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Evolution of NICNET as an Incrementally Intelligent Network

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Abstract

The evolution of NICNET, the Computer-Communication network of the National Informatics Centre, is so oriented that integration and globalization are progessively implemented utilizing the latest cost-effective technologies available in the international market. With the choice of SSMA/CDMA based VSAT technology utilizing a C-band transponder, during the nucleating stage of NICNET, the top 500 cities and towns in India have been linked apart from more than 100 sites of mega projects and economically important locations. In the next step, high speed SCPC based VSATs with two-way as well as data broadcast capabilities utilizing a Ku-band transponder is enabling the realisation of the NICNET InfoHighway linking metropolises and big cities as an overlay network over the low speed NICNET. Dedicated high speed external gateways provide initial infrastructure for globalization of NICNET.

In the next phase, it is planned to introduce software based information networking architecture on NICNET for which the concept of structure-function matrix based incrementally intelligent network design is proposed in this paper. As the demand for sophisticated services like CUGs, virtual private network service, universal personal communications, mobile communication and multimedia services increase, NICNET will be required to respond with more flexible access, intelligent management and versatile charging regimes than what is possible currently, all within the frame-work of an open system architecture. Imperatives of globalization and service creation will be rendered incrementally intelligent utilising an approach based on intelligent hypermedia with imbedded expert system for realising intelligent navigation and

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integration. The same AI approach is determined to be advantageous for intelligent integration of traffic and facility with adaptive flexible routing. The design of NICNET as an intelligent global network providing a versatile local infrastructure with multiple gateway hooks to a global network employing low or medium earth orbiting satellite constellation, is identified as a desirable long term goal.

1. INTRODUCTION

In India there are a number of computer-communication projects which are evolving towards globalized systems. One of the extensive nation-wide networks, which is mainly dependent upon space communication, is NICNET, the computer-communication network of the National Informatics Centre (NIC) [1]. The evolution of NICNET is so oriented that the integration of computer and communication as well as globalization of the network is being progressively implemented utilizing low cost technologies of adequate reliability and through-put. Beginning as a network for decision support and project monitoring for the Government administration - more than 50 Ministries/Departments in the Central Government, Secretariats of the 32 States/Union Territory Governments and more than 500 District Administrations, the scope has progressively widened for giving support to monitoring of mega projects of public sector and autonomous organisations, to the private sector and the public [2]. More than 5000 databases, many of them based on distributed relational database approach, have been created on NICNET in the following 26 broad areas: Agriculture, Animal Husbandry, Building and Works, Civil Supplies, District Collectorate, Collegiate Education, District Planning, Employment, Fisheries, Ground Water, Industry, Irrigiation, Health, Rural Development, Social Forestry, Labour, Village Panchayat, Power, Public Instruction, Roads and Bridges, Social Welfare, Town Planning, Transport, Water Resources and Finance [3]. Distributed geographic information systems are being developed on the network.

In the first phase of development of NICNET, it was found adequate to create the network with an SSMA/CDMA VSAT in each one of the 32 States/UT capitals and over 500 district headquarters utilizing C-band transponder on INSAT satellite. With interference tolerance and random access as two guiding principles behind the choice, spread spectrum and code division multiple access system of satellite communication, was adopted. Each node of the network is a 32-bit computer with adequate local disc storage for online servicing of query accessible distributed databases. The adoption of CDMA has given the advantage for sharing a satellite channel among a larger number of transaction terminals. The master hub of NICNET with a 13 meter antenna located in New Delhi, is connected to a large mainframe host computer. Though local area networks and metropolitan area networks connected to NICNET are at present based on leased lines and dial up terminals from the POTS network, in the long run, CDMA based wireless loop technologies are expected to substitute them. One of the basic design philosophies of NICNET is to depend almost entirely upon satellite and wireless loop technologies bypassing the terrestrial cable networks as far as possible. Even within buildings wireless LANs are being set up with increasing demand for value added network services over NICNET as well as to avoid possible traffic bottleneck situations in the low speed NICNET. The next step under way is to establish a powerful NICNET Info Highway as an overlay network for the SSMA/CDMA network. As many as 150 economically important cities, towns and mega project locations will eventually host highway nodes.

2. EVOLUTION OF NICNET HIGH SPEED INFOHIGHWAY

The existing NICNET in the C-band is of contention type which is more suitable to distict level traffic. Whereas this is designed for district linkages which are bursty and short duration type it is unsuitable for linkages with state capitals where the traffic is steadier and of fixed type. In view of this a fixed assignment option is more suitable for the high speed network. There are two candidates for fixed assignment type the TDMA and FDMA/SCPC. Whereas both of them offer roughly the same capacity, delay and stability properties the two differ in robustness, cost, complexity and flexibility.

The overlay network is a star SCPC system on a Ku-band transponder providing typically the 64 kbps dedicated satellite links to each of the remote earth stations. The network will have the expansion capability to increase to any number of earth stations and each link will be capable of operating at a variety of speeds from 64 kbps to 2.2 mbps. (See Fig.1).

Each remote site on the SCPC network will have an earth station with a 1.8 meter antenna. The network will have multiple data channel capabilities combined upto an aggregate of 128 kbps. The Star hub will be in New Delhi with a 6 meter antenna. For each remote site a dedicated modem at the hub is provided. As each data link will have its own dedicated channel, blocking or congestion in satellite resources is avoided. The network is configured for modular expansion with not only modular additional sites, but also data rates can be altered as required and multiple data circuits to any centre can be added by installing a multiplexer.

The satellite system characteristics like coding tape and power levels can be modified to match the required link characteristics. The network control at Delhi will configure all aspects of the network utilizing a Star Network Management System (SNMS). The SNMS is a monitoring and control system that will operate at the hub station so as to monitor the status of the hub and remote site. The SNMS typically runs on a 486 microprocessor operating under WINDOWS environment.

The data broadcast network over NICNET overlay operating in the Ku-band will have a multiplexed hub which can be located to go with the SCPC hub in Delhi and controlled by an appropriate Network Management System. Initially, the data broadcast network will be uplinked from the Delhi hub, but later, it will be carried out also at a few other locations. The network can either operate in a multiplexed or multichannel mode at aggregate speeds upto 256 kbps or in a clear channel mode without multiplexer at speeds upto 2 mbps.

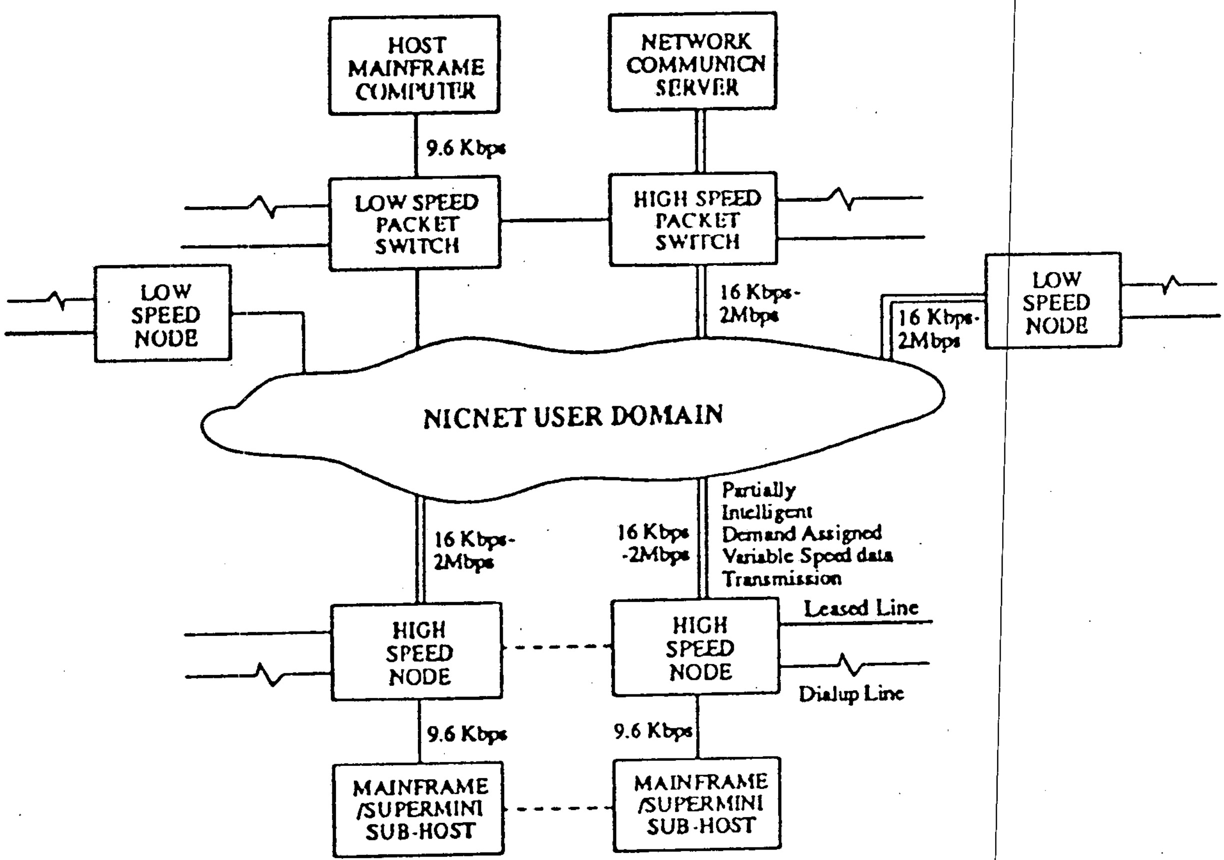

Fig. 1: PRESENT NICNET ARCHITECTURE

The NICNET InfoHighway, which is in an advanced stage of implementation, is a satellite based universal broad band network (UBN). Efforts are being made for UBN to have a uniform, universal and suitable standard for basic switching and transmission to encourage users who will be willing to invest in the facilities required for the network. The standard requirement is critical and some flexibility will be built in. The NICNET InfoHighway has network hardware, basic control and software which will enable such standardization so that any conceivable service application may travel on the highway. The least common denominator of digital encoding and signalling allows for service integration without perceptible loss of transmission speed.

Each node has 2.2 mbps maximum rate of transmission per module. The variability will be adjusted between 16 kbps and 2.2 mbps. An intelligent network management system will adjust the rate at each node depending upon the forecast of the demand. An hour or two ahead, however taking care to see that the summation of the rates over all the nodes does not exceed the value corresponding to the total available bandwidth on the satellite transponder.

The Star hub at Delhi should not be construed in the same sense as the hub of the SSMA/CDMA hub of NICNET. Though there is a network management control system used at the Star hub, it is to be considered only as a cluster of point-to-point communication in which one of the points for each pair is located at the Star hub.

Each node of the network can also be clustered as parallel pairs connected to the Star hub in order to increase the overall transmission rate modularly in mutiples of 2.2. mbps. Thus, the InfoHighway is being designed for modular expansion spacially as well as capacity-wise.

On the ground segment, special low cost technologies for effectively linking widely separated local area networks, Network FAX & Image servers and multimedia communication services are proposed. Special features for accommodating a large number of close user groups and offering virtual private networks are designed to increase the propensity for the spread of the IT culture as well as prod the growth of demand.

A widespread BISDN use is expected to take place in the near future. BISDN protocol and services can be effectively provided over satellite links. The fast cell switching technique of ATM can be used so that all services such as voice, video, image and data, can be provided using the ATM adaptation layer (AAL) and ATM protocol layers with 150 megabit per second access. Digital television and high definition television can be accommodated. With ATM, voice and video are broken up and packaged in 53 byte cells carried from the source across multiple nodes and perhaps multiple networks and finally, reconstructed as continuous stream at the destination. The network will not distinguish between voice, video or data cells.[4]

Satellite based networks are flexible and can quickly be set up for meeting communication services to business and government customers from distributed locations using small and medium ground terminals located at the customer premises. In the near future, ATM can be provided over satellite by introducing an ATM earthstation interface line card. Such cards are already under development and pilot scale experimentation. Two major facilities proposed to be provided on the NICNET InfoHighway are the close user group facility and virtual private network facility.[5]

A close user group (CUG) facility as a shared network is possible in which membership is limited by some a-priori specified restrictive criterion,e.g. corporate headquarters along with all its branch offices, a bank along with all its branches, a super market and its customers, a large multi-branch central Government office, etc. This helps the users to pool their demand for a customised service or solution and thereby obtain the same advantage as a very large user. This facility helps in globalization by external linkages to users with shared concerns. For example, when a number of Indian banks become members of the SWIFT, the international banking network, they become part of a CUG. With NICNET Highway becoming available, this would enable a very large number of banks and their main branches to be connected to SWIFT through NICNET InfoHighway. There are many other applications where CUG of NICNET can help the enterprise go globally.

With NICNET InfoHighway acting as a computer-communication carrier, virtual private network can be offered for using software control to carve out a portion of NICNET and place it at the virtually exclusive disposal of the user. Such virtual private networks have several advantages. Users need not make large investments in network facilities. They would need a minimum skilled technical staff to operate their network. The amount of capacity of network can be altered and network can be reconfigured on demand. The users gain access to some of the network management systems of the public carriers. More importantly, users begin to share in network economies of scale and scope.

NICNET is connected to international networks through GPSS of VSNL located at Bombay. Through linkage, X.25 networks worldwide are being accessed. For example, NICNET users access the National Medical Library at Bethesda through the MEDLARS as well as DIALOG databases. NICNET is also connected to UUNET for international E-mail services for its users. E-mail and NICMAIL are the electronic mail services available on NICNET. UUNET is a UUCP network connecting a number of UNIX hosts and acting as a gateway to many other networks. NIC is providing UUNET connection to the users to send E-mail to various international sites which are also on UUNET or are accessible via UUNET. All mails generated on NICNET are routed through the gateway machine located at Delhi. NIC provides connection to GEMS-400 based E-mail service provided by VSNL. GEMS-400 is resident on a VAX system located at Bombay. EDI, a value added service,based on an OLTP system is being implemented in the first half of

1993. This value added system is being interconnected to international EDI networks through VSNL gateways for global transaction of NICNET users.

Two 64 kbps external gateways are being connected to NICNET, one through the GPSS of VSNL and the other as ADMD. These will make use of the SPRINT transit network in USA to enable NICNET users to access more than 47 networks in 39 countries around the world. With the NICNET InfoHighway, the number of high speed external gateway links can be modularly increased depending upon the demand.

3. IMPERATIVES OF GLOBALIZATION OF NICNET

Certain concepts of data networks have been forecast which is taken as the current basis for the design of NICNET at the third level of integration and globalization. Based on the concept of NICSAT earlier proposed [6] [7], a series of very low cost microsats are proposed to be launched for an internally operable dedidcated space-com data network with user end to end communication capabilities, built in features for promoting specialized value added services, built in access security and expert system based network management. Low cost on-board features, a versatile space link scenario and low cost ground infrastructure are under consideration.

It is proposed that NICNET should be incrementally converted for providing global intelligent network services over a strong skeleton of data highway utilizing application gateways in a global intelligent network, inter-operability of the service management system, service creation environment and operations system as well as support the interaction of the intelligent network components in intra-network and inter-network cases. Initially the connectivity will be provided and the basic network infrastructure will be put in place over which global private networking facilities will be created. Subsequently new services will be made available on the basic international network infrastructure built on global intelligent networking like those proposed for GLOBALSTAR or IRIDIUM. By this time, a full band-width-on-demand is likely to become global with the extension of Asynchronous Transfer Mode (ATM) from national networks to the global networks.

To integrate new cost effective technologies and services with existing operations of NICNET, for facilitating transparent network access by users for their computers, a protocol intependent transparent network design will be adopted until all major telecom standards of ISO are implemented. Greater through-put from communication lines connected to host computers and the ability to interconnect with public data networks, will have to be provided for. To become a global network, in addition, round the clock availability must be ensured. The demand of the user having multi locations business systems over spacially spread functional entities performing the same or similar transactions, to the point of accommodating multimedia EDI services, are required to be addressed while catering to reliability, quick response, information security, information integrity, data veracity and localised maintenance. The network design should be incremental, in the sense of modular expansion of the network, to accommodate growth, simply by blocking modules, with least disruption to the users. The network recovery operation should be incrementally automated. The design should be made insensitive to network topology. The network resources should be optimised automatically. Above all, the total system cost should be minimised at every stage of the expansion of the network.

As NICNET is basically a data communication network, the network architecture during global expansion in the initial stages, will continue to be hierarchically packet switching. The remote user access nodes are connected to central nodes or central concentrator in a tree structure. The traffic from a number of remote user access nodes may be multiplexed before passing on to the central concentrator over high bandwidth links. The central nodes themselves are connected in a star topology to switchers. The switchers are, in turn, connected to each other as a mesh network. An intelligent multiplexer can be installed between the user and the remote user access node so that a number of user terminals can be multiplexed as a synchronous error correction data stream to the port of a single remote user access node.

A packet switching mechanism delivers data over the less congested routes. The remote user access nodes internalise the external communications protocols. Data integrity can be maintained through packet acknowledgement.

Network gateways are provided between NICNET and the PDNs over an X.25 synchronous link with multiple logical channels accessed over corresponding switched virtual circuits. PADs are located with the user enabling the multiplexing of a number of asynchronous terminals over a single high speed X.25 synchronous link analogous to the intelligent multiplexer. With host PADs we can interface NICNET and non-NICNET hosts for enabling the translation of NICNET internal network protocols to the protocols recognised by the receiving host.

The effective operation of the network on the above basis is possible only when an effective network management and control system is designed along with. In the face of a continuous expansion of NICNET towards globalization, such a management and control would require an incrementally intelligent management and an incrementally adaptive control [8-12]. This is the subject matter of the next Section.

4.CONCEPT OF AN INCREMENTALLY INTELLIGENT NETWORK

The complexity of a global network is portrayed in vivid detail by Robert K. Heldman in his book 'Global Telecommunications - Layered Network's Layered Services' (Publ: McGraw-Hill INc., 1992). According to his global layered network's layered service model, we can categorise the ascendance of complexity in terms of ten layers as given below:

Local:	1.	Customer Premises Network (CPE)
	2.	Transport Access Nodal Networks
	3.	Switched Packet Information Network
	4.	Network Application Service Centres
	5.	CPE Application Service Centres
Regional:	6.	Regional/State point of Presence (POP) Access/Service Nodes
National:	7.	National Inter-Exchange Carriers (IXC)
	8.	National Application Service Centres (ASC)
Global:	9.	Global Value Added Networks (VAN)
	10.	Global Application Service Centres (ASC)

For the introduction of network intelligence in the above Heldman hierarchy, we postulate that the following functional hierarchy is required as an additional dimension giving a matrix of (structural hierarchy x functional hierarchy) at the elements of which intelligence has to be infused.

1. The layered architecture networking functions

   a) Planning function
   b) Client-Node function
   c) Server-Node function

2. Signaling Function

   a) User-User Signaling
   b) Node-Node signaling
   c) User-Network Signaling

3. Service Management function:

   a) Service Object creation
   b) Service Database and Knowledgebase creation
   c) Network Management Database and Knowledgebase creation
   d) Expert Interpreter function
   e) Adaptive Scheduling function.

4. Integration of Traffic and Facility:

   a) Facility restoration
   b) Flexible routing

5. Master Executive Function

   a) Demand Assigned Variable Speed Data Transmission
   b) Demand Assigned Call Processing
   c) Access Channel Processing
   d) Monitoring and Control

The above order of functional hierarchy is only indicative. The priority may change depending upon the technological preparedness for increasing intelligence, operational convenience, etc. Each of the 17 functional categories given above may not apply to each of the layers in the Heldman Hierarchy. In other words, the structure-function matrix may have a number of zero elements. Once the priority grading is established as part of a macro plan, each element may be taken step by step for infusing intelligence. It is this step by step process of introducing intelligence in the network which we call as structure-function matrix based 'Incrementally Intelligent Network' (IIN).

There are two aspects of IIN which basically decides the type of AI methods that are required to be employed gainfully. Customer or service based functions related to service delivery and traffic navigation. Integration of sub-functions in a function, sub-structures in a structure as well as structure-function integration call for intelligent integration.

In a knowledge-base that is created, containing production rules for decision making or problem solving, it is necessary to understand how the database and the corresponding knowledge-base components communicate with each other.[13] Typically, how the expert system decides which of the rules, decision trees or objects in its knowledge-base correspond to the situation described in its database should be resolved by the inference mechanism. It is assumed that the knowledge-base has been created in the form of a combination of production rules, decision trees and object oriented networks. The problem posed here is resolved by searching for patterns of logical relationship between the knowledge-base and the database. In an object oriented network, the pre-determined patterns of inheritance within the classes of objects, trigger certain actions or events to occur within the expert system. These objects in turn, might activate specific functions or rules to lead to a specific result or conclusion. For such a process of testing rules in an optimal sequence, the standard inferencing techniques of forward chaining or backward chaining are utilised as outlined in the well known and standard flow diagrams described in Fig.2. To infuse the intelligence in any of the elements of the matrix for efficient management, the hypermedia tool is essential for enabling

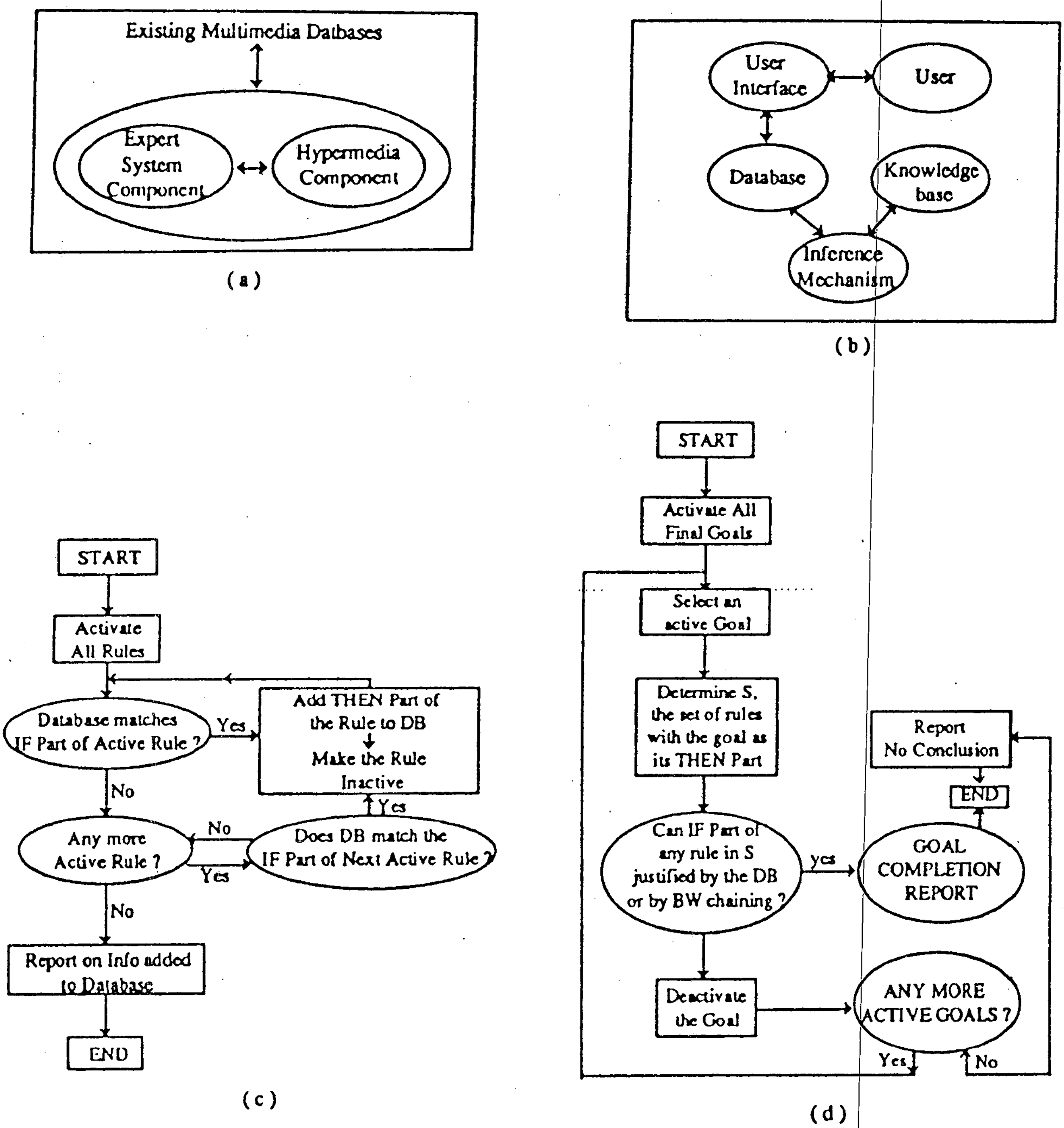

Fig. 2 : (a) & (b) : Intelligent hypermedia with embedded Expert System
(b) & (c) : Standard Flow Diagram for forward chaining and backward chaining

navigation through information in a non-linear manner. Hypermedia also simulates our ability to organise and retrieve information by referential links in the form of relational object oriented network. The non-linearity helps in moving or jumping from one point in the programme to another based on the patterns of relationships that are explicitly defined.

Though a powerful tool for intuitively inter-connecting information, hypermedia cannot directly render intelligent applications. While providing a flexible context for representing knowledge, the application of the hypermedia tool does not lead to reasoning or inference ability. For this reason, there would have been compulsions to take hypermedia tool only as a supplement to AI techniques like expert systems and Neural nets. However, there are other more important considerations which prompted us to take the reverse aproach, ie., designing the intelligent system based primarily on the hypermedia, but including an imbedded expert system component [13, 14]. The existing information resources in massive quantity, are drawn to create the backbone structure of the system, while the expert system components are required only to provide specialised local functions. AI technology is veering more and more towards text-based approaches than intelligence-based approaches in the form of rules as systems can be built faster by side-stepping the laborious knowledge engineering process. This will emphasise hypermedia as the core of the intelligent system with the expert system components carefully imbedded in it to infuse intelligence.

A development tool that can combine hypermedia technology with expert systems is KNOWLEDGEPRO windows which works under the Microsoft Windows environment [14]. This tool was chosen because of its features like field hypermedia handling, excellent string manipulation ability, use of inheritance windows library of screen design tools and a powerful programming environment for expert system development, apart from the basic requirement of a high level of integration between expert systems, hypermedia and windows component. The supplementary use of another software product, KNOWLEDGEMAKER, can introduce a rule set from a group of examples that developers can directly import into KNOWLEDGEPRO or a number of other development tools. Although KNOWLEDGEPRO's inference mechanism is primarily backward chaining, it is possible to programme to chain in a forward direction also.

The above approach for the use of AI techniques in the process of infusing intelligence into any of the elements of the structure-function prioritization matrix, is found to be appropriate and convenient in the design of IIN. A brief description of the requirement of intelligence in the 5 main categories of functions outlined above is given respectively in the next five sections.

5. INTELLIGENCE IN THE PLANNING OF THE LAYERED ARCHITECTURE

Global IN interconnets network of networks synergetically assuming seamlessness of the component network. Both virtual private networks (VPN) and universal personal telecommunication (UPT) are by and large seamless. Coordinated provision of services over network boundaries is essential to ensure personal mobility of UPT users globally. In VPN, coordinated provision of services over a wide area is necessary to ensure the same service capabilities at different locations of network access. Further, providing enhanced service over international boundaries requires analysis of distribution of functions for them. Selection of the best scheme among those possible can be made under certain criteria like impact on inter-exchange signaling, flexibility and expandability, performance and efficiency, security, etc. All such requirements point to multi-lateral activities across network operators. At each network level, such activities may include physical, transport, routing, services, etc. To provide global services, increasing cooperation in coordination will be required in the adaption of international standards with respect to services creation, services interaction, security, etc. All these emphasise a macro level planning requirment on a layered architecture model as shown in Fig.3. This model incorporates a mixed scenario of

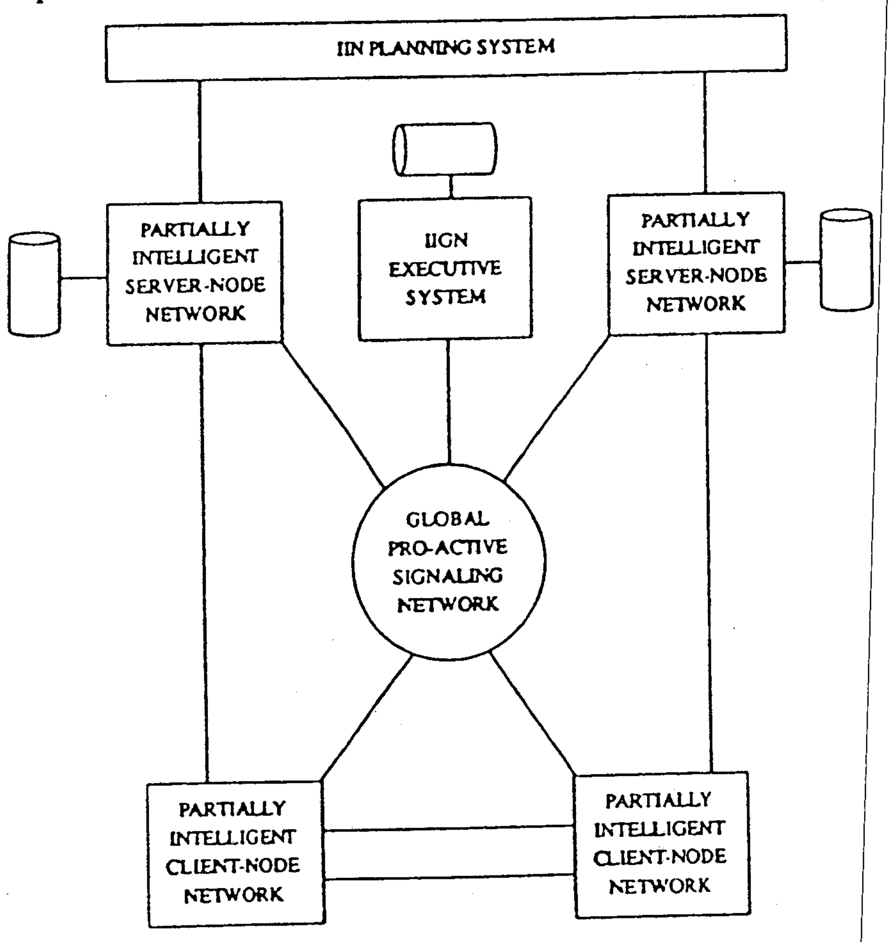

Fig. 3 : Basic IIGN Layered Architecture Model

(a) Service data and associated service control functions local to each network are provided in the IN in individual networks and signaling capabilities are provided for interaction between them, and

b) a shared IN system is provided for a common use among different networks, which is to be accessed from individual networks through a global signaling network.

For planning navigation and integration at this macro level, hypermedia technique with embedded expert system of Fig. 2 can be utilized to chart out a course for infusing intelligence incrementally in the process of globalization of the network. In the context of an intelligent planning of the route map infusing intelligence, subject to the availability of various technologies, one can intelligently plan for a contemporary service management function as described below:

6. USER-NODE EXCHANGE OF SIGNALING INFORMATION

The signaling information can be exchanged between the user and the network node as shown in Fig. 4. Many signaling protocols have evolved in the ISDN framework to support such interaction. Two major signaling ISDN protocols, viz., digial subscriber signaling No. 1 (DSS-1) and Signaling System No. 7 (SS7) are currently available for providing real time control and operation in the distributed telecom networks by supporting the exchange of information between intelligenet elements like terminals, switches and databases within and between private and public networks [15-18]. These protocols provide functionality similar to what is found in the application layer protocol in the Open System Interconnection (OSI), i.e., they provide a context along with the necessary functionality for the various applications to communicate with little knowledge of the network infrastructure on which they operate. As SS7 was originally designed for

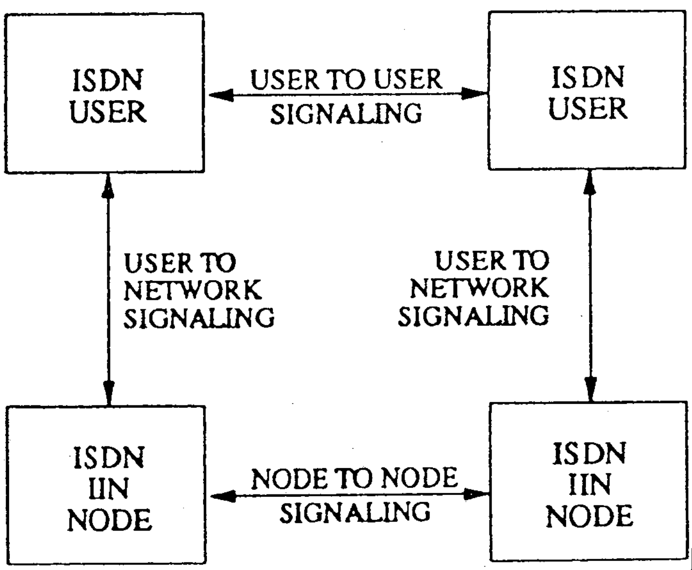

Fig. 4 : User - Node Exchange of Signaling Information

use within and between the public carrier networks, the SS7 protocol has been chosen for the IN overlay of NICNET. It is expected that with long term ISDN control architecture getting based on the OSI application and presentation layer structure and protocols, thereby furthering the alignment of ISDN and OSI, an upward evolution along this path is likely to be a smooth passage to the unified protocol that may emerge merging DSS-1 and SS7. Eventually, SS7 will also facilitate smoother interconnection of ISDN networks as it has a mature set of network management functions. The SS7 also provies the following advantages in inter-connecting telecom networking :

- It supports the rapid exchange of large amount of information between nodes in the same or different networks, thus allowing for a wide range of new services.

- The ISDN transport capabilities and interface support band-width alternatives ranging to 2 Mbps

- The ISDN network management capability supports both layer management and OSI system management applications.

ISDN supports distributed communication. This makes possible global networking requiring coordination between processes in different networks.

VSAT-enhanced ISDN has been the subject of indepth studies [19] [20]. It is demonstrated by Rana et.al that ISDN over satellites can be achieved since a satellite network provides a digital communication system with flexible band width and offers wide area communication using numerous configurations like private satellite based ISDN, integrated broadcast, interactive station, SS7 support, intelligent network support, etc. In a country like India, where substantial investment in terrestrial infrastructure has not yet taken place, VSAT-enhanced ISDN can be an economical solution.

7. ADAPTIVE INCREMENTALLY INTELLIGENT NETWORK SERVICE MANAGEMENT

Services creation and provision environment is conditioned by the user-demand for variation in service capability, flexibility and convenience, which is satisfied by intelligent network functions [21-25]. Such a provision can also be made through powerful networking functions and signaling capabilities faciltated by ISDN at the user-network interface and within the network. Service customisation can be realised by providing services which allow the customer or network providers to freely define newly required services. It may be required to provide an applied interface with service control processors in the real network under multi-vendor conditions. Such an interface should have facilities for handling databases and protocol. For the former, an SQL is utilized while for the latter, signaling system

No. 7 (SS7) is utilized. Both are widely accepted standards. The system has a service description language, network initiated service and user-initiated service.

The requirement of shortening the response time of the network to the service request of the customer as well as the freedom for customer in-service provision, as required by the service customisation, require computer-based processing. For maximum flexibility and efficiency of such a computer processing we require intelligent hypermedia with imbedded expert system. Such intelligently programmable network based services are intrinsically more convenient and powerful tending to the introduction of ISDN in the IN architecture. An intelligent signaling capability provided in ISDM inside the network as well as at the network-user interface would enable service customisation to take full advantage of the ISDN features. With the creation of not only a network database, but also network knowledge-base, direct registration of service parameters by a customer to the service database and knowledge-base would be provided.

We assume that the basic Bellcore model to IN comprising of service switching point (SSP), signal transfer point (STP) as part of the SS7 Network, service control point (SCP), service management system (SMC), etc. for global coverage, multiplicity of SCP atleast one in each region or country would be required with the service data distributed to the database of these SCPs. As far as possible, it is necessary to ensure that SSP to SSP signaling is independent of IN services and should not be used for transfer of information related to IN services. This calls for a direct SCP to SCP communication for transfer of information related to the services. The design is such that the ISDN user accesses an SCP and SMC easily. The design also should ensure that the service network is independent of both hardware systems and services provided.

In service customisation, one has to cope with not only a variety of services, but also their unpredictability thereby calling for flexibility in the environment for service creation and provision. As multiple service components cooperate to provide a service, a standard interface is necessary to bridge the various components. Portability of service components is another requirement for achieving flexibility.

Service creation and execution is carried out in four basic steps. A language is required for describing individual services by an appropriate combination of service components and their control flow. A translator subsequently translates the service description into an executable form as an object programme referring to a library of service component software parts. Subsequently, the service object programme is loaded into appropriate nodes in the network so as to additionally keep track as to where each service programme has been loaded and decide where to load new programmes. Lastly, the service execution provides for execution of programme services according to the control sequences.

For providing a service requested by the customer, the necessary components required for each service has to be prepared which would include service control processes, like database access and authentification of service access codes, call processing routines, resource management message storage control and switching control. If the service control processes and call processing routines can be divided into components, the synthesis of an appropriate set of service components along with their control sequences would represent the service. Such an integrated scheme is conducive to more flexibility in service creation.

The Kokusai Denshin Denwa Co (KDD) of Japan has developed an experimental system in ISDN development for advanced services [21]. The system proposed here for implementation on NICNET has a broad conceptual similarity with the KDD system. However, in the KDD system, a marginal extrinsic use of AI is made which cannot lead to intelligent service management. In Fig. 5, we describe an adaptive incrementally intelligent service management system for development as an overlay to NICNET.

SSP, SCP and SMS will be implemented by dedicated minicomputers - Call Controllers (CC), Service Handlers (SH) and Service Managers (SM). The minicomputers are interconnected through an SS7 network along with SS7 protocol in addition to the communication between SCP and SMS.

A brief description of the hypermedia based expert system for service object creation, network management database and knowledgebase, intelligent service execution, expert interpreter function and adaptive scheduling function are given below:

Service Object Creation: For the definition of the service to be provided, the source scenario is described in the service description language after obtaining the customer's inputs and marketing inputs for the creation of service specifications (See Fig.5). The source scenario so constructed is then translated by the translator in the SMP into an object scenario by a hypermedia based navigation in a scenario management library with source information such as identification codes, parameters of already defined scenarios, definition of reserve words and the library consisting of databases as well as knowledgebases. The expert system decides which of the rules, decision trees or objects in its knowledgebase correspond to the situation described in its database through an inference mechanism. For each CC or SH node in the network, scenario is defined along with conditions under which each scenario is invoked.

Network Management Database and Knowledge-base: An object scenario so created is loaded into the computer nodes in the networks and becomes the input to a subsequent stage of intelligenet service management with hypermedia-based expert system. To enable efficient retrieval when the scenario is executed, information about which nodes the scenario has been loaded into is registered into the network management database in t he target nodes. A corresponding

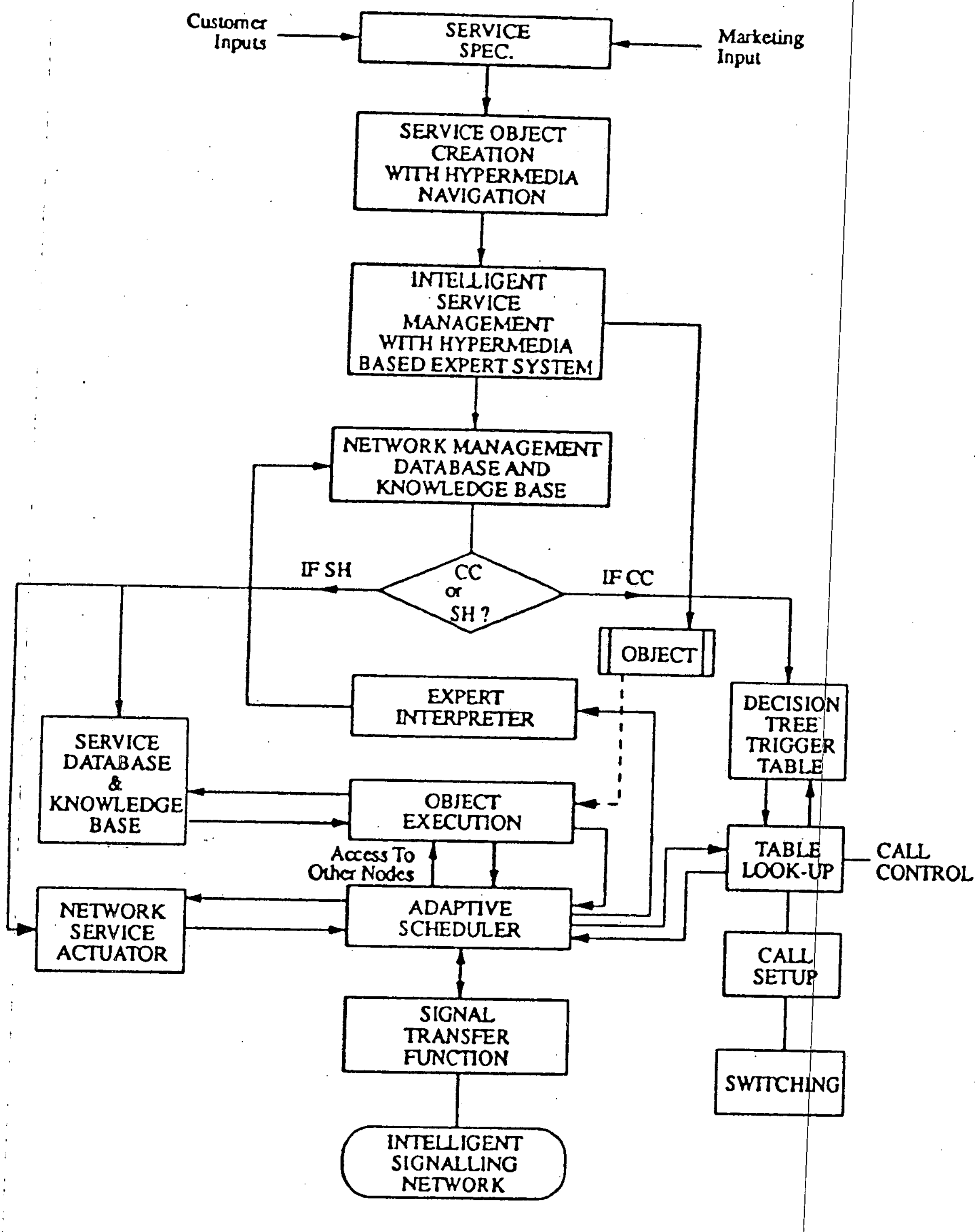

FIG. 5 : Adaptive Incrementally Intelligent Service Management

knowledge-base is created in the form of a combination of production rules, decision trees and object oriented networks. The trigger conditions are also registered in a decision tree structure of a trigger table in the target call controllers based on the information received in the service definition stage. The trigger table identified is a table to be invoked for each subscriber at each face of a call.

Intelligent Service Execution : The call processing routine looks up the decision tree trigger table to get the scenario number for invocation. If a scenario is required to be executed for a particular subscriber at a particular call face, the call processing routine requests its invocation to the adaptive scheduler with the scenario number.

Expert Interpreter Function: The adaptive scheduler refers to an expert interpreter routine to execute specific scenario. To enable this, an interpretation knowledgebase is created for the expert interpreter to operate on. Such a knowledge-base can be part of the network management database and knowledgebase. By accessing this database and knowledgebase, location at which specified scenario is stored is read out for execution. If the scenario in the CC calls another scenario guided by the network management DB and KB, the expert interpreter requests its invocation to the remote node through the adaptive scheduler. A similar system exists for the service handler. However, the SH is assisted by a service database and knowledgebase for being accessed by service scenarios. A network service actuator in the Service Handler realises the network initiated services in the same way as the call processing routine functions in call controllers. An example of such a service is the reservation based call service for which a call between users concerned is initiated at specified point in time from the network.

Adaptive Scheduling Function: For processing multiple services, the adaptive scheduler controls multiple expert interpreter routines in each service execution environment and appropriately allocates or de-allocates them to various scenarios. The adaptive scheduler also manages all dialogues between the expert interpreter routine and external routines including call processing routines, network service actuator and the interpreter routines. The adaptive scheduler works on the basis of a hypermedia navigation through information in a non-linear manner. Hypermedia also enables the adaptive scheduler to organise and retrieve information by referential links in the form of relational object oriented network. The non-linearity helps in moving or jumping from one point in the programme to another based on the patterns of relationships that are explicitly defined.

The above described adaptive incrementally intelligent service management system utilizes a development tool called, KNOWLEDGEPRO Windows which can combine hypermedia with imbedded expert system. The software, KNOWLEDGEMAKER, can introduce a rule set from a group of examples that developers can directly import into the KNOWLEDGEPRO. In the above context, the inference mechanism in KNOWLEDGEPRO makes use of an upward chaining predominently and forward chaining supplementarily.

8. INTELLIGENT INTEGRATION WITH FLEXIBLE ROUTING AND CAPACITY CONTROL

The design of the global IN overlay of NICNET allows flexible band-width allocation technique at the link layer and flexible routing technique at the network layer, so as to maximise network performance quality through intelligent capacity control mechanisms [25-27].

Each node in the NICNET overlay has 2.2 Mbps maximum rate of transmission per module with the vairability adjusted between 16 Kbps and 2.2 Mbps. The intelligent network management system will adjust the rate at each node depending upon the forecast of the demand a hour or two ahead. However, the summation of the rates over all the nodes will not exceed the value corresponding to the total value of band-width on the satellite transponder.

Band-width allocation methods, signaling protocols and per call control of network components can permit the capacity sharing in a multimedia environment. For the advance packet switch environment, we may either specify the maximum band-width to be used for each service at a specified time or assign a portion of digital capacity to be shared by all traffic types and split the remaining bandwidth into one or more band-width categories dedicated to particular services.

The global IN overlay would increasingly depend upon intelligent flexible routing strategies enabling high availability under a range of network conditions including failures and overloads. Such flexibility enables quick, automated response to rapid changes in network loading to maximise utilisation of available capacities. At the design stage both time dependent routing and state dependent routing were considered. The latter was finally chosen because, the network state information gets determined online for responding to real time traffic fluctuations. Out of the three possible main flexible routing methods, viz., flow optimisation, state dependent strategy and learning automaton, the latter which adopts a decentralised call by call strategy with either linear reward inaction automaton or dynamic alternative routing or a combination thereof, is preferred in view of the scope for the application of AI techniques in a natural manner. As indicated in Fig.6, the adaptive facility restoration and the strategies of integration of traffic and facility lead to an intelligent integration of traffic and facility with adaptive flexible routing. In the adaptive facility restoration method, automatic cross-connects are implemented under intelligent control of the IN control nodes such that failed facilities are reconnected in accordance with the provision of facility restoration capacity, which is used until physical repair can be attended to. A provision is provided as described in Fig. 7 for multiple infow/outflow routing which allows the concept of toll switches, end offices or homing to more than one switch. It is possible to combine AI techniques with operations research models to determine economical network solutions.

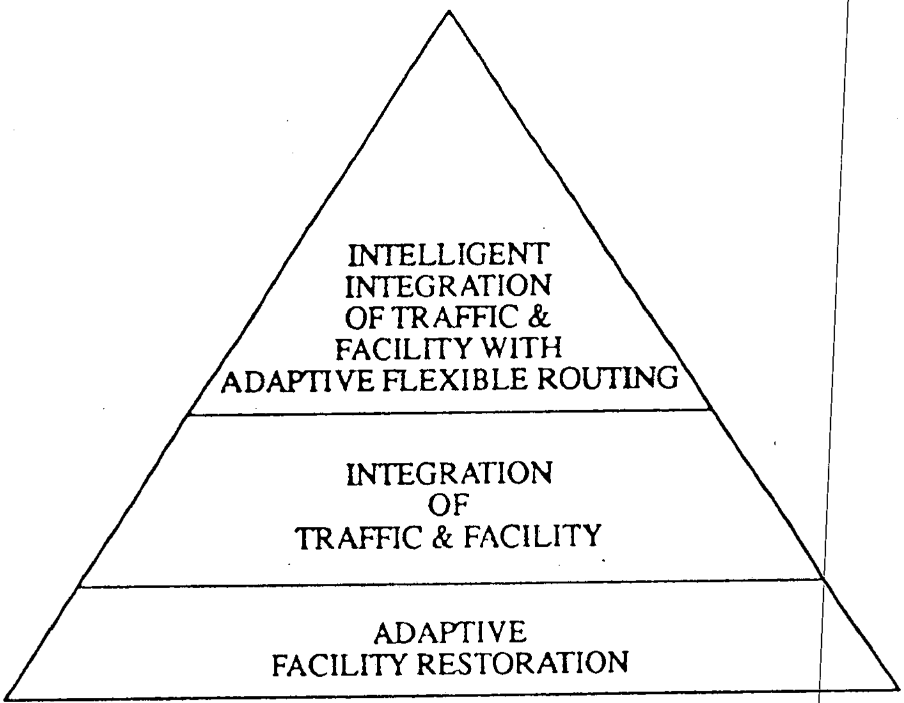

Fig. 6 : Intelligent Integration with Flexible Routing

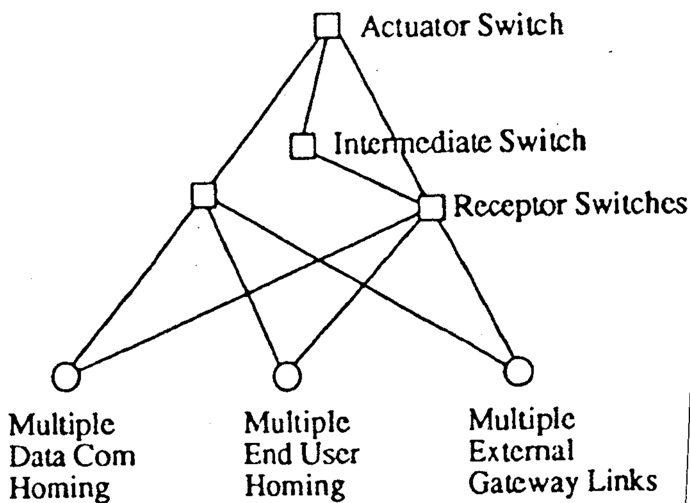

Fig. 7 : Flexible Inflow / Outflow Routing

9. NICNET HOOKS FOR LINKING TO LOW AND MEDIUM EARTH-ORBITING SATELLITE CONSTELLATION

A number of world-wide message networks based on constellation of low and medium earth-orbiting satellites are planned for the Nineties [28] [29]. Three of the major ventures are: IRIDIUM of Motorola, GLOBALSTAR of Laurel Qualcomm Satellite Services Inc., PROJ ECT-21 of INMARSAT, etc. A network like NICNET which is evolving to an incrementally intelligent network, can cut development time and costs substantially by providing adequate number of hooks for tagging along to one of these three global networks when they get stabilized. Negotiations are under way in this direction. Until a firm alliance with one of them is established, the evolution of IN overlay of NICNET will emphasize the design of generic hooks which can be easily re-designed when a collaboration or alliance gets firmed up.

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