A Scalable Multiphysics Modeling Package for Critical Networked Infrastructures Using PETSc DMNetwork

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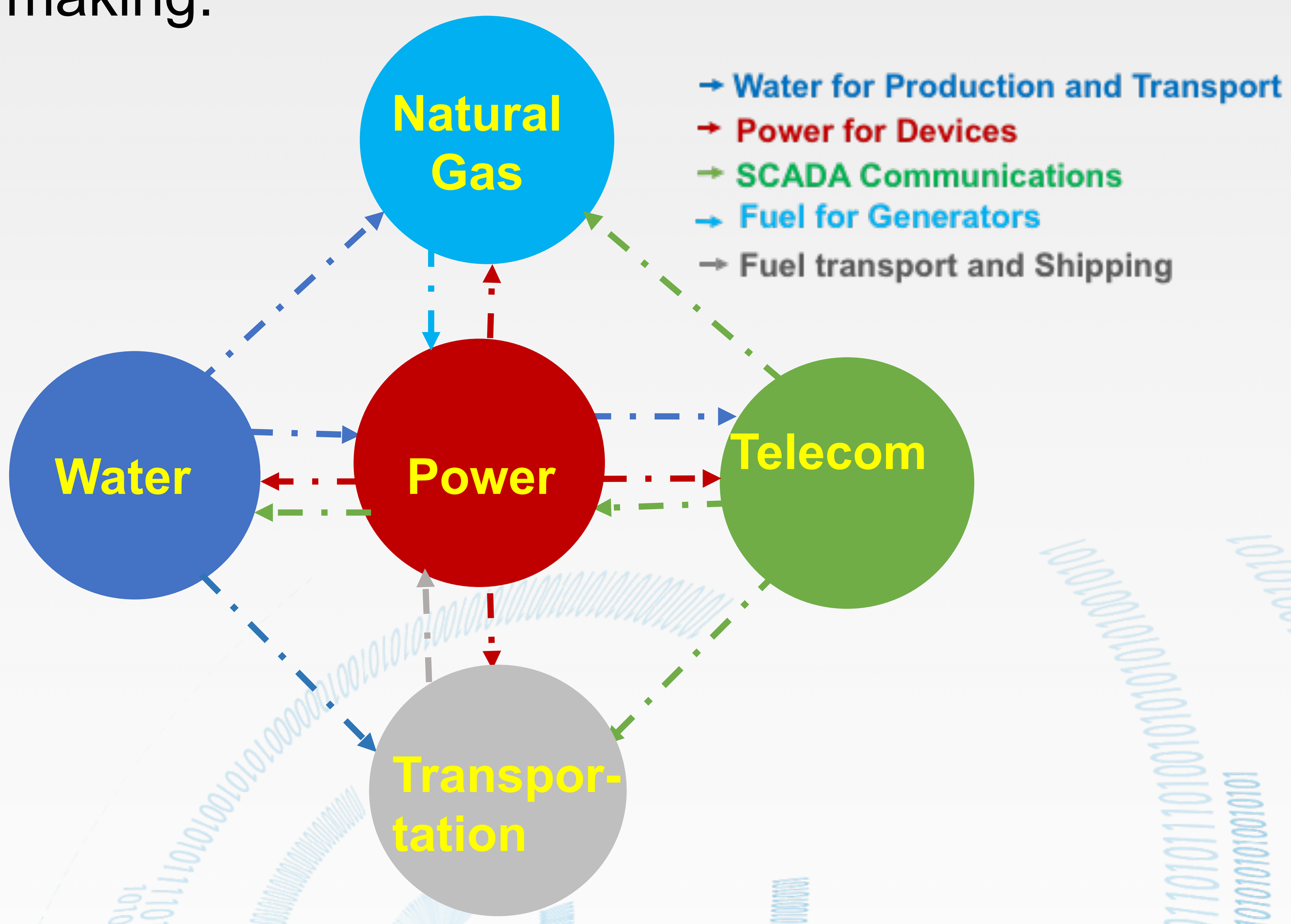
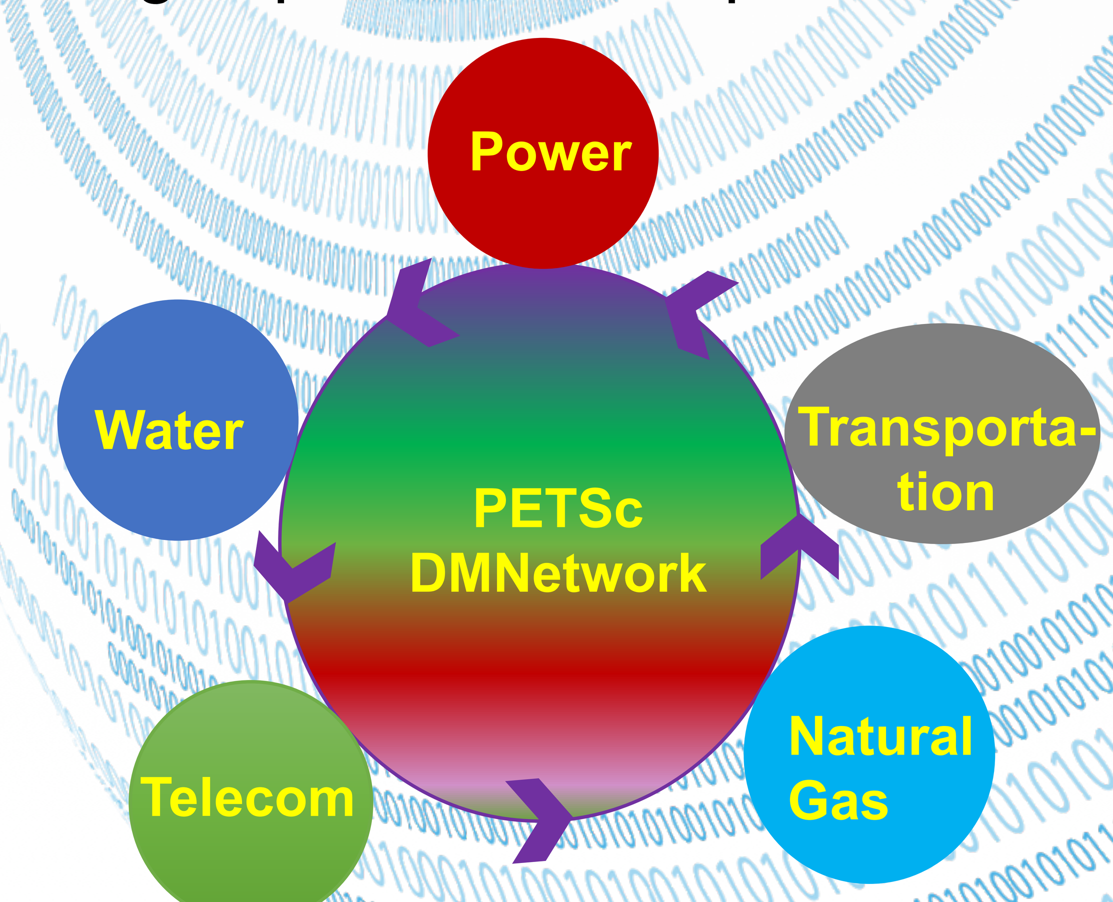
Introduction

Critical infrastructures involves multi-physics, cross-disciplinary, and interdependencies. Simulation of a system without accounting for the interaction is insufficient to support decision-making.



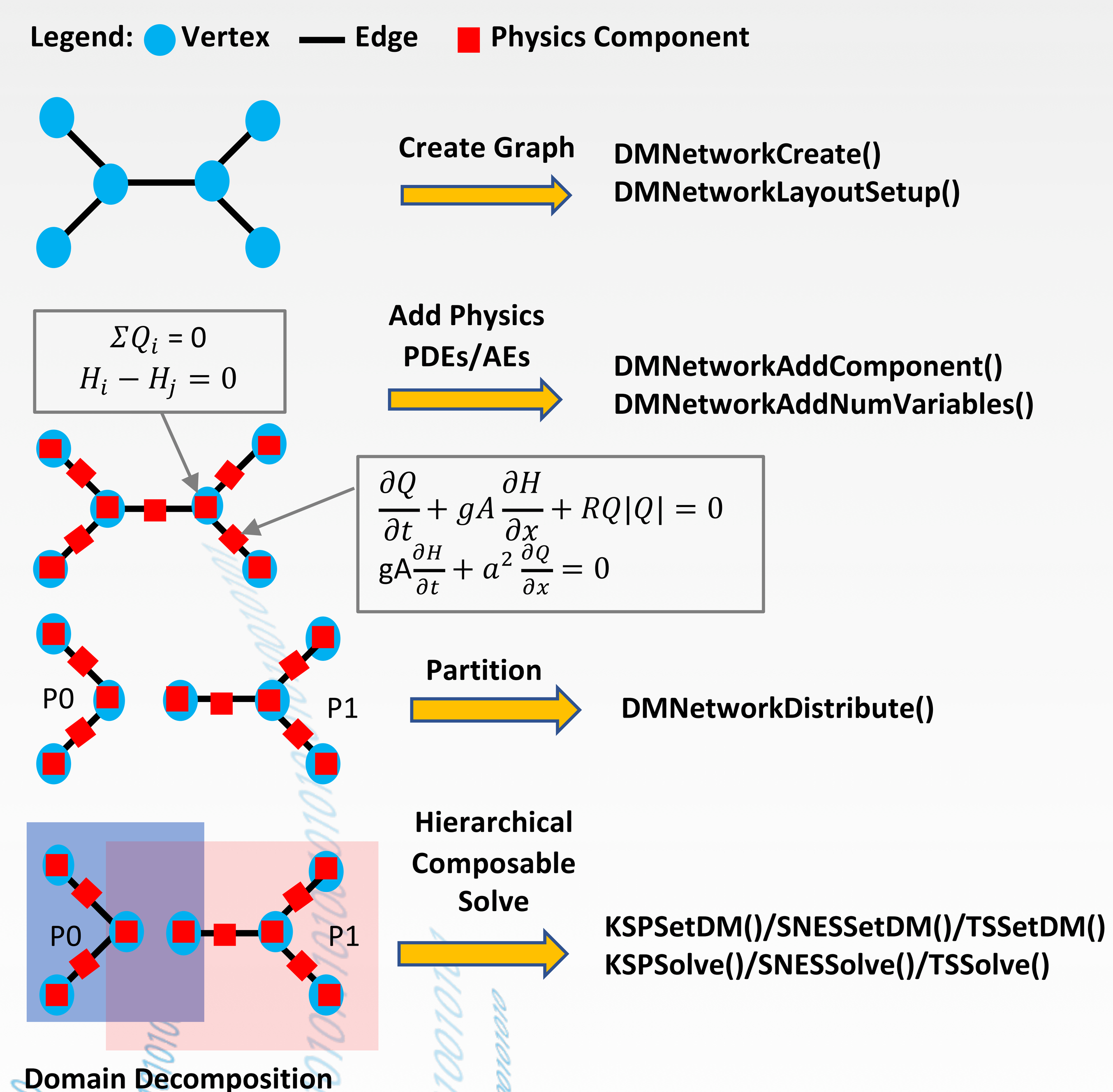
Existing tools are not suitable to understand the impact of one system failure on the other systems, simulate transient nature of the systems, or be applied for real-time problems at large spatial and temporal scales.



We are developing a scalable-multiphysics-modeling package using PETSc DMNetwork to address these limitations.

Package and Applications

PETSc DMNetwork allows simulating networked multiphysics systems that are represented by linear and nonlinear equations, as well as differential algebraic equations, on extreme-scale computers.



AC Power Flow

Solves real and reactive power balance equations.

$$P_i^{inj} - \sum_{k=1}^{n} |V_i||V_k|(G_{ik}\cos(\theta_{ik}) + B_{ik}\sin(\theta_{ik})) = \Delta P = 0$$

$$Q_i^{inj} - \sum_{k=1}^{n} |V_i||V_k|(G_{ik}\sin(\theta_{ik}) - B_{ik}\cos(\theta_{ik})) = \Delta P = 0$$

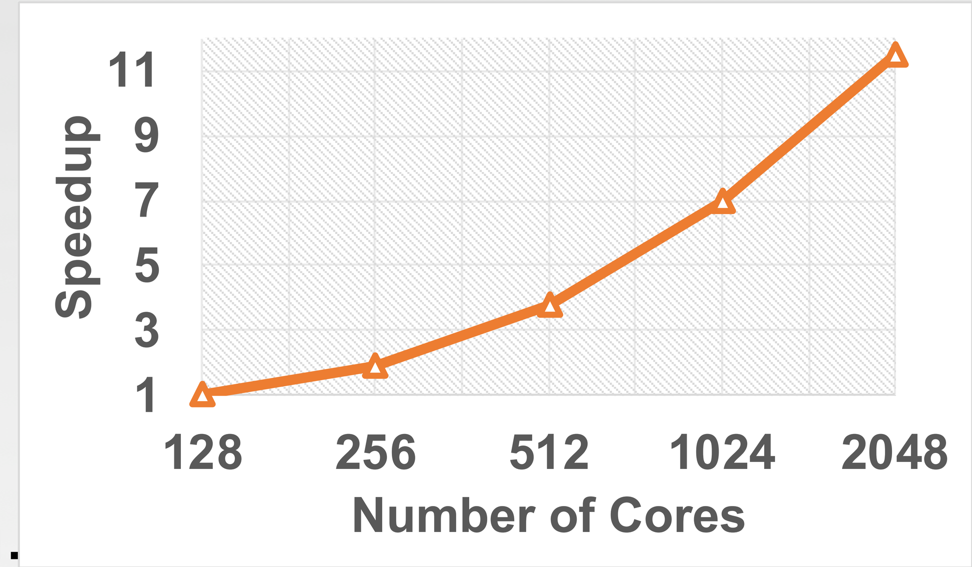
Water Flow Flow Model

Solves continuity and momentum equations.

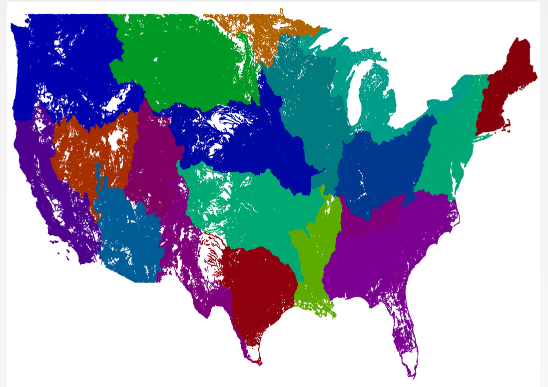
$$\frac{\partial h}{\partial t} + \frac{\partial (hu)}{\partial x} = 0$$

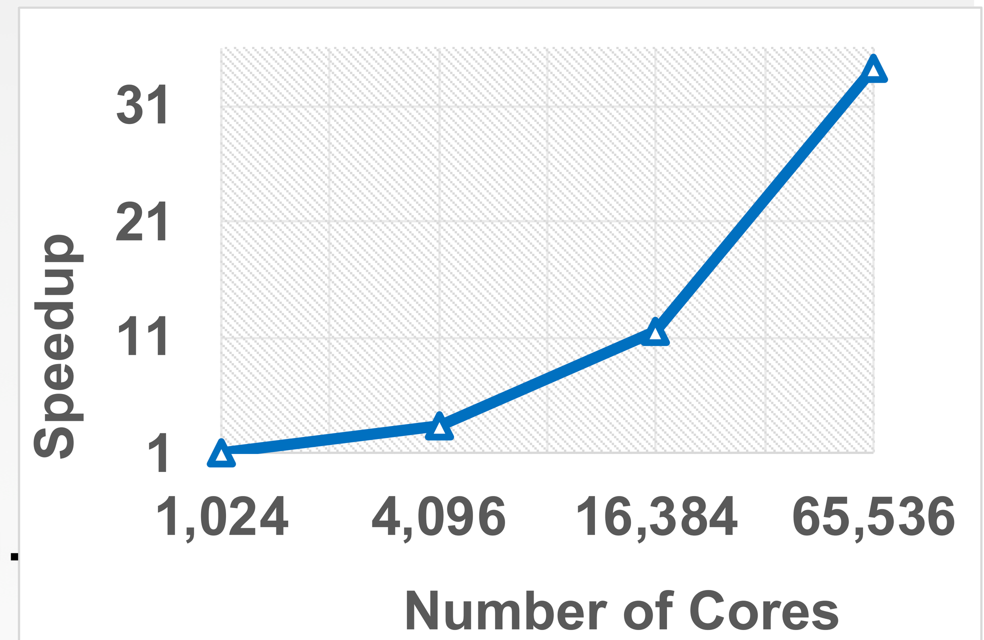
$$\frac{\partial (hu)}{\partial t} + \frac{\partial (hu^2 + \frac{1}{2}gh^2)}{\partial x} = gh(S_b - S_f)$$

Results



Variables solved equal to half million.



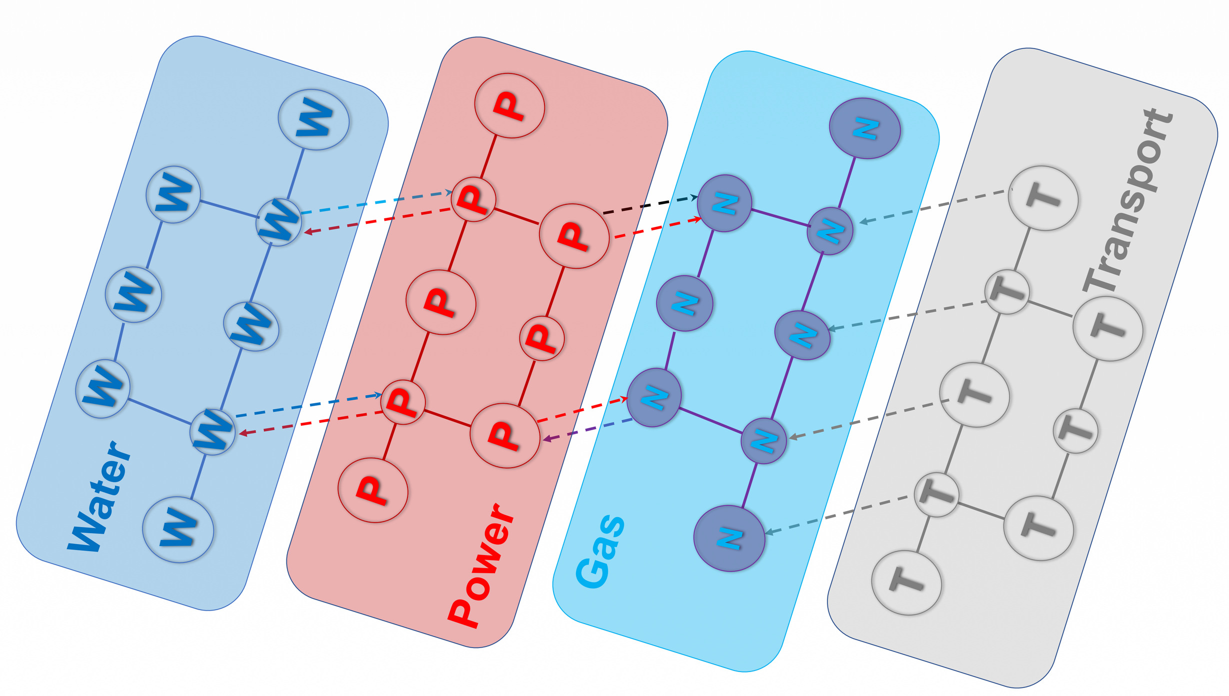


Variables solved equal to half billion.

Summary

- Simplifies programming parallel code to solve complicated problems.
- Simulations of power and water networks show the robustness and the scalability of the data structures and solvers.

Future Work



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