

**UNIVERSITY OF NAMIBIA**  
**DEPARTMENT OF COMPUTER SCIENCE**

**THESIS**

**DESIGNING AND IMPLEMENTING A SCALABLE, SECURE NETWORK  
USING EXPERT SYSTEMS.**

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**DECEMBER, 2007**

*A Research Dissertation submitted in partial fulfilment of the  
requirements for the Master of Science (MSc) in Information  
Technology of the University of Namibia*

## **DECLARATION**

I declare that “**DESIGNING AND IMPLEMENTING A SCALABLE, SECURE NETWORK USING EXPERT SYSTEMS**” is my own work. I further declare that it has not been submitted for any degree or examination in any other university and that all the sources that I have used or quoted have been indicated and acknowledged by complete references.

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## **DEDICATION**

To my daughter Mukobe and my son Muhenda-Katongo, the two little people who always got in my way and reminded me that they did need their free time with me too. These two little people always understood that I had to “work at the office”. To Stella, who tried to exercise patience throughout this study.

To the memory of our father, Grenson Hector Lukwesa Mpandamabula, my brother Mabula Mpandamabula, and my sisters Mukobe, Mwamba, and Mulenga.

To our mother, Edna Mukobe Mulenga Shapi Lukwesa, and my siblings, Beauty-Lukwesa, Kapembwa, Chileshe, Mwenya, Songwe, Mwansa and Chishala. This is the ongoing fulfilment of a family legacy that education is the only surest rung that gets us out of poverty.

To all those who believe that technology and knowledge must transcend social and professional progress.

## **ACKNOWLEDGEMENTS**

I learnt from early on that “Knowledge is power”, that “Fear is a lack of knowledge” and that “Nothing illuminates brighter than knowledge”. I have followed these tenets passionately in my pursuit for higher revelation in all areas of life’s endeavours. My late father, Mr. G. H. Lukwesa, had all these coined up to encourage us on this tortuous trip that is still ongoing. There is no greater acknowledgement and tribute than this to a man who most times denied himself that his offspring could advance even higher than himself. Through his inspiration, I find it worthy to acknowledge the strength and encouragement of my mother, and my siblings, departed and present, who picked up the mantle to keep encouraging each other and to celebrate milestones whenever and wherever they occurred.

Although there are countless individuals to acknowledge, I would like to single out particularly my supervisor, Mr. Emmanuel Lundere Mkusa who has been, not only a guide through my endeavour along the academic path, but also a spiritual light and mentor in times of joy and hardship on and off my study trail. He gently shaped the power factor by emphasising that ownership for the project and its outcomes were mine. I thank him especially for the generosity of knowledge sharing and discussing techniques of approaching my studies and life’s challenges. He helped me push further on my journey of self-discovery. In making this discovery, I realise that he could not have appeared in my life at a better time!

Along the way, however, I have had other, great help. It would be worthless to embark on a trip without drawing wisdom, companionship, and a sense of collective sharing. I am grateful to a whole host of individuals and groups for the successes that

I have achieved, and the burdens that have been lightened as a result of their indulgence in my pursuits.

To the Science Faculty at the University of Namibia for giving me and my colleagues the enviable and illustrious privilege to be the first ever entrants and graduates for the Masters of Information Technology as a full-fledged taught programme. The trip has not been easy, but the administration of the university in general, and the faculty in particular were patient along the pitfalls that we went through. I particularly drew great insight into the magnanimity of academics from this experience.

In a simple statement, I say “Thank You Very Much”.

## ABSTRACT

The area of network design has been viewed as an important area of computer networking installation over time. A number of paradigms have been proposed, including top-down methodologies, the three-layer architecture among others. The often neglected aspect of network design, as in most other areas of technology is the availability of expertise to implement networks.

A number of assertions have been made about the availability of expertise. Some schools of thought state that the number of expertise available for network design has shrunk in proportion to the number of networks that have sprung up. Put mildly there appears to be a shrinking of expertise; however, it is evident from the many areas that are being moved onto the platform of network that actually, it is the *growth* of networks that has far outstripped the availability of expertise available to both design and maintain them. Other schools of thought favour a more urban explanation. They state that the number of networks that have been put up have not measured up to standards that any network professional can adequately manage; this, they assert, is because of a lack of design plans, road map for the network, and an adequate understanding of the goals that an enterprise has enlisted the network for.

It was the desire of this paper to examine the mitigation of statements such as these alluded to in the paragraph above. The middle road envisaged in addressing this was seen to be the Expert Systems' deployment in the area of networking covering the design phase of networking, among other areas. In addressing this, the choice of the expert system was also key; as was the choice of the expertise that provided the processes to be enlisted by the expert system.

An Expert system known as the C Language Integrated Production System (CLIPS) had been chosen for the purpose of demonstrating the development of an expert system that addresses network design. Among the reasons for its choice are that it is a freely available tool, and it offers forward-chaining which is appropriate for the rules developed from the networking environment used. It was robust enough to offer the flexibility that allowed other programming environments to be used for the development of either interfaces, or sub-components to it. The predominant development program that has produced CLIPS is the C Language, which is a universally used and flexible programming language.

## CHAPTER ONE

# INTRODUCTION

### 1.1 Reasons for Network Design

Network design paradigm is crucial in designing a secure network. A lot of networking tools and skills are necessary for the design of an efficient network. Often, however, these skills and tools are not readily available, and therefore result in design being overlooked when implementing networks.

One aspect of network design is the need to develop a solution that satisfies scalability in the long run and which will contribute to empowering the organisation. However, a number of deficiencies result from these networks arising from a lack of proper consideration in coming up with networks. Some of these deficiencies result from:

1. Poor or a lack of identification of shortcomings in current systems.
2. Using the opinions of owners of existing networks regardless of the state of their networks,
3. Acquiring state of the art equipment, which may not necessarily be relevant to the network implementation needed.
4. Using the advice of vendors of networking equipment. Some equipment may not necessarily be useful for the situation at hand.

## **1.2 The Need for Network Design**

Today's network demands are dynamic in that a lot of hitherto unknown data types are now not only being envisaged to be carried via networks, but the pressure to accommodate these and the demand for a quality service are ever increasing.

Previous, earlier designs focused on carrying of data. Now there is demand on the need to carry voice as well. There is now the demand for voice, multimedia, and video conferencing.

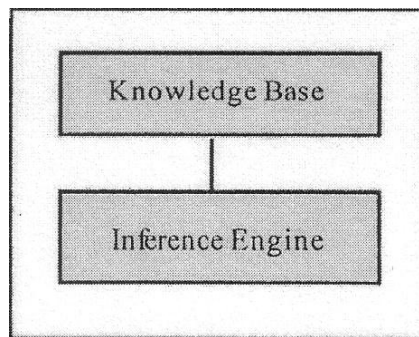
The aspect often overlooked in deciding on networks is the skilled expertise necessary to design and maintain a network. This is perhaps one of the most significant elements in the quest to keep a network current. It is clear from the scarcity of skilled hands and the cost of maintaining such skills that a repository is one way of ensuring a well-designed, maintainable system. One of the limitations inherent in network design is the very evolution of network systems resulting from ever increasing demands that change objectives for which networks are designed. An iterative approach to network design is one way of ensuring that some of these changes do not inflict too much harm on existing (or newly designed) networks.

The need to deliver a well-designed and maintainable network entails the use of the expertise from skilled network designers to plan, implement and scale the network later. This necessitates using these skills as a consistent function that can be relied upon regardless of the human resource possessing these skills. It is always every network owner's goal to have a network that has this factor as a basis. One of the

many solutions is to provide a handbook that can be used in the implementation of a workable, secure network.

### 1.3 What makes up an Expert System?

The makeup of an expert system can be basically defined as comprising the two main parts, namely the Knowledge Base, and an Inference Engine. To understand the concepts of how an expert system is comprised of, consider two main concepts, namely the Expert System Kernel Architecture, and the Expert System Architecture itself.



*Figure 1. Two main parts of the Expert System.*

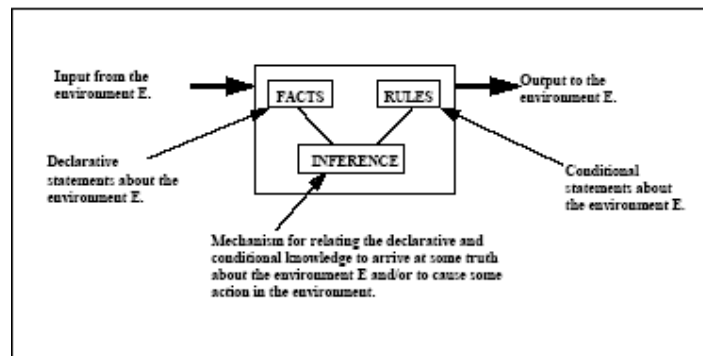
#### a) *Expert System Kernel Architecture*

The kernel of an expert system contains the basic components that are required for all expert systems. These can be identified as a fact base, rule base, and an inference mechanism. Usually the fact base and the rule base

make up the knowledge base for the kernel. At the highest level of abstraction we have the environment, E, and the expert system ES is connected to or embedded in it. This level can be represented as:

$$E \leftrightarrow ES.$$

The environment (E) establishes the domain of application for the expert system (ES).



*Figure 2. Expert System Kernel Architecture*

The environment of the expert system Kernel is regarded as the source from which the knowledge used in the expert system (ES) is derived. Additionally, the environment (E) also has the data which drives the behaviour of the expert system.

As earlier stated the system knowledge base consists of the fact base as well as the rule base. The approach commonly taken is to use the rule base that

has antecedent, or LHS, which we call “A”, and an consequent, or RHS, which we call “B”. The representation of the relationship is given as:

$$A \rightarrow B$$

Interpreted as “if condition A is satisfied then do B”. This is a basic, but generic representation of the rule-based expert system that will be treated in the implementation of the expert system for the project at hand.

The condition “A” may be a conjunction of conditions,  $A_1, A_2, \dots, A_k$  which must all be satisfied in order to trigger any actions stipulated by B. Any component in this conjunction may involve a negative subcomponent.

Similarly, “B” may be a sequence of actions  $B_1, B_2, \dots, B_k$  all of which are taken if the conditional part of the rule is satisfied. Launching a rule that has satisfied conditions is also known as firing the rule.

We could view the “A” or antecedent as the **fact base**, which must satisfy the rule(s) contained in the **rule base**, “B” in order to get a satisfactory firing as required. [2]

To further appreciate the antecedent/consequent relationship, it is worth discussing the two control strategies by which the inference engine manages rules to come up with a conclusion or in order to fire rules. These are respectively forward and backward chaining. Most expert systems support

only one control strategy. Some support both. What are these two strategies?

For the purpose of this discussion, some definitions are given:

i) *Forward Chaining*

Evaluation by forward chaining is also known as the data-driven approach. This strategy starts from a set of given facts (data). When the premises of rules are confirmed on the basis of these facts, the conclusion parts of the rules are executed, or as earlier defined, they are “fired”.

Fired rules can result in the creation of new facts which in turn cause new rules to fire. The forward-chaining strategy ends when there are no more rules to fire, or when the inference mechanism encounters some other end criterion.

ii) *Backward Chaining*

Evaluation by backward chaining is also known as the hypothesis-driven, or goal-driven strategy. In backward chaining, the start is a conclusion (or more appropriately a hypothesis, hence the terminology). This hypothesis is selected by the inference mechanism, generally based on the data requested from the user during an interactive session.

If the initial hypothesis cannot be verified, a search is made for rules which have this initial hypothesis as their conclusion. A premise will be satisfied if the facts that verify the premise already exist. In the event that this is not the case, each of the facts not yet verified is treated as temporary hypothesis. These are then examined and verified where applicable as if they were the initial hypothesis.

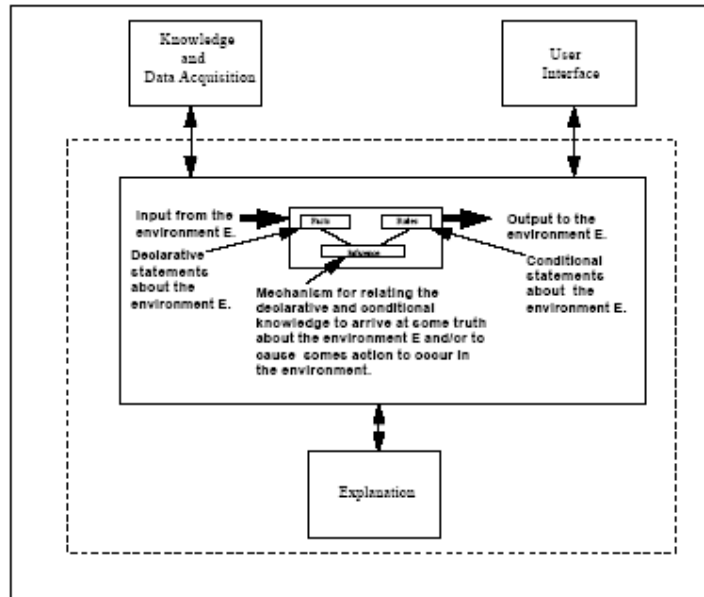
In illustrating these two basic principles, we could consider them in the form:

“If *Fact x* is true and if *Fact y* is true,  
then *Fact z* is also true and *Action a* must be taken” [1]

b) ***Expert System Architecture***

When we take the kernel of an expert system and embed it into an operational context there is bound to be an expansion of the function. This new context will have to cater for the interaction and interfacing with a user, there will be a need for knowledge and data acquisition and a process for the support of general explanations for rule firings and advice to the user. When these aspects are taken into account, the architecture for an expert system is realised.

The figure below illustrates the expert system architecture.



**Figure 3. Expert Systems Architecture**

Building on the definition of the kernel for the expert system, we see that augmenting this with processes for data and knowledge capture, user interfaces and interactions, and a process for generating and presenting explanations further defines the kernel and results in an architectural framework, that is simply referred to as the Expert Systems Architecture. The *knowledge and Data Acquisition* process is used by the expert system to acquire new facts and rules within its specific domain. Through this process capabilities can be added to or subtracted from the expert system. Closely linked to this is the concept of knowledge engineering. In knowledge engineering, knowledge from an expert or group of experts as well as or from

other sources are gathered, formatted, verified and validated, and input into the knowledge base of the expert system.

The *User Interface* process is a mechanism used by the expert system to present user information to a human user on its functioning, and specifically information on its determination of the state of the environment to which it is associated and its actions relevant to its understanding of the environment's state. Most current user interfaces are supported by multimedia technology and are designed to provide the user with the most complete and unambiguous presentation of information possible.

The *Explanation* process is used by the expert system to provide the user with a reasoned history of its actions or recommendations (or both). This is usually generated by providing a textual commentary identifying the sequence of rules it has fired with associated canned or automated commentary generation on why the rule was fired. This can be used by the user to verify that the reasoning mechanism being utilized by the expert system is correct. It also provides additional information to the user that can be used to establish a more complete context for understanding both the state of the environment in question and the rationale for any advice or opinion given by the expert system.

## 1.4 Expert Systems and Network Design

Expert systems as a means of enlisting skills for designing of networks can be used to implement a working system.

Expert systems are programs designed to simulate the way in which human experts solve problems. As human problem solving skills are complex and often times scarce, the expert systems capture this knowledge and analyze it for further problem solving.

Expert systems have been around for a long time, but are not as wide spread as would be required.

Expert systems are already being employed in almost every area of human endeavour where human decision-making plays a role. According to Dieter Niebendahl (1991), expert systems have and are being used in designing systems using different approaches. However, the use of expert systems in creating and using adequate repository for the design of networks has not been substantially explored. Expert Systems may be used by organisations that will tap into, and use, the skills for network design for scalability and efficiency. Further, the peculiarity of third world economies with their skills flight and pressures from globalisation initiatives poses even more interesting and relevant challenges to the design of scalable and secure networks.

In their discussion of Expert Systems, Pomykalski et al, [**Expert Systems Discussion**, Feb., 1999] point out that Expert Systems have been used in various disciplines, such as medicine (the pioneer expert system was MYCIN in the area of

medical diagnosis), law and more recently in the area of e-commerce and even loan applications in banking. In addition there have been attempts at developing expert systems that could address other areas of societal discipline such as robotics where human workers may be exposed to hazardous chemicals and situations, as well as in more intuitive areas such as design and forecasting.

Examples of expert systems' application abound. One example of an expert system is one presented at the Third Conference on CLIPS Proceedings (September 12-14, 1994). This expert system was used in assisting a user to configure a network for Air Force terminals using the Milstar Satellite system. The network configuration expert system approach used CLIPS. This rule-based system was aimed at solving the problem of having a user with limited knowledge take advantage of the many network configuration capabilities of the Milstar system and successfully launch a terminal that would use adaptation data to manage the transmit/receive capability from small airborne units with limited transmission power to stationary sites with large fixed antennas. This expert system brings out the various benefits, but also the limitations of expert systems. The obvious limitation of expert systems is that there is no one standard to apply them. Just as varied as human problem solving is, so is the variation of applications into expert systems. The two broad distinctions are in certainty and uncertainty management. Some solutions can clearly obey rules and inferences from rules. Other solutions require a more heuristic approach, hence may rely on cumulative knowledge and inferences such as those based on probabilistic theories. An additional limitation is that most areas of application may not be served by one approach of expert systems, even in the same field! There is a need to either use one approach, or an aggregation of approaches in arriving at a solution. The

choice, however, is largely dictated by the problem at hand and the clarity of the possible solution envisaged.

Although the high trends that attracted the extensive use of Expert Systems have somewhat subsided, we can still find scope to revisit this in order to use it again as a tool to assist with the design of Networks, in this instance, and also in other areas where expertise is lacking especially in the case of the developing world. Namibia is one of the countries that has a critical need and would hence benefit from the use of Expert systems in many professions.

## CHAPTER TWO

# LITERATURE REVIEW AND PROBLEM STATEMENT

### 2.1 Literature Review

From literature and background reading done, a number of points were highlighted. Tanenbaum [*Computer Networks, 1996, pp 4*] gives the motivations for building computer networks as essentially being economic and technological in nature. He draws attention to data storage and traffic. However, he also does make clear that today's traffic not only consists of data, but voice and video as well. The bulk of networks designed before the advent of voice and video addressed the data traffic primarily, and there are many of such networks existing today. Coupled with this is the fact that a lot of investment went into equipment and technology to address this type of networking. As a result of this therefore, it is clear that most networks are not built with the video/voice considerations nor do they take into account the need to reasonably adapt to these new requirements. The ever-changing technological demands mean that there is a need to keep abreast with these changes as well as to keep the knowledge current. This necessarily points to scalability.

The generic definition of scalability is three-fold, according to the **Encarta Encyclopaedia Dictionary (v. 2002)**. *1. able to climb up or over. 2. used to describe computer graphics fonts generated by an algorithm that permits the size to vary proportionately over a wide range. 3. used to describe a computer, component, or network that can be expanded to meet future needs.* Before networking became

widespread, the first and second definitions were in vogue. However, with the presence of networks, it is clear that the third definition has taken centre-stage more so because of the involved requirement to keep up with change, new technology, and various design approaches and paradigms. The need to get connected is a factor affecting the proliferation of networks. The **IP Network Design Guide** [IBM *Redbooks*, 1999] discusses the need to have a network that scales well given the various options and alternatives available for the implementation of an addressing scheme that will scale well for any network that is designed. There are various approaches out there all depending on the business objectives and the available resources. However, the major challenge that managers face is the ability to put together a working network that will cater for the inevitable evolution of users', organisational, policy and business needs. It is a known fact that as the needs of any network user changes; the network must also change, in design, in outlook, and in its applications. The underlying issues affecting the keeping up of network changes do lie with the technologies involved and how they are implemented in order to respond to these changes.

There is a need to look at issues affecting network design in order to bring out the critical factor of scalability. A consequence of scalability is the security aspect for a network. A network that does not scale well is usually prone to security threats and inadequacies. It is clear to see that a scalable network will in itself form a basis to security at the minimal level and will then offer a platform for higher levels to implement their security protocols with ease and compatibility. This aspect has been

lacking in a lot of networks as evidenced by literature on the subject of security and design. (**CCIE Fundamentals: Network Design Manual, 2005**)

Various design methodologies are available for the design of networks. The International Network Services (INS) gives three basic ones in a survey paper. In its white paper, the INS [*Basic Network Design Methodology, Nov, 2002*] points out three basic methodologies namely, the Scientific method, the Discovery Method, and the Requirements-driven method. The typical problem facing designers and managers alike is which approach to use for which situation. Experts in the field attest to critical decision-making at this stage that can affect the running of a network at implementation, as well as its scalability and security. There is a need to examine a blend of these methodologies in order to come up with the network design that will scale well. This could be used as a way of resolving the problems affecting the design of scalable and secure networks.

Cisco Systems, one of the leading networking corporations, looks at the campus design as a possible solution to a well designed network encompassing LAN and WAN technologies. These principles can be used in designing a scalable and secure network. In this approach to network design, there are three layers of focus in implementing campus networks, namely, the Core, the Distribution, and the Access layers, respectively. This approach has reasonably blended the different design approaches making decision-making less of a challenge on the future functioning of networks. Following these structured ways of network design will help to solve

scaling problems that are often faced in the design and implementation of networks today, especially in developing countries where such needs are severely felt.

The ever increasing number of attempted solutions to designing tools for network design and the revolution of the network and demands have shown the ever growing gap in the need for network expertise. In their white paper on **Designing, Implementing and Managing Converged Voice/Data Networks** (Avaya White Paper, 2002), Bruce Hill and David Raanan point out that the challenge that most organisations face is that their staff have neither the time nor the training to design complex networks (or reasonably capable networks at that). With their hands full from routine day-to-day running of other IT functions, this demand is impractical when placed before a typical IT team.

Further, according to a paper '*What's the "Big Deal" About Network Design*' [2005], the pool of net-wise professionals has not grown to keep up in numbers or in technical sophistication with the growth of networks in terms of new products, modules, and technologies respectively. The gap between the needed expertise and available expertise has continued to grow. This has impacted quite a lot on the quality and design structure of networks, especially in third world countries. The paper further contends that: "Many such [Monitoring] tools are based on simulation, rather than incorporation of design expertise". The paper further asserts that one of the effective solutions is the use of technology to manage technology. Automated network design means that whole groups of network-aware personnel can be enlisted to quickly design and modify networks, solving the crisis in expertise. One of the

needed solutions in this regard is to enlist the help of expert systems. The result of this would be that managers would be able to do what they have to do faster as the expertise available to them would aid most of the shortcomings in their knowledge resulting from the difficulty in keeping up with the ever changing technologies and the proliferation of different products and trends resulting from ever changing demands.

One of the definitions of an expert system, by Dieter Niebendahl [1991] is that these are special computer programs that simulate human problem solving. Attempts are made to capture the knowledge of an expert as he is solving problems and, by way of a computer make them available for analysis by programs. What this results in is a system that can be used to make timely decisions and ease pressure on the few design experts available to work on development of systems. In turn, these experts can then devote more time to research and devising new ways of problem solving.

Expert systems could be used to gather the expertise required while designing a network that can in turn be used in the design of similar and other networks that can be used in areas deficient of expertise in the field.

A number of approaches and technologies are available for expert systems' implementation. Some of these include expert system shells that can be used to acquire expert knowledge, such as CLIPS. Other approaches to implementing expert systems use Artificial Intelligence Languages (PROLOG, LISP, Smalltalk etc.). Shells are typically built from these languages and have the advantage that not too much effort is put into putting the framework together to come up with a fully

functional expert system. Shells have evolved into a new artificial intelligence approach to solving problems.

Equally varied are the methodologies that can be used in both solving a problem of this nature as well as building a system. Analytical problem solving methodologies such as those proposed by Moran and Shapiro (4<sup>th</sup> Ed. Wiley, 2000) are among the approaches that have been used in assessing engineering and scientific problem solving. The basic approach of this is to approach a problem by breaking it into simpler steps that can then be solved with the hypothesis of the problem closely in sight.

The software engineering methodologies to systems building such as iterative prototype development are approaches that have been found suitable in modelling problems that require systematic problem solving and development. Turban et al (2005) contend that the prototyping development approach is suitable because it allows for a project to be started small and over time be expanded enabling refinement as the system is deployed and utilised by users.

In the design of networks expert shells can be enlisted in the formulation of an advisory repository for network design for organisations.

## **2.2 Problem Statement**

Most organisations are embracing networks for various reasons. Some wish to use these networks for Internet presence as in the e-commerce area, others wish to enhance their productivity by utilizing the tools that networks offer. However, most of these organisations do not have the capacity to build sound, scalable networks.

This is because of the lack of skills that are ever in demand with the revolution of the networking field and technologies as well as the need for the financial justification to enlist skills to design networks well. It is also because the tools available for designing networks are expensive.

The design of a good network using modern methods is what most organisations want and, fortunately, need.

A lot of methodologies have been in existence for a number of years and have been used to design networks. However, a number of problems still exist in the way in which networks are designed and consequently implemented. The problems have been attributed to:

1. A shortage of skills in the design area for scalable networks.
2. Poor documentation of networks, both new and existing ones.
3. Poorly designed networks that result in compromised security in a network.
4. Few repositories that less skilled, but network-aware professionals can resort to timely in the design of scalable networks.

This leads to the need to address the following questions:

1. Can organisations use innovative approaches to ensure good design practices in view of the ever-changing design paradigms?
2. Can network design benefit from expert systems' application similar to other areas of application?
3. Can a model incorporating the various networking design approaches through the use of expert systems be developed?
4. How can the model be used with expert systems be used to design networks that are scalable and secure?

### **Statement of Hypotheses:**

1. An innovative approach can be used to ensure good design practices in view of the changing design paradigms.
2. Network design can benefit from the application of expert systems with appropriate adaptation.
3. A model incorporating the various networking design approaches is feasible through the application of expert systems.
4. The model can be used to provide a repository that is needed; it can act as a guideline for use in designing networks.

### **OBJECTIVE**

The Overall Objective of this thesis is:

1. To use expert systems to design scalable, secure networks.

Specific Objectives leading to the Overall Objective are:

1. To demonstrate that organisations can use innovative approaches in the design of networks in changing design paradigms.
2. To demonstrate that expert knowledge can be developed using an expert system using a shell-based expert system shell.
3. To develop a feasible network design model incorporating sound design approaches using an expert system shell, CLIPS.
4. To develop an expert system prototype that can be used to demonstrate the design of scalable and secure networks.

## CHAPTER THREE

# METHODS AND MATERIALS

### 3.1 Methodology

The basic methodology involved choosing a random sample of organisations. All of these organisations came from Namibia. The use of stratified random sampling techniques to study these organisations was deemed desirable.

The strata under consideration was divided in terms of Non-governmental Organizations, Governmental Organizations, and Commercial organizations, respectively. This had been arrived at considering the different levels of expertise available to each of these strata and their focus in terms of provision of service as well as extent of use of Information and Communication Technologies.

A population size of 42 organizations was considered. Out of this, the sample size was targeted at 30. In considering this research, 3 strata were be taken into account as: Governmental, Private, and Non-Governmental Organisations.

The determination of strata in random sampling is given by the formula:

$$n_1/N_1\sigma_1 = n_2/N_2\sigma_2 = \dots = n_k/N_k\sigma_k$$

where  $\sigma_1, \sigma_2, \dots, \sigma_k$  denote the standard deviations of the  $k$  strata,  $N_1, N_2, \dots, N_k$  denote the sizes of the  $k$  strata, and  $n_1, n_2, \dots, n_k$  denote the sample sizes of the  $k$  strata. The formula that will be used for determining the sample sizes for different strata will be:

$$n = \frac{n \cdot N_i \cdot \sigma_i}{N_1 \sigma_1 + N_2 \sigma_2 + \dots + N_k \sigma_k}$$

This part of the methodology was mainly target the fulfilment of hypotheses 1 and 2 respectively.

The general formula to give an acceptable sample size when dealing with an infinite sample size given by:

$$n = \frac{z^2 \sigma^2}{e^2}$$

Since the population under consideration was finite, the formula for the determination of the sample size was:

$$n = \frac{z^2 \cdot N \cdot \sigma_p^2}{(N - 1)e^2 + z^2 \sigma_p^2}$$

where

$N$  = size of population

$n$  = size of sample

$e$  = acceptable error (the precision)

$\sigma$  = standard deviation of population

$z$  = standard variate at a given confidence level.

Some of the variables under consideration included the level of expertise by designation, determined by, among other factors, level of awareness of expert systems, hands-on experience, and knowledge of tools available for network design. The existing organisational design requirements, baselines and management were determined by using four main elements.

In this case, a total of 42 respondents were collected as data. Of these, 13 came from the NGO community, 11 from Government, and 20 from the Private sector. The range of respondents was further subdivided into the designations within each strata. This was broadly divided as Manager (which included IT Supervisors, IT Manager, and Line Manager), and Operations Specialist (which included Programmer, Network Administrator, Systems Administrator, and Computer Technician).

5 Questionnaire responses were rejected because they were incomplete; the respondents had only answered an average of four questions in the whole questionnaire; therefore it was felt that the data was not useful for the analysis. There were 2 respondents from the Government group, and 3 respondents from the private group, which reduced the size in that area to 9 and 17 respondents respectively. The total useful population therefore was 37. The desired population sample was regarded as 30 across the board.

Some biased sampling was brought to bear by taking all the 9 Government respondents, who fairly represented the sub-strata in question. However, for the other two groups, simple random sampling was applied to two main sub-strata in

each group, namely Managers and Operations Specialists. A target of five in each sub-strata was targeted.

In addition to the division in the private group, a random 11<sup>th</sup> selection was made to complete the population target for the sample at 30. This explains why the resultant values were arrived at as: 10 NGO, 9 Government, and 11 Private.

### **3.2 Questionnaire/Survey Design**

The Questionnaire/Survey was created as an online questionnaire and respondents invited to log in and answer it. A web design tool called Ironspeed was employed to achieve this. A database with three tables was created to ensure data collection efficiently. The first table collected general questions that were common to both those respondents knowledgeable in Expert Systems and those not knowledgeable in Expert Systems. One of the two tables after this general table hosted questions (and hence answers) directed towards those who were knowledgeable about Expert Systems. The second table hosted questions (and hence answers) directed towards those who were not knowledgeable about Expert systems.

The first biggest gain from this approach of data collection was that the cost of collecting data was very low. In addition, respondents could easily get feedback within reasonable time as to their participation in the survey.

A backup version of the questionnaire was made for those who could not use the web-based questionnaire. However, only two respondents used the physical/email version of the response. The site was closed as soon as the desired levels of questionnaire responses were received, and a consolidated data table compiled that is reproduced as an Excel spreadsheet in this report.

The advantage of this approach to answering questions for the questionnaire/survey was that there was no need for a respondent to see further questions on a subject that he or she did not have knowledge about.

### **3.3 Expert System Framework**

A theoretical framework was developed for the analysis of expert systems models and protocols and their efficacy. This was based on existing techniques and available ideas derived from existing tools for analysing problems. Additionally suitable modelling concepts were used for the problem at hand. Secondly, the project assessed the problems with respect to their significance for practical deployment using suggested models.

Finally, the deployment of new practical experience based upon the analyses and implementations were made, arising from the research.

Design as an iterative process used the prototype approach form of systems building methodology in the successful development and deployment of the model. This was

based on the problem solving methodology that approaches the problem in systematic, step-wise fashion.

The justification for the use of prototyping was found useful in aligning with the general approach to expert systems design itself. The two approaches generally available are the traditional systems development life cycle, SDLC, and the Evolutionary prototyping, shown in the figures (*n and m*) below:



**Figure 4. The Systems Development Life Cycle (SDLC)**



**Figure 5. The Evolutionary Prototyping**

Prototyping presented a more efficient way to design the system. With this method, the user is made aware of the costs and benefits, and most importantly is made to feel part of the development team. Additionally, there will be a number of modifications made as the system is being tested and analysed until it is desirable.

The second reason is that the networking design approach with Expert Systems enables the networking experts and the beneficiaries or users of the system to benefit from such an approach. It further serves to allow additions to the system to be made effortlessly without the need to unravel the entire process.

CLIPS was chosen because it was flexible and powerful enough and offered a lot of possibilities to interface with a number of other programming and interface environments.

## **CHAPTER FOUR**

### **DATA ANALYSIS AND DISCUSSION**

The Questionnaire had two important aims, namely (1) to ascertain the awareness among the local IT professionals of Expert Systems in general, and (2) to ascertain the awareness among the local IT professionals of the possibilities that Expert Systems have particularly in the deployment of network design from any level.

This research restricted its demonstration on the recommendation of network infrastructure up to recommendation of the three layer design format used in modern networking design, especially with top-down methodologies.

Business Goals and orientation was assumed. Hence, Oppenheimer's recommendations could be used for further work in ascertaining the top-most requirements from the Business Goals right down to the smallest statistics.

A sample size of 30 was determined, divided into groups as follows: 10 from the Non-Governmental Organisations' (hereinafter NGO) environment, 9 from the Government environment, and 11 from the private sector environment.

#### **4.1 Discussion of Questionnaire Findings**

It is clear from the overall questionnaire findings that although a sizeable number of respondents are aware of Expert Systems as a technical definition, they lacked

a specific understanding of the deployment of the Expert Systems in various disciplines, least of all Network Design.

Some respondents, however, could identify tools for network design which are closely linked to expert systems.

In terms of awareness of Expert Systems, 4 respondents from the NGO showed awareness of Expert Systems, representing 40% of respondents in that area; 6 respondents from Government showed awareness of Expert Systems, representing 67% of respondents in that area, and 9 respondents from the private sector showed awareness of Expert Systems, representing 82% of respondents in that area.

One key reason for NGO knowledge rates is partly due to the fact that networking is not a key area in NGO practice generally, chiefly due to the fact that most of their activities are not using Information and Communication Technologies at a level where they would work with networks in their work.

Another reason for this representation was that a lot of NGO's have very specific assignments and usually networking is not a core implementation in their operations. Most could work with standalone gadgets and mobile cellular phones in their work assignments as opposed to a fixed networking infrastructure.

The private sector was the most aware about Expert systems and its deployment. Most of the respondents even had an idea that Expert Systems could be deployed in areas other than Networking, for example. A key reason cited for this generally was that they are exposed to expos and seminars where new technologies and methods are showcased, exposing them to the new possibilities.

Most respondents in this category, however, noted that their access to Network Design with Expert systems is limited by cost of the tools available in this area. Respondents in the Government Sector showed reasonably good knowledge about Expert Systems and noted that mostly, they could use these tools if their various units made them available. They did not cite cost as a limiting factor, but political will to get them the gadgets to use in order to eliminate or mitigate dependence on external expertise. They also bemoaned the high turnover of IT staff to the private sector and felt that using an expert system as a possible repository would therefore help them continue with high quality service while they sought replacement staff to take care of their IT infrastructure.

Overall, across the sectors, there was an agreement that it would be a good idea to use affordable expert systems to enable the design and running of scalable, secure networks.

On the knowledge of networks, 70% of respondents in the NGO, 80% private sector, and 100% of the Government knew what networks were; however, none of the respondents in the NGO sector, 5% in the Government sector, and about 20% in the private sector was aware of design paradigms available in network design, such as the three-layer top-down methodology.

This lack of knowledge of design paradigms is attributable to the fact that overall most network infrastructure is put in place by external consultants, and mostly as an adhoc measure whenever connectivity is required. Some respondents pointed to the fact that there was not much information about network design, except for those that had attended a Cisco Networking course, or were studying Microsoft

Courses as well as A+ and N+ courses. Beyond this, however, they were not very conversant with intrinsic requirements for network design.

## **4.2 Results from Questionnaire Findings**

### **INTRODUCTION**

This section presents a consolidation of the statements of the results drawn from the sample of 42 respondents. The study used a questionnaire-method approach to collect data and responses of the sampled population were recorded. The names of the sampled population of thirty institutions are listed in Appendix *n*. These institutions represented the population of interest (30 IT institutions) and are mostly concentrated in Windhoek. A copy of the questionnaire used is attached as Appendix *m*. Respondents were asked to use a scale to rate to what extent they believed each statement applied to their respective organizations. Responses were grouped into two Sections as follows;

- Section A presents the findings from responses to statements on **General awareness of Expert Systems**
- Section B presents the findings from responses to statements on **Networks and Design**

#### 4.2.1 Section A General Awareness Of Expert Systems

This section presents the background of Expert systems and how its awareness is perceived by users and IT professionals in the population of interest.

**Table 4.2.1.1 Do you know what Expert Systems are?**

Response	NGO		Government		Private	
	Frequency	%	Frequency	%	Frequency	%
Yes	4	40	6	67	9	82
No	6	60	3	33	2	18

#### *Discussion*

- 60% of respondents in the NGO group showed little or no awareness of Expert Systems. In the Government group, 33% showed little or no awareness, while in the Private group, only 18% showed little awareness. One cursory explanation for the markedly high rate in the NGO points to their orientation in terms of the type of service they provide. Most NGOs are engaged in non-profit and often poverty alleviation function that has little to do with intricate networking to the extent to understanding detailed alternative technologies.

**Table 4.2.1.2 Have you worked with any Expert System in your line of work?**

Response	NGO		Government		Private	
	Frequency	%	Frequency	%	Frequency	%
Yes	0	0	0	0	0	0
No	4	40	1	11	1	9
Not Sure	6	60	8	89	10	91

***Discussion***

- 40% from NGO and 11% from Government claimed not to have worked with expert systems at all. Only 9% from the private sector claimed not to have worked with expert systems. Remarkably, though, nobody claimed to have worked with expert systems; on the other hand, large percentage rates (60% NGO, 89% Government, and 91% private) admitted ignorance (or not sure), casting a possibility that they may not be certain what exactly constitutes an expert system in the first place.
- The results of this question support the first set of results. It could be that although there may be an awareness of the definition, it is not clear practically what these expert systems may be. It could also support a further notion that it may perhaps not be a widespread application in everyday functions of the respondents.

**Table 4.2.1.3 A typical expert system takes an expert's skills and automates them, freeing existing professional skill to move on to other value-adding jobs that may be less routine. In light of this, would Expert Systems Be Ways of enabling you do less routine work?**

Response	NGO		Government		Private	
	Frequency	%	Frequency	%	Frequency	%
Yes	6	60	8	89	9	82
No	3	30	1	11	2	18
Not Sure	1	10	0	0	0	0

***Discussion***

- An attempt to reposition the definition of an Expert System with a bias towards the labor implication seemed to have impacted a more positive response. This was quite unexpected as the earlier trend seemed to imply a definite direction towards a not-so positive attitude towards Expert Systems.
- The number of unsure respondents in the previous question, however, seemed to have moved approximately to the positive view of what Expert Systems would actually do for them, having understood what it was. It is not clear what the result would have been if the questionnaire was presented in a flat, physical form where respondents were able to see all the

questions in advance. This could be a result of a one-question-per-screen approach for the online respondents.

- An overwhelming number of respondents felt that it would be beneficial to have Expert Systems free up professionals to explore other areas of their jobs while routine work was left to the Expert System (60% NGO, 89% Government, and 82% private).

**Table 4.2.1.4 Would you view Expert systems as a way of replacing human labour?**

Response	NGO		Government		Private	
	Frequency	%	Frequency	%	Frequency	%
Yes	5	50	7	78	2	18
No	5	50	2	22	9	82
Not Sure	0	0	0	0	0	0

***Discussion***

- 78% of respondents from Government respondents seemed to view Expert Systems as a way of replacing human labour. It is not clear how this response relates to the previous view that Expert Systems would free up professionals. The contradiction in these two could stem from an afterthought often held in labour circles about the possible threat that automation is generally perceived to have to job security. NGOs and the

private group, on the other hand seemed consistent in their positive view of Expert Systems (50% NGO felt it was not a way of replacing labour, compared to 82% of the Private group).

- It would be worth exploring the position of Government groups to ascertain a clearer view on automation in general, and Expert Systems in particular in this regard.

**Table 4.2.1.5 Would you encourage the use of expert systems in your environment to cover more areas if possible?**

Response	NGO		Government		Private	
	Frequency	%	Frequency	%	Frequency	%
Yes	2	20	3	33	8	73
No	8	80	6	67	3	27
Not Sure	0	0	0	0	0	0

***Discussion***

- From the previous observation, the Government group seemed consistent in their not-so positive view of Expert Systems. 67% seemed uncomfortable with the spread of Expert Systems in more areas. 80% of those in the NGO group also felt less positive towards this view. On the other hand, 73% of the Private group felt it would be beneficial.

- A likely explanation for this result could be that NGO functionality is quite labour-intensive and the obvious thought of Expert Systems would seem to imply robotics rather than intuitive skill-based Expert Systems. For the Government group, a likely view seems to be that currently, anyway, a large part of Information Technology function is taken up by outside entities as opposed to internal professionals. The private group seemed to be more comfortable with handling complete processes in their operations.

#### 4.2.2 Section B Networks and Design

This section presents the background of networks and design and how its awareness is perceived by users and IT professionals in the population of interest.

**Table 4.2.2.1 Who designed your network?**

Response	NGO		Government		Private	
	Frequency	%	Frequency	%	Frequency	%
Consulting Company	4	40	2	22	1	9
IT Dept	1	10	0	0	6	55
IT Dept & Consulting Company	2	20	5	56	2	18
I found it as is	3	30	2	22	2	18

## ***Discussion***

- A large number of respondents from Government were of the view that their network infrastructure was a joint effort between local IT staff and external Consultants. This is consistent, perhaps, with the initial view that Expert Systems are not looked at in a positive view. Perhaps it shows that the respondents could wish to have more influence on this, and view Consultants in similar light to Expert Systems.
- Consistent with the previous view on the private group, there seems to be a complete control over operations, as seen from the majority of respondents who claim network design was done by their IT department exclusively.
- It is worth noting that a fairly large number of NGO respondents observed their network design done by outside consultants. Possible factors affecting this could be that a good number of NGOs are externally funded and may, perhaps, not have much control on the implementation of IT infrastructure. This could further be a result of their target activities not being IT-intensive most of the time. A specific mitigation in this case, however, could be Schoolnet which expressed total control over its networking infrastructure design.

**Table 4.2.2.2 From the functioning of your network do you think it is working efficiently?**

Response	NGO		Government		Private	
	Frequency	%	Frequency	%	Frequency	%
Yes	3	30	4	44	5	45
No	7	70	5	56	6	55

***Discussion***

- 70% of respondents from the NGO group disagreed that their network is working efficiently, 56% from Government also disagreed, while 55% from the private group disagreed. Details of the functionality were not indicated so as not to bias the respondent’s view of efficiency in this case.
- The main factors that cause network users to view a network inefficient include network traffic throughput (speed), service provision including email and networked applications, and help-desk availability. Generally, however, this does impact greatly on the overall service provided by a network.
- The aim of this question was to gather, in a general sense, the feeling of a network that may not have provided forethought to the idea of scaling a network in line with increasing applications and security

implementations on a network, both of which could seriously impact the efficient functioning of a network.

- It is clear in this instance that users would expect higher than, or equal performance on a network even as their needs change (usually) upwards.

**Table 4.2.2.3 What is the constraining factor for your network function and design (including equipment quality and network running)?**

Response	NGO		Government		Private	
	Frequency	%	Frequency	%	Frequency	%
Money	4	40	3	33	5	45.5
Expertise	5	50	5	56	5	45.5
Other	1	10	1	11	1	9.0

***Discussion***

- The majority of respondents across the board felt expertise was the constraining factor for their network. In the case of the Private group, the single respondent who expressed the *Other* view felt that it was “neither money nor expertise” but did not elaborate. The other respondents in the other groups who expressed *Other* did not elaborate, but claimed “Other issues”, and “Not clear” as their respective responses.

- This response seemed to have impacted on the suspicion of the researcher that an expert system could, after all, mitigate the need to preserve the often scarce professional skills in the design of networks. Notably, money did not feature as a significant constraining factor in network function and design in this case.

**Table 4.2.2.4 If you answered *No* to Question 7 (Table 4.2.2.2), would you attribute the functioning to a design fault?**

Response	NGO		Government		Private	
	Frequency	%	Frequency	%	Frequency	%
Yes	7	70	6	67	8	73
No	3	30	3	33	3	27
Not Sure	0	0	0	0	0	0

### ***Discussion***

- It was the feeling of the researcher that owing to the generality allowed to the response in the question being revisited (Question 7 in Questionnaire), it was worth revisiting the responses, especially negative, with a few specifics. In this case, the bias was brought to bear on the design part of the network.
- Not surprising, though, a majority of respondents seemed to have been in agreement that there could have been a design fault in their network. A

general view of respondents spoken to (not a representative enough sample though) was that they did not view hired help from outside (be it within the environs, or outside of the country) experienced or skilled enough to put up a scalable network or installation.

- A particular view in the negative that the researcher took note of was that “...it is not so much the design fault as the use of the network that matters.” – cf. UUNET respondent. This seems to have the supported view from Oppenheimer’s approach of viewing Business Goals as a precursor to implementing a network. Often, networks could be implemented at a level that the Business Goals may not find them useful in attaining enterprise objectives.

**Table 4.2.2.5 If you answered *No* to Question 7 (Table 4.2.2.2) would you attribute the functioning of the network to a lack of expertise to maintain the network?**

Response	NGO		Government		Private	
	Frequency	%	Frequency	%	Frequency	%
Yes	5	50	4	44	7	64
No	2	20	2	22	2	18
Not Sure	3	30	3	33	2	18

### ***Discussion***

- It was the feeling of the researcher that owing to the generality allowed to the response in the question being revisited (Question 7 in Questionnaire), it was worth revisiting the responses, especially negative, with a few specifics. In this case, the bias was brought to bear on the state of the expertise available for the maintenance of the network.
- A majority of respondents across the board seemed to be in agreement that a lack of expertise to maintain their network impacted on the state of the network itself. The researcher suspects that this notion of the lack of expertise lends credence to the need to explore the deployment of Expert Systems in a lot more facets of network design and functionality as can be possible within profitable limits. This point, however, falls outside of the scope of the design focus of this research. The main purpose of this question, however, was to verify that there was, indeed, a need to use Expert Systems in the Design of networks in the first place.

**Table 4.2.2.6 Is your network able to take new users?**

Response	NGO		Government		Private	
	Frequency	%	Frequency	%	Frequency	%
Yes	4	40	4	44	6	55
No	3	30	1	11	3	27
Not Sure	3	30	4	44	2	18

***Discussion***

- The majority of respondents who answered in the positive to this question were of the designation *Administrator, Analyst programmer, and Network Engineer*. Most of those who answered in the negative were *IT Officer, Office Administrator, and Computer Technician*. It is worth noting here that the further away from administration of the network a computer personnel was, the less likely (s)he would be to be in a position to envision scalability.
- The main aim of this question was to assess respondents' general view on scalability of networks at a functional, logical level.
- Of those that responded in the area of *Not Sure* were those whose installations were being run and maintained by external

consultants. In the case of some government departments, there is central control by the Office of the Prime Minister that takes care of their functional needs especially at inter-network level.

**Table 4.2.2.7 If you had to make a decision on how your network is designed and maintained, would you choose (see table for choices):**

Response	NGO		Government		Private	
	Frequency	%	Frequency	%	Frequency	%
An Expert System	1	10	2	22	4	36
Outside Help, not Expert system	3	30	1	11	1	9
Internal IT & Expert System	4	40	3	33	4	36
Other	2	20	3	33	2	18

### ***Discussion***

- There was an interesting favour towards using a mix of internal IT skills with Expert Systems. This is particularly interesting when viewed against the backdrop of an earlier response asserting that Expert Systems were viewed as a replacement of labour. This response met the expectation of the researcher in that it could be that with control over both their needs and their tools, IT experts would feel more comfortable embracing the introduction of Expert Systems than if it was thrust upon them without prior awareness campaigns.
- It appeared, at this stage, that respondents felt fairly comfortable with the notion of Expert Systems and what they were probably capable of as an aid to their IT activities.

**Table 4.2.2.8 In relation to the human expert, do you consider Expert Systems (see table for choices):**

Response	NGO		Government		Private	
	Frequency	%	Frequency	%	Frequency	%
A replacement of human jobs, therefore a threat	3	30	5	56	2	18
A necessary tool to aid existing workforce	7	70	4	44	9	82

***Discussion***

- A majority of the respondents viewed Expert Systems as an aid to existing workforce. The design of this question was deliberate; it aimed to try and reposition an earlier assertion that perhaps Expert Systems would replace jobs. The whole idea of aiding existing workforce seemed

to have brought out a possibility that should the application of Expert Systems be embraced, it would be a clearly preferred view to introduced them not as a total implementation of labour application, but as tools to aid a part of a process initially.

- 70% of NGO respondents, 44% of Government respondents, and 82% of private respondents felt it would be a necessary tool to aid existing workforce. It is worth noting that the Private sector respondents seemed most consistent in their responses throughout the Questionnaire process thus far.

**Table 4.2.2.9 In relation to skills base in the country, do you consider Expert Systems (see table for choices):**

Response	NGO		Government		Private	
	Frequency	%	Frequency	%	Frequency	%
A timely alternative to skills shortage	6	60	3	33	8	72
Unnecessary for this country's setting	4	40	6	67	3	27

### ***Discussion***

- This question was an attempt to address the responses obtained in Question 8 of the Questionnaire. Although the response obtained was not entirely expected, it is clear that given the choice, an Expert Systems approach could be looked at as a good alternative to skills shortage. A majority of Government respondents, however (67%) seemed to share the view that it was unnecessary for the country's setting to have Expert Systems. A respondent interviewed on this view felt that the population and the skills base currently was such that enough IT personnel could adequately cater for the requirements of networking in the country. The researcher did not pursue this view further as it was not intended to be a discussion on population density versus appropriate skills.
- Generally, Expert Systems were viewed in positive light as an alternative to skills shortage in the country, which was an expected support to the researcher's objectives of providing Expert Systems to Network Design.

**Table 4.2.2.10 In relation to cost, do you consider Expert Systems (see table for choices):**

Response	NGO		Government		Private	
	Frequency	%	Frequency	%	Frequency	%
Justifiable within financial investment	5	50	4	44	7	64
Unnecessary drain of resources	5	50	5	56	4	36

***Discussion***

- The responses to this appeared to be consistent especially in the case of respondents from the Government group. It is clear that while the NGO group were split in the middle in their response, the Private group appeared to be more receptive in their view of an investment in Expert Systems. The balance in Government, however, could be tied in with earlier responses that did not seem to view outside consultants in positive view (Question 12, and 13).

- It is clear to see in from this response that given the right conditions, Expert Systems could be welcomed much easier than perhaps imagined.

### **4.3 Concluding Remarks**

Overall it could be seen from responses obtained that given enough awareness and orientation, Expert Systems could be welcomed in a lot of networking activities in the Namibian context.

It is also clear to see that although there appeared to be some reservations expressed from the Government group, it was still possible to sensitise them on the important role that Expert systems could eventually play in ensuring that skills shortage, and most importantly secure and scalable networks were designed in as many areas as possible.

## CHAPTER FIVE

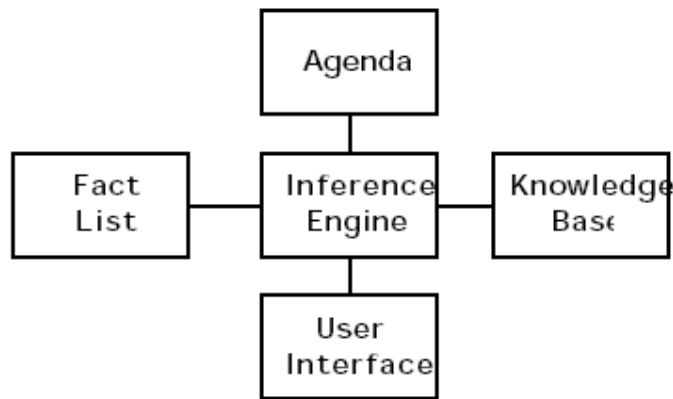
### FRAMEWORK DESIGN AND IMPLEMENTATION

The framework tool that was used in this research was the CLIPS, an acronym for C Language Integrated Production System. Rules and objects form an integrated system too since rules can pattern-match on facts and objects (*Clips Reference*). The choice of the CLIPS was mainly because it is readily available; it is free to obtain. The other reason was that it is an expert *tool*. This is because it has a complete environment for developing expert systems which includes an integrated editor and a debugging tool.

The application discipline used in this framework is network design. Care was taken to look at the specific area of the development phase for the recommendation of hardware equipment and system software implementations, including Access Control Lists. For the purpose of ensuring a framework demonstration, and within time constraints, Business Goals, Flow statistics, and other intricate parts were excluded but are also demonstrable given complete lifecycle duration in terms of time.

#### 5.1 The CLIPS Language

CLIPS is a type of computer language designed for writing applications called **expert systems**. The components of the CLIPS environment is shown by the figure below:



**Figure 6. CLIPS Basic Components**

1. The **User Interface** is the mechanism that allows the user and the expert system to communicate.
2. The **Fact-list** is a global memory for data. Using the example in the figure (*n*) below, the primary symptom of a patient is represented in CLIPS syntax.
3. **Knowledge-base**: This contains all the rules that the expert system uses. In the ongoing example, consider the rule for a patient:

**IF** user has a primary symptom of cerebellar ataxia  
**THEN** the primary symptom is cerebellar ataxia.

In CLIPS syntax, this rule and the associated dialogue is written as shown in Figure (*n*).

CLIPS uses a general syntax for storing facts, as shown in the example below:

```
(defrule rule_name "optional_comment"
```

```

(pattern_1      ; Left-Hand Side (LHS)
(pattern_2      ; of the rule consisting of elements
                ; before the "=>"
.
.
(pattern_N)
=>
(action_1)      ; Right-Hand Side (RHS)
(action_2)      ; of the rule consisting of elements
.               ; after the "=>"
.
(action_M))     ; the last ")" balances the opening
                ; "(" to the left of the "defrule". Be
                ; sure all your parentheses balance
                ; or you will get error messages.

```

**Figure 7. The Defrule Syntax.**

A rule often has multiple patterns and actions. The number of patterns and actions do not have to be equal, which is why different indices, N and M, are chosen for the rule patterns and actions in the figure above.

More specifically, an example of facts entered into CLIPS using the syntax is given:

```

English:
  The primary symptom of the patient is cerebellar ataxia.

CLIPS:
  (deffacts user-data
    (ms symptoms primary cerebellar ataxia)
  )

```

**Figure 8. CLIPS Syntax for storing facts.**

These facts are stored in a rule base as shown below:

```

(defrule ms-symptoms-primary
  ?phase <- (phase ms symptom)
=>
  (retract ?phase)
  (printout t crlf "What is the primary symptom of the MS
    patient? ")
  (bind ?answer (readline))
  (if (not (stringp ?answer))
    then (printout t crlf "Please check again!" crlf)
    (assert (phase ms symptom))
    (if (stringp ?answer)
      then (bind $?sym (str-explode ?answer))
      (assert (ms symptoms primary $?sym secondary))))

```

**Figure 9. CLIPS Syntax for rules**

4. **Inference engine:** This makes inferences by deciding which rules are satisfied by facts, and prioritises the satisfied rules, then executes the rule with the highest priority.

A rule is activated if its patterns are matched by

1. a brand new pattern that did not exist before, or
2. a pattern entity that did exist before but was retracted and reasserted, that is, a “clone” of the old pattern entity. This clone, then becomes a new pattern entity. The inference engine sorts the activations according to their salience. **Salience** orders the activations on an agenda in terms of increasing priority. CLIPS executes the RHS of the rule with the highest salience on the agenda, and removes the activation. This execution is called firing the rule, analogous to firing of a neuron. After a neuron fires, it undergoes **refraction** and cannot fire again for a certain period of time. Without refraction, neurons would just keep firing over and over again on exactly the same stimulus. An example of activations and firing of a rule is shown in the following figure:

```
CLIPS> (clear)
CLIPS> (defrule Multilayer
  (Switch-suits larger networks)
=>
  (assert (implement-in Core Layer)))
CLIPS> (wacth facts)
CLIPS> (watch activations)
CLIPS> (assert (Switch-suits larger networks)
➔ f-0      (Switch-suits larger networks)
➔ Activation 0 Multilayer: f-0 ; Activation salience 0 by
<Fact-0>      ; default, then rule name:pattern entity index
CLIPS> (assert (Switch-suits larger networks))
FALSE
CLIPS> (agenda)
0  Multilayer: f-0
For a total of 1 activation.
CLIPS> (run)
➔ f-1      (Switch-suits larger networks)
```

```

CLIPS> (agenda) ; Nothing on agenda after rule fires
CLIPS (facts) ; Even though fact matches rule,
f-0 (Switch-suits larger networks) ; refraction does not
allow
f-1 (implement in Core Layer) ; activation because rule
already
For a total of 2 facts. ; fired on this fact
CLIPS> (run)
CLIPS>

```

**Figure 10. Defrule and Firing of a Rule**

This rule can be made to fire again if it is retracted and then asserted as a new fact.

The framework will contain the rules from the Design Framework that will be loaded into the CLIPS shell. Being a rule-based expert system, the facts, and objects are the data that will stimulate execution via the inference engine.

5. **Agenda:** This is a prioritised list created by the inference engine of instances of rules whose patterns are satisfied by facts in the fact list. The figure (*n*) shows the contents of the agenda at some stage:

<b>Agenda</b>	
2 ms-symptoms-primary:	f-5
1 ms-symptoms-secondary:	f-6
0 ms-symptoms-secondary-more	f-7, f-8

**Figure 11. CLIPS Agenda**

## 5.2 Designing the Framework

The framework will be designed by initial assessment of the current expertise. In this case, the determination of network size and suitable implementation (assuming cost and labour standard and affordable within each level) will be assessed and rules drawn up in a suitable table. After this, the rules will be loaded into the CLIPS shell, along with the various patterns that will be triggered. In this instance, the Knowledge base, as it is known, will be populated by the expert.

### 5.2.1 The Network Design Framework

The Network design Framework was taken out of standard top-down design approach (Oppenheimer). It follows the design of networks by starting at the upper layers of the Open System Interconnect (OSI) model and proceeds down to the lower levels. In this instance, the Layers concentrated on are particularly Layer 3 to Layer 1 for the purpose of presenting the Expert System. As earlier stated, the upper layer documentation has been assumed due to time factor. The three-layer network design approach (A. Bruno, J. Kim) was adopted in devising the rule for the network design.

#### 5.2.1.1 Setup

In setting up the Network Design Framework, the following Stages were devised:

- i. **Stage 1:** Define Network Size

A rule for top-level equipment in each layer was devised to define size. Typically, 1-router, 3-switches, 1-Server (defined by the author

as the 131 rule) for small networks; a more general form is further defined as  $m$ -router,  $n$ -switches,  $p$ -Server (defined by the author as the  $mnp$  rule) for medium to large networks. The factors  $m$ ,  $n$ , and  $p$  are determined by the number of interconnecting buildings in the network. Minimum value for each factor is 1 for each variable is made, except for  $m$ , which may default to a minimum of 0. This is an appropriate assumption for networks that need no connection to the internet for any reason. It is worth noting, therefore, the formula

$$\sum n_i + \sum m_j + \sum p_k \leq q, \text{ where } q \text{ is a given constraint that may be}$$

controlled statically, or dynamically when using inference reasoning.

In this case, however, the boundaries have been set using crisp reasoning instead, so that  $q$  is assumed constant in a given domain of size, that we can call  $S$ . Hence, the formula statement:

$$q \mid \sum(n_i + m_j + p_k) \leq q, q \in S, \text{ where } S \text{ is the domain of network size.}$$

The equation derived gives the constraint that will be used to determine the size of a given network within the bounds of the rules and facts provided. An optimal value for  $q$  will be considered between 3 and 10, or more effectively, 0.3 to 1, taking the summation as a factor divided by 10 for future scaling manipulations. Technical reasons would follow the 80/20 rule and also allow for constraining the network once security is added to the functioning of the resulting recommendations.

ii. **Stage 2:** Assign Equipment Type(s)

A rule for equipment type based on two main factors: 1) Traffic load on the network, and 2) Number of users connecting to the network.

This rule was used to functionally demonstrate the efficacy of recommending a workable network. Any further set of factors could be added as appropriate.

iii. **Stage 3:** Recommending Network Layer Security

A rule for network security Access Control Lists and Anti-virus implementations (including Management protocols) based on the *mnp* rule in addition to two factors, namely: 1) Type of Business environment (*Public* to cover cafés and libraries, and *Private* to cover enterprise networks and intranets), and 2) *Level of Access* to cover either Entertainment or Production environments.

These three stages covered the Logical, Physical and Testing and Optimizing stages of Network Design, which is the focus of constructing the expert system.

The next step in the setup was to work out the explicit set of rules that would be loaded into the Expert System, here defined in table form (below) as the LHS and RHS entries.

LHS	Response		RHS			q (salience)	Knowledge Base ( <i>Explanation</i> ) <i>Tutoring/Justification</i>
	Y	N	<i>n</i>	<i>m</i>	<i>p</i>		
<b>Buildings:</b> 1	X		1	1	0		You will not need any fibre backbone; Optical cable will be optional depending on cost. Use Category 5 cabling.
<b>Size:</b> 10 – 50	X						Scalability for this is about $n*1.5$ ; your stacked 24-port switches (three) can be used
<b>Applications:</b> Email: X OAS: X Non-Tech: X			0	1	1		A server will be sufficient for these combination of applications; a non-technical environment may not require multiple server farm implementation.
<b>Frequency of Internet Access:</b> Every 30mins: X Every 1 hr: Every 8 hr: Constant:			0	1	0		A proxy solution with a dialup will work out a lot less than a constant connection in this instance; <i>proxy</i> software solution must be implemented.
<b>Data Critical:</b> Mission: Moderate: X Public:			0	0	0		A weekly backup must be implemented as a minimum measure. For this strategy, however, a twice weekly backup must be implemented.
<b>Security:</b> Public Access: Internal Access: Mixed Access: X			0	0	0		Implement ACLs on router for controlled access Implement corporate solution antivirus for internal network.
<b>Privacy:</b> A Must: Can Share: Mixed: X			0	0	0		An access level of 10 – 50 computers, but a mitigated population of 30 PCs will enable critical access and public domain sharing feasible. One is <i>privacy-effective</i> the other is <i>cost-effective</i> .
<b>Total Rating</b>			1	3	1		A network of this size will suffice with the following listing: 1 router for external access 3 switches for stacking solutions 1 server to work in a

							client/server environment 30 – 50 workstations for client access Category 5 cabling (measurement will ascertain amount) 30 – 50 Cable connectors and keystones Trunk to house cabling Locate private location for key equipment, that is, server, router, and switches as central point of connectivity
--	--	--	--	--	--	--	---

*Table 5. The case of a small network*

### 5.2.1.2 Observations

The table above is a sample of the various implementations that will be used, in this case a small network, based on the input received by the expert system. The value of  $q$  is a salience level for the expert system framework at implementation.

The RHS is converted into the prompt that will accept input; the LHS are the triggers that will implement the recommendations inferred from the input; the explanations will justify/qualify the implementation recommended for the network choice.

## 5.2.2 The Expert System Framework

The Expert System Framework was initially put forward in its raw state, concentrating more on the functionality and logic first. It is envisaged that the various aspects that could result in a packaged application could be left for future work or commercial applicability. The present focus was to demonstrate its efficacy in helping non-network literate users to comfortably rely on it to implement a reasonably reliable network within constraints already noted above. Further, the code shows its scalability in terms of being able to adopt more features and sub-components in refining its reliability as a commercially viable product.

### 5.2.2.1 Setup

The setup of the expert system involved three major steps:

1. **Establishing the Interface**. An interface in this instance was dispensed with in preference to a command-line based interface that could prompt the user with questions once the system was loaded and set to run within the CLIPS environment. The typical use of the printout option was adopted to cater for informing the user about what the system was doing. The figure below shows a code segment from the printout option.

```
(defrule starter
  ?init <- (initial-fact)
  =>
  (retract ?init)
  (printout t " " crlf)
  (printout t " " crlf)
  (printout t " " crlf)
  (printout t " " crlf)
```

```

(printout t " ")
(printout t " W E L C O M E  T O  NETWORK DESIGN ADVISOR"
crf)
(printout t " " crlf)
(printout t " This Intelligent Network Design Advisor ")
(printout t "System will help the unknowledgable network ")
(printout t " " crlf)
(printout t "owner make sound equipment implementation decisions ")
(printout t " in the design of his/her network." crlf)
(printout t " " crlf)
(printout t "You, the owner, will be asked a series")
(printout t " of yes/no questions about the state of the network in" crlf)
(printout t "question. You will also be asked to perform")
(printout t " some simple tests. At the end of the " crlf)
(printout t "program a list of possible recommendations ")
(printout t "will be made to help you in the sound" crlf)
(printout t " " crlf)
(printout t " choice of your network design." crlf)
(printout t " " crlf)
(printout t "This system assumes that the owner wants a")
(printout t " secure, scalable and functional "crlf)
(printout t "network. " crlf)
(printout t " " crlf)
(printout t " " crlf)
(printout t " Hit <ENTER> to begin our consulting" crlf)
(printout t " " crlf)
(printout t " " crlf)
(printout t " " crlf)
(bind ?answer (readline))
(assert (screen 2)))

```

**Figure 12. A Screen design for informing the user about the system**

2. **Prompting User Input.** A design for user input was done using the *defrule* command with *?variable* option to allow for user input to be saved before being processed. A code segment of this is shown below:

```

(defrule first-scrn
  ?scrn <- (screen 2)
=>
  (retract ?scrn)
  (bind ?count 0)
  (while (<= ?count 25)
    (printout t " " crlf)
    (bind ?count (+ ?count 1)))
  (printout t " ")
  (printout t " I will take you through 3 test phases" crlf)
  (printout t " " crlf)
  (printout t " ")
  (printout t " 1. NETWORK SIZE" crlf)
  (printout t " " crlf)
  (printout t " ")
  (printout t " 2. BUSINESS ACTIVITY TYPE" crlf)

```

```

(printout t " " crlf)
(printout t " ")
(printout t "      3. SECURITY ADVISOR" crlf)
(printout t " " crlf)
(printout t " ")
(printout t "To begin, press <ENTER> " crlf)
(printout t " " crlf)
(printout t " " crlf)
(printout t " " crlf)
(printout t " " crlf)
(printout t " " crlf)
(printout t " " crlf)
(printout t " " crlf)
(printout t " " crlf)
(bind ?answer (readline))

```

**Figure 13.** A screen design to accept input from the user

**3. System Output.** The Expert System Output was done with the *printout* command as in the above two segments shown in the figures of code above.

Typically traditional programming constructs such as looping (*while* was predominate in this instance), and decision branching (here represented by segment code such as

```

?net <- (swt ?smallnet) (test (eq ?smallnet yes))
→
(assert (CATALYST SWITCH 2950 WILL DO))
(retract ?smallnet)

```

This represents an *if* statement with relevant action if the result is true (or *yes* in this case). Notice how the *else* portion is implied redundant if no action is necessary.

### 5.3 Implementation of the Framework

Implementing the framework in this instance requires the use of the CLIPS Expert System Shell. The feasibility of this was found relevant for the major reason that current CLIPS versions are available freely and the only value added to it is when it is used to implement an idea such as the implementation of designing of a secure network.

#### 5.3.1 Implementation

CLIPS is invoked either as a Disk Operating System-based pure command line version, or a Graphical User Interface-based version such as was used for the purposes of this research.

The listing resulting from the design was saved in a program called *network\_expert.clp*. *.clp* is an extension that enables the CLIPS system to pick up the program and execute its code. Two typical commands are necessary for the running of the system:

1. **LOAD**. Use **LOAD** to load the file containing the Expert System commands that will execute the network advisor program.
2. Use the **(reset)** and then **(run)** commands within the CLIPS shell to start the system executing. It is significant to do this because of the refraction of system inference executions that prevent activation from executing endlessly.

Aside from this, the system has an online help facility that gives guidance typical of a Windows-based (or GUI-based) application.

**Hardware Considerations.** CLIPS and most of its applications run very well on an inexpensive Personal Computer (PC) with modest features. A memory request of just under 8 MB under load of a functional application was noted, as in the case of the Network Design Expert System.

**Software Considerations.** The Software considerations favoured the use of the CLIPS environment. It could run competently on a Windows 98 machine as well as it could on a Windows Vista versioned machine. Space requirements are extremely low, seeing as most of the workings are character-based as opposed to Graphic User Interface-based. However, other circumstances would certainly come into play on introduction of interfaces that demand graphics in implementing a more commercial version of the application. The increase, however, is projected at just under 50% of the current memory load, which still makes the use of CLIPS for this purpose a very attractive one.

### **5.3.2 Some Issues and Constraints**

A significant issue noted during the development of the Expert System code was its massively accumulating lines of code. As shown in the appended line of code, over 10 pages was produced to implement the preliminary implementation of the expert system based on the design premises devised in the network design phase.

Despite this however, it was clear to see that the command-line based implementation and the friendly and easy to understand construct far outweigh

the issues that resulted from the implementation of the expert knowledge available.

***Rule-Based Constraints.*** Significant constraints experienced during the design of this Expert System were mainly due to the “gray” area of reasoning and decision making. Using a Crisp-Logic based system (typically forward-chaining such as is the case with CLIPS) brings the question of how to react in uncertain situations to bear. Having put in extended time and resource in developing the expert system with this crisp-logic based system meant that these needed to be mitigated by using a tight enough logic approach to ensure its applicability in this instance. For future exploration, however, it would be worth the while to look at fuzzy approaches in enhancing the decision making processes of an extended Expert System for network design.

***Physical Constraints.*** The physical constraints were mostly on assembling a willing team of collaborators who would double as both users and experts. In the real world, networking experts are so busy that enlisting their attention for a reasonable length of time is almost impossible. Most of the simulations had to be done by extensive reading of design manuals and texts, sometimes even doubling examination techniques with real-life simulations of network design and behaviours. This, too, was a challenge.

***Limitations.*** Limitations of the Expert System largely lay in its inability to address fuzzy situations. At the time of extensive development, some extensions were being made to the CLIPS expert system and currently the

FuzzyCLIPS version is available. For further work, hence, it would be worthwhile to explore its position in adding more leverage to the decision making process. The current implementation within the constraints provided was found suitable enough and sufficed for the duration of this research.

## **CHAPTER SIX**

### **SOME EXPERIMENTAL RESULTS FROM THE APPLICATION**

The application that was developed was used to experiment on four cases, namely, a small network, a medium sized network, and an *indeterminate* or error-prone response for a network design. Each had interesting results.

#### **6.1 Small Network**

In determining the size of the small network, the user's response was based on the following premises:

1. That the building coverage was not dispersed, that is, the network would be contained in a single building.
2. That there were no more than 20 workstations in the building, with an average of 5 printers attached to 5 of the workstations.
3. That the distance to be covered by the network was covering an average area of about 100m<sup>2</sup>.
4. Other considerations such as Humidity, Ventilation and Accessibility were not considered in this survey.

##### **6.1.1 Result Obtained**

The Expert System specified a network that would use networking using a star topology and a stacked set of two 12-port switches. There was a slight deviation in the prediction of the printing resources as the system reported 1 networked printer connected directly. This implication pointed to the use of a dedicated print server which in this instance may not be absolutely necessary. A router and gateway

resources were also well recommended. Security was recommended as an ACL (Access Control List) on the router, and firewall on the main server closest to the router.

### **6.1.2 Considerations**

It is worth noting that this application could be used reasonably well to assist less capable personnel to come up with requirements that will give them a functional, small network.

## **6.2 Medium Network**

In determining the size of the medium network, the user's response was based on the following premises:

1. That the building coverage was dispersed, that is, the network would be contained in more than one building, in this case two was used.
2. That there were no more than 100 workstations in the buildings, with an average of 10 printers. One of the printers was assumed dedicated
3. That the distance to be covered by the network was covering an average area of about 1 km<sup>2</sup>.
4. Other considerations such as Humidity, Ventilation and Accessibility were not considered in this survey.

The application specified two options for inter-building connectivity: grounded unshielded twisted pair copper wire (or UTP) where the respondent selected cost

effectiveness, and fibre optic cable where the respondent selected safety-over-cost considerations. The application recommended, in this case of two buildings, grounded unshielded twisted copper wire (UTP) that manages the potential difference of the two buildings by earthing as elaborately as possible. This was for the cost-effective option. In the other option, a multi-mode cable was selected for the campus inter-building cabling. This was over the single-mode cable which is used in excess of 3 km in most instances. This was interesting because in most situations it becomes a bit difficult to resolve when to use the easy to access, LED-based multi-mode as opposed to the costly Laser-based single-mode alternative.

### **6.2.1 Results Obtained**

The Expert System specified a network that would use networking using a hierarchical star topology (used normally in buildings that are not connected to each other physically) and a stacked set of 24-port switches. Interesting was the fact that modular switches were chosen over a single switch for the purposes of addressing single-point of failure incidents. The deviation in the prediction of the printing resources as the system reported two networked printers connected directly. This implication pointed to the need to obtain a second dedicated printer. A router and gateway resources were also well recommended. Each building was recommended to have a closet where connection points would house switches. The system did not accurately predict where the switches should be placed. This consideration could be refined although it could be seen that a physical placement would then determine the number of ports required in a particular site or building. This prediction was

therefore not taken as a margin of error at all. Security was recommended as an ACL (Access Control List) on the router, and firewall on the main server closest to the router.

### **6.2.2 Considerations**

It is worth noting that this application could be used well to assist less capable personnel to come up with requirements that will give them a functional, medium sized network.

## **6.3 Indeterminate Network**

In specifying the indeterminate network, the user's response was based on the following premises:

1. That the building coverage was largely unknown, but based on estimates of a metropolitan area (a large to very large network!)
2. That there were in excess of 500 workstations in the buildings, with an unknown number of printers. Dedicated printers were not known either.
3. That the distance to be covered by the network was covering an average area of about 10 km<sup>2</sup> or more.
4. Other considerations such as Humidity, Ventilation and Accessibility were not considered in this survey.

### **6.3.1 Results Obtained**

The application had difficulty determining what technology to use especially in determining the connectivity of the various buildings. Short of recommending

single-mode connectivity in terms of Fibre Optic, the application recommended satellite. The salience in this case favoured an intercontinental connectivity which was, in this case, an expense that a local authority could ill afford, assuming a metropolitan network. However, the use of wireless was vaguely recommended, although it was interesting that wireless salience was reasonably high for areas within the 10 km<sup>2</sup> radius. Connectivity equipment in terms of switches, routers and gateway equipment was exaggerated to “several” which perhaps was consistent with the unknown number of buildings available for connectivity and the scope of the equipment in each. Security was recommended as an ACL (Access Control List) on the router, and firewall on the main server closest to the router.

### **6.3.2 Considerations**

Although the result in this case was unplanned, the findings were consistent with an expert system (or an expert) that did not have enough information on which to act. However, in this case, the expert system went on to attempt a solution which was not too far wide off the mark, although it lacked specific numbers.

### **6.4 Other Observations**

In one trial, ten buildings were specified with 250 workstations and two dedicated printers and the expert system gave reasonable specifications which included a single building to act as a gateway, ten closets each with switches (the total number of switches was placed at 11) and two dedicated printers attached. Multi-mode Fibre Optic was also recommended as inter-building connectivity without the option of wireless in this case.

## **6.5 Conclusion**

It could be seen clearly that an expert system could competently work to help less capable or less skilled IT staff to reasonably put together a network of different sizes.

It could, as an entry-level tool, be used to help planners of networks as well as implementers to have a good idea of how to obtain the equipment that they need to place in their network.

For future work, it is recommended to explore further, the limitations that were identified in this discussion in order to make the tool a more useful implementation for network design using expert systems.

## **CHAPTER SEVEN**

### **CONCLUSION AND FURTHER WORK**

In this chapter, the significance of the research is reiterated, and a recapitulation of the approach is made. Additionally, concise summaries of previous chapters are also given. The contribution that this research intends to the body of knowledge is briefly expressed, as well as beneficiaries who would likely get their best, cost-effective returns from using this approach to solving their network design problems. In conclusion, research directions for the future are given, primarily focussed on leveraging Bayesian theory in fuzzyCLIPS in addressing possible levels of uncertainty.

#### **7.1. Significance of the Research**

The justification of the research lay in the fact that:

1. There was need for many organisations to have well designed networks.
2. To understand the importance of scalable, secure networks
3. To understand the importance of using guidelines in implementing networks.
4. To understand the significance of expert systems in design of networks.
5. The research was an applied research. It addressed the problems faced by organisations in network design for scalability and security. The expected output did help redefine the existing organisational methods and

implementations of networks and did help in recommending that networks are designed and implemented within acceptable guidelines.

## **7.2. Chapter Summaries**

Chapter One introduced the concept of network design and its significance in ensuring efficient networks whenever and wherever it is applied. The viewpoint that expertise is at a premium in this field was expressed as a backdrop to the discussion on expert systems and their role in capturing this expertise. A brief introduction to Expert systems along with its component parts is given, and a particular reference is made to the CLIPS shell that has been used in the development of the Network Design Expert System in this study.

Chapter Two examined relevant authorities that have tackled the subject of both network design as well as expert systems. A later part of this chapter looked at the problem statement at hand and further developed the objectives of the research. The significant admission is that it is possible to enlist expert systems to design networks that are secure and scalable.

Chapter Three looked at the methods and materials used in this research. The approach used was the stratified approach, because there was a need to divide the levels of application into the sectors that obtain in the environment of study, namely, the Namibian environment. It was found relevant, therefore to divide the groups into the Government, Non-government, and private respectively. The Questionnaire design was discussed as a consequence of this to address the

awareness of the use of expert systems in these three groups. Later in the Chapter, a discussion of both the Framework and the approach to be taken was discussed. The agreed-to approach to the design was the top-down network design, and the agreed-to shell system to implement this approach was the CLIPS Expert Systems shell.

Chapter Four discussed the findings of the questionnaire and what it impacted in lending impetus to the objective of enlisting Expert Systems to the design of networks.

Chapters Five and Six respectively discussed the specific steps of conceptualising the framework and implementing it and some Experimental results. It discussed the observations made, the limitations and issues noted in the design process and also noted ongoing improvements required to enhance the application. Some Experimental realisations were highlighted in Chapter Six.

### **7.3 Contribution to Body of Knowledge**

This research aimed to contribute to the ongoing knowledge accumulation on the need to keep networks current and well designed. Most significant was that it is important to keep scalability of networks as a standard factor in the design and implementation of networks.

The area of network design technology can benefit from this as the enhancement of Information and Communication Technology (ICT) design theory.

#### **7.4 Beneficiaries**

1. All public, private and non-governmental organisations.
2. Consulting firms and individuals.

#### **7.5 Recommendations**

From the questionnaire results derived from the sample that was used, it is clear to see that Expert systems is a little known environment in applying expert knowledge, yet a significantly acknowledged improvement in the way that professionals and organisations conduct their activities. It is beneficial if more applications are introduced to address often scarce human resources and help especially fledgling enterprises in getting standard, acceptable systems implemented. Expert Systems can be widely used not only to implement secure, scalable networks, but to provide ongoing solutions to their maintainability. It is highly recommended that attention is given to this area of Expert Systems to help organisations realise their full potential without necessarily devoting too much resources in getting expert help. The initial step of establishing a pooled research and development entity in an institution of higher learning by a consortium of enterprises could be a viable stage in ensuring this.

#### **7.6 Further Work**

As noted in the discussion on the development of the expert system for network design, a few decisions require intuition or uncertainty as input. In such cases, it is necessary to look into using additions that address Bayesian logic. The CLIPS development has enhanced the shell by introducing the FuzzyCLIPS environment. This could be used to address the top levels of Business Goals, and

further down look at the issues of enterprise orientation and training recommendations for users of these expert systems.

At a fundamental level, an exploration into the need to improve awareness of the use of expert systems in society is necessary, looking at the results from the questionnaire data that were collected.

### **7.7. Conclusion**

Working with an Expert system such as CLIPS has proven that it is possible to use expert knowledge and capture it in a shell that can help to serve as a repository of knowledge for users. Limitation of this approach is only in the availability of expert knowledge, and possible initial cost of harnessing such expertise. The long-term benefits, however, are that it will address the shortfall in human resources in particular areas such as network design, and additionally bring a form of standardisation in the approach to networking where it is widely used and implemented.

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# APPENDICES

# APPENDIX A

## QUESTIONNAIRE USED IN RESEARCH

### Questionnaire for Expert Systems and Network Design

This questionnaire is meant to find out your knowledge of expert systems through very simple questions. It further endeavours to find out the suitability of using expert systems in your environment.

What is your Designation: \_\_\_\_\_  
*e.g. Manager, Administrator, Programmer, etc.*

Is your Organisation a(n) (*Tick the appropriate*)

Non Governmental Organisation  Government  Private

### Section A. General

Expert systems are said to be a mimic of human decision making. They help collect expert knowledge from an expert in his/her field in order to assist less skilled workers to work efficiently. They also free the expert from the routine tasks so (s)he can concentrate on other areas of his expertise.

1. Do you know what expert systems are?
  - a. Yes
  - b. No
  
2. If you answered *Yes* to Question 1, have you worked with any expert systems in your line of work? (*If you answer No, you can proceed based on the brief definition above*)
  - a. Yes
  - b. No
  
3. **A typical expert system takes an expert's skills and automates them, freeing existing professional skill to move on to other value adding jobs that may be less routine.** In view of this, would expert systems be ways of enabling you do less routine work?
  - a. Yes
  - b. No
  
4. Would you view Expert systems as a way of replacing human labour?

- a. Yes
  - b. No
5. Would you encourage the use of expert systems in your environment to cover more areas if possible?
- a. Yes 
    - i. Why? \_\_\_\_\_
  - b. No 
    - i. Why not? \_\_\_\_\_

**Section B: Networks and Design**

Computer networks are a means of helping users connect to each other and do a lot of things on the internet. A number of networks have been designed, including yours, to achieve these objectives.

6. Who designed your network?
- a. Exclusively by a Consulting Company
  - b. Exclusively by Internal IT Department
  - c. IT Department with the aid of a Consulting company
  - d. I found it there when I joined the organisation
  - e. Not sure
7. From the functioning of your network, do you think it is working efficiently?
- a. Yes
  - b. No
8. What is the constraining factor for your network function and design (including equipment quality and network running)?
- a. Money
  - b. Expertise
  - c. Other  \_\_\_\_\_
9. If you answered *No* to Question 7, would you attribute the functioning to a design fault?
- a. Yes
  - b. No

10. If you answered *No* to Question 7, would you attribute the functioning of the network to a lack of expertise to maintain the network?
- a. Yes
  - b. No
11. Is your network able to take new users?
- a. Yes
  - b. No
  - c. Not sure
12. If you had to make a decision on how your network is designed and maintained, would you choose:
- a. An Expert System
  - b. Outside Help, not an Expert System
  - c. Internal IT Staff using an Expert System
  - d. Other \_\_\_\_\_  
*Please specify*
13. In relation to the human expert, do you consider Expert Systems:
- a. A replacement of human jobs, therefore a threat.
  - b. A necessary tool to aid existing workforce.
14. In relation to skills base in the country, do you consider Expert Systems:
- a. A timely alternative to skills shortage.
  - b. Unnecessary for this country's setting.
15. In relation to cost, do you consider Expert Systems:
- a. Justifiable within financial investment.
  - b. Unnecessary drain of resources

--oOo--

# APPENDIX B

## User Instruction for Running Expert System

The Expert System being run is using the CLIPS shell. CLIPS is obtainable free for non-commercial purposes from various sites where it has been extensively used. Before installing and using CLIPS ensure the following:

### 1. Hardware Requirements


CLIPS uses very little hardware resources. You will require at least 20MB of space and as little as 5MB of RAM for minimal functionality such as this program. If you are running the Windows 9x, XP, Vista flavours of windows, you may use the CLIPSWIN for Windows or invoke the DOS-based CLIPS with a DOS session from your Windows environment.

### 2. Software Requirements

CLIPS works under the Windows environment as well as the DOS environment. There are versions that have been adapted to work under a UNIX/Linux environment as well. Any Windows 9x, or higher will suffice for the launch of a CLIPS software.

### 3. Installing CLIPS

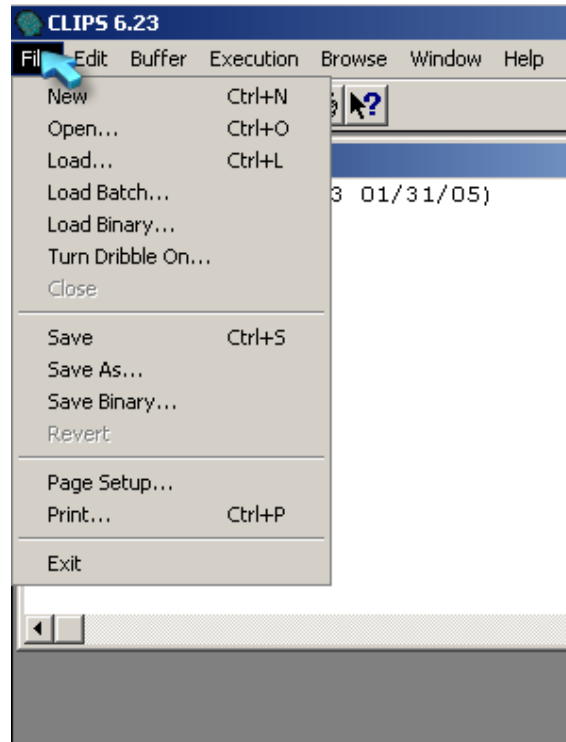
CLIPSWIN is delivered as a zipped file. Upon extraction, launch a setup file that will install the CLIPSWIN folder and subfolders as well as the

executable. The CLIPSWIN executable is usually a bust icon  that can be located either in the CLIPSWIN folder or on the desktop. Usually,

though, there is no automatic desktop shortcut and it may have to be created there for easy, future reference.

#### 4. Running NetEX

The NetEX application is run by loading the program into the CLIPSWIN environment. A pulldown menu enables you to do this:



The loaded program can then be executed by issuing the “reset” and “run” commands in succession to begin the system running. After this, the application will then begin to interrogate the user as to his/her preferences. Use the online help menu for any further help and guidance, and, as with most GUI-based environments, the pulldown for File loading will also enable a user to quit the CLIPSWIN environment.

# APPENDIX C

## CLIPS Listing for Preliminary Design

```
;;;=====
;;; Network Design Expert Problem
;;;
;;; NetEX: The Network Expert system.
;;; This preliminary code selects a suitable
;;; network according to your queries.
;;; The complete listing is available for production experimentation!!!
;;; Email: kluwesa@gmail.com to request full code for execution of
;;; production-based implementation of scalable, secure network
;;;
;;; CLIPS Version 6.0 or Higher
;;;
;;; To execute, merely load, reset and run.
;;;=====
```

```
(defmodule MAIN (export ?ALL))
```

```
;*****
```

```
;* DEFFUNCTIONS *
```

```
;*****
```

```
(deffunction MAIN::ask-question (?question ?allowed-values)
```

```
  (printout t ?question)
```

```
  (bind ?answer (read))
```

```
  (if (lexemep ?answer) then (bind ?answer (lowercase ?answer)))
```

```
  (while (not (member ?answer ?allowed-values)) do
```

```
    (printout t ?question)
```

```
    (bind ?answer (read))
```

```

        (if (lexemep ?answer) then (bind ?answer (lowercase ?answer)))

?answer)

;;*****

;;* INITIAL STATE *
;;*****

(deftemplate MAIN::attribute

  (slot name)

  (slot value)

  (slot certainty (default 100.0)))

(defrule MAIN::start

  (declare (saliency 10000))

  =>

  (set-fact-duplication TRUE)

  (focus QUESTIONS NETWORKS PRINT-RESULTS))

(defrule MAIN::combine-certainties ""

  (declare (saliency 100)

    (auto-focus TRUE))

  ?rem1 <- (attribute (name ?rel) (value ?val) (certainty ?per1))

  ?rem2 <- (attribute (name ?rel) (value ?val) (certainty ?per2))

  (test (neq ?rem1 ?rem2))

  =>

  (retract ?rem1)

  (modify ?rem2 (certainty (/ (- (* 100 (+ ?per1 ?per2)) (* ?per1 ?per2))

100))))

;;*****

;;* QUESTION RULES *
;;*****

(defmodule QUESTIONS (import MAIN ?ALL) (export ?ALL))

(deftemplate QUESTIONS::question

  (slot attribute (default ?NONE))

  (slot the-question (default ?NONE))

```

```

(multislot valid-answers (default ?NONE))

(slot already-asked (default FALSE))

(multislot precursors (default ?DERIVE)))

(defrule QUESTIONS::ask-a-question
  ?f <- (question (already-asked FALSE)
             (precursors)
             (the-question ?the-question)
             (attribute ?the-attribute)
             (valid-answers $?valid-answers))
  =>
  (modify ?f (already-asked TRUE))
  (assert (attribute (name ?the-attribute)
                    (value (ask-question ?the-question ?valid-answers)))))

(defrule QUESTIONS::precursor-is-satisfied
  ?f <- (question (already-asked FALSE)
             (precursors ?name is ?value $?rest))
  (attribute (name ?name) (value ?value))
  =>
  (if (eq (nth 1 ?rest) and)
      then (modify ?f (precursors (rest$ ?rest)))
      else (modify ?f (precursors ?rest))))

(defrule QUESTIONS::precursor-is-not-satisfied
  ?f <- (question (already-asked FALSE)
             (precursors ?name is-not ?value $?rest))
  (attribute (name ?name) (value ~?value))
  =>
  (if (eq (nth 1 ?rest) and)
      then (modify ?f (precursors (rest$ ?rest)))
      else (modify ?f (precursors ?rest))))

;*****
; * NetEX QUESTIONS *
;*****

(defmodule LOCATION-QUESTIONS (import QUESTIONS ?ALL))

```

```

(deffacts LOCATION-QUESTIONS::question-attributes
  (question (attribute main-component)
    (the-question "How many separate buildings do you have? One,
Two, or Unknown? ")
    (valid-answers One two unknown))
  (question (attribute has-two)
    (precursors main-component is one)
    (the-question "Do the buildings have a walkway connecting them?
")
    (valid-answers yes no unknown))
  (question (attribute has-walkway)
    (the-question "Is the area prone to lightning when it rains? ")
    (valid-answers yes no unknown))
  (question (attribute lightning)
    (precursors has-lightning is yes)
    (the-question "Is the lightning rare, irregular, frequent, or
negligible? ")
    (valid-answers lightning rare irregular frequent negligible))
  (question (attribute power)
    (the-question "Is the supply of power consistent, erratic, or
generator-based? ")
    (valid-answers consistent erratic generator-based unknown))
  (question (attribute User-access)
    (the-question "Are your users light, medium, or heavy in network
usage? ")
    (valid-answers light medium heavy unknown))
  (question (attribute Internet-mode)
    (the-question "Do your users access internet regularly or on-
demand? ")
    (valid-answers regularly on-demand unknown))
  (question (attribute network-security)
    (the-question "Do your users work on critical, normal, or
trivial systems? ")
    (valid-answers critical normal trivial unknown)))

;;*****
;; The RULES module

```

```

;*****

(defmodule RULES (import MAIN ?ALL) (export ?ALL))

(deftemplate RULES::rule
  (slot certainty (default 100.0))
  (multislot if)
  (multislot then))

(defrule RULES::throw-away-ands-in-antecedent
  ?f <- (rule (if and $?rest))
  =>
  (modify ?f (if ?rest)))

(defrule RULES::throw-away-ands-in-consequent
  ?f <- (rule (then and $?rest))
  =>
  (modify ?f (then ?rest)))

(defrule RULES::remove-is-condition-when-satisfied
  ?f <- (rule (certainty ?c1)
              (if ?attribute is ?value $?rest))
  (attribute (name ?attribute)
              (value ?value)
              (certainty ?c2))
  =>
  (modify ?f (certainty (min ?c1 ?c2)) (if ?rest)))

(defrule RULES::remove-is-not-condition-when-satisfied
  ?f <- (rule (certainty ?c1)
              (if ?attribute is-not ?value $?rest))
  (attribute (name ?attribute) (value ~?value) (certainty ?c2))
  =>
  (modify ?f (certainty (min ?c1 ?c2)) (if ?rest)))

(defrule RULES::perform-rule-consequent-with-certainty
  ?f <- (rule (certainty ?c1)
              (if)

```

```

        (then ?attribute is ?value with certainty ?c2 $?rest))
=>
(modify ?f (then ?rest))
(assert (attribute (name ?attribute)
                  (value ?value)
                  (certainty (/ (* ?c1 ?c2) 100))))

(defrule RULES::perform-rule-consequent-without-certainty
?f <- (rule (certainty ?c1)
            (if)
            (then ?attribute is ?value $?rest))
(test (or (eq (length$ ?rest) 0)
          (neq (nth 1 ?rest) with)))
=>
(modify ?f (then ?rest))
(assert (attribute (name ?attribute) (value ?value) (certainty ?c1))))

;*****
;* CHOOSE NETWORK TYPE RULES *
;*****

(defmodule CHOOSE-QUALITIES (import RULES ?ALL)
                          (import QUESTIONS ?ALL)
                          (import MAIN ?ALL))

(defrule CHOOSE-QUALITIES::startit => (focus RULES))

(deffacts the-network-rules

; Rules for picking the suitable network and user access

(rule (if has-lightning is yes and
        lightning is rare)
      (then best-backbone is fibre Optic or grounded-STP))

(rule (if power is consistent)
      (then best-backup is normal UPS))

```

```
(rule (if power is irregular)
      (then best-backup is normal UPS with certainty 30 and
            best-backup is medium-term UPS with certainty 60 and
            best-backup is heavy-duty UPS with certainty 30))

(rule (if power is generator-based)
      (then best-backup is medium-term UPS with certainty 40 and
            best-backup is heavy-duty UPS with certainty 80))

(rule (if has-lightning is yes and
      lightning is frequent)
      (then best-backup is medium-term UPS with certainty 40 and
            best-backup is heavy-duty UPS with certainty 60))

(rule (if user-access is heavy)
      (then user-access is heavy with certainty 40))

(rule (if user-access is medium)
      (then user-access is medium with certainty 40))

(rule (if user-access is light)
      (then user-access is light with certainty 40))

(rule (if user-access is light and
      user-access is heavy)
      (then user-access is medium))

(rule (if user-access is heavy and
      user-access is light)
      (then user-access is medium))

(rule (if user-access is unknown)
      (then user-access is light with certainty 20 and
            user-access is medium with certainty 20 and
            user-access is heavy with certainty 20))

; Rules for picking the best internet access
```

```

(rule (if main-component is one)
      (then internet-access is leased with certainty 90))

(rule (if main-component is unknown and
      has-two is no)
      (then internet-access is ISP with certainty 90 and
            internet-access is leased with certainty 30))

(rule (if main-component is two and
      has-two is yes)
      (then internet-access is leased with certainty 80 and
            internet-access is IPS with certainty 50))

(rule (if main-component is two)
      (then internet-access is ISP))

(rule (if main-component is-not two and
      has-lightning is yes and
      lightning is negligible)
      (then internet-access is leased))

(rule (if has-lightning is yes and
      lightning is frequent)
      (then internet-access is ISP with certainty 40))

(rule (if internet-mode is irregular)
      (then internet-access is leased with certainty 40))

(rule (if internet-mode is regular)
      (then internet-access is ISP with certainty 40))

(rule (if internet-mode is unknown)
      (then internet-access is leased with certainty 20 and
            internet-access is ISP with certainty 20))

; Rules for picking the best security

(rule (if has-lightning is yes and

```

```

        network-security is critical)
      (then best-backbone is Fibre-optic with certainty 90 and
        best-backbone is grounded-UTP with certainty 40))

(rule (if network-security is critical)
      (then best-backbone is Fibre-optic with certainty 40))

(rule (if network-security is medium)
      (then best-backbone is Fibre-optic with certainty 40))

(rule (if network-security is trivial)
      (then best-backbone is grounded-UTP with certainty 40))

(rule (if network-security is medium and
      network-security is critical)
      (then best-backbone is Fibre-optic))

(rule (if network-security is medium and
      network-security is trivial)
      (then best-backbone is grounded-UTP))

(rule (if network-security is unknown)
      (then best-backbone is Fibre-optic with certainty 20 and
        best-backbone is grounded-STP with certainty 20 and
        best-backbone is grounded-UTP with certainty 20))
)
;*****
; * NETWORK SELECTION RULES *
;*****
(defmodule NETWORKS (import MAIN ?ALL))

(deffacts any-attributes
  (attribute (name best-size) (value any))
  (attribute (name best-access) (value any))
  (attribute (name best-security) (value any)))

(deftemplate NETWORKS::small
  (slot name (default ?NONE))

```

```

(multislot size (default any))
(multislot access (default any))
(multislot security (default any)))

(deffacts NETWORKS::the-network-list
  (networks (name Small) (buildings one) (access light) (security trivial))
  (networks (name Small) (buildings two) (access medium) (security medium))
  (networks (name Medium) (buildings two) (access medium) (security
critical))
  (networks (name Medium) (buildings two) (access medium heavy) (security
medium critical))
  (networks (name unknown) (buildings unknown) (access trivial) (security
medium))
  (networks (name unknown) (buildings unknown) (access medium heavy)
(security medium critical))
  (networks (name Large) (buildings unknown) (access heavy) (security
critical))
  (networks (name Large) (buildings twp) (access heavy) (security critical))
  (networks (name Large) (buildings two) (access medium) (security
critical))
  (networks (name Unknown) (buildings unknown) (security medium))
  (networks (name Unknown) (buildings unknown) (security trivial))
  (networks (name Small) (buildings two) (access heavy) (security trivial))

(defrule NETWORKS::generate-networks
  (networks (name ?name)
    (buildings $? ?c $?)
    (access $? ?b $?)
    (security $? ?s $?))
  (attribute (name best-size) (value ?c) (certainty ?certainty-1))
  (attribute (name best-access) (value ?b) (certainty ?certainty-2))
  (attribute (name best-security) (value ?s) (certainty ?certainty-3))
  =>
  (assert (attribute (name network) (value ?name)
    (certainty (min ?certainty-1 ?certainty-2 ?certainty-
3))))))

;*****

```

```

;;* PRINT RECOMMENDED NETWORKS *
;*****

(defmodule PRINT-RESULTS (import MAIN ?ALL))

(defrule PRINT-RESULTS::header ""
  (declare (salience 10))
  =>
  (printout t t)
  (printout t "          RECOMMENDED NETWORK" t t)
  (printout t " NETWORK          CERTAINTY" t)
  (printout t " -----" t)
  (assert (phase print-network)))

(defrule PRINT-RESULTS::print-network ""
  ?rem <- (attribute (name network) (value ?name) (certainty ?per))

  (not (attribute (name network) (certainty ?per1&(> ?per1 ?per))))
  =>
  (retract ?rem)
  (format t " %-24s %2d%%n" ?name ?per))

(defrule PRINT-RESULTS::remove-bad-network-choice ""
  ?rem <- (attribute (name network) (certainty ?per&(< ?per 20)))
  =>
  (retract ?rem))

(defrule PRINT-RESULTS::end-spaces ""
  (not (attribute (name network)))
  =>
  (printout t t))

```