Urban-Net: A System to Understand and Analyze Critical Infrastructure Networks for Emergency Management

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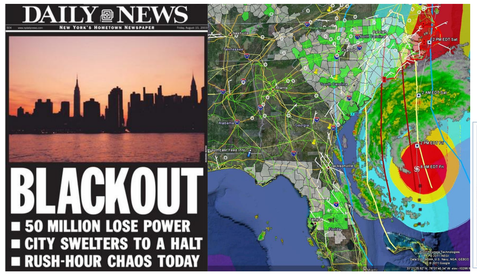
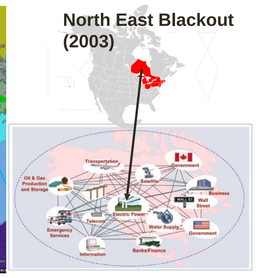
INTRODUCTION



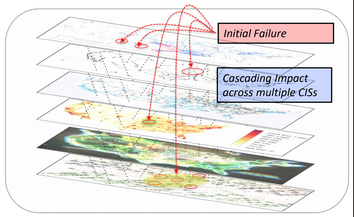


- **Interdependencies** between CIS (Critical Infrastructure Systems) are capable of causing **cascading** and **escalating** failures leading to catastrophic consequences
- How to manage the effect of cascading failures on interdependent CIS networks?

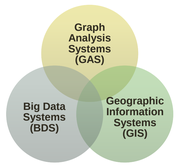
URBAN-NET FRAMEWORK

Objectives

- **Visualization of complex interdependency across CISs**
- **Identification of vulnerable components in CISs**
- **Simulation of what-if scenarios**

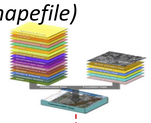


Core Technologies

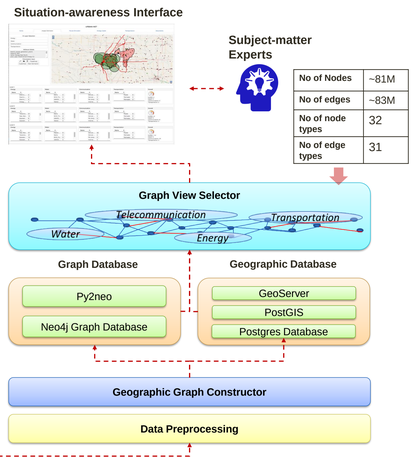


Dataset

The Homeland Security Infrastructure Program (HSIP) Gold Dataset (Shapefile)

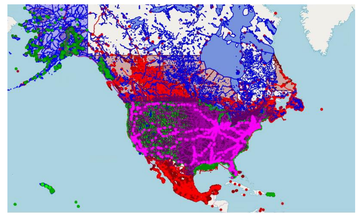


System Architecture/Workflow

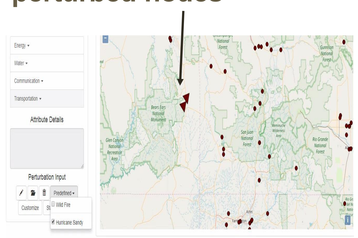


TOPOLOGY-BASED ANALYTIC MODULE

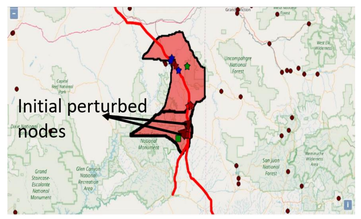
Step 1: Visualizing CIS in terms of graph networks



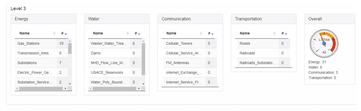
Step 2: Selecting perturbed nodes



Step 3: Visualizing affected CIS components



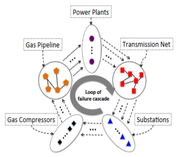
Step 4: Three level overview of number of each type of affected CIS



The affected entities in **15** edge hops due to interdependency of the perturbed nodes

SIMULATION-BASED ANALYTIC MODULE

Step 1 :Configure heterogeneous energy network and failure cascade model



Each node has four user control parameters:
β: time to lose control for turning in inactive node
α: recovery time
L: load
C : capacity

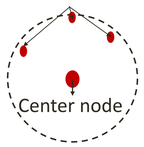
Step 2: Selecting initial failures (a what-if scenario)

By State

Randomly sample nodes from the selected state

By Point

All nodes in 10km radius



Step 3: Iteration

- ✓ Identify and enlist the failed nodes due to current cascade whose L>C
- ✓ Schedule recovery time for each failed node
- ✓ Distribute load of failed nodes to the connected components
- ✓ Finalize, when all node becomes active or Recovery time of all failed nodes reaches its maximum
- ✓ Identify critical facilities which may lead to large failure spread over the entire system

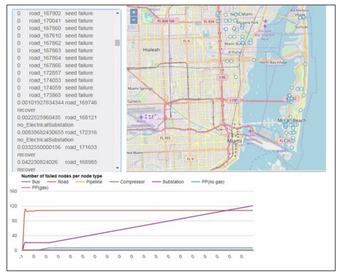
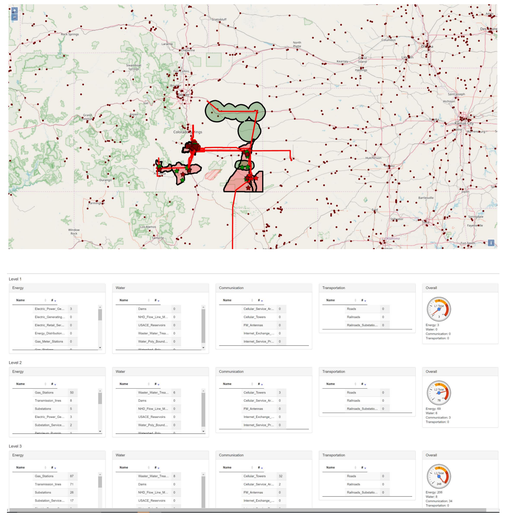


Fig: Snap-shot of simulation-based module

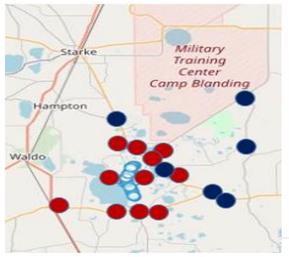
DEMO SCENARIO 1



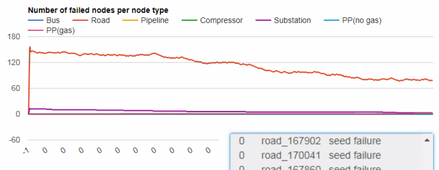
Topology-based Analytics

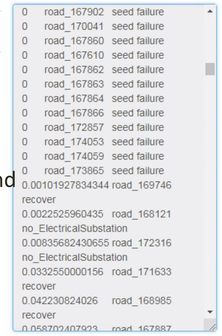
- ✓ Three electric power generator fails within a small region
- ✓ Failures affect components **multiple** layers
- ✓ Cascading can impact components that are **geographically not close**

DEMO SCENARIO 2



Simulation-based Analytics





Preparation:

Selecting the state Florida: the most affected state due to Hurricane Irma

Initial failure nodes: Random nodes centered around hurricane region (random perturbation)

Final cascade: ends after 3 mins of simulation

Consequence:

Heavily damaged road networks when hurricane time (simulation time) is over

REFERENCES

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2. Chen, Liangzhe, et al. "Hotspots: Failure cascades on heterogeneous critical infrastructure networks." Proceedings of CIKM, 2017.
3. Lee, Sangkeun, et al. "URBAN-NET: A network-based infrastructure monitoring and analysis system for emergency management and public safety." IEEE International Conference on Big Data Workshop, 2016.