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Analyzing Network of Networks at Scale

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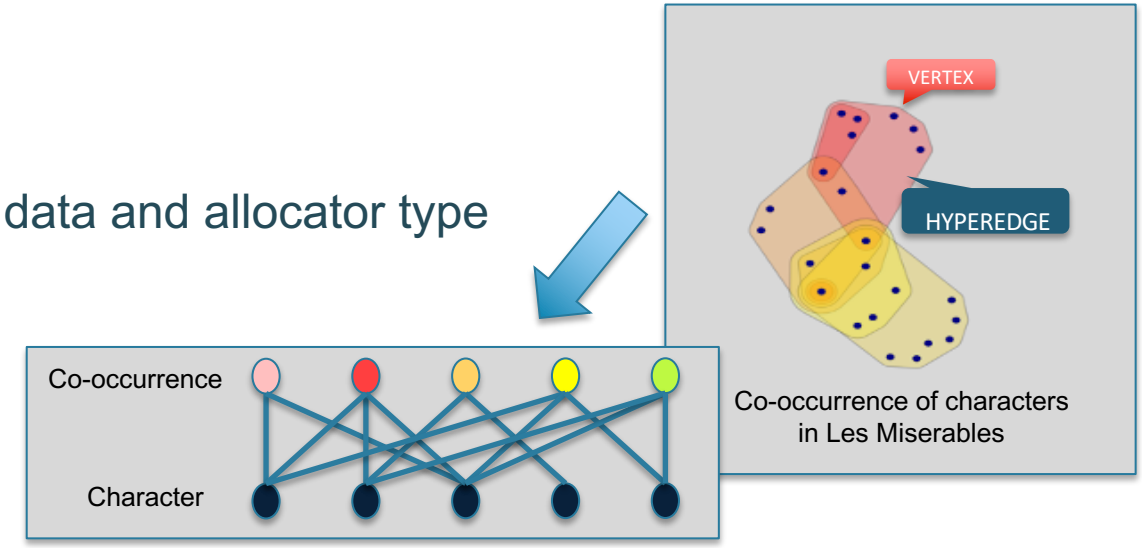
CLSAC
SEPTEMBER 2020

PNNL's platform supports scalable mixed analytics

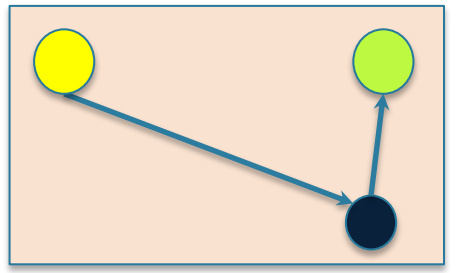
- Data views
  - Matrices – dense and sparse integer and floating point
  - Tables – heterogeneous data columns; tensors
  - Graphs – property graphs and hypergraphs
- Composable method libraries
  - Matrix and linear algebra routines
  - Relational database and machine learning methods
  - Graph methods for line and hypergraphs
    - Streaming
    - Fuzzy matching
- Scalability
  - Billions of vertices and edges
  - Shared memory and HPC cluster implementation

Recent enhancements

- Linear Algebra Library
  - Basic matrix operations and solvers
  - Matrix and vector data structures are templated by data and allocator type
  - Allocators are used to
    - modify data layout and distribution
    - target accelerators
    - support external libraries (SLATE, ScalaPack)



- Hypergraph Library
  - Represented as bipartite property graph
  - Collapse, BFS, Louvain, s-overlap, s-shortest path, s-components
    - Modify simple graph algorithms for “wedges”
    - Construct hyperedge – hyperedge graph OR vertex – vertex graph



A problem with hypergraphs

- Small data sets everything is fine … but
- Large data sets MAY result in an explosion of work or edges

Say you have a hypergraph with **10M hyperedges** and **1M vertices** and
100K hyperedges have 100 vertices and each of those vertices belong to 100K hyperedges, then

those just 100K hyperedges generate 100K * 100 * 100K wedges of work in the simple algorithm

OR

100K * 100 * 100K edges in the hyperedge – hyperedge graph

Collapse graph or filter out work while preserving accuracy

SHADes

- Client-server analytics platform, inspired by Arkouda
- Jupyter Notebook / Python frontend, SHAD backend
  - Front-end commands are mapped to SHAD functions
  - The SHAD server implements an interpreter for client commands
- Multiple clients can connect to the same server at the same time
  - Multiple users can explore or query same data images
- Clients can connect to multiple backends or separate data views

https://github.com/pnnl/SHADes

Platform for system of systems analysis

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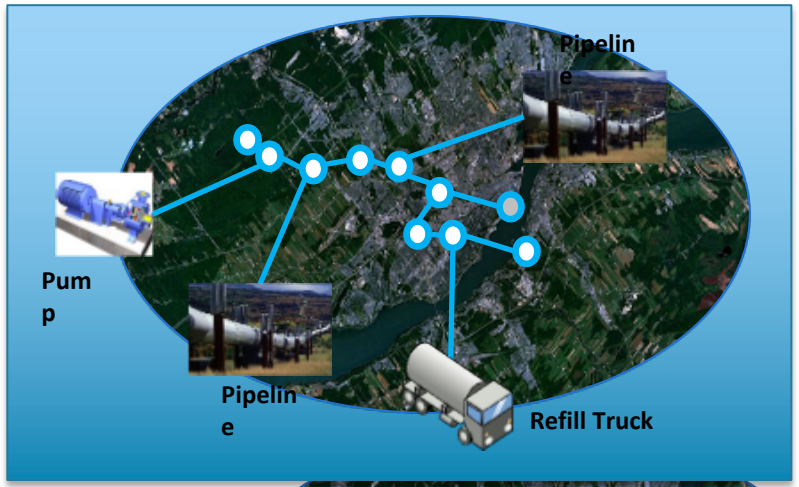
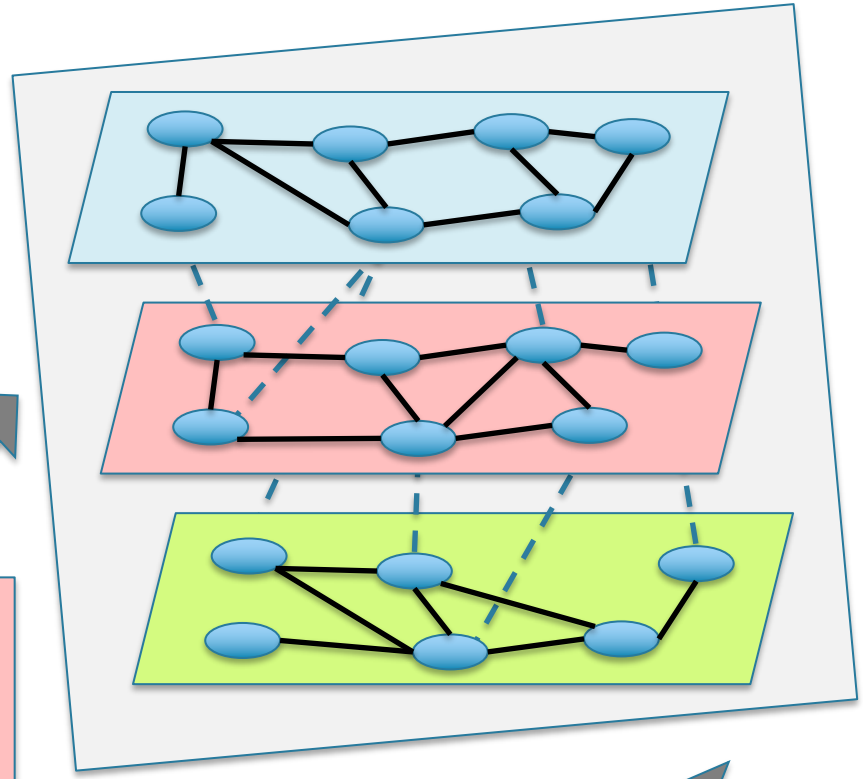
PNNL's Analytic Platform models multiple systems as one enabling cross system analysis, consequences, and decision support

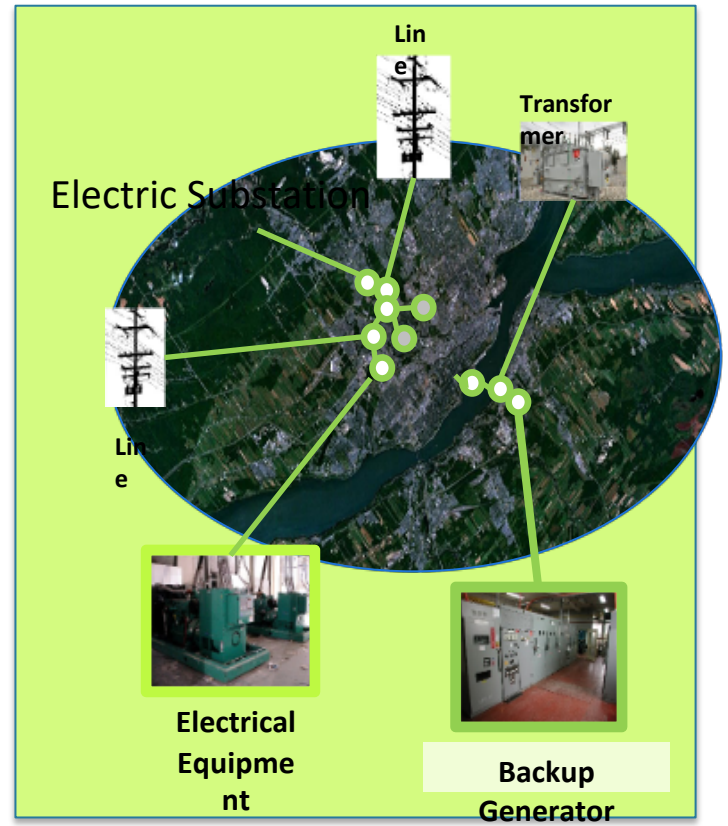
NATURAL GAS



COMMUNICATIONS

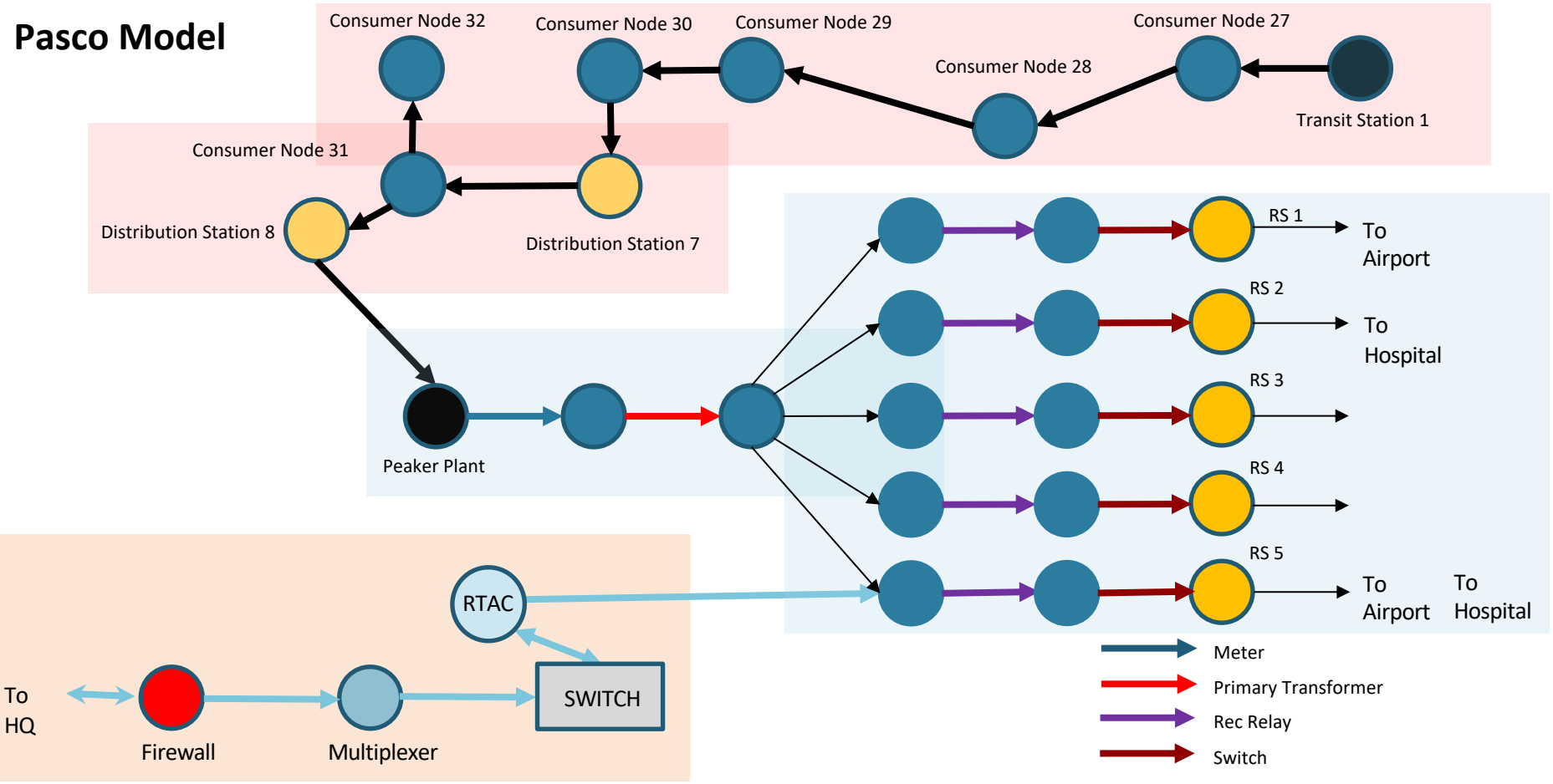


POWER GRID



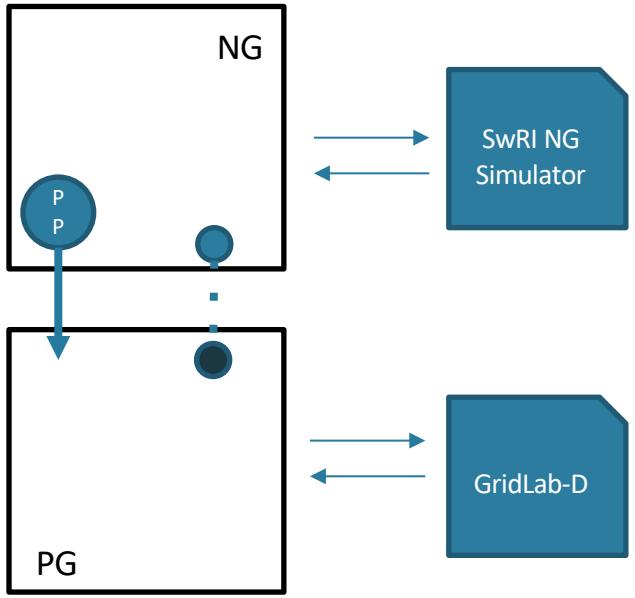
Predictive Consequence Modeling

- Model consequence of an action or event on one network on all networks



Action Graph = Properties + Methods

- Vertex and edge type definitions now include METHODS
  - Methods can take local action
  - Send messages to neighbors causing them to take actions
  - Invoke global functions

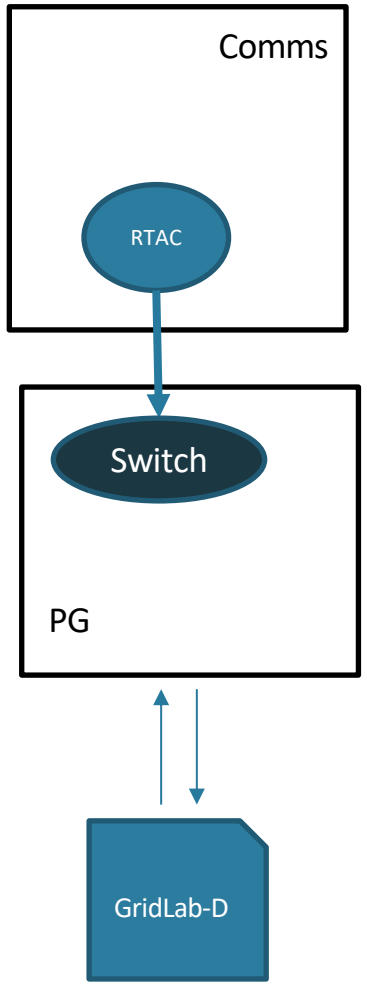


What is the impact to the Pasco hospital if I destroy the transformer that feeds the airport?

- Destroy transformer and collocated distribution station
- Status change launches PG and NG simulation with Δt time step
- Change in gas reaching Peaker Plant reduces power output change in output launches PG simulation
- Trace the electrical power reaching the hospital over time

Cybersecurity modeling

Edges are now asynchronous message queues between vertices



Coupled Rule-based / Scientific simulation

- Launch cyber attack to open switch

  Firewall/Router –
  - Message arrives at Firewall
  - Firewall accepts message
  - Message calls BOT subroutine.
  - BOT subroutine sends remote procedure request to Multiplexer

  Multiplexer –
  - Message arrives from Firewall
  - Multiplex accepts message and executes OpenSwitch

  OpenSwitch –
  - Open SSH session on RTAC
  - Send SEL protocol command to RTAC
  - Receive list of RecRelay that use SEL protocol (say RecRelay 4 is on the list)
  - Send command to send a message to RecRelay 4 to open switch
  - Send Logout command

  RTAC –
  - Listen for SSH session
  - Opens connection
  - Accept and execute command until Logout command

- Open switch and launch PG simulation
- Run until convergence or commander's decision window