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This service is intended for the exchange of technical information among members of the performance evaluation community. To have your name added, mail a request to performance-request@crys.wisc.edu. To send an item, mail it to performance@crys.wisc.edu.

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Performance Evaluation Review is a quarterly publication of SIGMETRICS, the Association for Computing Machinery's Special Interest Group concerned with computer system performance.

Subscriptions, address changes, and other business communications should be sent to ACM SIGMETRICS, c/o Association for Computing Machinery, 11 West 42nd Street, New York, NY 10036, (212) 869-7440.

Contributions should be sent to the Editor in "camera-ready" form: typed or typeset single-spaced with one inch margins. Unless otherwise indicated, contributions represent unrefereed working papers, and are to be interpreted as representing personal rather than organizational opinions.
From the SIGMETRICS Chair
Ed Lazowska, University of Washington

SIGMETRICS Election Results

The "SIGMETRICS People" listing on inside front cover reflects the results of our recently-concluded elections: I was re-elected as Chair (I promise not to run again); Tom Keller, our excellent Secretary/Treasurer for the past four years, is now Vice-Chair; Derek Eager is our new Secretary/Treasurer; and Domenico Ferrari and Alan Jay Smith were re-elected to the Board, where they are joined by first-termers Mary Vernon and John Zahorjan.

I'd like to thank these people and the other candidates (Jeff Brumfield, Rick Bunt, Larry Dowdy, Dan Reed, John Sanguinetti, Connie Smith, Satish Tripathi, and Elizabeth Williams) for their willingness to serve.

I'd also like to thank Herb Schwetman, my predecessor as Chair and a Board member for the past two years, for putting together a slate of candidates that ensured SIGMETRICS would emerge a winner no matter who was elected.

Finally, I'd like to thank the outgoing officers for their work over the past two (or more) years: Herb Schwetman, Ken Sevcik, and Connie Smith.

SIGMETRICS '87 Conference in Banff

This conference was an outstanding technical and social success. (My only concern is that some photos of the banquet may be included elsewhere in this issue.)

Thanks to Rick Bunt for his excellent job as General Chair; to Derek Eager as Program Chair, and to his entire Program Committee; to Connie Smith as Tutorials Chair; to Doug Konkin (Local Arrangements), Darwyn Peachey (Treasurer), Ursula Maydell (Registration), and Brian Unger (Local Promotions); to the authors, the tutorial speakers, and our invited speaker, Jim Gray; and to Domenico Ferrari for shepherding several outstanding papers through IEEE Transactions on Software Engineering.

International Workshop on Petri Nets and Performance Models

This workshop, co-sponsored by SIGMETRICS, will occur between the time I write this and the time you read it. Thanks to Mike Molloy and Mary Vernon, the organizers, for including SIGMETRICS as a co-sponsor. Workshops like this are critically important to the field.

SIGMETRICS '88 Conference in Santa Fe

Connie Smith is General Chair and Ken Sevcik is Program Chair of our next conference. Santa Fe is a unique location, and the technical program will build on our recent successes. Plan now to contribute a paper and to attend.

SIGMETRICS '89 Conference in Berkeley

Domenico Ferrari has agreed to be General Chair and Alan Jay Smith has agreed to be Program Chair of the 1989 conference, co-sponsored (as happens every three years) with IFIP Working Group 7.3 on Computer System Modeling.

New Institutional Sponsors

You see from the inside front cover that SIGMETRICS now has seven Institutional Sponsors. This support is critical to SIGMETRICS. If your company might be willing to help SIGMETRICS in this way, please contact me.
Letters

June 26, 1987

Dr. Edward D. Lazowska
Computer Science FR-35
University of Washington
Seattle, WA 98195
206-543-4755

Dear ACM Sigmetrics Chairman:

Could you explain why the “ACM copyright policies” are in the best interest of the SIGMETRICS member? I pay annual dues primarily so that I can receive technical papers of interest. Now I find that of the 27 papers presented at this year’s conference, three were so good as to be published in an IEEE journal, and as a result, the (apparently) best SIGMETRICS papers are not available to this SIGMETRICS member!

How in God’s name does not-publishing an ACM paper because it might appear in the future in some other publication promote technical interchange in our field? How does an ACM conference surrender its papers (without publication) to IEEE?

Is this a typical example of how the rules of National ACM constrain the Special Interest Groups, or is this simply an inappropriate interpretation by someone in SIGMETRICS.

All three papers must be published in the next PER if membership in SIGMETRICS is to serve any purpose.

Merrily yours,

H. W. Barry Merrill, Phd
President-Programmer

CC: All SIGMETRICS People

7 July 1987

Barry Merrill
Merrill Consultants
10717 Cromwell Drive
Dallas, TX 75229-5112

Dear Barry:

I can’t “explain why the ACM copyright policies are in the best interest of the SIGMETRICS member”, because like you, I don’t think that they are.

My understanding is that these copyright policies are currently under review and are likely to be changed in ways that will make both you and me happier.

In the meanwhile, what SIGMETRICS can do and has done is (a) lobby for these and other changes within ACM, and (b) adopt a course that is in the best interests of the membership, given the existing constraints.

This is not the first year in which a small number of “award papers” has been forwarded to a journal and thus has been omitted from the Proceedings. In fact, this has happened during every recent year.

The value of forwarding these papers to a journal is that this action addresses the widely-perceived “insularity” problem within performance evaluation: a set of papers that are felt to be representative of the best current work in the field receives wide exposure within the computing community. This is a significant benefit to SIGMETRICS members, albeit an indirect one.

The cost to the membership is the non-appearance of these papers in the Proceedings. As noted above, I don’t like this, and I believe ACM policy in this regard will change, but it still is worth noting that several things mitigate the situation. First, the papers are distributed on-site to conference attendees. Second, anyone can obtain a copy of any paper by writing the author, and abstracts appear in the Proceedings to allow recipients to evaluate their interest in the paper. Third, SIGMETRICS is in fact one of the last Special Interest Groups to continue distributing its Proceedings to the entire membership, rather than requiring a separate purchase; despite the omission of the “award” papers, we are way ahead of most of our sibling SIGs in terms of this form of membership value.

The IEEE vs. ACM issue is a red herring. We happen to use an IEEE journal because the editor of that journal is more accommodating towards SIGMETRICS, and because the readership of that journal is somewhat more interested in the sort of work that our membership does. There is no IEEE Technical Committee in the performance area, so SIGMETRICS serves both constituencies. If there’s a skirmish to be found here, then it’s between SIGMETRICS and ACM Transactions on Computer Systems rather than between ACM and IEEE.

I hope this answers the questions raised in your letter. I’ve taken the liberty of forwarding your letter, and my reply, to the ACM Publications Committee as one more salvo.

Peace,

Edward D. Lazowska
Professor and SIGMETRICS Chair
A PROPOSAL FOR IMPROVING OPTIMIZER QUALITY VIA DYNAMIC ANALYSIS

Current optimizing compilers are quite complex, and generate fairly good code. Nevertheless it should be possible to achieve much better results, if the SIGMETICS and SIGPLAN communities pull together.

0. The problem:

Consider a CASE statement, with 5 possible branches, in the middle of a longish module (say a total of 1000 lines). For simplicity, we assume that the first and last 200 lines are executed sequentially (no jumps), but within the CASE statement the control logic is quite involved. Furthermore, we assume that there are not enough registers, so "spills" to memory will be required.

The optimizer will have no problem with the two sequential sections, and may in fact produce optimal code. The CASE statement presents an interesting challenge – which path will most frequently be executed? At compile time this is practically impossible to determine. Typical heuristics seem to be (1) the first branch is most likely, (2) the last, (3) the shortest, (4) the longest.

One may well ask, what difference does it make? A lot! Optimizing for the wrong path requires more data movement (registers to/from memory – resulting in loss of accuracy as well as decreased performance), will fail to take advantage of the pipeline (such as in new RISC machines), blow the cache unnecessarily, etc.¹

This is where SIGMETICS comes in.
1 The Solution

Consider the way a programmer uses a profiler tool to optimize code. First we chose a sample data set to run through the program, then we time the cost of each module. We then examine the top CPU hogs, and iterate.

If the profiler output were made available to the optimizer, most notably execution counts (time each line is executed) and timing (cost of each line) the optimizer can concentrate on those sections along the critical path. Since the paths are (typically) data dependent, it should be possible to perform multiple runs, producing cumulative execution statistics.

One may object, noting that timing each line, would slow down execution by a factor of a 1000 or more. But just as the human analyst does not need to examine each line of the entire program, neither should our automated system. The compiler should id questionable blocks, the analysis tool should take the compiler flagged items, combined with those items flagged (interactively) by the user, and time only the flagged sections. Furthermore each sequential block of code need only be examined at its start and stop. The cost will then be quite minimal. Knowing which blocks are the bottlenecks, really powerful techniques could then be automated – the system could determine which modules should be expanded in line, if global registers are available they could be optimally employed, etc.. Wall86 suggested deferring final register allocation to link time – but even then we can't know the actual execution path.

3 Conclusion

Implementing this scheme will be a bit difficult, but probably more for political reasons than technical ones, the cooperation of two disparate groups being required. But the payoff should be quite significant: faster code, and quite possibly simpler optimizers.

---

1 For the purposes of this discussion we lump all performane related compiler decisions into the term optimization. Compiler writers like to distinguish between register allocation, instruction scheduling, etc.

2 SIGPLAN 86 Global Register Allocation at Link time
From the Editors Desk

Due to the outstanding success of the Banff conference, we can look forward to two more issues before the Santa Fe conference. In other words, once again quarterly!

Submit criminals may now be sent on 5.25 inch Mini-floppy Disks using Microsoft Windows Write TM, Microsoft Word TM, WordStar 3.3 3, WordPerfect TM, or pre-formatted text via E-Mail.

Performance Evaluation Review is now running a backlog and thus future papers exceeding three pages will be refereed. Jon Clark, and Shyam Johari are helping out in this area.

Blaine

Abstract

A Comparison of Performance Petri Nets and Queueing Network Models
Mary Vernon
Department of Computer Science
University of Wisconsin
John Zahorjan and Edward D. Lazowska
Department of Computer Science
University of Washington

Queueing networks (QNs) and performance Petri nets (PPNs) are two approaches to answering performance questions about computer systems. While QNs were originally designed to model resource contention among independent jobs and PPNs were designed to model parallel systems containing synchronization, there is clearly some overlap in the systems that can be modeled using each. In this paper we address this overlap with the goal of indicating whether the two models are fundamentally the same, or whether there are intrinsic differences that make one approach more powerful than the other for particular application domains.

There seem to be two characteristics of a modeling approach that are most important in determining how it may be profitably employed. The first is notation: what models can be expressed and perhaps more importantly, how convenient is it to specify a particular class of models? The second feature is the evaluation technique: what performance measures can be computed from the model, and what computational effort is required to do so? Our comparison of QNs and PPNs therefore concentrates on these two aspects.

It is conceivable that the shortcomings of either approach in a particular environment might be addressed by adopting features of the other better suited to that environment. We consider this possibility for making improvements to the notations and evaluation efficiencies of the two modeling approaches.

Book Announcement


Back cover blurb: This monograph is a compilation of the author's research (done in collaboration with Nathan Goodman and Rajan Suri) on the effect that concurrency control by locking has on the performance of a centralized database system. It examines the limits on transaction workload, the influence of hardware contention, the resolution of lock conflicts, and the benefits of predeclaration. The effects of access pattern and shared locks and the choice of lock granularity, multiprogramming level, and transaction length are also treated. For the database designer, there is also a detailed literature survey.

Workshop

Second Computer and Telecommunications Performance Engineering Workshop

Performance Engineering – Theory and Practice

This workshop was held in Edinburgh on the 25 and 26th September. The object was to bring together commercial, industrial, and academic interests in performance evaluation. This year, a theme was chosen of “Theory and Practice”. Thirty people attended the workshop, of whom ten presented papers or gave verbal presentations. It is hoped that one result of the workshop will be an increasing awareness of performance engineering problems and activities and of successful applications.

A wide variety of topics were presented in the papers, from theoretical queueing models, by way of simulation environments, to strictly practical measurement and evaluation exercises on running systems. The discussion session ranged widely over the field, but particular heat was generated over the lack of a suitable forum in the UK for such work. Another topic which created wide interest was that of education (or lack of it) in performance engineering topics.

The papers presented at the workshop were:

Successes and Failures in Modelling an ICL VME System
- A.R. Butler

Graphics and Modelling - R.J. Pooley

Receiver Contention on a Cambridge Ring
- P. Lloyd and S. A. Sorensen

The Design of a Performance Modelling Environment
- P.H. Hughes

Benchmarking and Workload Characterisation
- R. Longbottom

The G/M/1 Priority Queue - P.A. Whiting

Performance Modelling of Parallel Computer Architectures
- P.G. Harrison and A.J. Field

Implementing Cut-Through in a Buffered Banyan Network
- P.W. Matthewson

Presentations were also made by A. Bayes and R. Beckett on “Experience with Queueing Network Models”, C. Smyth on “Optical Switching Networks”, and C. Harvey.

The papers are available from Dr. A.S. Wight, Computer Performance Workshop, Computer Science Department, University of Edinburgh, The King's Buildings, Mayfield Road, Edinburgh, EH9 3JZ, price 5 pounds.

Next year's workshop is provisionally scheduled for September 17th and 18th 1987. If you wish to be kept informed about current or future workshops, send your name and address to Dr. A.S. Wight, at the Computer Performance Workshop.

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or (if you are undomained)
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UUCP:...lu kc!cs.hw.ac.uk!pjbk
Invited Speaker: Jim Gray of Tandem Computers - Spoke on Database System Performance Measures

Tutorial Speakers: Connie Smith, Jeffrey Buzen, Mary Vernon, Alan J. Smith, Domenico Ferrari, Ingrid Bucher (not shown)

Conference Banquet - Banff Springs Hotel
There was a surprise for the conference organizers and officers: Domenico Ferrari, Ursula Maydell, Ken Sevcik, Darwyn Peachey, Rick Bunt, Ed Lazowska, and Connie Smith.
Call for Papers
1988 ACM SIGMETRICS Conference
on Measurement and Modeling of Computer Systems
May 24-27, 1988
Santa Fe, New Mexico, USA

Performance modeling is a fundamental part of designing and understanding the behavior of computer systems. This conference is a forum for presenting state-of-the-art work that studies computer system design and usage through the application of performance measurement and modeling techniques. Contributions advancing the state-of-the-art via new techniques, or furthering our understanding of existing techniques, are welcome. Topics of interest include:

Representing and Evaluating the Performance of
- Parallel processing systems
- Distributed systems
- Communication networks
- Interconnection networks
- Supercomputing
- Computer or chip architecture
- I/O systems
- Software performance engineering
- Database systems
- Reliability & fault tolerance

Techniques & Algorithms for
- Workload characterization
- Model verification/validation
- Queueing theory
- Timed & stochastic Petri nets
- Graph models
- Simulation and statistical analysis
- Software performance predictions
- Solutions of queueing models

Performance analysis software
Performance expert systems
Practical, original case studies

Paper publication is very competitive; usually less than 25% of submissions are accepted. We wish to increase participation in 1988 while maintaining the traditional level of quality. Thus, we will provide our referee criteria in advance to prospective authors. We will also accept a limited number of papers for a poster session. We solicit instructors’ proposals for pre-conference tutorials. For more information contact either chairman below.

Proceedings will be published as a special issue of the SIGMETRICS Performance Evaluation Review. Papers of exceptional merit will be submitted to an appropriate journal for publication.

Important Deadlines
- July 24 – abstract submission
- Sep 30 – paper submissions/tutorial proposals
- Oct. 30 – poster session extended abstracts
- Dec 22 – author notification
- Jan 31, 1988 – camera ready copy due

Abstracts should be less than 1 page; extended abstracts for the poster session and tutorial proposals should be 3–5 pages; papers should be less than 20 pages. Author identification (including available net addresses) should appear on a separate cover sheet but not within the paper itself. Electronic submissions of abstracts, extended abstracts, and tutorial proposals are acceptable. Six copies are required for materials not electronically submitted. Submit appropriately designated materials to the Program Chairman: Kenneth C. Sevcik, Computer Science Department, University of Toronto, Toronto, Ontario, CANADA M5S 1A4, 416/978–6219 (kcs%csri.toronto.edu@csnet-relay.arpa).

General Chairman: Connie U. Smith, L&S Computer Technology, 1114 Buckman Rd., Santa Fe, New Mexico 87501, 505/988–3811 (csmith@lanl.arpa). The conference committee can be contacted at: sigmetrics@lanl.gov.arpa.
Recent PROGRES Reports


Distributed systems characterized by a high degree of inter-computer resource sharing generally perform better if resources are managed utilizing as much knowledge of the current global state of the system as possible. Decentralized resource management schemes have been preferred over centralized schemes for reasons of reliability, autonomy, speed, and symmetry. Yet, distinct computers in a distributed system often view the global system state quite differently. Consequently, decisions which produce system-wide effects made by distinct computers can often conflict, invariably causing inefficiency in resource management and therefore leading to downgraded performance.

To address these and related problems, a system is proposed which provides the following:

* a mechanism for monitoring events of interest in a distributed system;
* a mechanism for distributing monitored data throughout the distributed system;
* mechanism which uses heuristic-based specifications to interpret received monitored data from remote sources so that appropriate actions can be taken when necessary.

The novelty and power of the proposed system lies in its application of expert system technology to deal with uncertain, incomplete, erroneous and out-of-date observation data which is inevitable when one tries to efficiently monitor remote events in a distributed system.


As technology advances, computing environments composed of large numbers of workstations and mainframes connected by a high bandwidth local area network become attractive. These systems typically support a large number of application classes, and the heterogeneity of their workload, coupled with the decentralization of the systems, can lead to load imbalances across the network. This work attempts to study the benefits of load balancing strategies in the context of a particular application, distributed database systems. It was felt that, by focusing on a specific area, the problem would become more tractable. The choice of database management systems can be justified not only by their intrinsic importance, but also by the adaptability of load balancing strategies to query optimization algorithms.

In order to determine whether load balancing strategies can indeed be adapted to current
optimizers with a moderate amount of effort and to see whether the resulting performance benefits are sizable, both benchmarking and simulation experiments were carried out. The approach taken was first to construct a simple model in order to gain some insight into the problem. This was followed by some benchmarking experiments on a running system, the R* distributed database at the IBM San Jose Research Laboratory. Finally, a model of distributed INGRES was constructed and validated by measurements of INGRES queries and of UC Berkeley's TCP/IP implementation. It was hoped that, by utilizing two different techniques, simulation and measurement, and by examining two very different distributed database systems, R* and distributed INGRES, the results of this thesis would be of both greater reliability and wider applicability.

The conclusions of this study are that query optimizers are relatively easy to modify in order to incorporate load balancing strategies, and that the increase in the running time of the algorithms is negligible. Furthermore, load balancing results in a sizable performance improvement even in environments with a moderate load imbalance. It should be pointed out that the results of this work are important not only from the viewpoint of load balancing studies, but also provide useful insights into the construction of distributed database systems.

86.3 - S.Zhou, An Experimental Assessment of Resource Queue Lengths as Load Indices, Rept.No. UCB/CSD 86/298, University of California, Berkeley, June 1986.

Load indices that accurately reflect the current loads at computer system resources are crucial to the success of any dynamic load balancing scheme. However, few load indices have been experimentally validated as being suitable for load balancing. We conduct such a validation study for the resource queue lengths. We find that the CPU and disk queue lengths have very high correlation to the response times of CPU and I/O bound jobs, respectively. However, for the type of system that we studied, the system load changes very rapidly, making the response time highly unpredictable. Simulation results suggest that load balancing will drastically reduce load fluctuation. The CPU is by far the most heavily used resource in the systems we studied. While this is also true in many other environments, measurement studies are called for before reaching such a conclusion in other systems.

86.4 - S.Zhou, A Trace-Driven Simulation Study of Dynamic Load Balancing, Rept.No. UCB/CSD 86/305, University of California, Berkeley, September 1986.

A trace-driven simulation study of dynamic load balancing in the homogeneous distributed systems supporting broadcasting is presented. We use information about job CPU and I/O demands collected from a production system as input to a simulation model that includes a representative CPU scheduling policy and considers the message exchange and job transfer costs explicitly. Seven load balancing algorithms are simulated and their performances compared. We find that load balancing is capable of significantly reducing the mean and standard deviation of job response times, especially under heavy system load, and for jobs with high resource demands. The performances of all hosts, even those originally with light loads, are generally improved by load balancing: The reduction of the mean response time increases with the number of hosts, but levels off at around 30 hosts. Algorithms based on periodic or non-periodic load information exchange provide similar performance, and, among the periodic policies, the algorithms that use a distinguished agent to collect and distribute load information cut down the overhead and scale better. They are also the most appropriate algorithms for adaptive load balancing, which has the potential of offering near-optimal performance under a wide spectrum of system configurations and load conditions. System instability in the form of host overloading is possible when the load information is not up-to-date and the system is under heavy load; however, this undesirable
phenomenon can be alleviated by simple measures. Load balancing is still very effective even when up to half of the eligible jobs have to be executed locally. The trace-driven simulation approach to the study of load balancing is found to be efficient and effective, and is recommended for use before implementation efforts.

86.5 - D.P. Anderson, P.V. Rangan, A Basis for Secure Communication in Large Distributed Systems, Rept. No. UCB/CSD 87/328, University of California, Berkeley, January 1987.

Large distributed systems have properties that, from the point of view of security, distinguish them from LAN-based systems. We describe these differences, and show that the security mechanisms found in current distributed systems are not well-suited to large systems. We propose a secure communication architecture for large systems that puts security below the transport level. We argue that this is preferable to putting it at higher levels, and that in fact it can simplify and improve the performance of transport protocols.


Expert systems can be used effectively to manage distributed computer systems which are base on decentralized control of shared messages. These distributed systems can exhibit high reliability and performance. Yet, designing such systems pose formidable problems. These problems involve real-time distributed decision-making where decision-makers to not know with full certainty the state of remote nodes. We identify what characteristics an intelligent decision-making agent must possess to successfully attack these problems, and argue that expert systems share these characteristics. We also present the architecture of an Expert Manager, an experimental system which uses expert system techniques to manage a distributed computer system.


This paper discusses the upper and lower bounds on the accuracy of the time synchronization achieved by the algorithms implemented in TEMPO, a distributed clock synchronizer running on Berkeley UNIX 4.3BSD systems. We show that the accuracy is a function of the network transmission latency, and depends linearly upon the drift rate of the clocks and the interval between synchronizations. Comparison with other clock synchronization algorithms reveals that TEMPO may achieve better synchronization accuracy at a lower cost.


The design and implementation of a prototype load balancer on a loosely-coupled distributed system are discussed, and the results of a large number of measurement experiments performed on the system under artificial workloads we constructed using frequently executed system commands are presented. The impacts on the system's performance of the load balancing algorithms, as well as of the values of their adjustable parameters, and of the various types of workloads, are evaluated. The effects of load balancing on the performances of individual hosts and on each type of job are also quantitatively investigated us-
ing measurements. The results of our study show that automatic load balancing at the job level can have very beneficial effects on the mean and standard deviation of job response times while causing little overhead and requiring no modification to the system kernel or to applications programs. This is the case even when only a relatively small fraction of the jobs can be executed remotely, and the reduction in response time is uniform across all job types, including those that are not moved for execution to another machine.


Expert systems which maintain knowledge about objects whose attributes are time-variant must have an awareness of time. This awareness can be made manifest by incorporating time in the quantification of uncertainty of aging knowledge about such objects.

Many expert systems use some method to quantify the degree of belief, or uncertainty, of their knowledge. Examples of these methods include Bayesian probability theory, certainty factors of EMYCIN, the Dempster-Shafer theory, and fuzzy logic. These methods offer different representations for measures of confidence, and different calculi for combining these measures. We describe an extension to such confidence measures by adding a dimension of time.

We propose the concept of Decaying Confidence Functions to express the time-varying uncertainty of aging knowledge. Decaying confidence functions specify how confidence in knowledge should decrease as the knowledge gets older. We describe how this can lead to efficiencies in expert systems which must deal with time-varying information, such as expert systems used for monitoring real-time systems.


A very large distributed system (VLDS) is one based on a fast wide-area network connecting numerous organizations and individuals. The design of a VLDS involves problems and issues not present for smaller systems. These issues are centered in the areas of naming, communication paradigms and architectures, security, and kernel architecture.

DASH is a research project aimed at investigating VLDS design issues. The goals of the DASH project are 1) to predict the advances in computer and network hardware and application software that apply to VLDS; 2) to propose a set of design principles for VLDS; and 3) to experimentally validate these principles by building and testing a prototype VLDS kernel.

This report is a high-level view of the DASH project as of December 1986. After summarizing our ideas about the potential uses of VLDS's and our assumptions about the environment in which they will exist, we examine several design areas. In each area, we offer some possibly controversial assertions, attempt to justify these assertions, and describe how the assertions have guided the design of DASH.