StarKeeper® II NMS — Management of a Cell Relay Network

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The StarKeeper® II Network Management System (NMS) was developed to manage cell relay networks. Network administrators use this distributed graphical system to monitor, administer, and troubleshoot the network. StarKeeper II NMS manages a single AT&T BNS-2000 data switch or a network of BNS-2000 data switches. This paper describes how designers of StarKeeper II NMS incorporated customers' requirements for network management systems into the architecture of their product and its software.

Introduction

Cell relay technology has been making networking industry news recently. Cells, uniform-sized data units, can be processed by the hardware of a cell relay switch much faster than traditional switches can process variable-sized data units. Because broadband networking is characterized by higher bandwidths (e.g., speeds of 155 megabits per second [Mbit/s]), the speed of cell relay technology is fundamental to the asynchronous transfer mode (ATM) technology and Switched Multi-megabit Data Service (SMDS) standards. (Switched Multi-megabit Data Service is a service mark of Bell Communications Research.) (See Panel 1 for definitions of abbreviations, acronyms, and terms.) The StarKeeper II NMS was developed to manage AT&T's cell relay networking equipment. This paper emphasizes what customers need to know to manage complex cell relay networks, and how StarKeeper II NMS supports these needs.

StarKeeper II NMS. StarKeeper II NMS manages the AT&T BNS-2000 data switch, a cell relay switch that supports both frame relay and SMDS access and trunking interfaces, as well as other data networking interfaces and functions. (Frame relay is another networking standard based on variable-sized data units [frames] and speeds up to 1.5 Mbit/s.) StarKeeper II NMS provides management functions such as configuration, surveillance, performance analysis, and maintenance for the BNS-2000.

A distributed graphical system, StarKeeper II NMS can be used on a single workstation or on multiple, geographically dispersed, workstations. To help network administrators perform traditional network management activities, StarKeeper II NMS provides three sets of applications: the Network Monitor, Network Builder, and Performance Reporter, described in detail later in this paper.

AT&T Cell Relay Customers. The customers of StarKeeper II NMS and AT&T's cell relay switches provide either public or private data-networking services. Customers that provide public data-networking services include telecommunications providers. Those that provide private data-networking services are usually corporations that use AT&T's cell relay switches as the networking infrastructure for their internal corporate networks. Although these two types of customers supply different types of products and services to their respective customers, StarKeeper II NMS fills both network management needs.

Customer Networking Needs. With the proliferation of local-area networks (LANs) — networks that interconnect customers within a building or in several adjacent buildings (the local area) — many businesses and organizations have been faced with the need to interconnect LANs that are geographically separated across a wide area. High-speed LAN interconnection is one of the applications supported by both frame relay and SMDS networks. Customers also need more traditional data services, such as the consolidation of LAN servers into a centralized computer center, and newer services, such as image transfer. Other customer applications include operations support networks for service providers,

service transaction networks for service corporations, and research and development networks for research laboratories.

Customer Requirements for NMSs. StarKeeper II NMS represents an evolution of network management features for our customers. Designers of this system closely analyzed customer requirements, and determined that the major ones were:

- Ease of use,
- Scalability,
- Flexible functionality,
- Customization tools,
- Stringent performance criteria, and
- Open interfaces to other NMSs.

Ease of use. Customers have learned to use new desktop software technology that offers multiple display windows and point-and-click operations. They also want these capabilities in their network management systems.

Scalability. The network management system must easily support both large and small networks. Customers with start-up networks want to begin with small network management systems, but be assured that the system can expand along with their network.

Flexible functionality. Some functions may be centralized for an entire network, others may be supported region by region. Some functions in a location are supported 24 hours a day, others only during business hours. Some features may be "read only" for some network administrators and "read/write" for other network administrators. This functional flexibility applies to multiple concurrent users.

Customization tools. The administrators who implement networks want StarKeeper II NMS to provide them with customization tools so that they, in turn, can offer value-added features to their network customers. Customized reports, engineering analyses, and other functions tailored to customers' specific needs can produce additional revenues and/or usage of the network.

Stringent performance criteria. Operations are crucial to any network offering, either public or private. Any network management system must adhere to performance criteria, such as high reliability and rapid response time. As the bandwidth, speed, and accuracy of networks and applications increase, the ability to react quickly and accurately to changes and troubles must also increase.

Open interfaces to other NMSs. Because today's networks are complex, consisting of differing types of equipment from multiple vendors, it is essential to support

Panel 1. Abbreviations, Acronyms, and Terms

ATM — asynchronous transfer mode
CPU — central processing unit
LAN — local-area network
NMS — Network Management System
PI — Programmer's Interface
SMDS — Switched Multi-megabit Data Service
SNMP — Simple Network Management Protocol
SQL — structured query language
VCS — virtual circuit switch
X terminal — a graphics display terminal

open communication to other systems so that customers can manage their total network effectively.

The remainder of this paper describes the architecture and features of StarKeeper II NMS, as well as customers' experiences in using it. StarKeeper II NMS meets the requirements presented earlier, employing new computing and networking technology, yet addressing customers' investments in equipment, training, and data.

StarKeeper II NMS Product Architecture

This section describes the product architecture from three different perspectives: feature, logical, and physical.

Feature Architecture. The StarKeeper II NMS product architecture has two major components: Core Systems and Graphics Systems. Each of these has a specialized functional role. The Core System:

- Maintains a high-speed, multiplexed communications interface to each cell relay switch in the network.
- Collects — in a database — performance, accounting, and status information for analysis, storage, and subsequent use by applications programs.
- Supports interfaces to other management systems, including forwarding alarms to other network management systems so they can be consolidated using a local standard alarm interface. Also, the Core System supports an open customer network management interface (used by end customers of service providers) whose standard Simple Network Management Protocol (SNMP) exchanges data with SNMP managers at end customer sites.

The StarKeeper II NMS Graphics System provides most of the user-level applications. Its point-and-click graphical user interface was designed for operators
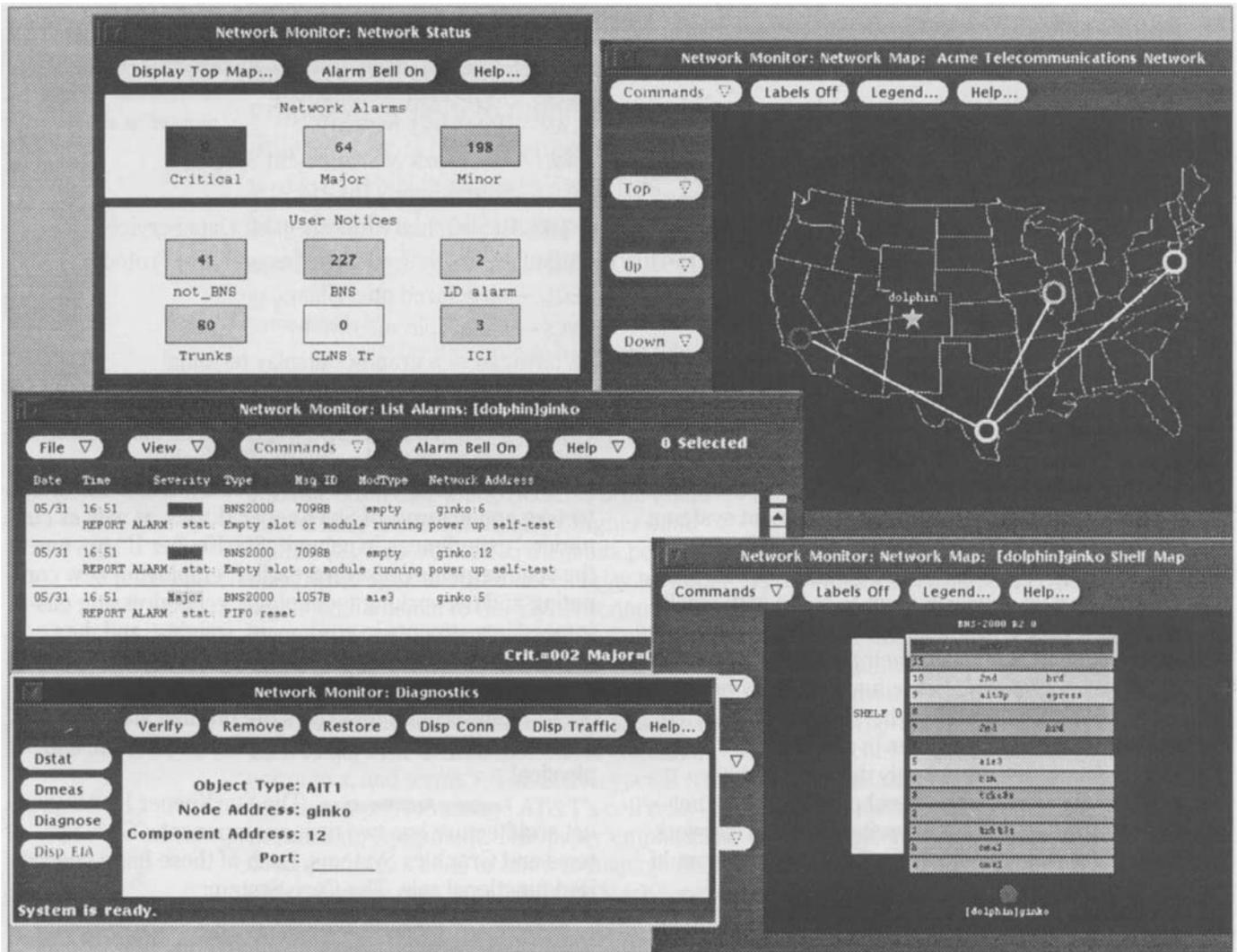
Figure 1. Network Monitor provides real-time network status displays. These multi-tiered graphical representations of the network are arranged from the highest level down to individual shelves and plug-in cards. A separate window displays detailed alarm text. By selecting a network element and an appropriate diagnostic command button, operators can activate a diagnostic request on the cell relay switch.

who do not have substantial computer backgrounds. Most applications can be selected easily using a mouse. Keyboard interaction is minimal.

The Graphics System has three main applications:
- Network Monitor,
- Performance Reporter, and
- Network Builder.

Network Monitor. Network Monitor, a sample screen of which is shown in Figure 1, provides real-time network status displays and multi-tiered graphical representations of the network. They are arranged from the highest level down to individual shelves and plug-in cards. Detailed alarm text, provided in a separate

window, is supplemented by context-sensitive "help" information. By selecting a network element and an appropriate diagnostic command button, operators can activate a diagnostic request on the cell relay switch. This suite of features makes it easy for the network manager to see the status of the network at a high level, and to gather detailed error information quickly if trouble occurs.

Performance Reporter. Performance Reporter analyzes and displays network performance data. The network operator can manipulate and analyze the data in the Core System database to improve its usefulness. For example, one operator may request an exception report of only those trunks that exceed 80-percent utilization during a specified time. Another operator might request a graphical plot showing the traffic profile on parts of the network for the previous day. Reports can either be requested immediately, or scheduled to run at a convenient time. Report results can be sent to the screen display, to a printer, or stored in a file for later use. These features allow experts to use their time providing value-added network analysis, rather than manipulating large amounts of raw data.

Network Builder. Network Builder helps operators allocate logical/physical network resources. This is particularly valuable when logical resources (e.g., group names, routing paths, etc.) provisioned on each cell relay switch must first be coordinated at a network level. Network Builder analyzes and enforces overall network disciplines before certain critical data are downloaded to the switch. This might be as simple as enforcing unique network-wide names, or it might involve adding programs that analyze how the routing would operate under failure conditions.

Logical Architecture. The logical architecture of StarKeeper II NMS encompasses both the Core Systems and Graphics Systems, as described in the sections that follow.

Core Systems. The StarKeeper II NMS Core System addresses customer needs for both scalability and flexibility. In many cases, a single Core System can monitor the entire cell relay network. In large networks, where multiple Core Systems are needed, customers can configure each Core System individually to meet specific needs. Figure 2 shows a sample arrangement using a hypothetical three-city network.

Some customers may prefer a functional split, in which one Core System is responsible for performance

and accounting data from all switches in the network, and another provides real-time alarm/diagnostic functions for all switches. This would satisfy the needs of a customer whose engineering organization uses the first Core System, and whose network operations organization uses the second Core System. For another customer, it may be more desirable for each Core System to control all functions for a given part of the network, especially for those customers who are organized geographically. The physical connection of the Core System to the network would be the same for either logical arrangement.

Graphics Systems. Like Core Systems, Graphics Systems have a scalable architecture. A single Graphics System can monitor the entire network, and provide support in all three functional areas. Conversely, multiple Graphics Systems can be used to monitor specific segments of the network, or to provide only a subset of the Graphics Systems' functions. If more than one Graphics System is present, the architecture permits each one to communicate with all Core Systems. This critical "ease of use" feature allows the Graphics Systems to collect data from all Core Systems and present a single, consolidated network view to the user.

In addition to the main Graphics System display, X terminals can provide system functionality to multiple users without requiring the purchase of additional full Graphics Systems. As Figure 2 shows, Graphics System 3 is coupled to two additional X terminals, which provides three positions from which a user can access the applications on that Graphics System. This flexibility is important for customers who have operations centers in which many people share network management tasks.

Physical Architecture. A flexible physical arrangement of the network management system is also important to managing the network. Figure 3 shows one possible physical layout of the logical architecture shown in Figure 2. In this case, the two Core Systems and three Graphics Systems are attached to the switch closest to each, using high-speed multiplexed fiber interfaces to carry bulk data transfer. As a result, the two Core Systems and three Graphics Systems are physically distributed throughout the network. This can be changed to reflect the user's organization/location of the network operations staff, and does not dictate a fixed topology. If the network operations staff were located in Chicago, all Core and Graphics Systems could also be attached to the Chicago cell relay switch. In either case, any Graphics

Figure 2. Logical architecture of Star-Keeper II NMS Core and Graphics Systems monitoring a BNS-2000 network. The ability to add multiple Core and Graphics Systems to manage larger networks — while still presenting a single, consolidated view of the network to the administrator — provides the scalability and distributed nature that customers demand.
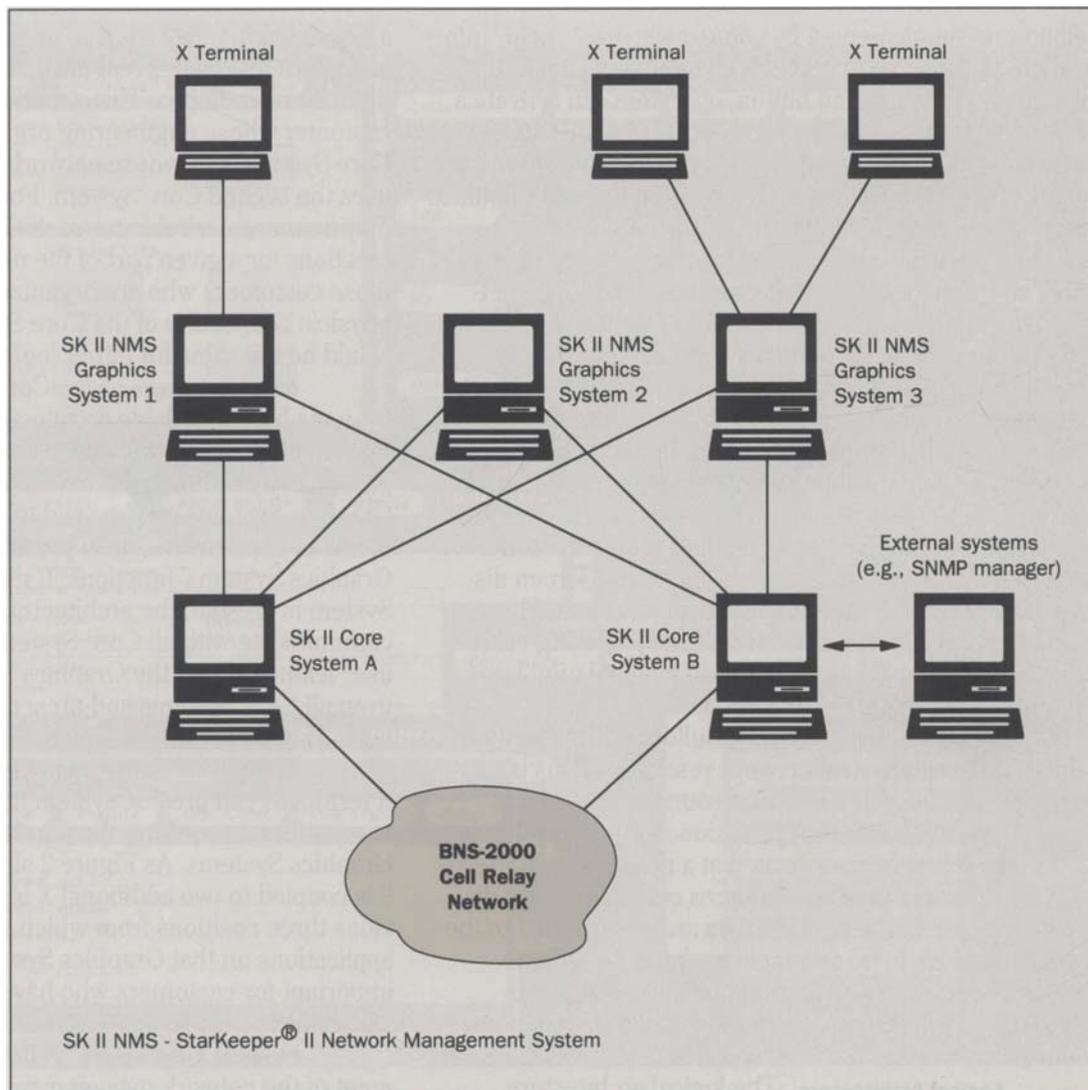
System can access information on any Core System, regardless of its location. Also illustrated in Figure 3 is the ability to install both Core and Graphics Systems on a single physical host, such as the host in New York. This is valuable for monitoring small networks, where keeping hardware cost low is important. Local Ethernet connections support local, lower-cost X terminal access to Graphics Systems, where required.

StarKeeper II NMS Software Architecture

The choice of operating system, database, architectural elements of StarKeeper II NMS's distributed capabilities, and customization capabilities are specific

elements of the software architecture that illustrate the influence of customer needs. This section highlights the close relationship between architecture and functionality.

Operating System. The choice of the UNIX Operating System for the StarKeeper II NMS is often taken for granted. (UNIX is a registered trademark of UNIX Systems Laboratories, Inc.) It was selected, however, to fill customers' needs for a multi-user and multi-tasking environment, in which more than one operator could interact with the system simultaneously, and each operator could invoke more than one operation at a time.

The UNIX Operating System provides a degree of platform independence desired by customers. This
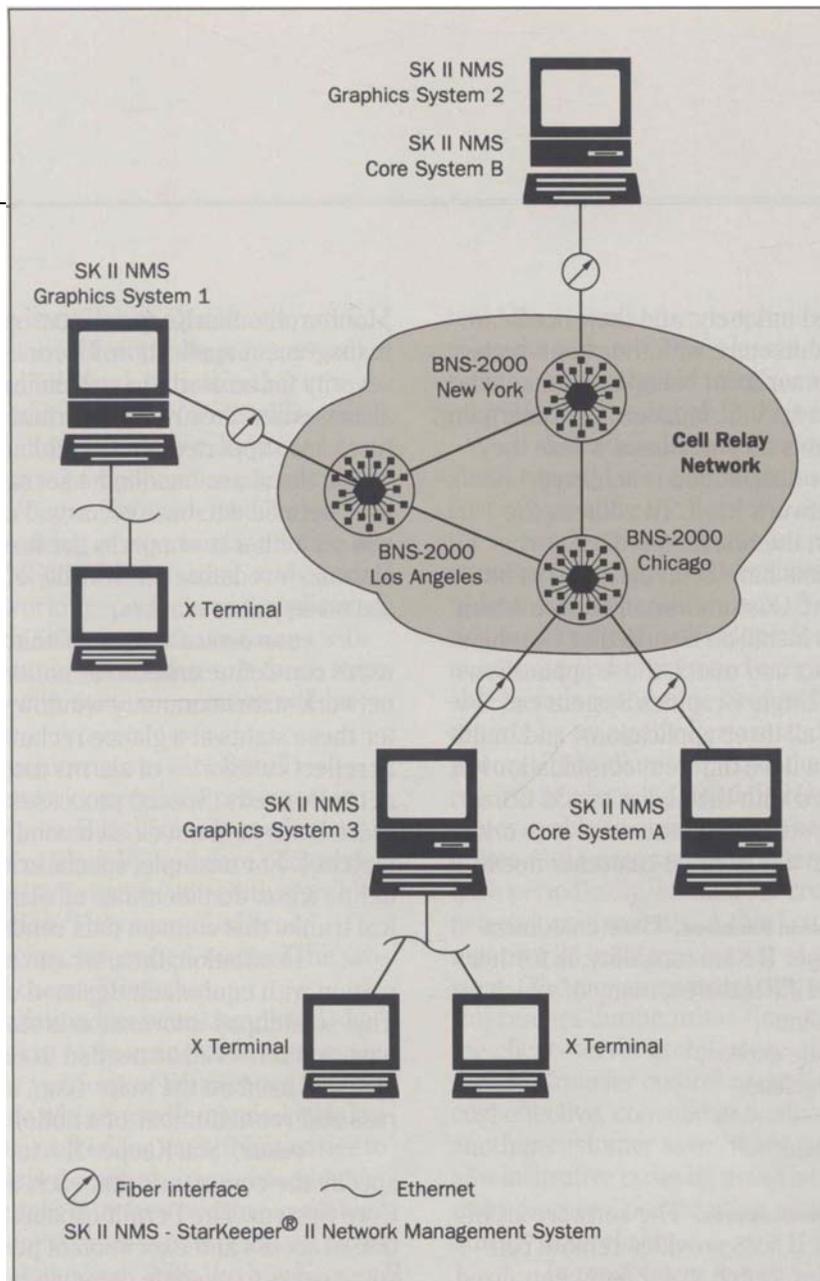
Figure 3. One possible physical layout of the logical architecture shown in Figure 2, illustrating the ability to distribute the StarKeeper II NMS components geographically.

Figure labels:
- SK II NMS Graphics System 2
- SK II NMS Core System B
- SK II NMS Graphics System 1
- BNS-2000 New York
- Cell Relay Network
- BNS-2000 Los Angeles
- BNS-2000 Chicago
- X Terminal
- SK II NMS Graphics System 3
- SK II NMS Core System A
- X Terminal
- X Terminal
- Fiber interface
- Ethernet
- SK II NMS - StarKeeper® II Network Management System

system has become available on a number of hardware platforms, fostering hardware evolution tracking. (A hardware platform is a specific type of computer system, such as the Hewlett Packard 9000 Series 700 workstations. Hardware evolution refers to changes in a particular platform to increase the speed of the central processing unit [CPU] or to improve other system characteristics.) Users can acquire a machine that fulfills their early modest needs, yet can be expanded by adding memory and disk space, meeting customer needs for scalability.

One of its more important characteristics is its rich complement of interprocess communication facilities, which promote the smooth operation of complex systems. Process interaction informs processes of significant events, passes data from process to process,

transfers control from one process to another, and monitors processes that are executing simultaneously.

To handle situations not anticipated by their vendors, users need a simple method to create their own processes. The UNIX shell not only enables network providers to create special tools for their daily operations, but also to enhance features for their customers.

Centralized Database. The INFORMIX Relational Database is a product that forms the basis for data collection, organization, storage, and further customization. (INFORMIX is a registered trademark of INFORMIX Software, Inc.) Each StarKeeper II NMS Core System is equipped with the INFORMIX SQL and the ACE report generator, tools that enable users to extract data in a wide variety of ways.

Distributed Architecture. StarKeeper customers are disparate: their networks vary in size, their

operations are distributed uniquely, and their needs are not static. A software architecture with the client–server paradigm frees the customer from being dependent on applications available in a specific location; customers can choose which functions they need and where they want to install them. This distribution is achieved through the cell relay network itself. To address the requirement of flexibility, the StarKeeper II NMS graphics-based applications have been designed to be modular and independent. Customers can choose which applications they want to install on a particular Graphics System. They can also mix and match these applications as their needs dictate. A single Graphics System can have any combination of all three applications, and multiple Graphics Systems can have different combinations of applications. This, coupled with the ability to add Core Systems and Graphics Systems as customers' networks expand, provides another way to meet customer needs for scalability.

Special Customization Features. User customization, a desirable StarKeeper II NMS capability, is further supported by several specific features, many of which are related to fault management:

- Centralized remote node access,
- The Programmer's Interface,
- Alarm conditioning,
- User-defined notices, and
- Permit capability.

Centralized remote node access. The software architecture of the StarKeeper II NMS provides remote console access to the cell relay switch to support centralized management of nodes. Users can access all the switches monitored by a single StarKeeper II NMS from that one host. They can customize tools that handle all their switches by repeating the same functions on each switch from the centralized position of their StarKeeper II NMS host. For example, they can create and execute a script that can sequentially run diagnostics for asynchronous interface modules on all nodes during inactive periods.

The Programmer's Interface. The Programmer's Interface (PI) allows users to act on one or more specific alarms. The action is entirely specified by the user, as are the alarms that the user wishes to trigger the action. For example, a user can create a script to send electronic mail to an administrator when a specific alarm occurs.

Alarm conditioning. Users can define criteria whereby alarms are, or are not, forwarded to Network Monitor, the StarKeeper II NMS graphics-based fault management application. Users can adjust the default severity for an alarm to suit their needs, or forward alarms when they reach a certain threshold. These features are supported by an architecture that embeds within the alarm handling a set of operations based on user-defined database records. For example, the user can set a filter to suppress the forwarding of all minor alarms, or redefine the severity of all informational alarms as minor alarms.

User-defined notices. Within Network Monitor, users can define criteria for notice boxes in a special network-status summary window. The user can administer these status-at-a-glance rectangles, shown in Figure 1, to reflect categories of alarms most appropriate to their network needs. Special processes help the user define these boxes and check all incoming alarms for criteria matches. For example, special criteria can be used to define a box that identifies all alarms associated with critical trunks that connect data centers.

In addition, the user can associate special information with equipment depicted on customized maps. This scratchpad information is stored in a special database and retrieved as needed to enhance the meaning of symbols used on the maps (e.g., noting the street address and room number of a node).

Permit. StarKeeper II NMS provides a feature to specify the commands that each user can access on a Core System. The Permit capability supports the definition of access and execution of permissions that allows some users to execute commands, while denying access to others. Similarly, on Graphics Systems, users can be given "read/write" or "read-only" access to Network Builder tasks.

Network Management Operations Experiences

By examining customers' operations experiences, the StarKeeper II NMS development organization can determine whether the anticipated customer needs are being met, discover unforeseen needs, and see how needs are being met in unexpected ways. This information is then used to define new features and improve existing features to enhance the value of StarKeeper II NMS.

Ease of Use. Initial requirements for this area generally aim at the daily operational features of the product, as they do for StarKeeper II NMS. However, a customer's first experience with a product is when he or

she opens the box and tries to get the product to work. Installation deserves as much design attention as traditional applications. Initial feedback indicates that customers want a simpler, faster process for installing software. After the CPU, monitor, tape drives, keyboard, mouse, and other hardware components are assembled, software installation can begin. Software installation requires loading and licensing of a particular version of the operating system, INFORMIX database, and performance monitoring, networking, protocol and application software packages. Each software package comes with its own installation and tuning procedures. If these steps are not performed correctly, system operation will be suboptimal.

It is difficult to achieve a one-size-fits-all approach, or to train network operations personnel in computer operations details. But this is often what customers accustomed to installing PC software packages expect. StarKeeper II NMS designers solved this problem by streamlining installation. They identified broad improvements in packaging, integrated some of the procedures, and simplified the user interface.

Long after installation has been completed, day-to-day ease of use is critical to ensuring continued customer satisfaction. Early versions of StarKeeper NMS had a command line interface whose use demanded training and expertise. Customers asked for something easier to use, so designers developed a simple menu-based interface. When a graphical user interface became available, customer expectations for ease of use were raised again; even more simplicity was desired. With the StarKeeper II NMS Network Monitor, operators can see alarms displayed on a customized map of their region, as shown in Figure 1. The alarms are shown as color-coded icons representing cities with aggregated equipment. Double-clicking on one of these icons displays a detailed network map of that city. The resulting window shows a diagram of network elements, color-coded according to their alarm status. Double-clicking on a specific element icon opens another window, showing individual circuit packs with a color-coded status. A final double-click on a particular circuit pack brings up a set of buttons and controls that provide diagnostic and administrative functions.

Although the graphical user interface is simple to use, some customers either feel more comfortable with the old interface, or feel that their operations are tailored to the older technology. Sometimes customers build their own software scripts or operational plans around a feature. New releases of StarKeeper II NMS retain many of the old interfaces to permit a gradual migration of operations to the new features.

Cost Management. Customers are very concerned about two aspects of network management costs: the cost of operating the network, and reducing the cost of the network management system itself. Innovative uses of network management features can lead to dramatic reductions in operating costs. A customer whose operation requires that network performance be constantly monitored and maintained at optimum performance is able to reduce the time needed to analyze performance reports by using the Performance Reporter thresholding feature. This allows the customer to focus only on those reports in which a potential problem exists. Another customer is able to create scripts and structured query language (SQL) programs that query the configuration database periodically, looking for costly idle or underutilized network components. A third customer has a requirement for 24-hour monitoring of a widely dispersed network. The customer maintains multiple monitor and control centers during prime-time hours. Custom scripts and the client–server architecture of StarKeeper II NMS allow them to transfer control of portions of the network to a cost-effective, consolidated, after-hours control site. Yet another customer saves more than $100,000 per year in administrative costs by using new Network-Builder data entry features, provisioning network configurations more quickly and reliably.

In most cases, the savings in operating the network quickly justify the cost of the network management system. However, when budgets are squeezed, it is still important to minimize the purchase and operating costs of the network management system. Customers can reduce staffing costs by reducing skill levels required for monitoring the system, generating standard reports, and performing routine data entry. StarKeeper II NMS has met this requirement by providing a point-and-click and forms-based interface for most tasks. Customers have constantly pushed for ever-increasing performance and capacity improvements to reduce the amount of network management hardware. StarKeeper II NMS software is designed to run on popular Hewlett Packard Series 700 workstations that are constantly being reengineered to ensure that customers will enjoy the full price and performance benefits of evolving technology.

Customization. The goal of simplified operations can be at odds with the need for user-level customization. Customization options can introduce operational complexity. StarKeeper II NMS maintains two user-interface models for customers: a simple model, to minimize the need for experience and training; and a more complex model, for more experienced "power-customers."

Customers can develop diagnostic and trouble-detection scripts to identify and correct problem areas. For example, one customer experienced intermittent network problems that could be detected by initiating a network connection to a specific endpoint. The customer wrote a script that periodically checks connections and reports failures.

A standard database product enables users to take advantage of troubleshooting and report-generation tools at no additional cost. One customer uses a customized report to extract performance numbers from a database and report on specific network utilization metrics that are of local importance.

Another example of customization includes user-defined notices, as provided by Network Monitor. One customer with a synchronous network uses an application that tends to stress the system in ways that produce a particular combination of alarms under normal but heavy load conditions. A filter was defined to detect these alarms and to trigger the colorization of a user-defined notice. This provides a simple alarm correlation capability, tailored to the customer's network and administration needs.

Reliability. The reliability of the network management system is second in importance only to the reliability of the network itself. Over time, as customers become more dependent on the network management system, this need becomes stronger. Customers are not often willing to pay the price of fully fault-tolerant hardware and software. To meet customer expectations, a cost-sensitive alternative required some creative engineering and customization. A large private customer with critical reliability requirements is able to use custom scripts that, with a single command, redirect monitoring functions of many network elements to powered, but otherwise idle, hosts. Another customer could not afford spare hosts, but is able to take advantage of the StarKeeper II NMS distributed architecture by using one Core System for alarms and surveillance, and a second Core System for collecting and analyzing performance data. When trouble occurs on the more critical surveillance machine, collection of performance data can be temporarily suspended to use that machine for alarm collection.

One customer is able to maintain high availability at low cost by being able to respond quickly to high-severity alarms, without the need to monitor the system constantly. The PI feature of StarKeeper II NMS is used to trap high-severity alarms and to run a custom script to activate a beeper carried by support staff. Problems can be addressed quickly, without the need for 24-hour staffing of a monitoring center.

Conclusions

The designers of StarKeeper II NMS continue to explore ways of adding value to their equipment, and to meet the needs of customers who face the challenges of maintaining mission-critical networks based on AT&T's cell relay switches. StarKeeper II NMS provides a rich, flexible feature set that addresses customers' needs for managing their complex networks. Keeping in touch with customers and seeing how the system is used in their environments has improved StarKeeper II NMS significantly.

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