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On the Use of Simulation in the Design and Implementation of Distributed Systems*

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1. Introduction

Simulation of computer systems and communication systems have been given substantial attention in the literature. Notable work in this area has been done by Kleinrock [4] and Buzen [1]. Work continues in each area by developing more sophisticated mathematical models which more closely fit a greater spread real life situations. In distributed systems the issues are more complex. We must trade-off computation-computer oriented features against communication characteristics. Also, the simulation needed is not only more complex, but must be done with more frequency to accommodate timing analysis and growth.

The above discussion points out some of the need for simulation and planning on a local level. On a more general level distributed systems planning must take into account changes in the following areas:

- regulatory changes in communications - the FCC and other bodies on a national and external basis are giving more attention to communication tariffs and competitive structure;
- price-performance improvements in the computer industry with the impact of new technology;
- changing user needs and a rising awareness of distributed systems;
- increasing shortages of qualified personnel due to rising demands;
- increased pressure from governments for privacy and security regulations.

Some comments are appropriate on the above. Note that we have not mentioned changes in the communication industry due to technology. In the current regulatory environment such changes are slow in effect because of the long life of current equipment with impact on depreciation schedules. The computer advances include advances in microcircuitry, memory, peripherals, and message processing. Thus, results showing alternative A over B at one time may be reversed at later times. This points to the need for longer term planning.

The market place is promoting distributed systems directly to the users. The use of embedded microcomputers, the direct acquisition of turnkey systems by users, and rising user interest all point to increased pressure from users. What do users expect? Local control, controlled cost, and improved response time are commonly stated objectives by users. Are these achieved? One approach toward assessing this is through simulation.

The number of general purpose minicomputer and mainframe computer installations is expected to double between 1977 and 1980. The announcement and delivery of IBM 43XX systems are one example of this wave. What is the effect? An increased demand for programmers, analysts, and managers. Also, a shortage of 25% is given as a minimal shortfall. Planning must anticipate this problem in design in order to staff remote, distributed sites.

Enslow 3 has cited the increased pressure in the areas of privacy and security. National laws in some countries mandate a distributed environment where basic transactions must be processed within national boundaries and only summary data transmitted to remote, central sites.

With this introduction to some of the issues and factors we can now identify some of the objectives in distributed systems planning. These are explored and a general planning framework given in section 2. In section 3 we consider how simulation could be employed to assist in planning. The limitations and benefits along with applications addressed by the author are considered in section 4.

2. Planning for Distributed Systems

The previous section outlined the need for planning and analysis for distributed systems. We begin here with a contrast with large on-line oriented settings. In such settings a single group of applications seldom derives the planning process. Simulation in these settings crosses a range of applications and users. This means an averaging and a lack of need for detailed sensitivity analysis for individual applications. Simulation models in such cases are very appealing since they can be employed using standard machine data, workload characterizations, and projections of terminal traffic and other factors. Such a simulation model is presented in Lientz and Weiss [7] based on a model presented in Lientz et al [12]. In [7] is a presentation of simulation applied to the evaluation of security measures. In Cady et al [2] an earlier version of the model is examined along with applications.

By contrast distributed systems may involve one or two applications heavily. Thus, the distributed system may depend on the business plan around the application. The overall recommended planning approach consists of the following stages:

Stage 1: Develop an assessment of technology and long range information service plan;

Stage 2: Using the plan in step 1 develop alternatives for an information service architecture;

Stage 3: Using the alternative architectures in stage 2 develop inputs for planning evaluation runs using a simulation model;

Stage 4: Conduct simulation runs using the simulation model and perform trade-off analysis.

The assessment of technology advances in stage 1 is described in Lientz [8] and has as its objectives the analysis of impacts of computer and communication technology. The steps in the assessment include:

- o defining a framework for the organization environment;
- o analyzing trends and forecasting technology;
- o assessing the impact of the previous work on the organization systems;
- o refining the assessment for particular aspects of systems.

The technology areas include hardware, system software, communications, application software and personnel productivity. It takes the analysis from a technical breakthrough or trend into its impact on product lines. The assessment produces several specific benefits including identifying areas where technology is not yet available, where technologies are not compatible or complete, or where technology is not at a cost-effective level. Thus, one point of the assessment is to avoid disaster by becoming bottlenecked in distributed systems with obsolete or incompatible products.

Of course this discussion only relates to technology. We also need an analysis of a business plan. The business plan will outline the status and direction of the user enterprises. However, it may be too general to be directly useful. Therefore, we must address the following:

- o What skills would be needed in user organizations for data collection/editing/analysis/output distribution/reporting? What training is needed?

- o Are the present approach/policies/procedures adequate to absorb and manage the technology?

These questions point to the critical focus of distributed systems. The shortage of staff and need to involve users as cited in Lientz and Swanson [9], [10] point to the almost certainty that certain functions will be distributed for many systems. The functions include data input, editing, and inquiry.

The impact of the technology and the business structure on planning includes the following:

- o which technologies are relevant to the application;

- o how each technology affects the applications in terms of:

  - schedule and timing
  - cost
  - performance
  - functions/features/benefits
  - reliability/security/integrity
  - sensitivity/risk of technology availability;

- o the characteristics of the applications in terms of growth and current status in:

- volume, frequency, timing
- sites served remotely
- need to replicate the system.

It would be good if we could use this data and build toward the simulation model. But we cannot until we have developed a long range information service plan for the users. Only then will enough information be available for simulation.

The long range information services plan provides a set of possible projects - some or all might be distributed which feeds strategic information services planning. Strategic planning here means the integration of long range plans and projects being maintained or built, hot-line requests, and carry over backlog requests. Distributed systems attain their potential only when placed in a context with the total systems of the user organization. After all, the users perceive an ensemble of systems, not just one system here or there. Their perception is often melded into place by the weakest system that they use. Thus, the result of strategic planning is a set of approved, consistent projects which encompass all work to be done - not just new projects. As pointed out in Lientz and Swanson [10] this helps in forcing a discipline to control maintenance.

With the plan and assessment of stage 1 we can consider the design of an overall architecture. In stage 2 alternative architectures are developed for an extended time span. Why develop an architecture? Why not collect data and run a simulation model? The answers to these questions include the following factors:

- o Any distributed system represents a substantial investment in hardware, software, communication, and human resources. Making substantial changes downstream will likely negate the investment in human resources and application software due to rework.

- If the concept behind the applications needs to be tested, the architecture can take into account the use of a prototype phase at the beginning.

- Having an overall architecture will provide a view for the user into a large scale system strategy responding to his business needs.

- An architecture will provide an assessment of growth potential for a distributed system.

An example brings out these points clearly. A large financial institution has eight statewide collection centers for collecting money on past due accounts. At one center there are 110 collectors. All others have 10-17 collectors. The trade-offs obviously involve semicentralized or distributed configurations. While a centralized minicomputer at the large site may be optimal at the first stage, it turns out to be inflexible with respect to 1) the organization's structure of decentralization, 2) potential growth to other regions, 3) the inability of many vendors to support the application cost-effectively. Only by building architecture scenarios and then using a simulation model will we be able to group concretely, the trade-offs.

The architecture alternatives must include specifications for hardware, system software, application software, data communications, and support (personnel, space, etc.). It must reflect the absorption and adoption of new technology (e.g., a portable non-intelligent terminal being replaced by a terminal with bubble memory in a point of sale application). With the work of the first two stages we are then prepared to set up and perform simulation runs and analysis which is addressed next.

3. Simulation Analysis

We first consider the overall structure of the simulation model and what it is to do. The model is to take as input data on hardware, software, communications and workload. As output it should provide information in the form of graphs and tables on costs, response time by part, throughput, utilization, and bottleneck analysis. Each simulation run evaluates a particular configuration. Multiple runs are needed so as to vary workload for a particular architecture. Hardware, system software, and communication parameters are changed and the process repeated. Analysis then is performed to assess the alternative archtiectures.

With this general view of the simulation process we can proceed to address issues that arise in resorting to simulation.

- What level of detail should the model address?

  It would be ideal if a model could get down to the individual job level. Better yet to the task level. Unless discrete simulation is used this is not feasible. Even then discrete simulation requires many more parameters on jobs. Worse yet it requires a fine timing of the model which can take weeks or months. In one case the project failed because of the inability to validate and because of disagreements in the project team on the simulation approach.

The most feasible approach is to use an analytic approach based on queuing theory. This approach is practically feasible, but costs and risks are incurred. The major concerns relate to the assumption inherent in any mathematical queuing model. Some of the assumptions might be:

- exponential type message by centers in a network;
- independence of intersurvival times and message length and job size.

These assumptions and others are necessary to make the problems mathematically tractable. While we can site studies which joint to the reasonableness of these assumptions, they remain assumptions and overshadow the analysis.

With this setting analytic simulation models can handle classes of jobs as well as on-line continuing systems and applications which appear to the operating system to be functioning as one job (e.g., CICS in an MVS environment on IBM 370 equipment).

o What steps are involved in the simulation process itself?

We have already cited the general inputs needed for simulation. The data collection process and manipulation of the data for model input are critical. They depend on a rather detailed understanding of the model. Before embarking on data collection the approach to the model itself must be defined. Building a model for one or several analyses is not economic ally or practically justified. Instead a common approach is to use one of the available simulation models available from systems and consulting firms. Another approach is to specify the alternative architectures to competitive bidders and to have them propose solutions based on their own internal simulation models. Before using a model, contact with previous users should be established to ascertain the validity and utility of the model.

After locating a model the following detailed inputs are commonly required for the model.

- Topology
  - location of each site in network
  - linking between various sites in network

- Communications
  - channel capacity
  - message size
  - packet size
  - acknowledgements
  - message routing approach
  - switching delay
  - packet arrival rate
  - cost parameters

- Hardware/system software
  - number of initiators
  - instruction rate
  - number of channels
  - average service time (seconds) per request
  - probability matrix associated with servers in center
  - CPU availability
  - cost framework

- Workload
  - job arrival matrix
  - job class characteristics
  - priority assigned to classes

Note these parameters are only intended to be examples. They are neither complete nor exhaustive for a particular model.

Although the mechanical processing of the model may be straightforward, it is useful to analyze intermediate results. These should be evaluated on the basis of logic as well as statistical testing.

For distributed systems the following alternatives are often assessed:

- distribution of workload between processors;

- increasing remote computing power to handle entry, editing, and retrieval;

- various communication topologies;

- alternative operating system configurations (e.g., initiator structure, channel balancing).

Note that we have not listed distributed data bases and distributed dbms. These are likely to be available in the 1980s and will permit the migration and segmentation of data. At that point distribution of data and migration could be addressed.

4. Discussion of Applications and Comments

Having developed the planning methodology using simulation in the previous sections, the use of the methodology can be explored. Several cases are given below. These cases do not present the political and organizational issues around distributed systems. Here we are exploring only the technical side. We explore a number of applications in brief due to space limitations.

The first case involves a large defense application involving the number and sizing of minicomputers on board a large naval vessel. The issues in planning were not only in handling the workload, but also in providing backup and in allowing for new functions. Although there are many stable factors imposed by the original design of a naval vessel, there are improvements to software to improve command and control systems. These systems then exert additional or different work on the system. Using this data the architecture alternatives were specified. Alternatives included different minicomputers as well as alternative communication paths.

The second application is for a point of sale minicomputer network to support leasing and personal lending and finance. The architecture specified substantial growth and the capability to establish duplicate systems on a national or international basis. The requirements included a host minicomputer system with full backup. Satellite sites have either microcomputer or small minicomputer. Portable handcopy dialup terminals are used in working with clients. The technology impacts are many and varied. Some of these are: 1) bubble memory portable terminals to reduce communication costs, 2) hardware and disk improvements to handle more functions on the minicomputer (i.e., more lines of service), and 3) statistical multiplexors and their growth in capacity. Proposals were sought for hardware and software. The finalist proposals were then evaluated using the simulation model providing input to the final selection.

The third case in progress is to analyze the hierarchy of computers now coming into being. For example, for IBM equipment three levels can be identified: 370 host, 43XX intermediate host, and Series I or 3790 local host. Using this example analysis is focusing on the appropriate functions that can be carved out in the hierarchy of systems. The effect then is to evaluate the use of layered hardware and system software structure.

There have been other cases analyzed using the simulation approach. In Lientz and Weiss [7] the effect of adding security measures to network performance is examined. Other examples appear in [8], [11], and [12].

We might close on the potential generality and use of the methodology developed above. It is clear that new mathematical methods can be inserted into simulation models to improve model accuracy, applicability, and use.

One area of application in distributed systems that is of interest is that of electronic office systems. A great deal of attention has been directed toward shared logic word processing and the merger of text and data processing. Because of the overhead involved in text handling and because of the potentially large number of terminals (with improved price-performance) this would appear to be a good subject for simulation. But there are inherent problems. For example, many systems do not offer performance monitoring and measurement tools. Also the limited power of such systems inhibits the capability for inserting probes and other methods. Of more interest long term is the simulation of the combination of electronic mail, data processing, and word processing. Why do this? The basic reasons are that 1) organizations may underestimate the effects of the workload, 2) the growth in usage may be more than planned, and 3) bottlenecks in communications and computing can be partially avoided.

The benefits and use of simulation have been mentioned. However, there are potential problems which cannot be minimized. Some problems that arise are: 1) inadequate data for simulation, 2) a lack of clear definition of architecture, and 3) shortage of knowledge about technology and trends.

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