National Knowledge Commission

A report on National Knowledge Network

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Chapter 1: Introduction

Research and Development activity world-over in various fields is increasingly being carried out through inter institution and trans-country collaborative approach. This has become necessary owing to the increased activity in computationally intensive and data intensive research problems and greater emphasis on numerical techniques for analysis. Besides, the infrastructure needed for the front-end, cutting-edge research and experimental simulation, requires investment which is beyond the means of several research institutions and its duplication, in any case, is economically unviable.

The key ingredients in this approach are:

- Consultations
- Data sharing, and
- Resource sharing

To achieve these objectives, the approach adopted worldwide has been the extensive use of ICT through dedicated networks created for Research and Education. In most countries, the onus of such front-end research and propagation of education, is a state responsibility and such networking efforts are invariably supported by the state with funds being provided either directly or through the institutions involved.

Towards the lower end of the institutional hierarchy, several countries have extended facilities to colleges and schools with a view to either popularizing scientific enquiry or increasing awareness amongst the larger population, in particular the younger minds in their formative stages. In addition, there is an approach of sharing of resources, in particular, on special course materials and interaction with specialized resource persons or faculty in an interactive fashion. The concept of e-books or digital books shared between various libraries has gained considerable popularity with libraries being at the forefront of setting up Library Nets.

The common denominator in the modern approach to all such research and development, educational, and other similar requirements, is the need for a network. The type and capability of such a network created at a substantial cost to the tax-payer is important, to ensure that the network does not become obsolete very quickly and is able to meet the current requirements of the participating entities.

This paper examines:

- The need and the possibility of intra-country and inter-country collaborative approach in India for R&D and education
- The approach adopted in several countries
- The efforts made in India on education and research networks so far
- Networking requirements and associated network design issues
- The status of infrastructure in India
- The possible approaches and associated infrastructure, financial implications and time frames needed, and
- The recommended approach.

Chapter 2: The Approach adopted by Other Countries

Countries such as the U.S., all European countries, several north African countries, several Asian countries bordering Europe, South Africa, etc. either have or plan to have high capacity exclusive networks with advanced research as the key objective. Several of these networks extend beyond national boundaries and linkup with other countries' Research and Education networks. Some key networks have been discussed below to bring out the essential themes of these networks.

The US National Lambda Rail

The National Lambda Rail (NLR) initiative is a high speed national computer network created for the exchange of data "in order to maintain United States' edge in research, technology and innovation (including research in network technology itself)". It will have extensive fibre optic, supercomputing, storage and visualizing capabilities to link universities and research organizations based on a dedicated network.

This network is owned and managed by a consortium of US universities and private companies. The university grouping Internet2 is a major partner. In available literature the main reason cited for university and research centres owning the network, is that it provides greater autonomy over research projects of the universities.

The stated goals of the network include: to push beyond the technical and performance limitations of today's Internet backbones, to provide growing set of major computationally-intensive science (e-Science) projects, initiatives and experiments with dedicated bandwidth, and to enable and to rekindle the possibilities for highly creative, out-of-the-box experimentation and innovation that characterized facilities-based network research during the early days of Internet.

The architecture of the network consists of NLR backbone with several regional nodes forming a trans-continental network. The regional nodes are components of the Core as

also regional access points to the NLR.

The technology used is the Dense Wave Division Multiplexing (DWDM) on nearly 15,000 route-miles of dark fibre. Four NLR wavelengths have been implemented using a a 10 Gigabit Ethernet Local Area Network (LAN).

European Research and Education Networks

European Universities and research institutions have been, in a sense, pioneers in adopting networking as a tool for research and education. This approach was adopted as early as the eighties with the setting up of national networks with pan-European connectivity. The latest pan-European network GEANT2 is in fact, the seventh generation network.

The most common legal model for a national network is a National Research and Education Network (NREN) which is a separate legal entity. This separate legal entity is controlled by the research and education community which itself is largely government funded.

In European countries, the provision of network services to research and education is organized at three levels viz. the Local Access Network to which the user is connected, the national infrastructure provided by the national research and education network and the pan-European level for which a separate network GEANT (latest version GEANT2) has been provided. In terms of network architecture, this amounts to a multi-level network with the services being managed by a pan-European organization at the top level and national agencies at the national level. The national networks, the NRENs, are themselves often organized in a multi-layer configuration with Regional and Metro Area networks. Diagrammatically this could be represented as follows:

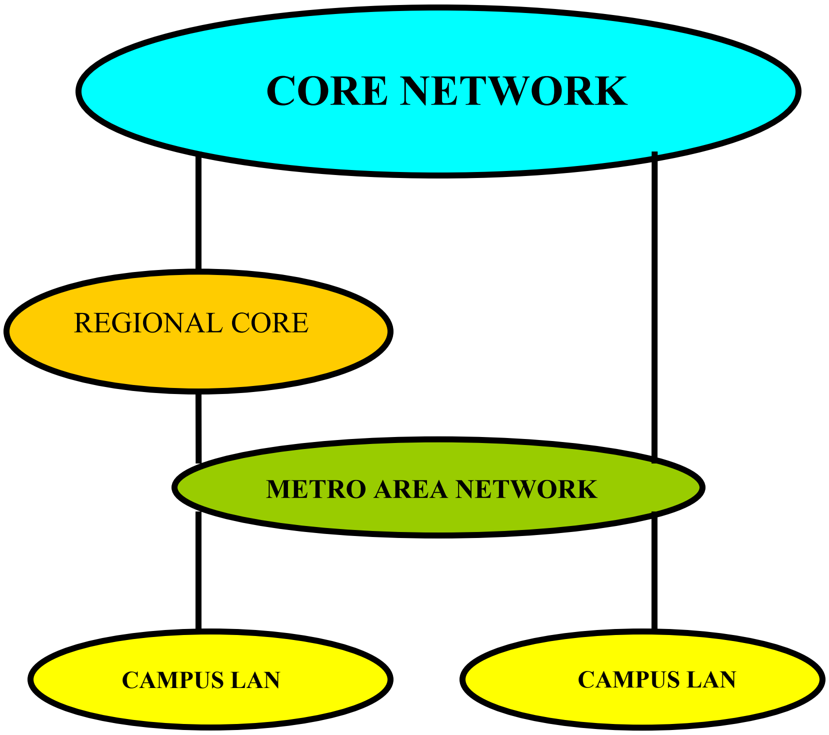

Figure 1: A typical National Research & Education Network configuration

National governments fund the network. This is particularly so because the responsibility of encouraging advanced research and education is a field which is the responsibility of the governments of the various participating countries.

So far as the bandwidth of the core network of the national networks is concerned, as of 2005 it was between 1 to 10 Gbps in most of the countries barring some small countries and some east European countries. In 2001, very few countries had 2.5 Gbps core. The rate of growth of the core and access networks has been quite phenomenal which is indicative of the large demand for such services. In fact, the rate has been higher in countries which have been late entrants to the networking arrangement for research and education. Herein lies a lesson for countries like India.

In Europe two pan-European organizations have been created[2]:

- DANTE (Delivery of Advanced Network Technology to Europe Ltd.) is the not-for-profit company, owned by a number of the NRENs in Europe. The task assigned to this company is to organize, manage and provide international advanced data network services for the research community.
- TERENA (the Trans-European Research and Education Networking Association) has four main tasks assigned to it. These are:
  -fostering new initiatives,
  -supporting joint work in evaluating, testing and integrating new technologies
  -organizing conferences and workshops for information dissemination, and
  -representing the common interests and opinions of its membership.

The existence and structure of these organizations have played a very important role in the success of the European networked research and educational programme.

The experience of this network has brought out certain key issues which need attention in the setting up and operations of such networks. These are:

- Traffic congestion is most evident in the entity LANs and to a smaller extent in the MANs and the Regional networks but not so in the core.
- Authorization and authentication need special attention with the growing utilization of Grid applications.
- Coordination and operating organization has to be carefully shaped and put in position for smooth functioning.

[2] David Williams (editor), et.al.,Summary Report on the SERENATE studies 'Study into European Research and Education Networking As Targeted by eEurope', Document no. D21, 31 December, 2003

- Funding of the network both at the stage of setting up as also for operations has to be such that maximum independence is ensured and the users have a role to play in the setting up/expansion as well as operations.
- Defining and ensuring Quality of Service in the IP network is an important challenge.
- Security of data is another concern.

South African National Research Network (SANReN)

Currently an organization called TENET arranges general internet access for some of the institutions as a “bandwidth consortium”. The coverage includes all universities and technical universities reaching more than 600,000 users. The bandwidth is offered at half the commercial rates but is regarded as expensive even after this substantial concession.

A need was felt for an increased bandwidth NREN based on certain demands. The key driver for SANReN seems to be research in the area of Radio Astronomy and the presence of a large Radio Telescope-The Square Kilometer Array Radio Telescope (SKA) and the need for international collaboration for the data analysis. South African Government is creating such a network (called SANReN) through TENET’s assistance. Several research areas are expected to benefit including astronomy, high energy physics, bio-informatics and medical science. This network will have a dedicated connectivity (initially at 1Gbps) to GEANT-the European network via the satellite. This along with submarine cable SAFE connectivity will ensure South Africa’s connectivity to over 3000 research institutions world-wide.

Architecturally, the SANReN will have a 10 Gbps backbone with up to 10 Gbps connections to sites. The network will be commissioned in several phases. In the first phase 10 sites including TENET gateway will be connected. In the second phase another 10 sites will be connected and more sites will be covered thereafter. A key aspect is that the government is committed to use legislative and regulatory options to reduce cost of research bandwidth.

Chapter 3: Efforts made in India on Research and Education Networks

The first steps in India for utilizing ICT potential towards promotion of education and research in the country was through ERNET- a Society under the Ministry of IT&C in the Department of Information Technology. This, of course, does not take into account the satellite based experiments-SITE- and later deployment of satellites in broadcast mode for education now being practiced by institutions such as the Indira Gandhi Open University. Initially, ERNET set up a network based on satellite channels, for the use of educational and research institutions. This network has gradually expanded utilizing leased circuits on optic-fibre cables to have the capacities offered to institutions in the range 565 kbps to 34 Mbps through direct Internet connectivity. ERNET's backbone is currently an 8 Mbps network connecting about 13 cities with 342 radials connecting more cities. There are 1389 institutions which are already covered by the ERNET. The backbone has 13 points of international connectivity using submarine cables of International Long Distance Service providers. This network offers circuit switched connections with contention ratios ranging from1:1 to 1:4. A 45 Mbps international connectivity through an international leased line, has been provided from Mumbai to the European network GEANT. This capacity is mostly being utilized by the Department of Atomic Energy (mostly Tata Institute of Fundamental Research). This capacity is proposed to be raised to 622 Mbps. It has been proposed to upgrade the entire network to a MPLS based network with a core network capacity of 1Gbps. For provisioning a Core network of this capacity, leasing of lines is being proposed. Further enhancement of the Core capacity is also being considered.

Recently a separate programme for providing 100 Mbps connectivity to 45 computers for Grid networking, under the project 'GARUDA', has been taken up in which 30 institutions are being connected in the first phase as a proof of concept project.

There is a proposal to combine the two networks into a single MPLS based VPN capable network with a core of 1 Gbps.

In addition to the ERNET efforts, the National Informatics Centre (NIC) has taken up a major project for the introduction of e-governance in India. This proposal envisages creation of a Gigabit backbone based on leased lines to provide broad band access up to the district headquarter level with hardware procured, installed and maintained by the NIC. This network will have a Data Centre at Delhi and will be controlled by NIC. The network is later to be expanded to block headquarter level. The proposed network will be a converged services network which will provide data, voice and video services to the end users. The basic scope of the proposed network is to provide G2G and G2C applications by developing IT infrastructure to network government departments for dissemination of information to citizens. It also envisages providing help in developing a knowledge society. It is further claimed that though the Gigabit National back-bone over NICNET will be primarily a Government network, resources can be extended to Research and Educational Institutes, such as universities, CSIR, DRDO, Bio-technology laboratories.

The basic architecture of the network is a partial mesh connected core connecting 6 nodes at 10 Gbps. Below this hierarchy will be the Distribution devices located at state capitals and connected to the core at 10 Gbps and below this level will be the Access Devices which will be connected to the Distribution layer at 1 Gbps. At the core, there will be deployment of MPLS for services like L3/L2 VPN. As already stated, the proposal envisages creating a leased line based network. The reason cited by NIC for this approach rather than using the commercial networks is to have control of the government over routing and data storage hardware for security reasons.

Besides these networks and network proposals, there is a proposal from the CSIR to set up a Scientific Knowledge Grid, interconnecting CSIR Labs on a separate network. The project envisages provisioning of 2 Mbps access to each of the connected entities with one Data Centre which will have 155 Mbps connectivity. The objectives of the project are to provide Enterprise Resource Planning, Laboratory Data sharing, video conferencing, HRD training, Facility management and Data Base services. This network is to replace the current RENNIC (Research and Educational Network) of NIC which was created to provide primarily e-mail and text based internet with connectivity to 38 laboratories and headquarters. The access speed provided by this network was 1200/2400 bps. Subsequently, a SCPC-DAMA satellite based network was set up by CSIR which provided a 2x64 kbps connectivity of various laboratories to the headquarter and direct interconnectivity between two nodes at 64 kbps.

It is thus seen that several parallel attempts are being made to cater to narrow focus applications though the network proposal of NIC claims a much wider applications base. The key aspect in all these approaches is that they are based on the old concept of leased lines for private networks with considerable capital investment besides manpower deployment for operations and maintenance. There also appears to be some tendency towards duplication.

Chapter 4: Networking Requirements and Associated Network Design Issues

Connectivity to be provided to around 5,000 nodes covering all universities, technical institutions, medical and agricultural institutions, related R&D laboratories and libraries. This is the requirement of the final and ultimate network. The actual implementation could be in phases picking up 500 to a 1,000 nodes in the first phase. The design of the network will have to be based on the final network. The method of selection of nodes in the first phase will have to be decided. The prioritization of the nodes for implementation purposes may be on the basis of the nodes which are most likely to use the network from day one and which would be able to demonstrate the benefits of such a network.

The access bandwidth will be 100Mbps to begin with and has to have the capability of upward or downward revision depending upon the experience of the user. It could be argued that not all nodes need 100 Mbps bandwidth. It is possible to go into the details of the likely requirement of bandwidth by each node. However, such estimates without a network being in place will at best be educated guesses. The approach being suggested here is that the existence of good infrastructure is likely to provide incentive to possible development of innovative applications. Since this is a major requirement of the NKC's concept of a Knowledge-net, it is recommended that the proposed approach of planning for plenty rather than planning for poverty, is adopted.

Network configuration will be hierarchical with built-in reliability. The network will consist of a nation-wide **Core network** connected in a ring or mesh configuration at the first level of hierarchy. The Core network could be a single hierarchy or a two stage network with a higher speed network at the top to accommodate network architecture flexibility and security concerns in a VPN based network of commercial IP-MPLS networks. The available bandwidth in this core has to be such as to provide networking sessions between various institutions without congestion. The bandwidth will depend on the flow of traffic but as a first estimate has to be at least 2.5 Gbps and preferably 10

Gbps or higher. It should be possible to connect several common interest institutions in groups whose network should be independent of the other similar groups and yet have the flexibility of interconnection of the groups so formed, if required. The next level will consist of an **Aggregation or Distribution network** level which again will be in a ring (but not mesh) configuration. This could be a city-wide area network for a multi-organization city or a regional ring linking a few cities. Lastly, the final level will be the LAN on which the entity data centre and user terminals will be located and this LAN will be connected to the Aggregation network either directly or through a suitable Access network. The access segment, which we could call the **last mile,** will generally be optic fibre cable due to the requirement of 100Mbps access bandwidth. Though this will be the bandwidth up to which the Access network will be capable of functioning in the first phase, it is evident that this bandwidth will not be required at all times and by all the user entities. Therefore, to economize on the cost, it will be necessary that appropriate rate limiting arrangements with linked charging schemes be available. Ideally, bandwidth on demand should be available. The Access or Edge network could be a ring or a PON or a point to point link providing access to the core network through the aggregation level.

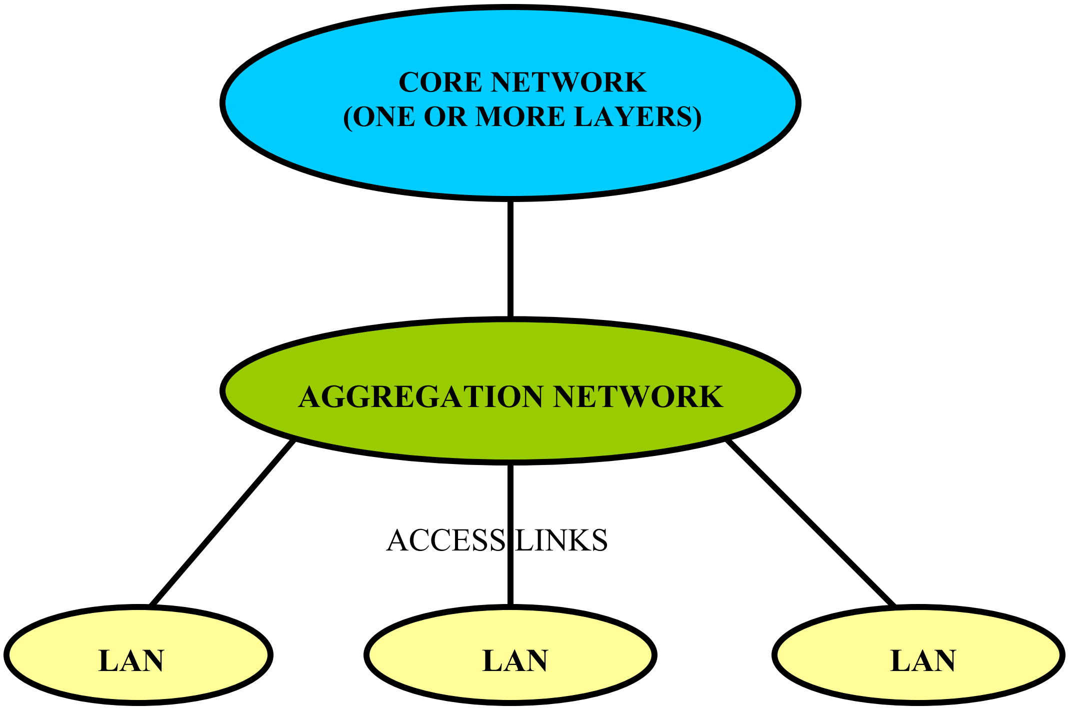

Figure 2 : Network Configuration.

Single terminal based access to the network for all applications including internet based applications, is the preferred arrangement based on feedback from some prospective major users. This would require ability to access and use Internet at high speeds. The connectivity to the International bandwidth could be made at two or three routers located on the core network, at locations where cable landing stations are available.

Connection Reliability/SLA will be a key concern for most of the operators. In the network design this will translate into duplication of links and homing nodes. This has a direct implication on costs. Higher the redundancy, higher will be the cost though not in direct proportion. The cost implications of connection reliability will be the highest (both in terms of the capital required for network buildup and in operational costs for the maintenance staff required) if dark fibres have to be leased. The cost implications will be the least for the solution based on operators core network (due to the distribution of such costs over a large number of user organizations sharing the costs).

Bandwidth guarantee has to be provided on the access link of the LAN of each entity. It is to be considered whether within a LAN a specific terminal needs to have bandwidth priority at a given instant for a specified period of time under the control of the software command of the administrator to ensure the requisite availability of bandwidth by that terminal. A typical case would be to cater to the needs of a video conference in which large quantities of data is sought online from another location.

Security, Privacy and Confidentiality are issues of major concern when this type of networking is envisaged. Methods will have to be evolved both at the time of commissioning of the network as well as during operations, to ensure security of data along with privacy and confidentiality. Access to the data from the Data Centre of a given entity should be under the control of the entity being addressed. An arrangement for authentication and authorization with the participation of the connected entities will be required to be firmed up and put in place.

The considerations and issues listed above and the brief discussions on them, give the flavour of the network requirements. Not all requirements can be met to their ideal limits if costs are to be kept within reasonable limits. More importantly, several parameters such as the SLA parameters, the authentication and authorization scheme, etc. will have to be firmed up as a follow up of this concept paper.

e- Governance: Another issue which needs critical analysis is ‘whether this Knowledge Net and the proposed network for introduction of e-governance in the country should be a single network?’ The motivation for this question is that when both the Knowledge Net and the network for e-governance are to be funded by the government – former to promote R&D and education and the latter to make the G2C communication efficient and transparent – why shouldn't one attempt optimization of costs and maximize utilization of funds. In this context it is useful to refer to the relevant recommendation of the National Knowledge Commission which is reproduced below:

> *National Infrastructure*—It is important to provide nationwide secure broadband infrastructure and associated hardware, software and hosting facilities with easy access at all levels. This infrastructure should be based on user-pays principle and Public-Private partnership in investments and mutual accountability and efficiency. This infrastructure creation should be led by the central government to enforce a high level of security, uniformity and standards at every interface, regardless of state language, culture, legacy and financial health.

In the above recommendation, the NKC has clearly indicated the need for networking but has not attempted to define the nature of the required network. It is therefore necessary that while designing another knowledge related network, the possibility of using the same network for e-governance purposes must also be analyzed and commented upon.

The entire set of issues covered above have been kept as the basis for the network design and commented upon in detail in chapter 6 on 'National Knowledge Network – Possible Approaches'**.** In chapter 6 a set of alternatives have been developed and analyzed and the most economical and quickest to implement alternative, which fully meets the network design objectives outlined earlier, has been recommended.

Chapter 5: The Status of Infrastructure in the Country

Thanks to the visionary thinking of the Department of Telecom in the eighties and the nineties and the subsequent aggressive approach of public sector and private long distance service providers subsequent to the liberalization and opening up of the telecom sector, India is today endowed with over 700,000 route kms of optical fibre cables of various sizes and at least some of the operators cover all parts of the country. The break up is as follows:

- **BSNL:** BSNL has a countrywide 550,000 route kms of optic fibre cable network with a fibre POP in over 35,000 locations throughout the country. This amounts to an average of 15 kms between the POP and any village in the country. A 10 city based MPLS network has existed since 2003. Currently MPLS Core network has over 100 nodes with 2.5 Gbps connectivity with 5 fully mesh connected nodes which is being upgraded to 10 Gbps. The core network nodes other than these 5 nodes have 2.5 Gbps dual homing arrangement in a ring configuration which is also being raised to 10 Gbps. This figure of over 100 nodes is slated to rise to 600 nodes by 2007-08. Currently 350 cities have a Gigabit Ethernet network for Access for Broadband services. Optic Fibre access is made available up to the customer premises. There is a main Network Operating Centre (NOC) at Bangalore with a disaster recovery NOC at Pune.

- **VSNL:** VSNL has a 40,000 route kms optic fibre network covering 300 major cities. It has 6,000 route kms of local loop covering over 2,700 cities. It has a 9 domestic node and 4 international node MPLS Core network with 114 domestic POPs and 14 international POPs. In addition, it has 255 Metro Ethernet POPs across 8 cities. MPLS core is directly over DWDM fiber with full mesh implementation.

- **RELIANCE:** The network has 80,000 route kms of optic fibre cable covering 226 cities. The cable is a 48 core cable. The core network is based on DWDM technology and has 40 Lambda capability. The network offers IP VPN backbone with SDH and Metro Ethernet services at access. In the Access network Optic fibre ring topology is deployed. The network has two centralized NOCs with 24x7 monitoring and fault tracking of the network. VSNL also has 60,000 route kms of optic fibre under sea cable for international bandwidth. It connects 12 countries across 4 continents. Another project, the Falcon, is on hand for enhancing international capacity.

- **AIRTEL:** The Airtel Optic Fibre consists of over 70,000 route kms of OFC with 30,000 route kms on DWDM. Each DWDM route has 32 channels of 10 Lambda each. Airtels MPLS network is a 3 layer network providing IP services presently on SDH but later on DWDM. The network has 29 Backbone rings, 47 Collector rings and 475 Access rings. The network presently has 125 POPs. 6 cities are on STM Backbone Capacity. The 2nd tier has 18 cities with DS3 (34 Mbps) connectivity with dual homing fully redundant POPs. The 3rd Tier has 96 cities nxE1 capacity. The number of POPs is proposed to be increased to 250 by Dec'06. A separate NOC is provided for enterprise customers.

- **RAILTEL:** Railtel has a 30,000 route kms optic fibre network along the railway tracks. The ultimate plan is to reach 43,000 route kms. The transmission technology currently used is STM-16 (2.5 Gbps capacity) or in near future DWDM with multiple lambda capability. Each railway station has a STM4/STM1 POP. There are a total of about 400 POPs. The network has MPLS capabilities with 10/100 Mbps Ethernet as well as gigabit Ethernet. In the Access network, more than 2600 stations have been covered with at least 155 Mbps capacity out of which Railways use 2 Mbps only.

Presentations were given by all the above service providers on the possibility of setting up a National Knowledge Network utilizing their infrastructure. During the extensive discussions that followed these presentations it became clear that there was considerable excitement in the industry about the proposal for such a network and there was tremendous enthusiasm expressed by each entity to be part of such an effort either singly or jointly. In terms of the technology status, it is clear that at least three and potentially all five service providers have or will shortly have the technical competence and physical infrastructure to handle the requirements of such a broadband network along with the necessary wherewithal to provide the desired service quality and operations support.

Chapter 6: National Knowledge Network

Possible Approaches

Several conclusions can be drawn from the material presented in the earlier chapters. These are summarized below:

- **Interconnectivity of research** and educational institutions has been practiced since the eighties in Europe and **successively more advanced networks have been created** for this purpose.
- The success and popularity of such networks is evident from the fact that the European networks **have not only expanded geographically** and into countries which can not be categorized as advanced **but also newer networks are getting created.**
- **The traffic flow has been increasing in as much as the core capacities** have risen from an earlier figure of less than 1 Gbps to latest networks **coming up with 10 Gbps and more**.
- The **funding of such ICT based initiatives comes from the government of the country** either directly for the network or through funding of the participating entities.
- The **networks have been set up** and run **utilizing either leased or owned infrastructure** in the form of long term Indefeasible Right (IDR) amounting to temporary ownership. As a result of such an arrangement, organizational infrastructure has had to be set up which is answerable to the legal entity owning the network.
- **International cooperation** through **inter-national connectivity** of networks with arrangements for data and resource sharing is a **common denominator** of all such networks.
- Intra-national spread of the networks varies substantially from nation to nation depending upon the **policy imperatives and national priorities**. Some countries have kept their networks for higher end R&D while others have extended the networks to schools, etc.

- **More than adequate infrastructure based on optic fiber cables is available in the country** to set up such a network.
- Not only is the infrastructure available in abundance, it is available from a number of operators offering the possibility of intensely competitive pricing.
- There are at least 3 and potentially 6 latest technology MPLS and DWDM based commercially run networks in the country capable of offering the infrastructure for such a network.
- Some limited and highly fragmented efforts have been made in the country to network institutions or computers, etc. The key characteristics of these efforts appear to be that they are limited to certain very specific areas or applications and are generally not visionary enough to take care of the full future potential of exploitation of ICT for research, development, education, and sharing of highly specialized infrastructure available at a few institutions in the country for the benefit of the common man at large.
- National Informatics Centre (NIC) of Govt. of India has taken up the task of setting up a network for e-governance based on the approach of hiring leased lines on the infrastructure set up by various service and infrastructure providers. This approach is equivalent to setting up an additional MPLS based Core network and the necessary access network.

With the knowledge of the above background, we can set about determining the possible physical arrangements of how the objectives outlined in Chapter 4, can be realized at a reasonable if not optimum cost.

Network Architecture:

In theory, once routers are located at adequate number of points, it is possible to have the traditional leased line network serving thousands of nodes which could have any to any connectivity. However, the economics when compared to other alternatives will need close examination. The present day technology is able to offer the type of connectivity desired, even by creating Virtual Private Networks with assured Quality of Service. However, security from Critical Information Protection or Critical Infrastructure Protection perspective will remain an unaddressed issue.

The conceptual architecture has been outlined in chapter 4 on 'Networking Requirements and Associated Design Issues'. The architecture is pictorially depicted in Figure 2.

The network is proposed to be in the Next Generation Network (NGN) format where the access and core layers will be based on the Internet Protocol (IP) on top of the optical layer based mainly on wavelength division multiplexing WDM or DWDM. The Internet layer will be enhanced for Quality of Service and control by deploying Multi-Protocol Label Switching (MPLS). Such an approach is expected to provide connection oriented features as also guaranteed service levels. It has been reported in the literature [3] that for the success of this approach a well designed platform is necessary which will control the way in which connections are established, maintained and terminated. Standards such as GMPLS and ASON (Automatically Switched Optical networks) are available from standardization bodies such as Internet Engineering Task Force (IETF) and ITU-T's standardization divisions. In fact, IETF supports the extension of MPLS and MPLambdaS to GMPLS that deals with an integrated control plane for multiple layers (MPLS, SDH, WDM, fiber). No effort is being made to define any of the protocols such as SNMP, etc. in the IP layer. Such an approach is expected to be able to provide on-demand bandwidth- another design issue mentioned in Chapter 4 rather than manual configuration. Discussions reveal that the cost effectiveness of the software based reconfiguration of networks continues to be a far from settled issue. Perhaps the service

[3] Folis Karayannis, et.al. "In-Field evaluation of a managed IP/MPLS over WDM provisioning solution"' IEEE Communications Magazine, Nov 2005, volume 43, no.11.

providers in India may have plans to adopt some suitable platform in the near future; but it might await international technology trends and commercial viability.

Ownership of the Network:

For the realization of the proposed Knowledge Network, four alternative approaches are possible:

The **first approach** would use dark fibers leased from one or more telecom service providers or Infrastructure providers (with IP-1 license). In this approach, all the hardware such as Gigabit and Fast Ethernet Routers, etc., set up for a Network Operating Centre along with a Disaster Recovery Centre at a physically different location, the necessary software for MPLS based networking, etc. will have to be procured. For this a separate agency would be required. More importantly, an agency will be needed for the operations and maintenance of the network. This is a highly specialized activity and would require a fair complement of well trained staff. Thus, in this approach, while the ownership of the entire network including the physical transmission media rests with the operator, the transmission and data network hardware as well as the control of the network access will be with the agency installing and operating the network. It will have to bear the cost of capital as well as recurring operating expenses.

The **second approach** is essentially the same as the first approach, except that instead of hiring dark fibers, **Lighted Fiber** will be hired from one or more operators. The difference with the first approach is that only limited equipment is to be procured and emphasis will be on wholly owned IP and MPLS equipment. In this approach also an agency to carry out procurement of equipment and later on for operations and maintenance will be required similar to the first approach discussed above.

In the **third approach** emphasis is on outsourcing. Initial version of the proposed network will be created using the existing MPLS based DWDM commercial network of one or more telecom service providers. However, the ownership and the responsibility of operations as well as ensuring a guaranteed bandwidth, as desired, will rest with the network service provider. The apex level coordination will rest with the team of the Network owning entity. This entity could typically be a consortium of the participating agencies. Owing to the relatively little experience of government agencies, in particular, about the use of the VPN approach based on commercial networks for their own networks, concerns relating to security and safety of the research data when a commercial network is used, still persist.

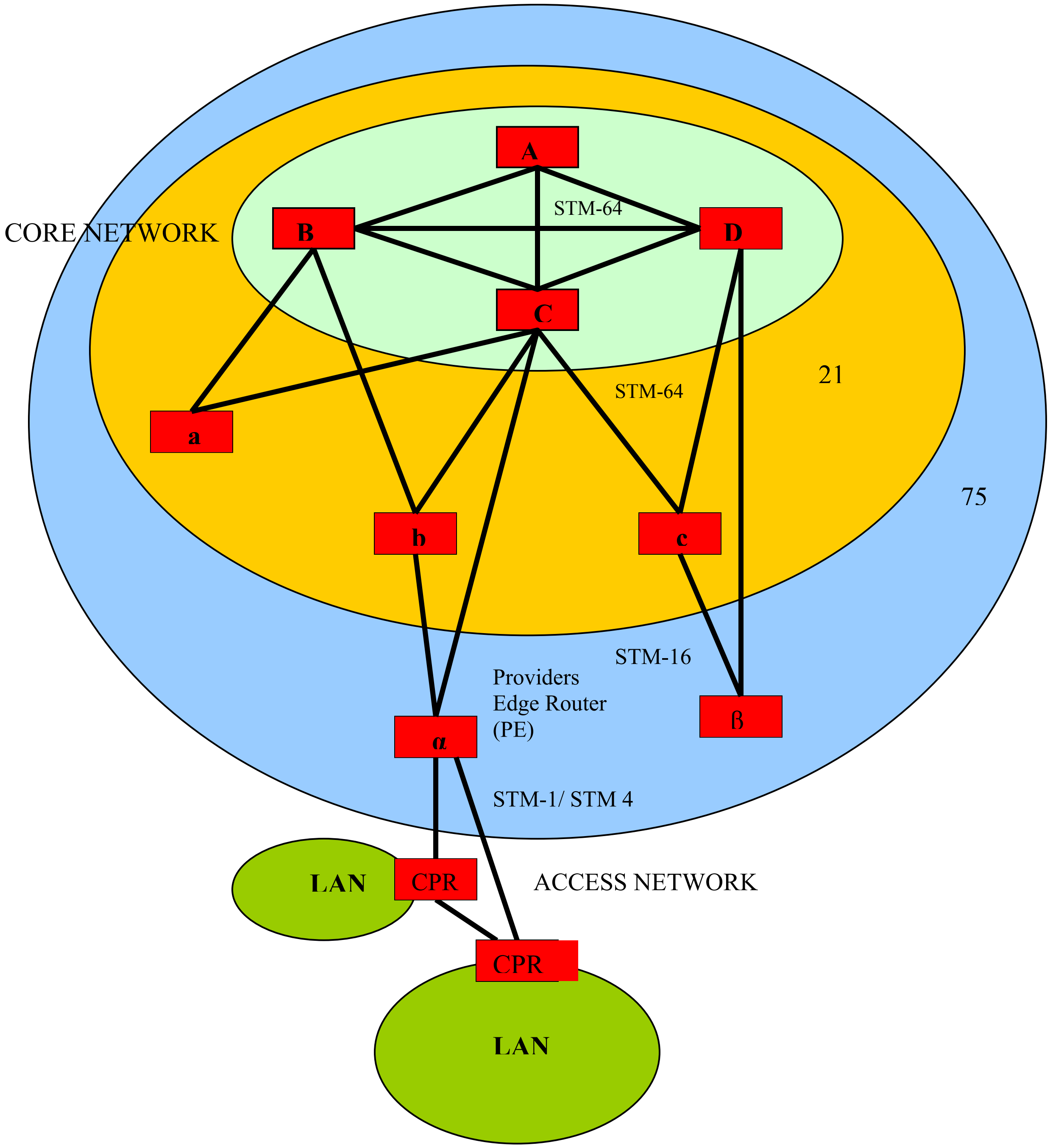

Figure 4 : Sample Network Configuration for Comparison of Options.

(1000 Node Network with a core of 100 centres)

The background material, presented in the earlier chapters of this report, indicates that most countries have gone for the first approach. These are the countries which had gone in for NRENs quite some time back when the normal approach for creating a private network was based on leased lines. These networks have been upgraded to MPLS base but the ownership pattern continues to be the same viz. these are owned by the participating entities while the operations activity is outsourced to an appropriate agency. One of the reasons quoted for this approach is that with complete ownership of a network by Universities and R&D institutions, they have complete freedom in setting up connectivities as they desire. They are even able to carry out research in new networking protocols and technologies. **Often, the less articulated reason is national security.**

While one approach to overcome these doubts would be to extensively test the network security and network architecture flexibility aspects on an actual VPN based network using commercial IP-MPLS networks, extensive discussions with some network experts have resulted in an alternative **fourth approach** which is a hybrid approach. In this approach the core will consist of two layers in which the inner higher speed layer will be wholly owned by the stakeholders while the lower layer of the Core will be the Core network of the commercial service providers. The Distribution and Edge segments of the network will be covered by the network of the service providers – but all of them have the same IP-MPLS-VPN framework. The major stakeholders will own, operate, and manage the inner Core through the Special Purpose Vehicle to be formed. The inner Core will have speeds orders of magnitude higher than the rest of the network. Besides, the Core will have the ability to connect all those institutions that have a need to directly connect to the Core due to performance, reliability, security, and architectural reasons. However, since such connectivity will entail considerable cost, careful screening of all such requirements will have to be done before undertaking a request for direct connectivity to the inner core. Interconnection protocol related issues will have to be extensively discussed with the service providers at the time of finalization of the specifications. A diagrammatic conceptual presentation is given in Figure 5 below.

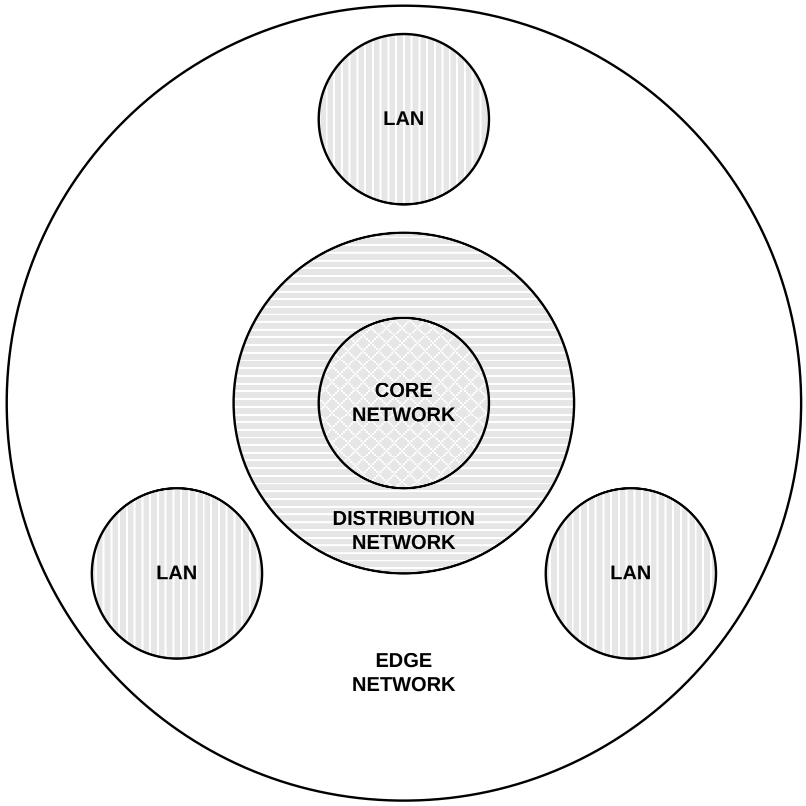

Figure 5: Recommended Hybrid Architecture

The latest trend in provisioning of private networks is to go for MPLS based networking which provides huge flexibility to the owners in respect of bandwidth they pay for and the set up they want to create besides maintaining total confidentiality of data by having layer 3 switching. Further, organizations find that cost optimization is possible with outsourcing i.e. the cost of keeping an infrastructure for operations and maintenance is avoided and service quality is guaranteed through service level agreements. Extensive research is being done for testing and finalization of standards which would permit seamless connectivity of networks of different operators having equipment of different manufacturers.

seamless connectivity of networks of different operators having equipment of different manufacturers.

Network Costs:

The first two approaches differ from the third approach in that both of them require capital expenditure besides the recurring expenditure on operating and maintaining the network. In the third approach the capital expenditure may be quite small if the operator chosen has an already deployed and well established infrastructure thereby minimizing the need for additional expenditure on ownership basis i.e. capital expenditure. The expenditure will mostly be on operations of the services that is of recurring nature.

Budgetary cost estimates were sought from various operators. Certain assumptions have to be made whenever such cost estimates are worked out since the actual cost based on best commercial policies, etc. become available only after competitive bids are invited. While most of the operators responded, the cost data of one of the operators which was most exhaustive has been used to estimate the cost of the network under option 2 and option 3 situations.

The cost estimation has been done for a 1000 node network in the architecture given in Figure 4 above. It has been assumed that 4 routers constituting the inner ring of the Core network will be mesh connected on STM-64 and another 21 constituting the regional collectors will have dual homing arrangement with the 4 main core routers again on STM-64 links. In addition, the remaining 75 routers (which will be purely edge routers) will have double homing with the inner 25 routers on STM-16 links. The connectivity of the LANs will be on STM-1/STM-4 optic fibre rings. It is to be noted that this is not necessarily an optimum network design but its hierarchical nature brings out the clarity required for understanding the network and comparing the financial implications of the three ownership options discussed earlier. In actual practice, a more complex network with aggregation arrangement using possibly Ethernet switches will be deployed. If we had used such a network for comparison, the complexity of the network would have overtaken the basic objective of arriving at an appropriate option. The detailed calculation sheet is at Annex 1 while the conclusions are presented below.

It is evident that the network based on option 2 viz. based on leased bandwidth involves heavy capital (Rs 375 crores) besides the annual recurring cost of Rs 858 Crores. In the case of option 1 while the bandwidth costs viz.Rs 858 crores will be eliminated, these costs will actually shift to the capital cost head in the form of expenditure on transmission equipment and their maintenance. However, the most interesting aspect is that if Option 3 is followed i.e. the existing commercial MPLS network of a service provider is utilized, only the annual recurring cost will be involved. Based on the estimate given by one of the operators, this figure is around Rs 40 lakhs per port. At this rate a 1000 node network will cost Rs 400 Crores annually at the commercial rates. The operator has indicated that this cost may come down to a much lower figure of the order of around Rs 200-300 crores annually for a network of the type being proposed. For this option, some operators who do not have a very widespread network have indicated that some capital investment may also be required to cover all the institutions being included in the list. One operator has suggested a capital cost sharing model where some fibres will be used by the operator and some by the Knowledge Net. All operators have indicated their preference to the option of utilizing their MPLS based network for setting up this network rather than leasing bandwidth or dark fibres. In fact, one operator has indicated that though he has a vast network, dark fibres are not available up to the district headquarters. Some IP-1 service providers have indicated the availability or willingness to lay fresh fibres on shared cost basis.

For the hybrid architecture i.e. **the fourth option**, the actual cost estimation becomes rather difficult at this stage because a number of variables continue to be unknown. These are:

- Number of nodes on the inner Core.
- Number of entities which will be directly linking to this Core and will therefore have a leased line based access.
- The Core bandwidth is likely to be multiple 10 Gbps for which the router costs are not easily available.

However, if we are able to restrict the number of nodes and the number of entities directly linking with this Core, the cost maybe of the order of Rs 1000 crores.

The analysis and discussion presented hitherto imply that we need a judicious mix of approaches to address all concerns and the least cost solution may or may not work out as the solution answering all questions. One of the ways is use the 3rd approach to start with and seamlessly slide into using the 4th approach within a 12-18 months period, in order to meet all the design requirements outlined in chapter 4. Besides, in terms of the time frame needed for implementation of a 500 or 1000 node network, a mixed approach will be the fastest.

In our view therefore, the 4th approach, which is the hybrid model is the most promising and practical model and is therefore recommended.

Motivation and Assistance for setting up FE LANs:

We have earlier commented that the responsibility of setting up or upgrading LANs to have adequate capabilities to be able to utilize the Core and Aggregation networks of the Knowledge Net should be that of the user entities. A question however arises whether all the entities proposed to be linked on the Knowledge Net, will want to spend the money to set up suitable LANs. Further, even when they have the desire and motivation, whether will they have the resources to do it. Time frames are another important consideration. There is a need to assess the financial requirements of all the institutions and a one-time incentive to set up such LANs is provided by the government. The costs which would need to be covered should include FE LANs network and equipment only and not the terminal or customer equipment (computers, etc.) unless social objectives such as coverage of colleges in backward or remote areas are involved.

Chapter 7: <u>Conclusions and Recommendations</u>

The key conclusions from the discussion presented are as follows:

1. It is evident that a National Knowledge Network interconnecting all universities, all technical institutions, all medical institutions, all agricultural institutions, all related R&D institutions, all libraries and all Universities with an access network providing up to 100 Mbps connectivity for optimal utilization of resources to give a major push to research and spread of quality education, is required and is entirely feasible.

2. It is recommended that the complete list of institutions to be covered is identified for the design of the 'Vision Network' but the implementation is carried out in phases. In the first phase those institutions should be chosen which are most likely to utilize the networking arrangements to establish the validity and usefulness of the network in Indian conditions. The total number of such institutions could be 500 to 1000 depending on the criterion found acceptable.

3. The network will consist of multiple levels- Core Network, an Aggregation or Distribution Network, an Access or Edge Network of appropriate optic fiber based technology, and a Campus LAN.

4. The network will have the capability to create Virtual Private Networks (VPNs) in groups which have commonality of interest such as one VPN for all particle physics related institutions, another VPN for all biotechnology related institutions, and so on. If required, these VPNs can interconnect for temporary or permanent consultations. For example, if an educational course material is to be shared between two or more institutions interactively, the creation of VPN or VPN interconnectivity for the

duration of the session will have to be the task of the Network Operating Centre (NOC).

5. The network will deploy a combination of routers and Ethernet switches to optimize costs based on the likely usage of bandwidth by any given institution.

6. Rate limiting features will be deployed to enable charging for bandwidth on actual use basis while providing the facility for access speeds up to 100 Mbps to any LAN.

7. From the viewpoint of cost, the approach based on the utilization of the commercial MPLS based networks available in the country appears to be most attractive to start with. This is because in this approach the capital expenditure may be negligible if the operator chosen has a well established network which is being used by a number of customers. However, lack of experience, particularly, in government entities of architectural flexibility and security aspects on VPN based networks set up on commercial IP-MPLS networks, does not give enough assurance to allay all the fears of the prospective users. The recommended approach is therefore to begin with a commercial IP-MPLS based VPN network and then slide into a hybrid network in which there will be a central core, hopefully of a relatively few nodes, with the remaining outer network constituted by practically each one of the other operators network.

8. In line with the recommended evolved hybrid option, work on the setting up of a core network at the highest hierarchical level to link several commercial networks and act as the architectural flexibility provider with a very few nodes, has to be taken up even as the commercial VPN based network is getting commissioned. Such a core will require procurement and installation of IP based network. Its maintenance and operations will be a highly specialized task. Preparations to ready a competent team

for this task will also have to be completed. This task may be carried out by the creation of a SPV manned by a limited number of staff.

9. The actual cost of setting up of the network will consist of the capital cost incurred by the participating entities in upgrading their existing LANs to have compatibility with a core network capable of providing access upto 1 Gbps and the annual recurring cost of creating a Multi-Gigabit IP based core network. Besides this initial expenditure, the capital cost of setting up the higher level core will also be involved over a period of time.

10. A 1000 node commercial IP-MPLS based network will be feasible at an annual recurring cost in the range of Rs 200-400 Crores, based on the optimized network design once the actual node sites and locations are identified and surveyed for the availability of access infrastructure. The cost of the higher level core network will consist of the bandwidth hired for this purpose as a recurring expenditure and the capital expenditure on routers and other IP equipment. There will also be an expenditure on the manpower maintaining and operating the network as part of the SPV, but this cost will vary with the number of nodes set up in the high level core.

    For the changeover to the hybrid architecture the actual cost estimation becomes rather difficult at this stage because a number of variables continue to be unknown. These are:

    - Number of nodes on the inner Core.
    - Number of entities which will be directly linking to this Core and will therefore have a leased line based access.
    - The Core bandwidth is likely to be multiple 10 Gbps for which the router costs are not easily available.

    However if we are able to restrict the number of nodes and the number of entities directly linking with this Core, the cost maybe of the order of Rs 1000 crores.

11. Once a decision has been taken on the actual implementation of the Network, we recommend the formation of a group of experts to firm up the specifications and carry out the actual task of procurement and implementation of the network. This group will also be required to firm up the Organizational setup needed for running the network on day to day basis.

12. The question 'whether the e-governance network and the Knowledge network or S&T network should be one single network' assumes importance and relevance depending upon the approach adopted for realization of the network. In the recommended approach in the first phase viz. Virtual Private Networks (VPNs) on commercial MPLS networks on DWDM, this question becomes a non issue because several VPNs can be created on a commercial network and they could be entirely un-correlated as may be the case with these two networks. If we were to go for a purely owned network on lighted fibres, this question would assume importance. On the other hand in the hybrid approach also, the e-governance network with entirely different geographical spread and much lower bandwidth requirements, can be realized as VPNs and the security and flexibility aspect could be addressed by the inner core. The issue of congruence of the two networks therefore no longer remains important and the issues can be totally dis-linked.

13. Establishment of a Special Purpose Vehicle (SPV) consisting of major stake holders is recommended. Such an SPV should have professionals pooled from various stake holder institutions for controlling and guiding the establishment of the network through various private vendors working on actual implementation. In this model, the policy and security control shall be within the autonomous structure and the operational support requirements shall be met from the industry. One of the compelling reason for such a mechanism, though it may not appear to be optimum, is to give assurance to the security community in the country, that use of cyber space will in no way compromise the security concerns of the country.

14. A high cost penalty continues to be paid by research networks for international bandwidth costs. The attempts of the Regulator to bring increased competition have not yet produced the desired results though there has been a decline in costs lately. In line with certain other countries such as South-Africa, legislative or other form of government intervention is recommended for lowering costs of international bandwidth .

Annexure I

Item	Quantity Required	Rate in Rs lakhs	Total in Rs lakhs
Core Network			
Core Routers	25	70	1750
STM-64 Interface in Core Router (3 for 4 routers and 2 for 21 ro	54	35	1890
Gigabit Interface (*2) for connecting to Edge Routers (2*75)	150	35	5250
STM-16 Interface in Core Routers for Edge Routers	150	20	3000
Edge Network			
Edge (PE) Routers	75	40	3000
Gigabit Interface (*2) for connecting to core at STM-16	150	18	2700
Fast Ethernet Interface at STM-1/STM-4 to serve 100 loops	200	22	4400
(100 loops will have at least two ports for completing the loop)			
STM-16 Interface for Core Routers 2*75	150	20	3000
Total IP Equipment Cost			24990
NOC including disaster management NOC	2	4500	9000
Total			33990
Installation Cost @10% of total equipment cost			3399
Grand Total Fixed Cost			**37389**
say			**37500**

Annual Costs:
Cost of bandwith lease on Transmission Links

STM-64 links	48	500	24000	
STM-16 links	150	360	54000	
		Cost of access links @STM-1/4 not included		
Total bandwidth cost			78000	
Maintenance Cost @10%of Total Fixed Cost			7800	
Total Annual Cost			**85800**	

Thus for the 1000 node network, Option 2 of leasing bandwidth will cost as follows:

Capital component		**375 Crores**
Annual recurring expen		**858 Crores**
		Depreciation cost not included
The cost of access network to connect the LAN to core net	10 loops of STM-1/4	These costs are common in all three options.
Cost of LAN equipment and OFC		