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A Modular Knowledge Base for Local Area Network Diagnosis

Jürgen M. Schröder
Wolfgang Schödl
Institute of Communications Switching and Data Technics (IND)
University of Stuttgart
Seidenstraße 36
7000 Stuttgart 1
Federal Republic of Germany
Telephone: +49-711-121-2488
Telefax: +49-711-121-2477
E-Mail: SCHROEDER@DS0IND5.Bitnet
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Local Area Networks (LANs) interconnect individual computing systems to form large distributed systems which are used more and more in Computer Integrated Manufacturing (CIM) and in office automation systems.

Since the proper functioning of the entire system depends highly on the error-free functioning of LAN components, utilities are required to support the user in network trouble shooting. For this a diagnosis system is developed. The kernel of the diagnosis system is an expert system.

LANs for CIM have rather complex structures which are maintained by experts sharing some common knowledge of the entire system. Typically, the knowledge is distributed among all experts involved. Therefore, the solution of problems often calls for cooperation between individual experts.

This approach has been mapped into the construction of the knowledge base of the expert system. The knowledge base has a modular structure.

1. Introduction

In office communication as well as in manufacturing automation the interconnection of computer systems with LANs becomes more and more state of the art. On the one hand, LANs speed up communication between the different divisions; (development, production, store, sale, etc.). On the other hand, the production depends on the reliability of the network. A network failure can stop production and will be costly. Since LANs are the backbone in manufacturing automation systems, the user needs support in trouble shooting.

Networks for CIM consist of many different components, as for example:

- Personal computers (PCs)
- Mainframes
- Workstations
- LAN segments
- Transceiver access points (TAPs)
- Repeaters
- Communication protocols

The different components are normally provided by many different manufactures. Typically, the topology of a network changes daily, as components are added or removed. Therefore, a lot of knowledge is necessary to maintain the network [2]. In most networks the knowledge is distributed between field experts [4], who work together when a failure occurs. This cooperation is coordinated by the system manager. The communication between field experts for problem solving is mapped into a modular knowledge base which is presented in this paper.

2. Diagnosis System

2.1 Architecture

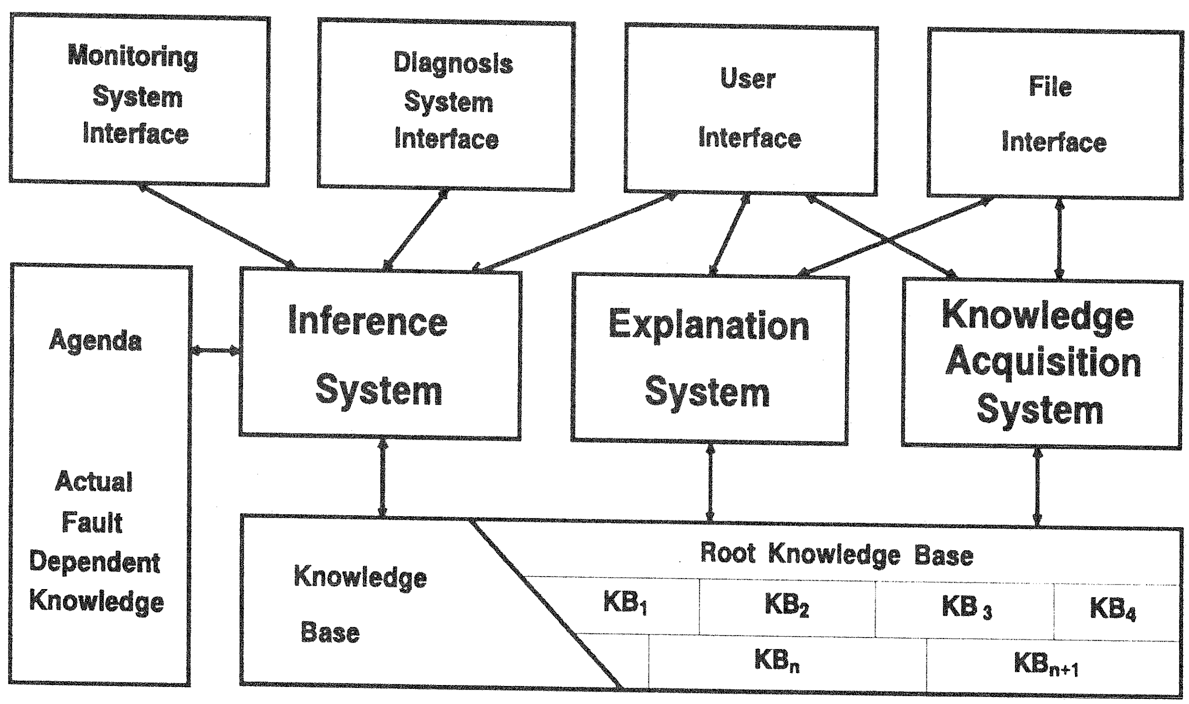

Figure 2.1: Architecture of the Diagnostic Expert System for LANs

The main components of the architecture are the inference system, the knowledge acquisition system and the explanation system. These three components have a connection to the modular knowledge base in which the static knowledge is stored. For user communication, for fault dependent knowledge acquisition with help of a monitoring system, for diagnostic system intercommunication and for file I/O, several interfaces are provided [3, 6].

The major differences between standard expert system architectures and the architecture presented in this paper are the modular knowledge base and the interface to the monitoring system for automatic acquisition of fault dependent knowledge. Figure 2.1 shows the architecture of the diagnostic expert system for LANs.

The inference system works with knowledge stored in the knowledge base and the fault dependent knowledge acquired during the session which is stored in the agenda. Depending on the actual diagnosis state, the inference system uses one of the following problem solving and search algorithms [6,7]:

Problem solving algorithms:

- Forward chaining
- Backward chaining

Search algorithms:

- Depth first
- Breadth first
- Refinement
- Tree completion

The knowledge acquisition component is used to acquire the expert knowledge and to store it in the knowledge base. Expert knowledge is mapped into objects and relations between objects. The knowledge typically is described in a description file using a specially defined syntax. The knowledge acquisition system reads the description file and produces the corresponding knowledge base.

The knowledge of the field experts is stored in knowledge base modules. These knowledge base modules can be built independently of each other with the same knowledge acquisition tool. The modules can be used for different networks where the same components are used. Also, the modules are knowledge bases for diagnostic expert systems for the component. Only the so-called root knowledge base, its links and mapping tables to the knowledge base modules are specific to any given network.

Due to the modular architecture of the knowledge base it is easy to build a diagnostic system for a network if modular knowledge bases for the components used are available. The root knowledge base must be built and the links and mapping tables to the modules established. Therefore it is easy to keep track of changes in network configuration.

For fault dependent knowledge acquisition the expert system has an interface to the monitoring system [6,7,8]. With this interface the system is able to monitor and test the network without any user action. This relieves the user from making complicated measurements and setting up LAN monitoring tools. For automatic testing of a component nearly every test program delivered with the component is usable.

At IND a distributed network monitoring system for Ethernet has been developed. This system allows online time-domain reflectometer measurement on Ethernet segments, throughput measurement on Ethernet transceiver cables, connectivity tests (echotests) and protocol stack performance measurements [7, 9]. For this last task distributed measurement systems are controlled via Ethernet by the monitoring system.

For the interaction between diagnostic systems a designated interface is planned. This will be useful for larger networks. Also an interface to the OSI standard network management and Siemens SINEC H1 configuration management is provided through the monitoring interface [5].

2.2 Knowledge Representation

Knowledge in the expert system is represented in the following objects:

- Components
- Final diagnoses
- Diagnoses
- Symptoms
- Symptom test methods
- Explanations
- Knowledge bases

The Components are all of the physical and logical units of the system. Each component can be defective in different manners - it can be totally destroyed or repairable. The diagnoses (the faults the diagnostic system is looking for) are therefore subdivided into final diagnoses and diagnoses. Confirming a final diagnosis means that the inference system stops at this point. No further fault analysis is undertaken.

Symptoms describe the appearance of faults. Each diagnosis has a set of symptoms, so that it is clearly recognisable.

Symptom test methods associate the possibilities to test the appearance of a symptom in the network to the symptoms. The default symptom test method is to ask the user for the appearance of a symptom. A useful knowledge base knows many symptom test methods for automatic LAN inquiry.

Explanations can be text or graphic files with explanations. They can be associated with the objects diagnosis, symptom and knowledge base. They explain, e.g., what the user should do if a diagnosis appears suspect, or how a symptom can be measured.

The object knowledge base is used to create links to other knowledge bases.

There are two ways in which a system can be represented in a knowledge base. The first is to represent the system hierarchically. In a hierarchical representation, a component may have only one predecessor. The number of successors is not restricted. For example, a PC has the sub-components hard-disk, motherboard, graphicboard, power supply etc.. The first component of the tree is called root component. The predecessor component is called the parent of the considered component, a successor is called a child. Figure 2.2 a shows an example structure of a component tree.

This kind of representation is good for the description of local, non-distributed systems. The diagnosis knowledge for e.g. PCs or workstations is described this way.

For network or distributed components description, a heterarchic knowledge description is used. This description model allows as many connections between the objects as necessary. Furthermore, any component may be refined when necessary. The use of refined and unrefined components in parallel is possible. Figure 2.2 b shows the refinement mechanism for a component. In Figure 2.2 b component 2 is most suspicious. For problem solving component 2 needs to be refined. The structure shown in Figure 2.2 c will be used to replace component 2. The problem solving algorithm will use the adjusted model for further searching.

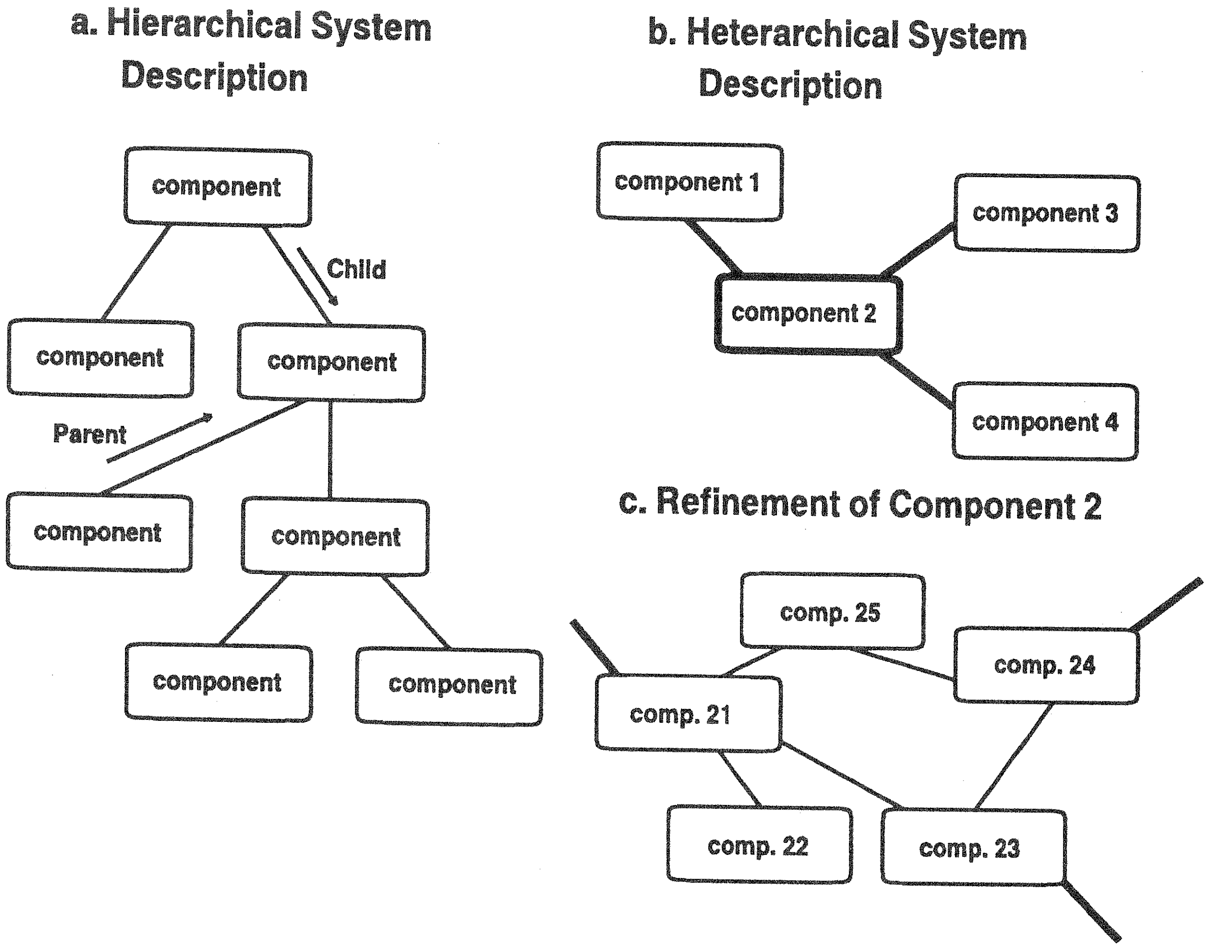

Figure 2.2: Knowledge Modelling Types:
a. Hierarchical system description
b. Heterarchical system description
c. Refinement mechanism

Figure 2.3 shows the modelling of the network depending on the malfunction that occurs, e.g.: A subcomponent within component K2 will communicate with a subcomponent of component K4. Testing components K1 and K3 shows that these components are working properly, so only component K2 and K4 have to be refined. The model used for problem solving consists of the components:

Refinement Layer 1	Refinement Layer 2	Refinement Layer 3
		K21, K22, K23
	K1	
	K3	
		K41, K42, K43, K44, K45

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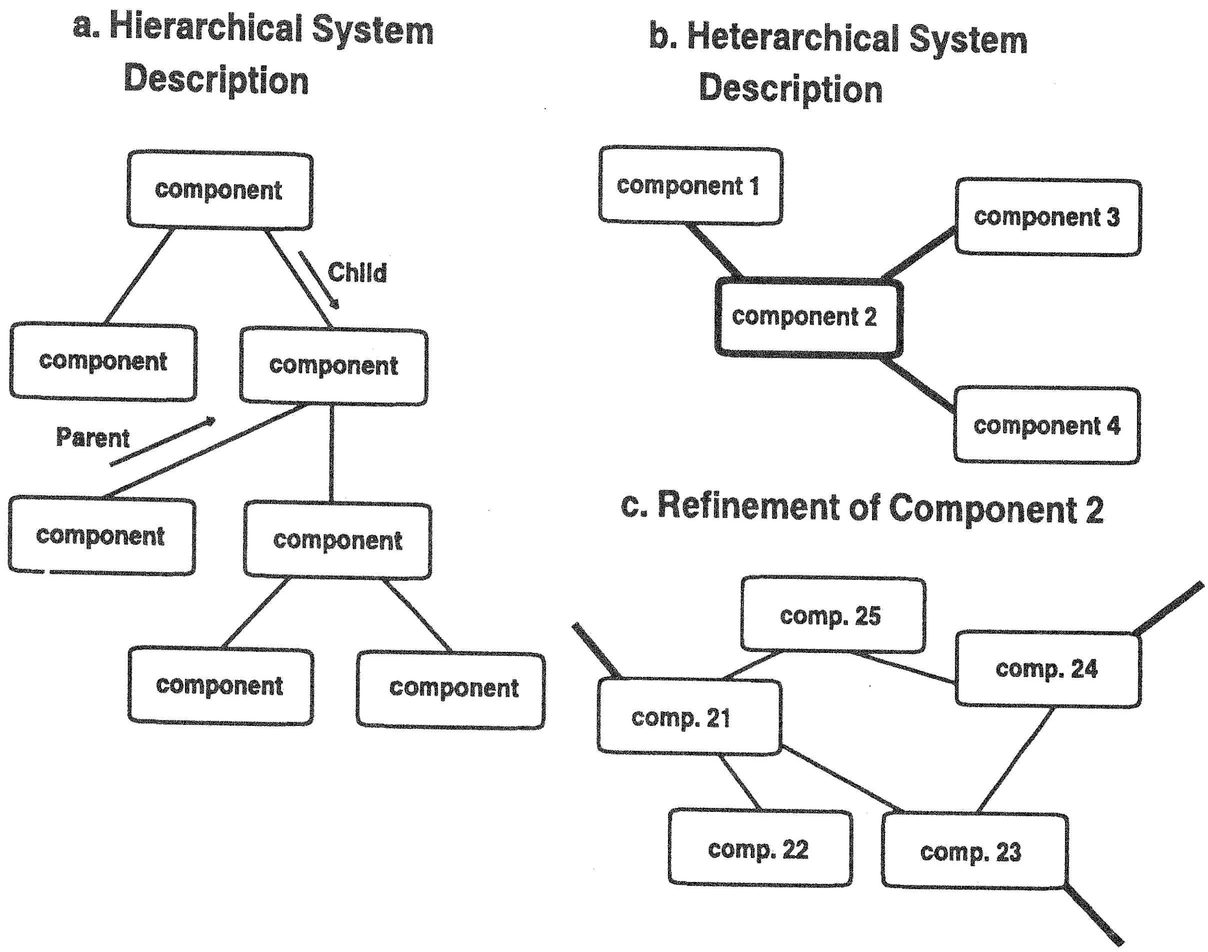

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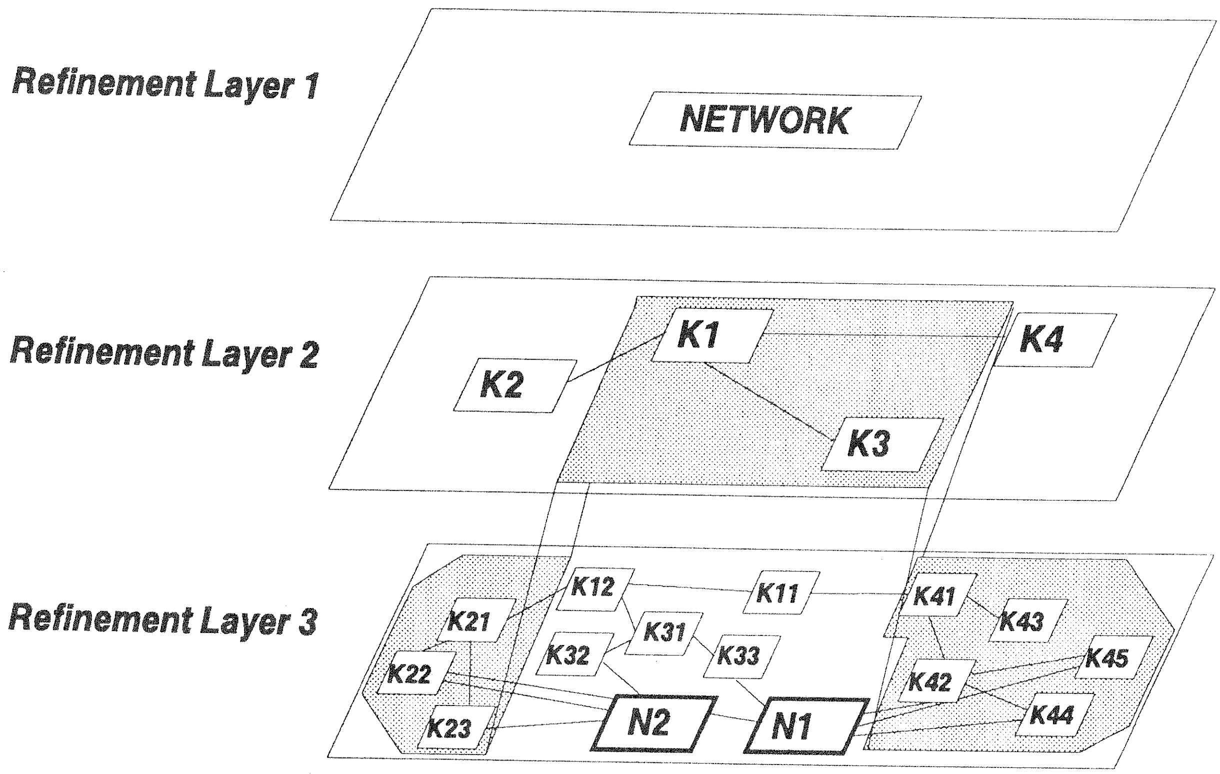

Figure 2.3: Hierarchical Refinement Layers for Dynamic Modelling

In the refinement layer 3, shown in Figure 2.3, new components (N1, N2) and connections appear. With them, new connections between components can be modelled, depending on the possible refinement degree, e.g. communication connections between stations.

Detailed knowledge is represented with the relations between objects. The following relations are usable:

Component	-	Diagnosis
Component	-	Final Diagnosis
Diagnosis	-	Symptom
Symptom	-	Symptom Test Method
Symptom	-	Explanation
Diagnosis	-	Explanation
Component	-	Knowledge Base

Figure 2.4 shows the relationships between objects for the hierarchical knowledge representation. The relationships in a heterarchical knowledge base are shown in figure 2.5.

3. Modular Knowledge Base

3.1 Description

The knowledge base consists of the root knowledge base and a number of subordinate knowledge bases. For each type of network subsystem a knowledge base, treated as a knowledge base module, should be available. A knowledge base can be of the type hierarchical or heterarchical.

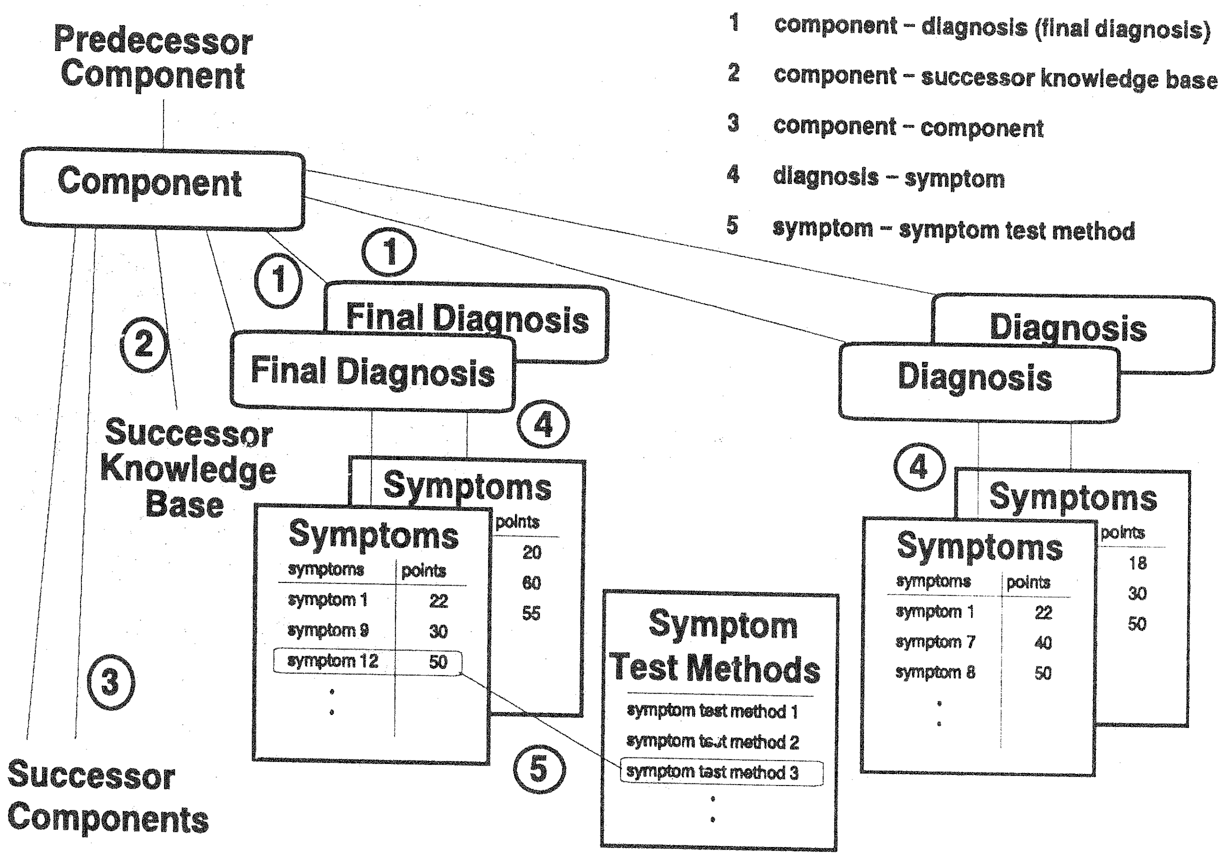

Figure 2.4: Relations between Knowledge Representation Objects in a Hierarchical Knowledge Base.

In the root knowledge base the network is described with all components. This knowledge base is typically a heterarchical knowledge base.

Experts communicate using a so-called agenda. For example, the system manager observes something going wrong in a part of the network. He writes his observations in the agenda and asks a field expert of the suspect network area for help. The field expert will examine the agenda and then start, with its own suppositions, its search for the fault.

Since every knowledge base module is developed independently, a mapping table is used. In this table, symptoms stored in the knowledge base module and symptoms stored in the root knowledge base are associated with each other. That means each symptom that is interesting to another knowledge base module becomes a global symptom. Symptoms exclusively used within the knowledge base module are called local symptoms. This mapping table is built by the knowledge engineer when he links the knowledge base modules to the root knowledge base or to other knowledge base modules. It is not obligatory to build a mapping table. If the mapping table is empty, there are no more suspect diagnoses when a new knowledge base is loaded, so the inference system will start at the root of the diagnosis hierarchy.

As described above, the communication between experts is mapped on the agenda. For that purpose, there is a global and a local agenda for the global and local symptoms, respectively. The inference system uses the current local agenda when it tries to find a problem solution. The global agenda is used when a new knowledge base is loaded. Figure 3.1 shows the loading procedure for a new knowledge base.

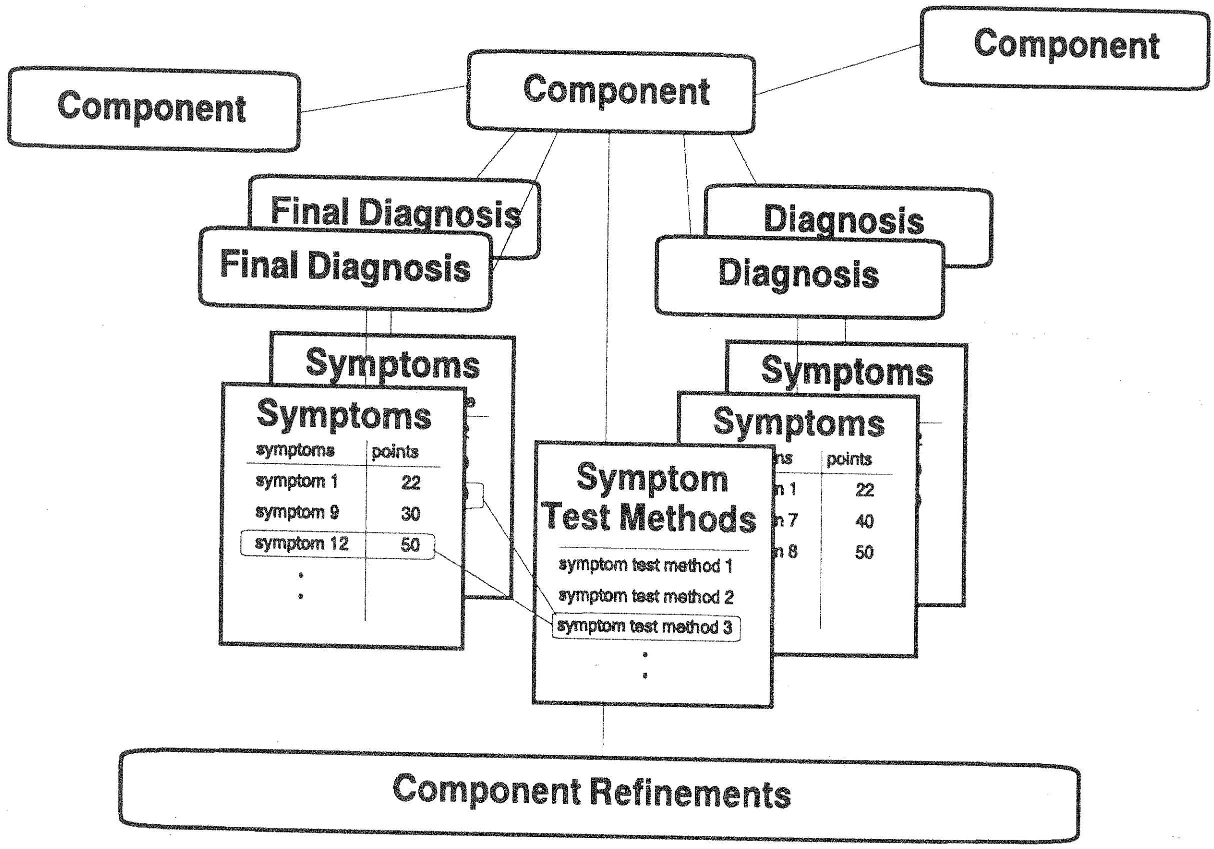

Figure 2.5: Relations between Knowledge Representation Objects in a Heterarchical Knowledge Base.

If a diagnosis has no successor but only a relation link to a new knowledge base module, the inference system first updates the global agenda. For this purpose it uses the mapping table of the current knowledge base. Then it loads the new knowledge base and creates a new local agenda with the information in the global agenda and the mapping table of the new loaded knowledge base. With the symptoms included in the new local agenda, the inference system generates a tentative diagnosis, whereupon it starts the execution of the problem solving algorithm.

3.2. LAN Model

As described above, knowledge can be represented either hierarchically or heterarchically in the knowledge bases. To describe the structure of a LAN, a heterarchically structured knowledge base is useful. The top component is the LAN itself. The following layer refines the LAN into its segments. Each segment can be refined into subsystems describing the segment. New refinements branch out between hardware and software components. For the software description, new relations between components are modelled when a certain level of refinement is reached. This adds the logical part to the LAN model.

When a network fault occurs, the hardware connection between the components will be checked. After that the logical connections can be tested. Logical connections describe the

LAN from another point of view. Protocol types interconnect the stations on which the corresponding communication software is installed.

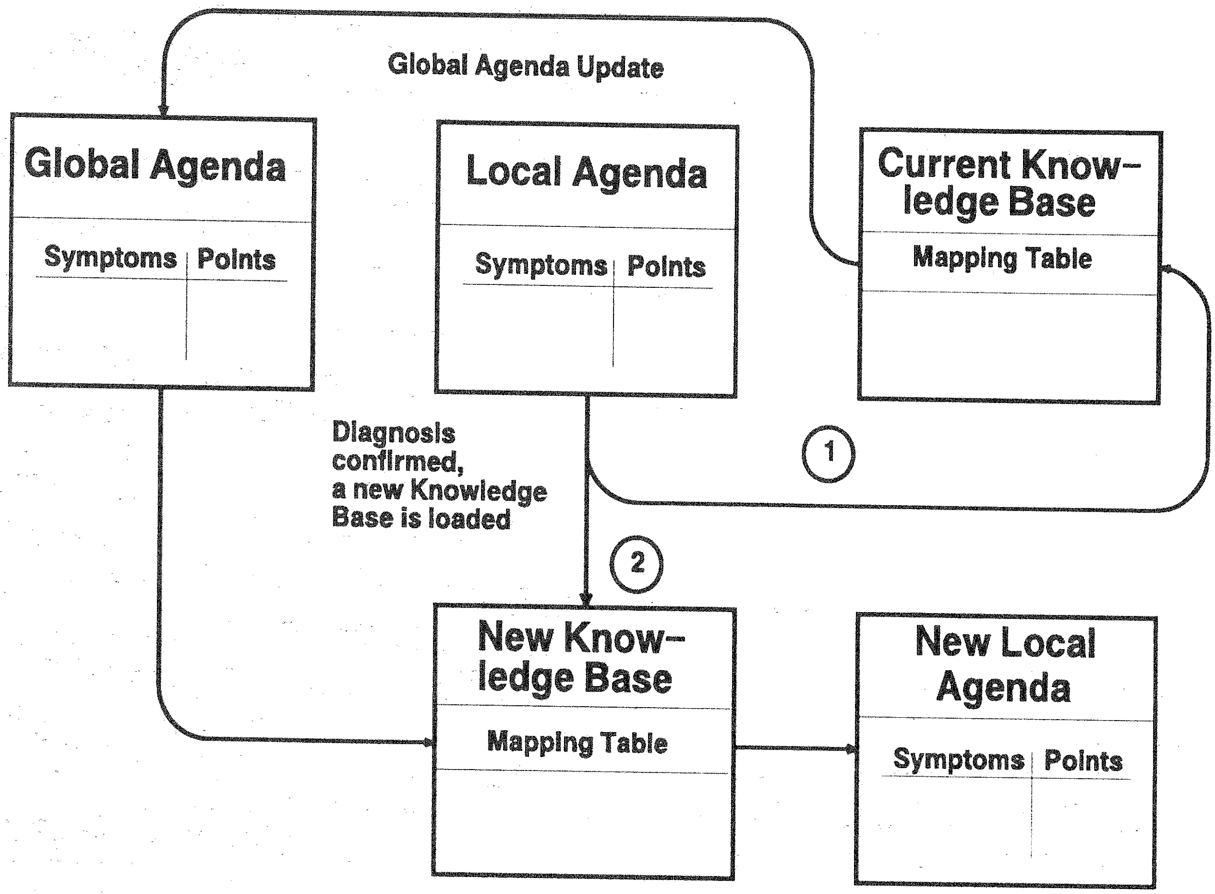

Figure 3.1: Hypothesis Generation for Newly Loaded Knowledge Bases

The root knowledge base refines the whole network only down to the station or protocol system level. For each station or protocol type another knowledge base module will be built and linked to the corresponding station in the root knowledge base.

3.3 Implementation Aspects

A prototype version of the presented diagnosis system on a Personal Computer running under MS-DOS (Registered trademark of MICROSOFT Corporation) and implemented in the programming language C is available since 1989. The database system R:BASE (Registered trademark of MICRORIM Corporation) is used for the knowledge bases in this system.

The MS-DOS operating system was detected as a bottle-neck. The single tasking quality and the support of only 640 kByte memory were the major reasons to look for another operating system. The decision was made to transfer (newly implement!) the diagnosis system to UNIX (Registered trademark of AT&T).

4. Experiences and Outlook

The experience with the system shows the simple adaptation to different LAN configurations. The modular structure of the knowledge base is demonstrated as significant for a diagnosis system for large, complex and distributed systems.

Knowledge bases for the LAN configuration at the IND, DECnet (Digital Equipment Corporation network), Multitronic PC and Siemens PC 16-20 have been created independently of each other. The use of the system shows that it is easy to expand.

A Siemens LAN protocol analyzer [1] and a LAN measurement system developed at the IND is connected to the diagnosis system for automatic testing and network monitoring. Also many manufacturer test programs for different components are used.

It was also recognized that it is not always useful to describe a network only in a hierarchical way, especially for the root knowledge base. This experience led to the construction of the heterarchically organized knowledge base described in this paper.

The new major components implementation under UNIX are almost finished. The inference system and knowledge acquisition system, are available. The work for the explanation system has been started.

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