Scalable Shared-Memory Multiprocessing

reviewed by Janusz Zalewski, Embry-Riddle Aeronautical University

This book is primarily devoted to Dash (Directory Architecture for Shared Memory), a multiprocessor system known from earlier publications (see "The Stanford Dash Multiprocessor," *Computer*, Mar. 1992, Vol. 25, No. 3, pp. 63–79). The book also provides readers with a comprehensive view of modern multiprocessing, as it describes where the technology is actually heading.

The major issue in multiprocessor architectures is communication: how multiple processors communicate with each other. Not so long ago, buses were the major component tying various computational pieces together. Multiple processors used a bus to access common memory or to communicate with separate memories, which caused a communication bottleneck. Strictly speaking, the problems started when users wanted to extend existing systems with several processors to much larger aggregates of dozens or even hundreds of processing units. In such cases, even hierarchically organized buses began to saturate, and designers faced a scalability barrier. Moving from a bus to a point-to-point network was an immediate solution, but then old problems persisted and new ones arose, such as cache coherence. One approach was to maintain shared memory (common address space) along the lines or across the network, without cache coherence. Another relied on message passing, but in both cases the memory latency problem emerged. Technological developments soon made possible widespread use of caches, and then other problems soared. Maintaining cache coherence across the bus (let alone the entire network) is not trivial, and most designers lost their hair before coming up with satisfactory solutions.

This book is a concentrated effort to address such problems and provide a solution to maintain cache coherence across the point-to-point network of multiple processors. The authors call it scalable shared-memory multiprocessing (SSMP). The book's three parts are General Concepts, Experience with Dash, and Future Trends. The first is the most interesting. It is mainly a historical perspective on multiprocessor systems.

The book first discusses scalability problems in detail, concluding that hardware cache coherence is a key to high performance. To ensure scalability, one must apply point-to-point interconnections (as opposed to a bus) and base cache coherence on directory schemes. Scalability has three dimensions:

- How does the performance scale? That is, when speedup (in terms of execution time) can we achieve by using N processors over a single processor for the same problem?
- How does the cost scale when more processors are added?
- What is the largest number of processors for which multiprocessing rather than uniprocessing is still advantageous? That is, what is the range of scalability?

The book then proceeds to simulation experiments for six realistic practical problems: simulation of hypersonic flow using a particle-in-cell method, water molecule interaction, digital logic simulation, routing wires for VLSI standard-cell designs, Cholesky factorization of a sparse matrix, and hierarchical N-body gravitation simulation. To study the execution behavior of all six applications, the authors ran them on a simulated multiprocessor, with shared data uncached and cached under a simple PRAM memory model. The major finding was that reducing memory latency due to shared data is crucial for achieving good performance of parallel applications. The study of communication behavior revealed that, quite obviously, real memory system models increased traffic by an order of magnitude. Finally, directory-based cache coherence using an invalidating protocol matched the applications' behavior well. The text extensively documents this study.

Next, the authors tackle techniques to address problems of long latency and limited bandwidth. The latency problem increases with the number of processors, because the majority of memory must be accessed through the interconnection network. Similarly, because of high cost, the bandwidth to access memory cannot increase linearly with additional processors and memory. The book discusses two approaches to handling memory latency: latency reduction and latency hiding. The authors also describe the most likely cause of bandwidth problems but spots caused by references to synchronization variables.

The first part concludes with a discussion of implementation issues, including costs, and a critical overview of SSMP systems designed and built so far. These systems are grouped into six categories: directory-based, hierarchical, reflective memory, non-cache-coherent, vector, and virtual shared-memory systems.

The authors then thoroughly describe their experience in building the Dash system, its

Scalable Sharedmemory Multiprocessing

Jelica Protic,Milo Tomasevic,Veljko Milutinović

Scalable Sharedmemory Multiprocessing:

Scalable Shared-Memory Multiprocessing Daniel E. Lenoski,Wolf-Dietrich Weber,2014-06-28 Dr Lenoski and Dr Weber have experience with leading edge research and practical issues involved in implementing large scale parallel systems They were key contributors to the architecture and design of the DASH multiprocessor Currently they are involved with commercializing scalable shared memory technology   Shared Memory Multiprocessing Norihisa Suzuki,1992 Shared memory multiprocessors are becoming the dominant architecture for small scale parallel computation This book is the first to provide a coherent review of current research in shared memory multiprocessing in the United States and Japan It focuses particularly on scalable architecture that will be able to support hundreds of microprocessors as well as on efficient and economical ways of connecting these fast microprocessors The 20 contributions are divided into sections covering the experience to date with multiprocessors cache coherency software systems and examples of scalable shared memory multiprocessors   **Scalable Shared Memory Multiprocessors** Michel Dubois,Shreekant S. Thakkar,2012-12-06 The workshop on Scalable Shared Memory Multiprocessors took place on May 26 and 27 1990 at the Stouffer Madison Hotel in Seattle Washington as a prelude to the 1990 International Symposium on Computer Architecture About 100 participants listened for two days to the presentations of 22 invited The motivation for this workshop was to speakers from academia and industry promote the free exchange of ideas among researchers working on shared memory multiprocessor architectures There was ample opportunity to argue with speakers and certainly participants did not refrain a bit from doing so Clearly the problem of scalability in shared memory multiprocessors is still a wide open question We were even unable to agree on a definition of scalability Authors had more than six months to prepare their manuscript and therefore the papers included in this proceedings are refinements of the speakers presentations based on the criticisms received at the workshop As a result 17 authors contributed to these proceedings We wish to thank them for their diligence and care The contributions in these proceedings can be partitioned into four categories 1 Access Order and Synchronization 2 Performance 3 Cache Protocols and Architectures 4 Distributed Shared Memory Particular topics on which new ideas and results are presented in these proceedings include efficient schemes for combining networks formal specification of shared memory models correctness of trace driven simulations synchronization various coherence protocols   **Distributed Shared Memory** Jelica Protic,Milo Tomasevic,Veljko Milutinović,1997-08-10 The papers present in this text survey both distributed shared memory DSM efforts and commercial DSM systems The book discusses relevant issues that make the concept of DSM one of the most attractive approaches for building large scale high performance multiprocessor systems The authors provide a general introduction to the DSM field as well as a broad survey of the basic DSM concepts mechanisms design issues and systems The book concentrates on basic DSM algorithms their enhancements and their performance evaluation In addition it details implementations that employ DSM solutions at the software and the hardware level This guide is a research and development

reference that provides state of the art information that will be useful to architects designers and programmers of DSM systems **High Performance Computing Systems and Applications** Jonathan Schaeffer,2012-12-06 Major advances in computing are occurring at an ever increasing pace This is especially so in the area of high performance computing HPC where today s supercomputer is tomorrow s workstation High Performance Computing Systems and Applications is a record of HPCS 98 the 12th annual Symposium on High Performance Computing Systems and Applications The quality of the conference was significantly enhanced by the high proportion of keynote and invited speakers This book presents the latest research in HPC architecture networking applications and tools Of special note are the sections on computational biology and physics High Performance Computing Systems and Applications is suitable as a secondary text for a graduate level course on computer architecture and networking and as a reference for researchers and practitioners in industry

Reducing Communication Cost in Scalable Shared Memory Systems Gheith Ali Abandah,1998 DISTRIBUTED OPERATING SYSTEMS SINHA, PRADEEP K.,1998-01-01 The highly praised book in communications networking from IEEE Press now available in the Eastern Economy Edition This is a non mathematical introduction to Distributed Operating Systems explaining the fundamental concepts and design principles of this emerging technology As a textbook for students and as a self study text for systems managers and software engineers this book provides a concise and an informal introduction to the subject Semiconductor Memories and Systems Andrea Redaelli,Fabio Pellizzer,2022-06-07 Semiconductor Memories and Systems provides a comprehensive overview of the current state of semiconductor memory at the technology and system levels After an introduction on market trends and memory applications the book focuses on mainstream technologies illustrating their current status challenges and opportunities with special attention paid to scalability paths Technologies discussed include static random access memory SRAM dynamic random access memory DRAM non volatile memory NVM and NAND flash memory Embedded memory and requirements and system level needs for storage class memory are also addressed Each chapter covers physical operating mechanisms fabrication technologies and the main challenges to scalability Finally the work reviews the emerging trends for storage class memory mainly focusing on the advantages and opportunities of phase change based memory technologies Features contributions from experts from leading companies in semiconductor memory Discusses physical operating mechanisms fabrication technologies and paths to scalability for current and emerging semiconductor memories Reviews primary memory technologies including SRAM DRAM NVM and NAND flash memory Includes emerging storage class memory technologies such as phase change memory

Scalable and Distributed Machine Learning and Deep Learning Patterns Thomas, J. Joshua,Harini, S.,Pattabiraman, V.,2023-08-25 Scalable and Distributed Machine Learning and Deep Learning Patterns is a practical guide that provides insights into how distributed machine learning can speed up the training and serving of machine learning models reduce time and costs and address bottlenecks in the system during concurrent model training and inference The

book covers various topics related to distributed machine learning such as data parallelism model parallelism and hybrid parallelism Readers will learn about cutting edge parallel techniques for serving and training models such as parameter server and all reduce pipeline input intra layer model parallelism and a hybrid of data and model parallelism The book is suitable for machine learning professionals researchers and students who want to learn about distributed machine learning techniques and apply them to their work This book is an essential resource for advancing knowledge and skills in artificial intelligence deep learning and high performance computing The book is suitable for computer electronics and electrical engineering courses focusing on artificial intelligence parallel computing high performance computing machine learning and its applications Whether you re a professional researcher or student working on machine and deep learning applications this book provides a comprehensive guide for creating distributed machine learning including multi node machine learning systems using Python development experience By the end of the book readers will have the knowledge and abilities necessary to construct and implement a distributed data processing pipeline for machine learning model inference and training all while saving time and costs   Advances in High Performance Computing Lucio Grandinetti,J.S. Kowalik,Marián Vajtersic,2012-12-06 Most of the papers in this volume were presented at the NATO Advanced Research Workshop High Performance Computing Technology and Application held in Cetraro Italy from 24 to 26 of June 1996 The main purpose of the Workshop was to discuss some key scientific and technological developments in high performance computing identify significant trends and defme desirable research objectives The volume structure corresponds in general to the outline of the workshop technical agenda general concepts and emerging systems software technology algorithms and applications One of the Workshop innovations was an effort to extend slightly the scope of the meeting from scientific engineering computing to enterprise wide computing The papers on performance and scalability of database servers and Oracle DBMS reflect this attempt We hope that after reading this collection of papers the readers will have a good idea about some important research and technological issues in high performance computing We wish to give our thanks to the NATO Scientific and Environmental Affairs Division for being the principal sponsor for the Workshop Also we are pleased to acknowledge other institutions and companies that supported the Workshop European Union European Commission DGIII Industry CNR National Research Council of Italy University of Calabria Alenia Spazio Centro Italiano Ricerche Aerospaziali ENEA Italian National Agency for New Technology Energy and the Environment Fujitsu Hewlett Packard Convex Hitachi NEC Oracle and Silicon Graphics Cray Research Editors January 1997 vii LIST OF CONTRIBUTORS Ecole Nonnale Su rieure de Lyon 69364 Abarbanel Robert M   **Explorations in Computational Physics** Devang Patil,2025-02-20 Explorations in Computational Physics delves into the intricate world of computational physics offering a comprehensive guide from fundamental theories to cutting edge applications This book serves as an indispensable companion for both novice learners and seasoned researchers We cover a diverse array of topics meticulously unfolding layers of computational techniques and their applications in various

branches of physics From classical mechanics simulations elucidating celestial mechanics to quantum mechanics computations unraveling atomic and subatomic realms the book navigates through the vast landscape of computational methodologies with clarity and precision Furthermore we delve into electromagnetic field simulations statistical mechanics and thermodynamics equipping readers with tools to model complex physical phenomena with accuracy and efficiency High performance computing techniques data analysis and visualization methodologies are elucidated empowering readers to harness modern computational resources in their research With lucid explanations illustrative examples and insightful discussions on emerging technologies like quantum computing and artificial intelligence Explorations in Computational Physics fosters a deeper understanding of computational methodologies and their transformative impact on physics research

Neural Networks and Statistical Learning Ke-Lin Du,M. N. S. Swamy,2019-09-12 This book provides a broad yet detailed introduction to neural networks and machine learning in a statistical framework A single comprehensive resource for study and further research it explores the major popular neural network models and statistical learning approaches with examples and exercises and allows readers to gain a practical working understanding of the content This updated new edition presents recently published results and includes six new chapters that correspond to the recent advances in computational learning theory sparse coding deep learning big data and cloud computing Each chapter features state of the art descriptions and significant research findings The topics covered include multilayer perceptron the Hopfield network associative memory models clustering models and algorithms t he radial basis function network recurrent neural networks nonnegative matrix factorization independent component analysis probabilistic and Bayesian networks and fuzzy sets and logic Focusing on the prominent accomplishments and their practical aspects this book provides academic and technical staff as well as graduate students and researchers with a solid foundation and comprehensive reference on the fields of neural networks pattern recognition signal processing and machine learning *High-Performance Computing and Networking* Peter Sloot,Marian Bubak,Bob Hertzberger,1998-04-15 Proceedings Parallel Computing **Languages, Compilers and Run-time Environments for Distributed Memory Machines** J. Saltz,P. Mehrotra,2014-06-28 Papers presented within this volume cover a wide range of topics related to programming distributed memory machines Distributed memory architectures although having the potential to supply the very high levels of performance required to support future computing needs present awkward programming problems The major issue is to design methods which enable compilers to generate efficient distributed memory programs from relatively machine independent program specifications This book is the compilation of papers describing a wide range of research efforts aimed at easing the task of programming distributed memory machines

Computerworld ,1998-06-08 For more than 40 years Computerworld has been the leading source of technology news and information for IT influencers worldwide Computerworld s award winning Web site Computerworld com twice monthly publication focused conference series and custom research form the hub of the world s largest global IT media network

Multicore Software Development Techniques Robert Oshana,2015-11-18 This book provides a set of practical processes and techniques used for multicore software development It is written with a focus on solving day to day problems using practical tips and tricks and industry case studies to reinforce the key concepts in multicore software development Coverage includes The multicore landscape Principles of parallel computing Multicore SoC architectures Multicore programming models The Multicore development process Multicore programming with threads Concurrency abstraction layers Debugging Multicore Systems Practical techniques for getting started in multicore development Case Studies in Multicore Systems Development Sample code to reinforce many of the concepts discussed Presents the nuts and bolts of programming a multicore system Provides a short format book on the practical processes and techniques used in multicore software development Covers practical tips tricks and industry case studies to enhance the learning process *Parallel Computational Fluid Dynamics '98* Chiao-ling Lin,P. Fox,A. Ecer,N. Satofuka,Jacques Periaux,1999-05-26 This book contains the papers presented at the Parallel Computational Fluid Dynamics 1998 Conference The book is focused on new developments and applications of parallel technology Key topics are introduced through contributed papers and invited lectures These include typical algorithmic developments such as distributed computing domain decomposition and parallel algorithm Some of the papers address the evaluations of software and machine performance and software tool environments The application of parallel computers to complex fluid dynamics problems are also conveyed through sessions such as DNS LES combustion and reacting flows industrial applications water resources and environmental flows The editors believe this book will provide many researchers much beyond those contributing to this volume with fresh information and reference

Computer Architecture Exam Review Cybellium,2024-10-26 Designed for professionals students and enthusiasts alike our comprehensive books empower you to stay ahead in a rapidly evolving digital world Expert Insights Our books provide deep actionable insights that bridge the gap between theory and practical application Up to Date Content Stay current with the latest advancements trends and best practices in IT Al Cybersecurity Business Economics and Science Each guide is regularly updated to reflect the newest developments and challenges Comprehensive Coverage Whether you re a beginner or an advanced learner Cybellium books cover a wide range of topics from foundational principles to specialized knowledge tailored to your level of expertise Become part of a global network of learners and professionals who trust Cybellium to guide their educational journey www cybellium com *Emphasizing Distributed Systems* ,2000-06-29 As the computer industry moves into the 21st century the long running Advances in Computers is ready to tackle the challenges of the new century with insightful articles on new technology just as it has since 1960 in chronicling the advances in computer technology from the last century As the longest running continuing series on computers Advances in Computers presents those technologies that will affect the industry in the years to come In this volume the 53rd in the series we present 8 relevant topics The first three represent a common theme on distributed computing systems using more than one processor to allow for parallel

execution and hence completion of a complex computing task in a minimal amount of time The other 5 chapters describe other relevant advances from the late 1990s with an emphasis on software development topics of vital importance to developers today process improvement measurement and legal liabilities Longest running series on computers Contains eight insightful chapters on new technology Gives comprehensive treatment of distributed systems Shows how to evaluate measurements Details how to evaluate software process improvement models Examines how to expand e commerce on the Web Discusses legal liabilities in developing software a must read for developers **Big Data in ehealthcare** Nandini Mukherjee,Sarmistha Neogy,Samiran Chattopadhyay,2019-01-15 This book focuses on the different aspects of handling big data in healthcare It showcases the current state of the art technology used for storing health records and health data models It also focuses on the research challenges in big data acquisition storage management and analysis

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dec 28 2022   pre matric scholarship scheme last date for l 1 verification ino level no extension last date for l 2 verification dno level 10th january 2023 post matric and

jk scholarship 2023 online registration - Jun 09 2022
applicants who are pursuing pre matric and post matric courses in jammu kashmir are eligible to the scholarship only 2 members from one family are eligible scholarship is providing to

nsp pre matric scholarship for class ix x sc - Jan 16 2023
oct 8 2023   softwares pre matric scholarships scheme for scs others for 26 lakh student scholarships in department of social justice empowerment scholarships for 26

j k pmsss scholarship 2023 24 eligibility application process - Feb 05 2022
jun 6 2023   j k pmsss scholarship 2023 24 the central government has announced the extension of the prime minister special scholarship scheme pmsss for the students of

directorate of social welfare jammu minority - Aug 11 2022
jul 26 2022   union territory of jammu kashmir directorate of social welfare jammu announcement of minority scholarship 2022 23 pre

pre matric scholarships scheme for scs others jkalerts - Feb 17 2023
centrally sponsored pre matric scholarship scheme for sc students jammu and kashmir 2022 is an initiative of the department of social justice empowerment government of india

j k scholarship 2023 online registration form login - Sep 24 2023
the scholarship amount will be paid through the following methods 1 the scholarship is payable from 1st april or from the month of see more

pre matric scholarship 2023 for minority students registration - Nov 02 2021
jan 13 2023   students of minority category up to 10th class can apply for pre matric scholarship 2023 till october to november month every year the moma pre matric

jammu and kashmir scholarship check age qualification details - May 20 2023
the all india council for technical education ministry of human resource development government of india offers pm special scholarship scheme for class 12 passed students of

government of jammu and kashmir jkdswdj jk gov in - Mar 06 2022

directorate of social welfare jammu subject applications invited for grant of post matric scholarship from students belonging to scheduled caste other backward classes

jammu kashmir scholarship 2024 application form download - May 08 2022

the eligible students of jammu kashmir scholarship scheme can download the j k scholarship application form 2024 to apply pre matric post matric and minority

jammu and kashmir state scholarship 2021 check scholarship - Jul 10 2022

jammu and kashmir scholarship 2021 schemes available the list below contains the details of scholarships provided by the state central and private organizations only for the students

register for pmss obc pcp sc dnt ebc jammu and kashmir - Jan 04 2022

post matric students may apply for post matric scholarship scheme in a form which has several fields pre filled by specifying the required details such as income category parent s

scholarship for students in jammu and kashmir aisee - Nov 14 2022

feb 16 2019   post matric scholarship for sc obc ebc pc dnt students j k the students belonging to sc obc ebc pc or dnt category can apply for this scholarship they must be

j k social welfare scholarship for pre matric post matric - Oct 13 2022

jul 29 2022   directorate of social welfare kashmir scholarship 2022 for pre matric post matric and merit cum means directorate of social welfare kashmir

centrally sponsored pre matric scholarship scheme for sc - Mar 18 2023

umbrella scheme for education of st students pre matric scholarship class ix x for st students jammu and kashmir closed on 15 01 2023 closed on 10 02 2023

class 1 to 10 pre matric scholarship in jammu kashmir 2023 24 - Jul 22 2023

jul 16 2023   st students in jammu kashmir can now benefit from the j k pre matric scholarships scholarships will be awarded on a monthly basis with scholars receiving rs

home national scholarship portal - Apr 19 2023

oct 11 2023   thousands of students from each state benefit from this national level scholarship pre matric scholarship scheme for minorities every year the government of