CENTER FOR ADAPTIVE SUPERCOMPUTING SOFTWARE

John Feo

Our Mission

A LEADERSHIP CENTER

WORKING WITH GOVERNMENT AND INDUSTRY PARTNERS

TO DEVELOP APPLICATIONS, LIBRARIES, AND NEXT GENERATION SYSTEMS

TO SOLVE THE MOST CHALLENGING IRREGULAR PROBLEMS

IN KNOWLEDGE DISCOVERY

Our Partners

Georgia Tech

Sandia National Laboratories

Ohio State

CRAY
THE SUPERCOMPUTER COMPANY

Least Squares

Berkeley Lab
Ernest Orlando Lawrence Berkeley National Laboratory

BBN Technologies

Pacific Northwest National Laboratory
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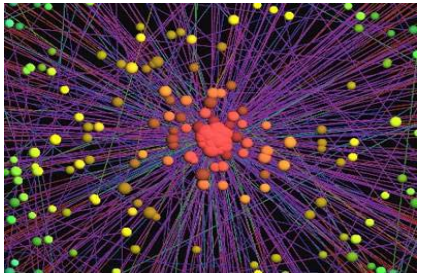
Irregular problems are everywhere

Big science

Application: System structures, outlier detection
Graph problems: clustering, connectivity

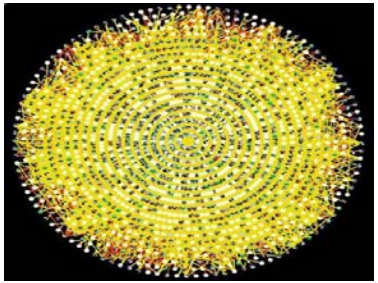


Social Informatics

Application: Emergent communities, social structures, information flow
Graph problems: centrality, clustering, flows, graph isomorphism, shortest paths

Machine Understanding

Application: Video surveillance, document search, semantic search
Graph problems: hashing, minimal cycles, parse trees, search



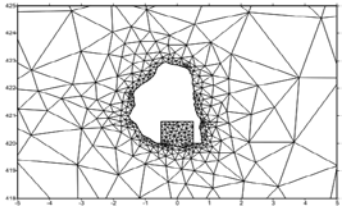
Bioinformatics

Application: Protein targets for drug compounds, DNA sequencing
Graph problems: clustering, substring matching, hashing

Graphs are not grids

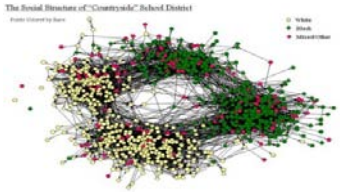
- Graphs arising in informatics are very different from the grids used in scientific computing

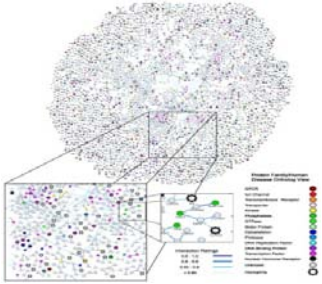
Scientific



Static networks, Euclidean topologies

Informatics



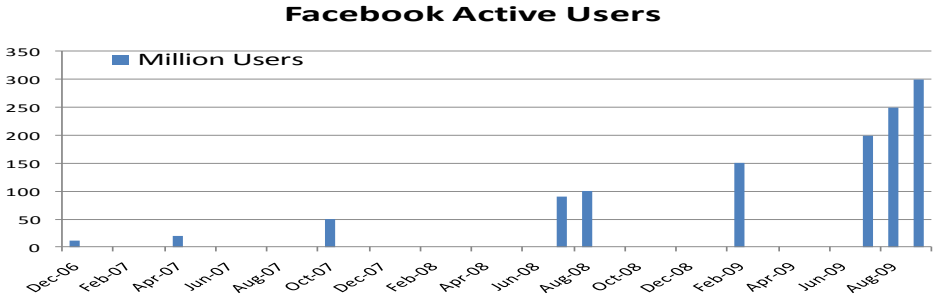


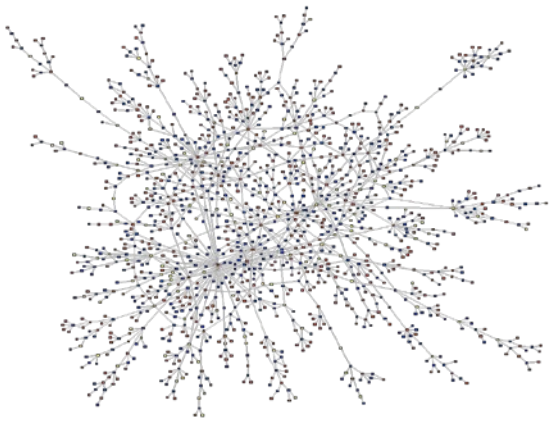
dynamic, high-dimensional data,
low graph diameters, power law distribution

Massive social networks

facebook has more than 300 million active users

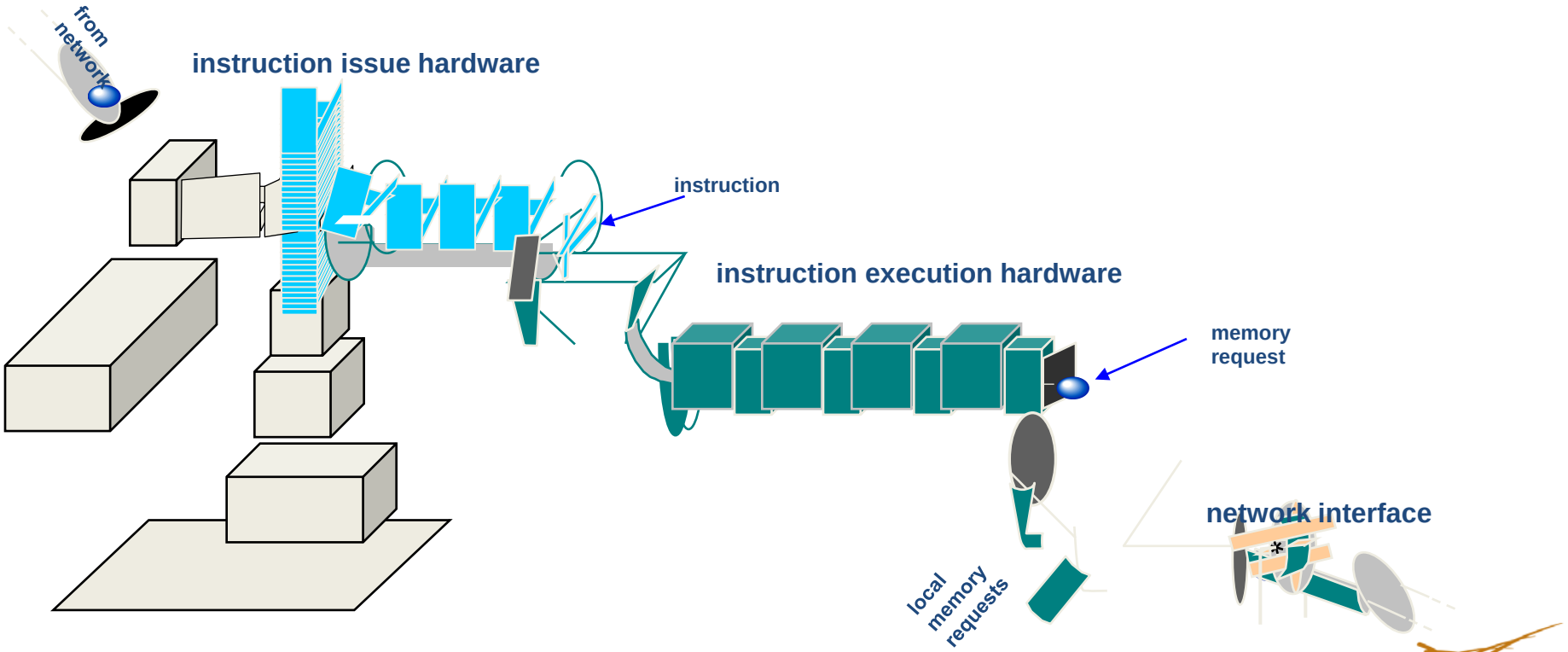
1000x growth in 3 years!



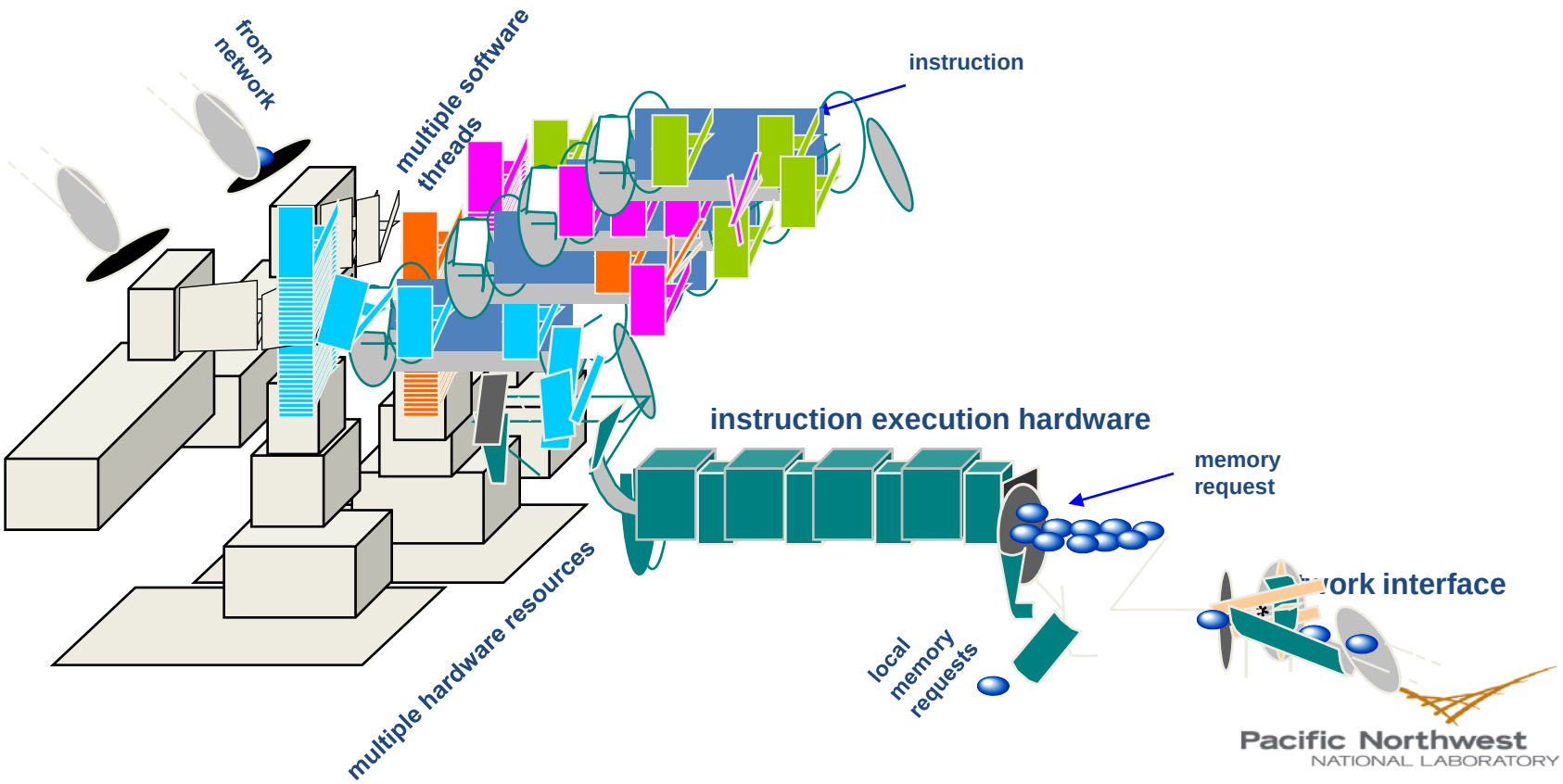


- Traditional graph partitioning often fails:
  - **Topology**: Interaction graph is low-diameter and has no good separators
  - **Irregularity**: Communities are not uniform in size
  - **Overlap**: individuals are members of one or more communities
- Sample queries:
  - **Allegiance switching**: identify entities that switch communities.
  - **Community structure**: identify the genesis and dissipation of communities
  - **Phase change**: identify significant change in the network structure

Memory stalls conventional processors

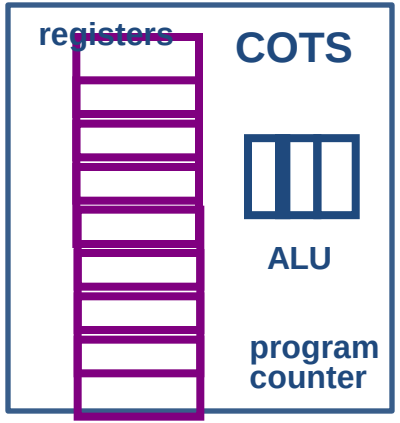


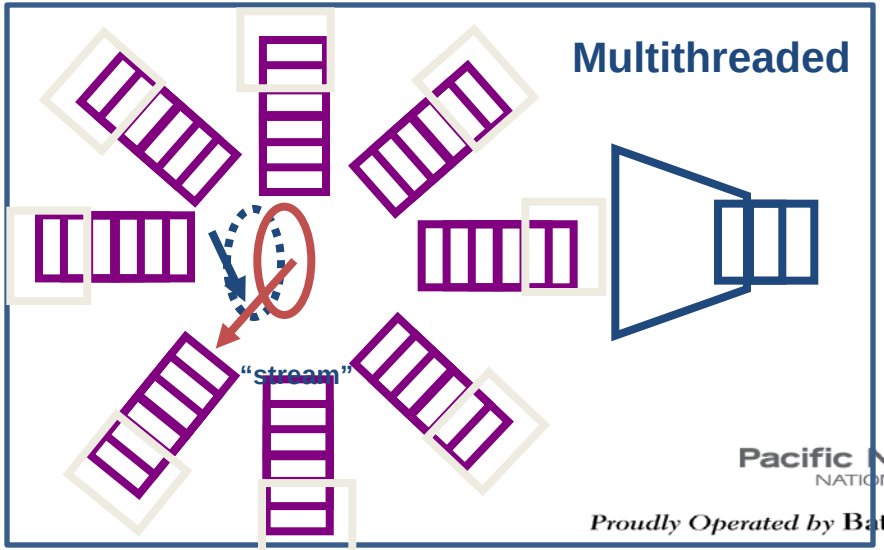
Multithreaded processors tolerate latencies



Multithreading

- Multithreaded processors are to conventional processors as Gatling guns are to conventional machine guns.
- Many threads per processor core; small thread state
- Thread-level context switch at every instruction cycle





Programming implications

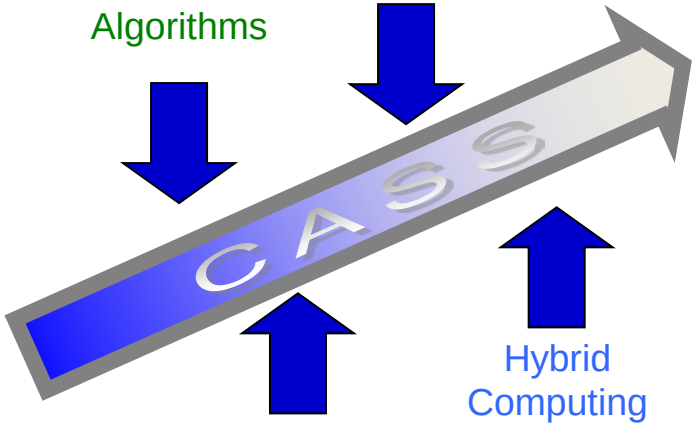
- No longer need to place data near computation
- No longer need to access data with stride one
- No longer need to partition programs into balanced computations
- No longer need to minimize communication or synchronization events
- *Adaptive and dynamic methods are okay*
- *Graph algorithms and sparse methods are okay*
- *Recursion, dynamic programming, branch-and-bound, dataflow are okay*

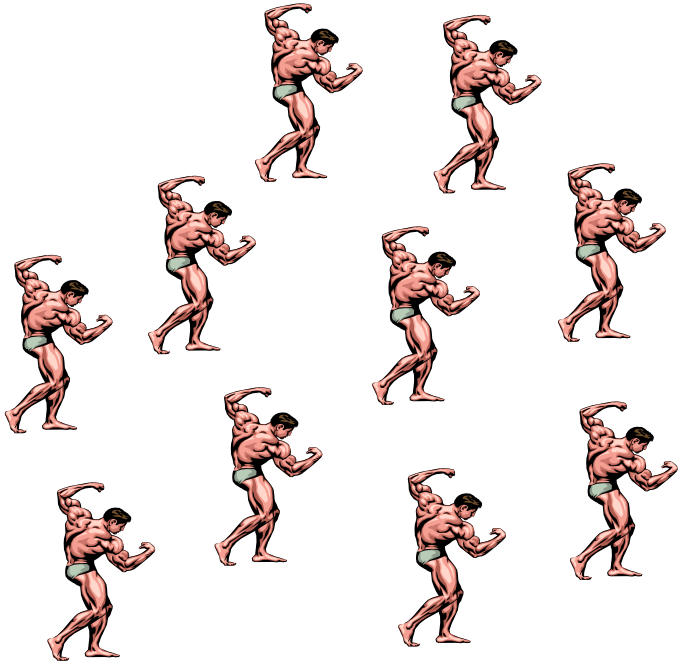
Our Focus

- Research irregular applications
- Develop scalable algorithms for irregular problems
- Develop software methods and libraries
- Optimize system software and programming tools
- Procure and evaluate multithreaded architectures
- Drive next generation hardware design
- Research coupled, heterogeneous systems
- Provide system access to internal and external users
- Evangelize the merits of multithreaded architectures

Focus areas

Programmability
Scalability





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Work Stack

Applications

Unstructured blog analysis

Contingency analysis for the electrical power grid

Understanding text documents

Unstructured video analysis

Methods

Bayesian networks

Social networks

Database systems

Languages

Chapel for hybrid systems

Runtime System

Compiler and runtime system

Performance analysis and tools

Communication software for hybrid systems

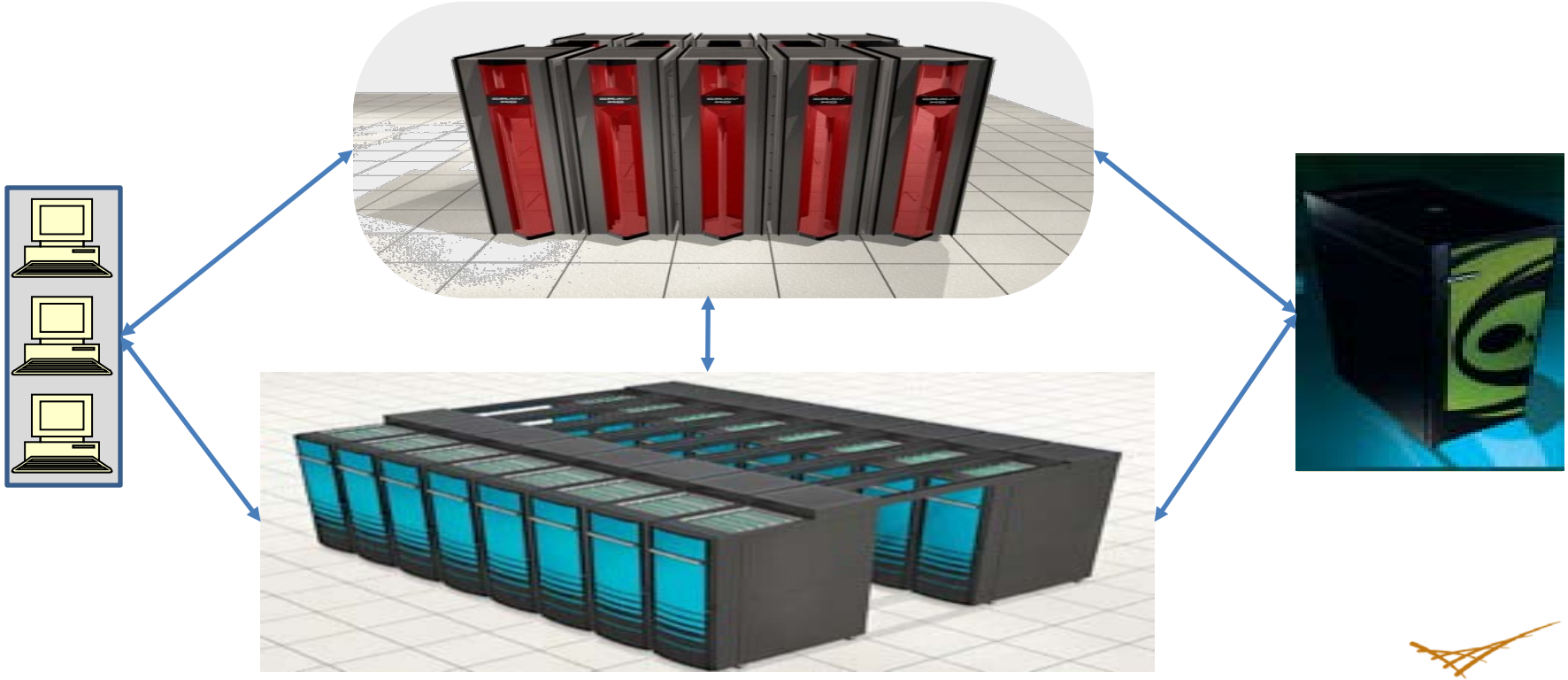
Architecture

Improving the effective bandwidth of MT architectures

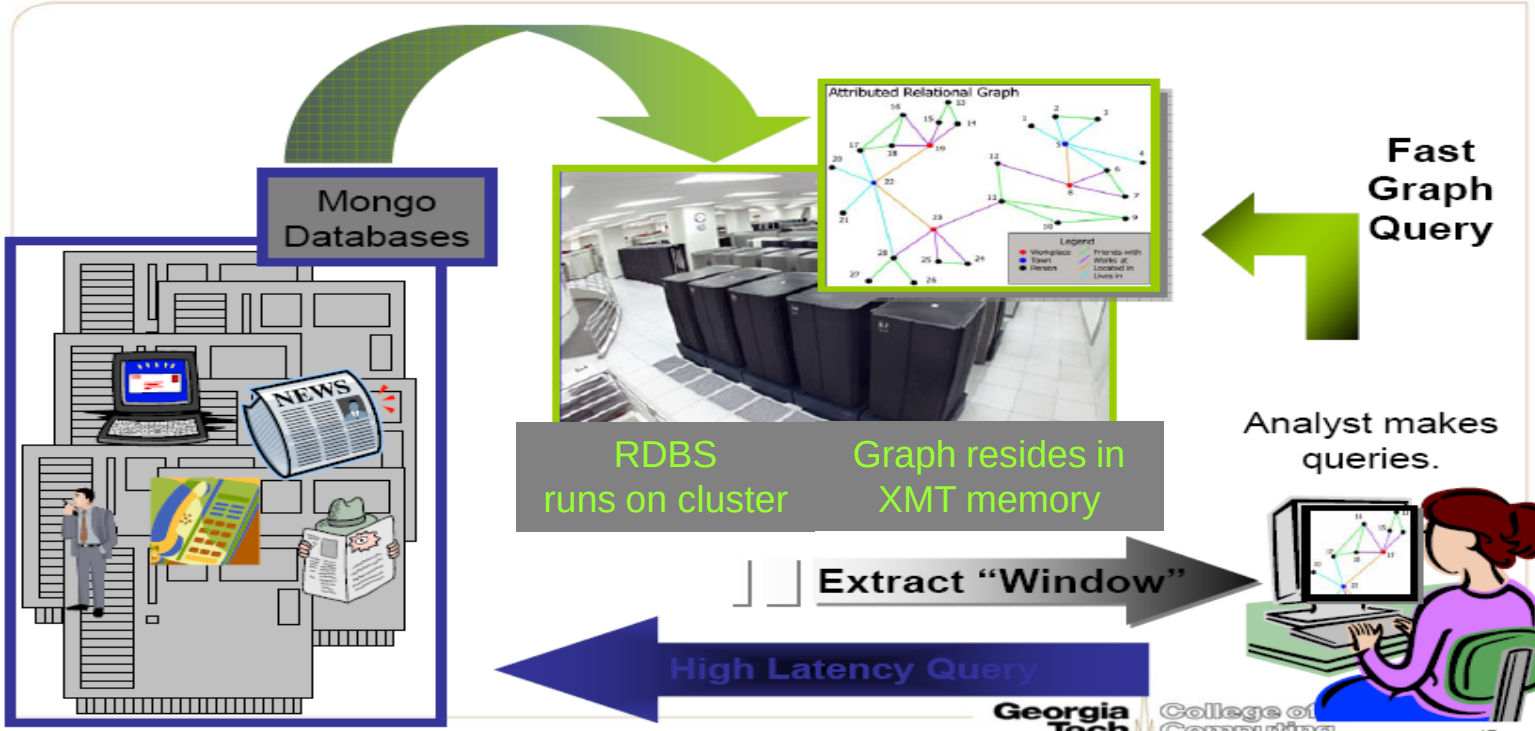
Improving BW of MT architectures

- Explore hardware changes to Cray XMT roadmap
  - Local data buffer
  - Reduce effect of memory hot spots
  - Explore different network topologies
- Drive design of future systems for irregular applications
  - Multi-core processors
  - Hybrid processors

Communications for Hybrid Systems



Semantic web database



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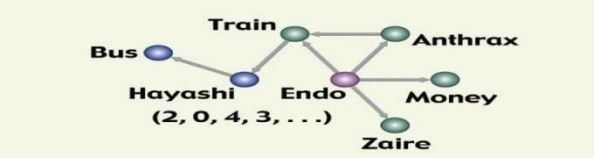
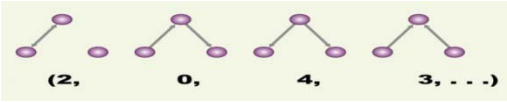
Performance Analysis

- XMT is not a PRAM
  - Parallelism alone is not the sole indicator of performance
  - Memory and network BW are bottlenecks
- Technical Approach
  - XMT machine characterization
  - Memory-centric performance tools
  - Benchmark suite for irregular applications
    - Measure speed and feeds of subsystems and parallel patterns
    - Cycles per element metric

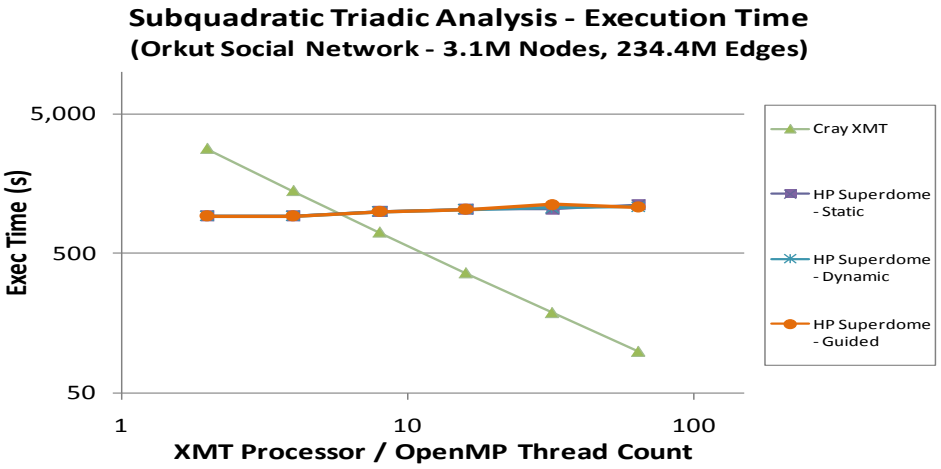
Dynamic Network Analysis





- Social networks are typically portrayed as directed graphs that show ties or relationships among people, groups, and/or organizations.
- Triadic analysis is one form of social network analysis that surveys and examines the relationships among every possible combination of three nodes in a social network.
- Frequencies and transitions of specific types of triads may be used to examine the structure, behavior, and evolution of a social network.
- Triad census acts as data signature summarizing social network.
- Applications: social networks, link analysis, computer networks

Cray XMT vs. HP Superdome



- Cray XMT
  - 64 Processors
  - 512GB Memory
- HP Superdome
  - 128 Cores
  - 256 GB memory

- On Superdome
  - Atomic operations account for 20% of the cycles
  - Atomic operations miss L1 cache

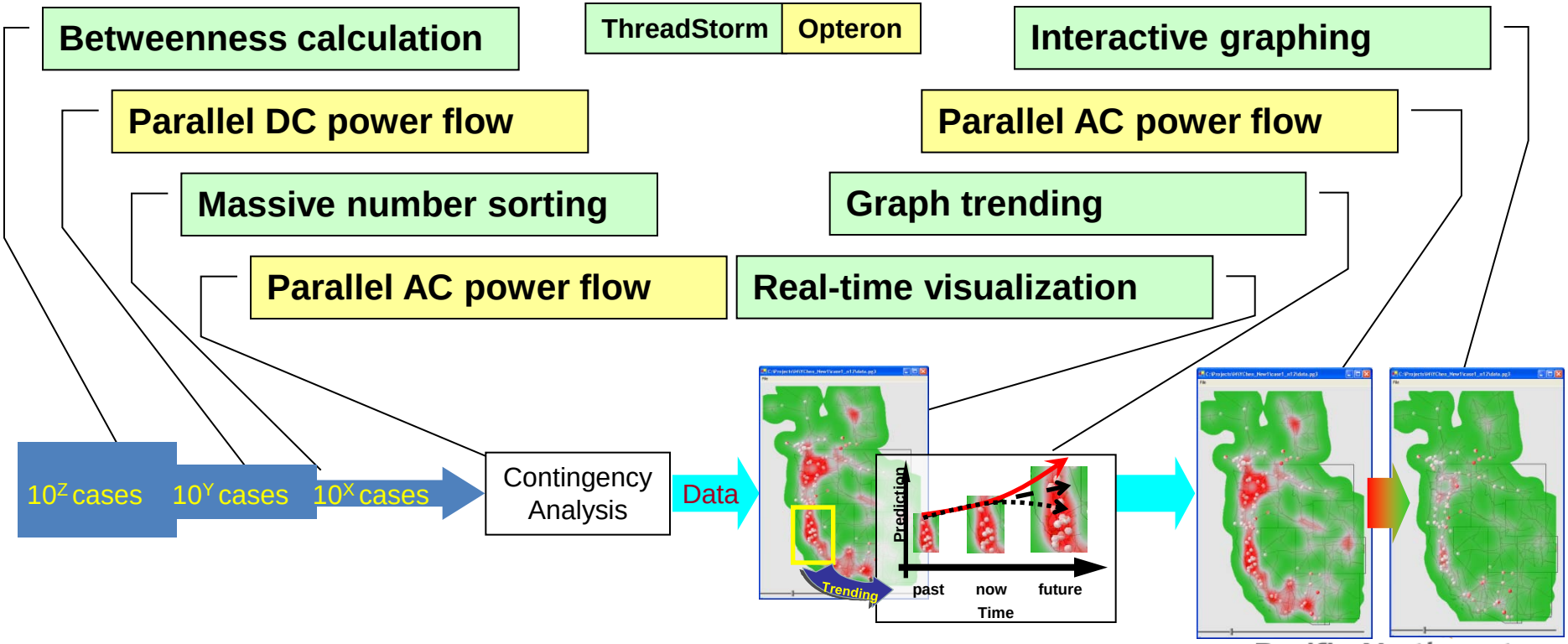
Text Document Analysis

- Extract general structural information from corpus
  - Bag of words
  - Inverted index
- Build efficient representation of spatial relationship among documents using Moore's “Anchors Hierarchy”
  - Efficient membership and similarity queries
  - Acceleration of spatial algorithms such as K-means clustering
  - Efficient visualization at multiple resolutions

Contingency Analysis for Power Grids

- Power grid operation relies on contingency analysis to gain situational awareness and design remedial actions.
  - Combinatorial numbers of contingencies are significantly larger than the capability of computing power
  - Large amount of analysis result data need to be presented to operators to support real-time decision making
- Apply **graph theory (betweenness centrality)** to power grid topology to determine the impact of elements
- Apply **advanced visual analytics techniques** for analysis result presentation
- Develop **graph trending analysis capability** using statistical methods to alert operators for deteriorating stability situation
- Develop interactive analysis capability to evaluate candidate remedial actions for real-time decision support

Use of XMT Computational Resources



For more information

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- http://cass-mt.pnl.gov
- Pick up a task flyer