Semi-Automatic Models of Communication Volume and Frequency for SPMD Applications

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Why Performance Modeling

- Understand application behavior on current systems
- Understand how applications will perform at different scales or on future systems
- Gain insight into performance bottlenecks
- Identify barriers to scalability

Performance Modeling Challenges

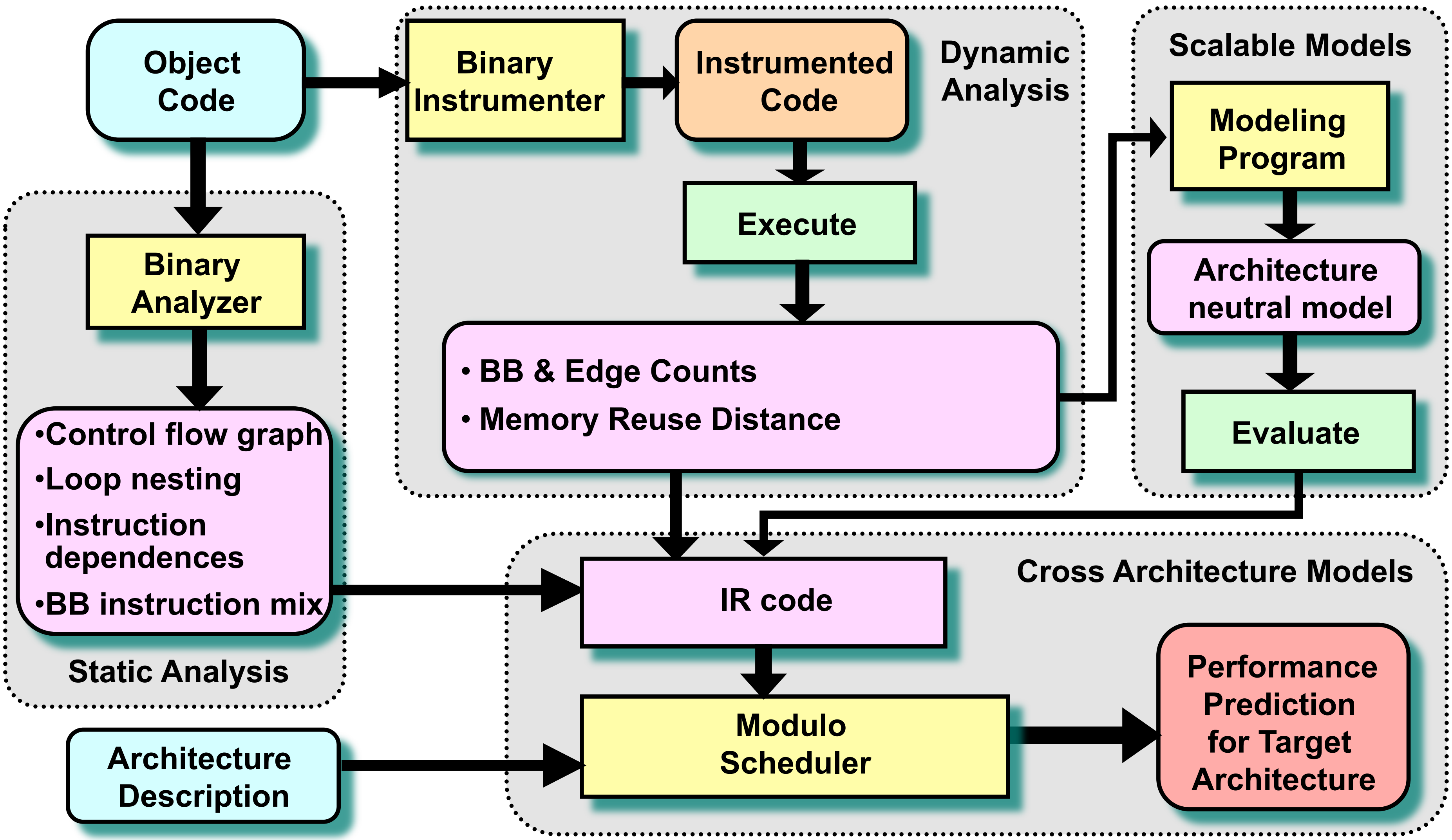
- **Performance depends on:**
  - architecture specific factors
  - application characteristics
    - memory access patterns
    - instruction mix and schedule dependencies
    - communication frequency and bandwidth
  - input data parameters
- **Analyzing performance at scale is expensive**

Approach

Separate contribution of application characteristics

- **Measure the application-specific factors**
  - —static analysis
  - —dynamic analysis
- **Construct scalable models**
- **Explore interactions with hardware**

Single Node Performance Modeling



How to Extend to Parallel Programs?

- Performance scales with
  - —input size
  - —processor count
- MPI traces not suited for scalable modeling
  - —number and type of MPI events in the trace vary with input size and processor count
- Prior work looked at
  - —identifying patterns in traces
  - —apply regression on the time spent in communication and computation

A Statistical Approach

- Think of program execution as a series of computation intervals
- Computation intervals bounded by two consecutive communication events
- Collect and aggregate data at interval level
- Model the frequency and cost of intervals as a function of
  - —input size
  - —processor count

An Early Preliminary Prototype

- Implemented on top of mpiP
- Modified mpiP to collect data at interval level
  - —intervals uniquely defined by the stack unwinds of the two delimiting MPI primitives
- For each interval collect
  - —information about computation cost
  - —message size and communication cost for the MPI primitive closing the interval
- Aggregate information into histograms
  - —histograms provide more insight than any single value statistic (e.g. median, mean+stdev)

Preliminary Results

- Collected data for Sweep3D on a Cray XT4 machine

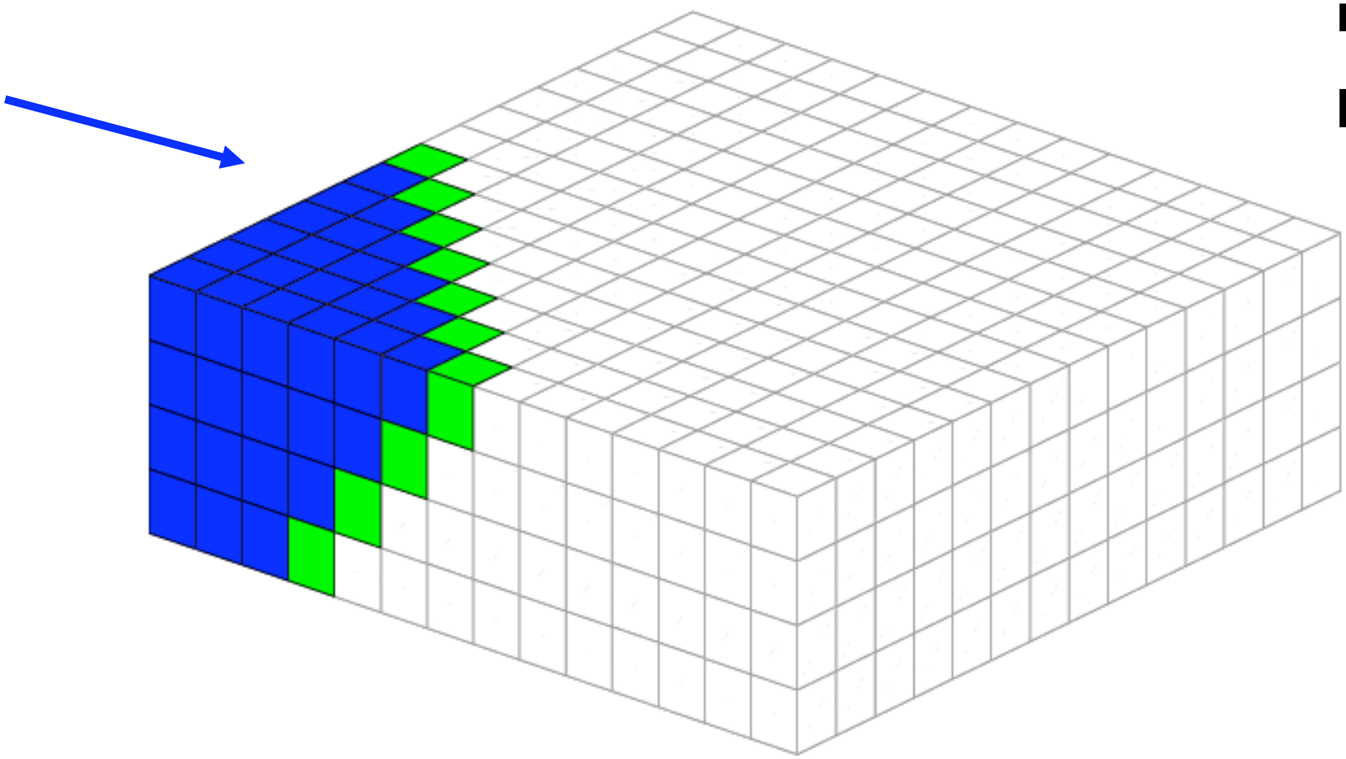
- Solves a 3D cartesian geometry neutron transport problem

iq loop

MPI communication

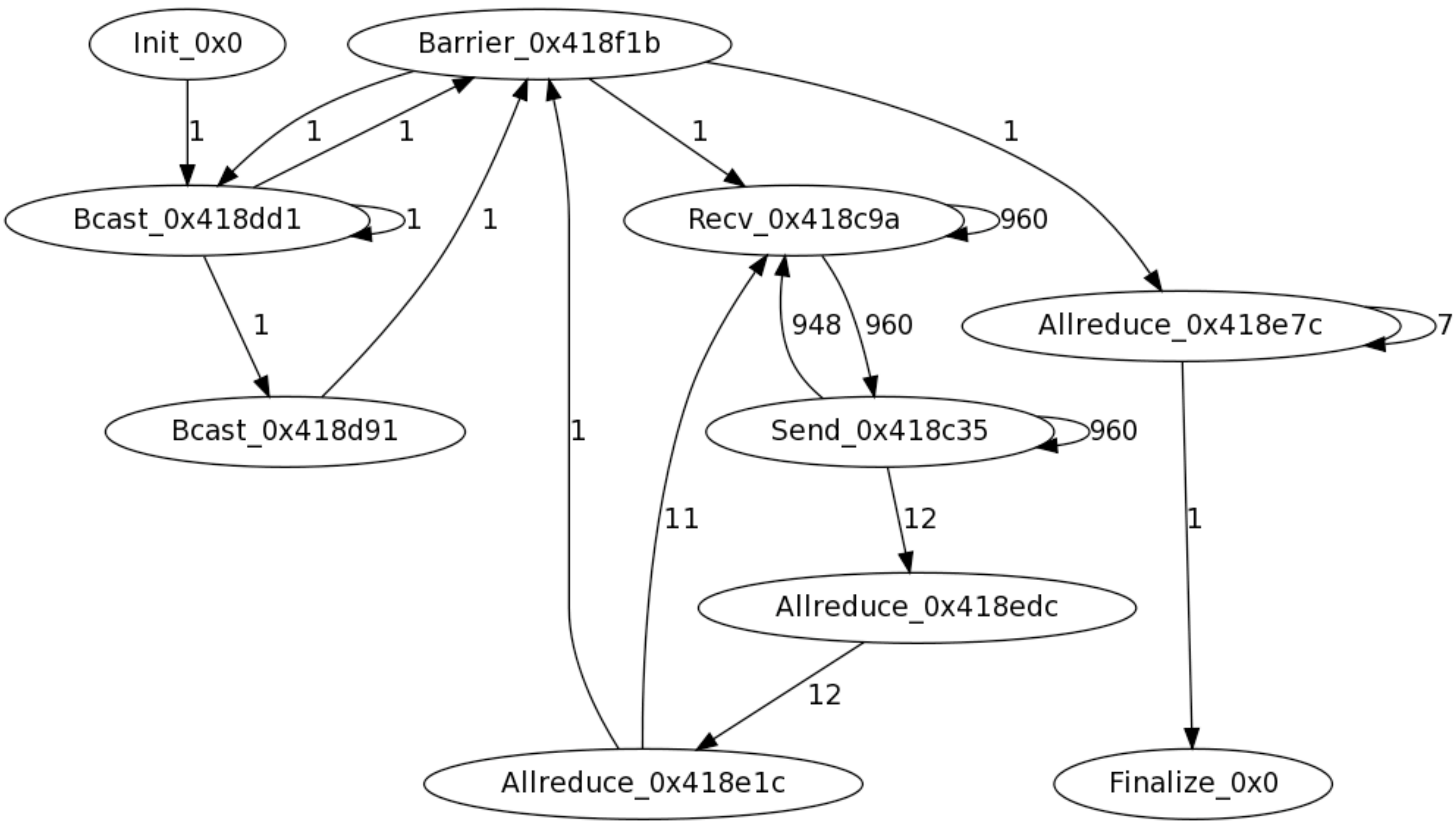
node computation

MPI communication



Flow Chart of Computation Intervals

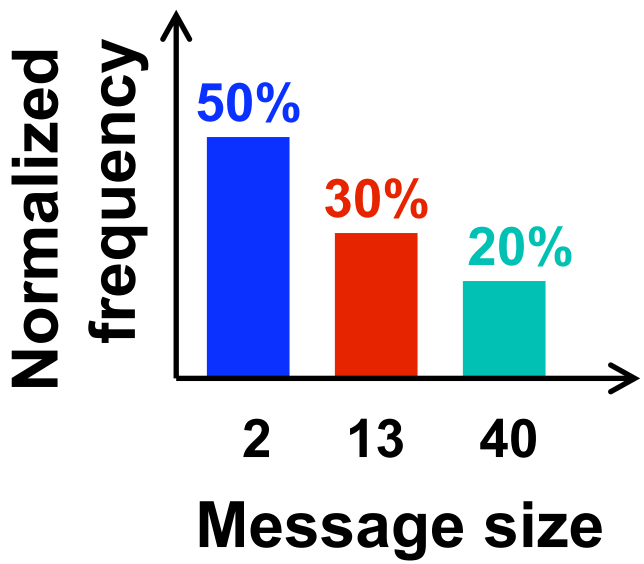
- **Nodes correspond to distinct MPI calls**
- **Edges represent different computation intervals**
  - **labels correspond to execution frequency**

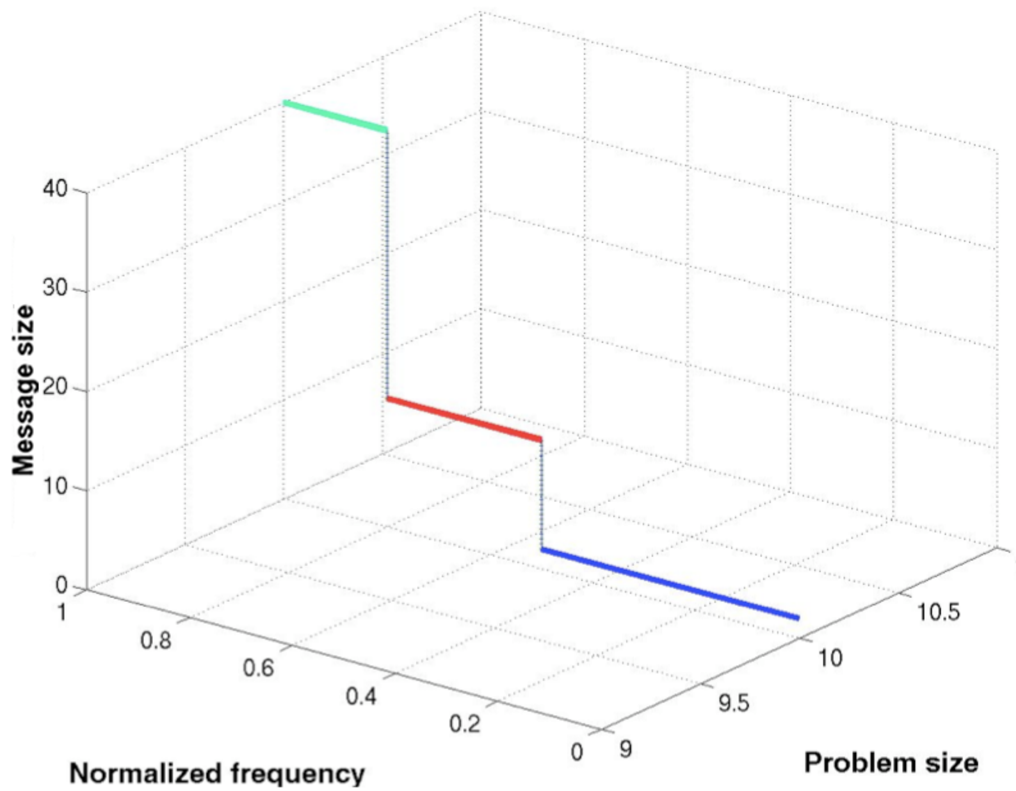


Data Collection

- For each interval collect
  - —distribution of message sizes
  - —distribution of communication times
  - —distribution of computation times
  - —several other scalar values
- Collect data for multiple input sizes and multiple processor counts
- Goal: model the structure and scaling of data histograms as a function of problem size and processor count

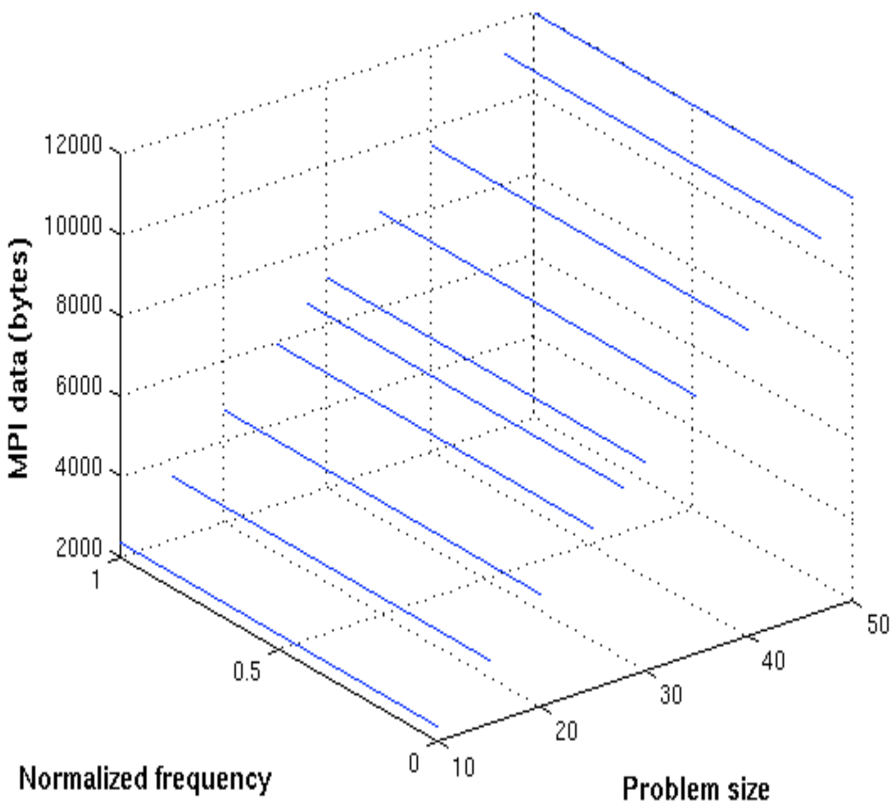
3D Histogram Representation

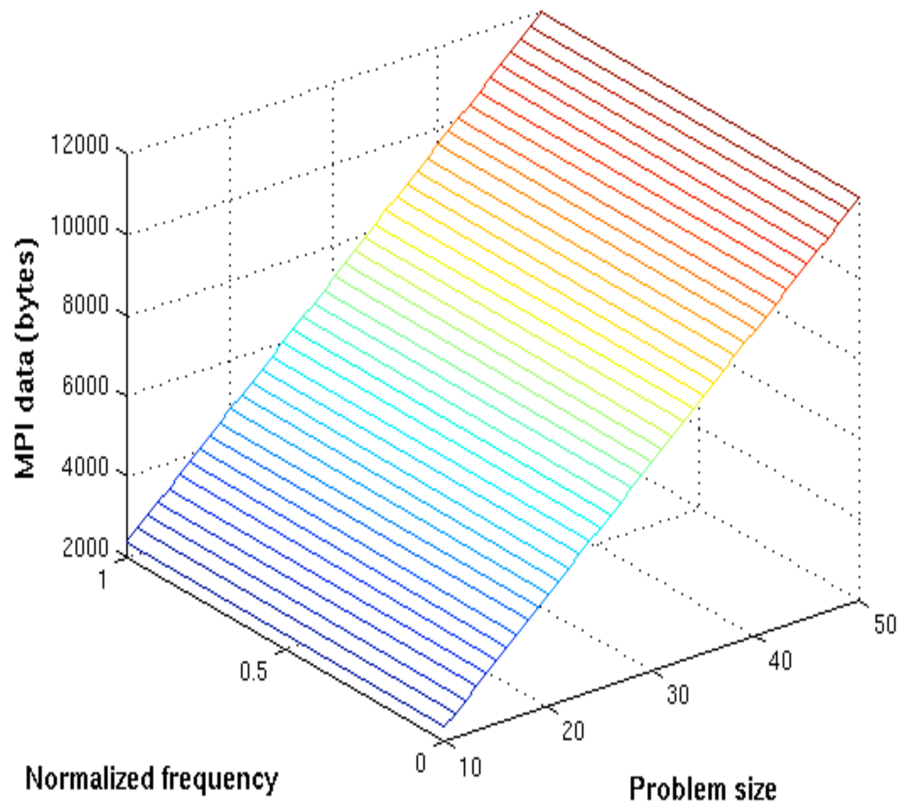




Distribution of Message Sizes

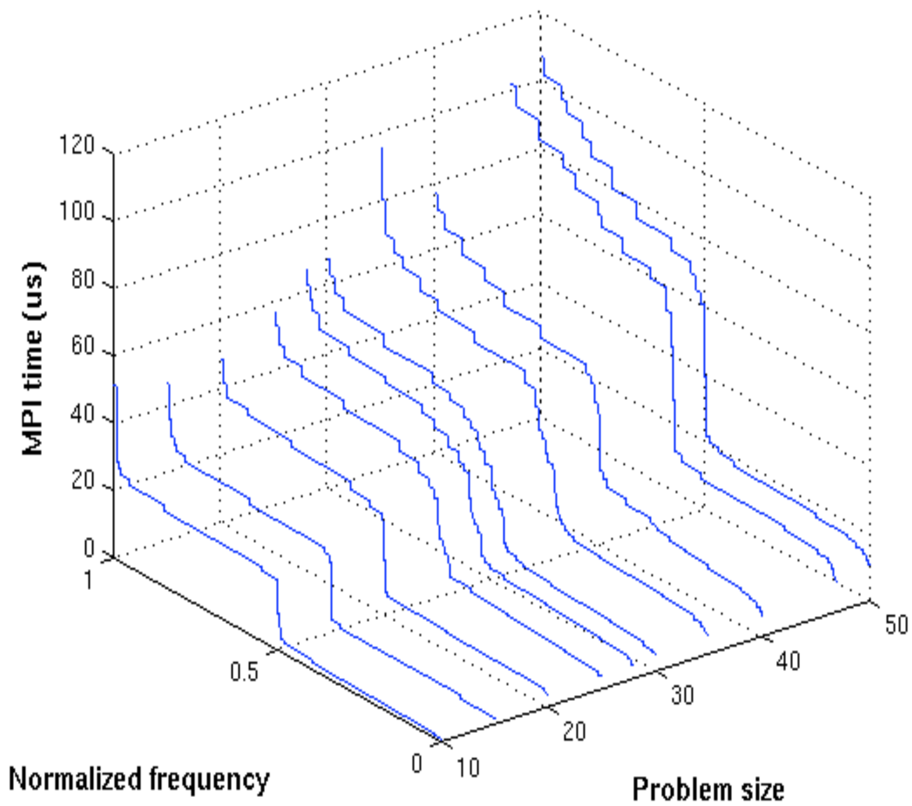
- **Interval Recv_0x418c9a - Send_0x418c35**

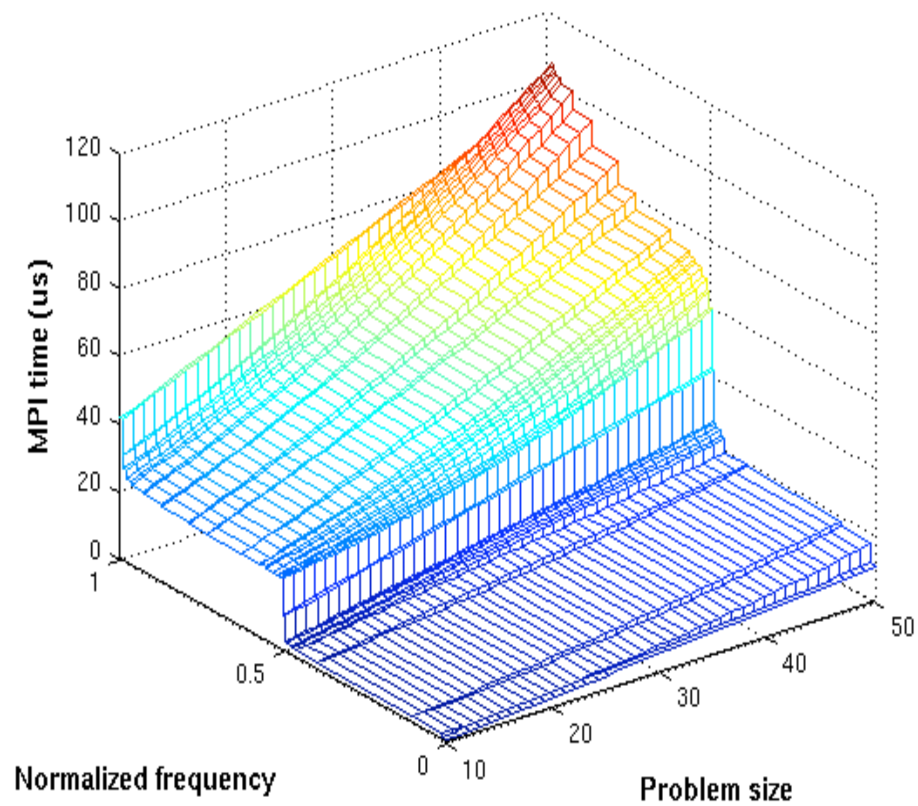




Distribution of Communication Times

- **Interval Recv_0x418c9a - Send_0x418c35**



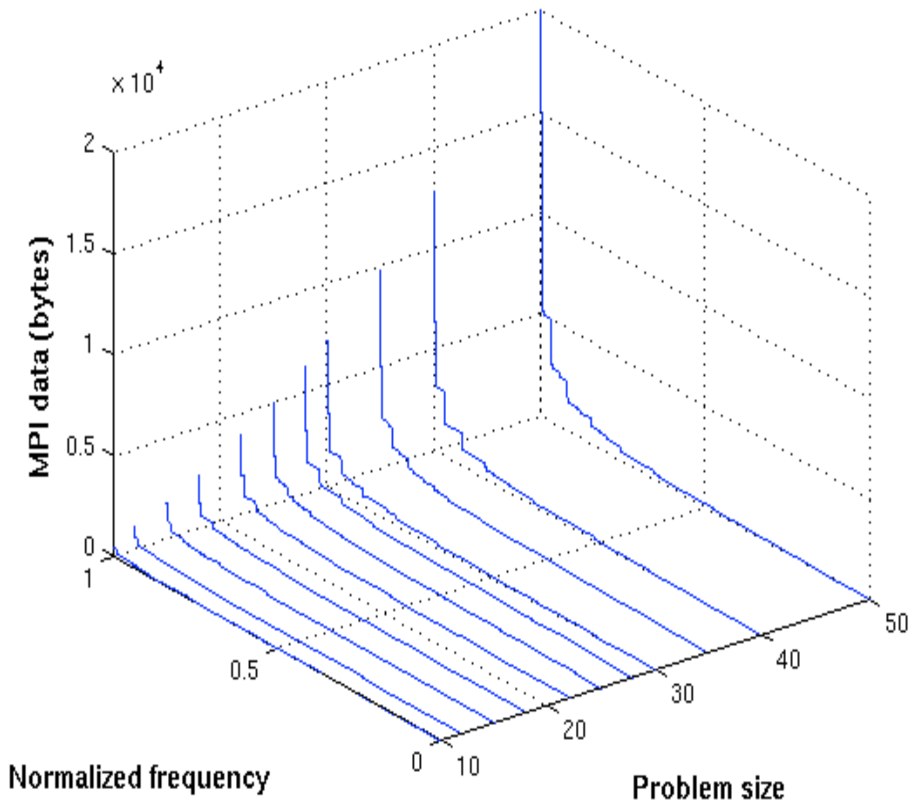


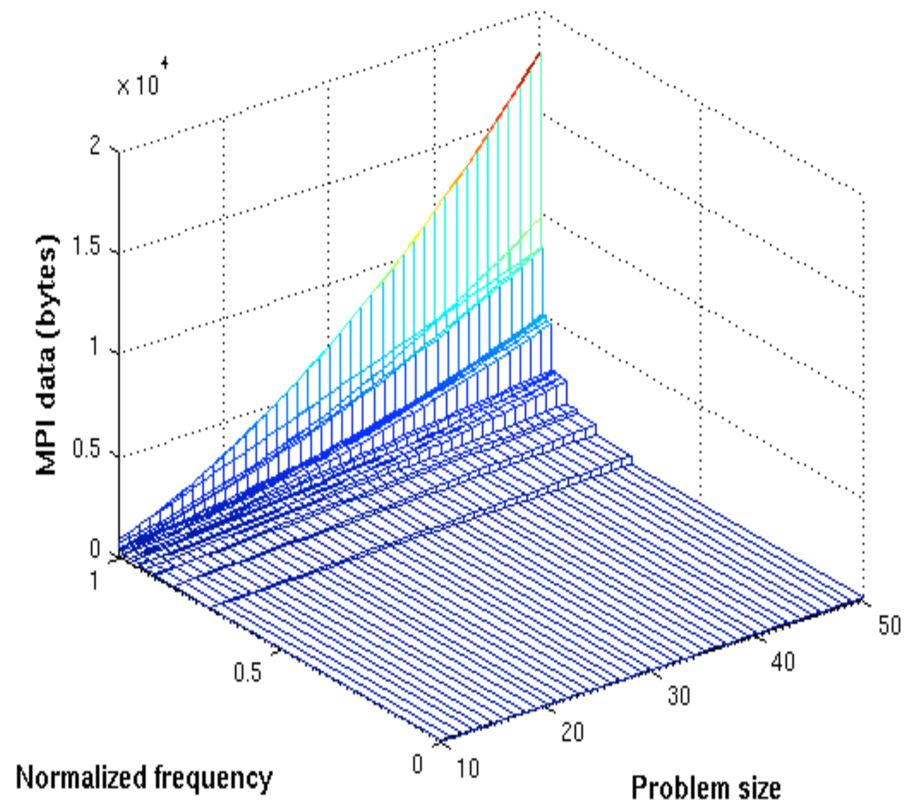
Results for SMG2000

- Parallel semicoarsening multigrid solver
- Modified solver to execute a fixed number of iterations
- Collected data at interval level for different grid sizes and different processor counts

Distribution of Message Sizes

- **As a function of grid size**





Distribution of Communication Times

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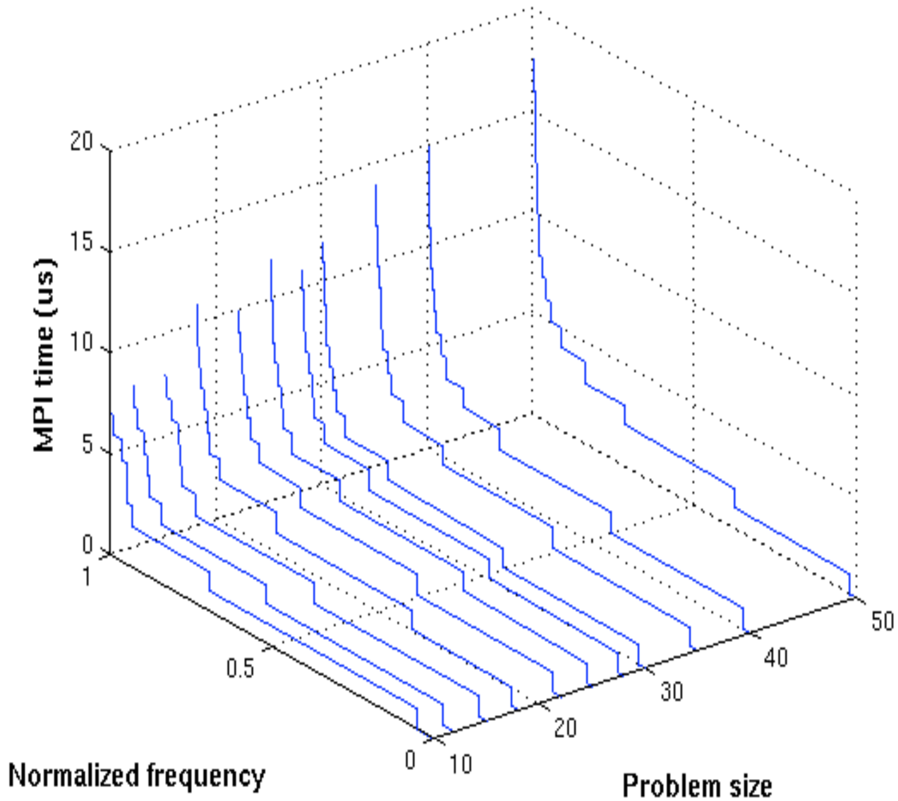
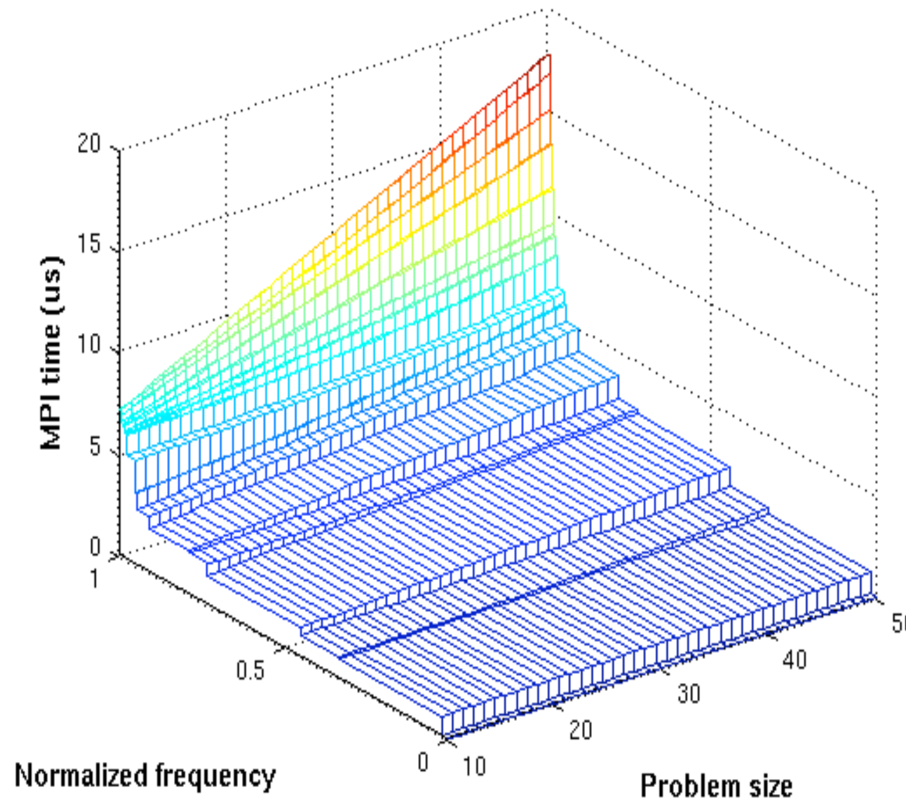
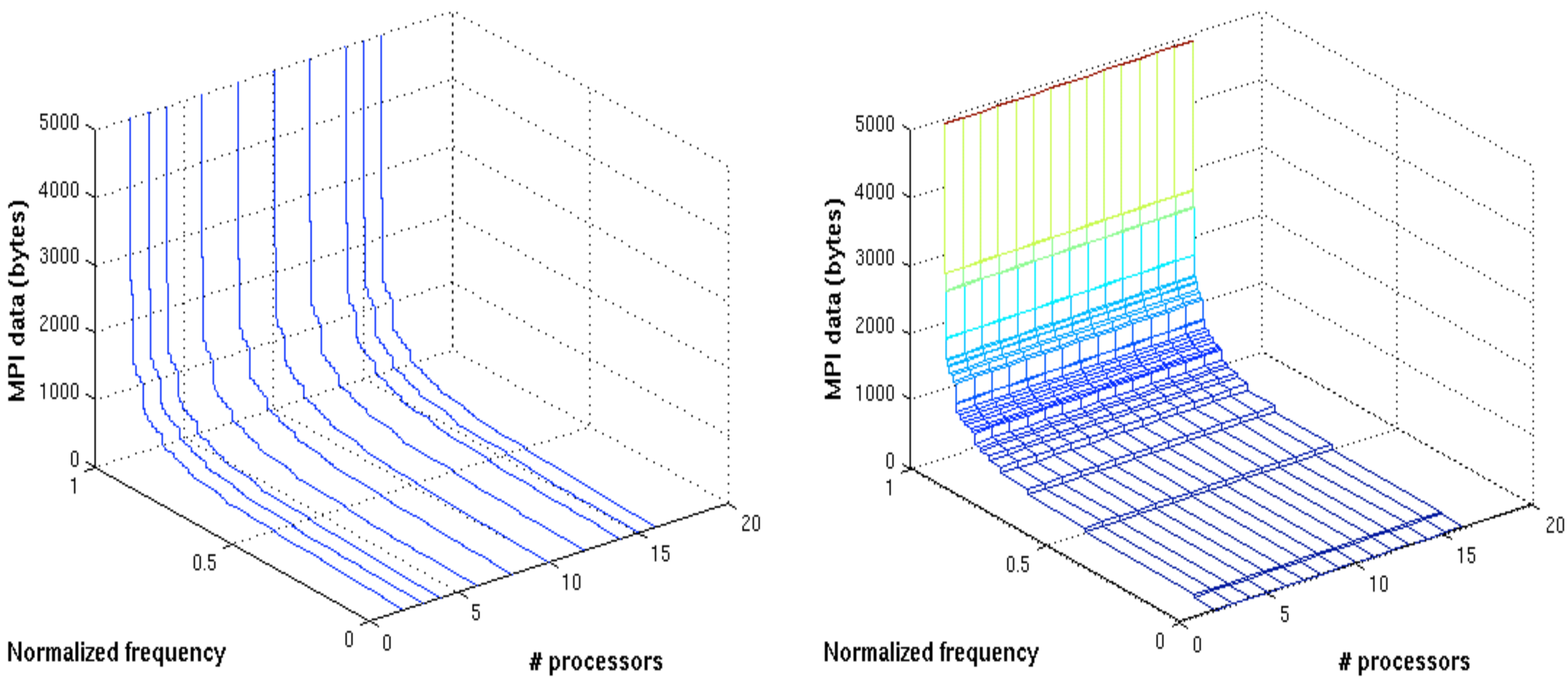




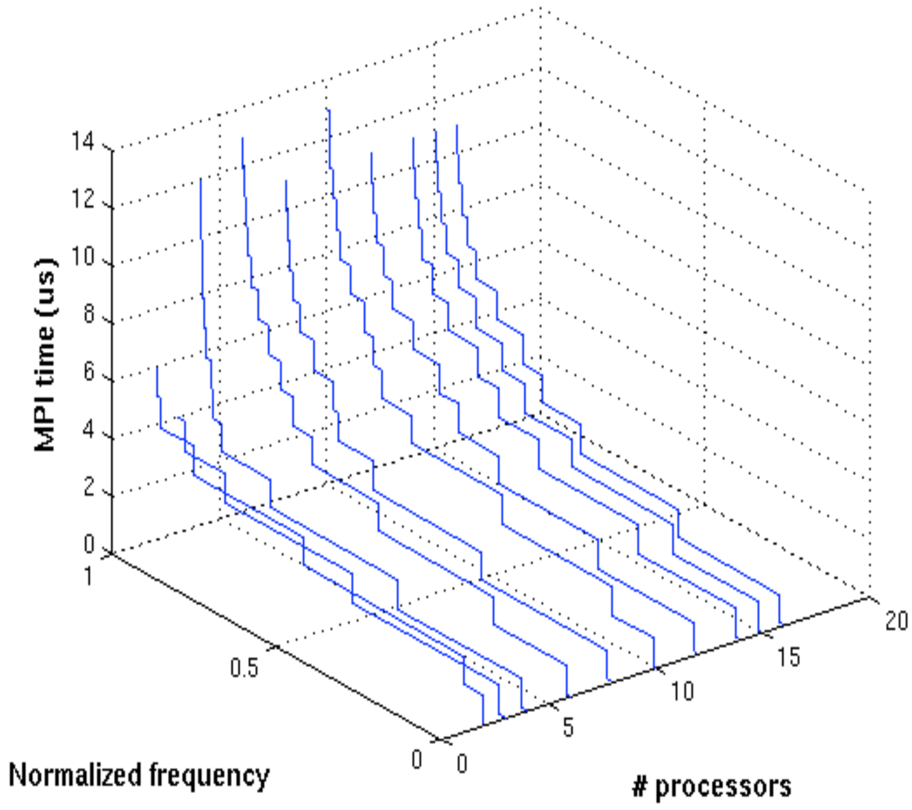
Distribution of Message Sizes

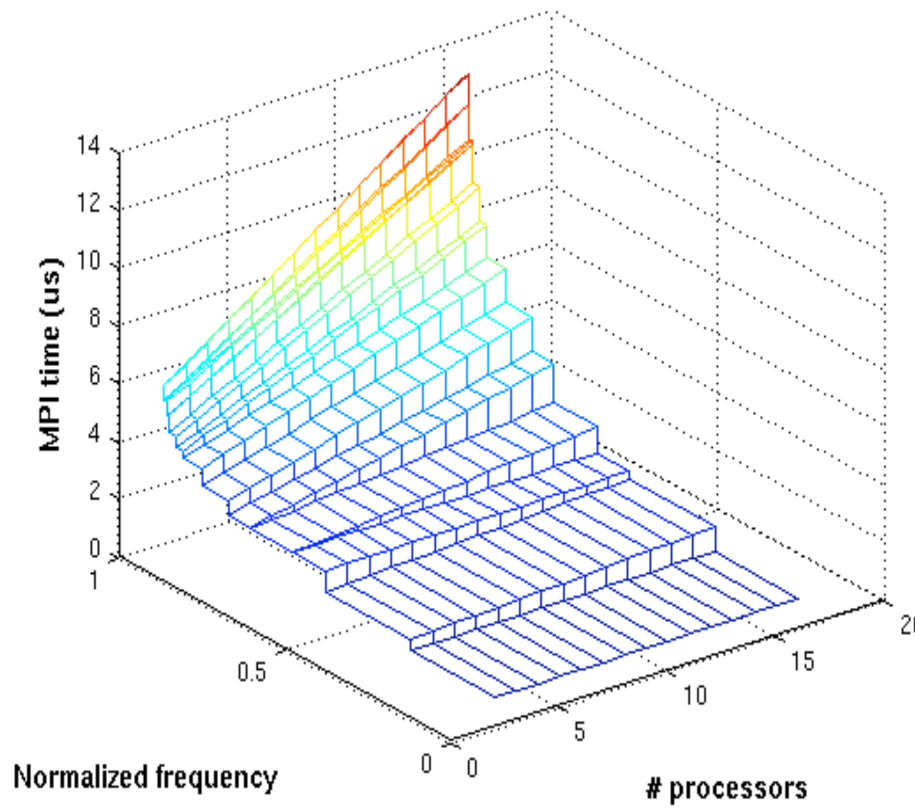
- **As a function of processor count**



Distribution of Communication Times

- **As a function of processor count**





Summary

- This is a work in progress
  - —no end-to-end predictions
  - —preliminary results do not contradict the approach
  - —Sweep3D results show that understanding topology is important
- Not a replacement for tracing and network simulators
- Wants
  - —StackWalkerAPI and SymtabAPI