Pacific Northwest NATIONAL LABORATORY

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"Similar to highway transportation systems, whose purpose is to allow all cars arrive at their destinations quickly and efficiently without any traffic jams, power grids are expected to assure electrons flow freely and efficiently to desired destinations (customers) without any "electron traffic jams", which would cause blackouts. We want to utilize high performance computing techniques to conduct comprehensive analysis of potential failures to achieve better reliability in power grids."

- Pacific Northwest National Laboratory Task Lead Yousu Chen

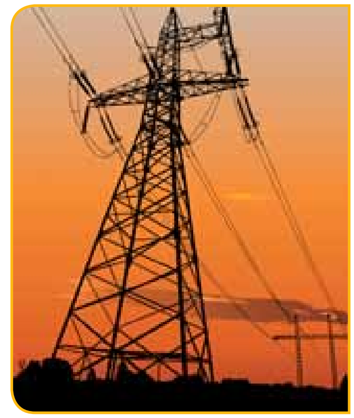
U.S. DEPARTMENT OF ENERGY

Center for Adaptive Supercomputing Software-Multithreaded Architectures (CASS-MT)

Contingency Analysis for the Electric Power Grid

Analyzing power grid stability using the CRAY XMT

At a glance



The demand for reliable energy is expected to increase, placing stress on the existing power grid. Researchers at Pacific Northwest National Laboratory (PNNL) are applying their expertise in high-performance computing to shape an interactive approach for improving power grid reliability. By addressing a massive number of "what-if" situations, PNNL researchers seek to help power grid operators identify failures before they become a worst-case scenario: A debilitating blackout.

What we do

At PNNL's Center for Adaptive Supercomputing Software-Multithreaded Architectures (CASS-MT), researchers are developing methods for advanced contingency analysis. Consider this analogy: If you are planning a road trip, you want to take the fastest route to your destination. Typically, this would be a frequently traveled highway. Now imagine if all the cars traveling the highway on a typical day were suddenly detoured onto a two-lane road. The sheer amount of traffic would grind travel to a standstill because a two-lane road cannot accommodate that many cars traveling at high speeds.

This scenario is similar to how PNNL researchers are using the concept of "betweenness centrality" in graph theory to analyze how disabling one heavily used power line could negatively impact the ability of the power grid to carry electrons and could ultimately cause cascading failures and blackouts.

Now imagine the impact of multiple roads getting blocked at once – some combination of blocked roads could be more hazardous than others. However, studying all possible combinations of "x" failures is computationally infeasible. PNNL researchers are using the concept of "group betweenness centrality", identify groups of x edges that have maximal influence on the connectivity in a graph, to address "N – x" contingency challenge in a computationally feasible manner.

How we do it

The Cray XMT supercomputer has the potential to substantially accelerate data analysis and predictive analytics beyond the limitations of traditional computing. The Cray XMT's multithreaded ThreadStorm processors allow multiple, simultaneous processing, helping researchers find the solutions to the world's most complex challenges faster.

Currently, researchers are simulating contingency cases using the Cray XMT supercomputer to determine the potential impacts from power grid failures. The power grid is treated as a graph, and the group betweenness centrality identifies a group of paths that have the largest impact in the graph. Potential failures of these paths are the most important and are selected for further analysis. Using this contingency selection method helps researchers pinpoint the most critical cases to analyze out of a collection that would be otherwise so large as to exceed the capability of computational resources.

After the high-importance paths are identified, the failures of these paths are evaluated by estimating their impact on power grid stability. The impact indices are ranked, and top percentage cases are selected for further detailed analysis. Researchers further apply multiple dimensional scaling techniques to present the similarity among contingency cases and advanced visualization techniques to the analysis results to overlay the impact of contingencies on geographical maps. The result becomes a presentation that is easy to understand and can quickly draw operator's attention to the most vulnerable parts of the power grid. As there are many contingency cases, there will be many layers of contingency impact superimposed on one map.

Ultimately, PNNL researchers are working to establish the full process of contingency selection, analysis, visualization and mitigation, and to develop the capability to provide real-time decision support to power grid operators.

Applications

Completed Applications

- Computed betweenness centrality for the actual 14,000-node western power grid
- Developed fast sorting capabilities on ThreadStorm processors
- Developed highly parallel k-means clustering algorithm on Cray XMT

Current Applications

- Enhancing parallel group betweenness centrality algorithm
- Developing a validation framework for power grid contingency selection
- Improving multiple dimensional scaling and advanced visual analytic techniques

Future Applications

- Explore mathematical tools beyond betweenness centrality
- Develop interactive remedial action evaluation
- Explore contingency analysis in the presence of missing or erroneous data

CASS-MT is dedicated to research on systems software, programming environments, and applications in a High-Performance Computing (HPC) multithreaded architecture environment.

We offer the only Open Science Cray XMT system, a one-of-a-kind supercomputer consisting of 128 multithreaded processors, 1 TB RAM, and a 7.7 TB Lustre parallel filesystem.

The Cray XMT supercomputer has the potential to substantially accelerate data analysis and predictive analytics beyond the limitations of traditional computing. Multithreaded processors allow multiple, simultaneous processing, helping researchers find solutions to the world's most complex challenges faster. The XMT can process irregular, data-intensive applications that have random memory access patterns. Unlike many applications where data delivery is dependent on memory speed, the Cray XMT's multi-threaded architecture tolerates memory access latencies by switching context between multiple threads that work continuously, overlapping the memory latency and preventing the processor from being held up while it waits for data to arrive.

The multithreaded technology powering our Cray XMT is ideally suited to perform pattern matching, scenario development, behavioral prediction, anomaly identification, and graph analysis.

Try it for yourself. We seek to create collaborations and provide expertise for porting and optimizing applications. The opportunity to use our Cray XMT system is available to internal and external research partners.

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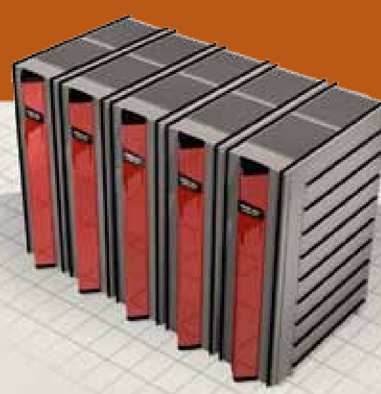

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