Enhanced System Monitor (ESM)

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Abstract

This paper describes the Enhanced System Monitor (ESM); a multipurpose computer site monitor developed at Pacific Bell® for internal use. ESM offers real time monitoring, predictive monitoring, and consulting functions for computer sites. Control Blackboarding techniques were developed to allow model based reasoning to be performed with a simple production rule expert system shell, owing to the lack of more powerful tools in the standard UNIX® environment at the time. The project was conducted in a manner unusual for large corporations: Domain personnel were used to build a large scale application and funding was secured in an "entrepreneurial" fashion. The resulting system offers greater flexibility and functionality than comparable commerical monitoring systems and was delivered at a cost of $250,000 - *one eighth the cost of a comparable commercial system.* Development, installation and training were completed in only 11 months - *a time frame comparable to deployment of a large commercial system.* Based on labor costs during outages, *the system is expected to pay for itself in less than 3 years.*

Definition of Problem

Pacific Bell® has many computer services which are required to be online 24 hours a day, 7 days per week. As residential and business customers increase in number, the need for these systems to be available to company personnel becomes more critical to meet corporate service and satisfaction goals. Unfortunately, the need for increased system availability is hard to meet by use of operator personnel alone. A typical computer site contains hundreds of processors and applications, requiring operators to be experts in a number of unrelated computer environments. Furthermore, the sheer size of the installations makes it difficult for operators to detect and correct problems before they become critical. In a typical data center, the schedule only allows for spot checking processors once every two hours, yet a common cause of outage happens within five to ten minutes of the manifestation of a symptom.

Description of deployed Application

ESM uses Expert System technology to provide complex decision support operations essential to the monitoring and maintenance of computer systems. ESM is the first significant Expert System application developed at Pacific Bell® for the UNIX® environment. ESM was designed and delivered entirely in the C programming language and optimized to use the intrinsically powerful and portable features of the UNIX® operating system. The system can be maintained and reconfigured by administrative personnel, and is designed to be able to monitor any type of computer site.

ESM was prototyped on AT&T 6300+ microcomputers and the first production system was delivered on an AT&T 3B2/600. EXSYS, a C-based commercial expert system shell, was used to program complex decision tasks. ESM has been installed in two major Pacific Bell® computer sites. Each ESM installation can monitor up to a hundred individual computers and provides the following functions (see also Figure 1):

- *Online Monitor:* This subsystem scans messages obtained directly from monitored CPU consoles. The monitor considers message patterns and thresholds to identify and prioritize alarm conditions. Priority alarms are announced on a public address system using a DECTALK® speech synthesizer. Online Monitor eliminates the need to have Operators roaming the floors to spot check the processors. It is accessible from remote locations via modem (see Online Monitor Architecture Diagram, Figure 2).

- *Forecaster:* This subsystem consists of a series of rule-based expert systems which periodically login to monitored CPUs, gather performance statistics, and notify support personnel of impending problems before they become serious (see Forecaster Architecture Diagram, Figure 3). Forecaster concentrates data which was once culled manually from thousands of pages of daily status reports into a summary consisting of a few paragraphs.

- *Consultant:* This subsystem provides online diagnostic consulting services and assistance with procedure manuals. End user personnel have been trained in the construction of rule-based expert systems and have assumed the task of maintaining and expanding this subsystem. Consultant improves Operator access to job aids and technical manuals, and is accessible from remote locations via modem. Consultant subsystem architecture is discussed under Blackboarding techniques, below.

ESM has proven popular with both operators and management because their feedback was continually sought during development. Significant outages were prevented even when the project was still in the prototype phase.

Innovation & technological breakthrough

In order for ESM to be a successful project, it had to be built with a minimum expenditure of resources and be maintainable by existing staff. An entrepreneurial project management technique was applied, special software utilities were developed to expand the capabilities of a low end expert system shell (EXSYS), and rapid prototyping lead to an early approval of the full project.

- *Project Management.* Funding for the project was secured by cooperation between several user management groups. These groups raised sufficient funding to conduct the project without a formal business case. In exchange for funding, the Pacific Bell Advanced Systems Group trained end user management and staff in the conduct of expert system projects and knowledge engineering techniques.

User interest and productivity was high, the quality of work excellent, and end user personnel received new promotion and training opportunities.

- *Blackboarding techniques.* The domain for ESM was seen to be very broad. It covers knowledge about many different kinds of computer equipment, as well as meta-knowledge about the inter- relationships of the equipment. At odds with the complexity of the domain was the desire to use simple, low cost, high performance tools to keep the knowledge bases straightforward enough to maintain by end user personnel.

A control blackboard utility, *Metashell* was developed at Pacific Bell in 1986 to allow construction of multiple state EXSYS knowledge bases with the capability of dynamic referral. Metashell waived the need for a more sophisticated, expensive structured rule tool, allowed development in standard UNIX® (sophisticated, structured rule tools were *not* available), and greatly simplified the training requirements for end user personnel (see Metashell Blackboard Architecture diagram, figure 4).

Metashell allows the **Consultant** portion of ESM to

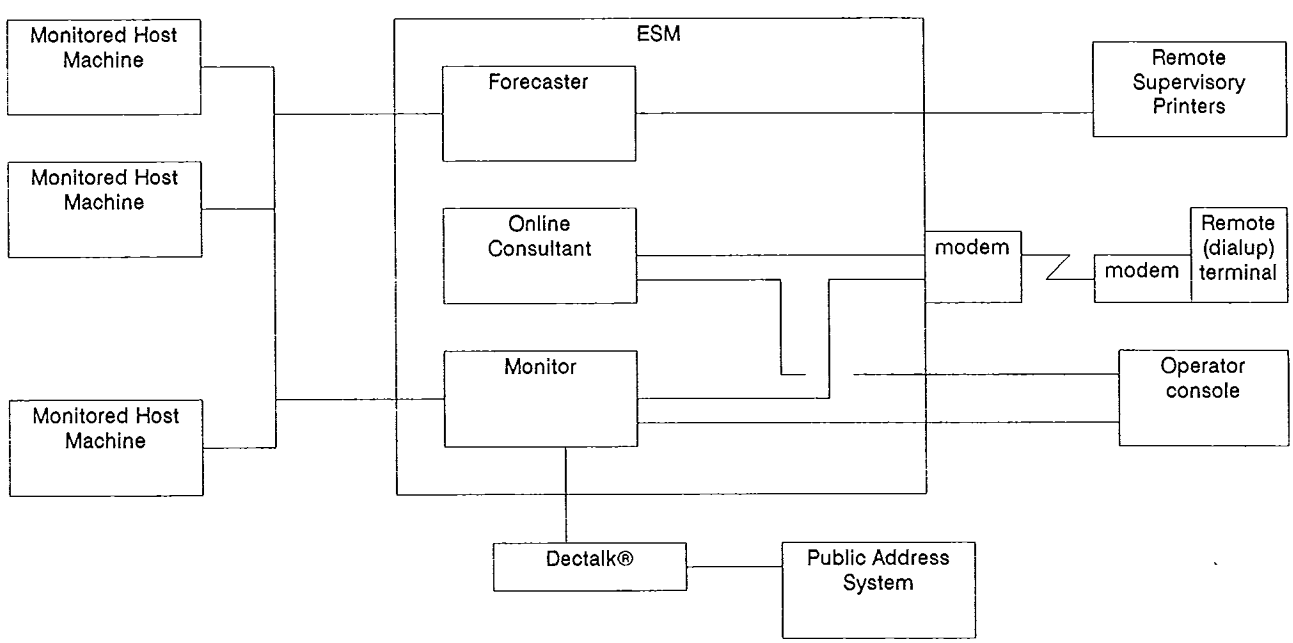

Figure 1. ESM System Architecture

contain multiple *topic* experts on specific domain subjects, that can call each other as needed to reach a cooperative answer to the user's questions. 10 topic experts had been constructed at the time of product delivery and more are added on a regular basis. There is no upper limit on the number of topic experts that can be created. Domain knowledge in the topic expert systems is scoped narrowly to allow coding from flowcharts and decision tables, which are the prevailing forms of knowledge documentation in the computer centers. The final goal in the topic expert systems can take one of three values:

1. The answer to your problem is: (manual pages are displayed)
2. No advice can be given; call the support center
3. Your problem is in another topic domain; check the following in order of certainty:
   next topic (certainty)
   [next topic (certainty)
   next topic (certainty)]
   and so on...

If the result of a consultation is the third value, the next topic list is passed to Metashell on a data blackboard and the new topic rule bases are loaded until a resolution is reached. Answers to questions already asked are kept in a data blackboard so that the user will not be questioned redundantly.

The narrow scope of topic knowledge, combined with the ease of use of the EXSYS developer's interface and the integrated EXSYS data dictionary makes it possible to train maintenance personnel in an average of 40 hours.

- *Rapid prototyping.* The power and flexibility of the operating system made it possible to deliver the first working prototype entirely in UNIX® Shell Scripts. Initial expenditures on software and training were minimal, yet the first prototype was sufficiently robust to obtain solid management support to continue the project.

Criteria for a successfully deployed application

- *Managerial commitment.* Management from several different company organizations cooperated to make the project a success. Funding for the project was shared informally and the effort was conducted as a "skunkworks" project.
- *Thresholding/priority handling.* Some error messages appear only once, while others are repeated many times and may propagate to other networked machines. Thresholding capabilities were added to the system so that repeated messages would be announced in a meaningful fashion.
- *User emulation.* In order to avoid additional processes on monitored machines, the **Forecaster** expert system appears to be an administrative user logging in to request the standard status reports. This technique

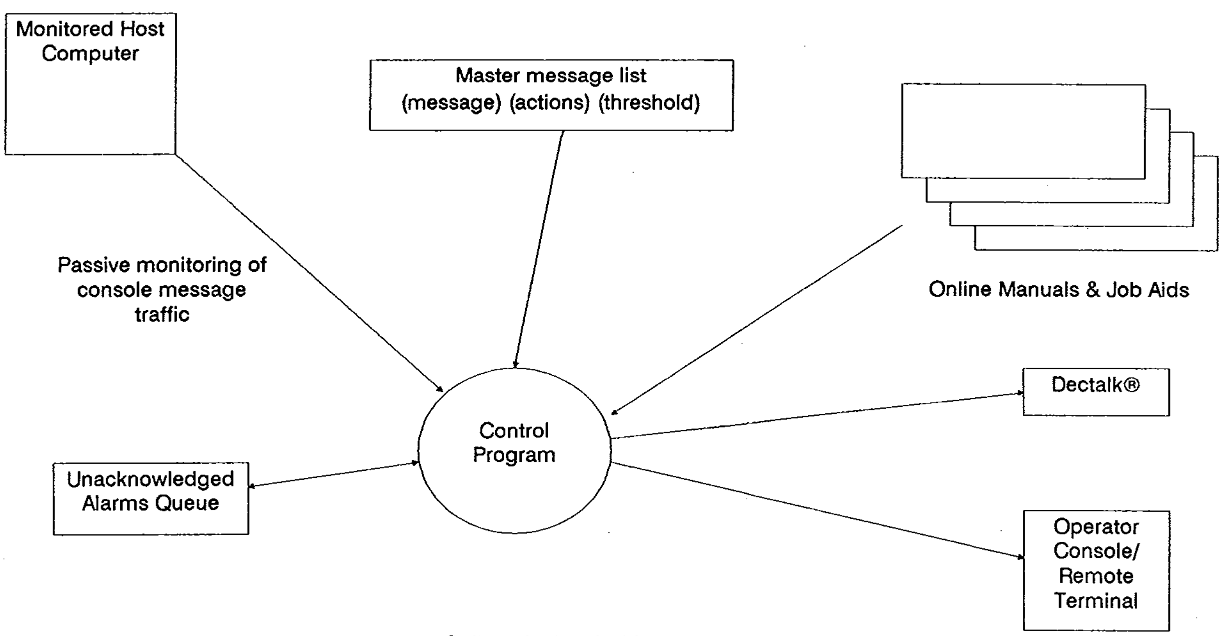

Figure 2. Online Monitor Architecture

was simple to implement using standard UNIX® features.

- *Voice announcement of alarms.* A DECTALK® speech synthesizer was used to generate public address announcements of high priority alarms and to call pagers.
- *Human Factors analysis.* Useability criteria were tested under real conditions in order to devise interfaces appropriate to the users.
- *Low cost.* Existing monitoring systems nearly capable of providing the needed level of service ranged in price from one to two million dollars. It should be noted that these systems did not provide predictive monitoring nor expert system consultation facilities, which were considered requirements. In contrast, a working prototype of ESM was delivered in 3 months at a cost of $60,000 including hardware. The production system was cut over 8 months later in two locations, on 3B2 hardware at a total cost of $250,000 including hardware.
- *Measurable and significant cost/benefit.* Several outages were averted while the original prototype was undergoing its first unofficial tests. The first two delivered systems paid for themselves within six months through reduced outages. User complaints about down time have been reduced by two thirds.
- *Expert and end user participation and support.* The Experts received knowledge engineering training and were made part of the project team. All development was conducted on user sites with constant scrutiny and input from the end user personnel. As a result, the project gained interest and support from a wide range of managers and technical personnel.
- *Provision for predictive diagnosis, interactive consultations, and online job aids in addition to real time monitoring functions.* This combination of functions was not readily available in commercial monitoring systems.
- *Maintainable by End User.* End user administration and Software Support Experts are easily trained to perform configuration updates and knowledge base maintenance. Approximately 20 hours of training and 20 hours of supervised exercises have proven adequate to familiarize personnel with the Expert System shell and configuration files. Program maintenance remains with the Advanced Systems Group.
- *Customizable and portable to meet new monitoring needs.* New versions of ESM for other monitoring purposes have already been constructed. The modular design and portable C language constructs facilitated porting ESM from the 3B2 to the SUN workstation environment to allow running multiple monitor views in a windowing environment.

Payoff for the organization

Operators are able to pursue more constructive tasks, confident that ESM will announce impending problems with time to spare. Time once spent scanning the machines

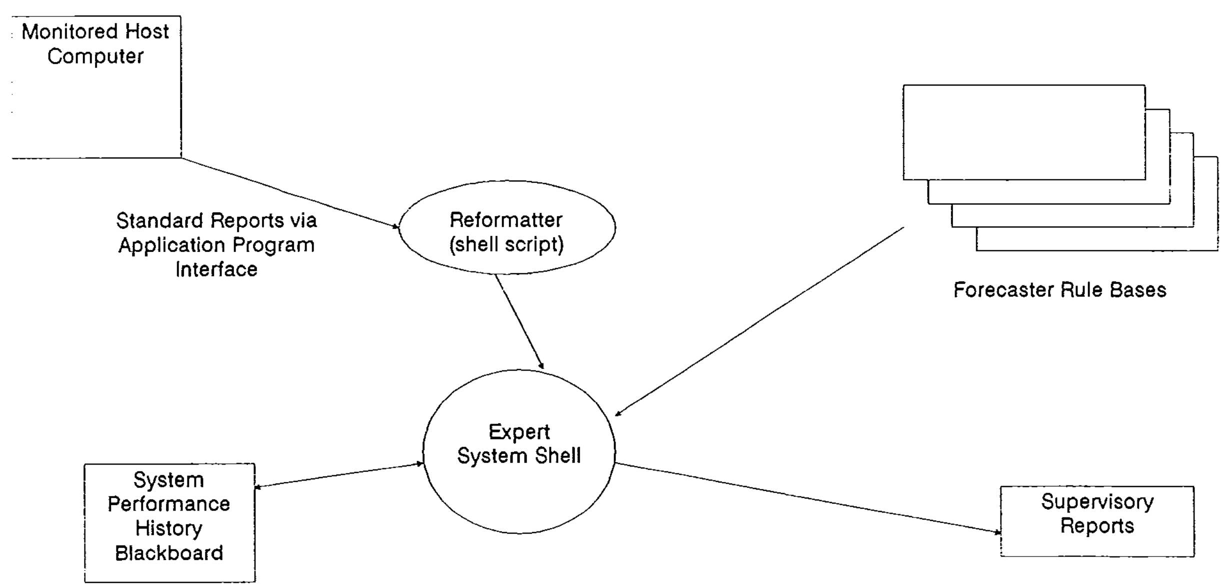

Figure 3. Forecaster Architecture

is now used to perform preventive maintenance, training, etc.

ESM is the first major AI system effort at Pacific Bell® to provide substantial, measurable cost benefit performance. It has proven for the first time to a wide audience of managers and craft personnel alike that AI technology is valuable and desirable. The success of ESM has opened serious discussions for many new projects.

Project Data

The first production system was delivered in May, 1988. Elapsed time from proposal to production was 11 months with a part-time staff consisting of 2 experts, 1 programmer, 1 knowledge engineer, and a group manager. The project cost approximately $250,000 including provisioning of two 3B2/600 machines to host the monitor at two sites. Each system monitors approximately 25 processors and has capacity to monitor 100 processors. Based on labor costs during outages, the system is expected to pay for itself in less than 3 years.

Two more systems were deployed in January 1989 on SUN® Workstations under the SunView® window environment. The new systems each monitor up to 60 processors representing three major application systems. These systems will serve as the trial platform for the expansion to a G2 icon-oriented front end, discussed below.

Future Expansion

The G2 real time expert system shell will be added to ESM during 4th quarter 1989 to provide an optional icon-oriented front end to the system. G2 will visually display alarms on an illustration of the computer site and allow support personnel to submit commands and effect repairs through the use of interactive graphics. The ability to migrate and expand monitor functions in the G2 environment will be pursued.

Acknowledgements

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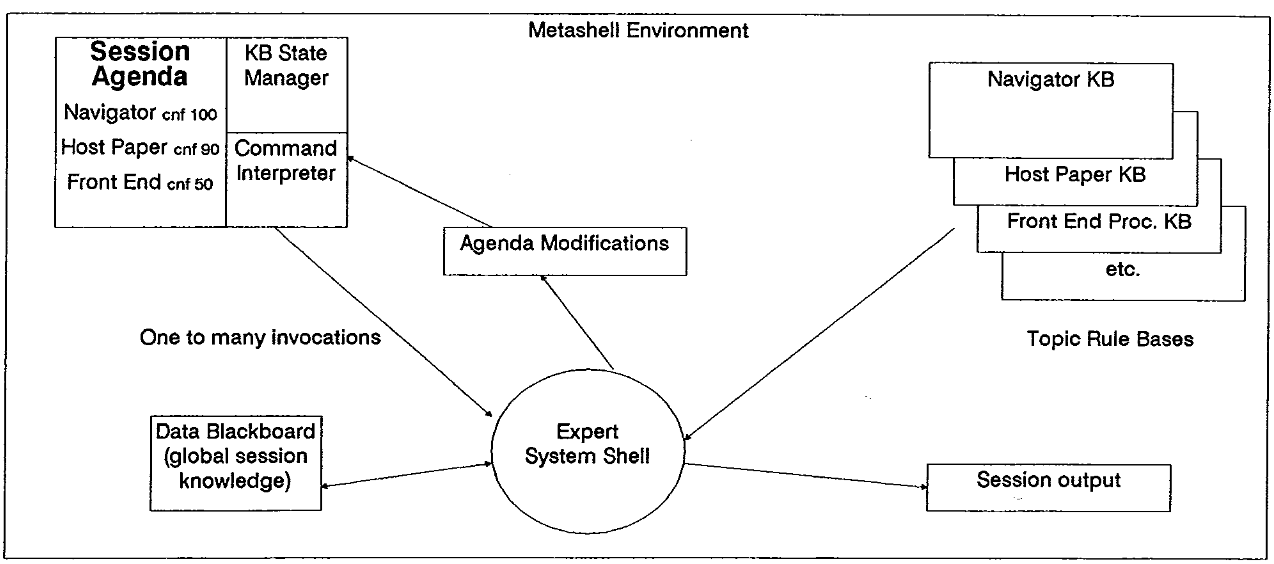

Figure 4. Metashell Blackboard Architecture (used in Consultant)