

# Experiences in Multi-domain Management System Development

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## Abstract

The deregulation of the global telecommunications market is expected to lead to a large increase in the number of market players. The increasing number of value added data services available will, at the same time, produce a wide diversification of the roles of these players. Subsequently the need for open network and service management interfaces will become increasingly important. Though this subject has been addressed in some standards (e.g. CCITT M3010) the body of implementation experience is still relatively small. The PREPARE<sup>1</sup> project has since 1992 been investigating multi-party network and service management issues focusing on an actual multi-platform implementation over a broadband testbed. This paper the problems encountered and the methodologies followed throughout the design and implementation cycle.

## Keywords

Multi-domain management, TMN, Implementation methodologies, Management platforms

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## 1. INTRODUCTION

The RACE II project PREPARE has investigated the development of Virtual Private Networks (VPN) services using heterogeneous, multi-domain, multi-technology, broadband network systems, cumulating in December 1994 in the public demonstration of an implementation of such a system over a working Broadband testbed network. The complexity of such a network management system and the large number of key players involved in realising the service (network providers, third party service providers, customers and end-users) made it clear from the outset of this work that a development methodology to support the full design and implementation cycles of the service was required. It is the aim of the authors to present an overview of the approach taken by PREPARE to realise this prototype VPN service, in order to provide some insight on how to address such problems inter-domain management in future Integrated Broadband Communications Networks.

## 2. PROJECT AIMS

The PREPARE project is part of the Research into Advanced Communications in Europe (RACE) programme sponsored by the European Commission. This programme aims to promote collaborative research between companies and research institutes across Europe to a pre-competitive level, though with a strong emphasis on producing exploitable results.

The PREPARE project was proposed with the aim of investigating network and service management issues in the multiple bearer and value added service provider context of a future deregulated European telecommunications market. The specific example selected for implementation in PREPARE was of a value added service provider co-operating with multiple bearer service providers to deliver a VPN service to a distributed corporate customer. In order that these investigations had a realistic focus a broadband testbed network was constructed over which the VPN service would be demonstrated. This testbed consisted of several different but inter-working network technologies. Each of these sub-networks possessed its own network management system which were developed according to the principles laid down in the CCITT Telecommunication Management Network (TMN) recommendations [M3010] and using implementations of the OSI CMIP mechanism [X.700]. The investigations into such multi-domain management involved the development of an architecture that allowed these separate network management systems to co-operate in providing end-to-end management services. This architecture was developed with a view to be conformant with the TMN development principles.

The make-up of the project consortium added a further important and realistic aspect to these investigations in that many of the roles played will be relevant to the realisation of future multi-domain management. The project partners and their relevant roles are:

- A network operator (KTAS), interested in integrating wide area network management with multi-domain service management based on TMN principles.
- A network equipment vendor (NKT Electronic), interested in the management of Metropolitan Area Networks (MANs) and the management of heterogeneous network inter-working.
- A customer premises network and management platform vendor (IBM: Token Ring and Netview/6000), who are interested in using their products in a multi-domain environment.

- A vendor of network management platforms (L.M. Ericsson A/S in co-operation with Broadcom Eireann Research), interested in the application of the TMOS Development Platform to value added service provision.
- Researchers into advanced network management techniques (University College London, Marben and GMD-FOKUS), interested in applying their platforms to the multi-domain environment.
- Researchers into multimedia applications (University College London), interested in the interactions of these applications with service and network management.

Each project partner therefore brought to the project their own specific interests, often overlapping but sometimes different or even contradictory. Therefore, though we were not operating in a true commercial environment, the view points of the customer, the value added service provider, the bearer service provider, the end user and management platform vendor are all genuinely represented. We can therefore assert that the methods we chose in arriving at our implementation were not purely influenced by the needs of a collaborative research project but clearly reflects an environment in which future broadband management systems will be defined.

### 3. MULTI-DOMAIN MANAGEMENT SYSTEM DEVELOPMENT

The process of defining management services and information models in an environment that contains several different types of player has received some theoretical attention but the body of actual experience with large scale developments is still very limited. This section reviews the standardised methodologies available for management system design and their relevance to the PREPARE work. It then describes the process actually followed in PREPARE to develop a multi-domain management system.

#### 3.1 Standardised Methodologies

The need for a methodology to support the identification and specification of the management requirements and capabilities related to the management of telecommunications networks, equipment and services is well understood by the standards and other related bodies. The main methodologies proposed to date include the ITU-T's M.3020 [M3020], Network Management Forum's Ensemble concept [NMFORUM] and ISO's ODP framework [ODP].

The TMN interface methodology, as defined in M3020, forms part of the wider TMN management framework as defined in the M3000 series of recommendations. The methodology is primarily designed to aid the specification and modelling of management functionality at any well-defined TMN interface. The methodology is designed to support either a network or network element viewpoint. The methodology is intended for use by three different groups namely; co-ordination users (at the network level), application specification users and protocol specifying users.

In general the standards concentrate on the specification of generic solutions for general management problems. However there is a need to tailor these solutions to solve specific management issues. The Network Management Forum group proposes the use of the Ensemble concept as a solution. The Ensemble approach is to select, from the pool of standards outputs, a solution appropriate the management problem and to enhance these with

other support items (management information libraries and profiles) to produce maximum effectiveness. A recommended ensemble template is provided in OMNIPoint 1.

The ODP framework provides five key viewpoints to support the specification of the problem domain. These are the enterprise, information, computation, engineering and technology viewpoints.

The major difference between the Ensemble and TMN methodology process is the scope of the two methods. The scope of the Ensemble is more focused in that ensembles are defined for specific management problems whereas M.3020 aims more at generic solutions, being intended more for use by standardisers rather than customer implementors. On the other hand the Ensemble concept defines conformance and testing requirements. The ODP framework is complementary to both methodologies in that the five viewpoints may be applied in both cases to enhance their approaches.

The major limitations of all these approaches in the case of PREPARE are that they either have not the needed scope or, in the case of ODP, are too general and the mapping onto TMN are not well defined. Furthermore the PREPARE project required a methodology that covered the service specification, design and implementation phases of the demonstrator work, whereas the scope of these methodologies only covers part of the specification and design process. Finally, and significantly for PREPARE, the three approaches are designed to support single system design. None of the methodologies provide sufficient support for designing and implementing co-operative, multi-domain management systems. These facts resulted in none of them been chosen by PREPARE, since they are unable to fully support the service specification, design and implementation requirements.

The project required that a mixture of the three approaches be taken. In effect it was realised that a pragmatic approach was necessary which would be primarily driven by the experience accumulated by the project members as a result of their involvement in similar work in other projects (e.g. RACE 1 Research Program). This approach is detailed in the following section.

### **3.2 The PREPARE Methodology**

At the outset a broad plan did exist which involved the following stages:

1. The definition of the management scenarios we wished to demonstrate, together with the supporting TMN architecture, management service definition and information models, conducted through 1992.
2. The implementation of the intra-domain systems required to manage the individual sub-networks making up the demonstrator testbed and the implementation and integration planning for the inter-domain management components, conducted through 1993.
3. The testing of the inter-domain components and their integration with the intra-domain management components and the actual testbed network. This work continues through 1994, culminating in a public demonstration event in December 1994.

The broadband testbed used for the VPN management service consisted of an ATM WAN, ATM multiplexors, a DQDB MAN, a Token Ring LAN, and multimedia workstations. The enterprise context in which the VPN service was assumed to operate dictated that the WAN and MAN were separate public networks while the ATM multiplexors and Token LANs were Customer Premises Networks (CPNs). Both the public networks and the CPNs had their own separate management Operation Systems (OSs). To provide the VPN

management system a separate third party Value Added Service Provider (VASP) OS was introduced. This coordinated VPN resources management via X-interfaces to the public network OSs and provided customer access and control to the VPN service via X-interfaces to the CPN OSs (see figure 1).

OS = operations system  
 x = TMN x reference point  
 q = TMN q reference point

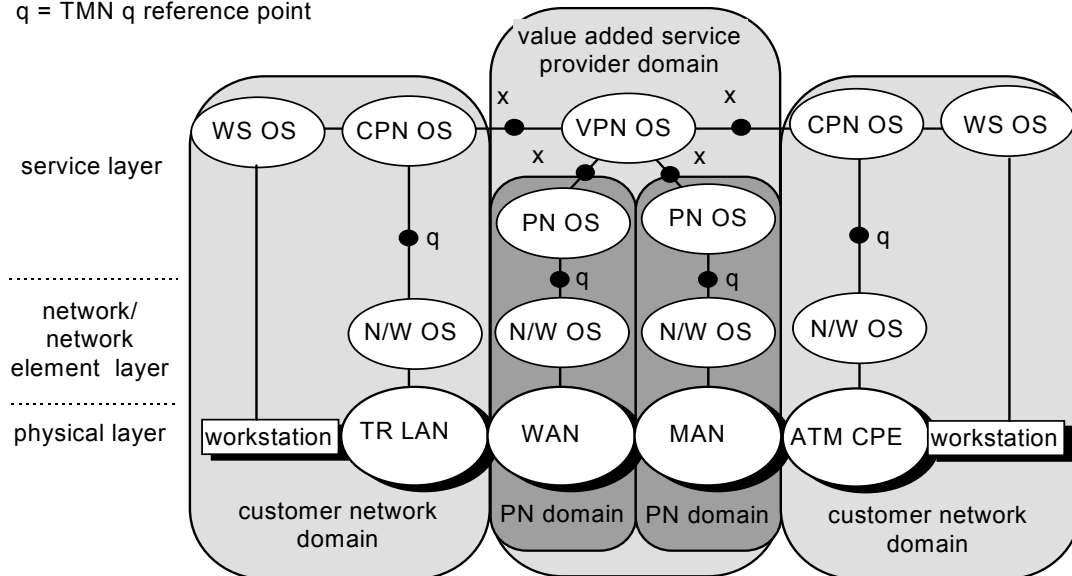


Figure 1.: PREPARE TMN Architecture

The fact that a different project partner was to implement the management systems for each of public networks and CPNs emphasised from the beginning of the project the administrative and human communication problems encountered in attempting to develop multi-domain management systems. This led to an emphasis in the project on the X-interface where these different organisation's management systems had to interact.

Against this background the first stage of the work proceeded with four different groups being formed to generate; management scenario definitions, a TMN based management architecture, management service definitions and management information model definitions. The objectives of these groups were as follows:

- The aim of the scenarios group was to produce a set of scenarios that would detail what would be demonstrated over the testbed network. Due to the large number of participants, components and requirements involved, these scenarios were essential in order to focus the work onto a manageable subset of demonstrable operations while at the same time presenting a coherent description of what was to be demonstrated.
- The architecture group had the task of interpreting the TMN recommendations in order to produce an implementable framework that specified how the components in the different domains should be interfaced to each other in order to provide end-to-end services.
- The management services group had to define a set of services that operated between the different management OSs in accordance to the Abstract Service Definition Convention Recommendation [ASDC].

- The work associated with the information modelling group consisted of defining the information models required by the various OSs which were involved in inter-domain relationships, according to the Guidelines for the Definition Managed Objects recommendation [GDMO].

Due to restrictions of time and man-power these groups contained only a small core of overlapping personnel and were generally conducted in parallel. At the beginning of 1993 a review was conducted of the work performed in the first stage and its suitability for supporting the implementation work.

The output from the scenarios group described the roles of the human users and organisations involved in the VPN service as well as the motivations for the operations performed. This was supplemented by documentation of the commercial service that the VPN provider should provide to its customers. The architecture group identified all the management components required for the intended end-to-end VPN services and the different interfaces required within a TMN framework. The relatively simple architecture produced is outlined in figure 1. It soon became apparent that the scenarios contributed greatly to everyone's understanding of the problem while the architecture was generally agreed upon as being suitable for the implementation of the VPN service. However it was also recognised that the outputs from the management services and information modelling groups suffered in many respects. Firstly these two sets of output were not mutually consistent nor were they totally aligned with the output of the scenarios and architecture groups. Co-ordinating this work while running the groups in parallel had proved too complex a task given the human resources available. Secondly it was felt that, given the goal of demonstrating the scenarios; the service and information model specification were not complete and did not contain the level of detail required by the implementors. For example, although the detailed GDMO specification of all the agents in the architecture was essential the managed object (MO) behaviour descriptions could not accurately convey the functionality of the operation systems which needed to be supported. Furthermore it was felt that a complete ASDC description of the management services would still require some additional integration with the information model to satisfy the implementors.

A path was therefore chosen which involved abandoning the further definition of management services and concentrating on refining the scenarios. The existing scenarios were therefore refined from a level where they described roles and their relationships, to a state where the same scenarios were described in terms of OSs with detailed descriptions of the management information flowing between them. Adopting this technique, a full GDMO specification for the whole inter-domain information model was quickly arrived at. This approach also had the intrinsic advantages of ensuring that all information modelling was directly focused on the desired implementation areas and provided an informal but relatively brief description of the functionality associated with the information model.

The entire information model for all inter-domain components was maintained in a single document referred to as the Implementor's Hand Book (IHB). It was apparent that although the aim at this stage of the design work was to arrive at a stable version of the information model, there would inevitably be changes required to the IHB as our understanding of the problem grew. For this reason the IHB was maintained as a living

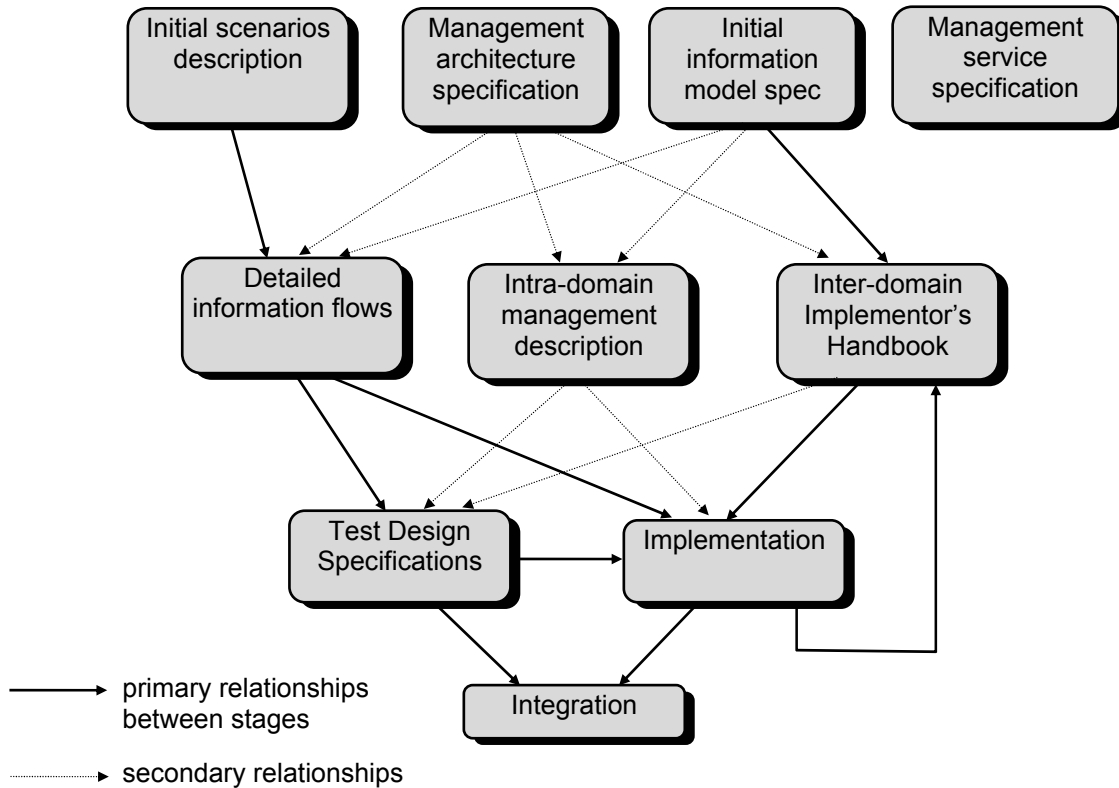


Figure 2.: Overview of Inter-domain Management System Development Methodology adopted in PREPARE

document. This task was made considerably easier with the help of Damocles a GDMO parsing and checking tool developed by GMD-FOKUS. This was used to check the IHB for GDMO syntax errors, open references but more importantly it checked for consistency and completeness throughout the information model. This was especially useful considering the number of partners involved in the writing of this document. A mechanism for requesting updates or modifications to the information model was also adopted since changes inevitably effected more than one partner's implementation work.

The IHB did not address intra-domain issues. However since each of the partners involved in intra-domain component implementation was represented during the scenario refinement and inter-domain information modelling, this work was performed separately and in much less detail. The more difficult inter-domain modelling was therefore allowed to dictate the project resource requirements with the relevant partners being responsible for their own intra-domain implementations.

As the IHB became stable and the inter-domain implementation began, the planning for integrating, the various hardware and software components commenced. This was conducted

broadly following the IEEE standard 829-1983 [IEEE829] which involved the generation of Test Design Specifications (TDSs) for all tests that would involve components from more than one partners. When this was performed for inter-domain management software components some interesting effects were observed. Firstly the refined scenarios proved to be ideal templates for defining the interactions that should be tested, ensuring once again that the work performed directly supported the final aims of the project. Secondly the TDSs were written to a level of detail that defined the actual CMIS primitives that should be exchanged between the OSs and the syntactical information required. This process of writing the TDS to such a level of detail provided much invaluable insight to the implementors in that it raised many issues that had not yet been recognised and allowed these problems to be resolved before the implementation work had progressed too far.

To summarise therefore, the method followed in PREPARE was focused on achieving a demonstrable result in a limited time frame. It was heavily influenced by its multi-domain context and the requirement to co-ordinate the different partners involved in the work. Figure 2 summarises the approach adopted.

#### 4. IMPLEMENTATION PLATFORMS

In addition to the development methodology, another key factor in management system design is the choice of platform. Due to a combination of individual partner's particular interests in this area and the large monetary investment often required in network management platforms, no single platform was adopted by the project, but instead each partner was free to independently select one, provided the platform was able to support: [D22A]: a Q3 and X TMN interface, the development of manager and agent management applications and the implementation of custom managed object classes.

The following platforms were used in the PREPARE testbed:

*OSI Management Information Service (OSIMIS)*: This was developed by the University College London [UCL] as a result of participation in a number of EU funded projects from the RACE and ESPRIT research programs. An object oriented API is provided for implementing management applications working in either the agent or manager roles. Within PREPARE, OSIMIS has been used to implement the Inter-Domain Management Information Service (IDMIS) [H430], Q-adapters for nodes of the BATMAN ATM pilot network and the OS that provided network management facilities and a service level x-interface for the DQDB MAN network in the PREPARE testbed.

*Netview/6000*: The management information associated with the Token Ring (TR) LAN that is being used as a CPN is made available to other OSs via IBM's NetView/6000 management system.

*OpenView*: Hewlett-Packard's OpenView CMIP development environment was used to develop the OS that managed the ATM MUX CPNs at the VPN service level.

*Telecommunication Management and Operations Support (TMOS)*: This platform developed by L.M. Ericsson was used by L.M. Ericsson and Broadcom Eireann Research to develop the VASP OS and operator user interface.



In order to test and adjust the various platforms so that they could interchange management data using CMIS, a test MO (based on the Network Management Forum test object) was initially used. This MO contained the basic GDMO structure of a generic managed object (i.e. packages, notifications, attributes, etc.) so that when implemented over the various platforms the interchange of its management data could be tested and any problems identified.

A number of different problems were identified while implementing this test managed object and subsequent development of the different OSs. These include the use of name bindings varied with each platform. For example, the information model within the TMOS platform starts with the network object being at the top of the containment tree whereas in the OSIMIS platform the standardised system MO is at the top of the containment tree. To overcome this, a translation function is necessary.

## 5. OPEN ISSUES

The experience of the PREPARE project in designing and implementing its VPN services reinforces the fact that realising inter-domain services is an extremely complex issue and requires the support of a methodology to integrate the service specification, design and implementation processes. The PREPARE approach provides a window into the type of issues that need to be addressed by this methodology.

### 5.1 Inter-domain Management and TMN

Where practical the project has attempted to base its approach on the work of the standards bodies. In particular the project's approach to defining an implementation architecture to support its design and implementation work is mainly based on the TMN architectural framework. The main conclusion of the project was that the TMN framework could support the design of inter-domain service management systems. However, having a view on the future IBC environment which emphasises dynamicity and openness it is clear that the framework requires extension to include support for a number of issues. This includes support for a globally available information service for storing, accessing and maintaining globally relevant information. A typical example is information about service providers, their offered capabilities, contact names and addresses, and "operational" information like e.g. communications addresses of OSs, information models and other information related to shared management knowledge. The OSI Directory provides a standardised approach to implementing the required technologies [CFSD370]. An approach to using the Directory in this way is demonstrated in PREPARE with the IDMIS system. This however has implications for the TMN Architecture. A proposal to; add a Directory System Function and corresponding d-reference point to the functional architecture; add Directory Objects to the information architecture and add Directory components like Directory System Agents (DSA) and Directory Access Protocol (DAP) to the physical architecture, has been presented to ITU SG IV, (Q.23/Q.5 meeting, May 1994) and subsequent meetings. We expect it to be reflected in the November '94 version of M.3010 [BjerTsch].

### 5.2 Security

Security within the PREPARE VPN management framework and particularly TMN is an important issue that has not been addressed so far within the project. Generally security

refers to the application of an appropriate set of logical and physical measures in order to ensure the availability, accountability, confidentiality and correctness of the management data accessible to other TMN-like systems [H211]. Open Network Provisioning (ONP) is expected to be introduced by the European Public Network Operators (PNOs) by the late 90's. In technical terms, the ONP concept emphasises the need to define and adopt open non-discriminatory standardised interfaces to the underlying public network infrastructure for the provision of new value added services [PLAGEMANN]. To address this new trend in the public telecommunications industry a high degree of security is necessary to reduce the possibility of large monetary losses being suffered by customer commercial organisations, the various PNOs and service providers as a result of allowing the use of services like VPN, etc. For example, US telecommunications fraud is currently estimated to be in excess of \$2.5 billion per annum [WALLISH].

## 6. FURTHER WORK

In 1993 the PREPARE project received additional resources to sponsor an extension of its work in 1994 and 1995. This new work has two main aims; first to extend the physical testbed from Denmark, where it is currently situated, to include ATM sites in London and Berlin [Lewis], and secondly to extend its multi-domain TMN investigation to include multimedia teleservice management. As part of the latter aim the project must go through another cycle of specification of demonstrator goals, architecture definition, information modelling, implementation and integration. This has to be performed in about half the time of the previous cycle and may prove more problematic since there are potentially more inter-domain relationships in the anticipated architecture. However the experience gain by project members in the work described in this paper should greatly mitigate these problems and has already led to a work-plan that follows the same scenarios centred development path.

## 7. CONCLUSION

The experience of the PREPARE project is that the development of multi-domain management systems is a very complex task made mainly so by the presence in the development process of several parties. It was found that though some standardised methodologies exist, none at this time address the complexity of multi-domain systems, nor do they address all the stages of the development cycle. PREPARE has therefore developed its own pragmatic approach to the development of such systems. This approach is centred around the establishment of a set of scenarios that embody the core aims of the system being developed and therefore ensures that all work remains explicitly focused on those aims. By documenting scenarios at a high level initially, any conflicts between the requirements of different parties may be identified and resolved early on in the development process. These scenarios are then refined into detailed information flows as part of the information modelling process and finally they provide the basis for integration and test documents. PREPARE has found this method well suited to developing, with limited resources, multi-domain management systems that satisfy core requirements. The project will reuse this method in a new cycle of multi-domain management system development it is currently embarked upon.

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## BIOGRAPHY

David Lewis graduated in electronic engineering from the University of Southampton in 1987 and worked as an electronic design engineer for two years. In 1990 he gained a Masters in computer science from University College London where he subsequently stayed as a research fellow in the Computer Science Department. Here he has worked on primary rate ISDN hardware development and Internet usage analysis before joining the PREPARE project in which he has worked both in B-ISDN testbed definition, integration of multimedia

applications and development and implementation of inter-domain management systems. He is currently conducting a part-time Ph.D. on the management of services in an open service market environment.

Sean O'Connell qualified in 1991, with an honours degree in Computer Science from the University College Dublin (UCD) following the completion of his scholarship funded final year project in secure E-Mail. He took up a research position with Teltech Ireland at UCD where he spent two years working on various security related projects including secure FTAM, the Security Management Centre, the AIM Project SEISMED and his masters degree. He left UCD in September '93 to join Broadcom Eireann Research where he is currently working on PREPARE and related security projects. His main areas of interest include cryptography, open systems security, OSI management, TMN and ATM technology.

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