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

Critical infrastructures involve 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.

\[
\begin{align*}
\sum_{k=1}^{N} P_I &= \sum_{k=1}^{N} V_l V_k \left( G_{ik} \cos(\theta_{ik}) + B_{ik} \sin(\theta_{ik}) \right) = \Delta P = 0 \\
\sum_{k=1}^{N} Q_I &= \sum_{k=1}^{N} V_l V_k \left( G_{ik} \sin(\theta_{ik}) - B_{ik} \cos(\theta_{ik}) \right) = \Delta Q = 0
\end{align*}
\]

**Water Flow Flow Model**

Solves continuity and momentum equations.

\[
\begin{align*}
\frac{\partial h}{\partial t} + \frac{\partial (hu)}{\partial x} &= 0 \\
\frac{\partial (hu)}{\partial t} + \frac{\partial (hu^2 + 1/2gh^2)}{\partial x} &= gh(S_h - S_f)
\end{align*}
\]

**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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