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NETWORK MANAGEMENT AND CONTROL SYSTEMS

Terrence P. McGarty and Larry L. Ball

NYNEX
White Plains, New York 10604

914-683-3188

1988 NOMS Conf.
IEEE # 88CH 2532-0
87-83457

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by

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Larry L. Ball

1 INTRODUCTION

The concept of network management and control has evolved from a set of tasks that relate to the monitoring and management of the existing twisted pair network to a set of more complex tools that drive the performance of the data networks of today. The primary driver in the new method of attacking the network management problem is the growth of computer communications and its divergence from just a simple hierarchical network to a much more complex networking concept.

The networking of large scale computer networks requires not only an understanding of the local and long distance Telco Plant, but also an understanding of the need of the total communications network. These needs are much more complex than those of the voice user of the system. Significant differences are those in response time and the ability to perform complicated networking. In addition, the need for higher reliability circuits combined with the pressure of reduced costs lead to the tradeoff of having alternate routing and automatic restoral procedures available.

Many companies have provided a communications systems that may at times be more expensive than the alternative telephone based system. However, these systems often do not include a sophisticated NMCS capability such as that provided by NYNEX that the end users value more than the communications. Thus the asset of such a company is not in the telecommunications network alone, but in the NMCS capability and resources to handle and support the end user requirements and needs.

This paper focuses on the concept of providing the data and computer communications user with a set of facilities that allow for the integration of many of the disparate tools that are presently available into one single network management utility.

In particular, in this paper we develop a new model for Network Management and Control Systems (NMCS) that expands the capability to support a sophisticated end user in a multi vendor environment and allows for the integration and optimization of multiple subnet control systems.

2 PROBLEM DEFINITION

The basic problem that is addressable by an effective network management and control system is easily stated. Simply put, an effective NMCS allows the end user to have a single point of contact for problem resolution whenever the user hits a key on the terminal and the response is not as expected. Such a definition is all encompassing and it is not anticipated that a solution to this problem is readily forthcoming. However, it is essential to understand the ultimate goal of network management and control.

2.1 Computer Communications

In the world of computer communications, the user sees a different set of problems than that of the voice user. The data manager is faced with the overall management of the computer users needs to ensure total end to end integrity of the process. This integrity is less tolerant of the errors that occur in the communications channel and also reflects the delays in the processing and transport of the data signals.

For example in an IBM SNA environment, the end user may have a network that is composed of the following elements"

- Host IBM Model 3091
- Front End Processor: 3725
- Modems: Codex
- Local leased RBOC line at 56 Kbps using X.25
- Inter LATA Network at T1 rates using a Cohesive controller
- Local RBOC multidrop line
- Modem: Codex
- Cluster Controller: 3274

2.2 End User Requirements

The end user requirements are generally similar in a computer communications environment. Consider a user in a large IBM based environment. The user establishes a session under an SNA environment and the connection is made between the 3725 front end processor and the 3274 cluster controller. The lines may be a set of polled multidrop lines operating at 9600 bits per second. The end user utilizes a standard 3270 display terminal.

In this environment, the end user expects the following:

• A rapid response time to all keyed requests. The response time for the last character in to the first character out should be less than 2.5 seconds 99% of the time.

• An error rate on the line that ensures overall system performance. The line error rate typically should be less than 1 in 10 E6.

• In the event of a line or system trouble, the user should have access to an 800 type number system that allows for rapid problem determination and restoral. In particular, no problem should last longer than 10 minutes.

• The problem reporting and the resolution should appear as a seamless process to the end user. The end user should not be made aware of the sets of players that may be in between the overall network of users.

2.3 Performance Requirements

The performance requirements for an NMCS system are based on the needs of the end user in terms of network availability and time to restoral. The specific requirements may be modified when there are needs of the underlying network that result in increased levels of errors and outages.

Typical performance requirements are as follows:

• Percent of undetected user faults. These are the faults that are detected by the user rather than by the system. Thus if 5% of the total faults are those that were first detected by the user rather than by the system, this may represent an unacceptable level of faults.

• Response time to fault isolation. This represents the time it takes to isolate a fault once it is reported. The system should have the capability to isolate faults to the source or cause in typically 5 minutes or less.

• Response time to resource reallocation. This is the time it takes for the network to respond with backup resources to allow for continued operation. This may vary dramatically from user to user. Some users may be willing to pay for total redundancy in the network and this time may be a fraction of a second. On the other hand users may not have direct redundancy in the network and alternate routing may be necessary.

• Response time to user complaint. The system must be able to respond to a user query in less than several seconds. This includes only the answering of the phone for a typical request. In addition, the system must be able to provide the customer service representative with the direct access to the end user and of all information on his account.

2.4 Interface Requirements

The NMCS must be capable of interfacing with all of the systems that are part of the total communications network. For example, in Figure 1 is depicted a typical communication network that operates within an IBM SNA environment. The front end processor, 3725, interfaces with a private network that utilizes a T-1 backbone. The backbone is part of a separately controlled network and the lines to the remote 3270 cluster controller are sub multiplexed onto the overall T-1 network. The specific interfaces are:

- The IBM SNA environment.
- The DEC DECNET Environment.
- The local RBOC terminations at each end. These may be in separate regional areas and thus may require separate control interfaces.
- The T-1 network managers and muxes.
- The local modems.
- The PBX switch through which the 9.6 Kbps lines are switched.

This is an example of how it is necessary to include all of the elements that are part of the total switched network as well as the dedicated network.

3 ARCHITECTURE ALTERNATIVES

The architectural alternatives for the NMCS systems are based upon the need to satisfy the end user requirements. The environment for the NMCS is that of a computer communications network and far exceed that of the standard voice or even data communications network. The computer communications needs are structured along the lines of the OSI layers and the NMCS must be designed to support those layers separately and in unison.

3.1 OSI Layers

The NMCS problem is one that encompasses all of the OSI layers. Most NMCS systems at the present are not layered in the OSI fashion but it will become quite clear that such layering elicits a clear understanding of all of the functions that have to be performed and where such functions are to be best performed.

The seven OSI layers and their NMCS functionality are best described as follows:

• Physical: This is the lowest level and is the one that the BOCs have a long history of addressing. The need at the physical level is to ensure that connectivity of the circuits is maintained.

• Data Link Level: At this level the issue is the ongoing point to point connectivity of the modems in the network. Typically this is provided by the loopback testing of the modes as well as the ability to utilize datascopes for protocol testing. A typical problem in SNA networks may be the setting up of SDLC framing sequences and the ability to provide the correct bit framing. In addition, with multi-protocol networks, those running SDLC, BISYNCH and X.25, the NMCS must have access to all of these remote protocols.

• Network: This is the point to point addressing issue in the network. Typically in a packet network, the control access to these points is in the network providers' PADs and is not readily accessible to the NMCS. In more sophisticated networks using T-1 switches, control may be available through the switch control ports.

• Transport: This end to end addressing capability allows for the total integrity of the signal. It is typically the purview of the CPU and its associated front end processor. In an IBM SNA environment, the control is in NPDA and NCCF.

• Session: As with the transport layer, the control is at the CPU site and typically resides in the same locations for SNA as do the transport functions.

• Presentation: At the present time, the presentation layer is not supported as effectively as the other layers. With increasing complexity of presentation formats, there is a need to expand this capability. For example, the use of X.400 type formats will require a closer control of this layer. A single terminal, for instance, could have multiple formats used for presentation and these must be supported.

• Application: This layer is not supported at all in most NMCS systems. In particular if the end user finds himself in a problem area, that problem may be in the application layer only, and not in any of the other layers. It will be essential for the NMCS to monitor and have access to this layer.

3.2 Functional Elements

The functional elements of the NMCS architecture include three major areas: software, hardware and interface integration. These functional elements are the same for all of the seven layers in the design and change only in the specific implementation at the given layer. The software functions of the architecture include the following:

• Operating System: At this level the requirements are those of the platform that is being used as the controller for the appropriate layer. In some cases there may be more than one due to there being more than one controller. The level also requires that the files and Database be compatible.

• Support Services: This level of the software functionality provides the necessary generics to ultimately support the end user requirements.. It may be viewed as a support shell to the overall system.

• Applications: These are the end user specific functions in the software that focus on layer specific support functions.

The software is typically layer specific and in most cases vendor specific. There is a communications interface that allows for the monitoring and control of the network subelement. It is generally through this port that the manager of the network will have access to the local software elements.

The hardware functional elements are not as structured as the software. In many cases the vendor specific equipment has a generic set of NMCS functions resident in its own hardware. In other cases the hardware for NMCS is a separate machine.

Figure 2 depicts a software architecture for a general NMCS system. In this architecture we have shown all of the three major software layers. The functions are generic and they must span not only each physical element in the network but also each layer in the OSI hierarchy. This latter requirement is a critical factor in delivering effective network management.

3.3 Layer Interfaces

In order to support the end user requirements, the seven layers of management must be interconnected in some fashion. In the present environment, the interconnection in many cases is by human interaction. There is a clear need to automate this function and to allow the end user to have access to that single point of problem resolution. Thus the layer interfaces must eventually adhere to a single set of standards. At present however the interfaces are nonstandard. In particular the interface at any one layer is different and may be nothing more than an RS232 interface to a monitor. Thus it is necessary to provide for support of this minimal interface.

3.4 Multi Domain Operations

In an NMCS environment there are multiple domains of operation. We define a domain as a partially enclosed environment that supports one host processor and concentrates on one level of the OSI domain. For example, in an IBM and DEC combined environment there may be seven domains for each host, for a total of fourteen domains. In this environment it will be necessary to provide the functional interface between the domains and to allow for the interexchange of information between the domains.

Consider the network configuration depicted in Figure 1. Here the network includes an IBM machine, T-1 network controllers, LAN's, Bridge's, and a DIGITAL VAX. The intention is to provide the user with the ability to access the control ports of all of the terminals and to allow for a single and unified control station for the system. In this case the user has two computer domains and is interested in the control of 6 layers in each domain.

3.5 Domain Interfaces

The domain interfaces can range from the simple to the complex. This is best described as follows:

- Independent: The user has a single screen for each of the elements in the network. This screen allows for the remote accessing of the managers for each of the separate network elements.

- Interconnected: In this architectural alternative the terminals are not just duplicated physically, but a single software shell interconnects the different control screens into a single effective system. The separate control formats are maintained however and the user is still using the separate control ports as was done in the independent case. However, the single shell interconnects the screens so as to allow the user to do this from a single terminal.

• Integrated: In this case the shell is more encompassing and is supported by a set of intelligent drivers that allows the controller to exercise commands to each of the network elements in a consistent format. The controller does not need to learn a large set of different diagnostic and control commands but only a single set. This allows for the rapid redeployment of network resources and dramatically reduces the cost of network management.

To effect these types of architectures, the resources vary drastically. The first approach is merely a remote monitoring and control of devices that are naturally part of the existing elements. The second approach allows for the signals to be transmitted and received as if they were separate monitors, but they are transformed at the presentation layer into a single screen. The last approach requires the development of separate drivers to support the different variety of network elements.

4 SYSTEM INTERFACES

4.1 SNA

Any NMCS system must support the interface to the IBM SNA devices, both physical and logical. With the introduction of NETVIEW, IBM has enhanced this access and thus will allow the user to utilize more sophisticated interfaces that will integrate many devices and ultimately, using the intelligent driver approach, will allow for a totally integrated system. In particular the IBM features of NPDA and NCCF will be essential in terms of supporting an IBM network.

4.2 ISDN

In the ISDN configuration, the end user will have access to the D signalling channel as well as other potential network services. The signalling channel, enhanced with the capabilities of Signalling System 7 will allow for the direct connection with the network control functions and will provide the basis for the interconnection of the Interexchange Carriers (IC) to provide data on the Data Link and Network layers.

4.3 Multi Vendor Interfaces

The development of the recent ANSI Standard XXX on Network Management provides a guideline to other vendor manufacturers that allows them to focus their attention on the development of consistent interfaces and data formats that will allow the support of fully integrated systems.

5 NMCS FUNCTION AND ELEMENTS

The NMCS has functions that are performed in both a foreground or near real time mode and a background or non-real time mode. The generic sets of NMCS functions are common amongst all of the OSI layers that have been described. These functions may be complete at a layer or may be limited in scope. In the RBOCs, the physical layer includes all of the functionality described. The interlinking of these functions even within the physical layer presents a significant task. As a figure of merit, the total lines of code in the NMCS for the physical layer exceeds 50 million lines.

The layers structure of the NMCS is described in Figure 3. For each level the functionality is generically the same. The ability to interconnect the layers is done through the communications layer.

The ideal NMCS architecture is one which allows the NMCS to act as the manager of managers. This concept provides for the support of all the functionality through interfaces to the individual subnet controllers and allows for a common presentation and control format to the network manager.

5.1 Foreground Functions

The foreground functions provide direct support to the near real time operations of the NMCS. Specifically:

5.1.1 Network Resource Management

This function provides for the real time network reallocation of resources. For example we can describe how this function may be applied at each layer:

- Physical: This will allow the reallocation of twisted pairs and fiber back up. It permits the alternate routing over different physical media.

- Data Link: This provides the alternate switching between modems in the network.

• Network: This permits the alternate routing in a packet network. In this case the NMCS function may be part of the protocol used in the PADs.

• Transport: At the CPU during an end to end outage, the CPU through NCCF may be able to reroute to an alternate host in a multi-domain SNA session.

• Presentation: When a user logs on with a different application, switching from 3270 emulation to VT 200 emulation, the NMCS may be able to in real time, down load a new presentation format controller.

• Applications: . At this level, there is the need to allocate different applications programs and this function is typically performed by the data base administrator.

5.1.2 Problem Determination

This foreground function provides for the real time determination of problems at each of the network layers. It collects data from the performance monitor and using sophisticated algorithms, provides a determination of the problem, its cause and a possible set of corrective measures.

5.1.3 Communications

The need to communicate is two-fold. First the system must be able to communicate in its own layer. This communication is between the NMCS at that layer and the elements that are being effected. Second, the NMCS must be able to communicate between the layers and the NMCS functions that transcend the entire network process. The communications function is robust to the overall needs of the network.

5.1.4 Performance Monitoring

The performance monitoring function is a data gathering function that acts as an input to the various elements that work as a whole in that layer. For example, the performance monitor at the Data Link level gathers data from the modems on the error rate, delays and queue sizes. This gives a performance measure on the protocol transmission and throughput.

5.2 Background Functions

The background functions are the most complicated functions and are those that are most often done in a manual form and may be left as the last to be implemented. As has been observed in many networks, the background functions are most often associated with the backoffice operations. The integration of these functions will assist in the full utilization of the network.

5.2.1 Network Configuration

The function provides the NMCS with a full inventory of what is configured as what in each level. For example the Transport configuration is set in a table in VTAM in an IBM environment and is accessible through NETVIEW.

5.2.2 Traffic Management

The function provides for the management of the traffic and the connectivity of that traffic in the network. At the lowest level it is comprised of the physical links in the network and at the highest level it is comprised of the utilization of certain applications programs and data bases.

5.2.3 Administration

This includes all of the standard back office functions that are performed at the appropriate level.

5.2.4 Customer Service Interface

The most important element in an NMCS is the ability to assist the end user with network problems. The CSI provides to the Customer Service Representative (CSR) a means to identify the end user, to determine the problem, to provide for problem resolution and to ensure that restoral of layer service has occurred . In most existing networks, the end user has no access to a CSR and typically has to negotiate through a maze of intermediaries. In the fully interconnected NMCS the CSR will assist in all functions.

5.2.5 Performance Analysis

The performance analysis function provides for the interfacing of the foreground data gathering functions and developing and displaying the results of the network performance. This allows for an ongoing level of quality of service and the visible monitoring of that service.

5.2.6 Billing

A billing function may be required at each layer. This is too often forgotten except as part of the common carrier networks. As part of any network and integral to the NMCS, the utilization and direct billing or expense allocation portion is a necessary element.

6 EVOLUTION

6.1 Status Now

The present state of NMCS systems is highly fragmented. In the IBM world the user is seeing a proliferation of NETVIEW and its options. Each separate vendor offers a network manager of some type and none of the vendors provide compatibility. The access to the networks that provide transport is sketchy if at all existent. The controllers are all independent and require significant training.

The managers of networks typically have a collection of network control devices and are continuously trying to keep up with the most recent releases of the software.

6.2 Desired State

The desired state of evolution is to have a manager of managers (MOM) that keeps the network and all of its elements working effectively. The network manager must recognize the needs of the end user and integrate into all of the OSI layers.

The manager of managers approach consists of the following elements:

• Interface: A common set of interface protocols that allows the MOM to interconnect with all subnet managers in a standard format.

• Control: A common command language that allows the manager to control all subnet elements from a single terminal control point. The common language must be capable of both query interaction and menu interaction.

• Presentation: The MOM must provide the manager with a single integrated set of information from each of the subnet controllers and should allow the manager to reformat the data elements in a single fashion to modify the presentation for specific application. This is typically driven by the need of each network to have custom driven management tools.

• Interconnect: The MOM must have integral to its operation the ability to interconnect with the customers other back-office system and support information to provide database support and report generation. All too often the approach is to provide a toll that satisfies the needs of the moment but neglects the customer's needs for ongoing support and growth.

• Problem Determination: The MOM concept should have the internal intelligence to anticipate, identify, isolate and circumvent network problems. This means that there must be some form of Artificial Intelligence that adapts to the network's performance and assists the network manager in performing his tasks.

This desired state for NMCS architectures is evolving and there appears to be no one approach that meets the needs.

6.3 Evolution Path

The path to get from where we are to the ideal state should include the ability to integrate and to interoperate with diverse elements. Thus, it will be critical that the providers of network management elements for sub-network elements recognize the need for the interfacing of their products in a global fashion and to assist their customers in developing and integrated NMCS system.

7 CONCLUSIONS

This paper provides an overview of the NMCS problem and a view of an architecture that is evolving in the future. The NMCS architecture for the future, especially in the world of computer communications networks, will require the ability to communicate and control all of the seven layers of the OSI model. It will require that the front end and back end systems be integrated and that the end user be the focal point of operations.

There is an evolution in the area of NMCS, and that evolution is to a totally integrated package of services. The goal is to provide the end user with a transparent connection to a support infrastructure that allows seamless service. However, with the proliferation of new network elements, the needs are directed at NMCS architectures that allow for the integration of dissimilar elements. This paper suggests such an architecture.

8 FIGURES

Figure 1
Typical Private Communications Network

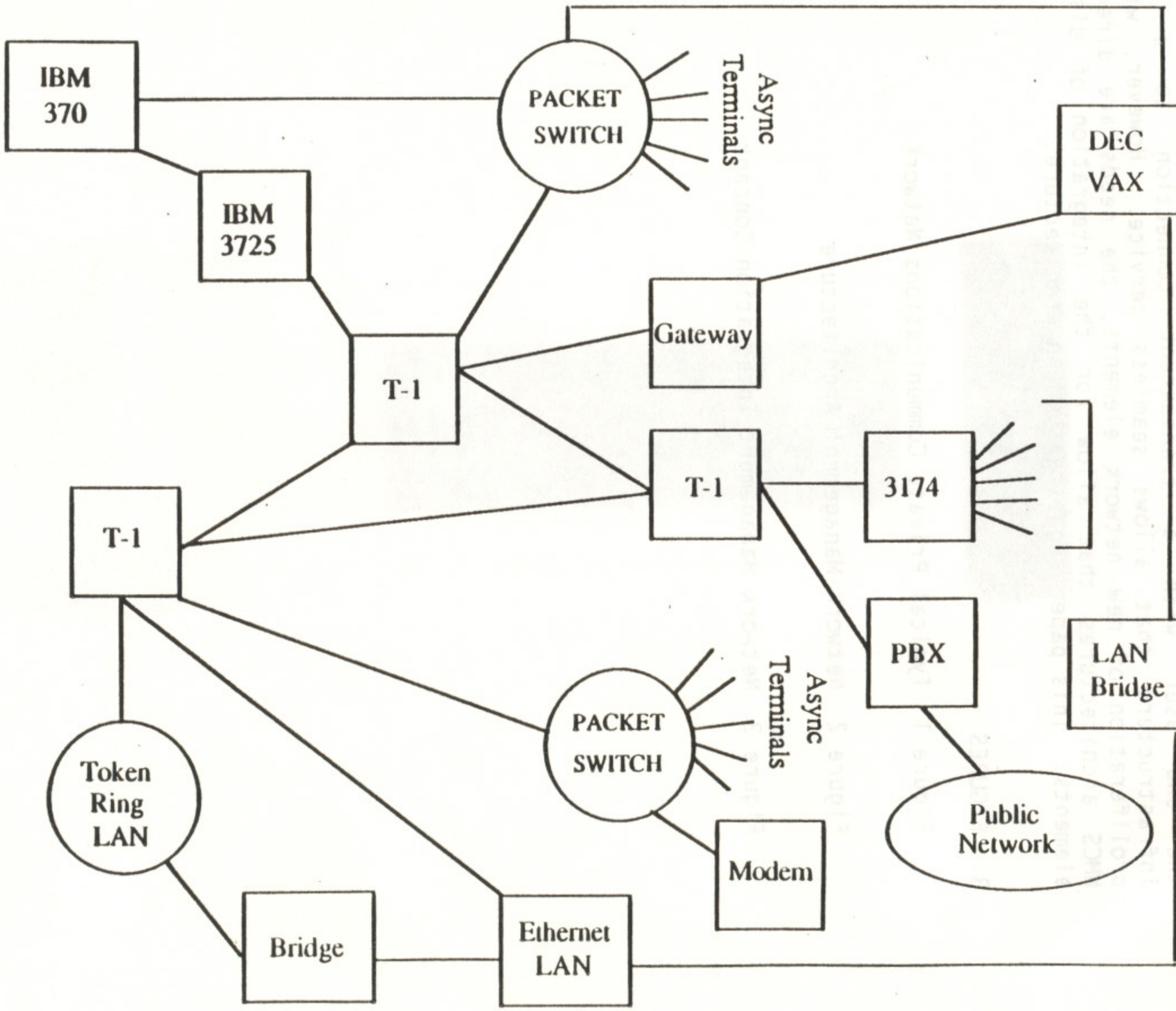

Figure 2

Network Management Software Architecture

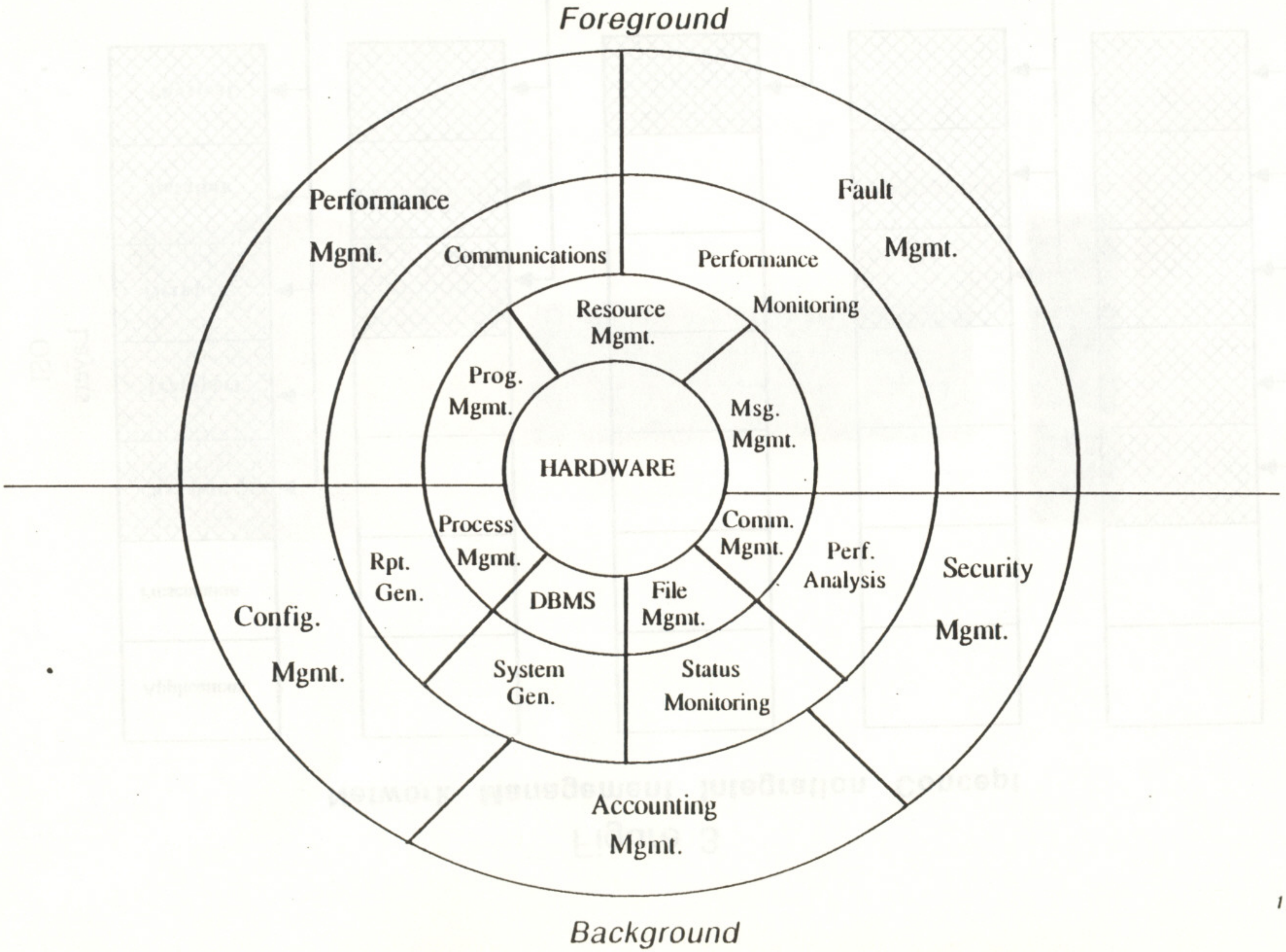

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Figure 3

Network Management Integration Concept