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Sandia National Laboratories

Scalability Studies for Simulation Codes Based on Varying Models of Interprocessor Communications

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Project Description

To write supercomputer simulation codes that will run well on future supercomputers, research in this project is directed towards implementing simulation algorithms, with a specific emphasis on interprocessor communications. The effectiveness of interprocessor features for simulation algorithms is evaluated. Models of the subsystems of future supercomputers will determine how well codes will scale up to run on future computers and help to develop codes with minimal degradation in the event of faults. The project focuses on communication features and coordinates with other projects focusing on other features. Existing simulation codes are used in the project.

Seven tasks will be performed at the discretion of the Sandia principal investigator; the first two tasks were completed in early 2006, and the rest are awaiting approval/revision:

- Develop a draft and final project plan, including a statement of the problem, technical issues, approach, research tasks, and duration and level of effort.
- Host meeting for follow-on work and produce meeting notes.
- With regard to the environments with different topologies: (1) develop data exchange algorithms for global exchanges, (2) develop estimates of exchange durations given different mechanisms of data delivery parameterized by the numbers of processing elements, channel bandwidths, and delays, and (3) determine the maximum number of processing elements for certain parameters.
- Investigate scalability (clusterization) variants for multiprocessor environments with different topologies and communication mechanisms, as well as variants for different forms of data exchange and external memory, and investigate communication parameters of the multiprocessor environments.
- Investigate the means of ensuring high multiprocessor environment reliability by adding redundant elements to the basic elements as a fail-safe.
- Determine main design parameters of multiprocessor environments with different topologies and conduct investigations of their hardware complexity.
- Provide final report with final results analysis and proposals for further study.

Technical Purpose and Benefits

Understanding how older and existing codes will run on future supercomputers is necessary because future supercomputers will have greater parallelism and shifts in the nature of some subsystems. Accurate and predictable mathematical models will permit developers to ensure that algorithms will run on petaFLOPS-class supercomputers with perhaps a hundred thousand to a million processors. Algorithms need to be formulated that work, even if processors are faulty or a node is removed, and if possible, they need to be friendly to low-cost, high-performance computers, such as clusters.

Estimation of time complexity for global exchange algorithms

	Environ-ment	Com-muni-cation type	A^1_ω / γ	A^ω_ω / γ	A^S_ω / γ	A^ω_1 / γ	A^T_ω / γ	Note
1	2	3	4	5	6	7	8	9
1	1D	1	$\frac{1}{2}\frac{Q}{V}\omega$ 1	$\frac{1}{2}\frac{Q}{V}\omega$ 1	$\frac{1}{2}\frac{Q}{V}\omega$ 1	$\frac{1}{2}\frac{Q}{V}\omega$ 1	$\frac{1}{2}\frac{Q}{V}\omega^2$ ω	$\gamma = \frac{T(A^i_j)}{T_{\lim}}$
		2	$T_c\omega + \frac{Q}{V}\log\omega$ 1	$T_c\omega^2 + \frac{Q}{V}\omega\log\omega$ logω	$\frac{1}{4}T_c\omega^2 + \frac{Q}{V}\omega$ 1	$\frac{1}{4}T_c\omega^2 + \frac{Q}{V}\omega$ 1	$\frac{1}{8}T_c\omega^3 + \frac{1}{2}\frac{Q}{V}\omega^2$ ω	
		3	$\frac{1}{2}T_c\omega + \frac{Q}{V}$ 1	$\frac{1}{2}T_c\omega^2 + \frac{1}{2}\frac{Q}{V}\omega$ 1	$\frac{1}{8}T_c\omega^2 + \frac{1}{2}\frac{Q}{V}\omega$ 1	$\frac{1}{8}T_c\omega^2 + \frac{1}{2}\frac{Q}{V}\omega$ 1	$\frac{1}{8}T_c\omega^3 + \frac{1}{2}\frac{Q}{V}\omega^2$ ω	
2	2D	1	$\frac{Q}{V}\sqrt{\omega}$	$\frac{1}{2}\frac{Q}{V}\omega$ 2	$\frac{1}{2}\frac{Q}{V}\omega$ 2	$\frac{1}{2}\frac{Q}{V}\omega$ 2	$\frac{1}{2}\frac{Q}{V}\omega^2$ 2ω	
		2	$2T_c\sqrt{\omega} + \frac{Q}{V}\log\omega$	$2T_c\omega + \frac{1}{2}\frac{Q}{V}\omega\log\omega$ 2logω	$K_1T_c + \frac{Q}{V}\omega$ 4	$K_1T_c + \frac{Q}{V}\omega$ 4	$\frac{1}{2}T_c\omega^{\frac{3}{2}} + 2\frac{Q}{V}\omega^{\frac{3}{2}}$ $8\omega^{1/3}$	$K_1 = \frac{1}{4}\omega^{\frac{3}{2}} + \frac{3}{4}\omega + \frac{1}{2}\sqrt{\omega}$
		3	$\frac{1}{4}T_c\omega + \frac{Q}{V}$	$\frac{1}{2}T_c\omega^2 + \frac{1}{2}\frac{Q}{V}\omega$ 2	$\frac{1}{8}T_c\omega^{\frac{3}{2}} + \frac{1}{2}\frac{Q}{V}\omega$ 2	$\frac{1}{8}T_c\omega^{\frac{3}{2}} + \frac{1}{2}\frac{Q}{V}\omega$ 2	$\frac{1}{4}T_c\omega^{\frac{3}{2}} + \frac{Q}{V}\omega^{\frac{3}{2}}$ $4\omega^{1/3}$	

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