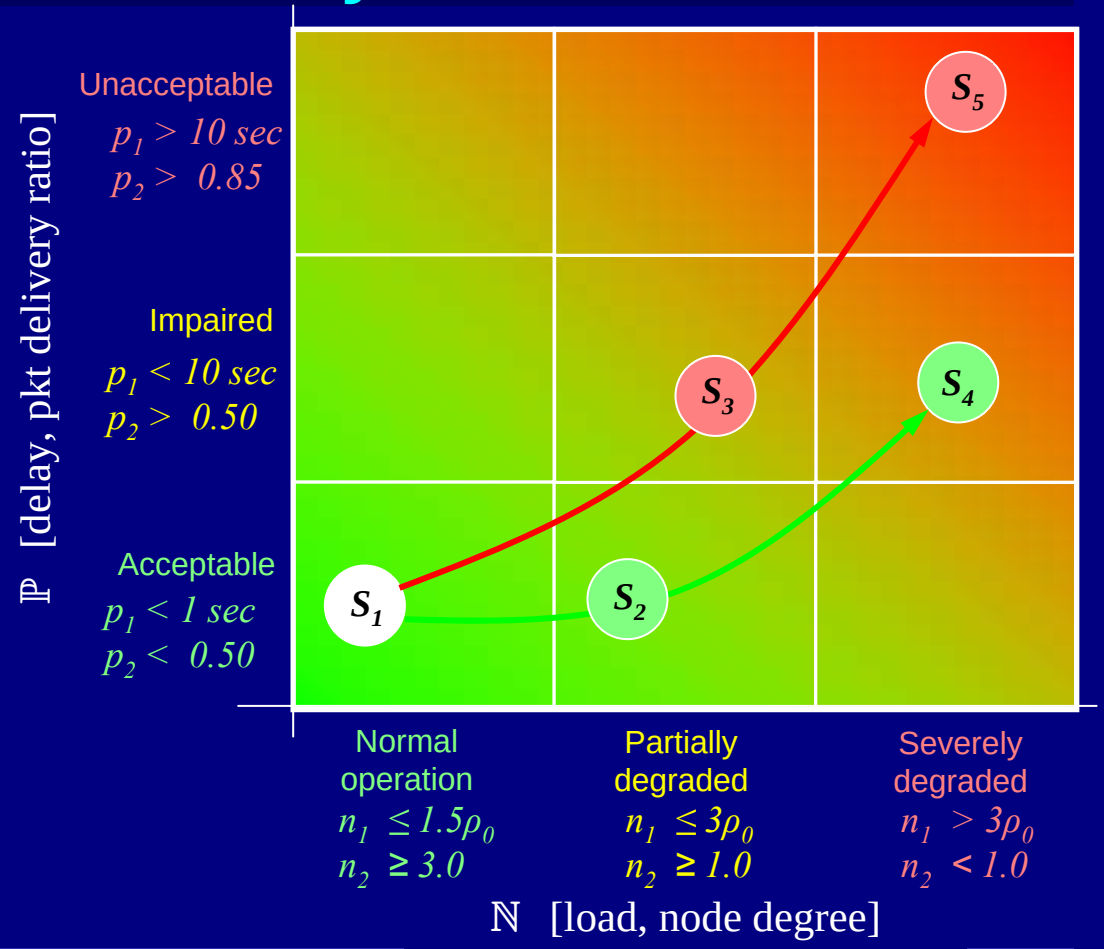
Resilience State Space
Service Resilience

- Service resilience
  - acceptable service
  - in the face of degraded operation
- Resilience state
  - remains in acceptable service



Resilience State Space
Resilience Trajectories

- Choose scenario
  - network
  - application
- Metrics
  - choose
  - aggregate
- Observe
  - under challenge



Resilience and Heterogeneity
Evaluation Methodology: Experimentation

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GENI
Overview

- GENI: Global Environments for Network Innovation
  - funded by the US NSF
  - managed by the GPO (GENI Project Office – BBN)
- Goal: new experimental network infrastructure
- 1st solicitation: 29 projects funded
  - grouped into 5 control framework clusters (PlanetLab, …)
  - including 2 regional testbeds (GpENI and MANFRED)
- 2nd solicitation closed and under final review
  - decisions hopefully by GEC5 (July in Seattle)
  - FIRE/GENI workshop in conjunction with GEC5

GpENI
Overview

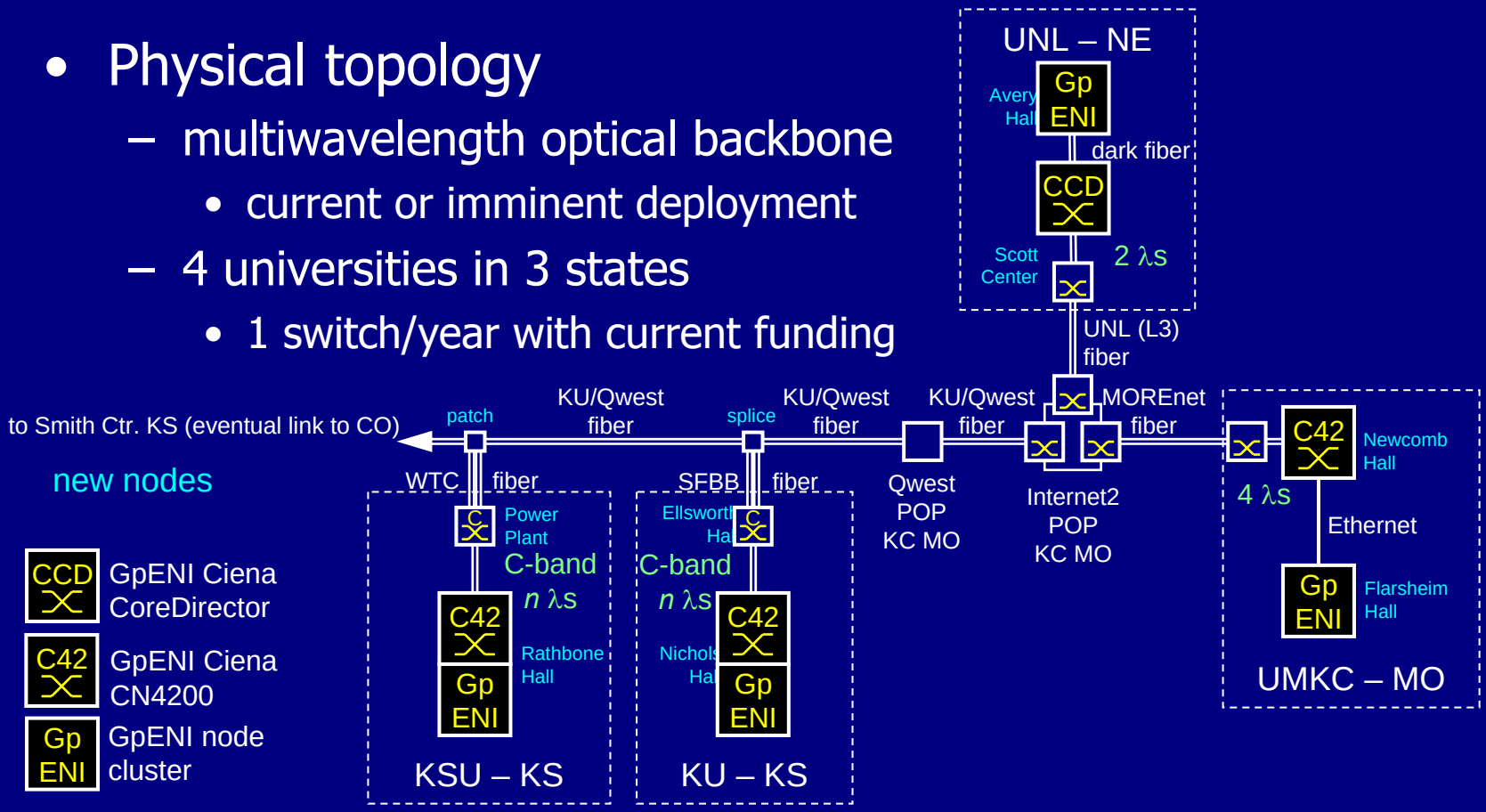
- GpENI [dʒɛ'pi ni]
  Great Plains Environment for Network Innovation
- Regional network part of Cluster B in GENI Spiral 1
  - exploiting new fiber infrastructure in KS, MO, and NE

GpENI
Project Goals

- Collaborative research infrastructure in Great Plains
- Flexible infrastructure to support GENI program
- Open environment for network research community
- Outreach to grow GpENI infrastructure
  - Great Plains region
  - internationally including EU FIRE

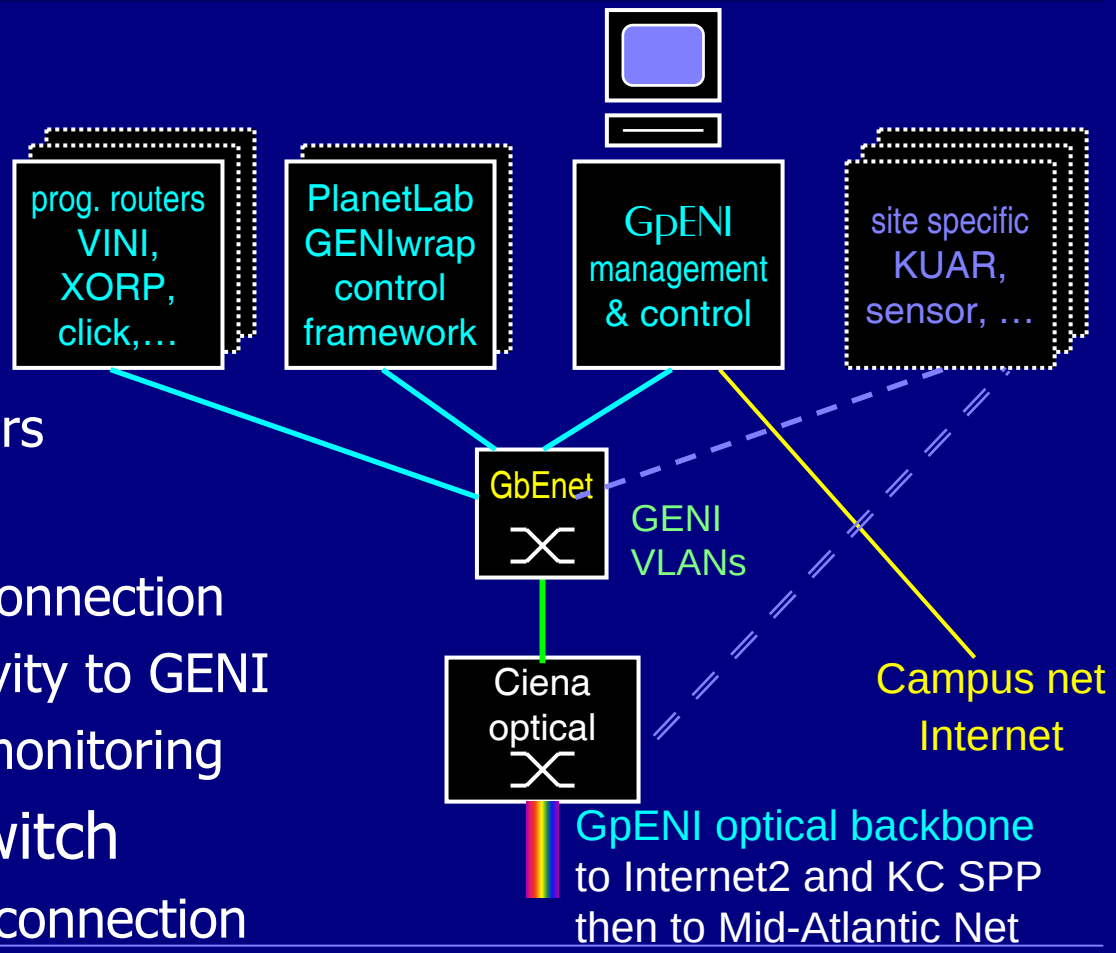
GpENI
Physical Topology and Network Infrastructure

- Physical topology
  - multiwavelength optical backbone
    - current or imminent deployment
  - 4 universities in 3 states
    - 1 switch/year with current funding



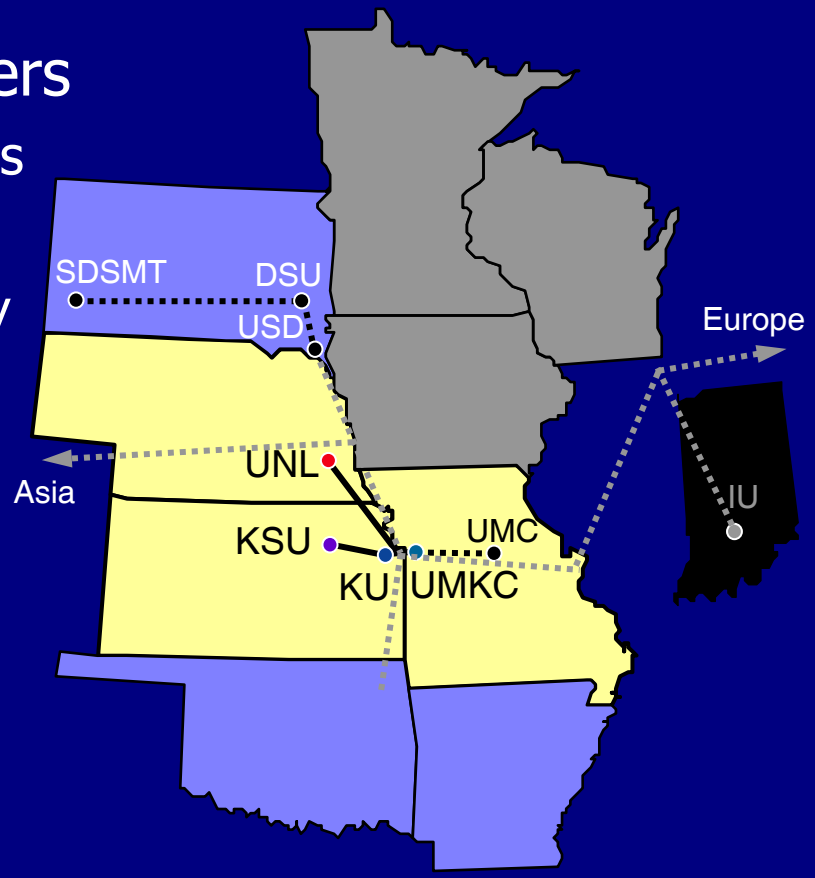
GpENI
Node Cluster

- GpENI cluster
- 5–10 PCs
  - GpENI mgt.
  - L4: PlanetLab
  - L3: prog. routers
- GbE switch
  - arbitrary interconnection
  - VLAN connectivity to GENI
  - SNMP cluster monitoring
- Ciena optical switch
  - L1 GpENI interconnection



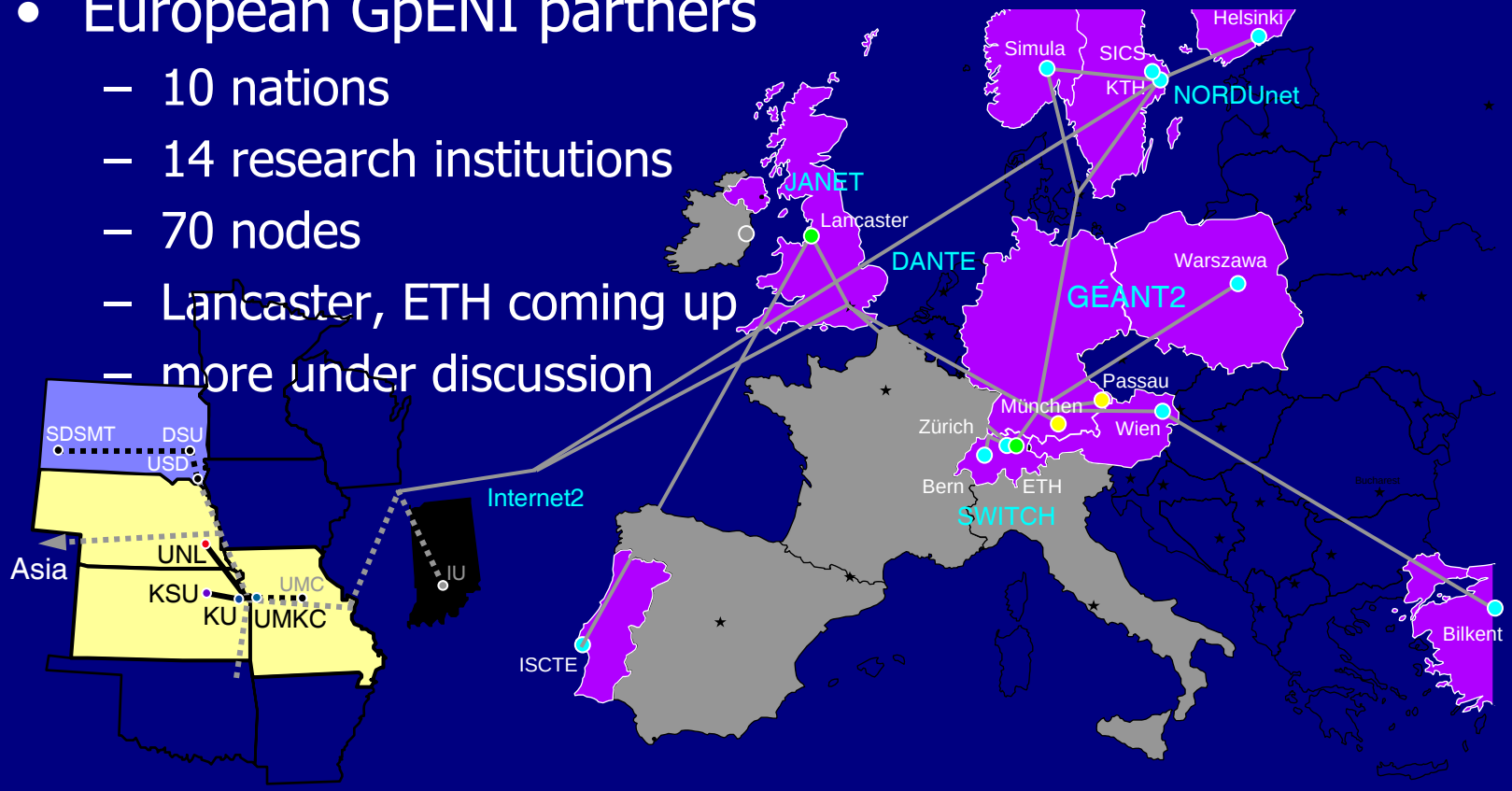
GpENI
GPN Proposed Expansion

- Regional US GpENI partners
  - South Dakota: 3 universities
  - Missouri: 1 university
  - GMOC at Indiana University

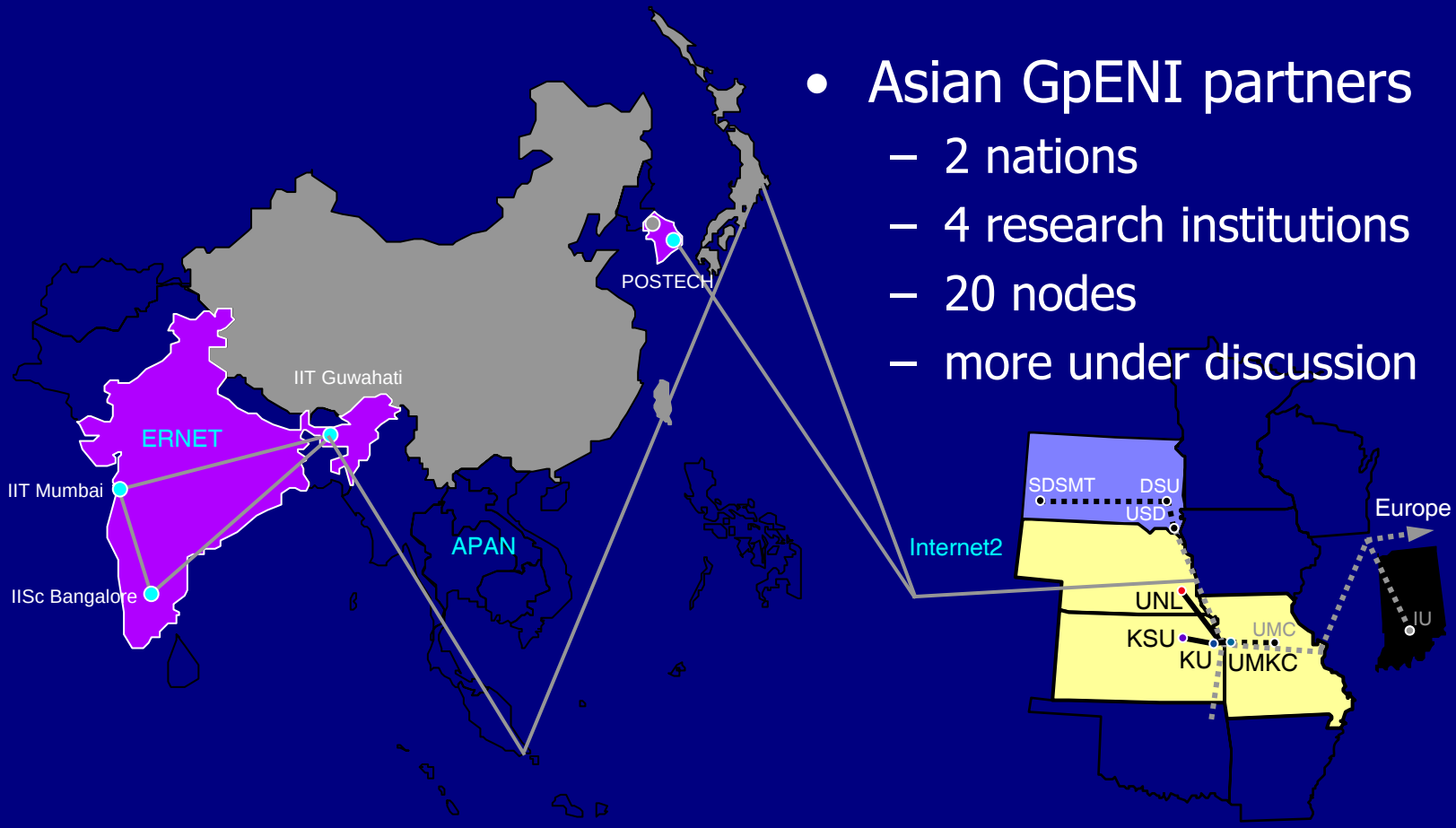


GpENI
European Proposed Expansion

- European GpENI partners
  - 10 nations
  - 14 research institutions
  - 70 nodes
  - Lancaster, ETH coming up
  - more under discussion



GpENI
Asian Proposed Expansion



- Asian GpENI partners
  - 2 nations
  - 4 research institutions
  - 20 nodes
  - more under discussion

End