

**Developing a Network Fault Management System
using
System Development Life Cycle (SDLC) methodology**

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Systems Development Life Cycle (SDLC) is a systematic and orderly approach to solving business problems and developing and supporting resulting information systems. This paper exemplifies the importance of systems engineering principles by applying System Development Life Cycle (SDLC) to the Automated Network Fault Management project.

1. Introduction :

In today's enterprises, the communication resources are complex and heterogeneous, and are produced by a wide range of vendors. In general, these communication resources tend to fall into two main categories: those that provide interfacility networking such as circuit-switching or packet-switching telecommunications networks; and those that provide intrafacility networking, such as some form of Local Area Networks(LAN).

Network management is frequently viewed as only a technical problem. However, the ultimate responsibility for management resides with people, not machines. Often many people within an enterprise are involved with network management, including users of networks who may need access to current network status information, managers throughout the enterprise who may be concerned about the effect the network performance may have on the performance of those parts of the enterprise for which they are responsible, the actual network administrator in charge of the day-to-day operation of the network. Thus, the integrated management environment within which network management resides is a combination of human, social, organizational and technological resources. The main components of this integrated management environment include the users of the network, the network and the system resources, the enterprise management, and the network management. The characteristics of each of these components are as follows :

Users of the network are those interested in the utility and operation of the network.

Network and Systems Resources consist of end systems(e.g. workstations, controllers and the file servers), intermediate or relay systems (e.g. bridges routers and gateways) and physical network components - in other words, the collection of resources that require management.

The **Enterprise management** directly affects network management by setting policies for the enterprise that have an impact on network structure and activities. For example the management would decide whether to adopt a centralized or distributed management structure.

Network management consists of a combination of human, software and hardware elements. The human elements consist of the network

administrator who makes decisions on network management. The software and hardware elements are the automated network management tools that provide management capabilities for the network. [2]

The elements needed for network management of a layered communication architecture are Network Administrator, Network Manager Application, Network Management Agents and Managers, Layer Management Entities (LME's), Managed Objects and Management Information Base.

2. Problem Formulation :

2.1 Problem Description :

We exemplify the problem scenario by taking an example of a real world situation where network faults affect day to day operations. Consider an enterprise like "Sears" using a "Sprint" network for running its business applications. Now in this scenario Sears is the customer and Sprint is the service provider. There are numerous business applications for which Sears uses Sprint's network: transaction processing at check-out lanes (a customer scanning his credit card) or a business transaction (Inventory at each store, daily sales figures at each store). As we can see from the applications, Sears business depends to a large extent on flawless or more appropriately faultless service provided by Sprint.

Under these circumstances Sprint cannot afford to have network faults as they would be deadly for their client as well as for their own business. This brings us to the problem of network fault management. Since it is impossible to prevent faults from occurring the focus is on reducing the effect of these faults on network operations.

2.2 What are these Faults :

A fault can be physical or logical in nature. A physical fault may mean a broken line while a logical fault is more complex to understand. Examples of logical faults includes : failure of parity checking software operating at the physical layer, inappropriate value used for control parameters (e.g inappropriate setting of threshold value for link utilization), misrouting of packets due to poor convergence of routing algorithm(e.g. vector distance routing algorithm).

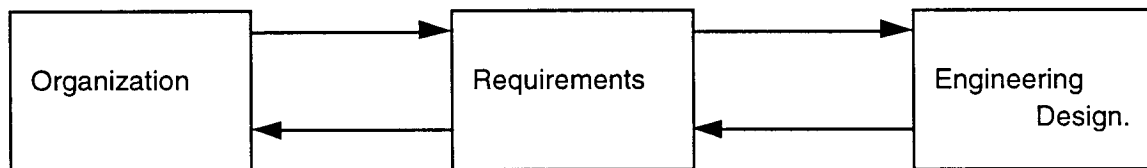
2.3 Assumptions :

We model a service provider with a WAN(Wide Area Network) and several geographically distributed sub-networks managed by a NMS (Network Management System). This NMS which involves considerable amount of human decision at the Network Control Center is used to manage network activities. Our model represents real world scenarios or problems faced during network management.

We envision the end product at the System Design Phase of SDLC as a prototype automated network fault management system which will meet the requirements set during system planning and analysis.

3. Project Overview :

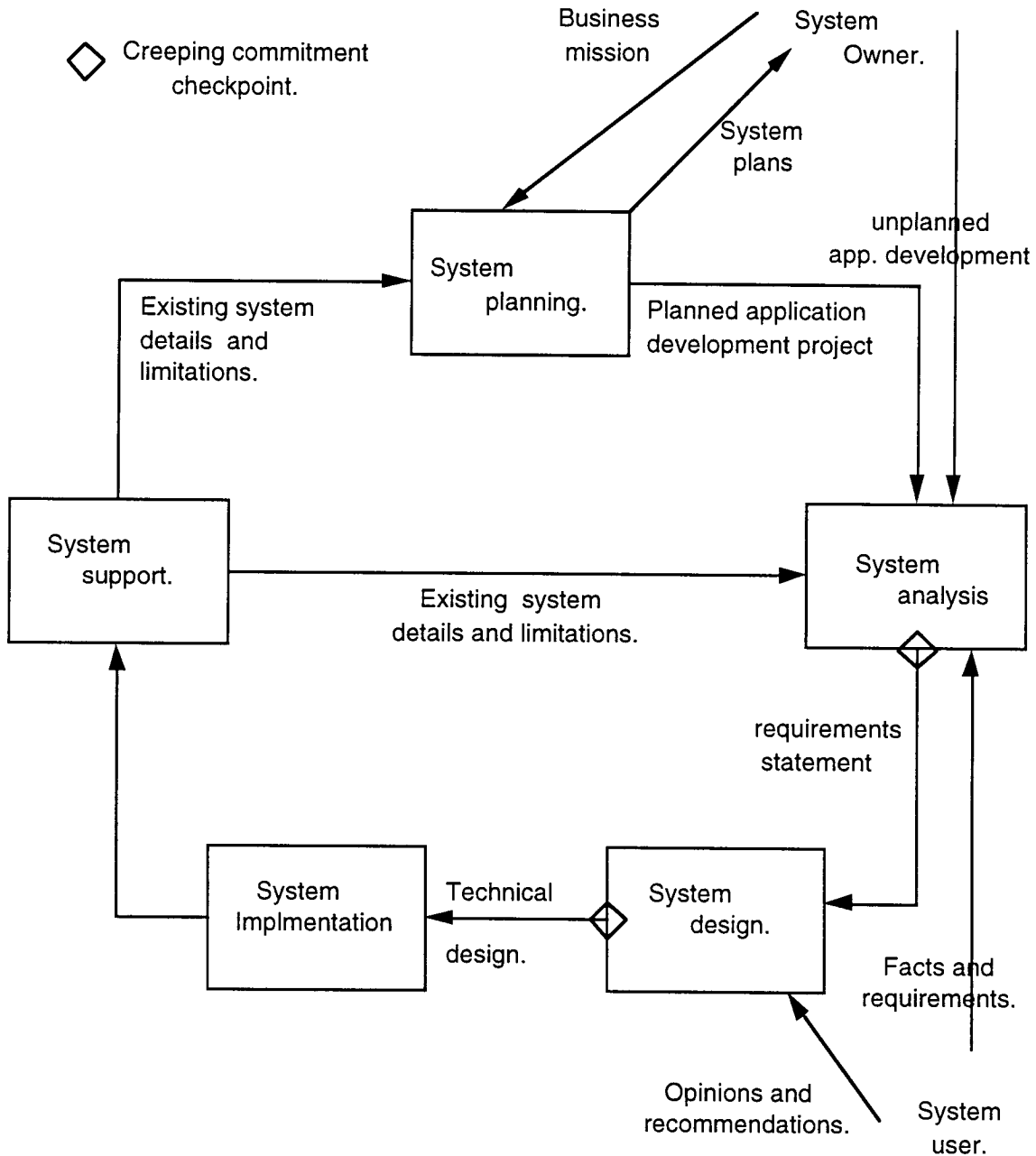
Current and future communication networks are rapidly becoming very complex and very heterogeneous. In addition they are required to support multiple services, multi-media and mixed-media, in a manner transparent to the user. Economic and social factors have created rapidly increasing vast market for network services. As a result of the multiple vendor products and environment there is an ever increasing need for integrated network management. Indeed integrated network management has become a strategic and critical market differentiator. The Automatic Network Fault Management system described here is a first step towards automated network management.



Top Level View of System Design Process.

To understand the project life cycle within an organization consider the figure shown above: organization represents the management of the firm, requirements represents the analyst who acts as an interface between management and the engineering resources, engineering design represents the technical resources (people) that implement the system. To follow up with our Automatic Network Fault Management project, we will look at it from the organization's or management's perspective, requirements or analyst's perspective and finally from an engineering design perspective. All

this is incorporated within System Development Life Cycle (SDLC) [3], which is a disciplined approach for developing systems. SDLC is a project management tool used to plan, execute and control system development projects. IBM and others refer to it as application development .



System Development Life Cycle.

Referring to the figure, [3] we limit ourselves with planning, analysis and design. We start with systems planning where we understand the organization's vision, objectives and goals. Then we move on to systems analysis, also called requirements analysis, where we focus on generating detailed requirements which explain what are the client/current system needs. The following list of questions must be addressed in parallel to the clients requirements or problems and the responses to those questions help in defining a baseline from which system design and development evolves.

- What is the system to accomplish in terms of operational and functional performance characteristics ?
- When is the system needed?
- What is the expected operational life of the system?
- How is the system to be used in terms of hours of operations per day, number of on-off cycles per month, e.t.c?
- How is the system to be distributed and deployed? Where are the various elements of the system to be located and how long?
- What effective requirements should the system exhibit? Effectiveness figures-of-merit may include factors for cost effectiveness, availability, dependability, reliability, maintainability and supportability.
- What are the environmental requirements for the system(temperature, humidity, shock and vibration, e.t.c)
- How is the system to be supported through its life cycle? This includes a definition of levels of maintenance, functions at each level and anticipated logistic requirements.

We will see that some of the requirements will evolve as direct answers to some of these questions. Once the requirements are obtained we perform system design which involves choosing from various design alternatives the best solution for the problem on hand.

In a nutshell, we deal with the systems engineering process which evolves functional details and design requirements with the goal of achieving the proper balance among operational, economic and logistic factors. It is directly concerned with transition from requirements identification to a fully defined system configuration ready for customer use.

4. Systems Planning :

The Systems Planning function of the life cycle seeks to identify and prioritize those technologies and applications that will return the most value to the organization. Not all organizations include systems planning in their SDLC. But systems planning is becoming increasingly common as organizations learn that systems should not evolve randomly- they should be planned.

Also systems planning is a continuous process that ensures optimal performance for the organization as it helps to identify potential problems and results in planned projects designed to overcome these problems. Systems planning is similar to systems analysis. The primary difference is in "scope"; systems planning deals with the larger portion of the organization, but in lesser details than systems analysis. The outcome of the systems planning phase is a planned application development project.

Systems planning consists of three phases :

1. Study the business mission(also called study phase)
 2. Definition Phase.
 3. Business Area Analysis.
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1. Study Phase : During this phase we try to understand mission, vision, goals and objectives of the organization (a Network Service Provider).
 2. Definition Phase: Here we define objectives from the organization's point of view, these are further refined during systems analysis.
 3. Business Area Analysis: This phase involves justification of the objectives from the organization's perspective. This process involves identifying business areas and grouping objectives by business areas and selecting those which benefit the organization the most.

The outcome at this phase is a set of high level requirements.

We will now illustrate these concepts through Automated Network Fault Management project.

Study Phase : The typical situation today in network management is the existence of network management centers (NMC) with many heterogeneous networks, each with their own management system and interfaces, which are principally integrated through human interactions of the operators of each management system. This is a very inefficient state of affairs; particularly since it leads to high costs, low quality performance and frequent errors. Therefore, there is substantial pressure towards the consolidation of the diverse information and towards network management integration on a single platform. This trend however brings to the forefront the staggering complexity of the resulting system and therefore the need to use automation in network management in order to improve performance and save cost.[1]

Definition Phase : The demands on network management systems and operations personnel capabilities will continue to grow. The amount and rate of information that needs to be serviced by current and future networks are also increasing exponentially. As a result fault management becomes a most important component of integrated network management. Without a systematic approach to network management automation and in particular fault management automation it would be impossible to prevent the

occurrence of critical network performance problems or faults. Fast prognostication and response are becoming impossible to achieve without automation. These considerations led to the identification of Automated Network Fault Management as an immediate objective.[1]

Business Area Analysis : Automatic Network Fault Management system is a key technological and market differentiator among companies marketing services or selling state-of-the-art networks. It will operate in either supervised or unsupervised modes. When operating in supervised mode, it will provide intelligent diagnostics and decision aids to the operator, helping him/her resolve quickly, diverse network fault management problems. Automation of NMC will push the field of network management to a new level of capability. Such automation and the associated tools have a pervasive impact. The resulting operator support capability has applicability well beyond NMCs; it is suitable for any transaction oriented environment. Commercial network operator automation products are now feasible, from a market perspective, due to the following technological factors that support and validate our technical approach. First, the field of network management is rapidly evolving to develop a set of standard interfaces and protocols. Second the standards orientation facilitates the commonality of network operations procedures. Third current technology capabilities support the product. Therefore, a product could be developed that has a wide range of applicability to a large segment of the standards based network operations centers supporting a variety of customers.

In addition to the self-evident benefits to network operation and business, the project will result in several additional benefits including : a new way of viewing network operations, facilitating the establishment of out-sourcing services and possibly creating new network applications and services to customers due to performance improvements and reconfiguration capabilities; resulting tools and methodologies would be applicable to command-control-communication types of problems and other resource management problems.[1]

This will lead us to objectives or Level 1 requirements but we will use this as an interface for transition from Systems Planning to Systems Analysis and will use it as a starting point for systems requirements/analysis.

There is a choice to be made between the **Waterfall** or **Spiral** model based on which to carry out systems analysis and design. Considering that it is a novel problem where continuous involvement of client/organization is necessary , the spiral model of operation is the best choice.

5. Systems Analysis :

The scope of systems analysis is a single business application. The purpose is to analyze the organization's problem situation and then to define the business requirements for a new improved system. The business/organizational requirements do not specify a computer-based (technical) solution; i.e. systems analysis can be thought of as a business problem solving independent of technology.

The input to systems analysis includes either a planned application development project (output of systems planning) or an unplanned application development project. Other inputs include existing system details and limitations and organizational limitations, facts and requirements. The key deliverable is a business requirements statements that explains "What" is needed not "How" we plan to design or implement it.

Systems Analysis consists of three phases :

1. Survey project feasibility or Survey phase.
2. Study and analyze the current system (or the study phase).
3. Define and prioritize user requirements (or the definition phase).

1. Survey Phase : System development can be very expensive. Thus, it pays to answer the important question, "Is this project worth looking at"? The survey phase of systems analysis answers this question. In different methodologies it is called the preliminary investigation , initial study or the feasibility study.

Building Blocks for the Survey Phase :

- To identify problems, opportunities, and/or directives that initiated this project request.
- To determine whether solving the problems, exploiting the opportunities, and/or satisfying the directives will benefit the organization.

2. Study Phase: Recalling the old saying, "Don't try to fix it unless you understand it." This phase of systems analysis deals with study and analysis of the current system. The study phase gives you more thorough understanding of the problems, opportunities, and/or directives. It is also called detailed study or problem statement phase.

The fundamental objectives of the study phase are :

- To understand the business environment of the system.
- To understand the causes and effects of the problems.
- To understand the benefits of exploiting opportunities.
- To understand the implication of non-compliance with directives.

3. Definition Phase : In different methodologies the definition phase is also called requirements analysis or logical design phase. Some methodologies split the requirements definition into two phases. For example STRADIS calls for a draft requirements phase and a total requirements phase, separated by a high level-design phase. However we have included high-level design in the next section on "System Design" to maintain the flow of processes.

Applying these principles to Automated Network Fault Management project, we start from Level 0 requirements and go to level 3 requirements and as we move along we will derive and group requirements according to functional groups; this will give us a good insight into system design which is described in the next section. The final output of this phase is a "Detailed Requirements Statement".

Level 0 : Requirements

Level 0 requirements can be summarized from the business or organization's problems, opportunities and directives. Here we start with a list of generic problems faced by network service provider. The set of problems or requirements described here are adapted from RREACT [7].

- 0.1 Impact of outage due to network failures very severe.
- 0.2 Rate of outages due to network management problems on the rise.
- 0.3 Government and commercial customer demands fast restoration time and reliability.
- 0.4 Commercial telecommunications networks have tight real-time requirements for restoring network failure.
- 0.5 Improvements shall be made in existing restoration methodologies using existing resources.

Level 1 : Requirements

In order to solve the business problems described by level 0 requirements and to state the objective of our system, we list a set of level 1 requirements [1] which are obtained at the end of the systems planning phase. These are high level requirements for business purposes and are obtained as direct solution to problems described at level 0.

- 1.1 The system shall drastically improve utilization and service quality of networks through faster response times to diagnose and reconfigure.
- 1.2 The system shall reduce the need for operations support personnel to tackle routine tasks.
- 1.3 The system shall respond to network growth and change in an efficient,

effective manner.

- 1.4 Develop products supporting these objectives which are applicable to a wide diversity of networks.
- 1.5 Develop a standard framework to view the work flow between operators and network management systems.
- 1.6 Apply state-of-the-art operator surveillance and computer learning to generate a means to systematically reduce the need for human assisted operations across a wide range of network management problems.
- 1.7 Develop a plan to create the next generation network management products with emphasis on automation.

Level 2 : Requirements

Level 2 requirements are obtained using the "STRADIS" methodology. We require an experimental set-up in order to realize the advantages of our system this consideration leads us to identify requirements 2.1 and 2.2. Requirement 2.3 evolves from the fact that we need to store information on network configuration, performance and faults. Requirement 1.7 at level 1 requires us to add automation to the process of network management. This leads us to requirements 2.4 and 2.5. Here we present these requirements from a very high-level systems design perspective which will be further refined in the next level.

- 2.1 Simulate a packet data network, which shall model the organization's business environment as closely as possible.
- 2.2 Create fault scenarios based on traffic statistics.
- 2.3 Develop Management Information Base as a repository.
- 2.4 Develop the architecture of a neural network to perform fault detection, isolation, diagnosis and learning by experience.
- 2.5 Develop a rule based system according to fault scenarios.
- 2.6 Develop an interface between simulation and MIB for data storage.
- 2.7 Develop an interface between MIB and expert system/neural network for data retrieval and storage.

Level 3 : Requirements

Level 3 requirements are detailed system requirements which can be obtained by expanding on level 2 requirements. We describe them by categorizing them by functional groups.

3.1 Simulation Model:

- 3.1.1 All nodes shall have a source of traffic. Each source should be capable of generating traffic at a defined rate.
- 3.1.2 Packet size shall be variable.

- 3.1.3 The system shall be capable of changing routing scheme at each node.
- 3.1.4 The system shall be capable of generating an increase in packet size/rate.
- 3.1.5 The system shall be capable to generate specific fault scenarios to train the decision making algorithm.
- 3.1.6 The decision-making element shall take into account cost while selecting the path for each packet.
- 3.1.7 The system shall be capable to handle issues like congestion control.

3.2 Database Model : [6]

- 3.2.1 Homogeneous interface : Shall present a uniform interface to the operator that is independent of individual sub-network characteristics.
- 3.2.2 Graphical Interface : Shall allow the operator to view the network at any level of detail, that is, to graphically navigate the MIB.
- 3.2.3 Scaleable Design : Shall add new sub-networks or increase the functionality of existing sub-networks without requiring complete restructuring of the database.
- 3.2.4 Fault-tolerance : Shall operate 24 hours on-line since the MIB is the core of the network management system.
- 3.2.5 Real-time Response : Shall store and process in real-time the "network health" data which is continuously gathered by external network monitoring tools.
- 3.2.6 Temporal Views : Shall provide a "snapshot" of the network as of some real world instant of time. This is necessary for postmortem fault analysis.
- 3.2.7 Active Mechanism : Shall support triggers that recognize and respond to special network situations without requiring operator initiation.
- 3.2.8 High-performance : Shall minimize the overhead of network management on the performance of the network. In addition, the network management performance should gracefully degrade under overload conditions.
- 3.2.9 Embedded Control : Shall efficiently execute on-line control algorithms (e.g expert system) to adapt the network routing, configuration, e.t.c. in response to changes in the network traffic or connectivity.

3.3 Expert System Model : [1]

- 3.3.1 Monitor Function shall process the client request and perform problem detection and identification.
- 3.3.2 Causal Analysis Function shall determine the probable network resource failure or outages, and identifies a list of recommended solutions.
- 3.3.3 Recommendation Resolution Function shall investigate further the viability of the recommended solutions by applying the business directives.
- 3.3.4 Action Control function shall initiate the selected action.

3.4 Neural Network Model: [1]

- 3.4.1 Knowledge Extraction Function shall extract fault management and operator task characteristics into intelligent software.
- 3.4.2 Shall be able to update knowledge or change knowledge from problem scenario.
- 3.4.3 Augmenting Knowledge or dynamic learning which copies operator learning process.
- 3.4.4 Shall generate facts from statistical information.

Now we have laid out detailed and exhaustive set of requirements absence of which leads to **creeping commitment** and endangers project feasibility.

6. Systems Design :

The scope of systems design remains the single business application from systems analysis. The purpose is to design a computer-based, technical solution that meets the business requirements as specified in systems analysis.

The key term is design. Whereas systems analysis is primarily focused on the logical, implementation-independent aspect of a system, system design deals with the physical or implementation-dependent aspects of a system(the systems technical specifications). The input to system design includes business requirement statement. Other inputs include design-related opinions and recommendations. The deliverable is a system design statement. Expanding our definition of design process to include the evaluation and selection of alternative solutions and the acquisition or purchase of computer software and hardware - as well as the more traditional physical design and integration of computer based components the system design can be classified into the following phases :

1. The Selection Phase.
2. The Acquisition Phase.
3. The Design and Integration Phase.

1. Selection Phase : Given the requirements statement we finally address how the new system - including computer-based alternative - might operate. One should never automatically go with the first hunch. During the selection

phase different alternatives are identified, analyzed and a feasible alternative is chosen.

Building blocks for the Selection Phase :

To identify and research alternatives to support our target system.

To evaluate the feasibility of alternative solutions and recommend the best overall alternative solution.

2. Acquisition Phase : The acquisition of software and hardware(computer equipment) is not necessary for all new systems. On the other hand, when new software or hardware is needed, the selection of appropriate products is often difficult. Decisions are complicated by technical, economic and political considerations. A poor decision can ruin an otherwise successful analysis and design.

Building blocks for the Acquisition Phase :

To identify and research specific products that could support our recommended solution for the target system.

To solicit, evaluate and rank vendor proposals.

To select and recommend the best vendor proposal.

To establish requirements for integrating the awarded vendor's products.

3. Design and Integration Phase : Now we come to a more traditional phase of system design, the design and integration phase. Given design and integration requirements for the target system, this phase involves developing technical design specifications.

Building blocks for the Design and Integration Phase :

To seek a design that fulfills the requirements and will be friendly to the users. Human engineering will play a pivotal role during the design.

To present clear and complete specifications to the computer programmers and technicians.

Clearly the design phase gets into considerable details; more than any previous phase of the SDLC. The design phase activities can be divided into General design and Detailed design.

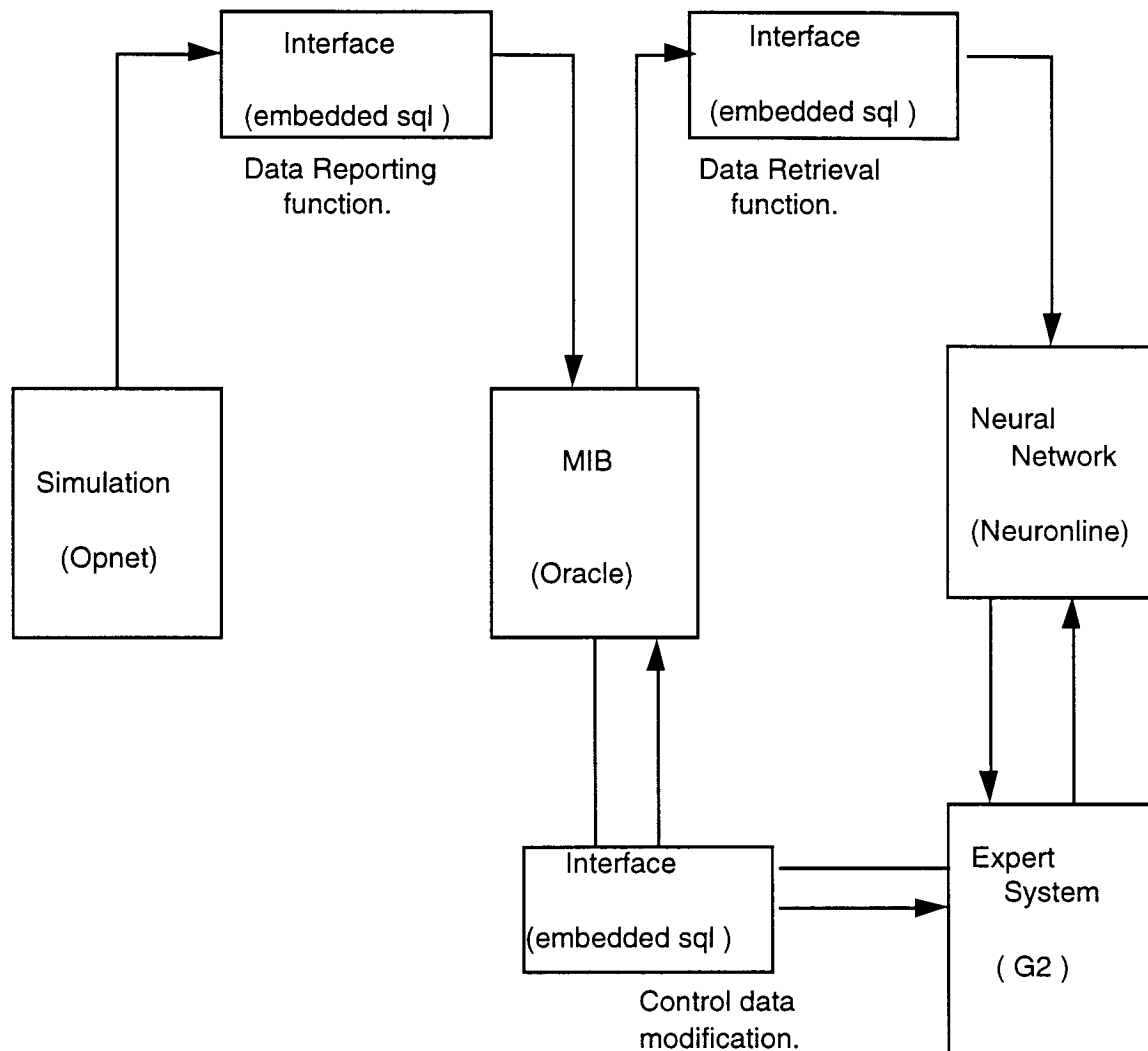
We will now illustrate these concepts through our Network Fault Management project.

Selection Phase : Looking at the requirements set as it evolves to level 3 requirements, we realized that it is necessary to use real world situations to learn about fault scenarios and their causes. Also considering the

organizational level limitation preventing any experiments with its communication network, it becomes necessary to use a simulation model (which closely emulates the real world network) as an experimental set-up for initial testing of our solution. Also the data storage requirements resulted into the need for a database management system(DBMS). Design of the database model includes a choice between object-oriented and relational model for data storage. Considering the real time requirement of the problem it is felt that the relational alternative is more suitable for performance data storage. Decision support requirements which emulates the decision making process of a human operator resulted in to the need of an expert system to be included in the design. Of the various design alternatives which include a semantic-network or a rule-based expert system, a rule-based expert system is selected to serve as a decision support function. Also, a neural network that incorporates dynamic learning is included in the design.

Acquisition Phase : In order to meet the requirements generated by systems analysis and considering the alternatives chosen in the selection phase, sufficient market research resulted in to identifying certain computer based tools to meet the requirements. "Opnet", a network simulation tool capable of simulating network operations is selected as a set up for initial testing. Opnet has more features than any other tool available in the market(e.g. C interface) and is capable of meeting all the requirements for the simulation model. In order to support real time requirement and be able to handle data reported in real time "Oracle", a relational database management system is selected to satisfy data storage requirements. There are several relational databases available in the market, these includes Oracle, Sybase and Ingres. Advantages of Oracle includes a kernel that runs in extended memory giving you more space for application development. It employs record level locking as oppose to some of its competitors that use page level locking. It provides support for development of graphical user interface by means of SQL*Forms and SQL*Reportwriter. G2/Neuronline a twin package for expert system/neural networks that has good cohesive properties, is loosely coupled and helps in fault classification and isolation is selected to provide artificial intelligence support to the system. Other advantage of G2/Neuronline is the fact that it provides an interface to Oracle.

Design and Integration Phase : We start this phase with a general design for our system which can be derived directly from level 3 requirements. Level 3 requirements derived during system analysis is an input to system design phase. Recall that we stated the level 3 requirements by grouping them into functional groups. Each of these functional groups forms a subsystem in our general design. The figure below shows the general design of our system.



General System Design

Once the necessary tools are obtained a detailed design of each sub-system is carried out. Enough consideration is given to the design of interfaces between these modules at all the times during the design phase.

Design features of the simulation model :

- Our simulation models a wide area network running X.25 protocol.
- It consists of three geographically distributed sub-networks which are not fully connected.
- Different subnetworks have links with different speeds.
- Some of the nodes in each of these sub-networks have users connected to it.
- A user connected to these nodes can run different applications having different priorities.

- Routing is based on an minimal cost routing algorithm where cost is a function of link utilization.
- The network is designed to employ SNMP monitoring. This is accomplished by having an agent at each network element reporting the status of this element to SNMP manager.

Design features of the Management Information Base model :

- Management information base is implemented using relational approach so that it is capable of handling data reported in real time.
- The design of MIB facilitates storage of configuration data, performance data and SNMP data logs.
- Our design facilitates simultaneous reporting of performance parameters and SNMP data logs into the MIB without having any lock conflicts.
- SNMP traps are reported through a separate module(interface) and are given highest priority.
- The design of MIB employs record level locking to avoid any conflicts between a query that reports data from network and a query from expert module that requires data for decision making.
- Versioning of the MIB is taken into account in its design.
- The design of the MIB facilitates the development of a graphical user interface on top of the MIB for operator interaction.

Design features of the Neural Network/Expert System model :

- For fault classification, our design includes a combination of radial function based neural networks and rho networks. The RBFN classifies the fault into one of the classifications and the rho network attaches a probability value to that classification.
- The neural network design facilitates classification into one of the three fault scenarios : disabled switch and links, degraded service capacity for switch and too much traffic.
- Here we employ a hierarchical approach to fault classification by employing a neural network at each level.
- The design for neural networks facilitates adaptive learning in real time.
- Once the fault is classified the next step is fault isolation which is achieved by employing a rule based expert system.
- A Knowledge base consisting of large number of rules is prepared by capturing knowledge of human operators at the network control center.
- At the heart of expert system operations is an inference engine that decides on which rule to fire and when. It is also developed by continuous interaction with expert operators at network control center.

So we can summarize saying that, by collecting detailed design specifications for each sub-system and substituting it into the big picture, the "General design" of the systems, gives us a prototype for Automated Network Fault Management system from which we will build the system during the system implementation phase. However, for this paper we limited ourselves with the design of this prototype Automated Network Fault Management system.

7. Conclusion :

We concluded this paper with a detailed design of the proposed network fault management system. Our fault management system developed using structured technique for system development will result into an efficient and economical system for service providers to meet a pressing demand of current communication networks. This will minimize human involvement in fault management operation which takes place in real time and ensures flawless operation at the network control center.

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