Future Internet Resilience

Summary of Networking Research at The University of Kansas ITTC

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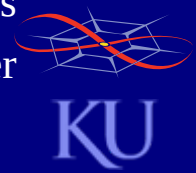
http://wiki.ittc.ku.edu/resilinets



ITTC Networking Research
Major Themes

- Major related research themes
  - future Internet architecture and infrastructure
  - resilient and survivable networks
  - information assurance and security
  - disruptive and novel communication paradigms

ITTC Networking Research
Collaborators and Funding

- Collaborators
  - regional: K-State, UMKC, UNL, …
  - national: Rutgers, Penn State, CMU, ORNL, …
  - international: U. Lancaster UK, ETH Zürich, TU-Munich, …
- Funding
  - NSF FIND, GENI, …
  - DoD DARPA, CTEIP, …
  - EU FP6 SAC, FP7 FIRE
  - Industry: Sprint, …

Resilient Networks
Motivation

- Increasing reliance on network infrastructure

⇒ Increasingly severe consequences of disruption

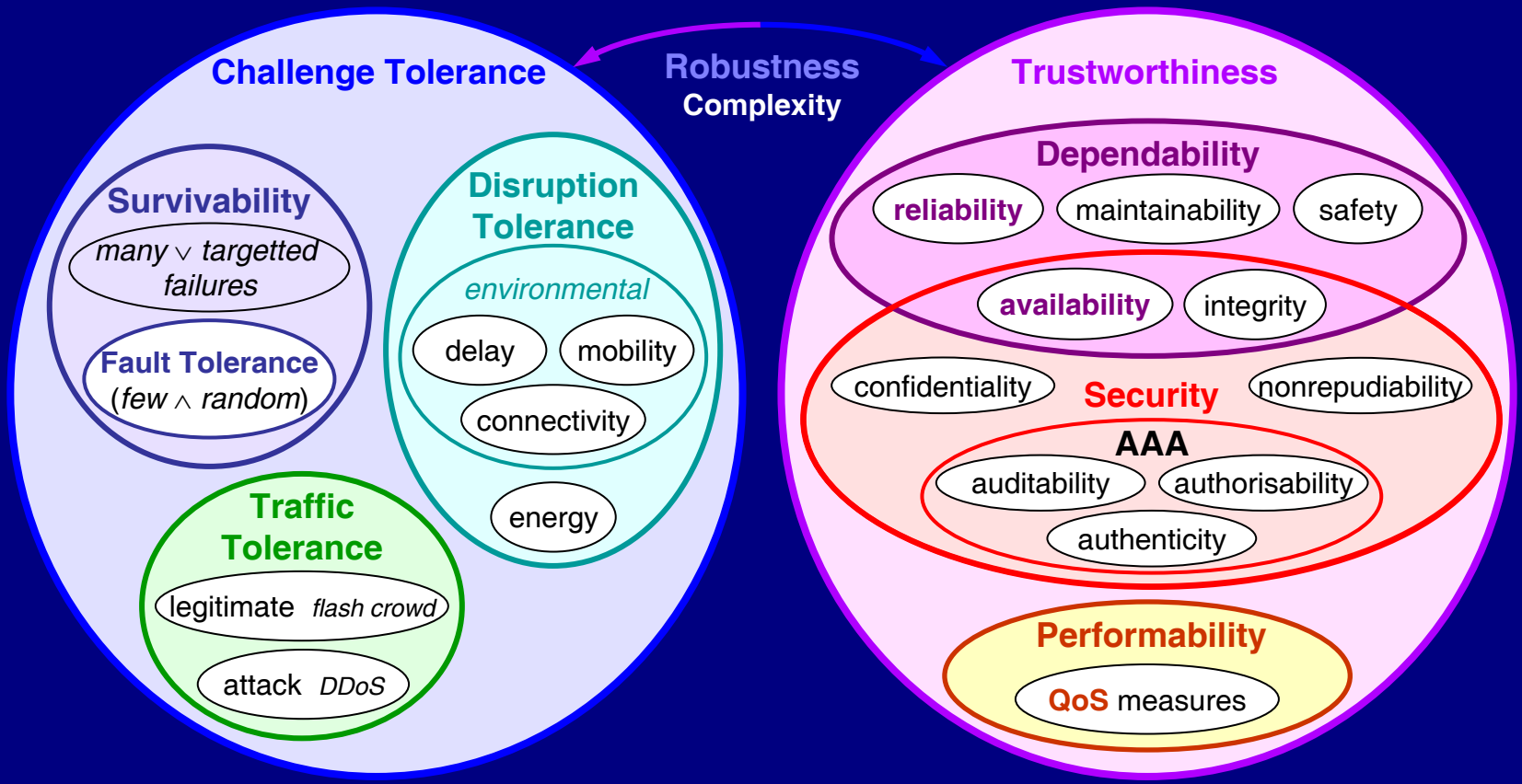
⇒ Increasing attractiveness as target from bad guys

- Internet is *critical infrastructure*
  - interdependent with other CI, e.g. power grid

Resilient Networks
Resilience Definition

- Resilience
  - provide and maintain acceptable service
  - in the face of faults and challenges to normal operation
- Challenges
  - faults
  - unintentional misconfiguration or operational mistakes
  - large scale disasters (natural and human-made)
  - malicious attacks from intelligent adversaries
  - environmental challenges (wireless, mobility, delay)
  - unusual but legitimate traffic
  - service failure at a lower level

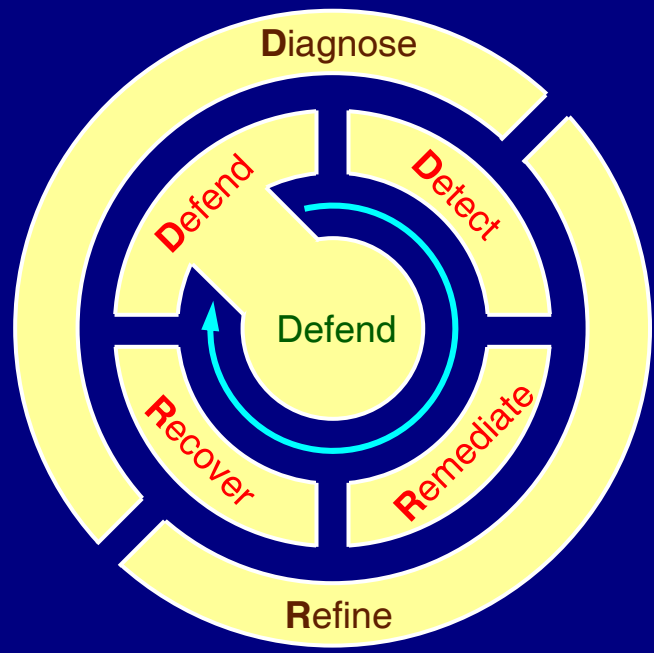
Resilience Scope
Relationship to Other Disciplines



Resilience Architecture
ResiliNets Strategy: D^2R^2 + DR

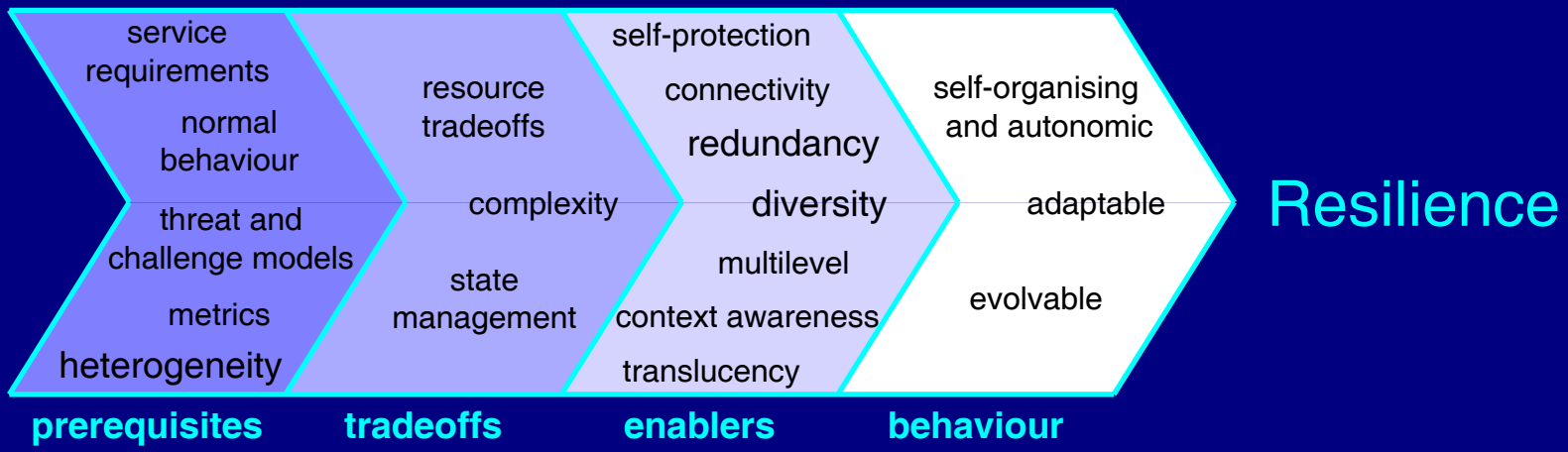
- Real time control loop: D^2R^2
  - defend
    - passive
    - active
  - detect
  - remediate
  - recover
- Background loop: DR
  - diagnose
  - refine

[ComNet 2010]



Resilience Architecture

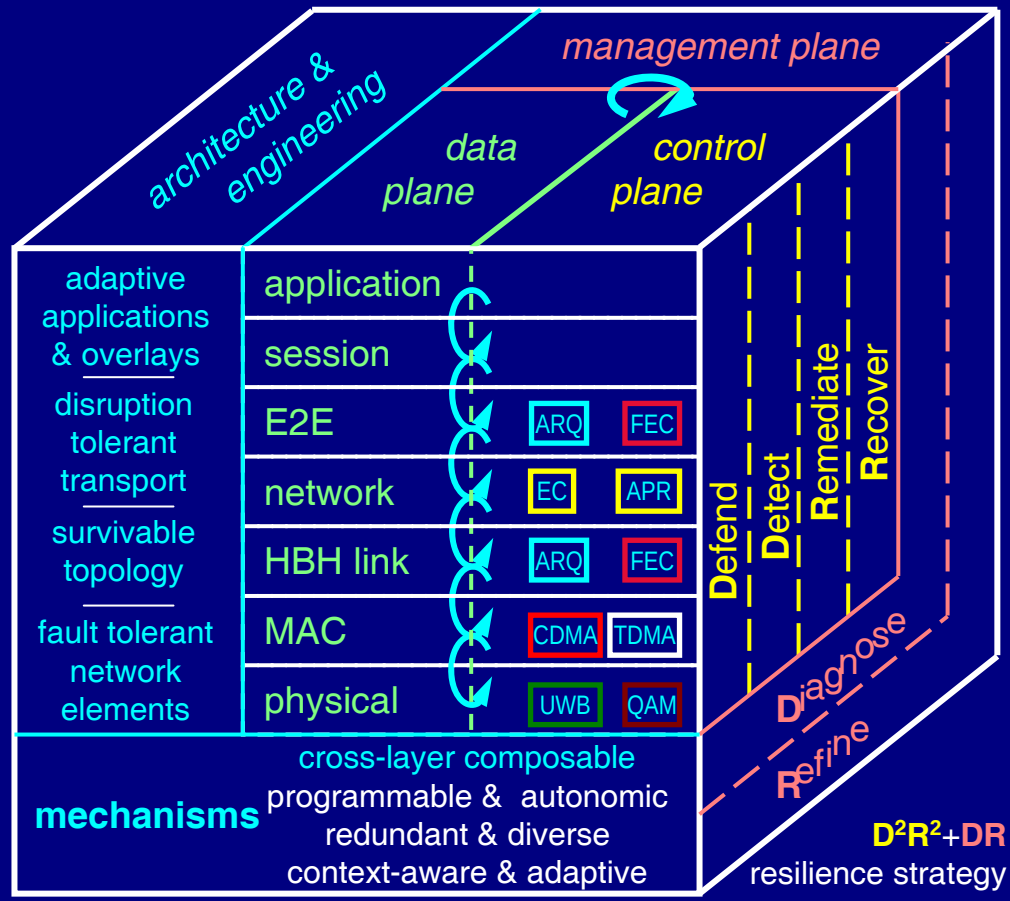
ResiliNets Principles



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

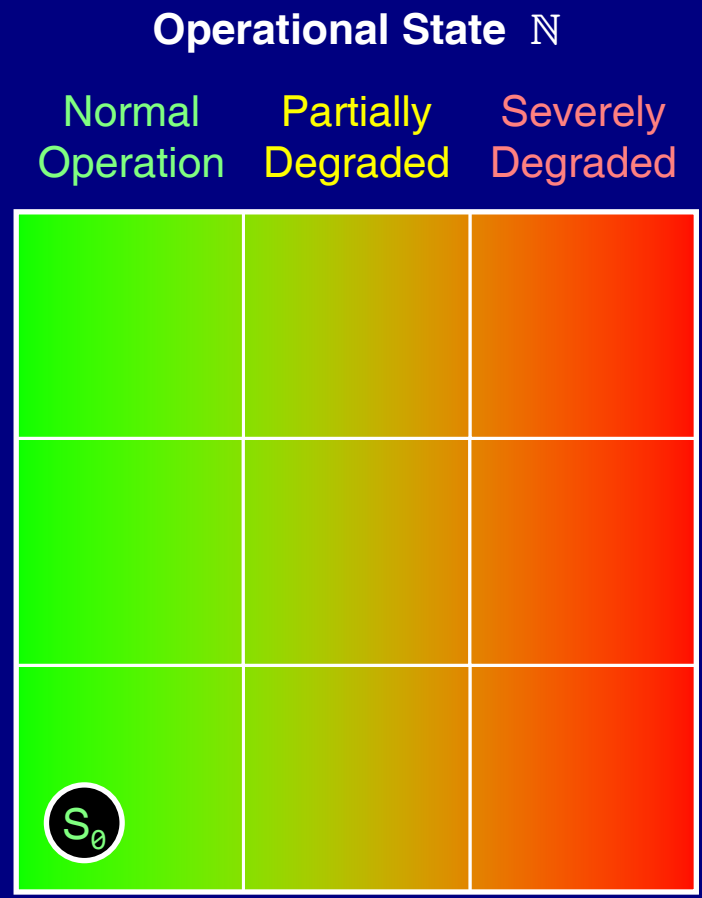
Resilience Architecture
Multilevel Resilience and Cross-Layering

- ResiliNets Cube
  - multilevel
    - protocol layers
    - planes
    - mechanisms
- D^2R^2+DR strategy
  - D^2R^2 control plane
  - DR mgt. plane
- Cross-layering
  - knobs and dials are metrics
  - $\mathbb{K},\mathbb{D} \subseteq \mathbb{N} \cup \mathbb{P}$



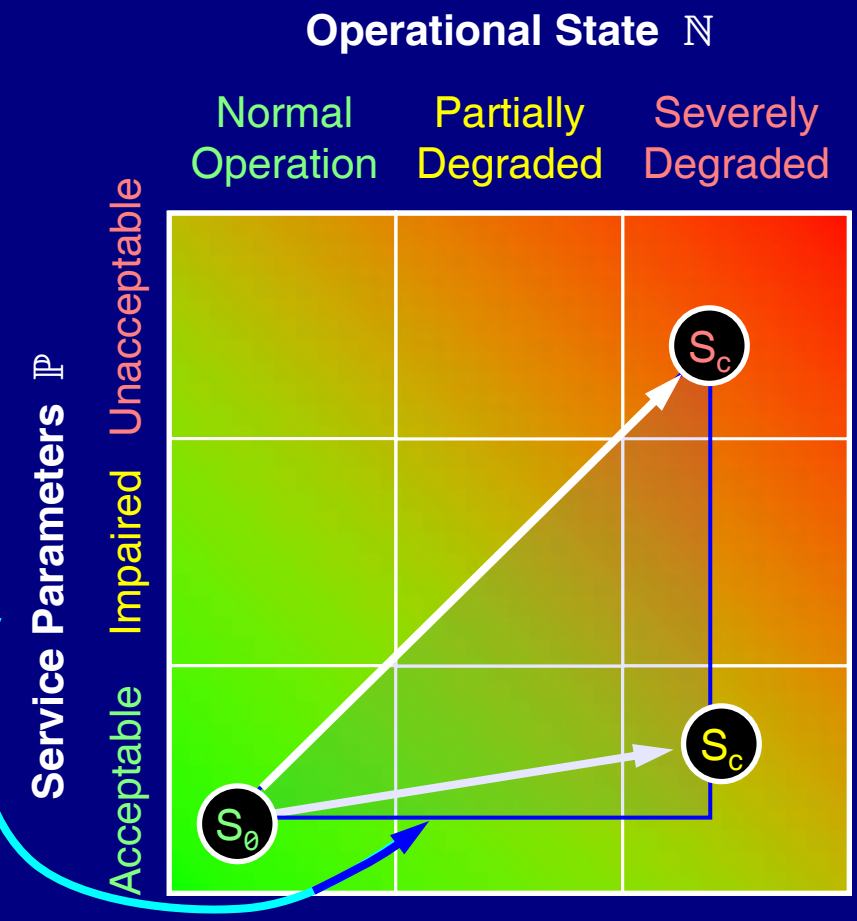
Resilience Quantification
State Space: Operational Resilience

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



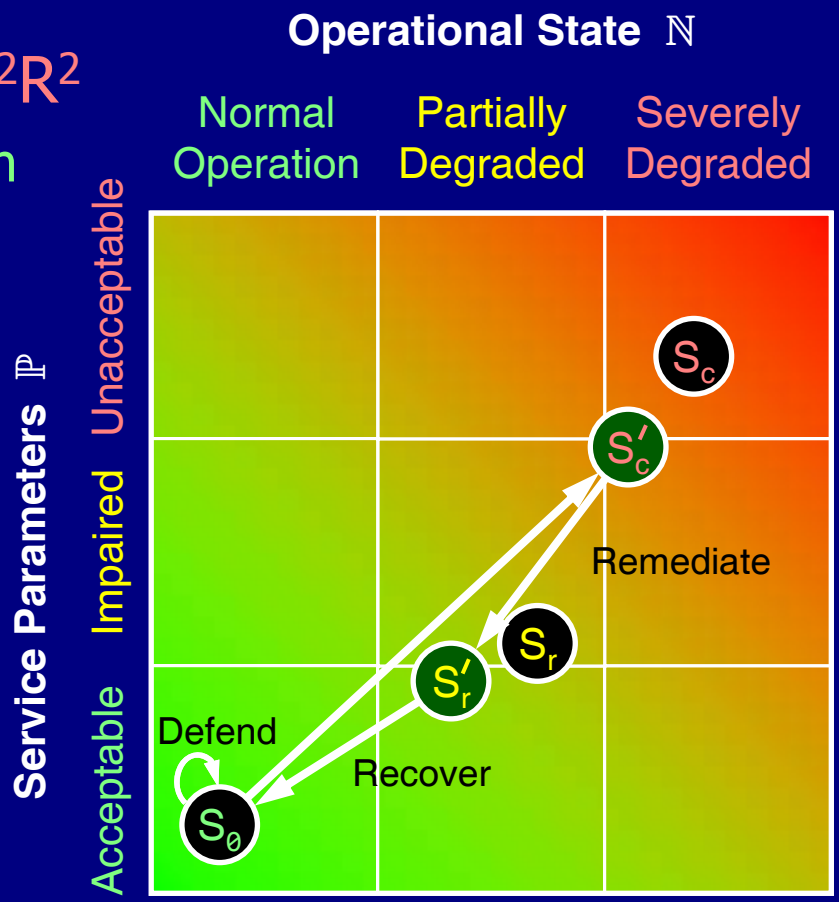
Resilience Quantification
State Space: Service Resilience

- Service resilience
  - acceptable service
  - given degraded operation
- Resilience state
  - remains in acceptable service
- Resilience
  - $\mathbb{R}$ = area under trajectory
  - for particular scenario
  - resilience $\Re$ over all scenarios

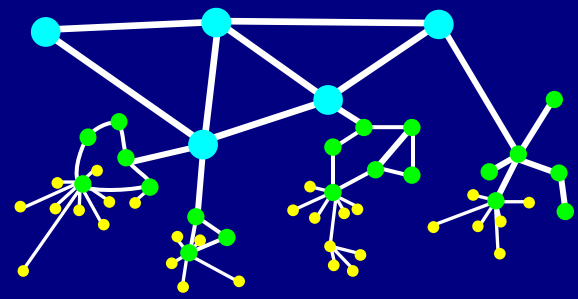


Resilience Quantification
D^2R^2 + DR Relationship to State Space

- Real time control loop: D^2R^2
  - defend keeps toward origin
    - passive
    - active
  - detect when leaves
  - remediate pushes back
  - recover back to origin
- Background loop: DR
  - diagnose
  - refine tightens trajectory



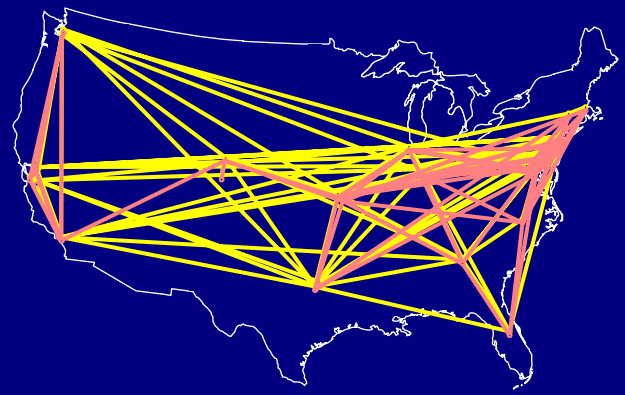
Resilience Evaluation
Topology Generation: KU-LoCGen

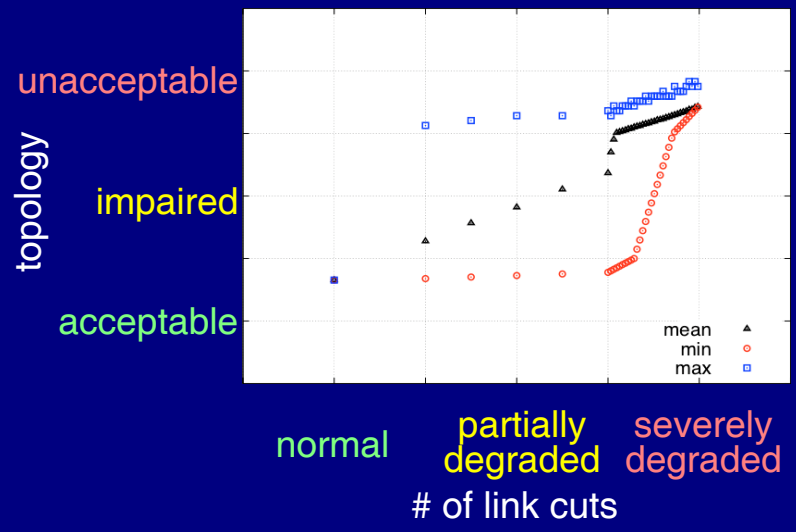


- Generation of realistic topologies
- Multilevel hierarchy
  - level 1: represents (tier 1) backbone
  - level 2: represents access networks around a backbone PoP
  - level 3: represents subscriber nodes
- Constrained generation
  - geographic node location (infrastructure or population)
  - constrained link location (based on exiting fiber runs)
  - constrained cost (fixed + variable cost)
  - graph-theoretic constraints for resilient diversity

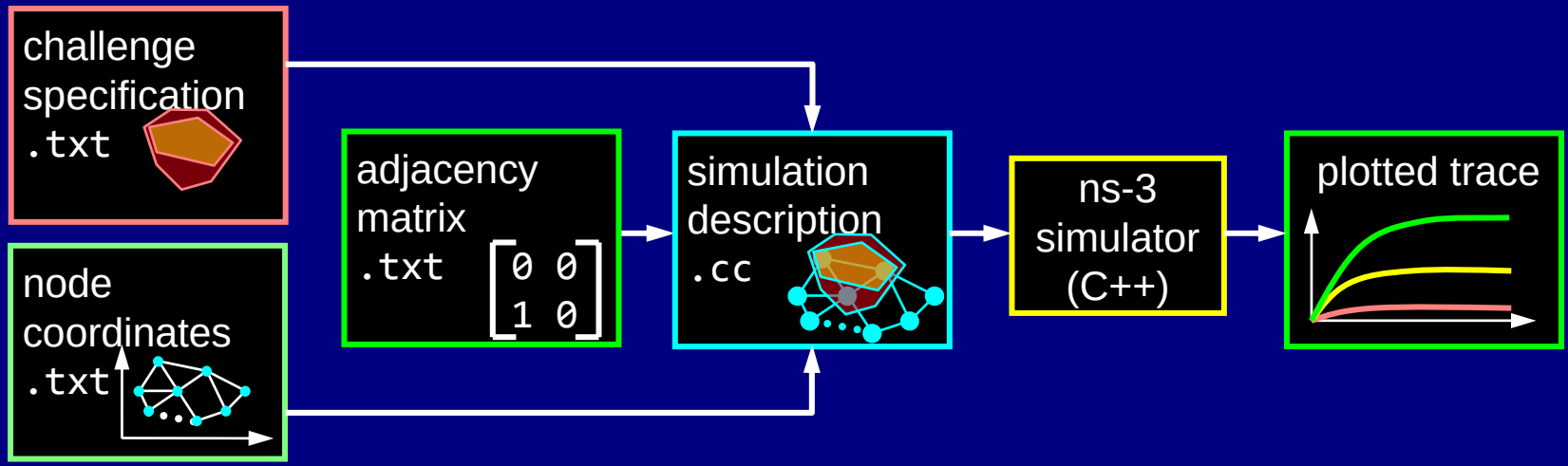
Resilience Evaluation
Evaluating Challenges in State Space

- Topology generation
  - use KU-LoCGen
- Challenge simulation
  - random failures
  - intelligent attacks
    - degree, betweeness, etc.
  - large scale disasters
    - hurricanes, blackouts
- Example
  - resilience of alternatives based on Sprint PoPs





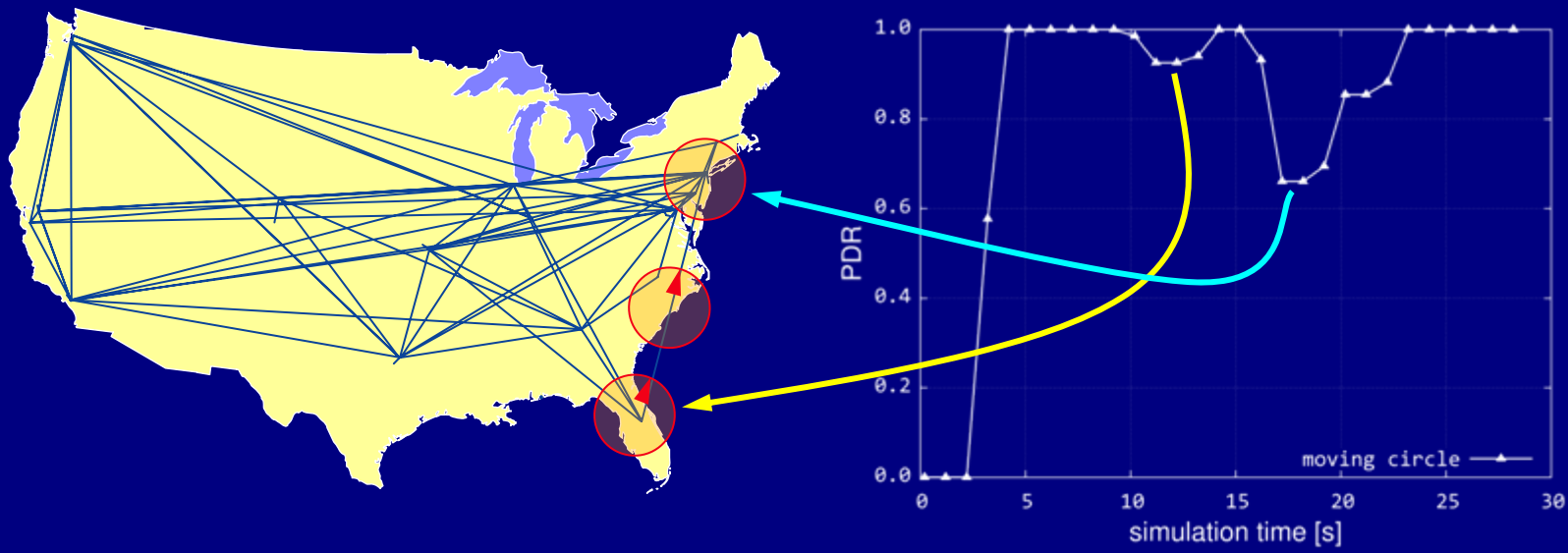
Resilience Evaluation
KU-CSM Challenge Simulation



- 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

Resilience Evaluation
KU-CSM Challenge Simulation



- Example: evolving area-based challenge example
  - circle moving from Orlando to NY
- Performability analysis: packet delivery ratio
  - PDR varies with # links nodes down

Enabling Future Internet Research
GpENI Overview

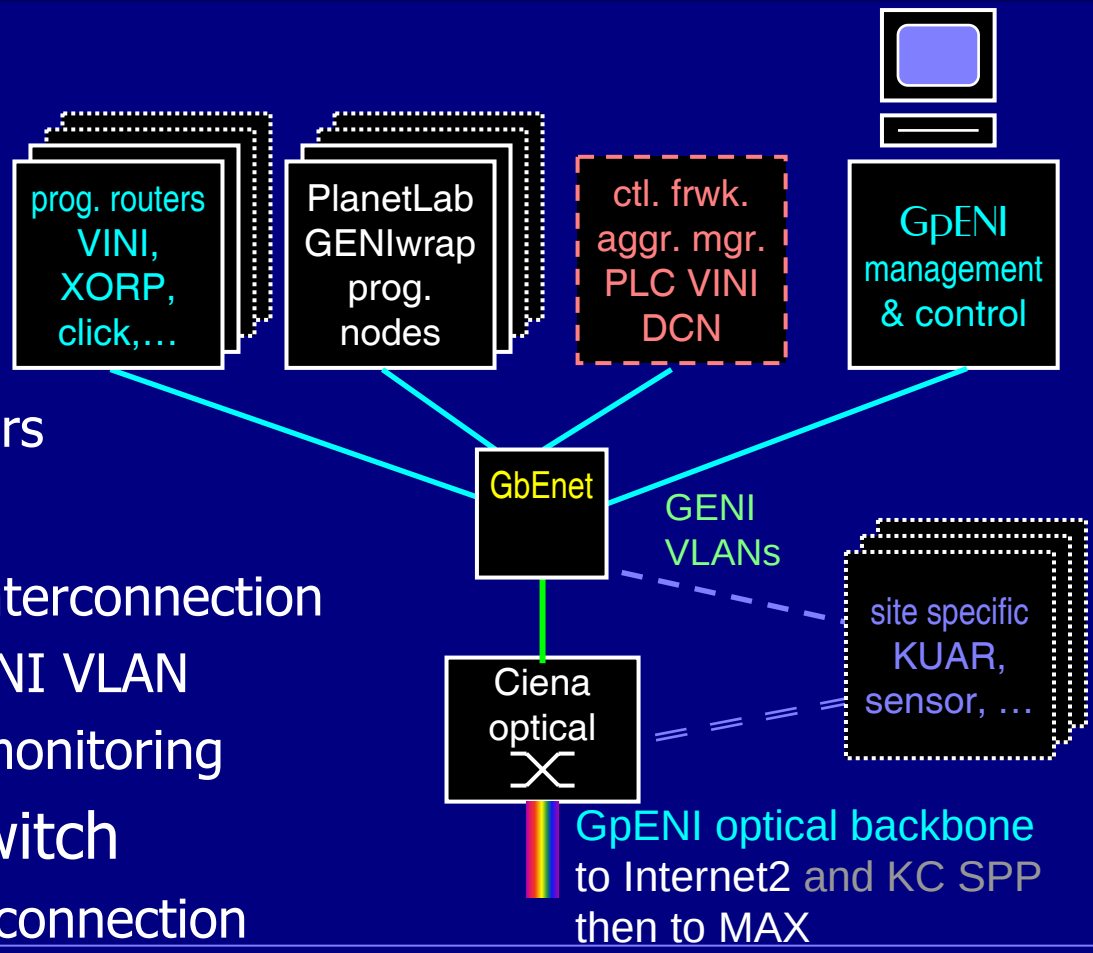
- Great Plains Environment for Network Innovation
  - part of NSF GENI program
  - affiliated with EU FP7 FIRE programme / ResumeNet project
- Programmable network infrastructure (L1–7)
  - Midwest US optical backbone
  - International testbed
- Conduct experiments in:
  - future Internet architectures
  - resilience and survivability
  - cross-evaluation with analytical- and simulation-based eval.

	GpENI Layer	Programmability
	experiment	Gush, Raven
7	application	PlanetLab
4	end-to-end	
	router	Quagga, XORP, Click
3	topology	VINI
	VLAN	DCN
2	lightpath	
1	RF,photonics	site-specific

[TridentCom 2010]

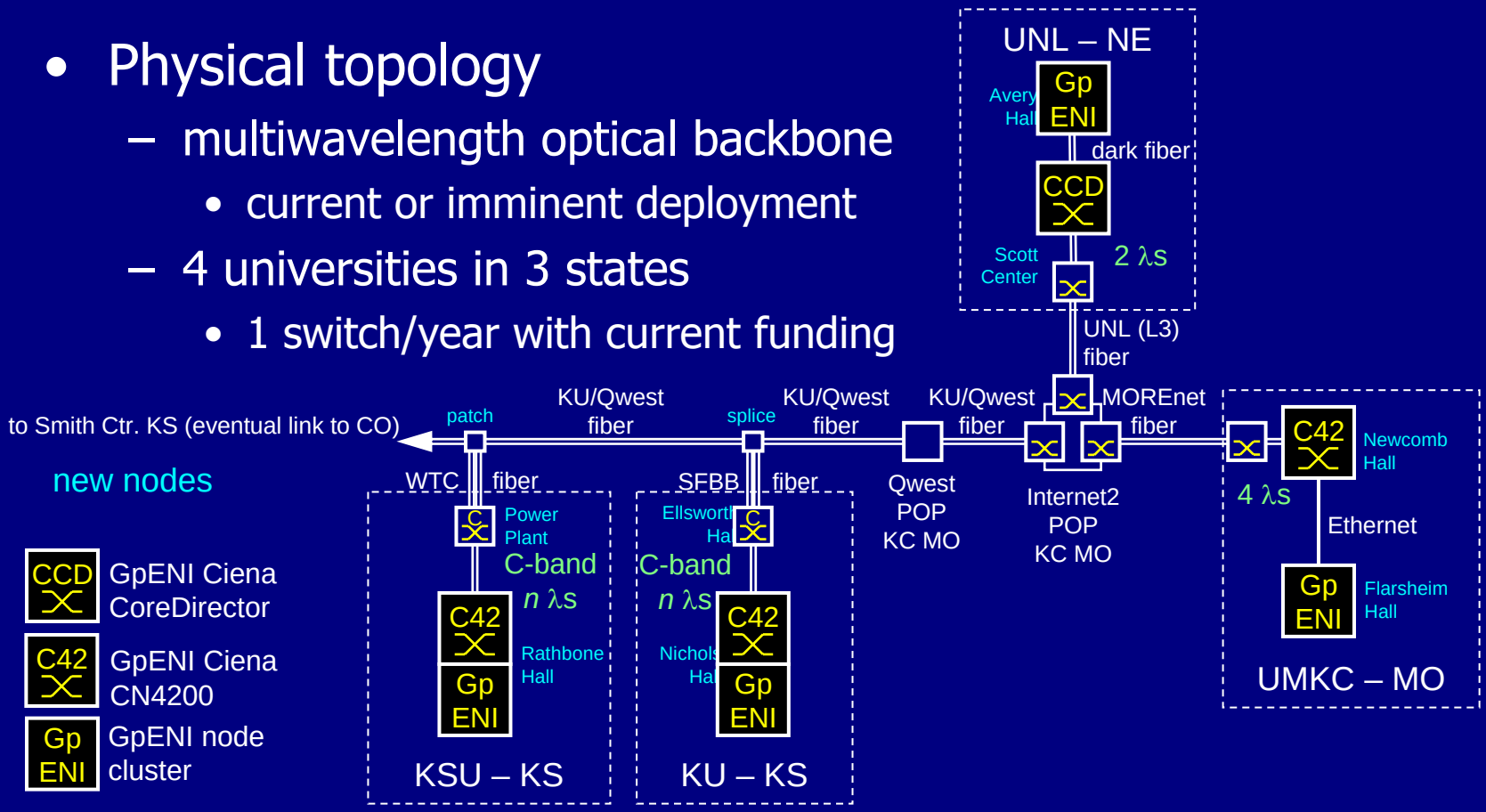
Enabling Future Internet Research
GpENI Midwest Optical Node Cluster

- GpENI cluster
- 5–10 PCs
  - GpENI mgt.
  - L4: PlanetLab
  - L3: prog. routers
- GbE switch
  - arbitrary site interconnection
  - L2: GpENI/GENI VLAN
  - SNMP cluster monitoring
- Ciena optical switch
  - L1 GpENI interconnection



Enabling Future Internet Research
GpENI Midwest Optical Backbone

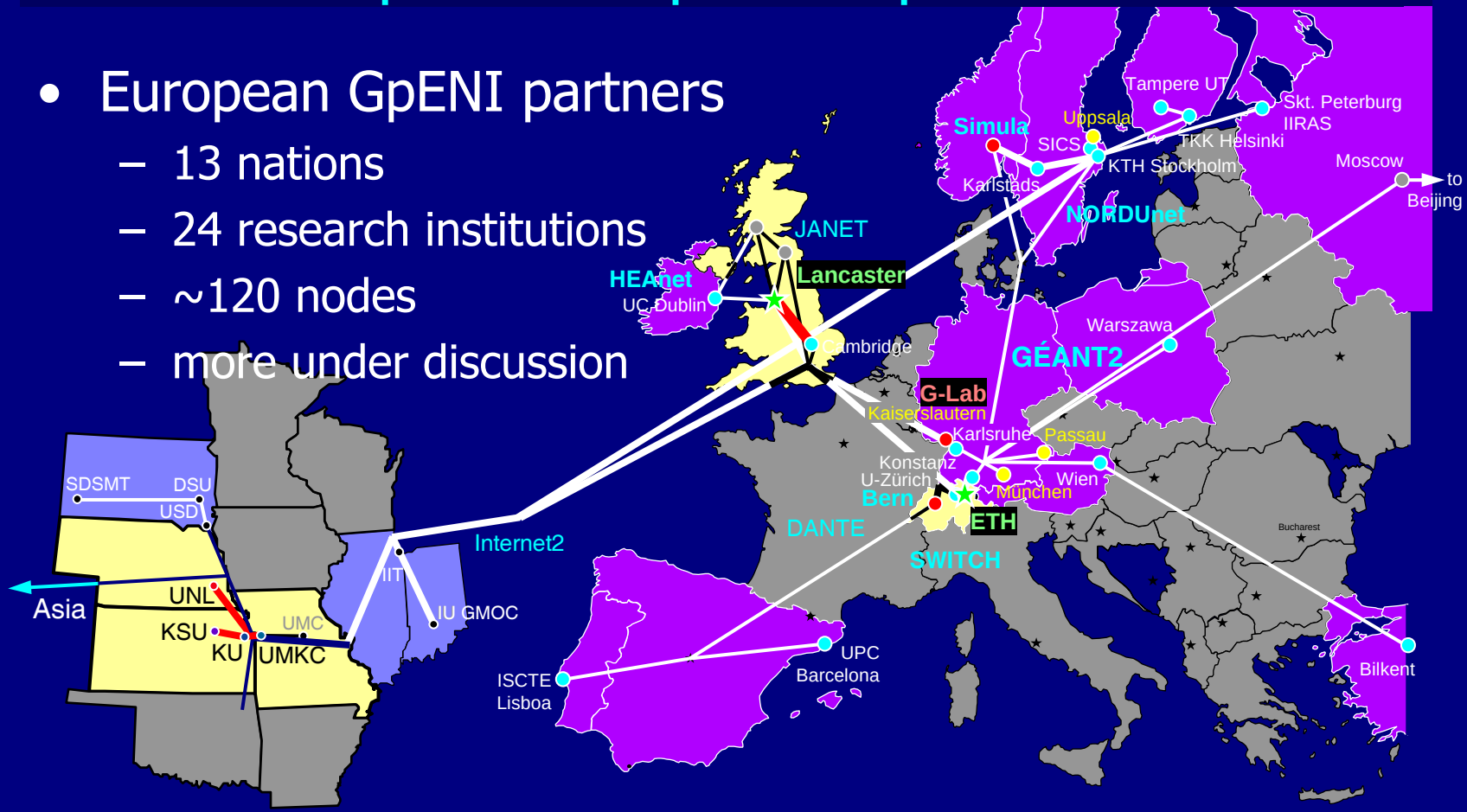
- Physical topology
  - multiwavelength optical backbone
    - current or imminent deployment
  - 4 universities in 3 states
    - 1 switch/year with current funding



Enabling Future Internet Research

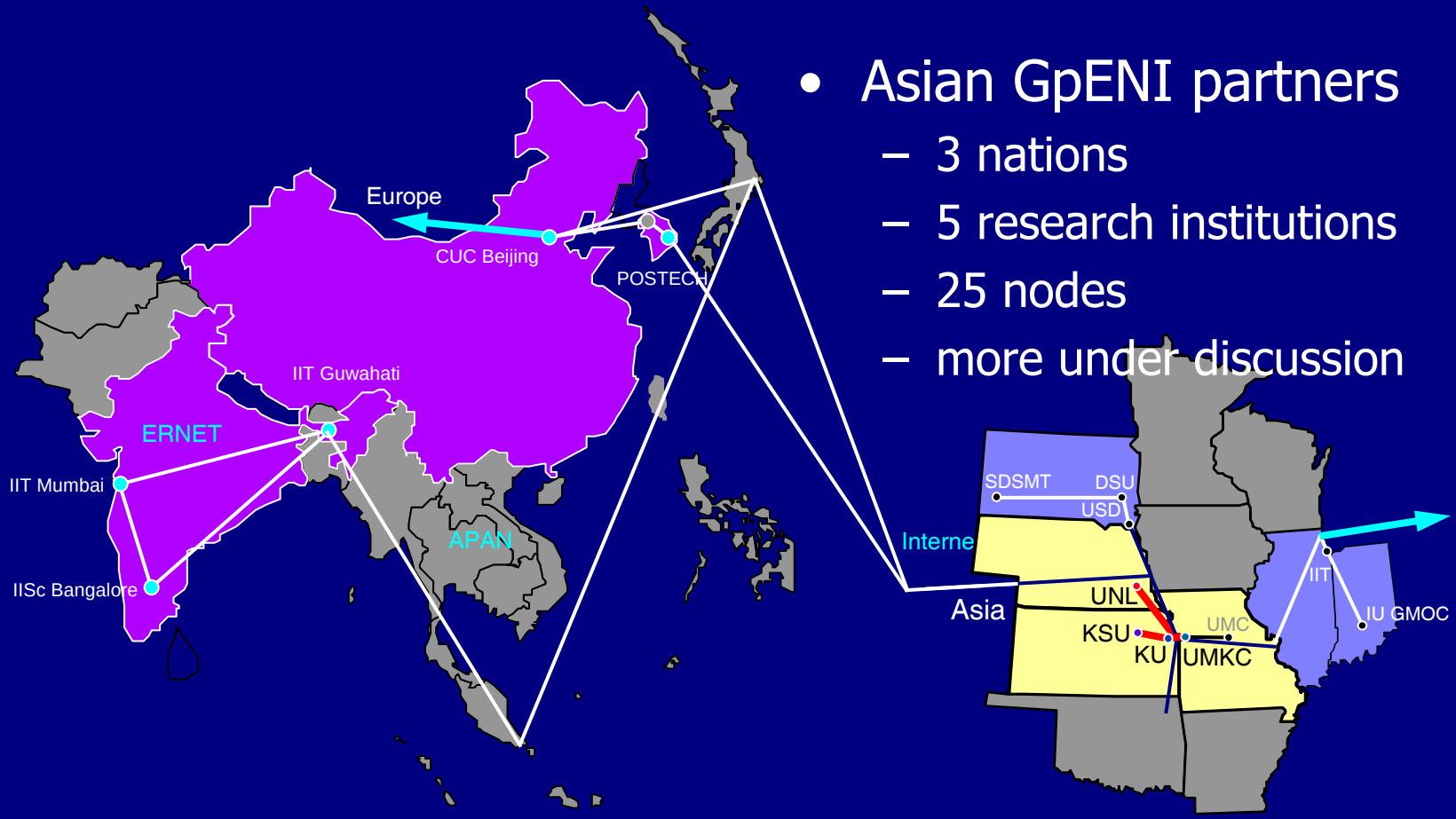
GpENI European Expansion

- European GpENI partners
  - 13 nations
  - 24 research institutions
  - ~120 nodes
  - more under discussion



Enabling Future Internet Research

GpENI Asian Expansion



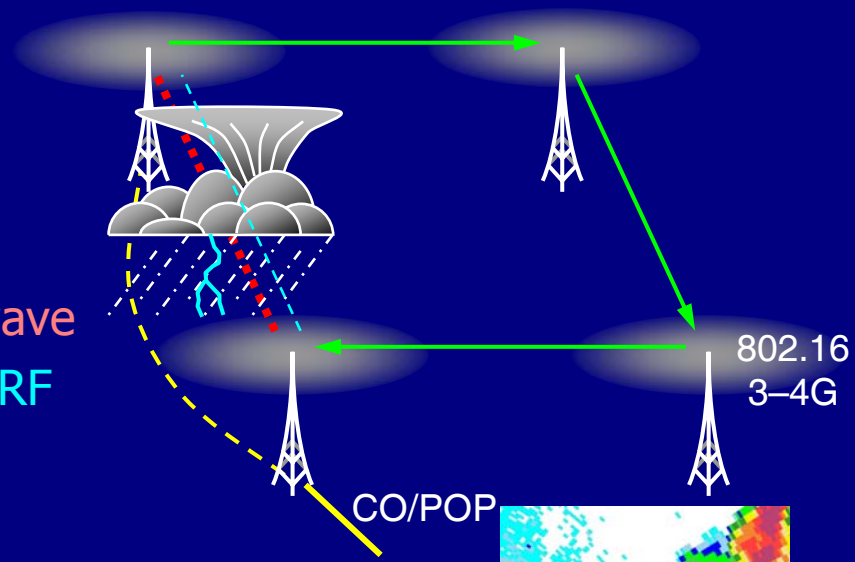
- Asian GpENI partners
  - 3 nations
  - 5 research institutions
  - 25 nodes
  - more under discussion

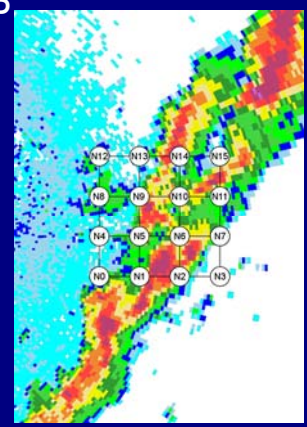
ITTC Networking Research
Selected Project Examples

- Weather disruption-tolerant networking (Sterbenz)
- Highly-dynamic airborne networking (Sterbenz)
- Information security and privacy (Luo)
- SDRs and cognitive networking (Minden, Evans)
- Sensor networking (Frost)

WDTN Project
Overview

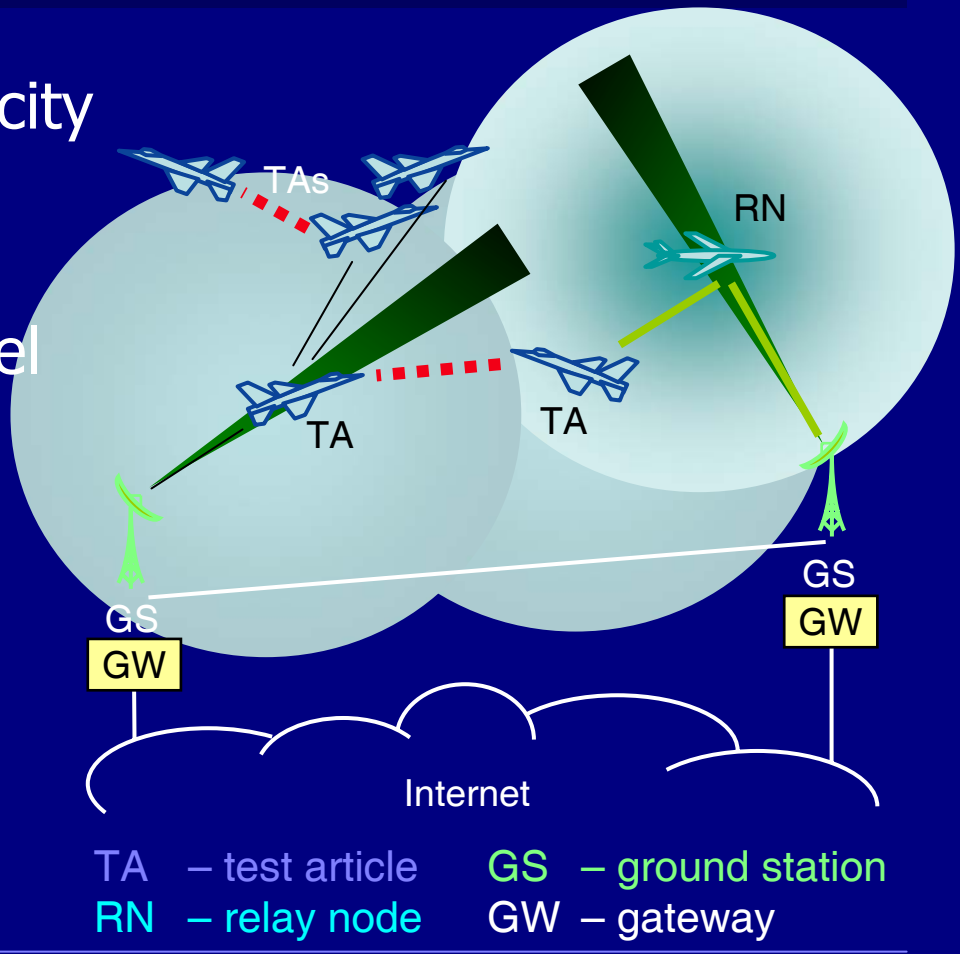
- Mesh architecture
  - high degree of connectivity
  - alternate diverse paths
    - severely attenuated mm wave
    - alternate mm, lower-freq. RF
    - fiber bypass (competitor)
- Solution [INFOCOM 2009]
  - reroute *before* link failures they occur
  - P-WARP predictive routing
    - image radar to predict weather
  - XL-OSPF instantaneously reactive routing
    - cross-layered with BER estimation



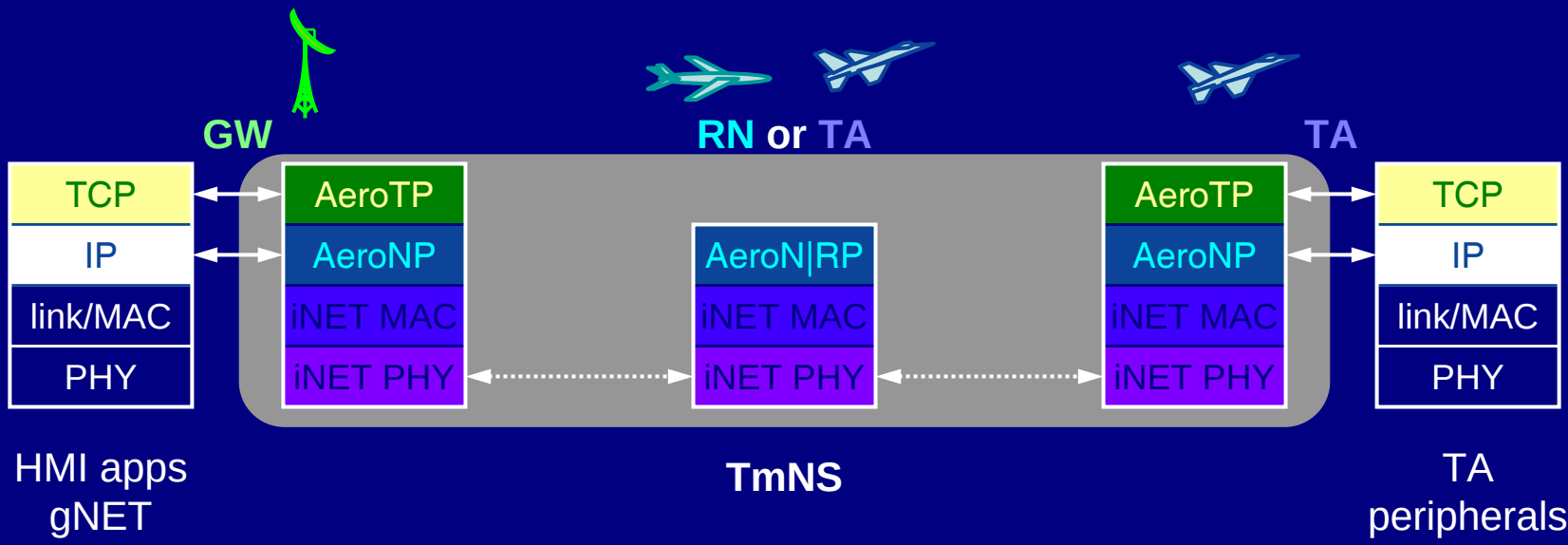


Airborne Networking Project
Scenario

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



Airborne Network Project
Protocol Stack and Interoperability



- AeroTP: TCP-friendly transport
- AeroNP: IP-compatible forwarding
- AeroRP: routing [MILCOM 2008]

InfoSec and Privacy Projects
[Bo Luo PI]

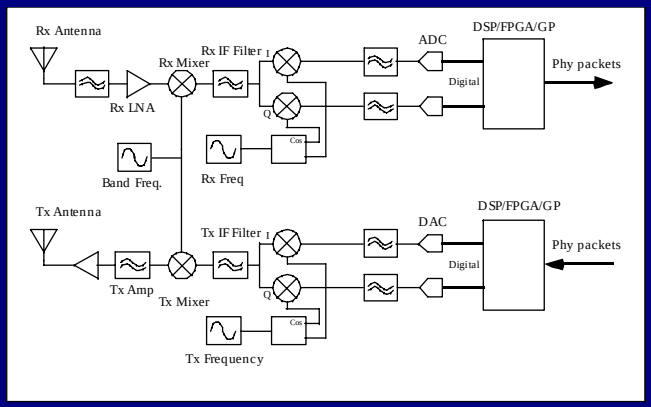
- CAT: A node-failure-resilient anonymous communication protocol through commutative path hopping [INFOCOM 2010]
  - protect the identity/privacy of communication participants
  - group-based path probing & commutative path hopping: resilient to relay node failures
- Secure in-network operations for smart grids
  - in-network operations: distribute operations (e.g. aggregation) into smart meters
  - Secure operations: perform operations without revealing the data, using applied crypto methods

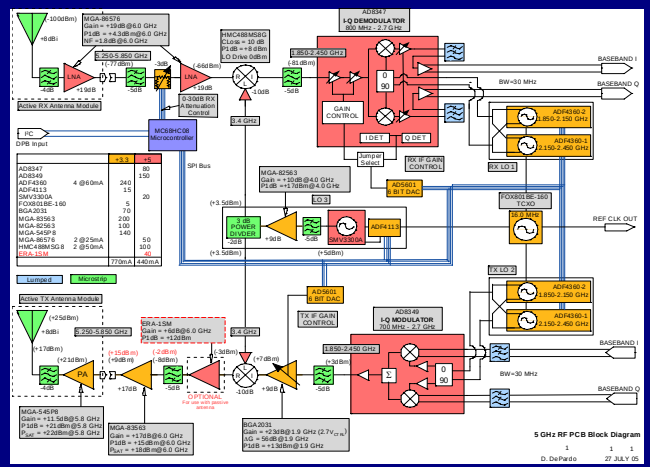
SDR and Cognitive Radio Projects
[Gary Minden and Joseph Evans PIs]

- KUAR: KU agile radio
  - experimental system: wireless networking & radio research
  - 5.8 GHz UNII band; independent 30MHZ tx/rx signal paths,
  - signal processing is entirely in an FPGA and GPU
- Application
  - sharing radio frequency spectrum with multiple users
  - configure radio software for specific missions
  - adaptation to dynamic RF environment and other users
  - radio network control and resource management
- Cognitive networking
  - new dynamic routing algorithms exploiting SDR technologies

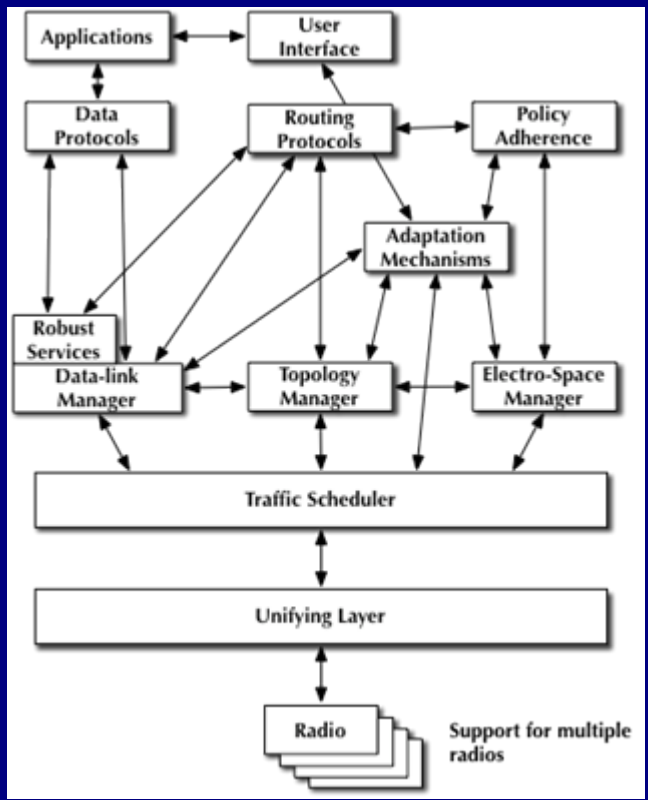
SDR and Cognitive Radio Projects

KUAR Diagrams





Software Organisation



Transportation Security SensorNet
[Victor Frost PI]

- Objective and problem
  - KC SmartPort is encouraging development
  - transport systems require
    - visibility, accountability, efficiency, security
- Transportation security approach
  - sensing, communications, and information integration
  - integrate sensor information and real-time tracking with… trade data documents to correlate
  - expand the ORNL SensorNet technologies
    - to mobile rail network environment

End

Questions?