



India's Bandwidth Revolution: An Impact Assessment of NKN

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Ministry of Electronics and
Information Technology
Government of India



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CENTRE



A Report on
Impact Assessment of NKN

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Project Director NKN
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--- IIPA Team

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EXECUTIVE SUMMARY

Before the conceptualisation of **National Knowledge Network (NKN)**, bandwidth connectivity in order of gigabits per seconds (Gbps) was relatively unheard of in majority of the academic and research institutes. NKN brought with it a bandwidth revolution that completely revamped the information industry and became **India's Digital Highway**. NKN was designed by the premier technical visionaries of the country with an aim to deliver up to 10 Gbps bandwidth to its partner institutes (dealing with various sectors like research and development, education, space, weather, healthcare, defence, e-Governance and so on) and it delivered the same with very fast speed and agility. NKN also expanded its reach by peering with International NRENs (National Research and Education Network) and caching with leading content providers. This interconnectivity over a secured network enabled its partner institutions to avail several value-added services and enabled them to collaborate with similar other institutes. It also became the primary backbone for Digital India, thereby fuelling the e-Governance initiatives of the country. With NKN project about to complete ten years of its inception, Indian Institute of Public Administration (IIPA), New Delhi, was entrusted to undertake impact analysis of the current phase of NKN.

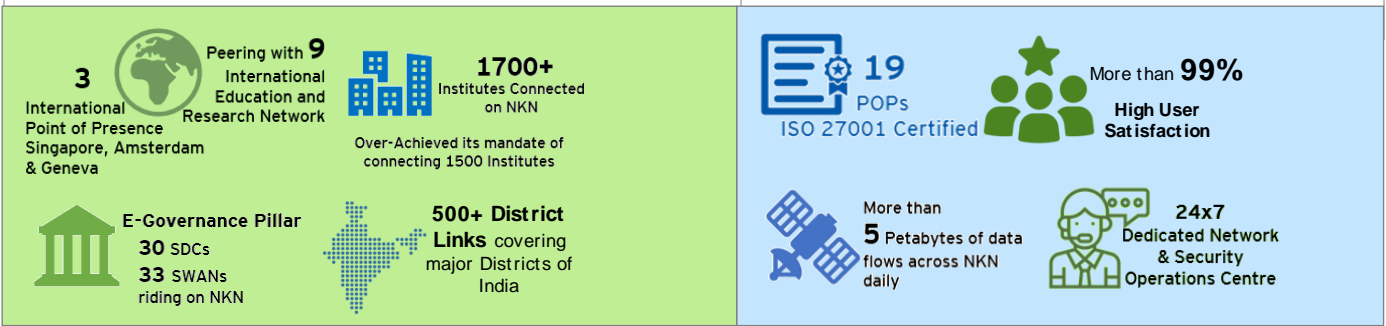
To do so, IIPA proposed a conceptual framework comprising of four essential parameters to be analysed *viz.*, **'Outreach', 'Quality of Service', 'Knowledge ecosystem'** and **'Value proposition'**, which were triangulated from three perspectives *viz.*, proposed **'Vision of NKN', 'Management perspective'** towards NKN and **'Perspective of Institutes'** that are using NKN with special emphasis on Digital India. To accomplish this, IIPA not just referred the available documents, official reports including Detailed Project Report(DPR), Cabinet Note, Minutes of all High-Level Committee meetings, but also conducted multiple structured/semi-structured interviews with NKN team and experts, as well as conducted a detailed primary study with a **Questionnaire Survey with the partner institutes of NKN**.

After this comprehensive and methodological evaluation, IIPA concluded that NKN has become an indispensable part to the R&D and educational community, as well as for the government. Observing the vital contribution of NKN, IIPA lauds its potential and **recommends the continuation of NKN**.

IIPA has also recommended that **NKN in its next phase should strive towards becoming a larger global** information exchange network than what it is today. It should continue to extend its connectivity with all major RENS across the world, should encompass more and more institutes and should also extend its local last mile connectivity till block level. By effectively leveraging the global and local connectivity NKN can provide more managed services to all its partner institutes as well as empower e-Governance initiatives, thereby ushering the next phase of Knowledge Revolution in the nation.

The table below shows the approach used for study, observation and recommendation from the perspective of each pillar.

<p>Outreach</p> <p><i>Approach:</i> Study of outreach of NKN amongst national and international institutions.</p> <p><i>Observation:</i> NKN has achieved its mandate of connecting 1500 institutions. More than 1700 institutes have been connected within the country. NKN has also provided backbone to Digital India by connecting NDCs, SDCs, SWANs, e-Governance applications, etc., thereby contributing significantly to the digital initiatives of Gol. Even on the international front, NKN has positioned itself as one of the known NRENs in the world by ensuring various international peering.</p> <p><i>Recommendation:</i></p> <ol style="list-style-type: none"> To consolidate its position as the largest network of its kind globally, it is suggested that in the next phase, NKN needs more entities on-board, thereby creating other government sectorial networks under the umbrella of NKN. This kind of approach would make NKN a Network of Networks. The knowledge domain of the complete value chain of the various sectors should be aggregated in NKN to ensure a fruitful utilisation by professionals, practitioners, industry and end users. For this, NKN must have various likeminded government organisations like ERNET, C-DAC, CCTNS, BBNL etc., on-board. This has also been whole heartedly endorsed in the initial proposed vision of NKN. On the technical front, NKN could imbue upcoming frontier technologies to stay future savvy. For instance, its core, in the next phase, can be upgraded with Dark Fiber technologies that would make the network more scalable and reliable. 	<p>Quality of Service (QoS)</p> <p><i>Approach:</i> Study of the technologies implemented in NKN that have ensured quality and expansion of NKN services to all the sectors.</p> <p><i>Observation:</i> A fail-safe three-layer architecture has been meshed at the super-core level to ensure redundancy and low latency. It was also observed that to minimise the turn-around time and have low latency without any bottlenecks, NKN had peered and cached with leading content providers. NKN also offers several value-added services as well as resilient customer support and security. Overall, NKN has performed well in this parameter, vouched by the primary survey too; more than 90% of institutes have rated NKN to be “excellent / very high” on all QoS parameters.</p> <p><i>Recommendation:</i> It is suggested that NKN needs to proactively increase the usage of NKN services and create more awareness in user institutes, may be by undertaking proactive multiple discussions and conduct workshops, video conferencing, etc. It would also be recommended to enhance peering and caching to encompass other leading content providers.</p>
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Knowledge Ecosystem

Approach: Study of how the secure and reliable connectivity of NKN has facilitated an increased flow of information and knowledge amid all its partner institutes.

Observation: NKN has acted as a platform and an enabler to bring almost all sectors, like research, learning and collaboration, education, health, agriculture, science, space, e-Governance, weather forecasting, under one platform. NKN, in the process, has connected more than 50 million end users.

Recommendation:

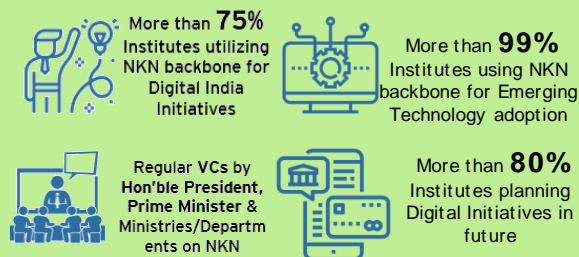
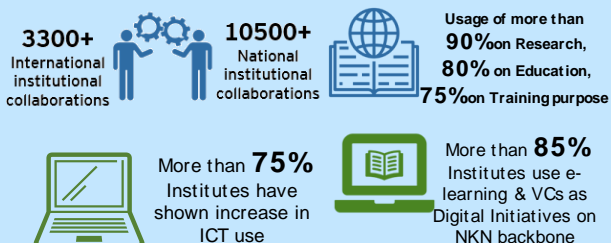
- Time is now ripe for NKN to be recognised as a one-shop stop for innovation, collaboration, sharing ideas, protecting and patenting them for which it needs to adopt a holistic Innovation Framework approach with a dynamic, self-explanatory Knowledge Dashboard.
- In its next phase, NKN should explore its virtual classroom ecosystem to achieve "One Class, One Nation".

Value Proposition

Approach: Study of the value proposition that NKN provides to the institutes in terms of cost saving, future services, branding opportunities and increase in the nation's wealth.

Observation: NKN has had direct impact on the knowledge, research and e-Governance economy of India. With its provisions of high-speed, connectivity, collaborations, information availability and global interface with minimal financial encumbrances, not just the partner institutes but the entire country has benefitted, explicitly and implicitly.

Recommendations: In its next phase, NKN must visualise itself as an umbrella that subsumes in it both NREN & National Government Network (NGN) of the country. This kind of convergence at all levels with existing government networks would help to maximise value addition to the country's economy sans duplication of efforts/ expenditure etc.



In short, the present study affirms that NKN has been able to successfully achieve the vision of its pioneers and holds a bigger potential for supporting the knowledge ecosystem of the country. Respecting the dreams of the national leaders and technology trends of the global ecosystem, NKN must recast itself as a citizen-inclusive Global Innovation Network with adequate outreach to its local grassroots. For achieving this, it must adopt a more structured knowledge management methodology that eventually culminates into an 'innovation management' approach. This would morph NKN from an 'information catalyst for the institutes' to a 'national tool for harnessing the innovation capital' of the nation.

Chapter 1

INTRODUCTION TO THE STUDY

1.1 CHAPTER OVERVIEW

The chapter delineates the objectives of the present study, starting with need for the study followed by the scope of work. The subsequent section depicts the stages of study undertaken. The chapter details the methodology of study under two phases viz., 'Review of Existing System' and 'Primary Research Analysis' and the various parameters of the assessment framework for the study that serves as a guiding template for the conduct of the study.

1.2 INTRODUCTION

The study of the impact of NKN is a challenge because of the enormity of the coverage not just in terms of its spread & growth, but also in regard to network penetration and technical superiority by which it can delight its users. The NKN journey started in India as early as 2008 (GoI, High Level Committee Meeting -1, 2008), wherein, reaching out to difficult terrains and far-off places was the major hurdle. NKN has proved successful in providing a pan-India connection on this network over a period of 10 years. Availability and accessibility of information is the doorway to the vast knowledge that till now existed in silos. Interconnectivity over secured network has opened up institutions to research and collaboration with others pursuing similar studies. NKN's regional connectivity to SAARC countries and Global NRENs has empowered indigenous

institutions to transcend the physical national boundaries in pursuit of higher academics and research. Exchange of knowledge, research, ideas has made many special programmes and models possible. An extensive study of the role of NKN in some key sectors viz., Education, Science, Technology, Agriculture, Healthcare, Space and Weather, is a matter of importance. Creating a centralised network and services has a value proposition for these sectors and the nation as a whole. Cost saving and other financial benefits are the other important aspects of NKN.

1.3 SCOPE OF THE STUDY

NKN got cabinet approval in March 2010, for a period of 10 years (GoI, Note for the Cabinet Committee on Infrastructure, 2010). It was started with a vision to empower the research and educational community of India by giving access to digital infrastructure, networking backbone, knowledge sharing platforms and applications. This project, as of now in 2019, is about to complete its 10 years of operations. Hence, there is a need that the achievement of its objectives is studied to understand the impact of the project, challenges faced, lessons learnt and volume of targets achieved. It is also imperative to study how the environment of technology, research, education, healthcare and governance has changed in a decade and the role NKN has played in this journey.

IIPA was nominated by NIC/NICSI, Government of India, to conduct the impact assessment study of NKN. The selection of method for any study is dependent on both - the nature of the study and the social phenomena to be probed. The general scope outlined by the NKN for the study is as follows:

1.3.1 GENERAL ASSESSMENT OF NKN

- To assess whether NKN has met its main objective as per the Detailed Project Report of the current phase i.e., “Bring together all the stakeholders in Science, Technology, Higher Education, Research & Development and Governance, with speeds of the order of 10 Gbps coupled with extremely low latencies. NKN will interconnect all institutions engaged in research, higher education and scientific development in the country over a period of time.”
- To assess how NKN has played an instrumental role in Digital India and has served as its backbone by providing connectivity to data hubs which in-turn support other initiatives of Digital India. Some of the initiatives could be Primary Citizen Services, NDCs, SDCs & SWAN under e-Governance umbrella.

1.3.2 ASSESSMENT OF NKN FOR USERS

- To indicate how NKN has helped Indian institutes in research by acting as a platform for collaborative research, innovation, developments on future technologies, multilateral collaboration, etc.

- To scrutinise the significance of NKN in promoting e-learning in Indian research and educational institutes via platforms like virtual classrooms, Cloud services, virtual routing and forwarding, video conferencing, etc.
- To check the influence of NKN as a platform for mission specific projects such as High Speed SCPC VSAT Connectivity, usage in weather forecasting, support to Mission Mars, support in Pragati programme, etc.
- To survey the effect of NKN on various sectors of Research and Educational community in before & after scenarios. Some of these sectors are Medical Research Institutes, Engineering Institutes, Agricultural Research, Armed Forces & Defence Labs, Quality Testing Labs, Art & Design sector, CISR, ISRO, Atomic Energy, Biotechnology, libraries, etc.
- To examine how NKN has set up a secured and resilient backbone network for the user community that can recover quickly from breakdowns and other cyber-attacks.
- To map how NKN was able to save considerable investment that would have otherwise occurred in case of segregated networks with low capacity.
- To analyse the benefits that State-Wide Area Networks (SWAN), State Data Centres (SDC) and National Data Centres (NDC) get from being connected in the network, especially in terms of uniformity of services.
- To gauge the importance of NKN for continuation of the Project.

1.3.3 BENCHMARKING WITH INTERNATIONAL NRENS

- To compare NKN as National Research and Education Network (NREN) with other international NRENS, for e.g., Internet2, GÉANT, NORDUNET, Asi@connect etc. and study the multi-dimensional (social background, user awareness, etc.) distinctions between the NRENS.
- To specify how NKN gives Indian research and educational institutions a platform to connect and exchange knowledge / research with other international counterparts.

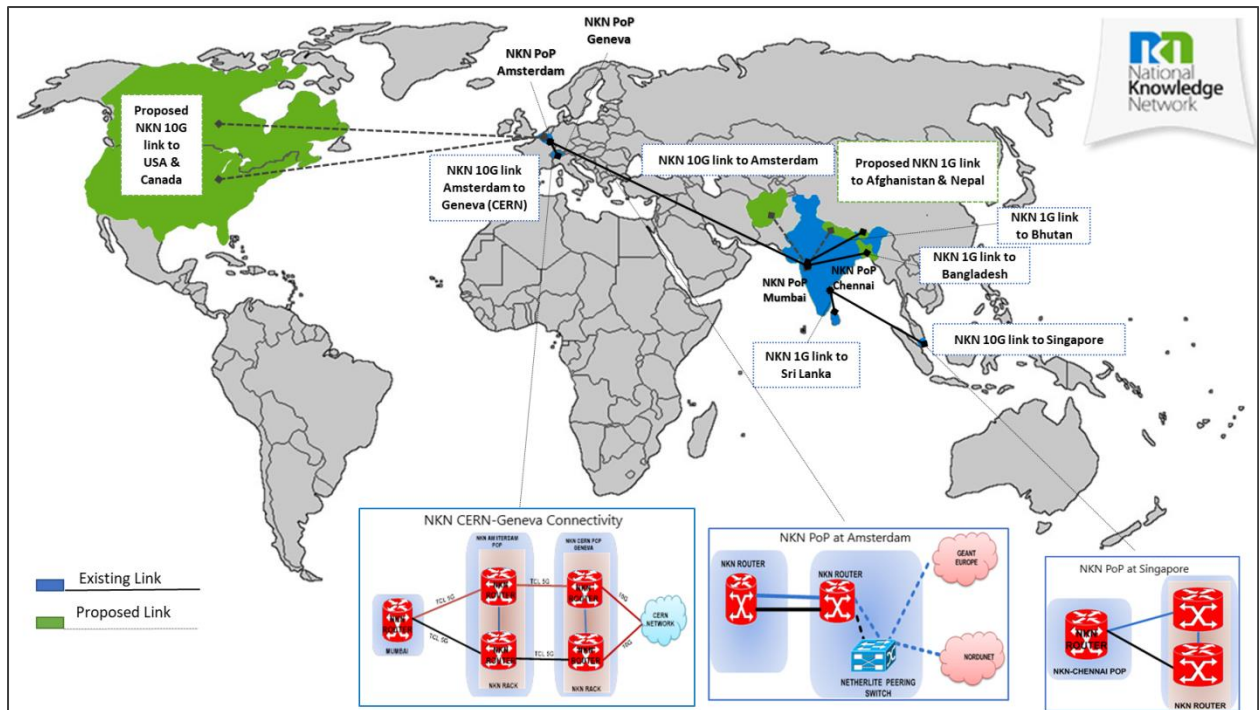


Figure 1.1 NKN International Presence

1.4 STAGES OF NKN IMPACT STUDY

The course of the study is segregated into five stages. Each stage is specifically identified through its deliverable viz., Inception Report in Stage-I, Detailed Action Plan in Stage II, Submission of Assessment Framework, Development of Data Matrix and Assessment Framework in Stage-III, Draft Report in Stage-IV and Final Report on Impact Assessment of NKN in the last stage.

- **Stage I:** The deliverable of the first stage i.e., Inception Report, was developed after the preliminary study and a macro level analysis of NKN. This report articulates the broad aspects for appraisal of the existing implementation schema of NKN and presented a suggestive list of parameters for the assessment to be undertaken through primary and secondary data analysis.
- **Stage II:** The second stage of the study i.e., Detailed Action Plan, was based on detailed preliminary study, undertaken to delineate in detail, the aim, objectives and methodology that is to be followed for undertaking the study along with the detailed action plan.
- **Stage III:** Further, to move on to Stage-III, the study was conducted in two phases viz., the review (Phase-I) and detailed research analysis (Phase-II).
 - **Phase-I:** The Review Phase of the Study - The first phase included an overview of the existing network and services as an outsider, then from the macro-perspective of institutes and other stakeholders, including management and citizens. In this phase, a basic comparison was done with similar initiatives prevalent elsewhere globally, viz., Internet2, GEANT, Asi@connect and NORDUNET. For preliminary study, these initiatives were studied in context of nature of services - network spread, speed & growth -, usage

of services and exchange of knowledge/ research and hence this phase was deemed the 'Review Phase' of the study.

- **Phase-II:** The Survey Phase of the Study - After understanding the system from the perspective of a casual user, it was deemed important to take rightful beneficiary agencies' opinion on the same. For doing so, a primary research analysis of NKN was undertaken using survey techniques.
- **Sample Used:** The study exercised a convenience sampling method to obtain responses from institute users of NKN. The idea was to represent NKN users in a non-discriminatory manner. Further, the survey was conducted across all institutes and efforts were made to engage maximum institutes from all categories and the participation in the survey was more than satisfactory. A test programme was also conducted through the video conferencing facility of the NKN to brief the state units of NKN on the survey process.
- **Stage IV:** The Stage IV is the consolidated output of all the above-mentioned phases. Here, all the data drawn from the review of system and primary research was collated. The observations and inferences drawn from the studies were complied with future prospects and aspirations.

The study was conducted with a vision to formulate the final report on impact assessment of NKN. The report is extensive in its reach and intensive in its context, deriving the strengths and crucial insights into this vast knowledge network and a service delivery platform.

1.5 DEFINING THE ASSESSMENT FRAMEWORK

The existing structure of the study of the project can be understood as resting on four pillars, each of which cover the four, key concerned areas related to connectivity, quality of services, expanding the scope through applicability in multiple areas and lastly, managing the resources to make it a lucrative venture.

The Research Tools Used - An assessment framework has been formulated based on the preliminary study comprising of Outreach, Quality of Service, Knowledge Ecosystem and Value proposition metrics.

Outreach: This pillar undertakes study of network spread of NKN in institutes for education, research, training and collaboration. Coverage of NKN with respect to NDCs, SDCs and SWAN to empower e-Governance in the country and connectivity with the SAARC countries were studied as well. Global NRENs connectivity and collaboration to participate in global knowledge ecosystem was always a key requirement of DPR and the HLC meetings. Connectivity to these NRENs is also covered under the outreach pillar

Quality of Service: The success and durability of any project rests on the quality of services it provides consistently. To evaluate the extent of the quality of services under NKN, redundancy,

high bandwidth and low latency were studied along with security, which is increasingly becoming an indispensable part, owing to global cybercrimes. This aspect of the study has also eased in understanding of how distant places, such as the North East, are utilizing the network and services for the specified areas.

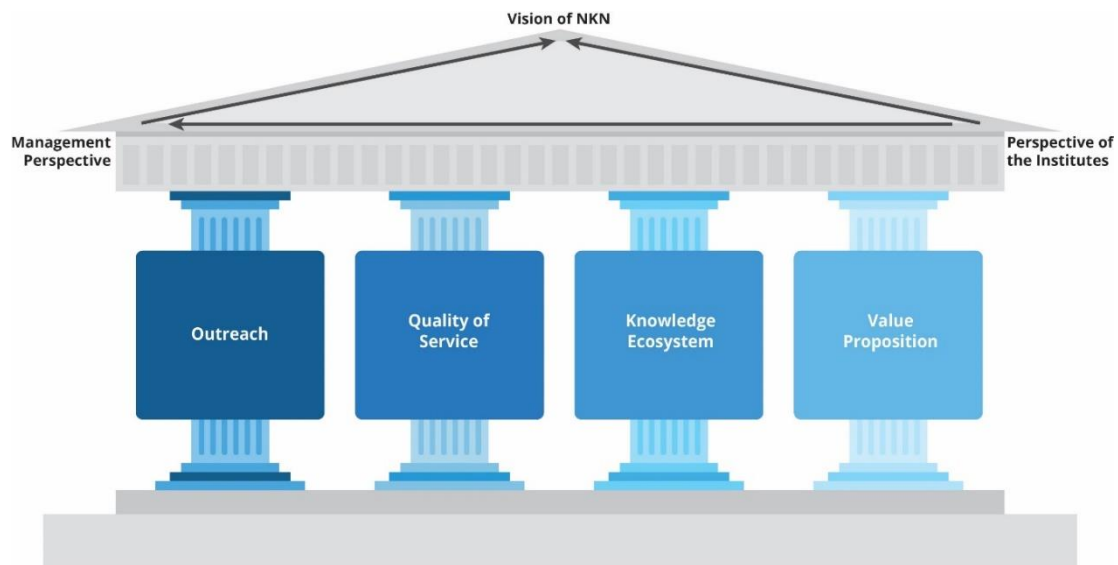


Figure 1.2 Framework of the study

Knowledge Ecosystem: Knowledge expansion, for which the whole project was undertaken, is an essential point of study. With the required infrastructure and networks in place, the attention then goes to how successful the whole project has been in facilitating collaboration in conducting research, both within the national institutes as well as international collaborative projects. Impact of NKN on the following specific sectors, Healthcare, Education, Space, Weather, Defence, Science and Technology, is also covered in this pillar.

Value Proposition: The project plan from a business point of view is an integral part of the study because for any project to be viable, one needs to have a self-sustaining structure in place. Time, cost and its management are the essential features that need to be explored. Cost-saving, increase in revenue and wealth creation for the country are the major foci of the study in this pillar.

1.6 STRUCTURE OF THE STUDY REPORT

This report is an outcome and an overview of the results attained through the review in stage III (phase-I) and primary research analysis (phase-II) undertaken in the study. A birds' eye-view of the same is represented herein:

Chapter One - 'Introduction to the Study': This presents the need and background of the study and further it gives scope of work along with an overview of the methodology and framework used to pursue the proposed impact assessment study.

Chapter Two- 'NKN Vision & Architecture': This chapter covers the need, genesis, architecture, scope of services and key decisions taken by HLC. HLC, as a team, played a critical role in monitoring, projecting, conceptualising new ideas and providing overall direction to the project.

Chapter Three- 'Review of Existing System': The vision of NKN is to have tens of Gigabits of high-speed network with very low latency all over India for the purpose of education & research. Understanding the current system in this context and on the four assessment pillars, is carried out in this chapter. Next, the coverage of network for institutes of research, higher education, collaboration, healthcare, agriculture etc., are described in detail. Study of Value Proposition is covered last from the perspective of the management.

Chapter Four- 'NKN Services': This chapter covers the bouquet of services provided by the NKN. The vision was to provide different platforms and services to the research and education ecosystem to empower them with future technologies along with the infrastructure. This chapter also covers the usage and benefits derived off NKN to the community.

Chapter Five- 'Security Assessment': This chapter covers the security systems put in place for different kind of security breach scenarios for the network and other assets. Backup and DR strategies are documented in this chapter along with the business continuity plans. Cyber-attack risk mitigation is a major requirement for such systems and readiness for such cases is covered in this chapter.

Chapter Six- 'Research Analysis of NKN': This chapter aims to convert the output of the primary research analysis of NKN gleaned through survey technique in stage III, phase-II of the study. The four pillars based attributes of the system have been analysed through a strenuous data collection tool. The output of 'stakeholders' consultations, undertaken through detailed meetings, round table interviews have also been summed up in the chapter.

Chapter Seven- "Global Benchmarking with Similar Initiatives": This chapter assesses the Global NREN initiatives which are similar in nature to NKN. The chapter starts with the description of each initiative on components like network details, history, connectivity and services offered. This is further analysed with a comparison of network, domains, spread and funding etc. Relationship of NKN is reviewed with these NRENs along with case studies of some collaborative projects.

Chapter Eight- "NKN: Empowering Digital India": The same network is the backbone for the NDCs, SDCs and SWAN which are empowering the states and districts for their usage, application hosting and other e-services. Digital India and e-Governance initiatives are also served through these NDCs, SDCs and SWAN along with the centrally enabled applications, services and platforms. Status of NKN since its inception is captured in this section.

Chapter Nine - "Key Observations & Recommendations": This chapter integrates all the findings collected through review and primary research conducted in this study. Based on these observations and analysis of consultation rounds, several relevant recommendations are put forth for strengthening important facets of NKN including its operational, technical, organisational functions and its sustenance.

Chapter 2

NKN VISION & ARCHITECTURE

2.1 CHAPTER OVERVIEW

Before analytically reviewing NKN, it was pertinent to first have a macro synopsis of the initiative so that the evolution of activities could be understood from the perception of its designers and implementing team. The vision, objectives, characteristics and the architecture of NKN has been studied in this chapter through various documents like the Detailed Project Report (DPR), Cabinet Note and Meeting Minutes of High Level Committee (HLC). This has served as a base for mapping the current system of NKN on these vision and objectives to see whether they have been fulfilled or not. The chapter begins with describing the background of incorporation of NKN, its characteristics and ends with a description of its network architecture.

2.2 INTRODUCTION

In the present scenario of economic growth, the capacity to process, store, share and transmit large quantities of data and information can be done economically not just within its national boundary, but also on the global platform to aid research and development.

The creation of National Research and Educational Network (NREN) can have a major impact on the socio-economic development of the country. In addition to Research and Education, establishment of NKN was termed as India's NREN with global outreach. NKN with its multi-

gigabit capacity has the capability to connect all major universities, research institutions, libraries, laboratories, health care institutions and agricultural institutions across the country as well as globally.

With this vision, the salient features of NKN (Technical Advisory Committee) were initially proposed to:

- establish connectivity for knowledge and information sharing;
- enable collaborative research, development and innovation;
- facilitate distance education and provide access to e-learning resources;
- facilitate an ultra-high e-Governance backbone for information sharing;
- link networks to collaborate with the research communities across the globe.

2.3 BACKGROUND

At the initiation of the project, Government of India had allocated INR 100 crore in the fiscal year 2008-09 to achieve the following objectives:

- To bring together all the stake holders in science, technology, higher education, research and development and governance, with speeds of the order of 10Gbps coupled with extremely low latency.
- To interconnect institutions, engage in research, higher education and scientific development in the country over a period of time.
- To minimise time and expenditure, it was envisioned to use fibre network of BSNL and other PSUs/NLDs to provide connectivity to NKN. It was also decided to subsume in it all networks in the country without compromising on the identity and purpose of these subsumed individual networks.
- To initiate this vision, a consortium of PSUs led by BSNL was given the responsibility to implement the same. The academic institutions were also consulted and their requirements were figured out.
- High Level Committee (HLC) and Technical Advisory Committee (TAC) were formed, having designated National Informatics Centre (NIC) as the Implementation Agency for NKN implementation with an initial allocated budget of INR 100 crores to accomplish the 'Initial phase' of NKN within six to nine months from the date of establishment. As per the advice of TAC, 56 institutes and 66 virtual classrooms had to go live in this initial phase. TAC also advised connection of NICNET to NKN at state level.
- With this basic understanding, NKN was formally inaugurated in the year 2009 (April 9) by the Hon'ble President of India, wherein a live demonstration was given by three BARC researchers who modified and designed a turbine by videoconferencing using NKN connectivity.
- In the same year (2009), the core backbone was tested by BSNL, PGCIL and RailTel for the availability of speed of 1/2.5/10 Gbps bandwidths. It is relevant to highlight that apart

from achieving the proposed targets of the initial phase, NIC was also able to connect 48 more institutes within the same allocated funds. This ensured the successful completion of initial phase and the cabinet approval was given in March 2010 for extension of NKN project for the next ten years. This approval marked the initiation of the existing phase of NKN.

2.4 CHARACTERISTICS OF NKN

As a next generation network, NKN incorporates the following:

Network Design Requirements

NKN architecture is designed in such a way that it has to follow all the industry standards including the ISO certification. The design and the standards of NKN is created in alignment with other NRENs.

NKN's architecture is designed in three layers namely super core links, core links and edge links.

Security Requirements

Critical data theft, cyber-attacks and other cyber security breaches were kept in mind while conceptualising the design architecture, hence aim of offering a secured and safe environment for research and innovation initiatives was the backdrop of the design process.

Service Requirements

Also considered was how transparent delivery of services will be obtained, based on either heritage or the general requirements for a particular service.

These requirements might differ in terms of service providers and possibly even between different tiers of a similar service.

Network Requirements

While designing the NKN architecture, network and device specific customised requirements were taken into account, which will cater to the overall performance goal of the NKN infrastructure.

Operational Requirements

NKN was designed to cater to the requirements of tracking, troubleshooting, health, monitoring and proactive performance monitoring. With the converged network, it is more important to proactively monitor the network for impending issues.

2.5 DESIGN ARCHITECTURE

To create an eco-system for knowledge creation and knowledge sharing, it was decided that the NKN would support overlay networks, dedicated networks and virtual networks.

By the virtue of its architecture, multiple domains were benefitted. NKN impacts health care domain where live heavy images and videos were able to be transferred without any data loss during video conferencing. In the education domain, resources were to be made available to the students and institutes, without the constraints of boundaries and distance. Similarly, in space, agriculture and other scientific domains, research initiatives required high data speed with low latency and grid computing.

NKN design uses the best possible design in terms of availability, technology and future proofing. To serve the users with uninterrupted connectivity, NKN ensures that multiple choices are available to the users for running various services. To meet the critical requirement, NKN has the capacity to scale and adapt to revolutionary requirements.

NKN is a hierarchical network divided into three basic layers (Figure 2.1):

1. Super Core Links: There are 7 super core Links connected in a full mesh topology.
2. Core Links: Connected to Super-Core and act as distribution centre to the edge links.
3. Edge Links: The institutes that are connected via a last mile connectivity.

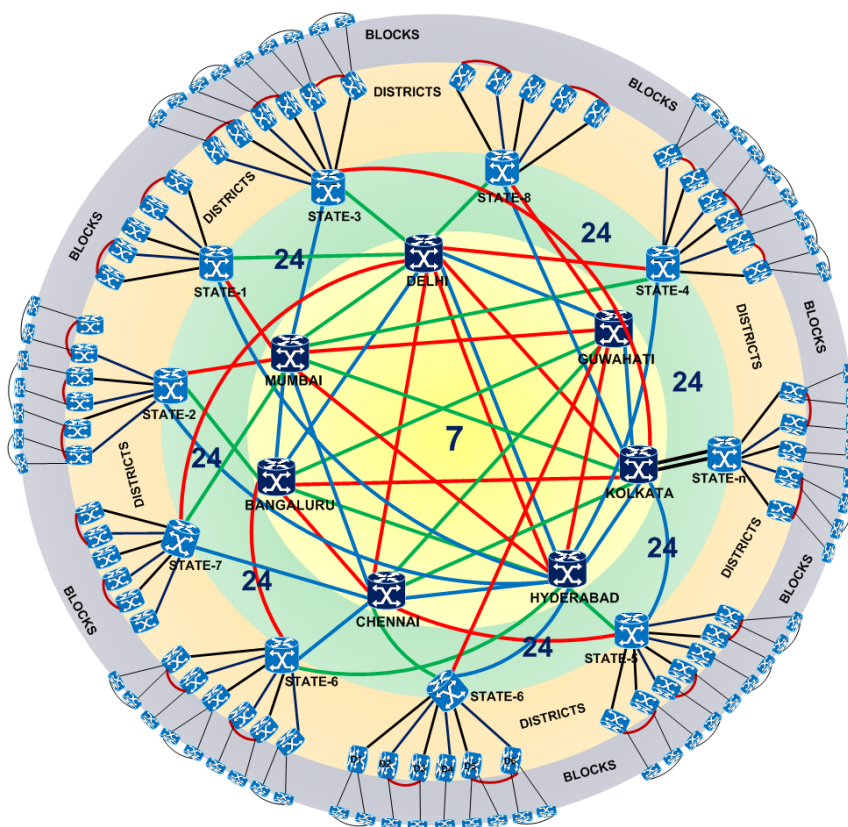


Figure 2.1 Architecture depicting network from the Core to the Edge

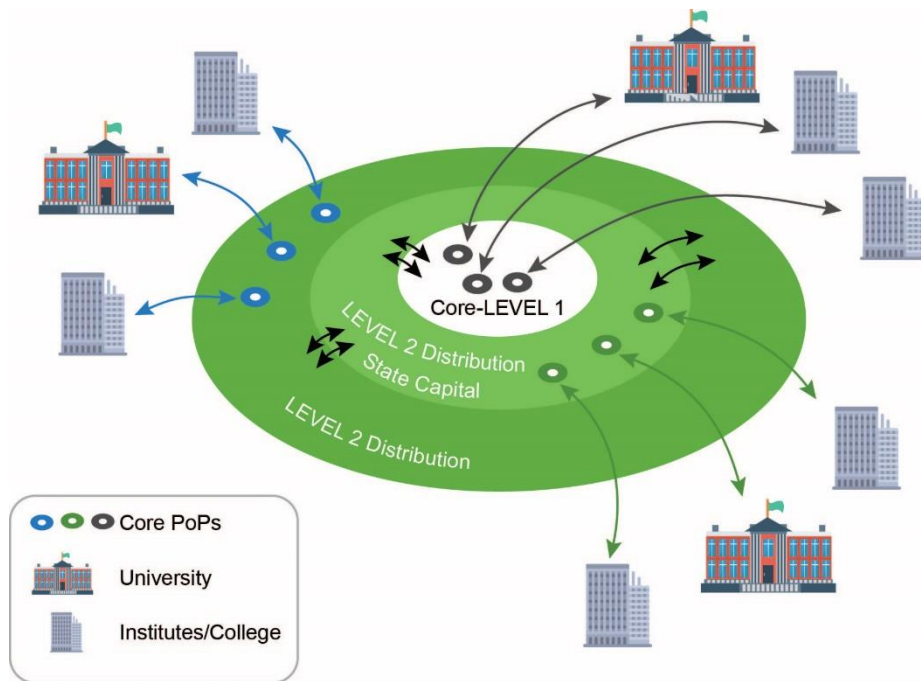


Figure 2.2 Connectivity to various institutes

Depending on the user organisation, geographical presence and the location of Points of Presence (PoP) of NKN (belonging to Core and Distribution), connectivity is provided to the institutes.

There are two different setups of three layers in NKN. The super-core and core are the common skeleton which are further connected to edge & district links.

The architecture of NKN backbone consists of a core layer that is inherently capable of moving data in multiples of 10/40/100 Gbps. The backbone of the network started from 2.5 Gbps and progressively moved onto 10 Gbps connectivity, designed on 7 Super Cores pan-India viz., Delhi, Hyderabad, Chennai, Kolkata, Mumbai, Guwahati and Bengaluru, with full mesh connectivity. It is depicted in the inner-most circle of the figure 2.3.

The network is then expanded out through 24 Core locations, mostly on 10 Gbps, following a partially meshed connectivity with super core locations. These 24 locations are located at State Capitals and are portrayed in the above figure in the outer ring.

The super-core and core are the foundation of the Edge and District links/ distribution layer. Regarding Edge links, 1700 plus institutes are connected to the core links in this layer with a connectivity of mostly 100 Mbps/ 1Gbps /10Gbps /n*10Gbps.

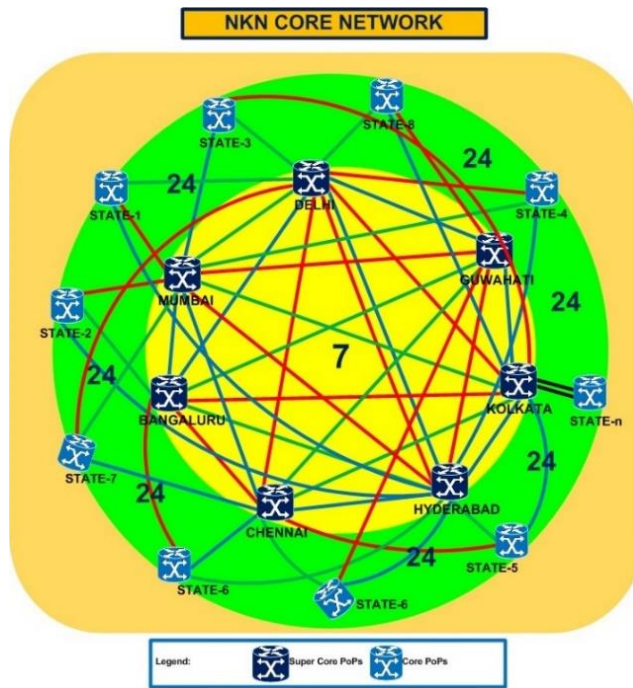


Figure 2.3 NKN network depicting Core and the Super Core

Another set-up of NKN connects the core links to the district links / distribution layer. The number of such district links is 506. These are rendered in the figure below where district links layer can be seen at Level 3 from the centre. It can clearly be seen that the 24 core links are connected to the district links which may further be connected at the block level.

One of the core principles is that the PoPs are using multiple links from different NLDs to form the mesh or partially mesh network via separate paths to ensure the working in case of a failure of a single NLD or accidental disconnection at one particular route. Thus creating a robust national NKN Backbone. Another diagram representing the redundancy in the Core layers is shown below :

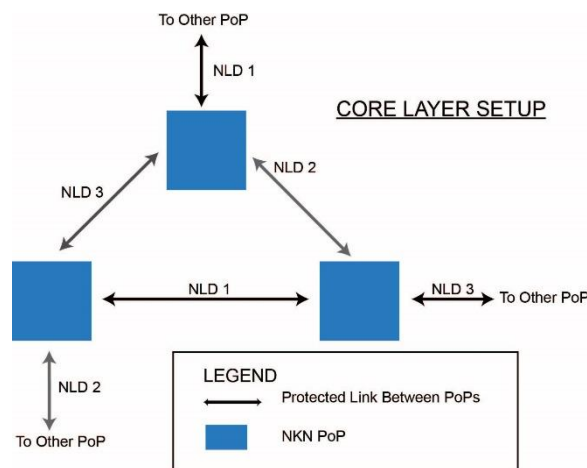


Figure 2.4 The Core layer setup

In some important cases, this model of redundancy is also replicated at the institute level. An illustration is shown below:

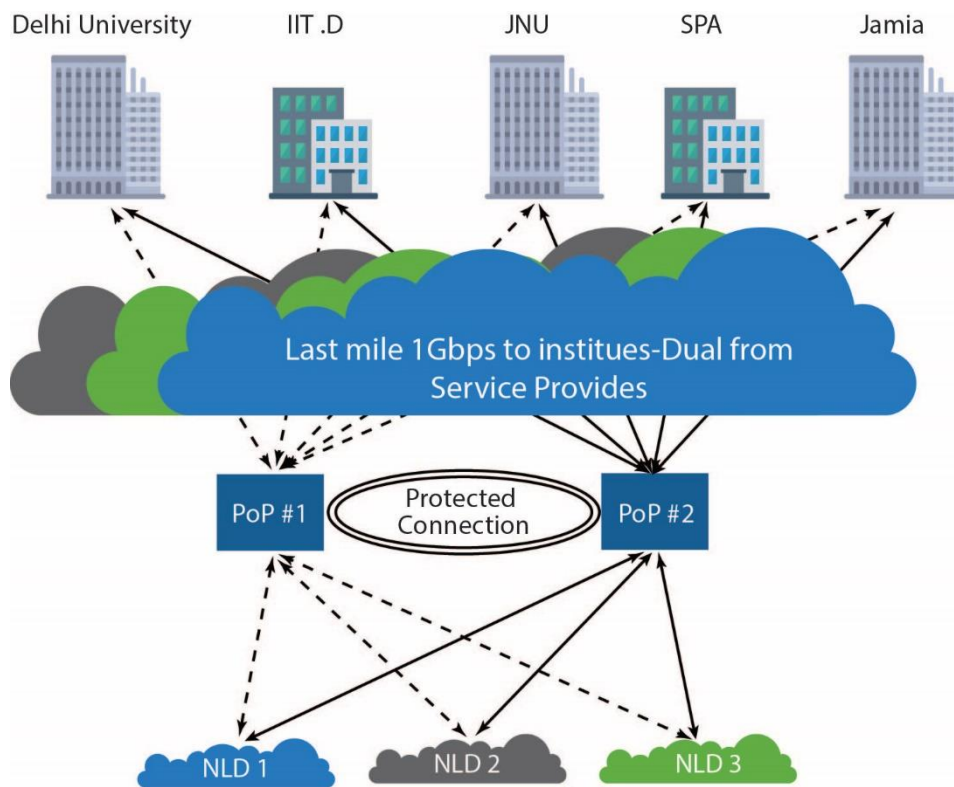


Figure 2.5 Typical connectivity in co-located cities-Example, New Delhi

Observations and Recommendations:

Let us accept that tech-reality does not stay the same. Transformative technologies, including augmented reality and 3D application possibilities coupled with 5G provisions, could insist on NKN to enhance its provisions to hundreds of Gigabits and more. User demands and hence their bandwidth requirements too would soar in emerging future. Therefore, envisioned plan of NKN to implement 'dark fibre' is eminent. Another possibility is complete disruption of existing technology implementation by some newer version of 'frontier technologies', such as 'Smart Dust' etc., could completely disrupt and disorient the existing NKN implementations strategies.

2.6 SUMMARY

In its existing phase, the NKN backbone has expanded to 31 Core & Super-core PoPs + 506 District links + 3 International PoPs along with peering with 9 International NRENs and has connected 1700 plus institutions as of May 2019.

As mandated, end nodes have been connected to the local PoPs in their region and provisioned with up to 10 Gbps connectivity. Some backbone links have also been provisioned with 10 Gbps capacity or more depending on the requirement/availability from NLDs. Added to this, the architecture of NKN enables scalability that could take care of all the future requirements.

NKN operates its own 24x7 dedicated Network Operation Centre (NOC) to monitor and manage all traffic on the network and provides technical support services to all of its members. Setting up of successful video conferencing infrastructure formed the initial phase of the NKN project, through which NKN has been able to facilitate collaborative research. Through access to Digital Library sources and electronic journals and web hosting, NKN has ensured active and regular participation in international collaborative research possible for the researchers and faculty.

With NKN it was aimed that India will stand tall in the comity of nations with tremendous potential and vitality to compete in global scenario.

Chapter 3

REVIEW OF EXISTING SYSTEM

3.1 CHAPTER OVERVIEW

This chapter aims at assessing the implementation of NKN by studying the existing system. The assessment shall be made from the management perspective, especially in the way plans were materialised and how the whole structure came to exist in its present form. The understanding about the NKN system for this assessment was gauged through various structured and unstructured interviews with the NKN team along with the documents provided on these aspects.

The chapter gives a brief introduction of the Assessment Framework, its four pillars on which the understanding of the NKN system is based namely Outreach, Quality of Services, Knowledge Ecosystem and Value Proposition. The study further explains the various aspects of NKN covered under each of the four pillars and shows how each of these have created an impact to strengthen NKN.

3.2 INTRODUCTION

The existing structure of the project from the management perspective can be understood as resting on four pillars, each of which cover the four, key concerned areas related to connectivity,

quality of services, expanding the scope through applicability in multiple areas and lastly, managing the resources to make it a lucrative venture.

- I. First pillar: Outreach
- II. Second pillar: Quality of Service
- III. Third pillar: Knowledge ecosystem
- IV. Fourth pillar: Value proposition

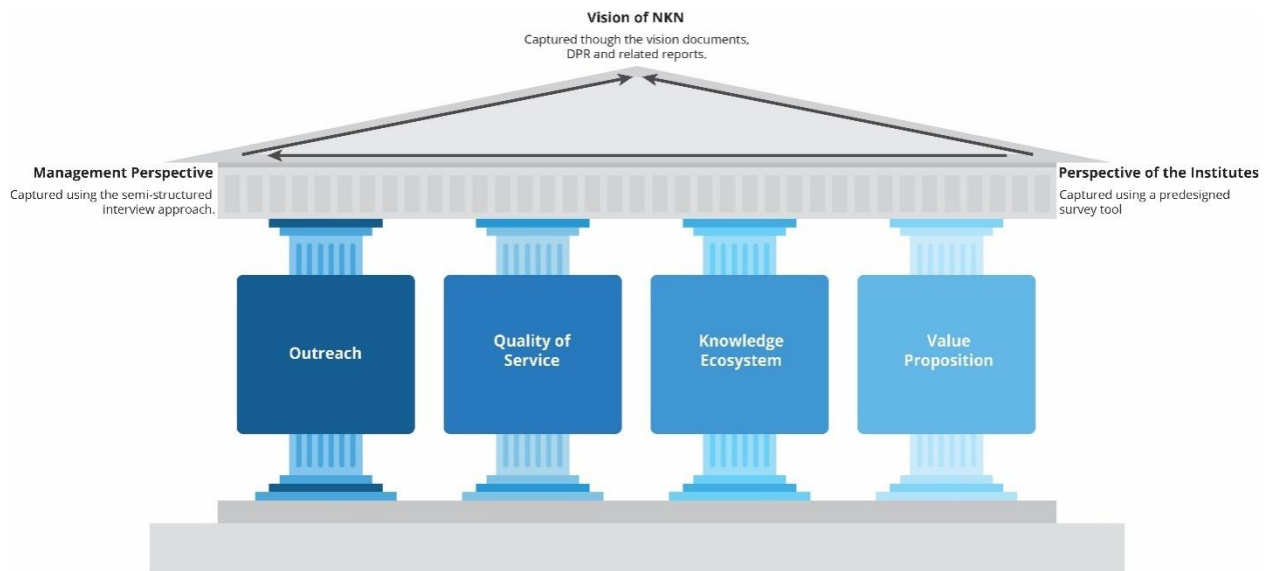


Figure 3.1 Assessment framework defining methodology

3.3 OUTREACH- FIRST PILLAR

National Knowledge Network (NKN) project was created to establish a strong and robust pan-India network which provides secure and reliable connectivity with a quantum jump in bandwidth. The vision was to usher a knowledge revolution in which institutions with a vision and passion for their field of work are able to transcend the limitations imposed by space and time. This vision was achieved by connecting knowledge and research institutions in the country using high bandwidth / low latency light paths, thus creating an e-Infrastructure for India. This was done by providing connectivity in all possible directions and levels, in order to create an integrated and interconnected strong network. As of today, NKN has ensured connectivity in all the possible areas growing both within the country at various levels and outside the country too. This was made possible by systematic build-up and enhancement of network through the following key initiatives:

1. Countrywide Connectivity through National Long-Distance Service provider (NLDS)
2. Bringing institutions on-board
3. Integration with SAARC Nations
4. Connecting with global NRENS

3.3.1 COUNTRYWIDE CONNECTIVITY THROUGH NATIONAL LONG-DISTANCE SERVICE PROVIDER (NLDS)

With the times changing fast, the importance of establishing NKN at a fast pace was felt. With the collective vision of the Chairman, NKC, the Principal Scientific Advisor to the Government of India and Chairman, NKN TAC, in the first HLC, while emphasizing upon the importance of NKN, it was suggested that the fibre network of BSNL and other PSUs could be used to provide connectivity in a lesser time and cost. It was planned that initially a couple of hundred nodes could be connected which could be subsequently increased to 5,000 nodes making the project running within a time span of 6-9 months. For this, the services of BSNL, Power Grid, Railtel and BSNL were utilised on cost plus basis model (Gol, High Level Committee Meeting -1, 2008).

The revolutionary bandwidth connectivity was put in place by using the extensive Optical Fiber Cable (OFC) networks of BSNL, Railtel and Power Grid Corporation of India Limited (PGCIL). Chairman, TAC, described the underground OFC network as “the buried treasure of the nation” which has now come in handy to create “an exciting win-win situation” through a co-ownership pattern where the network operators stand to gain by selling additional bandwidth, while it facilitates knowledge sharing for educational institutions.

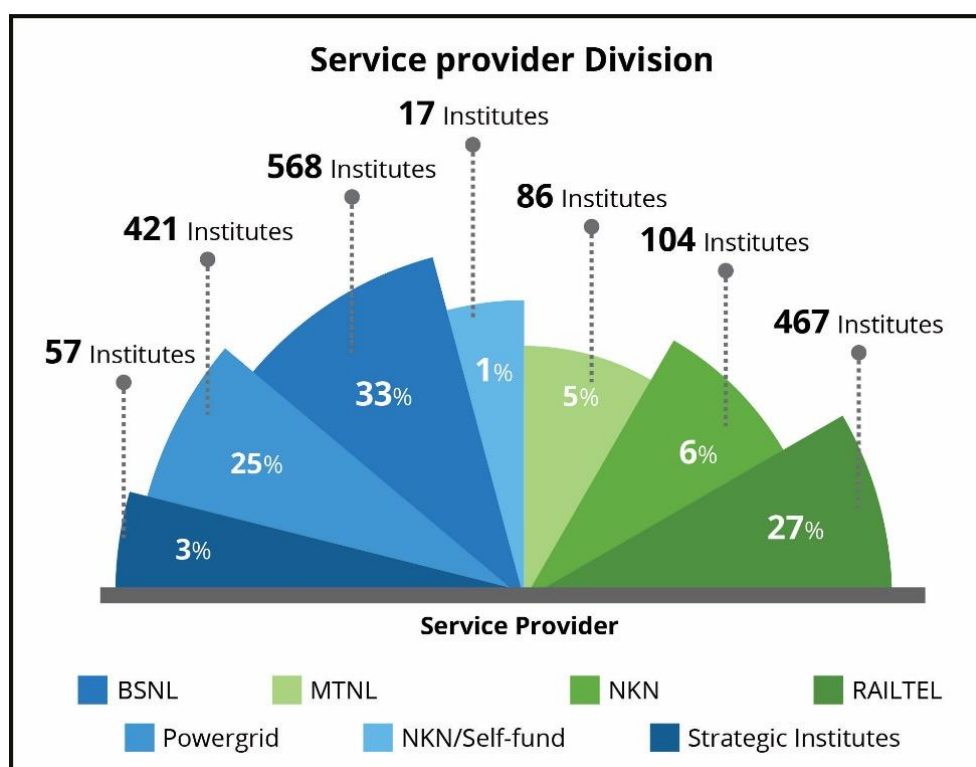


Figure 3.2 Distribution of 1700 plus NKN connected institutions based on the service provider (Source NKN connectivity list for IIPA as on May 2019)

By the start of 2009, the core for the initial phase of NKN was created using the links from BSNL, MTNL, RailTel and PGCIL. Care was taken to ensure redundancy to all state capitals, district and institutes (which has been discussed in detail in section of redundancy under Quality of Services). The connectivity to the North-East had been provided through earth wire and high voltage tension line, nearly giving 100% uptime. Lakshadweep andaman and Nicobar were two places where connectivity was established through VSAT in 2017 through ERNET centre in Bangalore (Gol, High Level Committee Meeting-19, 2017).

The distribution of institutes as per the division of service provider has been described in the figure 3.2.

3.3.2 BRINGING INSTITUTIONS ON-BOARD

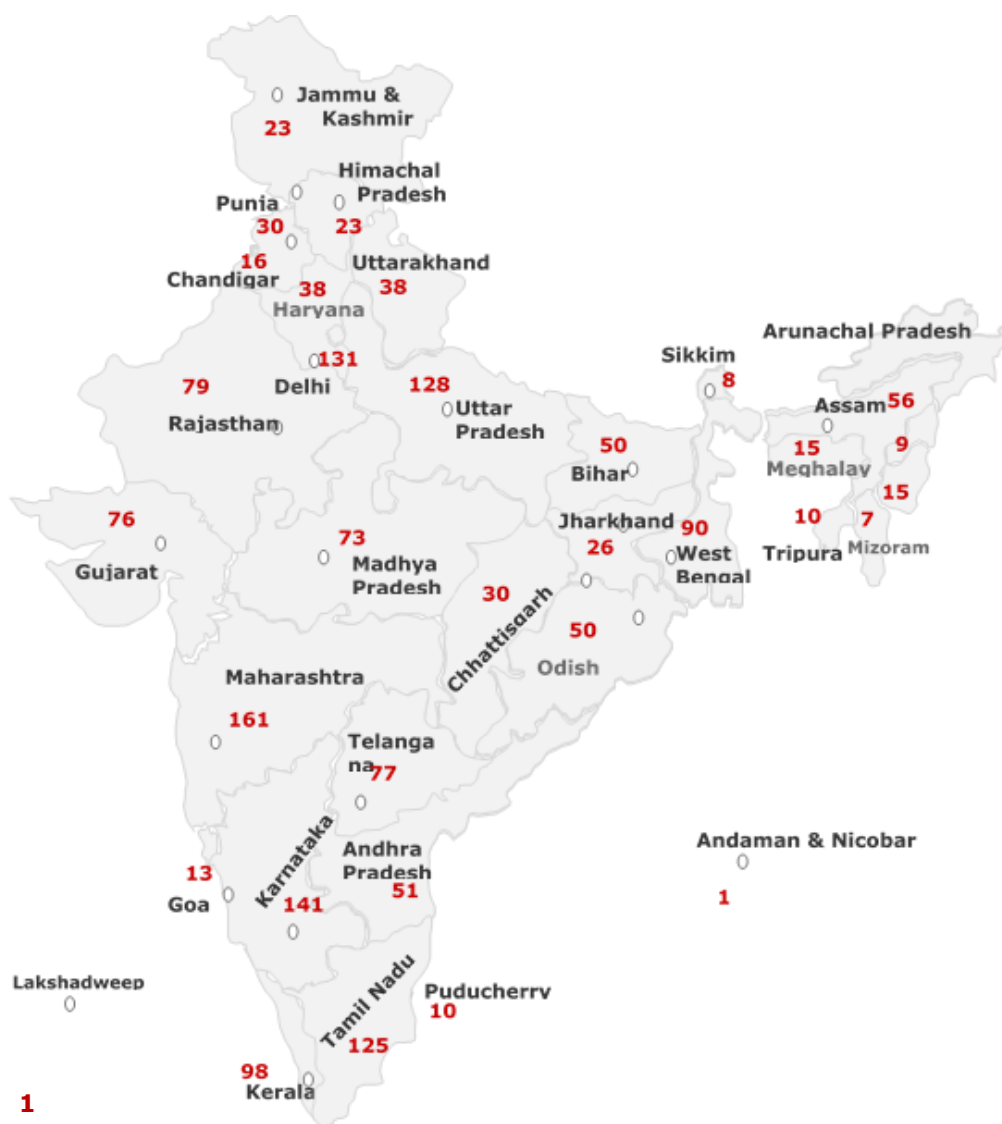


Figure 3.3 Distribution of 1700 plus NKN connected institutions across states and UTs (Source: NKN connectivity list for IIPA)

With the infrastructure of the core ready, the network was then made available to the educational and research institutes using edge connectivity. Connectivity to the major institutions was provided first followed by connectivity to small and mid-level institutes. These included IITs, IISc, C-DAC, CSIR, ISRO, IIMs and several central and state universities.

Since the inception of NKN, in one year, 130 institutes were connected. By 2012, 681 institutes came under NKN including 273 NMEICT institutes. By 2015, the number increased to 1404 institutes including 378 NMEICT institutes with 10 Gbps bandwidth provided to the institutes for the first time. The number of NKN connected institutes grew to 1700 plus including 388 NMEICT institutes by May 2019.

Such an increase in the number can be attributed to the efficient and structured on-boarding approach and process of NKN. Initially, the process for bringing an institute on-board included identification of an institute, allocation of TSP and then commissioning the link. In contemporary scenario, NKN requests institutes to connect on self-fund basis i.e., institutes pay for the last mile connectivity owing to fund constraint. A dedicated process for bringing an institute on-board and high efficiency of services caused a stupendous growth in the usage of NKN. This increased usage of NKN can be observed from the figure which shows that majority of NKN connected institutions belong to the category of research and education. This clearly indicates that NKN is helping the nation in achieving its aim of becoming a knowledge economy.

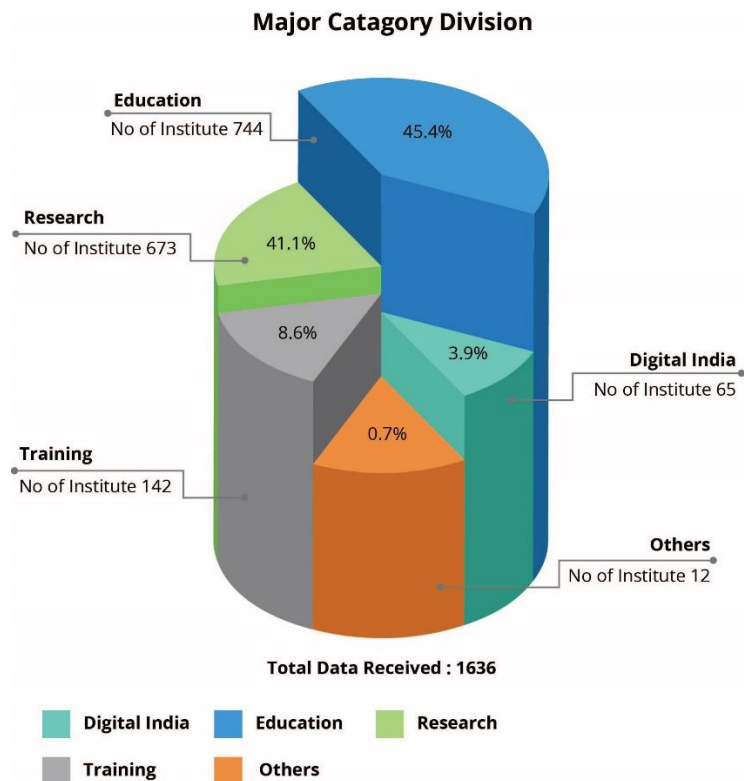


Figure 3.4 Distribution of connected institutes as per their category

Key observations and recommendations:

NKN connecting 1700 plus institutes on high speed is an achievement. Basic mandate to bring together all the stake holders in science, technology, higher education, research and development and governance has been achieved by getting 1700 plus institutes on-board. The next step is to bring 20,000 more institutes/colleges on NKN. This can be achieved by maximising the existing capacity, funding to increase the capacity to take that load and introducing the self-funding models of business. NKN has already taken steps to move in that direction. Some institutes are already on the self-funding modes.

3.3.3 INTEGRATION WITH SAARC NATIONS

The establishment of NKN infrastructure and connectivity extended connectivity to the neighbouring SAARC nations. This was done to enhance international cooperation in the field of education, research and allow students in South Asia an unimpeded access to digital libraries and networking sources. A state-of-the-art management centre and Network Operations Centre also help run NKN network for the international connection. The NKN connectivity to the SAARC countries such as Bhutan, Sri Lanka and Bangladesh has been completed. Out of these countries, the process of connecting Sri Lanka (figure 3.5) was completed in 2018 and that of Bangladesh (figure 3.6), in 2019. For the rest of the SAARC countries, the process is underway¹.



Figure 3.5 Hon'ble Prime Minister of India, Sh. Narendra Modi, acknowledging the connection of NKN with Bangladesh

¹ Pakistan is not part of this collaboration



Figure 3.6 Hon'ble Law & Justice, Information Technology Minister of India Sh. Ravi Shankar Prasad, acknowledging the connection of NKN with Sri Lanka

3.3.4 CONNECTING WITH GLOBAL NRENS

While connecting with the SAARC nations, NKN also considered broadening its connectivity to other NRENS. Globally, frontier research and innovation are shifting towards a multidisciplinary and collaborative paradigm requiring substantial communication bandwidth and high-end computational power. To this end, after understanding the international NREN landscape, NKN has peered with Research and Education Networks (RENs) such as Asi@connect in Asia Pacific, CERN and GEANT in Europe, SingAREN in Singapore, Internet2 in USA, LEARN in Sri Lanka, BdREN in Bangladesh, DrukREN in Bhutan and NORDUnet for Nordic countries viz., Denmark, Iceland, Norway, Sweden and Finland.

NKN established its international Point of Presence (PoPs) at Singapore, Amsterdam and Geneva (CERN). An NKN PoP in New York is being established. NKN international PoPs has helped its users and researchers to collaborate with their international counterparts through dedicated low latency high speed secure network (Gol, High Level Committee Meeting-19, 2017). These international collaborations have not only paved way for Indian researchers to be part of reputed projects, like Large Hadron Collider, but has also enabled them to conduct such path-breaking researches themselves.

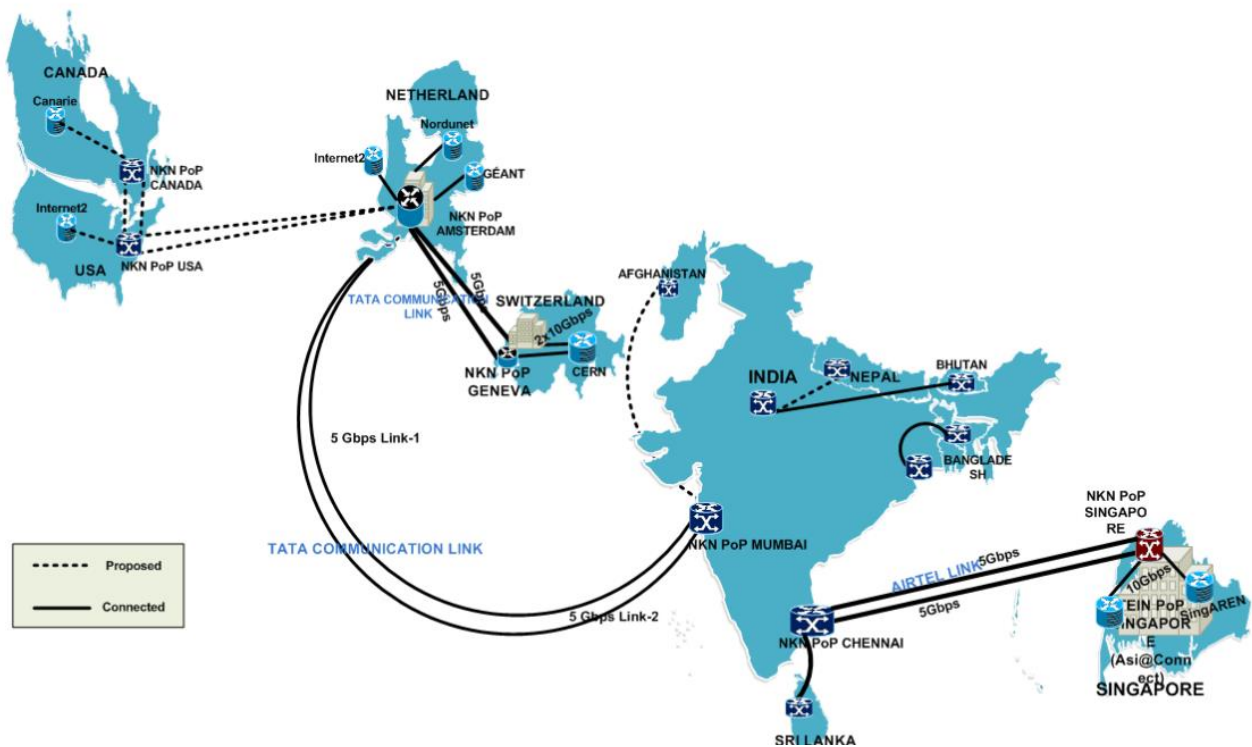


Figure 3.7 NKN international presence depicting connection with SAARC nations and NRENs around the globe (Internet2, NORDUnet, GEANT)

Source: The 3rd Asi@Connect Project Meeting presentation (March 26, 2018)

3.4 QUALITY OF SERVICE – SECOND PILLAR

The conceptualisation and creation of a product is followed by providing a strong support system and timely up gradation of its services and features. The Quality of Services (QoS) aspect was developed with a deep focus as this was an indispensable part while treading on the road to success for NKN project.

QoS refers to a network's ability to achieve maximum bandwidth and deal with other network performance elements like latency, error rate and uptime. In NKN, with most of the research and education institutes working on high power applications sensitive to delay, providing QoS became an indispensable part.

The team eventually zeroed it on the three key parameters of NKN essential for customer satisfaction namely – (1) accessibility (2) availability and (3) sustainability.

To ensure incorporation of these three features, NKN focused on high bandwidth, low latency and redundancy. While high bandwidth was achieved by collaborating with the existing partners and developing a better infrastructure, the low latency and redundancy part was tackled through a robust architecture. The following section presents a detailed analysis of the process followed by NKN to achieve accessibility, availability and sustainability.

3.4.1 ACCESSIBILITY - HIGH BANDWIDTH

Several institutes in India are dependent on NKN for conducting path-breaking research and hence a simple lack of sufficient throughput, can severely impact sensitive traffic. Since increasing the bandwidth is generally considered the best method of improving network communication, the architecture of NKN is such that it facilitates a dedicated and high bandwidth. The architecture in its basic form is described in chapter 2 section 5.

The dedicated high bandwidth link provided by NKN to the institutes has been shown in the form of a bar graph shown in figure 3.8.

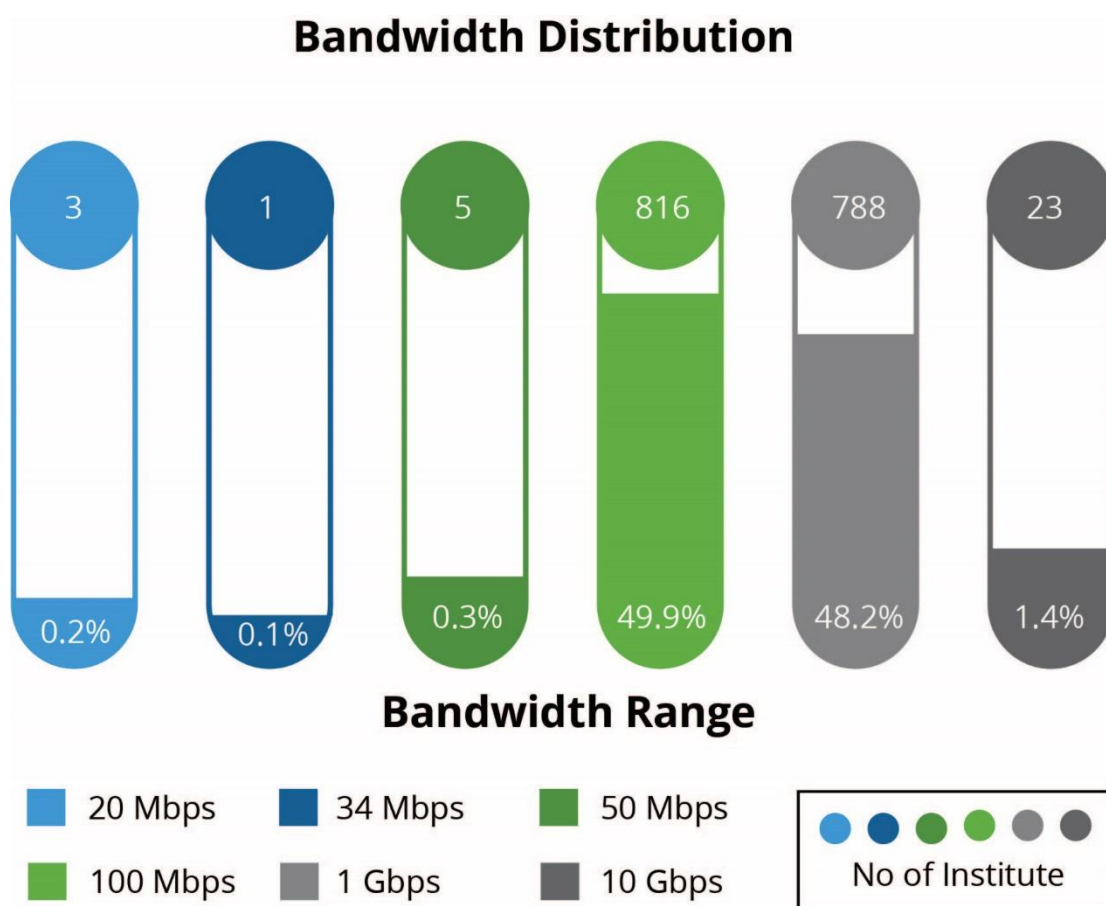


Figure 3.8 Bandwidth distribution of number of institutes connected over various bandwidth range

PERF Tool and Bandwidth Monitoring at NKN

The seven super core locations comprise the backbone of the entire network. It is at this place where the entire network converges and uses the shortest path to exit the super core from one to the next super core location based upon routing decisions. If the traffic flow takes the shortest path between the exit points keeping in mind the maximum available bandwidth, the entire NKN network remains stable. Each super core location is fully meshed with each other and the

physical link is laid out using third party Telecom Service Providers (TSP), there are times in the network where even after the best of routing protocol designs, a traffic flow does not use the optimal path.

Thus, to monitor the available bandwidth of the NKN core link between the super core locations, scheduled bandwidth tests are run on the perfSONAR servers and graphs are monitored regularly. Scheduled traceroute/ latency tests are run on perfSONAR nodes for core link latency and route path identification. One-way latency tests are performed on demand basis for asymmetric detection. In case of scheduled high traffic flows, perfSonar graphs are utilised to determine traffic engineering decisions for determining the best constant traffic flow path. It is also extensively used for finding the traffic paths taken by institutes collaborating with international partners so that direct lines between NKN and international partners are used and a seamless experience is guaranteed.

At the end user level, a centralised portal for delivering the Network Diagnostic Tool (NDT) of perfSONAR has been provided. This allows the NKN users to perform bandwidth test from their client machine's web browser and hence helps them in identifying the bottleneck of the link and bandwidth upload and download speed from the server. It also tells about other client parameters like MTU, TCP buffer, etc., for ease of use and management of tests performed by the NKN users. Such a need arose when it was observed that most of the complaints from the end user (regarding network speed) originated from end-user's LAN which was the choking point.

NKN has developed a management layer on top of NDT service layer known as NKN-perf. It is a centralised portal for performing bandwidth test using NDT from any of the deployed perfSONAR node located across NKN. It allows easy access of the test data (for all the tests performed by that user). Based on the user's identity, administrator also gets the statistics of the user's test (figure 3.9).

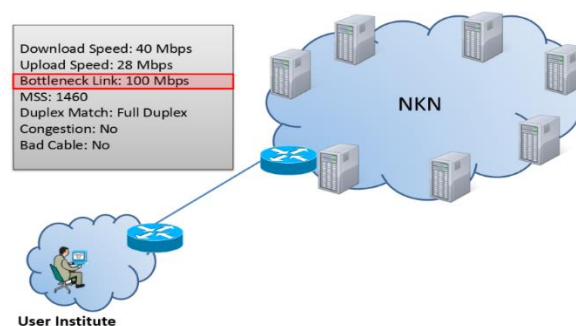


Figure 3.9 NKN users to perform Bandwidth Test

Apart from this, NKN also supports institutes which sometimes utilise NKN for delivering high amounts of real-time traffic. All these activities require following type of monitoring:

1. All links are uniformly utilised during normal operations
2. Proper failover to redundant links in case of failure and still maintain uniformity

3. In case of scheduled high traffic flows, existing traffic is not affected and the traffic flow is seamless

3.4.2 AVAILABILITY - REDUNDANCY

Network redundancy is a process through which additional or alternate instances of network devices and communication links are installed within network infrastructure. It is a method for ensuring network availability in case of a network device or path failure and unavailability. To maintain the continuity of NKN services at all levels, network redundancy has also been provisioned to all state capitals, approximately 450 plus district centres and even some premier institutes that are using NKN services.

The architecture of the network is such that a mesh is created i.e., one location is connected with multiple redundant links and a single point of failure at any location will not interrupt NKN's overall business model. A failure of a complete Point of Presence (PoP) will only affect the activities related to the specific PoP and not the entire infrastructure. The NKN architecture also ensures RTO (Recovery Time Objective)² and RPO (Recovery Point Objective)³ by the virtue of its design and hence guarantees unhindered flow of information and knowledge. Redundant links are mandatorily provided by two different service providers preferably with a different path as an additional measure of precaution. For some institutes based on the proximity, redundancy has also been extended from another institute. An example of such institutes is given below in table 3.1.

Table 3.1 Examples of Redundancy by Extension for Edge Links

State	Institute	Category
TELANGANA	AP SDC -AP SWAN	SDC-SWAN
KERALA	Kerala SDC - Kerala SWAN	SDC-SWAN
HIMACHAL PRADESH	HIM SWAN - HIM SDC	SDC-SWAN

Apart from the above-mentioned type of links, some important institutes also go for a secondary link so that in the rare case one of the links goes down, the traffic can flow from the other link and the services are not interrupted.

² RTO is the duration of time and a service level within which a business process must be restored after a disaster to avoid unacceptable consequences associated with a break in continuity.

³RPO is the age of files that must be recovered from backup storage for normal operations to resume if a computer, system, or network goes down because of a hardware, program, or communications failure.

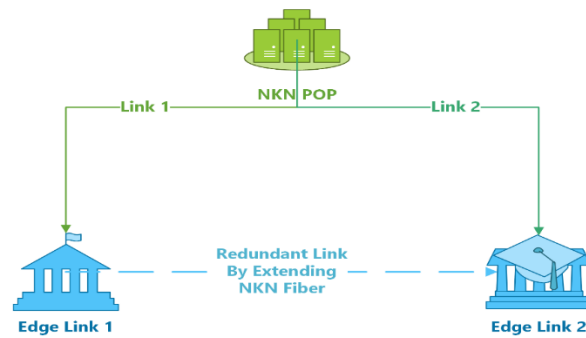


Figure 3.10 Redundancy by extending fibre

3.4.3 SUSTAINABILITY - LATENCY

Latency is a networking term to describe the total time it takes a data packet to travel from one node to another. A lower latency characterises a better network which has always been the aim of NKN. The low latency characteristics of NKN support operations that require near real-time access to rapidly changing data for experiments performed by NKN connected institutes.

Unlike NKN network, Internet works on the principle of “Best Effort” which means that the best available path at that moment will be used to visit the target location. Internet functions on a shared medium concept i.e., data travels through the best effort path of multiple service providers. This makes both the latency and bandwidth very unpredictable. The architecture of NKN has been designed in such a way that this unpredictability is eliminated. This has been done via the design itself. One of the core principles is that a PoP uses multiple links from different NLDs to form a MESH network. An additional design parameter is to keep the maximum number of hops between any two PoPs to three or four. Keeping hops to the minimum ensures that latency is improved. This allows NKN to give an end-to-end-guarantee of minimised hop and reduced latency via a dedicated monitored path. The low latency feature of NKN network also reduces jitters⁴.

Another architectural concept that ensures high-speed connectivity is the Maximum Transmission Unit (MTU) size, which is the maximum size of a single data unit of digital communications that can be transmitted over a network. Usually the internet supports a 1500 MTU size. Since MTU size is directly proportional to throughput, NKN operates on a Jumbo MTU size which improves network performance by making data transmissions more efficient.

Use-Case: The above explanations can be better understood with the help of an example. Consider two institutes - one situated in Kerala and another situated in Arunachal Pradesh - who wish to connect and collaborate with each other. Had they been using the Internet, an unpredictable best effort path will be used. Both the institutes might as well face problems like packet loss, excessive end-to-end delay, packet jitter, etc. On the other hand, through NKN network such problems will not be faced as NKN assures that any communication takes a

⁴ Jitter is the fragmentation in the output which occurs when traffic arrives at irregular times or in the wrong order. Jitter is, thus, a varying amount of delay.

maximum of three to four hops. The path that will be undertaken is demonstrated in the figure 3.11 below

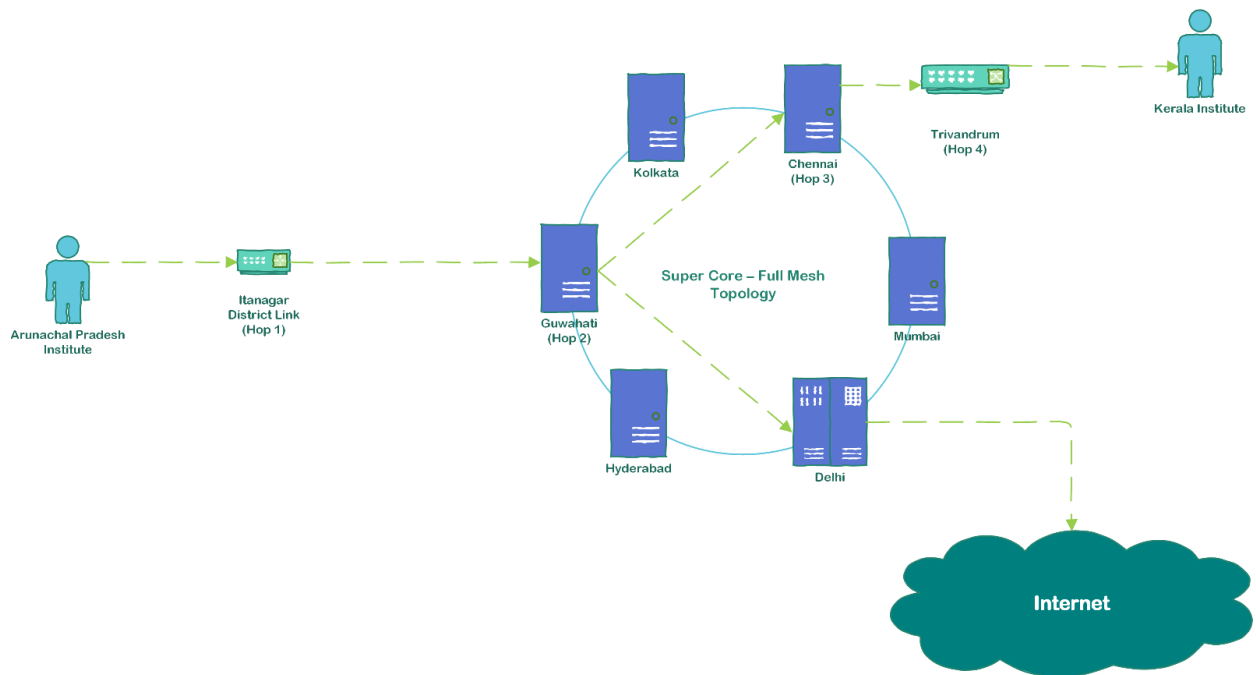


Figure 3.11 Network path connecting the institutes collaborating in two different states (Here Arunachal Pradesh and Kerala)

The same principle of low latency is also followed in case of international peering where the path becomes predictable till the institute.

3.4.4 INNOVATION- PEERING AND CACHING

National Knowledge Network (NKN) has always strived to become a secure and reliable network in providing connectivity to education facilities, R&D institutions and government deployments. With its impeccable service, it has also become the primary backbone network for the implementation of Digital India. The efficiency brought about by NKN can be rightly pointed to the various innovative measures undertaken by NKN since inception. *Some of the innovative areas where NKN has not only saved money for the Gol but also ensured numerous other benefits for the research and educational community are by ways of peering and caching.* These two are network traffic management technologies used by Internet Service Providers (ISPs) to accelerate content delivered over network while reducing related bandwidth costs. The need arose due to the increase in traffic from the content delivery platforms (which had been in GBs year after year with rapid surge of increase). It was evident that this use would only increase in the future. To cater to the increase in use while achieving uninterrupted net connectivity, low latency and saving time and cost, Peering and Caching were utilised.

Peering

Peering is a voluntary interconnection of administratively separate Internet networks for exchanging traffic between the users of each network. Peering is settlement-free, also known as "bill-and-keep" or "sender keeps all", meaning that neither party pays the other in association with the exchange of traffic; instead, each derives and retains revenue from its own customers. In simple terms, Peering is a process by which two Internet networks connect and exchange traffic. It allows them to directly hand off traffic between each other's customers, without having to pay a third party to carry that traffic across the Internet for them.

Peering has led to NKN having more control over its traffic. Had there been no peering, NKN would have sent or received traffic over a transit connection. After this, it would have gone across the Internet via whatever path the transit provider decides to use i.e., path of the "Best Effort". If there is a problem – slow connections or packet loss, for instance – the network would have been at the mercy of its transit provider. With peering NKN has more control over external paths and can easily adjust routing to avoid problem network segments. Therefore, keeping the traffic local and leading to improved performance. NKN has peered with Google, Facebook and Microsoft. NKN has enhanced Global Collaboration by peering with RENS such as Internet2, GEANT, SingaREN, CERN, NORDUnet, Asi@connect, LEARN, DrukREN and BdREN. It has brought benefits such as dedicated high-speed links, quality distance education, resource collaboration, enhanced multilateral collaboration and connecting research communities.

Peering has led to the following benefits for NKN

- Helps NKN to save its internet bandwidth usage and consumption, resulting in cost savings
- Provides better user experience through speed as user doesn't go on internet
- Reduces the element of best effort which in turn reduces latency and increases quality

Caching

A cache is a temporary storage area. When the user visits a web page, the files that are automatically requested by looking at a Web page are stored on the hard disk in a cache subdirectory under the directory of the browser. When the user return to a page recently looked at, the browser can get those files from the cache rather than the original server, saving time and saving network of the burden of additional traffic. Documents are stored in a nearby proxy cache instead of remote data servers. NKN has collaborated with Google and Akamai for caching services. Since caching stores the visited web pages in cache memory, it reduces the number of requests on the content provider. Caching also improves the access as the website load time is reduced. This helps in improving user experience. It can also act as backup in case remote server is not available due to crash or network portioning, hence one can obtain a cached copy at the proxy.

Caching has led to the following benefits for NKN

- Caching helps the user to cut down the time to open a link that already been open by any other user, moreover reduces the latency and minimises any delay

- Caching also helps in reducing the bandwidth consumption, therefore decreasing the network traffic
- Caching can also act as backup in case remote server is not available due to crash or network partitioning, hence one can obtain a cached copy at the proxy

The benefits of caching were also noted in the sixteenth HLC where it was told that cache engines were being placed for video flow. These cache engines had been helping NKN save close to 29 Gigabits per second, which would have been spent on internet bandwidth. The current fiscal year of 2018-19 saw NKN save close to INR 141 crores due to peering and caching. The total savings of NKN due to peering and caching is close to INR 648 crores.

3.4.5 NETWORK TIME PROTOCOL (NTP)

NTP is an Internet time synchronisation protocol. It is used to synchronise computer clocks to a time reference using the IP network/ internet. It is widely used in LANs and WANs to synchronise computer clocks to the national standard time. It sets up a reference server within the network to 'serve' accurate time to all NTP clients in the network requesting accurate time. NKN enables highly accurate and reliable synchronisation of computer systems by allowing measure of network latency. This in turn enables network engineers to optimise processes and transactions by identifying the bottlenecks in a transaction path. Time synchronisation also helps NKN to improve protection mechanisms as it allows identifying time manipulations.

NTP uses hierarchical system of "clock strata". Stratum levels define distance from reference clock and exist to prevent cycles in hierarchy

- Stratum 0: devices are atomic clocks, GPS clocks, radio clocks
- Stratum 1: computers attached to stratum 0 devices. Act as servers for timing requests from Stratum 2 servers via NTP
- Stratum 2: Similar to Stratum 1, but they also have peering relation to other stratum2 servers

National Physics Laboratory's (NPL's)⁵ time keeping is based on a bank of Caesium (Cs) atomic clocks and a Hydrogen maser. These clocks are so accurate that they would lose or gain one second in about three lakh years.

Looking at the requirement of NKN network, NPL stationed a NPL Controlled Remote Oscillator System at NKN, a secondary time standard of uncertainty better than 10^{-10} (which is sufficient requirement) at the site of NKN which is physically connected to NTP server. Hence NKN is a Stratum 1 server. At NKN, the oscillator system is composed of a Rubidium frequency source which works as a reference frequency source for NKN. Hence, we can call it as UTC-NKN. The output of this oscillator is fed to the NTP server which further synchronises the respective

⁵ National Physics Laboratory- National Physical Laboratory (NPL) is the National Metrological Institute (NMI) of India and has the responsibility of realizing the units of physical measurements based on the International System (SI units) under the subordinate legislations of Weights & Measures Act 1956 (reissued in 1988 under the 1976 Act).

network or NTP servers. Multi-frequency, multichannel GPS receives 1 PPS signal from Rb frequency source.

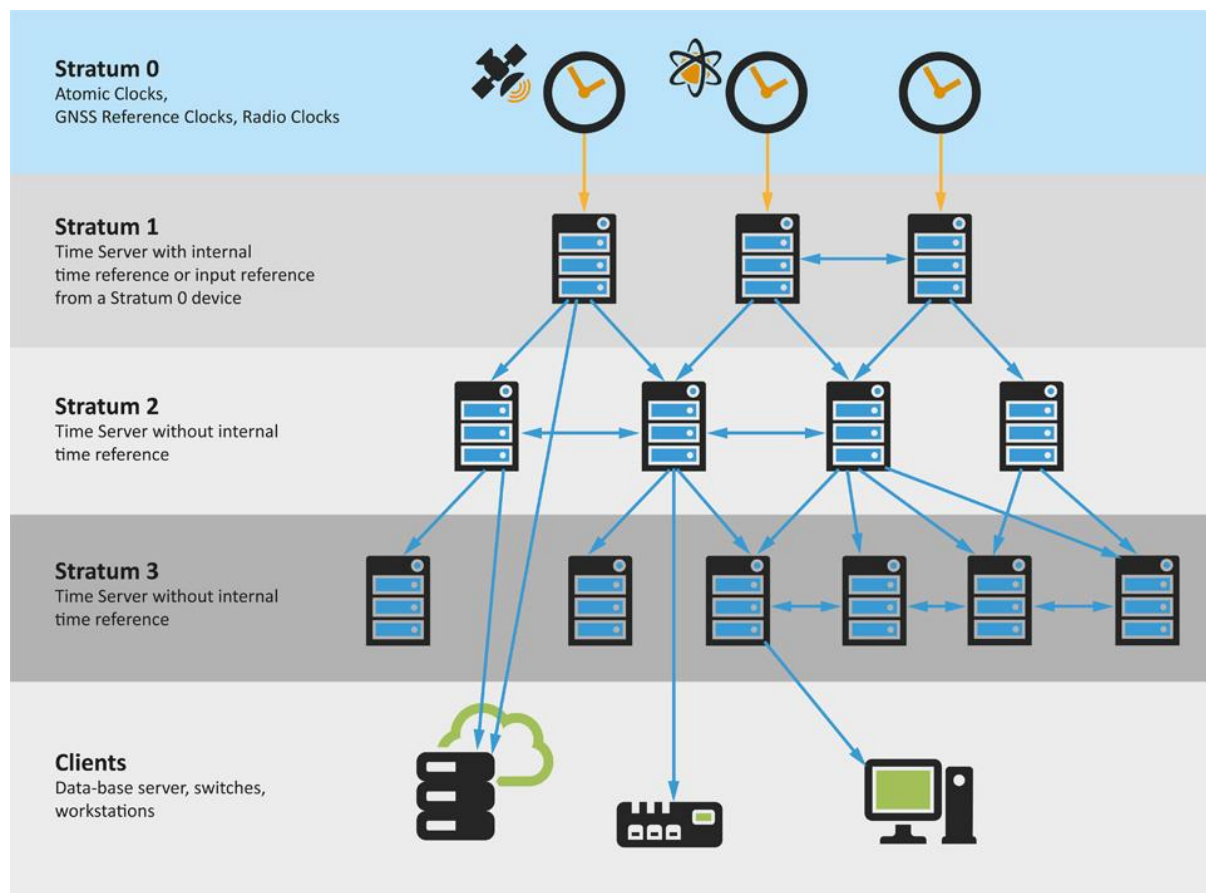


Figure 3.12 Hierarchical system of "clock strata" of NTP

NTP has led to the following benefits to NKN

Local networks are interconnected with other, larger networks, particularly over the Internet and correct time is the single common denominator. Real-world time is based on Universal Time Coordinated, or UTC⁶. Time synchronisation helps NKN to improve protection mechanisms against market abuse as it helps in identifying manipulated time stamps. The complete network of NKN uses a synchronised & standardised time which in-turn helps in forensic investigations, finance & cybercrime purposes as it provides accuracy up to millisecond & microsecond level. NTP helps in syncing the network devices to the accuracy of microseconds which helps the network administrators at NKN to determine the sequence of events in case of cyber-attacks. In case any fraud or another criminal act takes place, NKN system (that is synchronised with an NTP time server) possesses an auditable trail and because the time comes from an atomic clock source, it is irrefutable and can therefore be used in any potential legal proceedings.

⁶Networks operating on the underlying UTC share a common time base. UTC time is best obtained from an accurate, secure, reliable source and then converted to local time by all operating systems that reference that source. It is this common time reference that provides network managers the time-accurate information they need about their network to ensure optimal performance and avoid many problems

Key observations and recommendations:

Another aspect of the key objective was to have tens of Gigabits of connectivity with low latency features. NKN's understanding of management perspective has shown that it has performed extremely well on these expectations by achieving tens of Gigabits of network speed coupled with extremely low latency. The architecture design, along with the technical innovation, has given the required results. NKN's technical innovation is not only providing a robust network, it is also saving a lot of cost to the exchequer. To maintain the quality of service and to stay ahead in the competition, it is recommended to enhance NKN research team in the next phase of NKN. This team should primarily work on exploring on new network technologies, etc. NKN can explore collaboration with domestic and global industry and academia.

3.4.6 AWARENESS AND CAPACITY BUILDING

Awareness and capacity building of the partner institutes was high on NKN agenda. National level workshops and regional level workshops were organised to facilitate the same. NKN Annual workshops were held as per the following details:

IIT Bombay in 2012 with theme "The e-infrastructure of India"

The first annual workshop of NKN was organised in Mumbai. Representatives from all major academic institutions across the country participated actively in this workshop. This workshop facilitated increased collaboration among researchers from different national and international research & educational network to enable sharing of scientific data and remote access to advanced research facilities. The workshop was attended by researchers from USA, Europe and Asia Pacific region. Approximate 650 participants attended.

A live demonstration was made of Remote Operation & Control of European Synchrotron Radiation Facility for protein crystallography by BARC, Mumbai.

IISc Bangalore in 2013 with theme "Enhancing Research Collaboration Through NKN"

The Second NKN Annual Workshop was organised at Indian Institute of Science (IISc), Bangalore. The workshop was attended by representatives from major academic institutions across the country as well as overseas. The objective of the Second NKN Annual Workshop was to focus on "Enhancement of research collaborations through NKN" in different sectors/ areas where NKN played a significant role in delivering innovative services to the target groups. This has helped different user communities such as doctors, scientists, professionals, scholars, teachers and

students in their endeavours by providing them cost effective access to the desired data/information/ knowledge. Approximate 700+ participants attended.

IIT Guwahati in 2014 with theme “The E4 (Encourage, Empower, Enable Enrich)”

The 3rd NKN Annual Workshop was organised at IIT Guwahati. The workshop was attended by high level dignitaries and researchers from academia of national and international communities such as GEANT, Internet2, etc. The focus area for the workshop was exploring NKN as the Next-Generation Network (NGN) managing multiple types of traffic (such as voice, data and multimedia). The workshop covered the sessions on the leading practices in Cyber Security and Networking, on-going experiments on and experiences of NKN by few selected user institutes which would enlighten the NKN community to explore various possibilities in the future. Approximately 700+ participants attended.

Jawaharlal Nehru Technical University (JNTU), Hyderabad in 2016 with theme “NKN at the Core of Cyberspace”

The 4th NKN Annual Workshop was organised at Jawaharlal Nehru Technical University (JNTU), Hyderabad. The major attendees of the workshop were scientists, practitioners and researchers from national and international communities such as GEANT, Internet2 and Asi@connect. This workshop was focused on NKN at core of cyberspace, encouraging the use of NKN in e-Governance, education and cyber security. The workshop covered the sessions on the global practices in Information Security and advance digital technologies such as IoT, mobile security and cyber emergency response team and experiences of NKN by few selected user institutes in the area of advance research. The workshop was attended by around 1000 participants & 10 foreign delegates.

3.5 KNOWLEDGE ECOSYSTEM – THIRD PILLAR

NKN can attribute its birth for the empowerment of knowledge ecosystem of the country. Research, e-Governance, e-learning and collaboration usage in education, health, agriculture, science, space and weather, etc., are explored in the third pillar of the study. This study is based on the documents received from the NKN, sector and project specific information websites and the feedback received from the institutes.

3.5.1 EDUCATION

Today every country is revolutionizing its education sector as per the needs and demands of the market. United with scientific advancements, NKN has made dissemination of knowledge easier than ever before. Globally, NRENs were introduced by countries worldwide to fulfil the challenge

of meeting the needs of research, educational and library communities through a common network at the national level. In India, NKN fulfilled that role by connecting more than 1700 institutes of higher education, research and libraries across India with bandwidth ranging 100Mbps /1Gbps /10Gbps. These institutes have been using NKN for various activities, chief among them being effective digital enabled learning, collaboration and data sharing.

Digital enabled learning, or e-learning, was one of the applications that was proposed at the conceptualisation stage of NKN. Sixty-six virtual classrooms were established and used on NKN by some premium institutes. Empowering learning and higher education remained one of the core services of NKN. NKN has also aided in e-learning services, digital libraries, data centres, secure monitoring servers, video conferencing, etc. In the education sector NKN has been deployed quite heavily yet there is still a lot more scope for expanding its usage.

NKN for Virtual Classroom: e-Learning service

A virtual classroom allows learners to attend a class from anywhere and aims to provide a learning experience that is similar to a traditional real classroom. It facilitates instructors and students in teaching-learning scenarios, such as academic courses, seminar, interviews, discussion, or a live training programme. The virtual classroom is an advanced learning environment, created using high speed internet, video conferencing devices and other gadgets to help in classroom teaching. The classroom provides interactive and flexible approaches to e-learning including work-based learning & assessments. Additionally, the same technology can also be used for facilitating collaborative discussions across institutes as well as hosting seminars and workshops.

Educational institutes on NKN are connected through studio and web-based video conferencing services provided by National Informatics Centre (NIC) through the National informatics Centre Services Inc. (NICSI), New Delhi.

Some of the key features of virtual classrooms are:

- Extends the reach of teachers beyond the classroom and makes dissemination of authenticated and standard information easy
- Asynchronous learning - student learning anytime, anywhere and at their own speed.
- Multiple classrooms can be joined together into a single session
- Sessions can be recorded which facilitates easy simulations and virtual experimentations at a low cost which can be repeated any number of times
- Streaming of live lectures

NKN provides hardware based and web based access to virtual classrooms. This service is free of cost to the government funded institutes. NKN also has the web based access to virtual classrooms along with huge number of web casting and video conferencing services. For the hardware based virtual classroom, the infrastructure is created at the institute's end. At a time, the network can handle 900 simultaneous users. The service mostly caters to the institutes of higher education and research, although a school in Madhya Pradesh, India, is successfully using this facility. NIC provides a portal through which institutes can book the virtual classroom session. NKN also provides a help desk which is a centralised system for support.

Post inauguration of NKN, several institutes in India started using the facility of virtual classroom, like IITs, IISc, IISER, MNIT, MNIAT, TIFR, IIMs, etc. The infrastructure is provided by a service provider and had been bought by NICSI. It is also mentioned that the President of India also delivers lectures to the NKN connected institutes through virtual classrooms.

The year wise usage of the virtual classroom facility has been shown in the following graphs. The data provided here is only reported data i.e., data of the virtual classrooms booked on the portal. The actual data could be more than this. (Data received from NKN on virtual classroom).

1. Year wise usage –Total Lectures

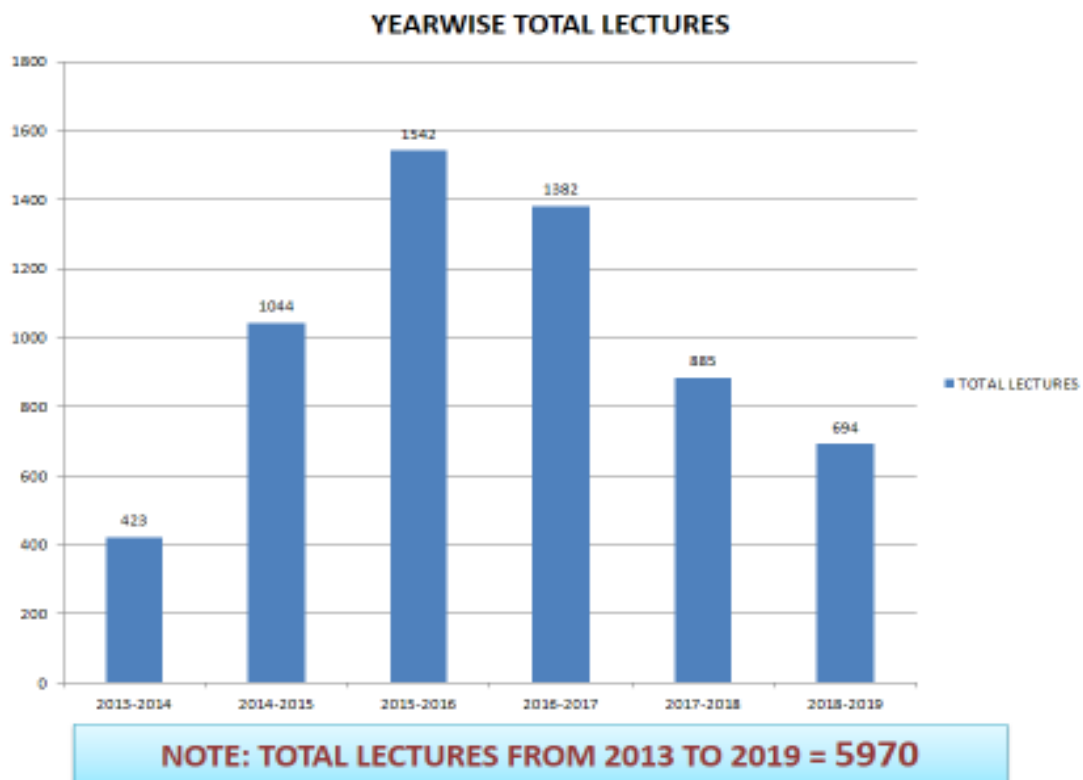


Figure 3.13 Year wise total lectures

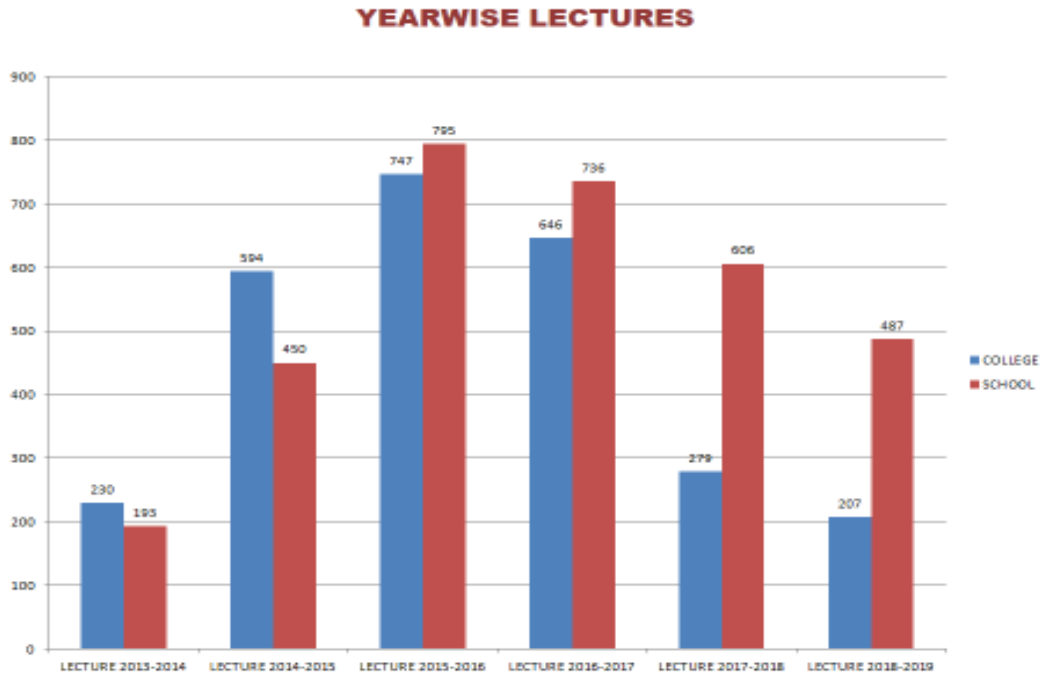


Figure 3.14 Year wise total lectures in Schools and Colleges

2. Year wise usage – Total Students Benefitted

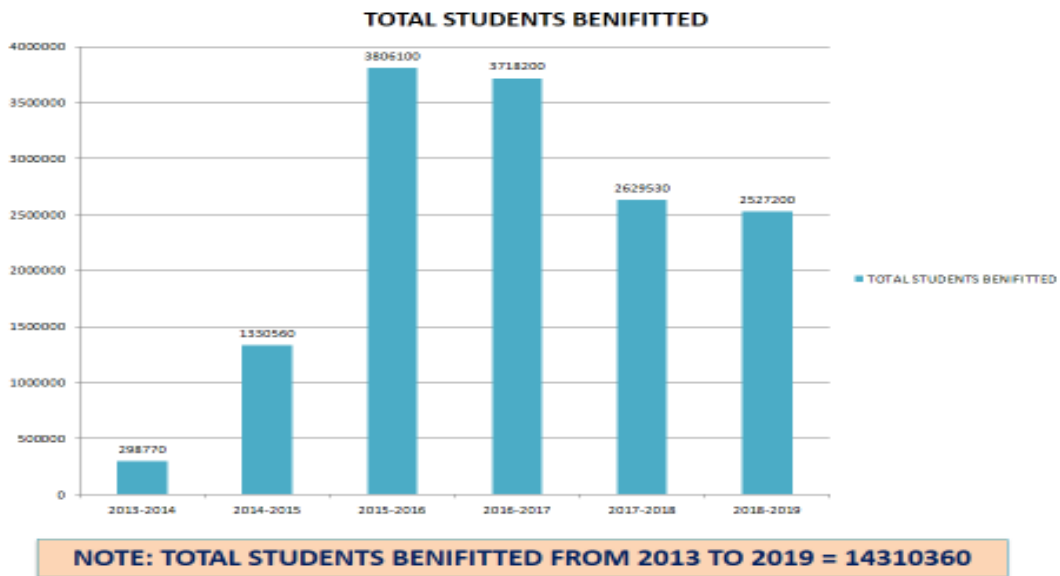


Figure 3.15 Total students benefitted from 2013-2019

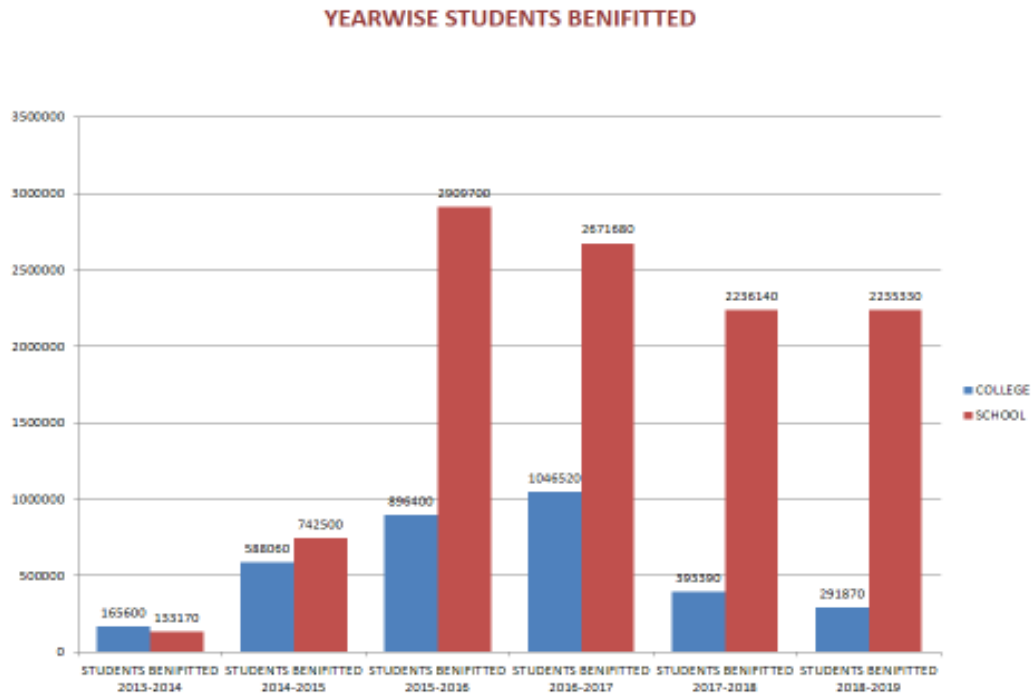


Figure 3.16 Year wise students benefitted in Schools and Colleges

3. Year wise usage - College and schools

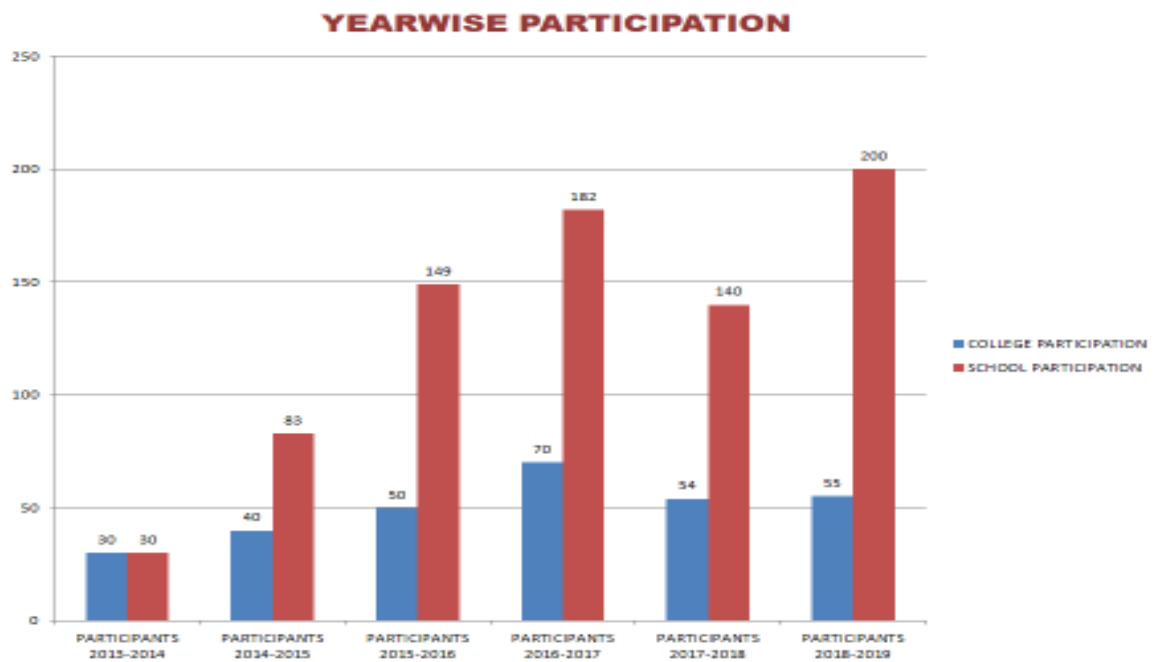


Figure 3.17 Year wise participation of Schools and Colleges

Key observations and recommendations:

The data captured from the virtual classroom portal shows the usage. It was started with a very high usage but is declining continuously. NKN team need to identify, whether the usage is decreasing or they are not reported on the portal. The user institutes can use it without booking it on the system. NKN need to rectify it and capture the usage data. It is a very important service of NKN and its success defines the success of NKN in education sector. It is important to note that as per the DPR, the whole NKN investment can be justified on this single point. Building awareness around this service and inclusion of more institutions is another area need focus. NKN should create the WBS (Work Breakdown Structure) for the growth plan and oversee it closely.

Connecting National Digital Library through NKN

MHRD, Government of India, under its NMEICT mission, entrusted IIT Kharagpur to host, coordinate and set-up a pilot project of National Digital Library of India (NDLI) towards building a national level asset. National Digital Library (NDLI), a pilot project developed by IIT Kharagpur, was undertaken to develop a framework of virtual repository of learning resources with a single-window search facility. The aim was to build a knowledge base to benefit students of all age groups. **The NKN network made it possible to ensure that every institute of higher learning had access to NDL so that the researchers throughout the country can find the reading material anywhere anytime.**

Filtered and federated searching is employed to facilitate focused searching so that learners can find out the right resource with least effort and in minimum time. **The online portal gives the layman access to over 65 million books and has come as a boon especially for the economically weaker students.** NDL India is designed to hold content of any language and provides interface support for leading Indian languages in various formats – text, audio and video. It is being arranged to provide support for all academic levels including researchers and life-long learners, all disciplines, all popular form of access devices and differently-abled learners. It is being developed to help students to prepare for entrance and competitive examination, to enable people to learn and prepare from best practices from all over the world and to facilitate researchers to perform inter-linked exploration from multiple sources. The pilot project is devising a framework that is being scaled up with respect to content volume and diversity to serve all levels and disciplines of learners. It is a 24x7 ubiquitous knowledge resource that is accessible to anyone with internet access and it is built to enable the rise of Digital India. It is the Single Window Platform that collects and collates meta data from premier learning institutions in India and abroad, as well as other relevant sources. It is a digital repository containing textbooks, articles, videos, audio books, lectures, simulations, fiction and all other kinds of learning media.

The objective of NDL is to make digital educational resources available to all citizens of the country to empower, inspire and encourage learning where the availability and accessibility is achieved through NKN links.

In earlier times, students had to struggle because of non-availability of books and other study materials, but this initiative has made the educational resources easily accessible. NDL aims to

make a paradigm shift in education and research in India by enabling every citizen with the knowledge resources they need to empower themselves. Education and culture are the cornerstones in the concept of India's 'Unity in Diversity' and **National Digital Library is a path breaking initiative by MHRD in this direction that is using NKN.**

Not only does it house thousands of books, manuscripts, thesis and other digital educational content, but also contains study material and question banks of at least 20 different competitive examinations, including the Joint Entrance Examination (JEE) conducted for admission to IITs, NITs and other centrally-funded technical institutes. All these are provided free of cost to the registered users.

The NDL has already attracted 35 lakh users so far, most of whom are educational institutions, students, teachers and researchers registered on the NDL website. To enable people to access the digital library on their mobile phones and other Android-based devices, the NDL team has developed an application which can be downloaded from Google Play and other platforms.

NDLI is also working closely with European Foundation (Digital Library of EU) in creating a platform for content and technology interchange between over a dozen digital libraries of the world. NDLI has also become a member of RightsStatements.org and sits on its Steering Committee to promote proper dissemination of copyrighted and non-copyrighted digital heritage items. Besides NDLI has also integrated contents from several international sources like OECD -Library, PubMed, WHO and a few leading global publishers.

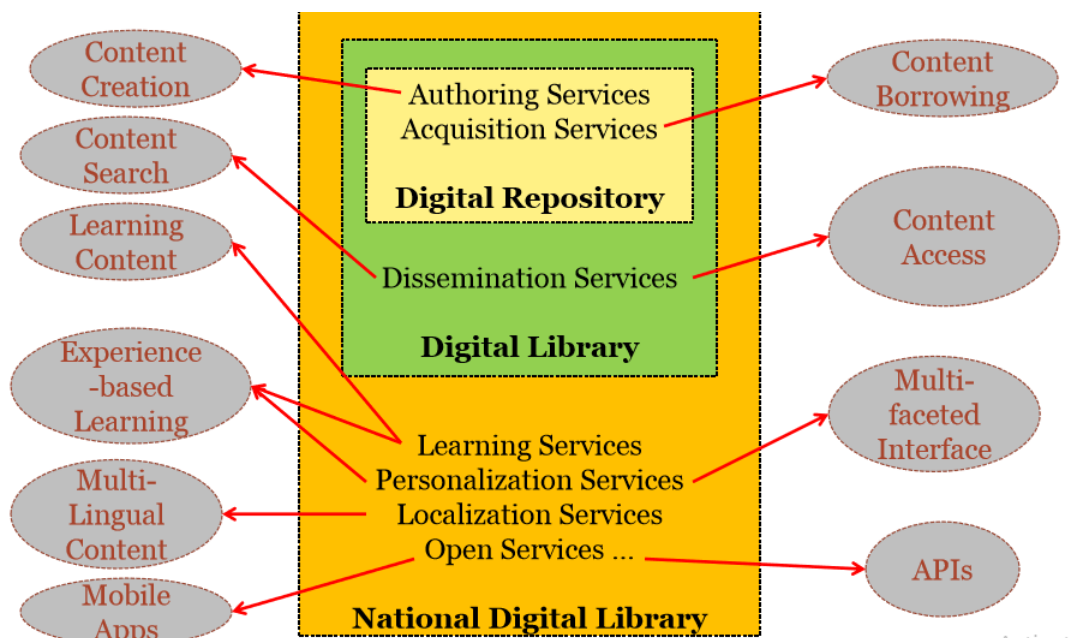


Figure 3.18 Digital Library Resources

Pan India delivery of NPTEL videos through NKN

The National Programme on Technology Enhanced Learning (NPTEL) is now more than a decade old. Conceived initially and still coordinated by IIT Madras, NPTEL is funded by the Ministry of

Human Resources Development (MHRD) to take quality education to remote areas. The National Video Server of the National Programme on Technology Enhanced Learning (NPTEL), makes the entire NPTEL content available through the Video Server located at IIT Madras through NKN. High Speed dedicated lease line of National Knowledge Network enables downloading of e-content to all the Universities and Colleges that have got connectivity under the NMEICT. At present, more than 250 universities/ university level institutions and nearly 11000 colleges connected on NKN and college VPN can straight away use or download the e-content for their storage and local use.

NPTEL is India's largest technical knowledge dissemination programme through ICT in the higher education sector. Its main objective is to increase the reach of high-quality engineering and scientific education across our country, which has the potential to transform India into a strong and vibrant knowledge economy. It involves developing innovative curricula and delivering the same as video and web courses with free and easy downloads from the NPTEL website.

Before the advent of NPTEL in the college, only a year ago, many lectures used to be over in 30 minutes, with the students whiling away the rest of the lecture time. Now the classes are utilised well and the students get a glimpse of how IIT students learn. Around the country, a large number of institutes are now making NPTEL videos available in campus classes. There are a few, which have made viewing of NPTEL videos compulsory. In other cases, students from around the country are viewing the lectures on their own, either as a substitute or as a supplement to class lectures. Recently, NPTEL launched certification programmes, which have also become popular among students. Colleges use NPTEL videos strictly according to their curriculum.

NPTEL facilitates the distribution of lecture materials using ICT while NKN serves as the medium for disseminating the content through its network.

Knowledge Management Centre's database accessible through NKN

The Knowledge Management Centre (KMC) at NID (National Institutes of Design) has acquired a vast collection of electronic resources in the form of databases, journals, archives, etc., under a user-centred approach. It is being widely used by the faculty and students at NID. **NKN has facilitated smooth access to this knowledge in the campuses across the country.** The e-Resources available include ACM Digital Library, Berg Fashion Library, Euro monitor International, EBSCO: Art and Architecture, EBSCO: Communication and Mass Media Complete, Euromonitor International Passport GMI, Grove Art Online, Newspaper Direct, ProQuest: Arts and Humanities, Vogue Archive, Women's Wear Daily (WWD) Archive etc.

The library has gone beyond its traditional usage of book-reading and with the help of technology has delivered the content to students at their doorstep. Just like virtual classrooms have liberated education, similarly NID's KMC has liberated libraries. Here NKN has facilitated the access to the rich collection of e-Resources through its high bandwidth network to all the institutes engaged in knowledge production.

A veritable art history degree's worth of books digitised by the Solomon R. Guggenheim Museum are now available for free. It provides access to e-Journals which are multidisciplinary, peer-reviewed online journals dedicated to publishing descriptions of artefacts, environments and experiences created to promote and support learning in all contexts by designers in any field.

This is just one of the essential steps towards making India a powerhouse of innovation and intellectual property creation.

NKN's contribution in Training 10 Thousand Teachers (T10KT)

'Train 1000 Teachers' programme was initiated by IIT Bombay in 2009, under the project 'Empowerment of Students/ Teachers,' sponsored by the National Mission on Education through ICT (MHRD, Government of India)

T10KT is a major initiative under the NMEICT to improve the teaching skills of engineering college teachers of the country in core Engineering and Science subjects. It is a national-level project which has been enabled by the presence of NKN at IIT Kharagpur. **The NKN infrastructure is being used to give live lectures and hold tutorials and labs by IIT faculty over NKN for the benefit of participating teachers attending at a remote centre close to their own college.** The lecture transmission and live interaction takes place through distance mode using the AVIEW technology and the internet, at selected remote centres across the country.

This project attempted to address a critical subset of important issues and adopted an approach to address these utilizing modern technologies. It uses an ICT enabled process involving both synchronous and asynchronous mode to reach out and engage a large number of teachers and through them, a much larger number of students. Using 385 established Remote Centres across India, the participant teachers are able to attend lectures being transmitted live from a single location.

This model allows all kinds of interactions possible – synchronous, asynchronous and face-to-face interaction between the participants and the coordinators. Such kind of collaborative learning has proved to be an important component in training. As the focus is now easily shifting from teacher centric to learner centric education, more and more such innovative ways of incorporating ICT for pedagogical purposes are being explored.

Key Observation:

NKN has come to the rescue of millions of researchers and other students throughout the country as it has helped in providing access to resource material through National Digital Library initiative. With the help of virtual classrooms, the learners can attend a class anytime from anywhere as geographical barriers no longer play deterrent. NPTEL videos have enabled the learners to learn at their pace and have eased the process of learning for students. In a country where student teacher ratio is deplorable, extra help and tuitions after classes has become a norm across the country. In such a scenario NPTEL videos provide that extra help to the students at no additional cost.

These are just some of the initiatives undertaken with the hope that such efforts will enhance national productivity and competitiveness as well as speed scientific and technical advances in a number of fields. An increasing reliance on the internet is ensuring that the education sector is expanding its use of electronic networks in every area which is a part and parcel of education.

3.5.2 HEALTHCARE

Healthcare is one of the key infrastructural foundations on which a nation rests. Being crucial in the developmental leap of country, it rests on two important categories: well-being of the citizens and the state of its health institutes. In this context, the healthcare sector is of fundamental importance. The healthcare sector in this country has evolved from its nascent stage to becoming one of the leaders in the developing world.

One of the key issues is interns of the urban-rural gap and limitation of expertise in certain locations which needs to be devolved and disseminated across. The other concern is non-culmination of research, scientific and technological advancements into a reality as the dissemination has been a limited one. In this context, medical sciences in India have greatly benefitted by the NREN network as it emerges as a source of innovation and creativity of both scientific and technological ideas.

The NREN has helped in the emergence of National Knowledge Network which has facilitated an environment in which many different worlds of the science, technology and health have converged together. It has facilitated knowledge and research in the country and has also connected us to the world outside. It has not only helped in seamlessly sharing of health and medicine related data and information amongst the host of players involved, it has also revolutionised the pedagogy and curriculum of institutes of health education and centres of excellence. It has made remote education and learning easier as the “classroom” has reached the learner.

This section attempts to look at the various initiatives facilitated by NKN in the health sector of this country. What one ascertains are the various great transformational capacities that NKN bears, at the same time elaborates on the various facilitation that NKN has undertaken. This section looks at two broad frames of references. First, NKN as a network builder and provider and second, its role in dissemination of Telemedicine and Health Research and Knowledge, NKN's availability as platform and portal and as disseminator of the same. The attempt is to understand NKN's role in healthcare research and access.

NKN AND NETWORK CREATION

NKN and Open Source Drug Discovery (OSDD)

Open Source Drug Discovery is a consortium led by CSIR's dedicated team in partnership with other key global actors. This is a key initiative that aims to provide affordable healthcare to the developing nations. It is a discursive platform that enables the coming together of healthcare and non-healthcare practitioners and experts to deliberate on resolving complex health concerns along with sharing the drug discoveries. OSDD, as a platform, is helpful in sharing of information regarding the neglected tropical diseases such as malaria, tuberculosis, leishmaniosis, etc.

Currently NKN connects the OSDD partners throughout the country. It is being used extensively by National centres of excellence on Health Research. NKN has been partnered by Institute of Microbial Technology (IMTECH), Institutes of Genomics and Integrative Biology (IGIB), Jawaharlal

Nehru University (JNU), Institute of Life Sciences. These institutes find NKN as their backbone, as it has the capacity to provide distributed environment to all their computing partners. **NKN helps them to be a unified platform for sharing Bio-Informatics along with being an open source platform for drug discovery.**

Collaborative Digital Diagnosis System

NKN funded Model project 'Network-Enabled Medical Diagnosis and Education in Skeletal Imaging: Using X-Rays', has been undertaken. This project has been invoked as a proof of concept to provide a network-based system for radiological and orthodontic diagnosis through X-Rays. This project is fascinating as well as complicated as it is not limited to the Orthodontics and Orthopaedics but takes expertise from the varied domains such as Radiology, Computational Methods, CAD/Rapid Prototyping, Image Processing and Pattern Recognition.

This project has been designed and planned in two phases: First Phase would be to develop an application which would enable visualisation and processing of radiological data over a collaborative platform. Second Phase would witness the effective rolling out and enhancement of the application as per the usage and requirements of the institute/ user.

NKN would be helpful in creating a national platform through this project for radiological diagnostics for the treatment plan of patients throughout the country which will help in bringing the urban and rural divide interims of access and usage of these diagnostics. As most of the higher healthcare centres are limited to the urban centres, the rural India gets neglected. Unfortunately, the concentration adversely impacts the quality of radiological teaching and understanding amongst the various medical students belonging to diverse medical and dental colleges. **Through NKN, organisations like National Informatics Centre, All India Institute of Medical Sciences, Indian Institute of Technology, Mumbai and CSIR- Central Scientific Instruments Organisation, which have expertise in different terrains, have come together in effective development, implementation and roll-out of this application.** This would bring about a significant shift in the way radiological diagnosis and teaching are being carried out.

In order to fill the urban-rural divide, NKN would help provide a national platform connecting the various parts of the country.

CANCER GRID:

NKN has also organised itself and its users in multiple grids. This includes Cancer Grid, Brain Grid, Climate Change Grid and many others. The idea of a grid formation comes from connecting users across organisations forming Special Interest Groups (SIGs). These could be disease specific or modality specific. These grids also have the possibility of forming smaller grids: as part of larger grid, referred to as Sub Grid

Cancer Grid is one of the initiatives that NKN has taken as part of this. This aims to bring together the conceptual integration of Science, Engineering and Medicine through bringing together researchers belonging to various institutes from across the country. It also involves interaction between scientists of various expertise and practicing clinicians along with the engineers who bring with them the art of machines and fine imaging. It has been found out that in the case of cancer, science in the understanding of the disease along with clinical practices and emerging new modalities in imaging and diagnosis are all interdependent on each

other. One cannot be taken in isolation, therefore through the cancer grid; NKN brings out the opportunity of carrying out interdisciplinary research at both basic and applied levels. Establishment of disease related biomarkers is a fundamental area that appears to remain relatively unexplored.

Forming grids consisting of users from a focused application in the medical use highlights the impact of NKN in knowledge integration and direct societal benefit. Also, NKN is connected to all leading research and development networks across the world; USA, EU, Japan and Australia.

Facilitation of collaborative research on EPILEPSY:

NKN network has extended itself in the research on brain and its related diseases, epilepsy being one of them. The Centre of Excellence (CoE) for Epilepsy is a collaborative project of the National Brain Research Centre (NBRC), Manesar and the All India Institute of Medical Sciences (AIIMS), New Delhi, supported by the Department of Biotechnology, Ministry of Sciences and Technology, Government of India. Recently, the Magnetoencephalography (MEG facility) has been set up at the NBRC in Manesar and is the first such setup undertaken in northern India. **The MEG data acquisition of each patient and its subsequent analysis, each of several gigabytes in size, is synchronised in real-time over the NKN network between NBRC and AIIMS, thus directly aiding epilepsy surgery.**

This is a one of its kind facility as a dedicated neuroscience research Centre has collaborated with a premier Medical institute in order to investigate the complex changes that results with the development of pharmacy resistant epilepsy in humans, using a multidisciplinary approach. A combination of Electrocorticography (ECoG), Magnetic Resonance Imaging (MRI), Electroencephalography (EEG), video EEG, as well as functional imaging techniques such as Positron Emission Tomography (PET) and Single Photon Emission Tomography (SPECT) along with the extremely sensitive Magnetoencephalography (MEG) are utilised to locate the epileptogenic area. The resected samples are further processed for cytological and molecular studies which includes cellular electrophysiological investigations, immunohistochemistry-based studies and genetic and transcriptomic profiling. The cyto-molecular data is then correlated with the imaging, MEG and ECoG score, which helps to establish a scientific path for the development of a non-invasive protocol. NKN becomes important in new non-invasive surgical methods as its networks become crucial in data sharing in real time.

Knowledge and Healthcare Delivery Network in SGPGI

NKN has been instrumental in sharing of Knowledge and creating healthcare network delivery. This can be ascertained by the usage of NKN facilities by healthcare research institutes. **In the recent times, Sanjay Gandhi Post Graduate Institute of Medical Sciences has been utilizing the NKN bandwidth created Wi-Fi zones in the wards.** This facilitated in easy access and sharing patient related information wherein doctors on duty could access knowledge content stored in the SGPGI Knowledge Park. This was also helpful in real-time access to data on surgery, interventional procedures along with mobile computing tools while facilitating access to live surgery sessions to the surgical residents.

NKN provides internet connectivity to JIMPER'S initiative of Nano drone

Jawahar Institute of Postgraduate Medical Education and Research (JIPMER) has introduced medical drone service on its premises to spruce up its healthcare facilities extended to the patients. **The medical drone services will be operated by using the internet connectivity provided by the National Knowledge Network (NKN).**

With the launch of this drone in this unit, it has been ascertained that the doctors along with the specialists in the institute that monitoring patients at the intensive care has been accomplished with great success. It has been realised that the drone would be useful in cases of close space emergency like fire accidents especially in spaces that cannot be entered, as it fetches the necessary information for resolving the crisis. This drone can also be used for other purposes like surveying classrooms, hostels and entire campus if necessary.

In one of the case studies on JIPMER Telemedicine, the usage of NKN is well elaborated:

Why telemedicine uses NKN?

Telemedicine is used for consulting the doctor, OPD, second opinion, specialist support and collaboration among medical fraternity. This service is provided to the patients at the remote and distant locations. This is also useful at the situations where specialisation is sparse and can be distributed only with the help of the technology. A high speed and low latency network is highly needed for smooth interactions, observations and recommendations and this need is addressed by NKN. This highly needed system becomes critical when doctors are collaborating on live surgery and life-threatening situations.

IMPACT OF TELEMEDICINE SESSIONS

The various telemedicine sessions as facilitated by NKN has been helpful in creating well entrenched networks between large number of healthcare professionals, institutes, experts, practitioners, scientists, researchers and students across the various states in the country. This has boosted confidence amongst the health and medical community to execute large technology-based initiatives.

These sessions have helped in covering the distance between qualified professionals located at distant & remote locations with care receivers. Sustaining this initiative will help not only in the dissemination of research and knowledge in healthcare sector but also in the actual delivery of healthcare services in India. **Pan-India existence of network like NKN will improve the quality of healthcare and will save some healthcare expenditure borne by the government in this sector.**

Key Observation:

A telemedicine session event information website where the recorded sessions of the past events are available will work as a knowledge repository. A dedicated dashboard should be created by JIPMER and hosted by NKN where the outcomes of the telemedicine services are shown on the basis of KPIs.

Scale the facility to more institutes.

More technology-based healthcare consulting and collaboration models can be built in conjunction with the healthcare domain. This can be done by creating similar platforms to educate and collaborate the professionals.

Both B2B and B2C systems can be offered. NKN could provide the backbone by helping in delivering last mile connectivity to its partners.

NKN and medicine research and knowledge:

Apart from being the platform for providing extensive networks for various medical institutes, NKN has played an important role in the dissemination and education of health in various institutes of excellence. NKN plays important role in bridging the gap between experts, faculty, practitioners and students. Usage of NKN can be explored for sharing “rarest of the rare” cases that has been path breaking with hosts of medical institutions connected through NKN. An interesting case study of usage of NKN facilities for health is that of All India Institute of Medical Sciences, illustrated below.

AIIMS

AIIMS, Delhi, completed a Model Project in establishing ‘Medical Classroom’ by bringing together 6 to 7 institutions for teaching courses. Course material was also developed by them which resulted in many new areas making itself part of the medical pedagogy and syllabus. Many of the courses offered as part of this project are now in digitised format, which makes it easier to share. In the feedback session of this particular project, the experience was encouraging and positive, as communicated mostly by institutes located in remote sites.

In another AIIMS’s Model Project ‘Centre for Dental Education and Research’ done in collaboration with CSIR-Central Scientific Instruments Organisation (CSIO) based in Chandigarh and National Informatics Centre, Delhi, a 3D imaging facility was implemented. This was done with the usage of CollabCAD, which is a software developed by NIC, algorithm perfected by CSIO and application endorsed by AIIMS for dental imaging. This project was received extremely well. Its success can be judged from that fact that the project team is extending it to 6 other medical institutions. This team is also involved in exploration of new vistas in 3D printing for dental implants.

3.5.3 SCIENCE AND SPACE

GARUDA

GRID GARUDA initiative is a collaboration of the scientific, engineering and academic community to carry-out research and experimentation on a nationwide grid of computational nodes, mass storage that aims to provide the distributed data and compute intensive high performance computing solutions for the 21st century. The availability of the efficient, high-speed (Multi Gigabit) network backbone the National Knowledge Network (NKN) and Garuda's migration to NKN gives ample opportunity to exploit the Gigabit speeds for the scientific and engineering applications being run on the GARUDA such as aerosol modelling, bioinformatics, collaborative e-learning. Currently the highly reliable and available NKN connects the resources of the Garuda grid with a dedicated bandwidth, with provisions of QoS and Security.

IIT Bombay - e-Foundry

e-Foundry provides teachers, students and casting industry professionals free access to teaching content in casting design and simulation developed at IIT Bombay. It is a part of the NKN mission to connect knowledge providers and seekers through a high bandwidth network. It has been envisaged and developed as a free online resource of knowledge accessible over the NKN network with the characteristics like authenticated content by domain experts, free and open access to anyone through internet and interactive and collaborative working environment (IIT Bombay, 2013).

Indian Space Science Data Centre - Mission Mars

NKN is being effectively used at Indian Space Science Data Centre (ISSDC) for all the science mission initiatives of ISRO, including "Mars Orbiter Mission", as per the feedback received from the Director of ISRO on April 6, 2017. It is India's first interplanetary mission to planet Mars with an orbiter craft designed to orbit Mars in an elliptical orbit. The Mission is primarily technological mission considering the critical mission operations and stringent requirements on propulsion and other bus systems of spacecraft.

CASE STUDY (Mars Orbiter Mission)

Mars Orbiter Mission (MOM) or Mangalyaan, after 15 months of manufacturing at a cost of INR 454 crores, was launched using a Polar Satellite Launch Vehicle (PSLV) rocket C25 at 09:08 UTC (Coordinated Universal Time) on 5 November 2013. It was India's first interplanetary mission. ISRO became the fourth space agency in the world after National Aeronautics and Space Administration (NASA) of the US, Russian Federal Space Agency (RFSA) and European Space Agency to have successfully undertaken a mission to Mars.

MOM was on a quest to fulfil dual objectives - Technological and Scientific.

Technological Objectives:

- Design and realisation of a Mars orbiter with a capability to survive and perform Earth

bound manoeuvres, cruise phase of 300 days, Mars orbit insertion, capture and on-orbit phase around Mars.

- Deep space communication, navigation, mission planning and management.
- Incorporate autonomous features to handle contingency situations.

Scientific Objectives:

- Exploration of Mars surface features by studying the morphology, topography and mineralogy.
- Study the constituents of Martian atmosphere including methane and CO₂ using remote sensing techniques.
- Study the dynamics of the upper atmosphere of Mars, effects of solar wind & radiation and the escape of volatiles to outer space.

Thirty Meter Telescope (TMT)

TMT is one of the world's largest telescopes built by an international collaboration, consisting of the US, India, China, Canada and Japan. TMT is being built at an estimated cost of about \$1.47 billion. India joined the TMT consortium as a full member on 12th February, 2014. The components, by-and-large, include parts associated with the main mirror of the telescope, like the mirror support system, the parts which align the mirror to make a single surface, the software for observatory control, telescope control and many of the mirror segments themselves. India's role in setup – create the control systems and software that keep the mirrors aligned and collect the data. This application and several others are connected by C-DAC on the NKN backbone through the grid computing model.

Weather Forecasting

NKN is one of the key enablers in expanding nation's presence in weather technology, with more preciseness and accuracy. Knowledge and skills of the NKN team offers a precocious support to our meteorological and space scientists. It also allows the country to collaborate with the global research communities, working for the same domain/s, for example EUMETCAST, NOAA-NESDIS (USA) and many more.

CASE STUDY (Weather Forecasting)

Knowing where storms are now can help forecasters predict where storms will be tomorrow and the next day. Technology, such as weather satellites and Doppler radar, helps the process of looking over a large area, as does the network of weather observations.

Weather forecasting is a complex and often challenging skill that involves observing and processing vast amounts of data.

Forecasting ultimately is a 3 steps process. This includes –

1. Observing
2. Forecasting
3. Communicating

A weather specialist first observes data received from a satellite – different images, numeric data and some surface data and reports. To predict long term weather he/she needs to rely on

different numeric data models too.

National Centre for Medium Range Weather Forecasting (NCMRWF) always tried installing a system that is capable of handling the volume of data received from the satellites near real time for more precise predictions on weather.

Effort of the NKN team has been acknowledged by the NCMRWF team for enabling them to connect and start receiving EUMETSAT (European Organisation for the Exploitation of Meteorological Satellites) data on a real-time basis. The NCMRWF team also added that this service uses SSM multi-cast and requires network level configuration to receive this broadcast. In this connection, it was acknowledged, a great support was provided by the NKN team in configuring the network, server and also high technological data handling. With this effort, India is able to receive EUMETSAT broadcast data.

Recently, with the help of the NKN team a new server was set up for receiving satellite datasets from NOAA-NESDIS (USA). This server is connected directly on the NKN router with network security provided by NKN.

All the above-mentioned efforts helped NCMRWF to enhance its observational data reception volume by about 30%.

ISRO (Indian Space Research Organisation) found NKN technology extremely useful for data dissemination and consolidation of the content generated at various Regional Centres for ISRO's geo-portal, Bhuvan.

As per Mr. Ratan Chetwani, Director ISRO, "The weather, meteorological and oceanographic data available on MOSDAC (Meteorological and Oceanographic Satellite Data Archival Centre) and NARL (National Atmospheric Research Laboratory) is also disseminated through NKN. The data transfer between Space Application Centre (SAC), Ahmedabad and INSAT Meteorological Departments Processing System (IMDPS) and SAC and NCMRWF for all ISRO satellites data and EUMETCAST data is through NKN."

He also added - "...with the increased need for utilizing space based data services by Central Ministries, the availability of NKN infrastructure is crucial and critical for dissemination of data products and services. In order for NKN to become a resilient infrastructure, the NKN team has top priority into the availability and resolution of the links without any disruption thereby reducing the turnaround time for providing additional NKN links.

Prototype fast breeder network

The design of the country's first fast breeder reactor, called Prototype Fast Breeder Reactor (PFBR), was done by the Indira Gandhi Centre for Atomic Research (IGCAR), Kalpakkam in Tamil Nadu using NKN.

3.5.4 AGRICULTURE

NKN has always been in synchronisation with the aim of empowering agriculture and has laid stress on narrowing the gap between scientific knowledge and field farmer implementation techniques. **The Krishi Vigyan Kendra (KVK), which is an integral part of the National Agricultural Research System (NARS) functioning as Knowledge and Resource Centres of agriculture technology, is linked with NKN.** This has helped farm schools with a linkage to KVKs to demonstrate and speed up the process of technological up gradation of crop and allied sectors.

Case Study: (e-Initiative for agriculture domain)

It was envisaged that the role of ICT will not be limited to urban needs but will carefully be designed and implemented to look after the critical needs of the rural India - especially for the farmers. The application of Information and Communication Technology (ICT) in agriculture is increasingly important. e-Agriculture is an emerging field focusing on the enhancement of agricultural and rural development through improved information and communication processes, more specifically, conceptualisation, design, development, evaluation and application of innovative ways to use ICTs in the rural domain, with a primary focus on agriculture. All stakeholders of agriculture production system need information and knowledge about these phases to manage them efficiently. ICTs are most natural allies to facilitate the outreach of Agricultural Extension system in the country.

Agropedia was created under the NAIP as an innovative knowledge sharing platform, expected to serve as a one-stop-shop for things related to agriculture. It has been widely acclaimed the world over. It is built on open access, has a digital library and a social networking site, besides other features. ICRISAT and IITK had a major role in the development of the Rice Knowledge Management Portal which was launched by the Prime Minister of India. Similarly, by using the Agropedia framework, ICRISAT and IITK are working jointly in developing KM Portals on Fisheries, Oilseeds and Horticulture.

The great vision of Agropedia is to have several 'mini' agropedias, one for each and every crop, animal, commodity and discipline. We count on ICAR to step up its efforts to adopt Agropedia in a big way. Each of its institutes has a definite mandate to cover a crop, animal or a particular discipline. Each institute should develop a digital knowledge repository related to its mandate using the Agropedia framework. The vast amount of data, information and knowledge found in different places, forms and in different languages should be collated and organised in a scientific way for easy access and quick retrieval of needed information. The participation of the academia, civil society organisations, farmers and other stakeholders in content development will make the content more refined and wholesome. The co-development will also make the content more relevant and localised.

As per Dr. Rajendra Hegde, Principal Scientist and Head of ICAR - "This gives us immense pleasure to record that NKN, which was commissioned and started functioning since January 2015 in our Centre, has given us extremely good and trouble-free services. Our Centre got NKN facility at right time. Our scientists were demanding for uninterrupted internet/ mail for Research/ Academic work. From the date of installation of NKN, we are able to disseminate large volume of Scientific and Research information among research, educational institutes and line departments of the state and central government. "

Key observations and recommendations:

NKN is being used in Education, Science & Technology, Agriculture, Healthcare, Space Research, Weather Forecasting and e-Governance extensively. Such a large number of telemedicine sessions empowers healthcare sector to take next level jump in technology-based healthcare services. Pragati implementation is effective for the ease of governance at the top. Space research is giving us the leadership in the global arena and precise weather forecasting is making life easier for people in general. Veterans of these fields have praised NKN in their feedbacks. A milestone is achieved. NKN has played its role in the growth of the knowledge economy of India.

The image is the Knowledge Economy Framework of the World Bank. It maps very well on the implementation of NKN in India. It is suggested that the knowledge disseminated & received should be measured and displayed in a dashboard like the Ujala Dashboard. Sector-wise data will flow from the institutes to the dashboard. For example, an innovation in agriculture may have a direct impact on the earnings of the farmer and that fulfils PM's vision to double the earnings of the farmer. This can be shown on the dashboard with appropriate parameters. The data in dashboard can be fed by the innovation and collaboration sub-portals which are two other requirements of the knowledge ecosystem.

Knowledge Economy Framework

The following pillars are four critical requisites for a country to be able to fully participate in the knowledge economy:



Education & Training

An educated and skilled population is needed to create, share and use knowledge.

Information Infrastructure

A dynamic information infrastructure—ranging from radio to the internet—is required to facilitate the effective communication, dissemination and processing of information.

Economic Incentive & Institutional Regime

A regulatory and economic environment that enables the free flow of knowledge, supports investment in Information and Communications Technology (ICT), and encourages entrepreneurship is central to the knowledge economy.

Innovation Systems

A network of research centres, universities, think tanks, private enterprises and community groups is necessary to tap into the growing stock of global knowledge, assimilate and adapt it to local needs, and create new knowledge

SOURCE: <http://web.worldbank.org>

3.6 VALUE PROPOSITION – FOURTH PILLAR

NKN is an investment project and its economic outcomes can be both tangible and intangible. Some of the types of savings can be quantified, whereas others are intangible savings. Respecting the kind of data available, the present study dovetails more from the point of view of cost saving, revenue opportunities for institutes and impact on GDP, as summarised herewith.

3.6.1 PEERING AND CACHING

Based on the various statistics that have been collected over a period and based on the feedback of researchers from multiple institutes, NKN noticed that the users have been using many content delivery platforms like Google, Facebook, Microsoft, Akamai, Powergrid, BSNL and RailTel. To cater to the increase in use while achieving uninterrupted net connectivity, low latency and saving time and cost, Peering and Caching were utilised.

As per the directions and recommendation of HLC and TAC, NKN has come up with in house innovations that directly affect the quality of services and savings for the Government of India, like setting up peering and caching with different content providers.

This has not only curbed the internet expenditure but has also enhanced the user experience within NKN connected institutes.

To this end, NKN has been able to save approximately INR 140 crores for FY 2018-19. Since 2012-13, the saving has been approximately INR 648 crores.

3.6.2 CONNECTING INSTITUTES

NKN has different negotiated rates for multiple distance slabs which are agreed upon with the NLDs. When an institute wants a new connectivity and there is already an NKN connected institute nearby, if feasible, there is an option to extend the connectivity from that institute (if all the stake owners agree).

The cost for extending the lease line from NKN connected institute to the new institute is substantially very less. This is true for any distance slab and for any specified bandwidth. Assuming that the distance slab of the newly connected institutes is same as that of the NKN connected institute from where extension is provided, the cost of new lease line connectivity is averaging out to be INR 22.6 lakhs. In comparison, the cost of extension is INR 3.5 lakhs. Taking other costs into consideration, NKN has been able to save almost INR 20 Cr by giving extensions to 128 institutes and redundant links through the same mechanism.

Therefore, based on the calculation provided above, some of the institutes in NKN are connected via extension which in turns saves huge amount of cost as the cost of extension is considerably less than the cost of new connection for any bandwidth for any distance slab.

3.6.3 DUE TO TRIANGLE FORMATION OF DISTRICT LINKS

Even in the case of district links, NKN has provided extension, thereby providing redundancy of the districts links in case one of the links is down, the network is still up and running at all times.

To maintain the continuity of NKN services at all levels, Network Redundancy has also been provisioned to all state capitals, approximately 400 district centres and even some premier institutes.

Redundant links are mandatorily provided by two different service providers preferably with a different path as an additional measure of precaution. In a normal scenario, a state capital is connected to many districts. Taking an example, previously a state capital and 2 districts links were connected via **4** links to ensure the redundancy.

During the course of time, due to the design architecture and innovation of NKN, restructuring has been done for the connectivity of the district links, in which ensuring the redundancy, presently a triangle is formed of **3** links that results in direct cost saving for NKN managing the same amount of data transfer. Below diagram depicts the same.

Apart from the cost saving in reducing the number of links, NKN has also increased the bandwidth capacity of the link in the process of restructuring.

Currently almost all the district links are connected on 1 Gbps.

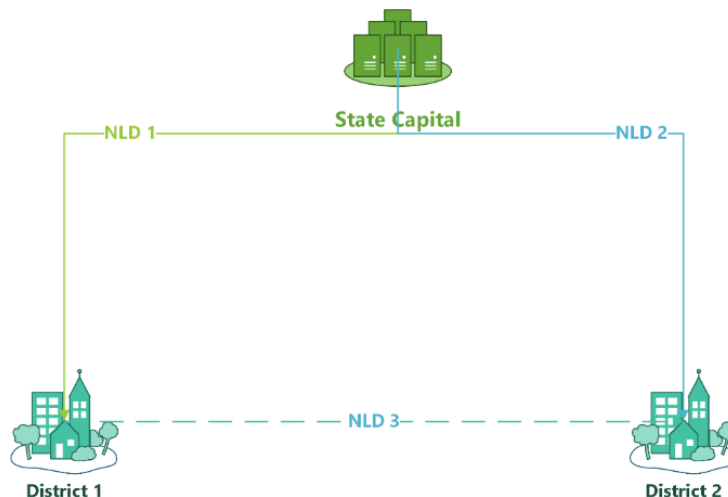


Figure 3.19 Redundancy in district links

The cost saving for the districts links can be calculated in a similar way.

3.6.4 DUE TO NKN APPROVED RATES

National Knowledge Network is considered as the National Research and Education Network (NREN) over which approx. 800 Gbps of traffic movement and over 5 Petabytes of data flows on

daily basis which is rapidly increasing year after year with introduction of newly connected institutes.

HLC advised for the creation of a Negotiation Committee from whom inputs were taken for the budget and subsequently on the finalisation of NKN emplaned rates with the Telecom Service Providers (TSPs) termed as the NKN approved rates.

Based on the discussion with the TSPs, rates were finalised for edge/ district/ core links. Detailed distance slab rates were finalised including the bandwidth for a period of 10 years.

The rates that were finalised by the Negotiation committee in year 2010 were very less as compared to the market rates.

- The reason for the difference in the rates was due to large quantity of links that were to be connected on NKN viz., Institutes/Districts/Core
- Another reason being the length of the MoU i.e., for 10 years
- Bandwidth capacity envisioned at that time was far more than any other organisation had ever demanded.

Due to aggregation of approved rates, a huge amount of cost is being saved.

3.6.5 DUE TO NKN ARCHITECTURE AND RING TOPOLOGY

NKN has regularly ensured that it uses its design architecture to its full potential in any innovative way possible.

Currently, NKN has around 28 ring topologies. A single ring has multiple institutes connected with each other. Some of the examples are AIIMS ring, JNU ring, IT BHU ring etc.

Total number of institutes connected in the ring are around 90, in which more than 35 institutes are connected via extension. NKN has connected these rings via WAN. **This results in direct cost saving for NKN as these links are connecting the institutes via extension and not as a new connection.** The cost has been covered in the extension sub heading as this is also a type of extension for NKN through innovation and design. This is also an example of interconnectivity of the institutes.

3.6.6 INTANGIBLE COSTS

It is very difficult to quantify all the cost savings due to NKN. Some of the costs are intangible i.e., they cannot be directly quantified; however, they need to be mentioned separately. Some of these are listed below:

- One of the most important and the necessary check on the quality and performance of TSPs is that they have to adhere to stringent SLAs which is monitored constantly by NKN Network Operations Centre and are quantifiable by penalties.

- For all the NKN connected institutes, NKN provides industry leading services free of charge, however, if the institutes had contacted different vendors for these services separately, such a good prospect i.e., NKN services would have not been available. Instead the institutes would have to incur a huge amount of cost for the services. NKN offers variety of services like e-mail, DNS, L-DAP, SSO, etc., which would otherwise have been chargeable to the institutes.
- NKN has constantly assured that the institutes are getting an exceptional Quality of Service (QoS) which, if taken locally, would not have been a dedicated lease line service and with such high consistency.
- All connected Institutes under NKN have a dedicated NKN team of professionals at their disposal 24x7, that give regular advices on regular and on demand basis mainly focusing on LAN designing, IT security, etc., which would otherwise be another cost head for institutes.
- NKN also has a dedicated support team at Network Operations Centre (NOC), along with a dedicated list of security professionals at Security Operations Centre (SOC) that has a high level of ICT experts and is always monitoring the connectivity. This saves the trouble and cost of hiring IT experts by the institutes themselves.

Key observations and recommendations:

NKN is the investment project which has done substantial savings on costs. NKN existence has created numerous tangible and intangible benefits. More than anything, it has had direct impact on the knowledge economy of India. Continuation of the project and the smooth funding is the need of the hour. If NKN can put together the knowledge dashboard, the visibility of the initiatives will make their task much easier.

Chapter 4

NKN SERVICES

4.1 CHAPTER OVERVIEW

NKN has made an exceptional success in the field of connectivity. NKN has evolved as the National Education Research Network (NREN) of India. The project has already made significant progress in boosting nation's knowledge economy by connecting over 1700 institutes in the network.

NKN network is designed with the aim of providing:

- Highest level of network availability, which has robust, secure & reliable connectivity.
- Highest level of scalability (specifically planned to match the unknown future demands which cannot be envisaged currently)
- High Bandwidth capacity: For NKN, various National Long-Distance Carriers (NLDs) have provided 2.5Gbps / 10Gbps capacity links. Further, the NKN is in the process of upgrading the core to 100 Gbps or more connectivity.

As this network is used by the premium research and educational institutes of the country, it is therefore important to install a safe and secured environment to protect IPR and prevent data theft. It also offers a safety net against any cyber-attack.

4.2 SERVICES OF NKN

NKN Services are broadly classified into four categories, they are as follows:

- NETWORK ORIENTED SERVICES
- CLOUD BASED SERVICES
- APPLICATION SERVICES
- COMMUNITY SERVICES

4.2.1 NETWORK ORIENTED SERVICES

Based on the usage, NKN provides five categories of Network-Oriented Services, they are as follows:

- I. GENERIC SERVICES
- II. SPECIAL SERVICES
- III. BANDWIDTH MONITORING SERVICE
- IV. DOMAIN NAME SERVER (DNS) SERVICE
- V. MAIL SERVICES

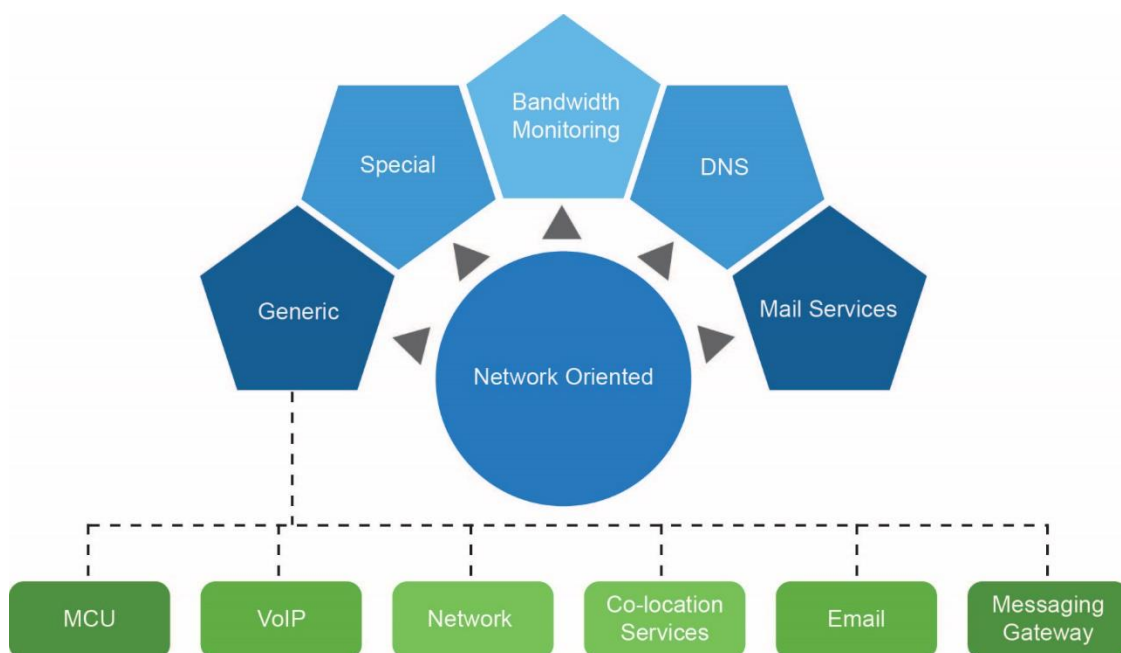


Figure 4.1 Network Services of NKN

GENERIC SERVICES

NKN Generic Services includes basic services provided via Intranet, Internet, caching, web-hosting, video streaming, video portals, etc. Mail service is explained in special services. Along with these services NKN also provides some additional features such as:

1. Multipoint Control Unit (MCU) Service

Multipoint Control Unit or MCU is a device that allows organising group video conferences between multiple video conferencing end points. NKN's MCU service is beneficial for the institutions as it enables connection between endpoint devices that work with different protocols. MCU servers help the institutions in managing multiple endpoints at once and coordinate their functions on video.

2. Voice over IP (VoIP)

Voice over IP or VoIP is the transmission of voice and multimedia content over Internet Protocol (IP) networks. This service of NKN is used by the organisations for voice communication over the network. The benefits of this service are that it reduces the network infrastructure costs, enables providers to deliver voice services over their private network and allow them to operate a single voice and data network.

3. Network Management Views

Network Management Views are also taken care of by NKN. It includes security, performance and reliability to ensure that the network is protected from unauthorised access. It is available to authorised users, providing availability of quick response to any service/network malfunctioning and elimination of bottlenecks.

4. Co-location Services

The Co-Location service provided by NKN gives its users control of moving their hardware off premises to the co-location service provider's data centres. The beauty of this service lies in the fact that NKN user organisations can choose and purchase their own hardware, own it, control it and maintain it in the provider's environment. This gives a huge benefit to users as this saves capital cost of building own data centres.

5. Messaging Gateway

Messaging Gateway provided by NKN provides an inbound and outbound messaging security. The SMS Gateway Service of NKN enables user to send and receive SMS text messages to and from an SMS capable device over the National Knowledge Network. The NKN SMS Gateway makes the messages compatible for delivery over the network and be able to reach the recipient. It also provides built-in data protection capabilities to keep the messages secure and confidential. It helps NKN users by providing them protection against spam, phishing attacks and other advanced threats. It also removes potentially malicious active content from an attachment, reconstructs the clean document, reattaches it to the message and sends to the end user.

SPECIAL SERVICES

Virtual Private Network or VPN is one of the special services provided by NKN. NKN has provided VPN service to its user organisations in order to give them the power to connect to remote users or regional offices using organisation's private network that runs over NKN. The various types of VPN are Multicast VPN, VPN Switching Service, VPN@L2 and VPN@L3.

1. Multicast VPN:

Multicast is communication between a single sender and multiple receivers on a network. Multicast VPN feature of NKN is used to efficiently transmit streaming media and other types of data to multiple users at one time within an organisation's VPN. NKN multicasting service enables a single transmission to be split up among multiple NKN users within an organisations' VPN network or outside the network and hence helps in significantly reducing the required bandwidth and time. NKN can utilise this service for various activities like video conferencing, web casting, sending other types of data such as news, notices, circulars, etc.

2. VPN Switching Service:

NKN's VPN switching service helps its users to stay secure over the network while the data transfer takes place. It can be classified as follows, based on how data transfer takes place.

Without VPN Switch

Unprotected internet sends your data through hundreds of computers where anybody can read



Figure 4.2 VPN Switching Service without VPN Switch

With VPN Switch

It protects the data of NKN users inside a VPN. The data is encrypted and then sent through the secure servers and hence provides data security. This feature of NKN also helps its users to keep their identity hidden from the outside world.



Figure 4.3 VPN Switching Service with VPN Switch

BANDWIDTH MONITORING SERVICE

NKN provides its users with the service of Bandwidth Monitoring Service System that gives them the facility of performing bandwidth testing at any point of time in the institute. Bandwidth means the amount of data that can be sent from one point to another in a certain period of time. It is measured as a bit rate expressed in bits per second (bits/s) or multiples of it (Kbit/s, Mbit/s, etc.). Bidirectional bandwidth tests can also be done between their desktop computers and the server located at NKN Point of Presence (PoP).

Domain Name Server (DNS) SERVICE

DNS service translates each domain name registered by a user through a domain registration provider to its corresponding IP address. Today, the DNS service is a very popular offer, with almost every domain registered company offers their own DNS service.

NKN DNS service provides two types of DNS servers, they are as follows:

DNS Cache Servers: NKN runs DNS cache servers for the members connected to NKN. The server IP is 14.139.5.5 and this is a multicast service. There are multiple of them running from various places in the NKN. These DNS IP could be used by any NKN user in case they need to use a DNS cache server.

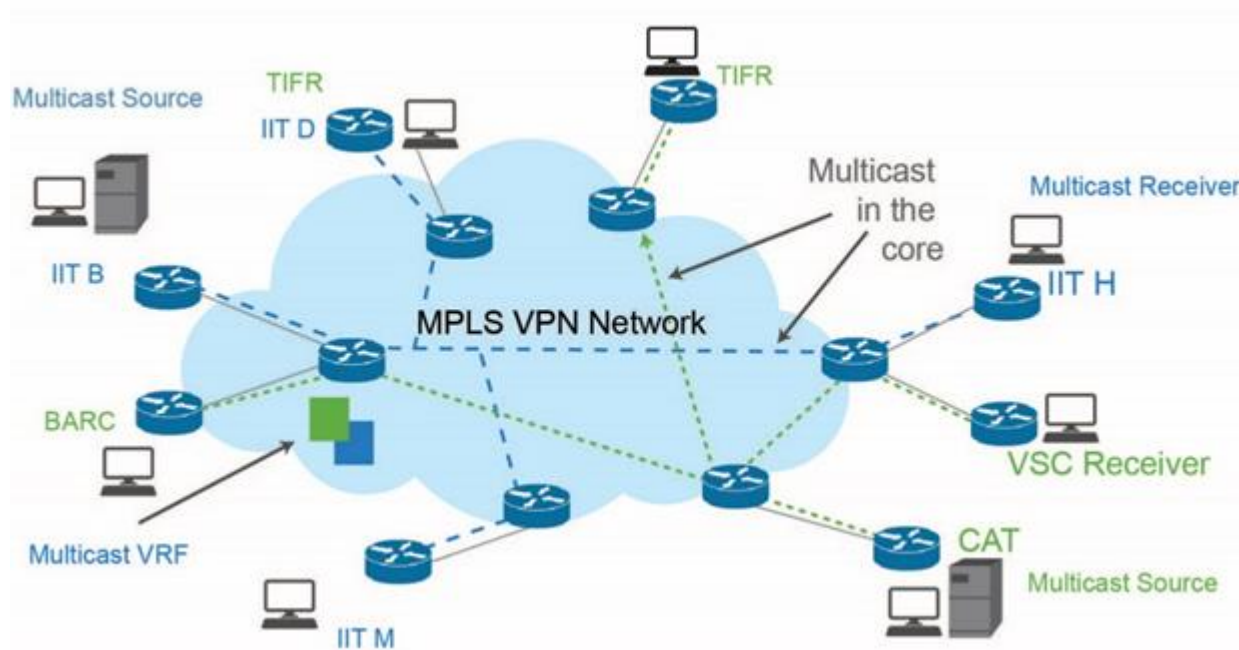


Figure 4.4 VPN Switching Service with VPN Switch

DNS Zone Server: NKN offers its members a facility where in the members can use the DNS Zone server from NKN Cloud. The DNS servers support DNS protocol and also DNSSEC protocol. For instance, if you are running a DNS for a Zone called ABCD.AC.IN or ABCD.RES.IN or any other, then you could off load the DNS service to NKN Cloud and be free from the hassles of running a DNS server 24x7. It is also possible for a member to run the DNS slave server on NKN Cloud. NKN Cloud takes care of any hardware or software at the member's side.

MAIL SERVICE

Mail Services can be divided into two categories, they are as follows:

MX Service: MX is mail gateway required to receive mail for a particular domain. This service allows NKN users to have their MX located at NKN Cloud and get all the e-mails scanned at NKN Cloud before receiving them. This enables enhanced security of the mails. NKN also has a DR (Disaster Recovery) as a back-up for this.

Relay Service: NKN also offers "Mail Relay" service. This service is primarily used by applications configured at Data Centres and institutions that are configured for sending mails as part of the feedback process or for intimation to users. The institute needs to ensure that the application that is configured to send mails is security audited. Unwanted traffic could carry mails that are infected with virus/worms and as a result the IP of the relay gateway might get blacklisted in the internet.

4.2.2 CLOUD BASED SERVICES

NKN Cloud technology involves delivering hosted services over the network. The Cloud-based technology of NKN enables organisations to deliver their services to a larger audience within a shorter span of time.

NKN provides two types of Cloud Based Services, they are as follows:

The NKN Authentication framework

The NKN service works in an authenticated framework, as authentication acts as a key for all applications and helps to ensure that a valid individual is accessing the NKN service. In order to access the data stored on the Cloud, users must be authenticated. NKN has defined a simple and handy authentication framework for the same.

It provides two types of log-in methods, they are as follows

Single Sign-On: In Single Sign-On (SSO), a user logs in with a single ID and Password to gain access to multiple applications.

Per Application Sign-On: In contrast to SSO, in per application sign-on, a user needs a different ID to access each application.

The service comprises of 2 parts, namely:

1. LDAP & PaaS
2. The NKN application Token Manager

LDAP stands for Lightweight Directory Access Protocol that gives authentication and authorisation to the users.

Process: It involves registration as the initial step. The user enters his/her username and password which is sent to the LDAP server and saved there. When user tries to login with the

username and password, the server matches the entered values with the values present in the database. If the match is found then the user is authenticated and given access to the services.

PaaS (Platform as a Service) is a Cloud-based application platform consisting of operating system and software that help run other applications on the Cloud. The overheads such as administrative details, installing libraries, virtual machines, managing servers, etc., are taken care of by PaaS itself and hence it works in favour of the organisation's productivity by freeing them from such tasks.

The Token authentication is a modern approach that helps in lowering the server load. All of the user metadata is encoded on the token. Once a token is generated, it enables the client to validate each subsequent request. The server and the client can pass the token back and forth forever and they don't need to store any user and session data.

The NKN BitAmbulator:

The NKN BitAmbulator is a Cloud-based storage service which provides a configurable amount of storage on the Cloud to NKN members. Using Cloud-based service, a single instance of an application runs on the Cloud and can serve unlimited users. The platform is available on the web which can also be accessed through any android device by using the BitAmbulator application. The authentication is done through the NKN's authentication framework; hence it gives the power to end institutes to manage their own users.

4.2.3 APPLICATION SERVICES

The various application services are as follows:

Open Source IP Registrar (OSIR)

OSIR is a full feature solution of NKN that provides Dynamic Host Configuration Protocol (DHCP) service and delivers client management feature. OSIR also provides feasible solution for IPv6 network migration by managing client IPv6 addresses. OSIR is available for all the NKN users with both IPv4 and IPv6 versions.

Smart Class

NKN offers Smart Class services and collaboration tools. The smart class service of NKN is based on e-learning technology, benefiting remotely based schools and colleges to meet the demand of good teachers and quality education.

Advantages:

- Smart Class enhances productivity and provides seamless collaboration among researchers, students and faculty.

NKN provides dedicated e-Learning portal for conduction of virtual teaching and also multi-tier feedback system for effectiveness and quality of e-content.

Smart Class (VIDYA) -MADHYA PRADESH

Smart Class (VIDYA) – It is a pilot implementation of desktop based video conferencing facility for remote learning & teaching for schools and colleges in Madhya Pradesh. Everybody has appreciated the quality of audio & video and effectiveness of remote delivery of content/lectures with two-way interactions. Today around 200 schools and colleges are connected and attending expert lectures using Smart Class facility along with the teachers of their local institutions. Department of Higher Education and School Education have framed subject and date wise timetable.



Smart Class Room Project has been awarded with SKOCH Smart Governance Award and SKOCH Best Technology Award.

4.2.4 COMMUNITY SERVICES

Community Services of NKN have been enhanced with an aim to serve the larger community of NKN users. Every individual institute is responsible for the development, operation and maintenance of its services. Community Services are initiated with a non-profit motive and objective is to cater issues faced by the wider community. The focus area is the common problems faced by a pool of users and provide them an easy access to tools and technologies through a centralised mechanism. The Community Services of NKN are as follows:

COUNTRYWIDE VIRTUAL CLASSROOM

Virtual Classroom is an e-learning application that supports educational institution in better mentoring remote learning. The NKN is a platform for delivering effective distance education where teachers and students can interact in real time. This is especially significant in a country like India where access to education is limited by factors such as geography, lack of infrastructure facilities, etc.

Advantages:

- This facilitates quality education and research at national level by interconnecting premier institutions.
- It has removed the barriers of boundaries.

- The faculty can do an interactive lecture and students can attend live classes from remote sites.

Case Study on Virtual Classroom (VC)

Virtual Classroom is an online, web-based tool, which virtually creates a classroom environment similar to traditional classrooms wherein professors and students login simultaneously. The main requirement of the VC is to have a high-speed net connection with extremely low latency.

What are the Technical stuff that NKN Virtual Class Room deals with?

The basic virtual classroom setup comprises of Document Cameras, Touch Panel for Teachers, Touch Panel cum Master Controller, Starboard, Audio-video Mixers, Amplifiers and Processors.

What are the basic requirements to get benefits from NKN?

It requires dedicated classrooms well equipped with Audio-Video and some Controlling & Switching devices and a dedicated NKN network with basic training to operate these devices. Technically it is termed as NKN-VCR i.e., Virtual Classroom over National Knowledge Network. NKN possesses the essence of Cloud computing with internet and other Clouds too in its background to deliver high end audio-video data transmission.

What are the features and speed of NKN?

NKN consists of an ultra-high-speed Core (multiples of 10Gbps and upwards) and over 1700 nodes. The participating institutions can directly, or through distribution layer, connect to the National Knowledge Network at speeds of 100 Mbps /1 Gbps/10 Gbps. To access Virtual Class, at the very initial level, institution must be within NKN network.

How can someone use NKN for inviting remote lectures?

For enjoying the facility of a remote lecture, if institute is within NKN network and registered under Gateway and the remote end is also fulfilling the same requirement, then the institute has to coordinate internally among NIC-NKN support team and schedule the classes with the other institute from where one wants to invite lectures.

The NKN has proved itself to be an effective platform for delivering effective distance education. The network enables co-sharing of information such as classroom lectures, presentations and hand-outs among different institutions. Till date a total of 66 Virtual Classrooms are being created over NKN and also 23 additional Virtual Classrooms at NIITs, IISC, IJSER, etc.

As per the feedback received from institutions, they get uninterrupted services from NKN. Virtual Classrooms have proved to be very economical as they help in substantial reduction in expenditure. Some of the institutes, namely Pondicherry University, Agriculture Knowledge Management Unit (AKMU), etc., also conduct training programmes using A-VIEW classrooms over NKN IP addresses. Extensive usage of Virtual Classrooms also helps the institutions in saving time and effort. Feedback says that the NKN link performance and high-speed internet services offered through it are very good and at part compared to private players. All the institutions gave full rating to the NKN Virtual Classroom facility on the scale of 1-5

From analysis, it is right to say that Virtual Classroom is an online solution that helps people interact with each other, regardless of the geographical barriers.

COLLABORATIVE RESEARCH

The basic premise of any research needs sharing of information, skills and experiences between people for analysing an evolving process from different perspectives. Any research requires a constant support of information and discussions. This is a challenge today that can only be mitigated by a 24x7 uninterrupted connectivity to handle the load of number of users. NKN aimed to establish a high-speed backbone connectivity which would enable knowledge and information sharing.

Advantages:

- The NKN provides secure and reliable connectivity for data transmission from one institute to the other, across the world.
- NKN also enables sharing of scientific databases and remote access to advanced research facilities.
- It requires low cost involvement and the processes are communicated through message passing technique. A case study to show the support provided by NKN for research collaboration is mentioned below:

Case Study on Research Collaboration

NKN provides international connectivity to its users for global collaborative research. Today, India has international connectivity with a 10 Gbps link between NKN & GEANT through the then TEIN4 (now Asi@connect) project (Asi@Connect, 2016). Here we discuss the experience that the CSIR had with NKN enabled environment, benefitting the team in their research programmes.

The CSIR-NAL mandate is to develop aerospace technologies with strong science content, design and build small and medium-sized civil aircraft and support all national aerospace programmes. NAL is a high technology oriented institution concentrating on advanced topics in the aerospace and related disciplines. CSIR-NAL is heavily dependent over collaborative research with domestic as well as overseas team. Besides having a strong communication medium within the organisation, they kept working closely with the external team. As per CSIR-NAL, ever since they have started taking NKN service, they have experienced a significant value addition in their productivity index.

As per Mr. Jitendra Jadhav, NKN supported CSIR-NAL restoring the link between two of their campuses whenever their inter campus linking cable failed. NKN connectivity plays a vital role in carrying out collaborative research between CSIR labs and other organisations. CSIR sister-labs (services such as high-speed data transfers, video conferencing) have improved since all are connected on the same MPLS network.

Similarly, Indian Council of Forestry Research and Education (ICFRE) have Regional Research Institutes and four Research Centres located in different bio-geographical regions of the country to cater to the forestry research needs of the nation. A Virtual Private Network (VPN) has been established among ICFRE Headquarters, Dehradun, its institutes and centres using NKN since September 2013. NKN services have enabled ICFRE team accessing various online applications/courses.

As per the feedback received from Mr. Joy Kuri, Chair, Telecom and Internet Access (TINA) Committee, "Indian Institute of Science is a premier academic institution in the country with primary focus on Research and Advanced training in all the areas of Science and Engineering. One of their major initiatives is to implement effectively, access to journals from leading publishers across the globe through the electronic mode. The faculty and students are benefitted immensely by having online access to resources, which undoubtedly increase their efficiency and productivity. Access to data from global resources in several frontier areas of Science and Engineering is one of the requirements of our faculty and students and this has increased multi-fold in the last few years, both in terms of the size and user base. NKN adequately addressed this concern for the institute."

NKN plays an important role for connecting teams sitting in different locations, working for a common research project, wherein the teams need to interact, share information access common repository of heavy files and many such activities that are required for intense research work.

NKN should enable different customised processes that are being used by research organisations as knowledge to be replicated for the benefits of new start-ups in the same domain.

NKN is Extending help in developing CoEs (Centres of Excellence) in the country, having similar standards and practices that are followed globally, in the collaborative research domain.

GRID COMPUTING

Grid computing is a group of networked computers which work together as a virtual supercomputer to perform large tasks, such as analysing huge sets of data or weather modelling. NKN also has a provision overlay grid computing which has helped in several grids based applications such as climate change/global warming, science projects like Large Hadron Collider (LHC) and ITER. The Garuda Grid initiative, which migrated on NKN, has enhanced its power and stability by migrating to NKN. It has facilitated aggregation of geographically distributed resources that were operational on the GARUDA grid. Resource intensive applications from various domains of e-Science, such as Bio-informatics, Astrophysics, Computer Aided Engineering, Weather modelling and Seismic data processing, have also been provisioned with the help of GARUDA riding on NKN.

VIRTUAL LIBRARY

Ministry of Human Resource Development (MHRD), under its National Mission on Education through Information and Communication Technology (NMEICT), had initiated the National Digital Library of India (NDL India) pilot project to develop a framework of virtual repository of learning

resources with a single-window search facility. Filtered and federated searching is employed to facilitate focused searching so that learners can find out the right resource with least effort and in minimum time. NDL India is designed to hold content of any language and provides interface support for leading Indian languages. It is now being arranged to provide support for all academic levels including researchers and life-long learners, all disciplines, all popular form of access devices and differently-abled learners. It is developed to help students to prepare for entrance and competitive examination, to enable people to learn and prepare from best practices from all over the world and to facilitate researchers to perform inter-linked exploration from multiple sources. It is being developed at Indian Institute of Technology, Kharagpur. It is riding on NKN backbone. Currently 27,814,879 items including books, journals, articles, magazines, research papers, etc., are hosted on NDL India.

Content is available in more than 70 languages. More than 60 types of learning resources are available. Educational materials are available for users ranging from primary to post-graduate levels. NDL hosts contents from multiple subject domains like Technology, Science, Humanities, Agriculture and others. 10 million items have been authored by 3 lakh authors.

SHARING OF COMPUTING RESOURCES

High-performance computing is critical for national security, industrial productivity and advances in science and engineering. The network enables a large number of institutions to access high-performance computing to conduct advanced research in areas such as weather monitoring, earthquake engineering and other computationally intensive fields. Pratyush and Mihir are similarly such supercomputers established at Indian Institute of Tropical Meteorology (IITM), Pune and National Centre for Medium Range Weather Forecast (NCMRWF), Noida, respectively, being the fastest supercomputers in India as of January 2018. The HCP facilities installed at both these centres are connected via NKN CUG7 network. Apart from these, other institutions under the Ministry of Earth Sciences – Indian National Centre for Ocean Information Services, the National Institute of Ocean Technology, the National Centre for Antarctic and Ocean Research and the National Centre for Earth Science Studies, extending to various other research and academic institutes working on climate/weather - use the same CUG and connect via NKN.

NETWORK TECHNOLOGY TEST-BED

NKN provides a test-bed for testing and validation of services before they are made available to the production network. This helps in early evaluation of services. NKN also provides an opportunity to test new hardware & software, vendor interoperability, etc. This facility has huge utility for the institutes and the industry with the possibility of a technology infrastructure that can be used as a virtual automated test centre for testing applications on different devices, platforms and environments.

⁷Closed User Group - A CUG is a group configuration that limits access beyond the defined set of group members

e-Governance

e-Governance expands to electronic governance which is an integration of Information and Communication Technology (ICT). The use of e-Governance is to overcome the boundaries of a traditional paper-based system. It aims at enhancing government ability to address the needs of the general public and making government services efficient, accessible and convenient.

Based on the specific types of services, e-Governance is categorised into four types namely Government-to-Citizen or G2C, Government to Business or G2B, Government-to-Government or G2G and Government-to-Employee or G2E.

PRAGATI (Pro-Active Governance and Timely Implementation) is one such system to encourage and have a system of e-transparency and e-accountability with a real-time presence and exchange among key stakeholders. Under this three-tier system, the Prime Minister holds a monthly programme once in every month, on the fourth Wednesday at 3:30 pm, to interact and discuss about the project's progression and to resolve project base problems immediately with Government of India Secretaries and Chief Secretaries through video conferencing. The video conferencing facility uses National Knowledge Network and, so far, the Hon'ble Prime Minister has presided over 40 PRAGATI VC sessions over NKN.

4.2.5 COMMUNITY APPLICATIONS

COLLABCAD

CollabCAD is an initiative of National Informatics Centre (NIC, Department of Information Technology), Bhabha Atomic Research Centre (BARC, Department of Atomic Energy) and Vikram Sarabhai Space Centre (Department of Space, VSSC). CollabCAD is a 3D CAD/CAM software system for collaborative design & development of industrial designs. It provides a total solution from product design, numerical control, visualisation, simulation, analysis to design data repository, workflow and enterprise resource planning. CollabCAD is developed on the Linux platform and is available on Windows and Linux. CollabCAD is developed using open source software tools such as Java/Java 3D, Open Cascade geometry kernel and supports open standards of data exchange such as XML, STEP, IGES and VRML to ensure interoperability.

Advantages:

- Economical CAD Solutions
- Collaborative & Comprehensive
- Parametric and Feature Based Modelling
- Flexible & Easy to Use Database Connectivity

Role of NKN:

CollabCAD helps in making mega projects that are developed by large number of designers under collaborative environment. NKN provides uninterrupted high-speed net connectivity, which is required in order to ensure smooth functioning between the system interfaces and the adjacent parts. Low latency and high bandwidth of NKN make the online interactions feasible among physically distributed users.

MAJOR PROJECT UNDERTAKEN:

Sub-Assembly in Prototype Fast Breeder Reactor:

PFBR is **India's first commercial fast breeder reactor**. It is a sodium-cooled fast reactor. There are 198 fuel subassemblies with mixed oxide fuel in the reactor. There are risks of sodium circuit contamination and the fission products blocking the coolant flow to the fuel subassemblies in case of clad rupture and release of solid fission products into the coolant. Hence, PFBR is equipped with elaborate failed fuel detection and location system. Failed Fuel Location Module (FFLM) is one of the subsystems used to identify the sub-assembly having fuel pins with clad failure. The Sub-Assembly of the 52 components which represent a 3D model of this FFLM was done in CollabCAD.

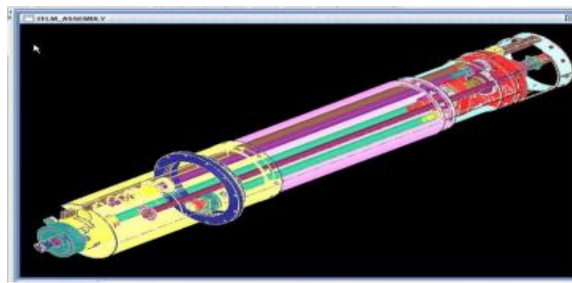


Figure 4.5 Prototype Fast Breeder Reactor

COLLABDDS

Collaborative Digital Diagnosis System or CollabDDS provides an integrated online environment to visualise medical and dental images for diagnosis and treatment planning. It is an application that was being developed as the result of a model project "Network Enabled Medical Diagnosis and Education in Skeletal Imaging using X-Rays" which was funded by NKN.

CollabDDS also enables the design and fabrication of orthodontic e-models, custom implants, prostheses and surgical instruments using CAD models created from X-ray/CT images. The repository of images with annotations by experts can also be used for education and research purposes.

Advantages:

- Efficient Digital Workflow of X-Ray Imaging (Skeletal and Dental).
- Improved Diagnosis and Treatment through Collaborative Consultation.
- Enhancement of Quality of Medical Services in Rural Areas.

- Reliability, Security and Accessibility of Medical Records.
- Education based on Expert Diagnosis.

Pilot Implementation of CollabDDS at Medical/ Dental Colleges

With objectives of proof of concept being successfully achieved, a pilot project at medical and dental colleges and hospitals for implementation of CollabDDS was undertaken. For the pilot implementation of CollabDDS, the medical colleges collaborated with the Department of Radiodiagnosis, AIIMS and the dental colleges collaborated with CDER, AIIMS.

The following colleges participated in the pilot implementation of CollabDDS: -

MEDICAL

- Andhra Medical College and King George Hospital, Vishakhapatnam
- King George's Medical University, Lucknow
- Sawai Man Singh Medical College, Jaipur
- SN Medical College, Agra

DENTAL

- Government Dental College and Hospital, Ahmedabad
- Government Dental College, Goa
- King Georges Medical University, Lucknow

Since October 2014, over 100 cases have been discussed during the collaborative sessions. The cases covered a wide range of modalities including X-rays, CT, MRI and scanned images of X-Rays. The cases discussed were from different domains such as Nervous System, Extremities, Abdomen, General Medicine, Paediatrics, T. B. & Chest, General Surgery, Surgical Gastroenterology, Orthopaedics, Ophthalmology, Otorhinolaryngology (ENT), Cardiovascular and Thoracic Surgery, Neurosurgery, Plastic Surgery, Urology, Cardiology, Neurology, Gastrology, Nephrology, Endocrinology, Obstetrics & Gynaecology and Dental. CollabDDS has successfully paved its way to be one of the prominently used applications in various medical institutes. One of them are mentioned as case study below:

CollabDDS @ NBRC

NATIONAL BRAIN RESEARCH CENTRE

The National Brain Research Centre (NBRC) is an autonomous institution under the Department of Biotechnology, Ministry of Science & Technology, Government of India and is dedicated to neuroscience research and education. The centre, created in 1999, was formally dedicated to the nation by the then Hon'ble President of India Dr. A P J Abdul Kalam on December 16, 2003.

The institute was integrated with the National Knowledge Network (NKN) in February 2011 and is connected from the Delhi-NKN-POP over the gigabit fibre link. The National Knowledge Network

is instrumental in supporting various R&D, healthcare, education, collaborative and e-Governance activities of the Centre in line with the vision of the NKN.

RESEARCH ACTIVITIES DEPENDENT ON NKN

The Centre of Excellence for Epilepsy is a collaborative project of the National Brain Research Centre (NBRC), Manesar and the All India Institute of Medical Sciences (AIIMS), New Delhi, supported by the Department of Biotechnology, Ministry of Science & Technology, Government of India. This is a one of its kind facilities where a dedicated neuroscience research centre is collaborating with a premier medical science institute. The aim of this Centre is to investigate the complex changes associated with the development of pharma co-resistant epilepsy in humans, using a multidisciplinary approach. A combination of Electrocorticography (ECoG), Magnetic Resonance Imaging (MRI), Electroencephalography (EEG), video ECG as well as functional imaging techniques such as Positron Emission Tomography (PET) and Single Photon Emission Tomography (SPECT) along with the extremely sensitive Magnetoencephalography (MEG) are utilised to locate the epileptogenic area. The MEG facility at NBRC is the first such setup in northern India.

The institute has a robust Local Area Network (LAN) running on a core fibre backbone of **Network Infrastructure of the Institute**

- 10 Gbps running over managed L2/L3 switches. The network is integrated with a campus-wide controller-based wireless network. An NMS is also in place to monitor the entire network.
- The institute network is fully compliant with IPv6 requirements; NBRC public servers such as DNS, web-servers and email servers are available in dual stack (IPv6 & IPv4) on public IPv6 and IPv4 pools provided by the NKN.
- The campus is integrated with the National Knowledge Network and further protected with firewall/UTM appliances and necessary IT policies in place.
- The Institute has an in-house mini datacentre for various IT infrastructure services viz., email-servers, web-servers, DNS-servers, VPN-services, application and storage servers, etc., which are directly dependent on and benefitted by the National Knowledge Network connectivity.
- All core and application servers hosting various infrastructural facilities as well as other web servers related to computational neuroscience are hosted in-house and are therefore directly benefitted by the NKN network.

LARGE HADRON COLLIDER (LHC)

LHC stands for Large Hadron Collider. Large due to its size (approximately 27 km in circumference), Hadron because it accelerates protons or ions, which are hadrons and Collider because these particles form two beams travelling in opposite directions, which collide at four points where the two rings of the machine intersect.

It is the world's largest and most powerful particle accelerator. The Large Hadron Collider (LHC) is a gigantic scientific instrument near Geneva, where it spans the border between Switzerland and France about 100m underground. It is a particle accelerator used by physicists to study the smallest known particles – the fundamental building blocks of all things. It will revolutionise our understanding, from the minuscule world deep within atoms to the vastness of the universe.

Data from the LHC experiments is distributed around the globe, with a primary backup recorded on tape at CERN. After initial processing, this data is distributed to eleven large computer centres in Canada, France, Germany, Italy, the Netherlands, the Nordic countries, Spain, Taipei, the UK and two sites in the USA with sufficient storage capacity for a large fraction of the data and with round-the-clock support for the computing grid. These so-called Tier-1 centres make the data available to over 160 Tier-2 centres for specific analysis tasks. Individual scientists can then access the LHC data from their home country, using local computer clusters or even individual PCs. A case study of LHC CERN is mentioned below:

LHC-CERN was first started on 10 September 2008 and still remains the latest addition to CERN's accelerator complex.



Figure 4.6 LHC-CERN

NKN Collaboration with LHC-CERN

NKN currently connects two Tier-2 centres namely VECC and TIFR. With a NKN PoP in their vicinity, they are instrumental in addressing the growing demand of enhanced bandwidth from different institutions keen of working on the LHC project. With NKN as the backbone they can provide the network speed for high-end processing, multiple and simultaneous transfers of data rates and low latency that real time applications require. NKN also provides multi-gigabit connectivity to the European grid.

VIRTUAL LAB

The Virtual Labs or Virtual Laboratory provides students a chance to perform experiments using the internet and visual aids without having the equipment at their end. The Virtual lab programme presents a unique opportunity to boost the quality of education, deepen understanding and provide the necessary practical skills to young minds through cost effective outreach and distance learning activities. Setting up of virtual laboratories has helped in remotely located areas to have the benefit of quality and relevant education, through ICT. These laboratories provide a platform for the students to conduct experiments in a virtual environment and enhance their capabilities.

Participating institutes in Virtual Lab are:

- IIT Delhi
- IIT Bombay
- IIT Kanpur
- IIT Kharagpur
- IIT Madras
- IIT Roorkee
- IIT Guwahati
- IIIT Hyderabad
- Amrita University
- Dayalbagh University
- NITK Surthkal
- COE Pune

4.3 SUMMARY

NKN has enabled scientists, researchers and students from diverse spheres across the country to work together for advancing human development in critical and emerging areas. It successfully catalysed seamless knowledge sharing and knowledge transfer between stakeholders across the nation and globally. NKN has also encouraged a larger section of research and educational institutions to create intellectual property. NKN has also enabled the use of specialised applications, which allows sharing of high-performance computing facilities, e-libraries, virtual classrooms and very large databases. The crux of the success of the Knowledge Network is related to the education-related applications, databases and delivery of services to the users on demand.

- NKN has helped to protect and keep critical data within secured Indian Government environment by creating networking and generic services.
- NKN Services has helped institutions to quickly rise in research and innovations.
- Community services and application helped in building collaborative products and services. Some of these platforms of services have a very high potential of growth and use for the betterment of masses.
- NKN services can save a lot of costs to the institutions. If put to good use, it can produce more revenue by building more offerings around the services.
- Some of the NKN services are excellent in design and deliveries. These services should be taken to the next level for use and continuous development.

CHAPTER 5

SECURITY ASSESSMENT

5.1 CHAPTER OVERVIEW

Most of the major research and educational institutes in India are dependent on NKN for network connectivity. These institutes are using the NKN to conduct path-breaking research, spread knowledge and improve processes. Besides this, NKN also empowers several government programmes like Digital India. With NKN carrying important proprietary and sensitive data, information along with important government processes and importance of NKN security, as a network backbone, cannot be denied. With the cyber world being challenged constantly with risks and threats of cyber-attack, the assessment of NKN's security becomes more important. Such an analysis not only helps in understanding the current system but will also help in providing recommendations for improving the system.

This chapter studies the security plan of NKN and elaborates on the practices followed by NKN in governing the IT network, application standards and practices. The security system of NKN is assessed on the framework of Identify, Protect, Detect, Respond and Recover (National Institute of Standards and Technology, 2018).

The assessment of the security system and categorisation helps in understanding if NKN has a secure and resilient backbone network set up for its user community that can recover quickly from random breakdowns and other cyber-attacks.

The chapter begins with a brief description of the framework for assessing the security system of NKN. Post this, an overview of the current NKN security system is given in the chapter. The overview of the system was obtained through various live demos arranged by the NKN team

along with detailed discussions at NKN premises. The assessment of NKN security system based on the framework has been done in the next section and concludes with the recommendations.

5.2 SECURITY ASSESSMENT FRAMEWORK

5.2.1 REVIEW OF THE CURRENT SYSTEM

Post understanding the security system of NKN, the U.S. Commerce Department's National Institute of Standards and Technology (NIST) 2014 cyber security framework was used for analysing the security system of NKN.

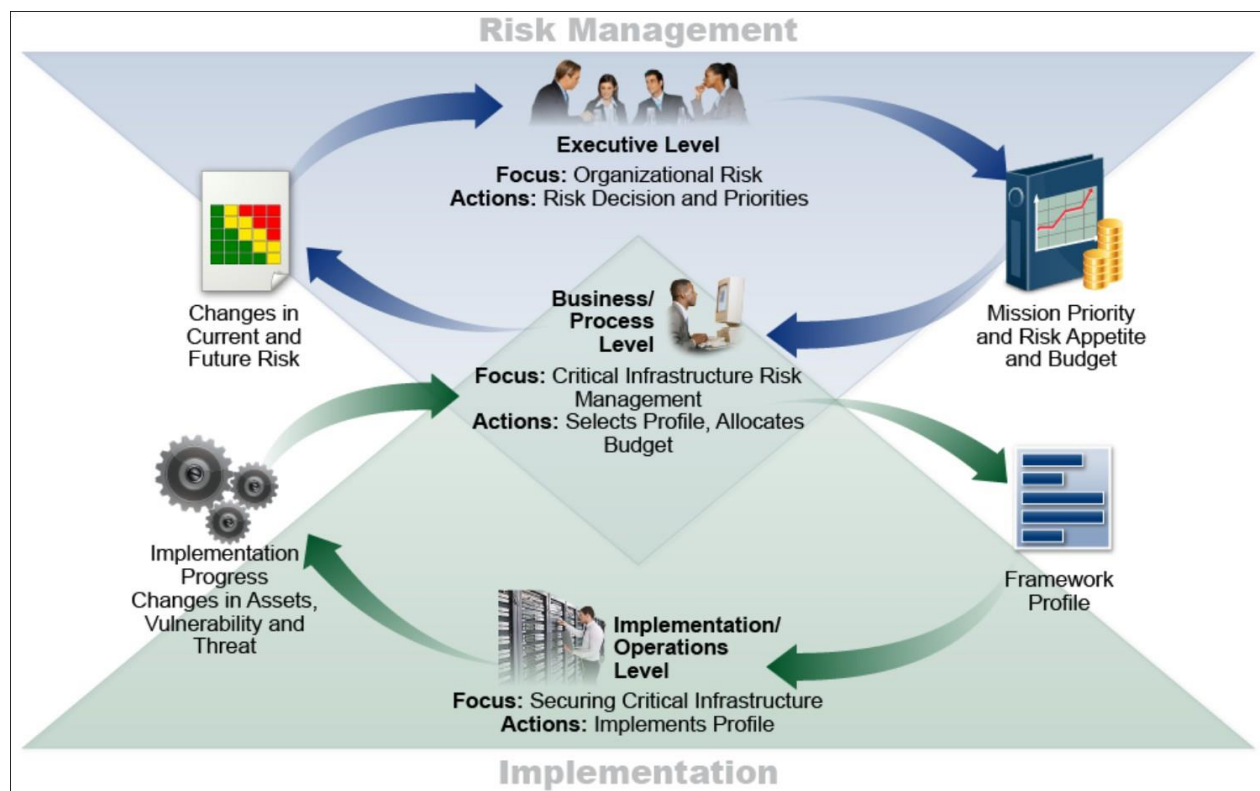


Figure 5.1 Cyber security Framework Process

(Source: <https://www.ssh.com/compliance/cybersecurity-framework/>, accessed on 27 April 2019)

According to the framework, the NKN security was assessed under five concurrent and continuous functions namely Identify, Protect, Detect, Respond and Recover. These functions are described in detail as follows.

Identify:

The Identify function assists in developing an organisational understanding to managing cyber security risk to systems, people, assets, data and capabilities. Understanding the business context, resources that support critical functions and related cyber security risks enables an organisation to focus and prioritise its efforts consistent with the risk management strategy of business needs.

Protect:

The Protect function outlines appropriate safeguards to ensure delivery of critical infrastructure services. This function supports the ability to limit or contain the impact of a potential security event.

Detect:

The Detect function defines the appropriate activities to identify the occurrence of a cyber security event. It enables timely discovery of security events.

Respond:

The Respond function includes appropriate activities in case of a detected security incident. It supports the ability to contain the impact of a potential security incident.

Recover:

The Recover function identifies necessary activities to maintain plans for resilience and restore any capabilities or services that were impaired due to a security incident. This function supports timely recovery to normal operations and to reduce the impact from a security incident.

5.3 REVIEW AND UNDERSTANDING OF CURRENT SYSTEM

5.3.1 INFORMATION HANDLING

Employees and staff create records as part of the normal course of conducting the business of the organisation. Records containing highly sensitive information exist only in areas where there is legitimate and justifiable business need and maintained under strict controls as outlined in this document. Mishandling of sensitive information is a significant risk and may cause considerable security and reputational harm. It is the responsibility of all NKN community users and employees, regardless of position, to protect sensitive information by being aware of any

they may store, process, or transmit. Users should manage the creation, storage, amendment, copying, back-ups, deletion or destruction of information in a manner which protects the confidentiality, integrity and availability of such information.

5.3.2 IDENTITY AND ACCESS MANAGEMENT

Introduction

Identity and Access Management (IAM) is the discipline for managing the access to enterprise resources. It is a foundational element of any information security programme and one of the security areas that users interact with the most. Identity and access management is based on a set of principles and control objectives to:

- Ensure unique identification of the members of NKN community and assignment of access privileges
- Allow access to information resources only for authorised individuals
- Maintain effective access mechanisms through evolving technologies

NKN has different types of assets classified as physical, logical, informational and so on. Each asset has its own significance and relevance in the context of NKN business. These assets have their owner and custodian defined and have been assigned their confidentiality, availability and integrity (CIA) values depending on the criticality and risk they possess. Every asset, thus, gets an asset criticality rating or value, based on which the relative access to them and its security can be decided.

With IAM, the access to critical information can also be restricted within the organisation. Access control refers to the process of controlling access to systems, networks and information based on business and security requirements. The objective is to prevent unauthorised disclosure of NKN information assets. NKN follows the laid down information security principles of ISO 27001:2013 which makes it mandatory to have an access control policy. This policy ensures that all the access is provided after a due-diligence process is followed. Since NKN provides high bandwidth network connectivity as its primary service therefore access to various services such as LDAP, Single sign-on, VPN, DNS, etc., is authorised, authenticated and accounted for all the NKN community users. The access to NKN's information systems is according to the principles of "least privilege" and "need to know" basis.

The objective of NKN's IAM strategy is to prevent unauthorised disclosure of NKN information assets. NKN access control measures include secure and accountable means of identification, authentication and authorisation.

Identification

Identification occurs when a user (or any subject) claims or professes an identity. This can be accomplished with a username, a process ID, a smart card, or anything else that can uniquely

identify a subject. Security systems use this identity when determining if a subject can access an object.

- In the context of NKN, two types of access controls are provisioned; physical and logical. The physical controls are designed & implemented using access card control systems, whereas security personnel for entry have different zones as per the access rights.
- Similarly logical access to various network systems and services is provisioned by TACACS (Terminal Access Controller Access Control System) server, where the access is granted on the basis of roles defined at different designations. The TACACS service is meant for authentication, authorisation and accounting (AAA) of all the users and accounts.
- The concept of Single sign-on (SSO) is used to identify users and accounts on different applications and NKN services.

Authentication

Authentication is the process of proving an identity and it occurs when subjects provide appropriate credentials to prove their identity. For example, when a user provides the correct password with a username, the password proves that the user is the owner of the username. In short, the authentication provides proof of a claimed identity.

- At NKN, authentication of different users for access to various network services is provisioned by TACACS server, where the access is granted on the basis of roles defined at different designations. Whereas, other NKN services are given through Single sign-on (SSO) mechanism.
- Authentication to services and systems is done by a robust password management policy.
- Two factor authentication controls such as OTP and geo-fencing is also done for critical services.

Authorisation

Authorisation is what takes place after a person has been both identified and authenticated; it's the step that determines what a person can then do on the system.

- The authorisation of users and accounts before they are given access to NKN's information assets is defined and governed. Access to information resources is controlled by a managed process which addresses authorisation, modification and revoking access and periodic reviews.
- All the authorisation of NOC users and accounts to network infrastructure is done via TACACS server. Role based authorisation is given to NKN community members.
- Authorisation to other NKN services is done through Single sign-on (SSO)

5.3.3 REMOTE ACCESS

Remote access to information technology resources (switches, routers, computers, etc.) and to sensitive or confidential information should only be permitted through secure, authenticated and centrally-managed access methods. NKN is a pan-India network and requires different users to connect remotely to avail different services. The remote access for NKN users is facilitated using Virtual Private Networks (VPNs). The remote access is controlled and allowed after following a due-diligence process.

5.3.4 PRIVILEGED ACCESS

System administrators routinely require access to information resources to perform essential system administration functions critical to the continued operation of the NKN. Such privileged access is often termed "super user," "root," or "administrator" access. Privileged accounts enable vital system administration functions to be performed and are only to be used for authorised purposes.

- At NKN, privilege access is based on the requirements of user's job role and function. To ensure the same, a centralised monitoring mechanism to control NKN's information assets is implemented through Active Directory (AD) for windows based systems and Network Information System (NIS) for Linux based systems.
- The roles, responsibilities and duties of all the system and network administrators having privileged accounts and root access are clearly defined to ensure accountability and transparency while carrying out the critical tasks.

5.3.5 SEGREGATION OF DUTIES

Tasks involved in critical business processes must be performed by different individuals. Responsibilities of programmers, system administrators and database administrators must not overlap, unless authorised by the Data Owner. Duties and responsibilities shall be assigned systematically to a number of individuals to ensure that effective checks and balances exist. Such controls keep a single individual from subverting a critical process.

- To ensure that there is no conflict of interest while performing duties, the information security roles and responsibilities are clearly defined in Job Responsibility Matrix (JRM) and Skill Matrix (SM).
- The JRM and SM are defined across NKN to ensure accountability and transparency.

Qualified and continuous supervision is to be provided to ensure that internal control objectives are achieved. This standard requires supervisors to continuously review and approve the assigned work of their staff as well as provide the necessary guidance and training to ensure that errors, waste and wrongful acts are minimised and that specific management directives are followed.

5.3.6 COMMUNICATION AND OPERATIONS MANAGEMENT

Information technology systems process large quantities of data. These systems – which include computers, networking equipment, storage media and other IT components – must be managed so as to protect information. The goal is to provide a robust, reliable and secure IT infrastructure that lends itself to information protection.

The key elements of system and communications protection are backup protection, boundary protection, use of validated cryptography (encryption) and public access protection.

The communications security at NKN is ensured by using MPLS technology among the institutes. MPLS ensures reliable and secure transmission of data between two end points. Other measures, such as AD and NIS, are in place too at NKN to ensure that data is secured.

Operations management refers to implementing appropriate controls and protections on hardware, software and resources; maintaining appropriate auditing and monitoring; and evaluating system threats and vulnerabilities.

Proper operations management safeguards all of the computing resources from loss or compromise, including main storage, storage media (e.g., tape, disk and optical devices), communications software and hardware, processing equipment, standalone computers and printers.

NKN is an organisation which is entrusted with the task of providing high bandwidth connectivity to the institutes through its Points of Presence (PoPs) across the country. To run its operations effectively and securely, NKN has a dedicated Network Operating Centre (NOC) which is a 24x7 facility to monitor the network traffic and bandwidth consumptions. Network Management System (NMS) tool is used for continuous monitoring of network. The end customers can contact NKN for any of the issues through its toll-free facility, service desk or an email. The operations' security controls at NKN is defined and ensured at various levels described as follows:

- A comprehensive change request process is implemented to ensure no changes are carried out without proper authorisation.
- All the important logs, such as event logs, AD and NIS logs, access logs, are enabled.
- Capacity management is done by regularly monitoring the utilisation index of all the links to ensure that it is well within 80% of its capacity.
- The anti-virus and anti-malware policy is in place to prevent any alteration or corruption of data.

5.3.7 NETWORK SECURITY

NKN maintains appropriate configuration standards and network security controls to safeguard information resources from internal and external network threats. In order to provide defensive

measures against these attacks, network security controls and mechanisms are used in a structured and consistent manner.

- NKN provides connectivity to institutes and universities hence it is NKN's responsibility to ensure security and safety of the edge routers installed at institutes. To ensure the same, NKN carries out vulnerability assessment of all the routers to track and mitigate the vulnerabilities. The MBSS (Minimum Baseline Security Standard) guidelines are also implemented for hardening of these routers.
- The network configuration standard at institute routers is done in such a way that the public network traffic doesn't reach the NKN network. Beyond this point, it is the respective institute's responsibility to secure their network resources.
- Necessary security appliances are installed and configured to protect from internal as well as external threats.
- A DDoS appliance is installed which monitors NKN's interface traffic. In addition to this, all the unwanted open ports at the institute's router are blocked by firewall.

Security Monitoring

Security Monitoring provides a means by which it confirms that information resource security controls are in place, are effective and are not being bypassed. One of the benefits of security monitoring is the early identification of wrongdoing or new security vulnerabilities. Early detection and monitoring can prevent possible attacks or minimise their impact on computer systems. At NKN, the security monitoring related aspects are handled by the NIC-CERT Division.

Regular cyber security trainings for NIC employees, government departments, stakeholders/end-users, CISO (Chief Information Security Officer) of ministries, HoGs, HoDs, etc., are conducted. Apart from trainings, NIC-CERT gathers threat intelligence and publishes regular advisories. It also manages 24x7 Security Operations Centre.

For prevention and detection of malicious traffic, NIC-CERT manages a centralised Unified Threat Management solution where it has also deployed DDoS Solution. Solutions are deployed for managing and monitoring of IP address infrastructure. NIC-CERT also routinely scans and reports issues in NKN infrastructure for vulnerabilities like open ports, malicious software, etc.

Security Advisories

NIC-CERT publishes advisories for security vulnerabilities as and when it is reported by various product vendors. Concerned teams, using the vulnerable products, are expected to take corrective actions by evaluating impact of the update. They may decide to take alternative approach instead of update, to mitigate the vulnerability. Advisories specific to the devices used in NKN are shared with NKN Team from time to time for appropriate action.

Virus Protection

Viruses are a threat to NKN as infected computers may transmit confidential information to unauthorised third parties, provide a platform for unauthorised access or use of the internal network, contaminate or infect other network connected devices, or interfere with information

technology resources. All the systems are mandated to have the latest anti-virus and anti-malware installed to avoid any corruption of data due to viruses/malware. This is also a mandate from ISMS guidelines to detect and protect information assets from viruses and malwares. Anti-virus is a service given by NIC and the latest updates and anti-virus signatures are given by NIC to all its users.

Backup and Recovery

Backup and recovery refers to the process of backing up data in case of a loss and setting up systems that allow that data recovery due to data loss. Backing up data requires copying and archiving computer data, so that it is accessible in case of data deletion or corruption. Data from an earlier time may only be recovered if it has been backed up. NKN provides backup and recovery facility to its users in the following manner:

- All the configuration files of network routers and switches are regularly backed up by NMS and saved in data centres.
- All the TACACS logs are saved and backed up in the syslog server. Similarly, all the application servers such as DNS server, NIS server and storage app server are backed up regularly by the respective teams.
- Storage as a service is given to institutes by NKN to store and back up their critical data.

Systems and Application Security

Application security is the process of making apps more secure by finding, fixing and enhancing the security of apps. Much of this happens during the development phase, but it includes tools and methods to protect apps once they are deployed.

Systems Development and Maintenance

- The NKN application development team follows the principles of software development lifecycle (SDLC). The security aspect of application development starts from information gathering and analysis phase. The members of application development team have been assigned different accounts to access the development, testing and production environment. Multiple instances of VM are created for this purpose and scalability of computing and storage resources are done by addition of more VMs as and when required.
- Before the applications are released and deployed in production environment, it undergoes functional and security testing to find out the possible flaws and vulnerabilities which could have potential impact on confidentiality, integrity and availability of the data. A vulnerability assessment is performed on the applications to detect most common flaws as published by Open Web Application Security Project (OWASP).
- The team uses a tool called as Mantis bug tracker which gives them the details for all the statistics of vulnerabilities by category, severity and closure time.

Physical Security Measures

- The NKN premises are divided into 3 zones. Zone-1 covers reception area, Zone-2 covers operational and support functional areas (Application development, UPS room, security and monitoring room) and Zone-3 covers NOC room and data centre. The physical security controls are defined and implemented as per the security guidelines defined for different zones.
- The physical security measures for ensuring information and asset security are implemented using solutions such as security guards, smoke detectors, fire suppression systems, water leakage detection, rodent repellent, CCTV cameras, etc. All these devices are sent for regular AMC and a periodic check is performed to ensure its availability.
- The physical security controls also take care of equipment delivery and installation. All the secure areas are appropriately protected from any unauthorised personnel access. A separate entry/exit registers along with access control systems are in place to ensure only authorised entry to NKN premises.

Business Continuity

- NKN network architecture and topology is designed with mesh topology which ensures resiliency and continuity in the network. One location in NKN is connected with multiple redundant links. Therefore, a single point of failure at any location will not interrupt NKN's overall business model. Although, if any of the NKN PoP goes down, only those institutes which are connected to that particular PoP will be affected, while rest of the network will not face any downtime.
- Network redundancy is provided till super core/core PoP router at state capitals, approximately 461 district centres and even some premier institutes that are using NKN services. Also, the redundant links are provided by two different service providers with different path for some of the institutes. For some institutes based on the proximity, redundancy has also been extended from another institute.

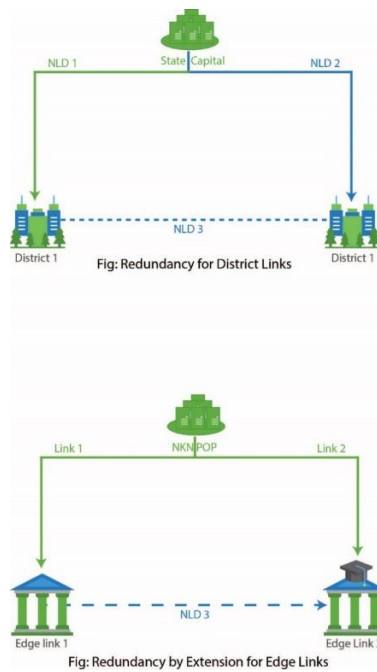


Figure 5.2 Network Redundancy

- The critical devices such as core routers, switches have their spare parts ready in case any of the components gets faulty. The application services in data centre will not get hampered, as a single node failure won't affect availability of that application because every front end application has a load balancer which distributes the network and application traffic across the cluster. In case a single server goes down, the load balancer will redirect traffic to remaining online servers.

Business Impact Analysis

A Business Impact Analysis should correlate specific system components with the critical services that they provide and based on that information, to characterise the consequences of a disruption to the system components.

It is the responsibility of both the Data Owner and Data Custodian to perform appropriate business impact analysis tasks. The business impact analysis consists of following steps

Identification of Critical IT resources

The NKN assets are assigned with CIA values to arrive at the asset criticality value. This asset value gives us an idea of the criticality of the asset which is further used to do contingency planning in case that asset malfunctions or becomes faulty. These assets are all prioritised according to their criticality values and the risk they possess in case of their unavailability.

Identification of Outage Impacts

Data Owners and Custodians should analyse the critical resources identified in the previous step and determine the impact(s) on IT operations if a given resource was disrupted or damaged. The critical systems, service providers and related parameters which will have a direct business impact on NKN's core service are

- TSPs- RailTel, BSNL, PGCIL
- Internet Gateways – Tata, Vodafone, Reliance
- ISPs - Airtel, TATA com
- Network core components- routers, switches, multiplexers
- Environmental safety controls

The SLAs are signed with the respective media providers (TSPs), ISPs and OEMs to ensure service continuity and availability. The following table briefs about the critical resources (Software, Hardware, Manpower, Environmental controls) and their outage impact along with the recovery objectives and priorities.

Risk Assessment to develop recovery priorities

Table 5.1 Risk Assessment

Critical Resources	Service provided	Criticality	Outage impact	Recovery priority
Telecom Service Providers	Media Provider (Fiber, Multiplexers)	High	Disruption in connectivity to institutes	High
OEMs	Network routers, security, server hardware	High	Issue with router resulting in network outage	High
Application development team	NKN applications and services	High	Downtime of NKN applications	High
Manpower service providers	Manpower	Moderate	Absence of resource performing NKN operations	Moderate
Internet service providers (ISP)	Internet services	Moderate	Disruption in internet service	Moderate
Infrastructure vendors	Desktop, Printers, AC, CCTV, smoke detectors, UPS, FM 200 WLD, rodent repellent	Moderate	Impact on day to day operations, outages of environmental and physical security controls	Moderate
Admin, HR and hospitality	Back end non-core functions	Low	Impact on matters like employee joining, resignation, salary etc.	Low
CPWD/DMRC	Office space for NKN facility	Low	Office space limitations, building assessment reports	Low

Risk assessment activity carried out at NKN includes a systematic approach of estimating the magnitude of risks (risk analysis) and the process of comparing the estimated risks against risk acceptance criteria. This is done to determine the significance of the risks (risk evaluation) and implementing controls to mitigate the risks (risk treatment plan). Risk assessment is carried out by an objective assessment of the asset, threats to the assets, vulnerabilities that could be exploited by the threats, impact that the loss of Confidentiality, Integrity, or Availability may have on the asset. A Risk Assessment effort will involve:

- Identifying the important assets and resources of the organisation
- Understanding their weaknesses (vulnerabilities) and threats that may expose them to risk

- Analysing the risks to determine priorities so that these risks can be managed to an acceptable level
- Determining the controls necessary to mitigate the risks that are not in acceptable limits

Disaster Recovery

- NKN has the necessary controls and processes in place which are in line with the disaster recovery processes. The NKN's network topology has a mesh architecture which provides redundancy in case any of the links goes down. All the traffic can be re-routed via a different link. In cases where a complete PoP is down, only the respective institutes which are connected to that PoP will face network outage, while others will not have any impact.
- Network redundancy is provided at core level at all the states. The redundant links are also provided by different service providers at some of the institutes.
- To ensure availability of power supply across the entire critical infrastructure, the backup power mechanisms of UPS and DG sets are available. Power budgeting has also been done for consistent and uninterrupted supply of power across all the racks in data centres.
- All the critical NKN applications are designed keeping in mind the disaster recovery scenarios. These applications run in cluster mode and failure of any single node will immediately divert the application and network traffic to other live node. Multiple VMs are configured on physical servers which make the applications fault tolerant.
- The escalation matrices are available at all levels for internal as well as external party stakeholders. This comes handy in case of disaster recovery situations when there is a need to escalate the issues due to multiple reasons. A Disaster Recovery site at Hyderabad is also in place.

Information Security Incident Response

Having an effective incident response is essential in mitigating damage and loss. Proper handling of such incidents protects the information technology resources from future unauthorised access, use or damage. At NKN, the standard operating procedure for DDoS security incident follows three steps namely reporting, analysis and mitigation. The three steps are detailed as follows:

1. Incident Reporting: The handlers monitor and escalate any suspicious traffic/activity to the specialised DDoS team for advance analysis.
2. Incident Analysis: DDoS Team's Tier 2 level engineer analyses the security event considering parameter baselines like Attack sources, Alert type, Target Victim, Impact (Volumetric/Packet Rate), Attack Vector, Severity of the security alert, Direction of the attack (Inbound/Outbound), Network behaviour analysis via traffic graph or via MRTG graph for the NKN institute under attack. In case of an Inbound attack, the issue is further escalated to the Tier 3 level engineer. Whereas, in an Outbound attack, NOC/SOC team informed regarding the security event.

- Incident Mitigation: Preventive action is taken by implementing the countermeasure, based on the attack vectors, by the Tier 3 level engineer after confirming the details from the institute. Analysis report is then shared.

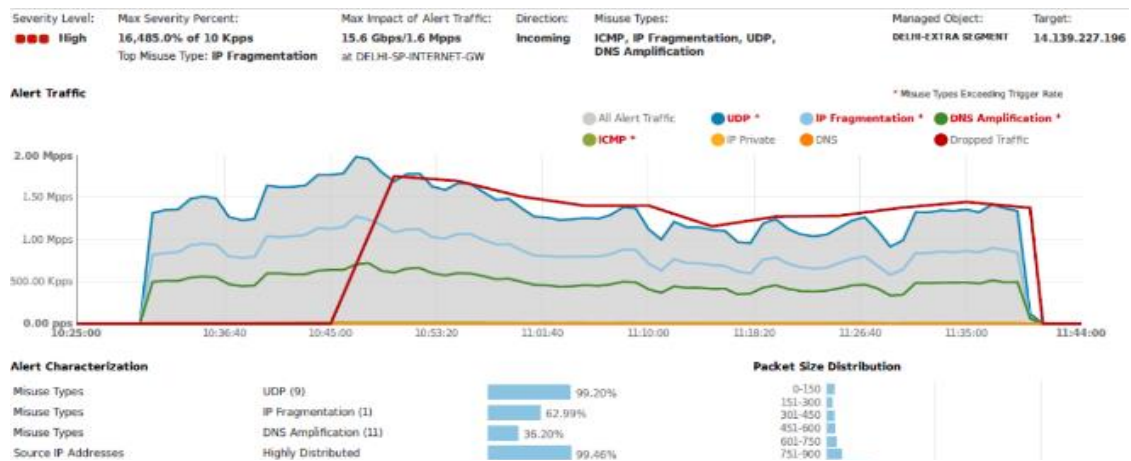


Figure 5.3 Security Case Study Report

Case Analysis Summary

NKN ensures identification, protection, detection, response and recovery mechanism through its DDoS security incident response. The procedure mentioned above can be understood with the help of a case study of Indian Institute of Science Education and Research, Mohali.

Observation

Abnormally high incoming UDP based multi-vector attack traffic was observed towards an institute from various multiple sources during the morning hours of 09th Nov, 2018. This event recorded a gigantic impact of 15.6 Gbps towards the targeted institute. Attacking vectors noted have been UDP based ICMP, DNS Amplification & IP Fragmentation. The total traffic for the UDP protocol was 1.24 Mbps while ICMP protocol was 10.02 Kbps

SUPPORT STRUCTURE

NKN provides a robust support structure to the user institutes for link monitoring and cyber security via dedicated 24x7 NOCs at all state capitals and SOCs. The issues associated with link monitoring include failure of link and equipment (or configuration failure). These problems are catered to by the respective teams of telecom service provider and internet service provider and proper escalation matrices are in place.

Apart from link monitoring, NKN also monitors cyber security abuse at institutes. Proper detection and mitigation steps are undertaken by NKN for DDoS attacks or in case of any spurious activity (either from outside the network or within the network). NKN also tracks and monitors in case any copyright infringement happens through the network.

The vulnerability reports are well documented in VA life cycle database which serves as a knowledge repository for the security teams to tackle any reoccurrence of similar incident or

vulnerability with minimal resolution time. The knowledge repositories help in analysing critical problems.



The user base of NKN has become quite proactive and it is vouched for as the response time is quite encouraging.

5.3.8 STUDY FINDINGS

Post detailed understanding of the security system of NKN, the various aspects of NKN security have been organised as per the cyber security framework, into five functions namely identify, protect, detect, respond and recover. Following is the classification of various security measures according to the functions

Identify

This function mandates the organisation to work actively to identify what information might be vulnerable to cyber threats. Amongst all the functions that NKN performs, the communication and operation management system, security monitoring system, business impact analysis and incident identification in security incident response come under identify. NKN monitors its critical assets through MPLS technology and has a dedicated NOC for continuous monitoring of the threat landscape. Besides this, identification of critical IT resources, outage impact, risk assessment is also undertaken.

Protect

Post identification, establishment of security protocols for storage and transfer of sensitive data and information are also in place. The information handling, Identity and Access Management, remote access, privileged access, segregation of duties, network security, communication and operation management, encryption, virus protection, physical security, business continuity and Information Security Incident Response are included in the protect function. NKN provides

requisite mandates for information handling, identification, authentication and authorisation. Mechanisms are in place for providing remote access and these are put in place after due diligence. Proper accountability and transparency are ensured while providing segregation of duties and privileged access. NKN also undertakes vulnerability assessment to track and mitigate vulnerabilities along with installing of appliances. Regular updates are also given to the users for being protected.

Detect

It entails having tools and mechanisms for detecting a possible cyber security breach. For systems and application security, NKN has proper mechanisms in place. Software development lifecycle (SDLC) is followed for ensuring the application security. A vulnerability assessment is also performed on the applications to detect most common flaws as published by OWASP. NKN also has mechanism for detection of DDoS attacks at the institutes and this is done 24x7.

Respond

An incident response plan is also created at NKN that provides instructions and procedures to respond and mitigate the consequences. NKN has proper incident response mechanisms present for DDoS attacks and escalation matrix are also present.

Recover

Develop and implement the appropriate activities to maintain plans for resilience and to restore any capabilities or services that were impaired due to a cyber security event. Through its backup and recovery mechanisms, disaster recovery mechanisms, NKN is able to ensure timely restoration of systems or assets affected by cyber security events.

5.4 SUMMARY

Observation of the NKN's security system in accordance to the cybersecurity framework of identify, detect, protect, respond and recovery shows that it is balanced and robust enough to provide a resilient backbone network for its user community that can recover quickly from breakdowns and other cyber-attacks. NKN is security compliant and has gone through the required certifications for security. NKN ISO certification is also around security which builds up the right processes for the robustness of the network and applications. STQC and CERT-IN compliance are also in place. Observations by these bodies are also rectified. Detailed understanding of the network security system also shows that it fulfils the industry standards related to network and security implementation. This instils trust in the institutes and the organisations using the NKN for performing path-breaking research, spread knowledge and improve processes. Cyber security is a constant challenge and requires regular enhancement in security systems and adoption of latest technologies from time to time.

Chapter 6

ANALYSIS OF USER FEEDBACK

6.1 CHAPTER OVERVIEW

This chapter aims to cover the analysis of the primary research of NKN gleaned through survey technique in stage III, phase-II of the study.

The vision of the survey was to understand from an institute's perspective, as to how they have been impacted by the four pillars based attributes of the system, namely, Outreach, Quality of Services, Knowledge Ecosystem and Value Proposition. These have been analysed through a strenuous data collection tool. Also, before & after scenarios and sectorial analysis has been captured. Furthermore, national & international collaborations, present & future digital initiatives have also been gauged as a part of the survey as subjective questions.

The study further explains the various aspects of NKN included in each of the four pillars and shows how each of these have created an impact to strengthen the network. The output of 'Stakeholders' consultations, undertaken through detailed meetings and round table interviews have also been summed up in the chapter.

6.2 INTRODUCTION

The existing structure of the project from the management perspective can be understood as resting on four pillars as illustrated earlier in the assessment framework. Each of the pillars covers the four key concerned areas related to connectivity, quality of services, expanding the scope through applicability in multiple areas across stakeholders and lastly, managing the resources to make it a lucrative venture.

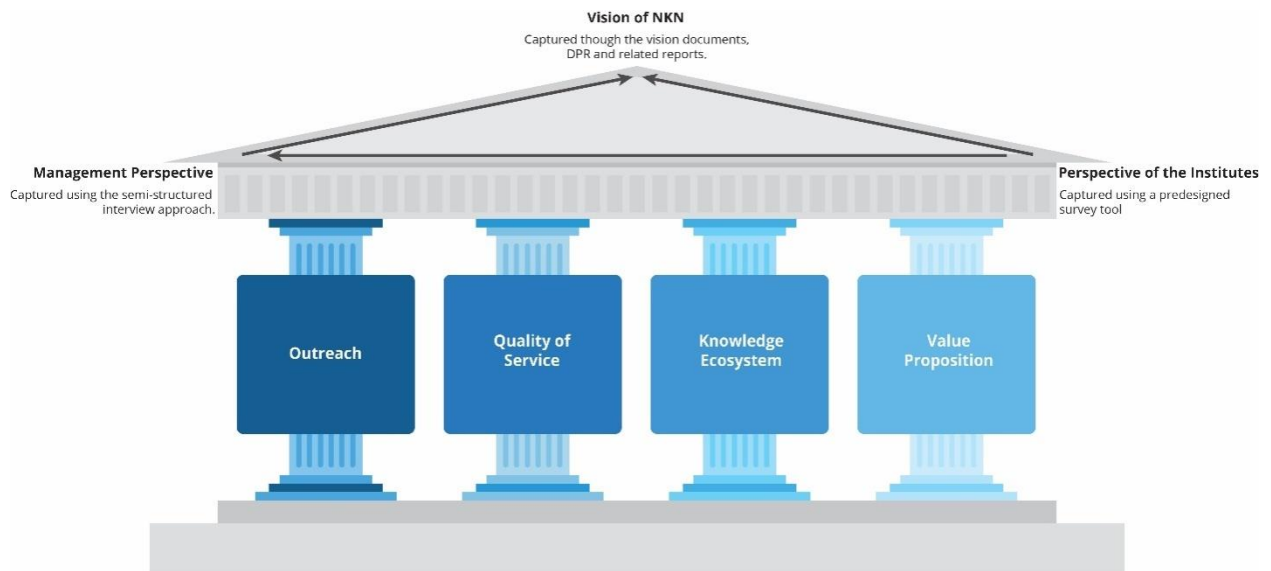


Figure 6.1 Assessment Framework based on four pillars

It is important, at the outset of this chapter, to understand the methodology adopted and process undertaken. The methodology includes

1. Semi-structured interviews with the management
2. Information received from NKN office records
3. Various reports and vision documents of NKN
4. Secondary research of related websites
5. Structured survey questionnaire conducted for the user institutions (refer Annexure).

It is important to understand that the study cannot be validated without the affirmation from the most important stakeholder which are, in this case, knowledge institutions utilising the services of NKN. The core facts of the study have been taken from the feedback of end users of NKN which, in this case, is 1700 plus institutes using the services of NKN. Of the institutes to whom the survey was sent to, **1262 responded to the same, which is a very good sample for the impact assessment analysis.** As a result, this study is based on the data collected and collated from 1262 Institutes. This study has been based on the multiplicity of methods which included survey tools designed primarily on the conceptual framework. **Through open ended and close ended questions, the survey focused on capturing the impact of NKN on four pillars of the study.** The information thus obtained helped to understand the management perspective and assess whether the vision of NKN has been achieved or not. It is of crucial importance to highlight that in the design of the survey tools, a variety of questions were asked while adhering

to the pillars of the study. This was done with the intention to seek responses for each of the pillars while studying the possibility of having a holistic perspective emanating from various vantage points.

The findings of the study have been presented in the subsequent sections of this chapter. These have been presented in the order of Outreach, Quality of Services, Knowledge Ecosystem and Value Proposition which also form the four pillars of the study.

6.3 OUTREACH

In the course of the study, Outreach of NKN has been ascertained through four important consideration which are as follows:

1. Number of Nodes
2. Number of Users
3. Percentage of Users
4. Geographical spread of NKN

Table 6.1 Primary findings on the first parameter of assessment framework "Outreach"

S No	Parameters	User Feedback			
		A	b	C	D
	Outreach				
		Less than 200	Between 200 and 500	Between 500 and 1000	More than 1000
1	No. of Nodes	38.50%	27.40%	16.80%	17.30%
		Less than 200	Between 200 and 1000	Between 1000 and 3000	More than 3000
2	No. of Users	35.10%	39.40%	17.50%	8%
		More than 75%	Between 50 and 75%	Between 25 and 50%	Less than 25%
3	Percentage of Total Users Using NKN	81.20%	13.40%	3.20%	2.10%
4	Geographical Spread of Network in Campus	75%	17%	6%	2%

6.3.1 NUMBER OF NODES

The question on number of nodes was to assess the devices connected in any institute. Firstly, with regard to the number of nodes, it was found out that, of the 1262 Institutes, **17.3% of the institutes had more than 1000 nodes connected, 16.8% had between 500 to 1000 nodes, 27.4% institutes had 200 to 500 nodes and 38.5 percent had less than 200 nodes.** This analysis helps to understand the NKN usage in institutions. **It was also found out that educational institutes had more nodes than the other institutions because of high component of student usage.**

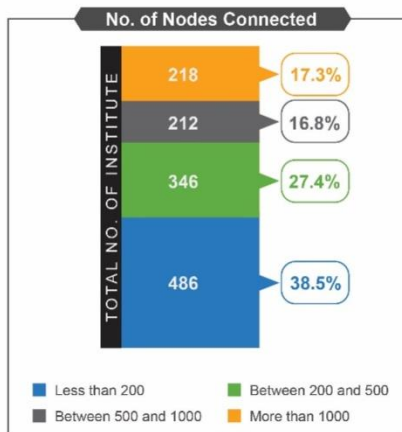


Figure 6.2 Number of connected nodes in an institute

At the same time, it is interesting to observe the categorisation of the nodes amongst different sectors and field of work. Some of the graphs given below illustrate the spread of these nodes across various sectors of work with these institutes.

% of Institutes in a given vertical who have less than 200 nodes connected

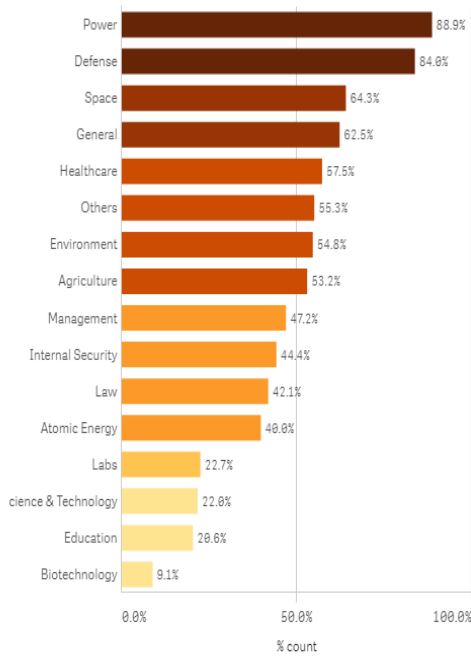


Figure 6.3 Percentage of Institutes who have less than 200 nodes connected

% of Institutes in a given vertical who have 200 to 1000 nodes connected

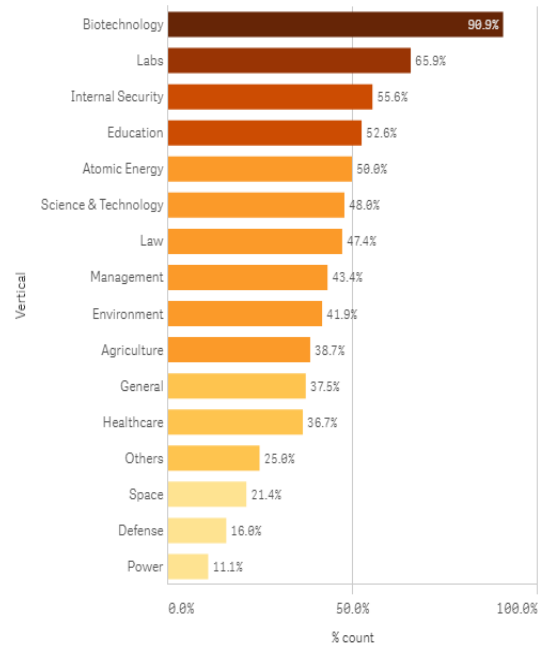


Figure 6.4 Percentage of Institutes who have 200-1000 nodes connected

% of Institutes in a given vertical who have more than 1000 nodes connected

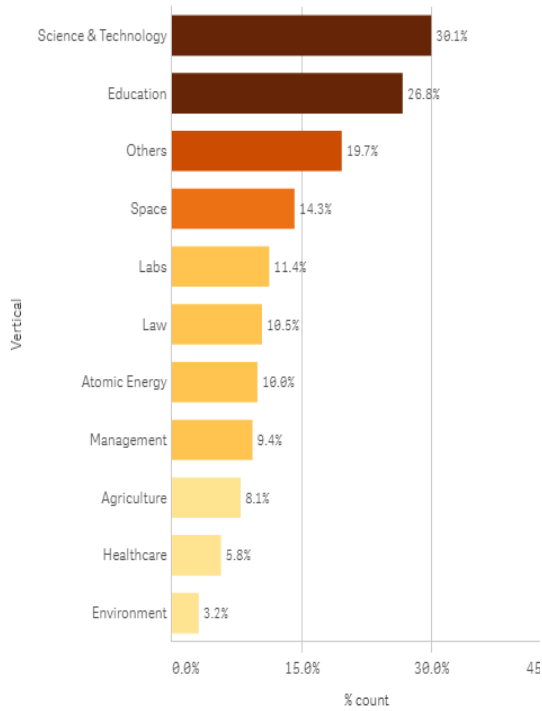


Figure 6.3 Percentage of Institutes who have more than 1000 nodes connected

6.3.2 NUMBER OF USERS

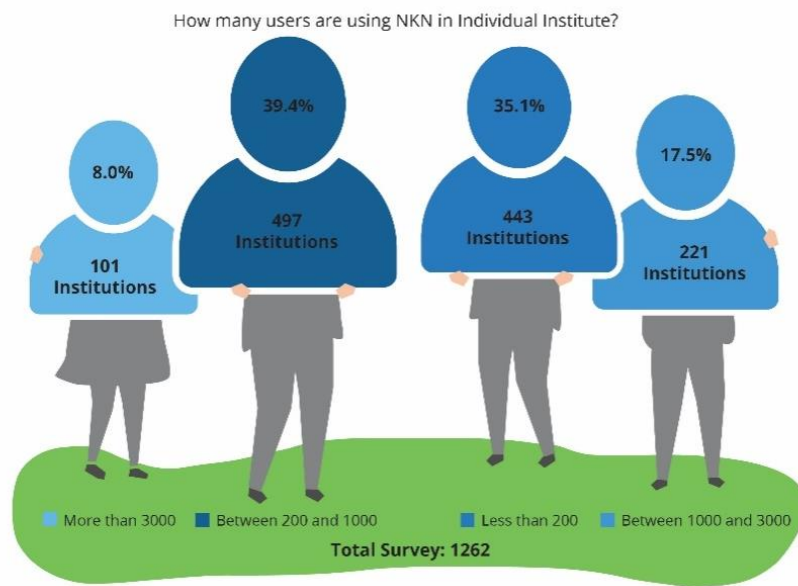


Figure 6.4 Number of users in an institute

Regarding the number of users, **it was found out that 8% of the institutes had more than 3000 users using NKN, 17.5% of Institutes had 1000-3000 users, 39.4% Institutes had 200-1000 users and 35.1% Institutes had less than 200 users. Cumulatively it shows that 25.5 % Institutes had more than 1000 users.**

The graphs below depict the percentage of users and bandwidth availability across various sectors/field of work. Most educational institutes are using 1 Gbps connection, followed by Law, Atomic Research, CSIR Labs and Science & Technology. Research facilities of different sectors are on 100 Mbps bandwidth. Sectors with the highest use of 100 Mbps are Defence, Internal Security, Power, Environment, Healthcare, Management, Space and Agriculture.

% of institutes in a given vertical who have 100Mbps connection

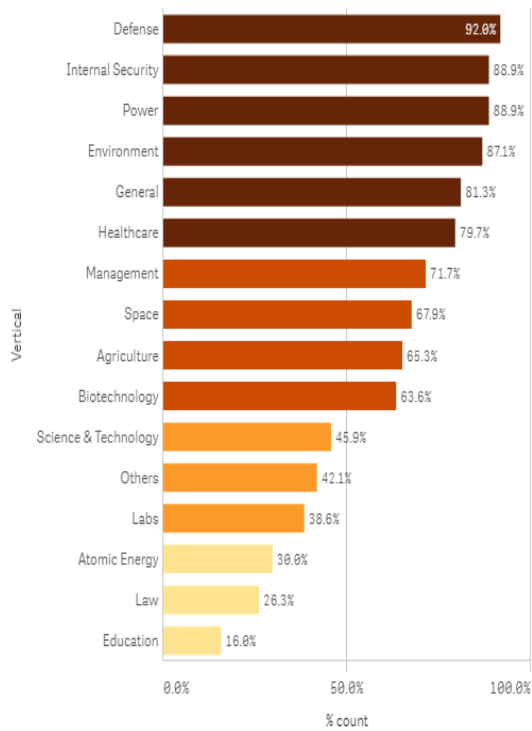


Figure 6.7 Percentage of institutes who have 100 Mbps connection

% of institutes in a given vertical who have 1Gbps connection

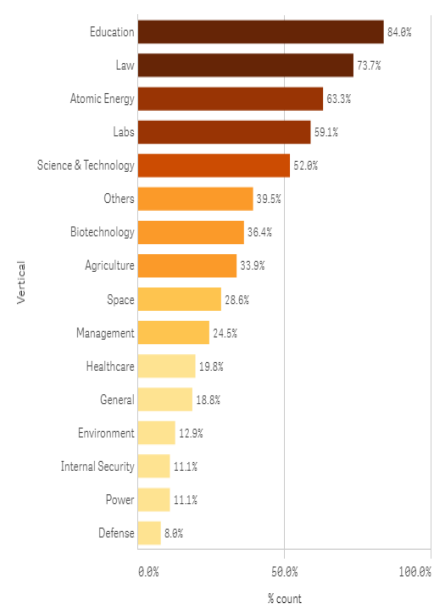


Figure 6.8 Percentage of institutes who have 1 Gbps connection

6.3.3 PERCENTAGE OF USERS USING NKN IN AN INSTITUTE

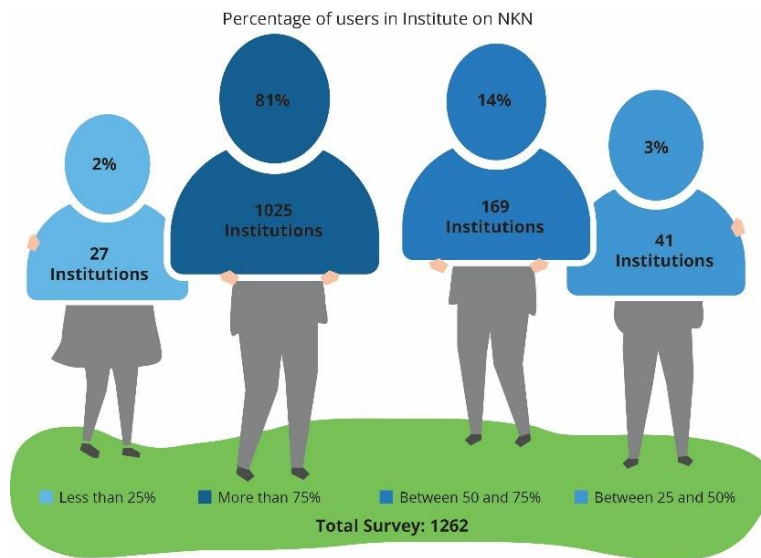


Figure 6.5 Percentage of users using NKN

Answers to this question of the survey gives the outreach in terms of percentage of users using NKN in any institute. Footprints of usage in the institutes have been excellent. **81% institutes**

have more than 75% of the users using NKN, 14% institutes have 50-75% users using NKN and 5% institutes have users less than 50%. NKN has performed very well in this parameter.

Key observations and recommendations:

NKN has performed very well on outreach parameters. Institutes are well connected internally and are using NKN.

As per the mandate/IP Policy, NKN only monitors the bandwidth utilisation and the speed of the bandwidth and resolves the issues if any. NKN should monitor the applications and collaborations inside institutes in the next phase of NKN. Monitoring connected devices, users, departments, applications and usage will help in understanding the future requirements from NKN. This will also help in understanding the NKN use for knowledge, research, education and collaboration. Already a tool is developed for bandwidth monitoring for the institutes. This tool can be further expanded for monitoring a little deeper within the scope of privacy norms from the central monitoring point of view.

6.3.4 GEOGRAPHICAL AREA COVERED BY NKN

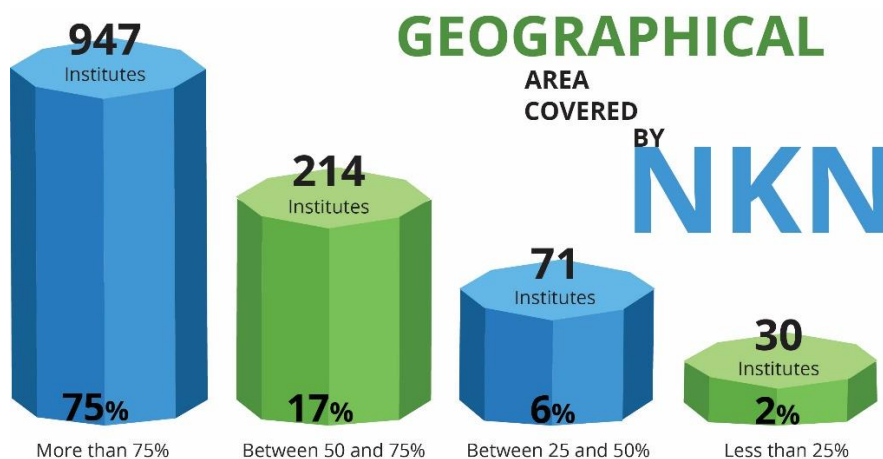


Figure 6.6 Geographical coverage of NKN inside institutes

Ideally, NKN was to provide connectivity up to the boundary. Further, the connectivity within the campus was the responsibility of the institute. This question of the survey judges the availability of NKN within an institute. In terms of geographical spread of NKN within an individual institute, **it was found that the 75% of the institutes were well connected internally, 17% Institutes had 50-75% range of coverage and another 8% were having less than 50% coverage.**

Institutes are well connected internally. Only a small number percentage is less connected. These institutes can be extended help if some technical issues are there.

Key observations and recommendations:

Inadequate LAN/Wi-Fi infrastructure and low penetration of ICT in some institutes to fully utilise the NKN services is a concern raised by NKN. NKN's responsibility terminates at the entry point of the institutes. Various national and regional workshops have been conducted in the past for providing technical support for enhancement of institute's internal connectivity that helps in effective usage of NKN. Some training programmes for the user institutes and state level NKN teams should be conducted in the next phase of NKN.

6.4 QUALITY OF SERVICE

Four important considerations for establishing Quality of Service are as follows:

1. Primary Connectivity
2. Reliability
3. Overall Experience of using NKN
4. Awareness

Questions pertaining to primary connectivity in the institutes, reliability of the NKN network, awareness of NKN within the surveyed institutes about its existence and usage were asked to the users in a manner of objectivity. **The feedback and results received from most of the institutes have been very encouraging.** A summarised view of the analysis is presented in the table below (Table 6.1).

Table 6.2 Primary findings on the second parameter of assessment framework "Quality of Service"

S No	Parameters	User Feedback				
	Quality of Service	A	B	C	D	E
		Primary	Secondary	Multiple		
1	Primary Connectivity	90%	2%	8%		
		Very High	High	Medium	Low	
2	Reliability	65.85%	26.39%	7.21%	0.55%	
		Excellent	Very Good	Good	Satisfactory	Poor
3	Overall Experience of using NKN	70.30%	20.80%	6.00%	2.60%	0.30%
		More than 75%	Between 50 and 75%	Between 25 and 50%	Less than 25%	
4	Awareness	77.70%	15.80%	5.30%	1.20%	

6.4.1 CONNECTIVITY

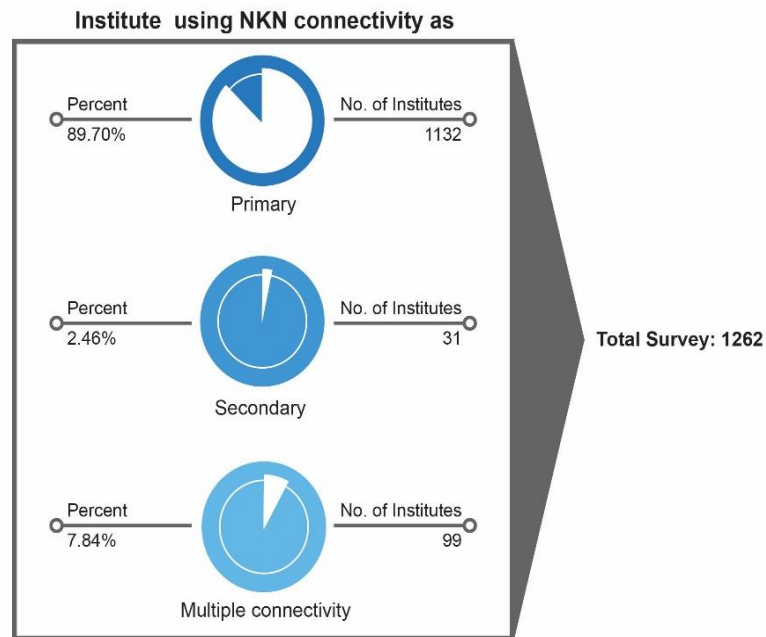


Figure 6.7 NKN as primary connectivity

It has been found out in the study, that with regard to connectivity, **89.70% of Institutes are using NKN as primary connectivity, only 2.46% of institutes are using NKN as Secondary connectivity and 7.84% are using NKN with multiple connectivity. Multiple connectivity is the case where institutes have taken connectivity other than NKN as well.**

6.4.2 RELIABILITY

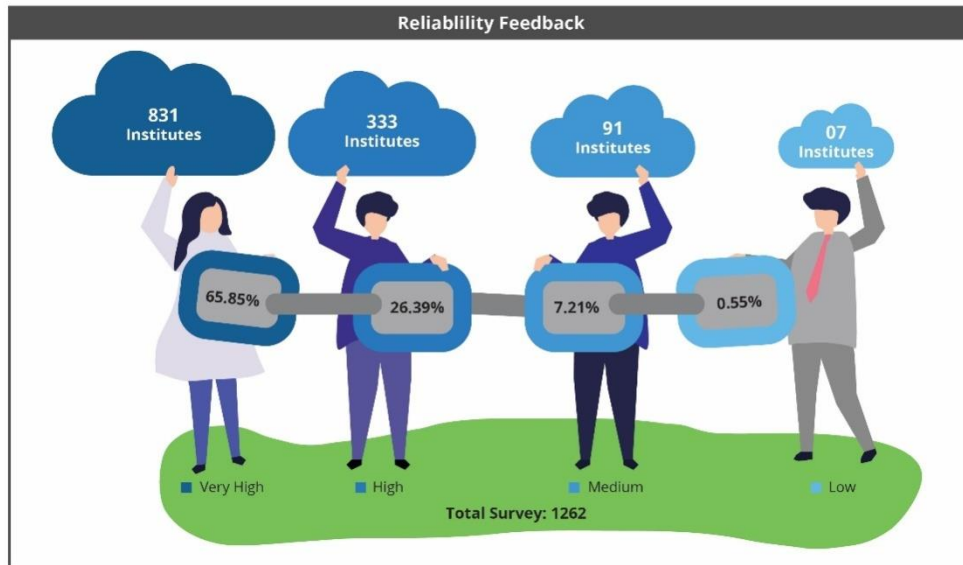


Figure 6.8 Reliability feedback of institutes

Answers to this question of the survey was the reflection of the work done by NKN team on quality of service parameters. Reliability is an important factor to judge the technological superiority of any network. With regard to reliability of NKN, it has been found that 65.85% Institutes rated NKN reliability Very High, 26.39% rated NKN's reliability as High, only 7.2% rated 'Medium' and only 0.55% felt 'low' on this parameter.

6.4.3 EXPERIENCE



Figure 6.9 Overall experience of NKN

Experience is another parameter that ascertains Quality of Service. 70% institutes have rated NKN excellent on overall experience. Inclusion of very good response makes it 91%. Only 2% institutes rated NKN just satisfactory.

6.4.4 AWARENESS

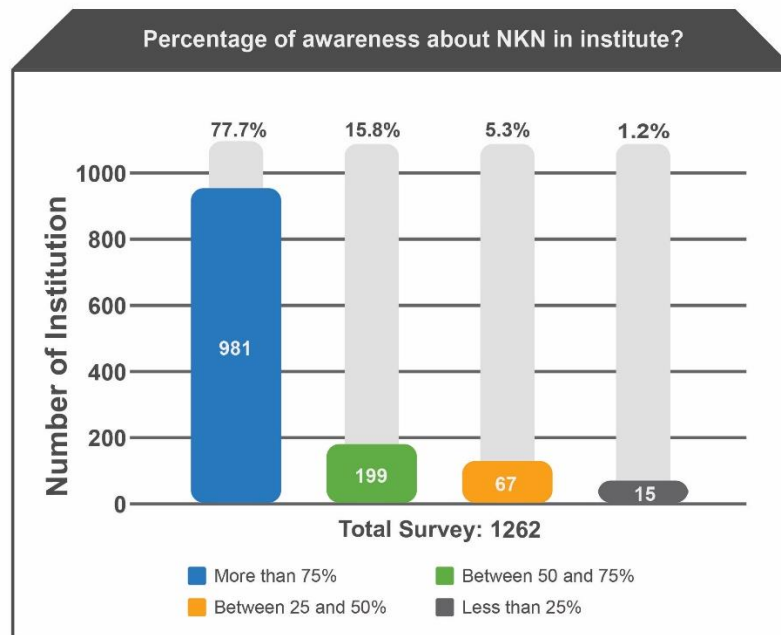


Figure 6.10 Awareness about NKN

With regard to Awareness, 77.7% Institutes felt that the awareness about the NKN was more than 75% amongst the institute users. Out of 1262 respondents, 981 felt that NKN's awareness has been very good in the institutes. 199 respondents felt that awareness has been about 50-75%. This is about 15.8% of the total respondents surveyed. Number of respondents who have been less aware of the NKN has been very low. Only 82 respondents replied that less than 50% in the institute were unaware. In terms of percentage, these are only 6.5% of the respondents.

Key observations and recommendations:

Institutes have rated NKN excellent on all quality of service parameters. Institutes are highly satisfied with NKN and they consider the network very reliable. About the awareness of NKN in institutes, the survey results show that the awareness level is very high. NKN has conducted four national level workshops and several regional workshops with high level of participation from the institutes. NKN efforts further can be strengthened by working on the following areas.

NKN website should be more dynamic and the complete ecosystem should be available on the website. This is the gateway to receive and disseminate knowledge and collaborate on NKN. NKN could emulate from the global NRENs like Internet2, as they have done excellent work on brand promotion. An internal branding and communication group is required that can work on awareness strategies and implement it.

NKN is the gateway of the intranet and internet for the institute users. As part of a strong awareness strategy, it has great potential for the promotion of NKN activities. NKN portal site should be the default page for the institutes, whereby all the information regarding NKN ecosystems should be available. As already stated, partners, research platforms, collaboration platforms and opportunities could also be listed here with information regarding availability of programmes, learnings, research studies, conferences, etc.

6.5 KNOWLEDGE ECOSYSTEM

This section is based on the parameters of the following:

1. Access of Information
2. NKN Usage in Institutes
3. Specific NKN Usage Areas
4. Digital Initiatives
5. Collaborations

Table 6.3 Primary findings on the third parameter of assessment framework "Knowledge Ecosystem"

Primary findings on the third parameter of assessment "Knowledge Ecosystem"								
S No	Parameters	User Feedback						
		A	B	C	D	E		
	Knowledge Ecosystem	More than 75%	Between 50 and 75%	Between 25 and 50%	Less than 25%			
1	Increase in access and availability of information , both internally and externally	81.50%	15.50%	2.50%	0.50%			
		Research	Education	Training	Technology	e-Governance		
2	Using of NKN for areas	91.00%	82.00%	73.00%	63.00%	22.00%		
		Live meeting/ Video conferencing	e-Learning/ Virtual Classrooms	Interconnectivity	NKN Services			
3	Activities On NKN	71.00%	61.00%	96.00%	40.00%			
		e-Learning	R&D Framework	Collaboration Framework	Consulting Framework	Virtual Classroom / Video Conferencing	Knowledge Portal	Increase of Digital coverage within Institute
4	Digital Initiative by Institutes on NKN	85	45	25	18	55	44	3
		No of Institutes	National	No of Institutes	International			
5	Collaborations	502	10453	296	3364			

6.5.1 ACCESS AND AVAILABILITY OF INFORMATION

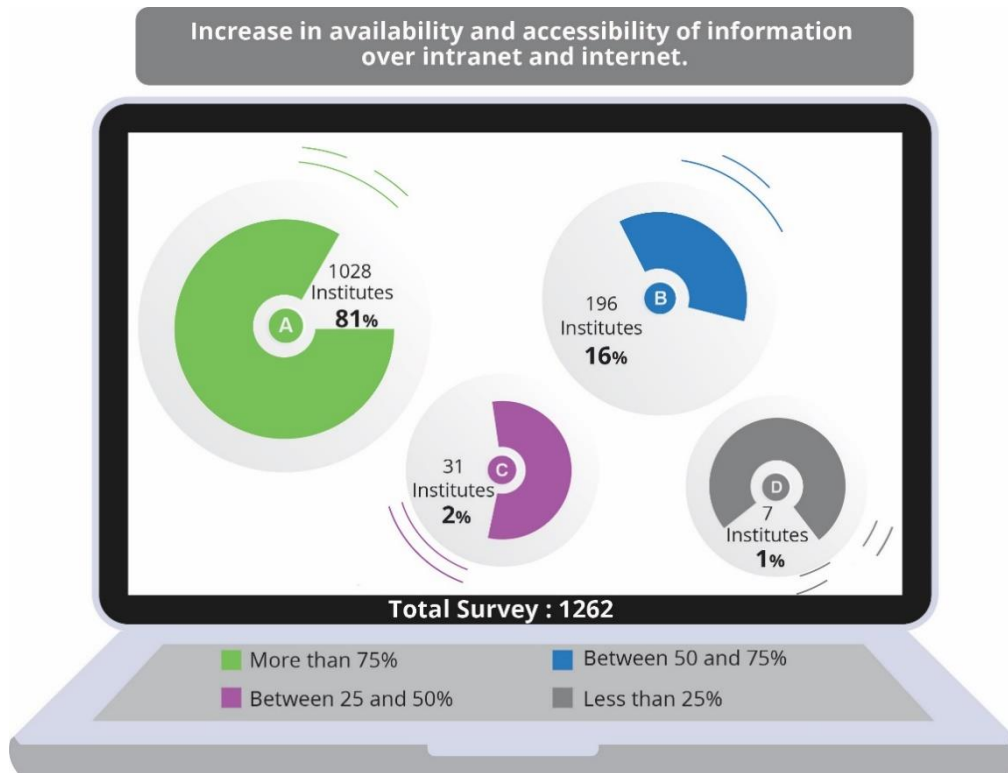


Figure 6.11 Availability of information

For the creation of a knowledge system, one of the primary requirements is 'Access to information'. This study found that NKN has been successful in terms of providing access to information with regard to the users as well as institutes. This has been ascertained from the feedback received. This question of the survey was posed on access and availability of both the internal as well as external information. Availability of information and the consumption by the users are foundational basic building blocks on which the knowledge community stands.

With 81% Institutes agreeing that the both internal and external information availability has increased to more than 75%. No body disagrees this if exceptions are ignored. This also helps in bringing transparency as a measure of Good Governance parameter.

6.5.2 NKN USAGE IN INSTITUTE

Sector wise usage of NKN connectivity

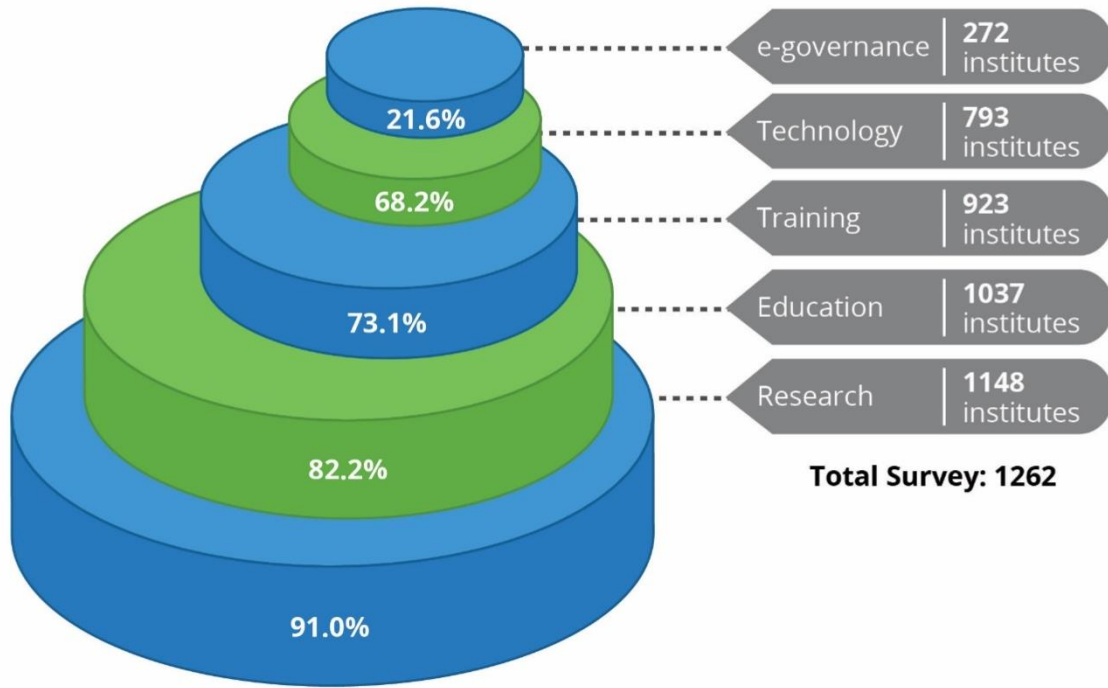


Figure 6.12 Sector-wise usage of NKN connectivity

The survey data reveals, 91% of the institutes are using NKN for research purposes, another 82% are using NKN for education, 73.1% for training and 68.2% are using NKN for other technology interventions. e-Governance usage are comparatively low at the institutes as these are mostly research and educational institutes whereas e-Governance initiatives focus mostly on government organisations. It was observed that e-Governance usage was comparatively high at the NDCs, SDCs and SWAN, where these initiatives are being used extensively.

Vertical VS the Area of NKN connectivity used (% of institutes)

Vertical	E-Governance	Education	Research	Technology	Training
Agriculture	68.3%	67.5%	100.0%	62.5%	78.3%
Atomic Energy	33.3%	53.3%	90.0%	60.0%	43.3%
Biotechnology	54.5%	81.8%	100.0%	81.8%	72.7%
Defense	48.0%	92.0%	84.0%	72.0%	92.0%
Education	56.4%	97.8%	91.9%	69.8%	75.4%
Environment	63.3%	63.3%	90.0%	53.3%	63.3%
General	50.0%	68.8%	87.5%	43.8%	62.5%
Healthcare	60.5%	88.8%	97.0%	59.4%	76.1%
Internal Security	75.0%	68.8%	68.8%	62.5%	93.8%
Labs	48.8%	74.4%	100.0%	60.5%	65.1%
Law	38.9%	94.4%	94.4%	50.0%	72.2%
Management	59.6%	69.2%	84.6%	51.0%	88.5%
Others	68.4%	53.9%	67.1%	50.0%	61.8%
Power	22.2%	55.6%	100.0%	44.4%	66.7%
Science & Technology	53.5%	90.9%	94.7%	66.3%	75.7%
Space	46.2%	34.6%	100.0%	88.5%	34.6%

Figure 6.13 NKN connectivity use in different verticals

Research has very high activity across sectors. This activity in agriculture, biotechnology, healthcare, labs, power, space and science & technology sectors is more than 95% each. Educational activities are also very high across sectors. Training activity is more than 90% in defence and internal security and more than 80% in management.

Case Study: NKN Connectivity @ IIPA

The Indian Institute of Public Administration (IIPA) is an autonomous academic institution of national eminence for training, research and information dissemination in streams related to the ethos of Public Administration. NKN had been established and was functional by the end of the year 2017. Propelled by its vision and mission, IIPA mandates to use NKN as a powerful tool for supporting the country achieving its knowledge supremacy on global scenario. NKN connectivity had been obtained by IIPA to broadly achieve following objectives:

1. To strengthen the institutional mechanisms.
2. To achieve international competitiveness.
3. To foster knowledge and information sharing with its partner organisations.
4. To ensure digital empowerment of human resources, including its employees and clients.
5. To enable collaborative research with its partner organisations in emerging areas.
6. To facilitate research resources for its faculty and participants and the related external researchers too.

The IIPA endeavours to roll out its strategy so as to fulfil the envisaged vision in a phased manner as illustrated in the figure below:

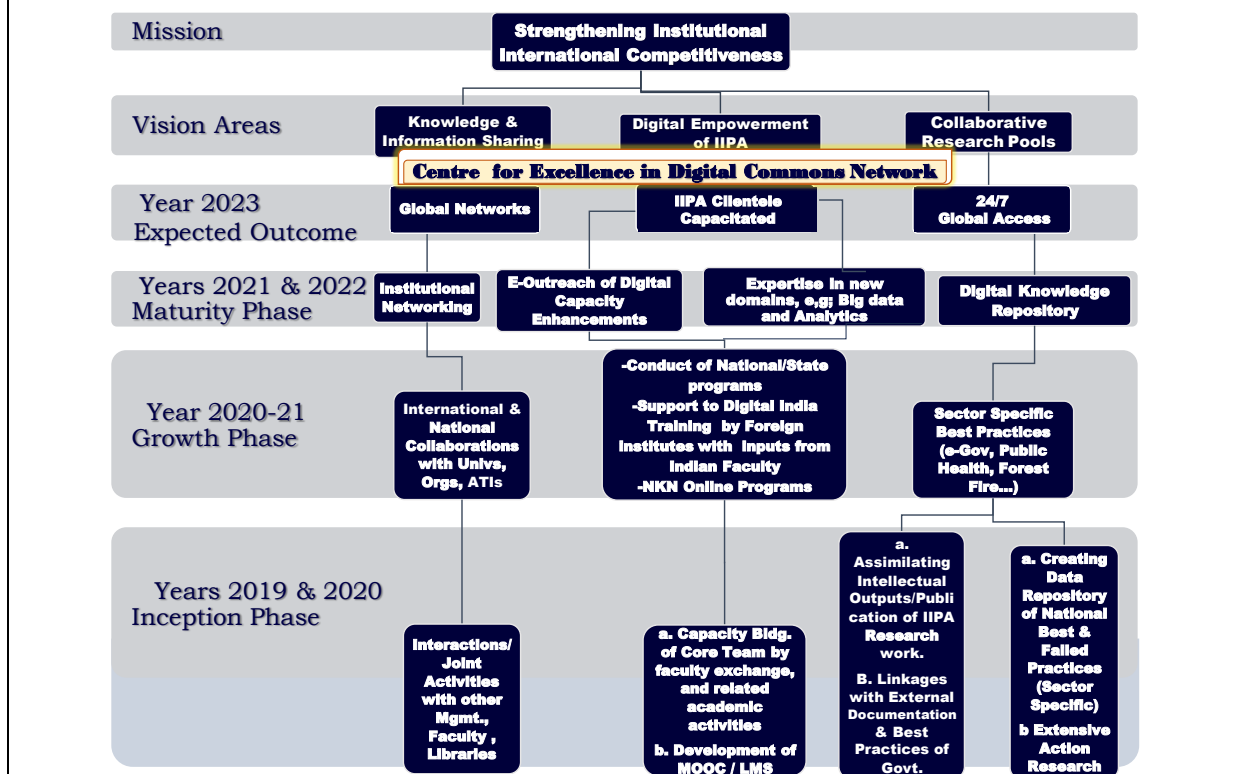


Figure 6.14 Schematic Representation of IIPA Action Plan for Optimally Using NKN Connectivity to Foster Knowledge Network Commons

Key observations and recommendations:

A large percentage of institutes are using NKN for research initiatives and this fulfils the basic purpose for which the NKN was created. A large percentage of institutes are also using NKN for training. This directly impacts the capacity building of the country and also inculcates the use of technology for capacity building and human capital development. In addition, a good percentage of institutes have technology-based consumption. A little deeper study in future can show the precise results on the type of technology usage.

e-Governance usage are comparatively low at the institutes as these are mostly research and education institutes whereas e-Governance initiatives focus mostly on government organisations. It was observed that e-Governance usage was comparatively high at the NDCs, SDCs and SWAN, where these initiatives are being used extensively. Internet connectivity and the traffic management of Bhavans and Offices connected through NICNET/NKN.

6.5.3 ACTIVITIES ON NKN

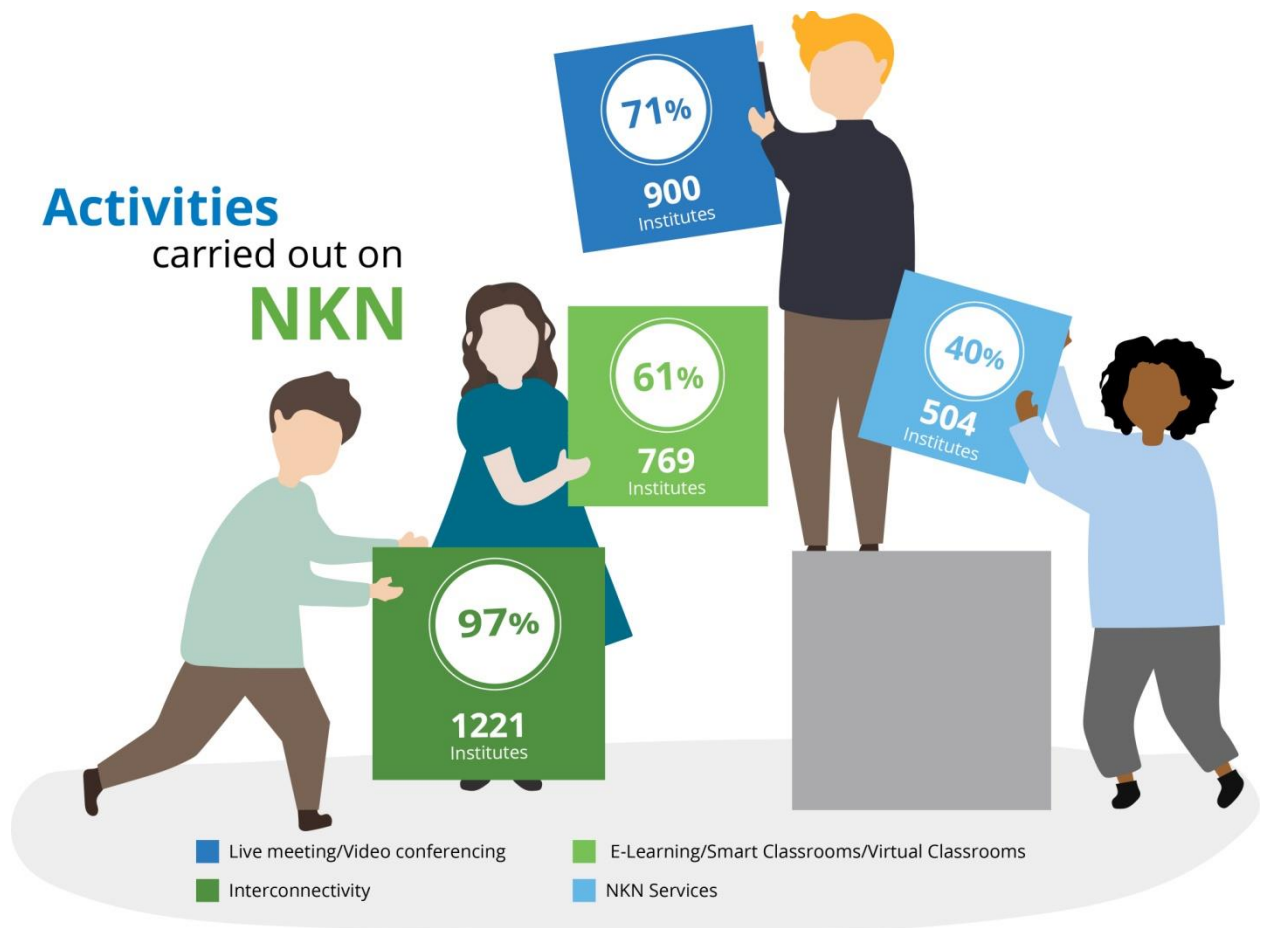


Figure 6.15 Activities on NKN

Activities performed using NKN was another assessment factor to estimate the extent by which the intended usage were achieved. Institutes response is encouraging on interconnectivity, e-learning, live meetings, etc.

Interconnectivity is the major activity on NKN and 97% of the institutes are using it for that purpose. 71% institutes use it for video conferencing or live meetings. 61% has shown interest in technology enabled learning and 40% use NKN services.

Vertical VS Activities carried (% of institutes)

Vertical	activities_carried		
		E-Learning / Smart Classrooms / Virtual Classrooms	Interconnectivity
			Live meeting / Video conferencing
Agriculture		45.8%	97.5%
Atomic Energy		26.7%	90.0%
Biotechnology		36.4%	90.9%
Defense		68.0%	92.0%
Education		71.0%	96.9%
Environment		40.0%	93.3%
General		37.5%	93.8%
Healthcare		64.0%	97.5%
Internal Security		75.0%	93.8%
Labs		30.2%	97.7%
Law		55.6%	72.2%
Management		65.4%	96.2%
Others		36.8%	94.7%
Power		44.4%	100.0%
Science & Technology		68.3%	97.5%
Space		26.9%	96.2%

Figure 6.16 Activities on NKN by the types of institutes

Interconnectivity as a major requirement of the project shows amazing results. Almost all the sectors show more than 90% uses with the exception of Law at 72% uses.

Use for digitally enabled learning is less in comparison to other uses. Defence, Education, Healthcare, Internal Security, Law, Management and Science & Technology are the sectors where 60 to 70% institutes are using it.

Biotechnology, Labs and Space are the largest users of video conferencing and live meetings with more than 90% use. Environment and Science and Technology use is also more than 80%.

Key observations and recommendations:

It is recommended for a provision of a dedicated public relations team. Such a team facilitated with chat bots can act as an exclusive information and data in charge coordinator, for advocating NKN services. This advocate team/chat bots could stay connected with the respective 'information and data in charge' of the institutes to keep these leaders updated about the emerging NKN services and their enormous potential. This could be best facilitated by creating a Knowledge Management system that also includes a repertoire of Best Practices/Cases around the theme of "Success Stories of Institutes by using NKN". This would inspire and support others too to emulate.

6.5.4 DIGITAL INITIATIVES BY INSTITUTES

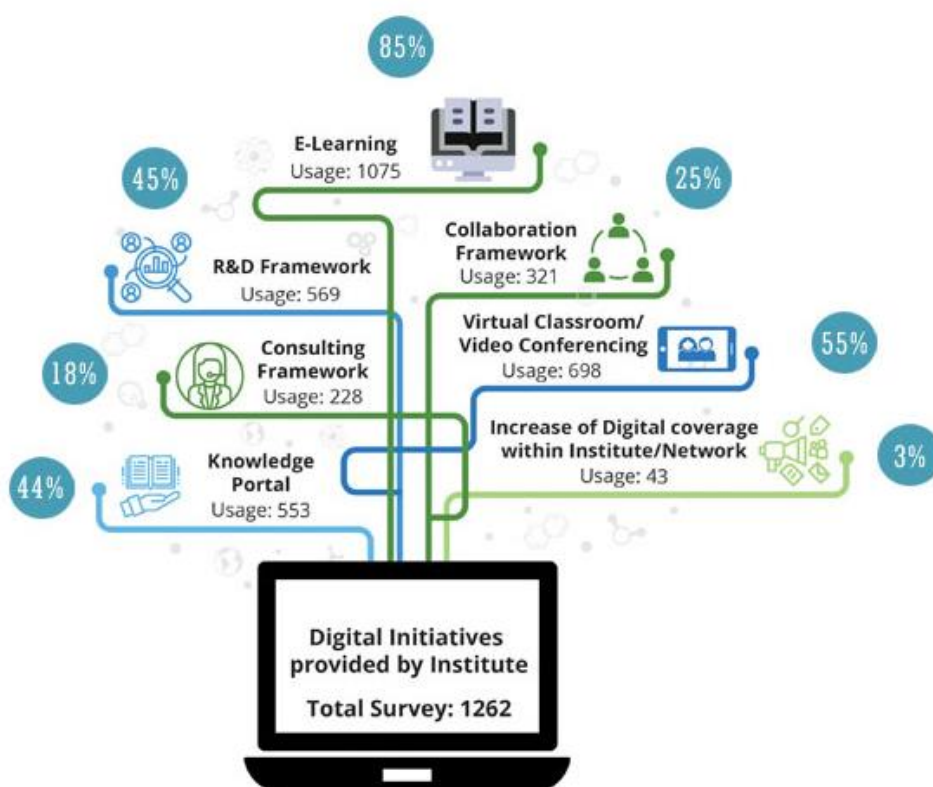


Figure 6.17 Digital Initiatives by the institutes

The aim of the question in the survey on digital initiative was to comprehend the interest of the institutes in providing e-Learning, Virtual Classrooms, Video Conferencing, R&D, Collaboration & Consulting Frameworks and Knowledge Portal. 85% of the institutes have chosen e-learning as the digital initiative, 55% have shown interest in synchronous learning or video conference and NKN is able to fulfil both these needs. Video conferencing facility is already being used very successfully on NKN. 43% are using for NKN for providing

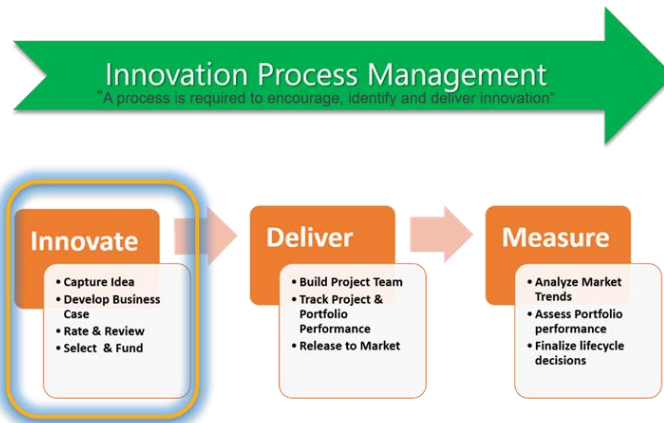
Knowledge Portal as the digital initiative. In addition, 25% are using NKN for collaboration framework and 18% for the consulting framework. Institutes are either digging this idea, or already providing the services.

Key observations and recommendations:

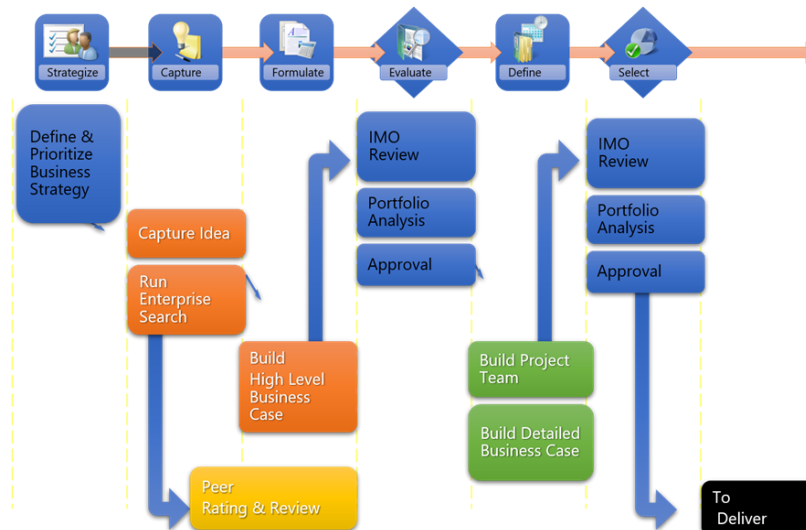
Institutes' feedback on Digital Initiatives is very encouraging. A very high level of interest in e-learning and video conferencing has again reinstated the need of technology enabled learning. Institutes are ready to experiment with R&D, collaboration and consulting frameworks. These frameworks can be developed in partnership with some expert institutes and can be deployed for everybody's consumption. One example of an innovation framework to manage innovation using technology is described in chapter 9.

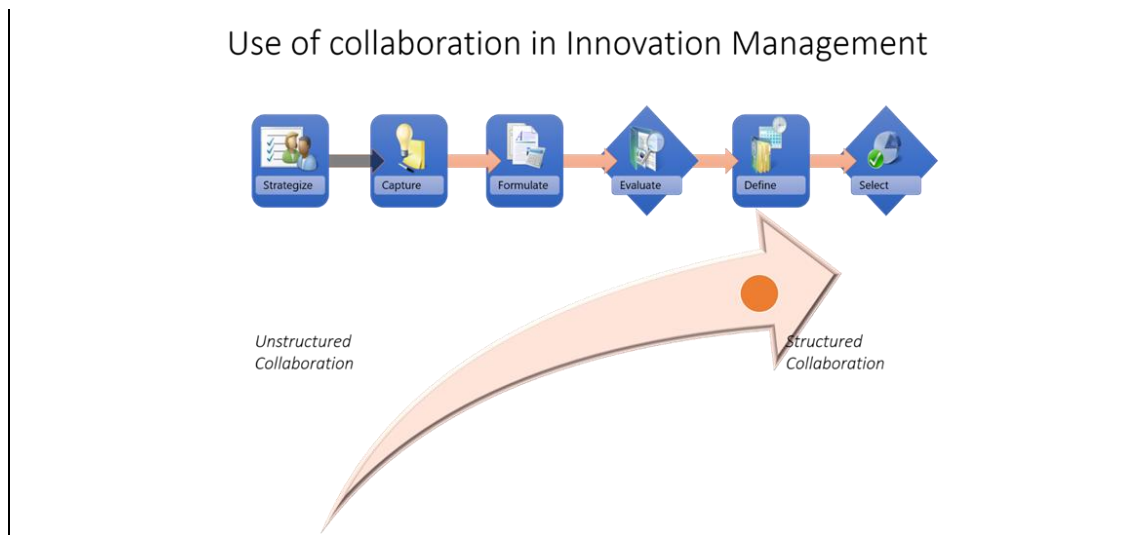
Innovation-Management Framework

A Process is Required to Facilitate Innovation Success



Innovate: Identify & Select Ideas





6.5.5 COLLABORATIONS

Data received on collaborations are very inspiring and definitely give a glimpse into the usage of NKN on collaborations. Approximately five hundred institutes are using NKN for actively collaborating with Indian institutes and organisations. Ten thousand plus collaborations are reported in the survey. Eighteen institutes have hundred plus collaboration partners each and collaborations by a single institute are as high as fifteen hundred.

NKN global connectivity has facilitated international collaborations. The survey has shown approximately three hundred institutes with twenty-five hundred plus international collaborations. Around fifty institutes have more than ten global collaboration partners and collaborations by a single institute are as high as four hundred and fifty.

Key observations and recommendations:

A lot of activity is happening on collaborations. This indicates a potential growth area for NKN. There is a definite need of a collaboration portal. This we could also gather from the remarks of the user institutes. The portal will list the areas of collaborations, participating institutes, case studies, business cases, best practices, risks & mitigations, list of projects, products, services and processes worth collaboration, etc. The portal can have both secured and public access collaboration environment and data. The outcome data can be published on Knowledge Dashboard also as suggested earlier. If required, this can be a paid initiative on subscription mode.

6.6 VALUE PROPOSITION

Value proposition is studied intensely in the third chapter from the management perspective, but it is imperative to have the view of the most important stakeholder i.e., user institutes. Value

proposition for institutes is not only the cost saving but also the opportunities created by the availability of the network, applications and services.

6.6.1 USE OF NKN CONNECTIVITY FOR THE ADOPTION OF EMERGING TECHNOLOGY

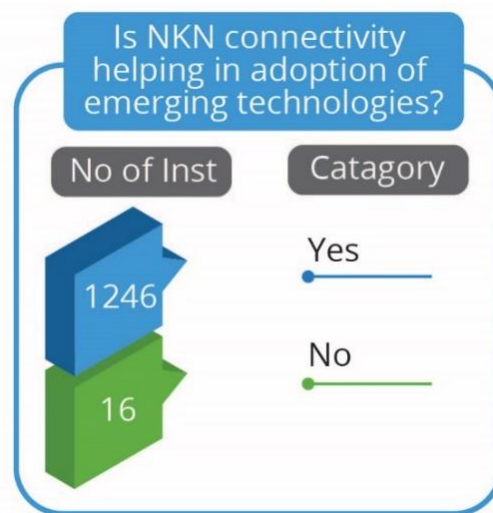


Figure 6.18 Adoption of emerging technologies

99% users agree that NKN connectivity is helping them in adoption of emerging technologies. Adoption of new technology is a challenge for the traditional institutes, but the network has opened up the knowledge and collaboration flood gates along which came the wave of new technologies. Everything looks within reach and users are ready to experiment with new ideas or technologies, primarily due to availability of NKN connectivity. Users are excited to try the new technological advancements and this trend is transcending to the institutes as a community need.

6.6.2 FUTURE PLANNING OF DIGITAL INITIATIVES BY INSTITUTES

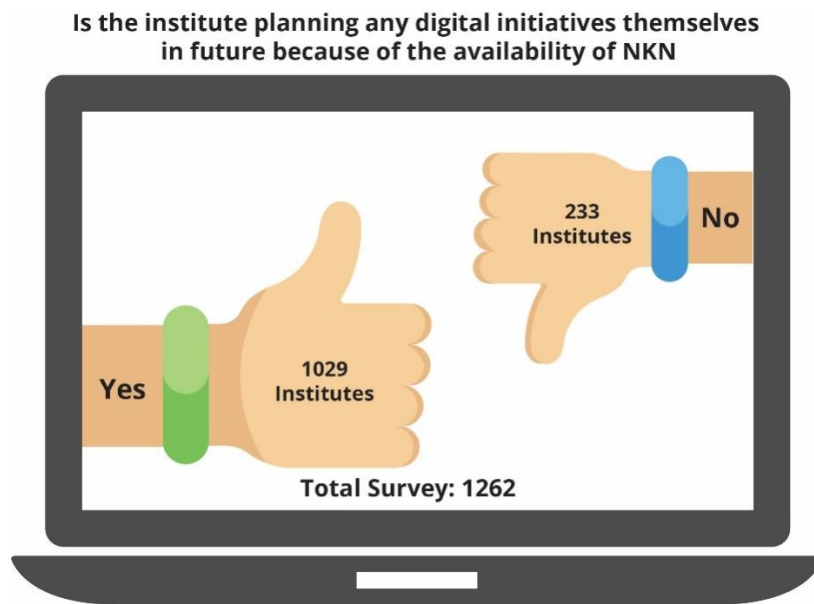


Figure 6.19 Planning of digital initiatives

The survey pointed that 81% Institutes are planning a digital initiative in future. This is a very healthy sign and definitely will impact the value proposition of an institute either in terms of earnings or expertise. NKN may like to further study and unearth some mutually beneficial outcomes to unlock this potential.

6.7 SOME MORE ANALYSIS GRAPHS

6.7.1 BEFORE AND AFTER NKN ANALYSIS

Some of the key observations emerging from the data received on various benefit aspects to user institutes before and after implementation of NKN are as follows:

- Increase in the use of internet after NKN is recorded, by 76% of the users, to be more than 75% and 16% responded with 50 to 75% increase in Internet use. Although 25% of the institutes feel that the use of internet has not changed.
- Similar kinds of trends can be seen on the use of ICT also. 92% users have marked the use of ICT increase by more than 50% after NKN.
- 72% of the users' institute mentioned that they observed more than 75% increase in Human Resource Development (HRD). This statistic was between 50-75 % for 21% of the users. HRD is another high impact area for NKN in this analysis.

- 99% replied with a YES on increase in adoption of technology after NKN. Use of technology makes users/institutes efficient while improving the products and services landscape. Communication delays are minimised and outcomes are improved. Technology adoption and use is a multi-faceted weapon in the armoury of the institutes enabled by NKN.
- Prior to NKN, 43% institutes were using less than 8 Mbps, 25% were using bandwidth ranging from 8 to 20 Mbps and 31% Institutes had more than 20 Mbps bandwidth. This has transformed with the entry of NKN in these institutions. Presently, 50% Institutes have 100 Mbps and 48% have 1 Gbps links. Clubbed with the NKN quality of service, this has led to good delivery as well. 26 institutes have 2 links and IIT Kharagpur has 2 links from NKN, where the third link is for the Kolkata campus. As inferred from the needs of the users, 30% of the respondents have requested for more bandwidth as their upcoming requirement.

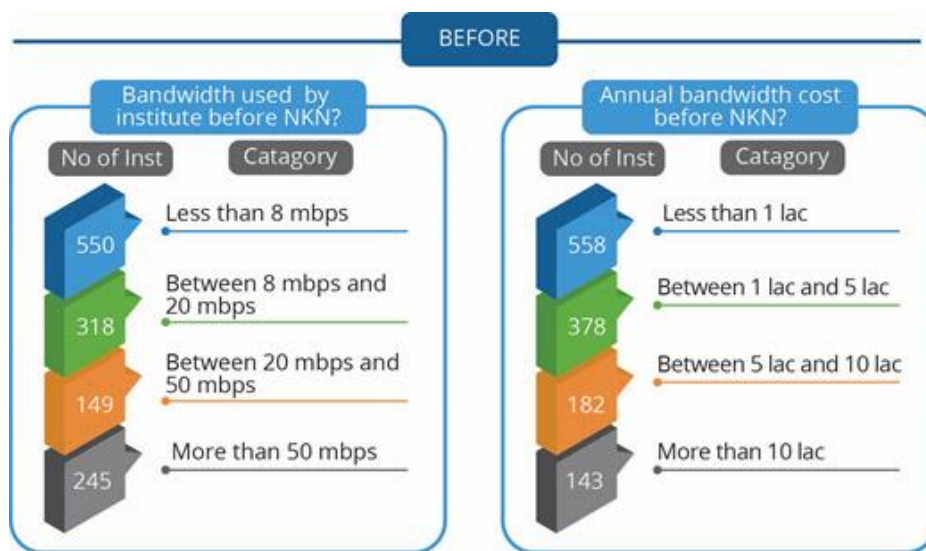


Figure 6.20 Bandwidth and cost before NKN

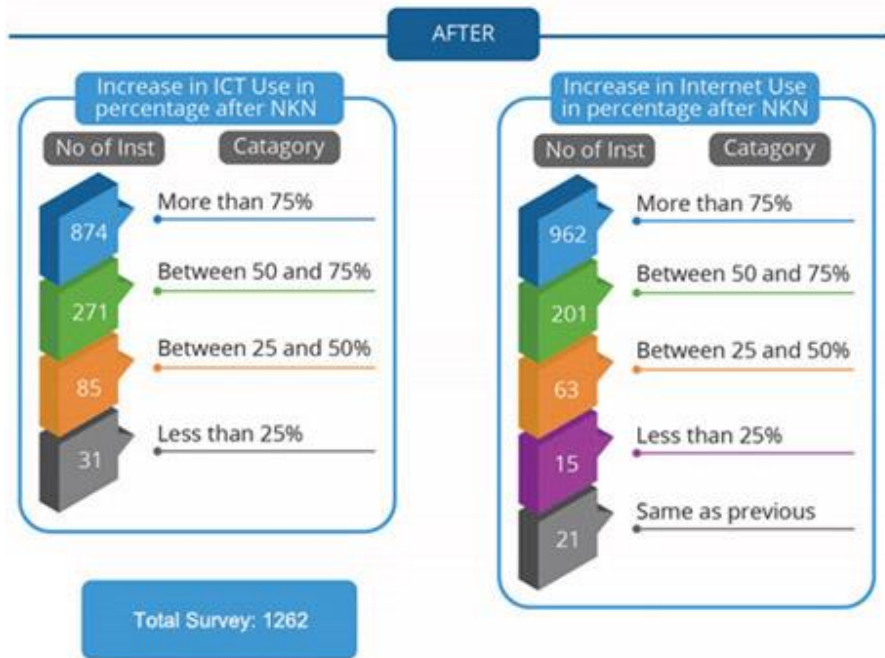


Figure 6.21 Increase in use of internet and ICT after NKN

6.7.2 RESPONSE ON OPEN ENDED QUESTION ON EXPECTATION FROM NKN

- The feedback from the institutions in subjective format was also gauged through the survey tool. Majority of the institutes had asked for an increase in the bandwidth and it is plotted with their current bandwidth. This is to illustrate the current bandwidth of the institute with their expectations of up gradation of the bandwidth.

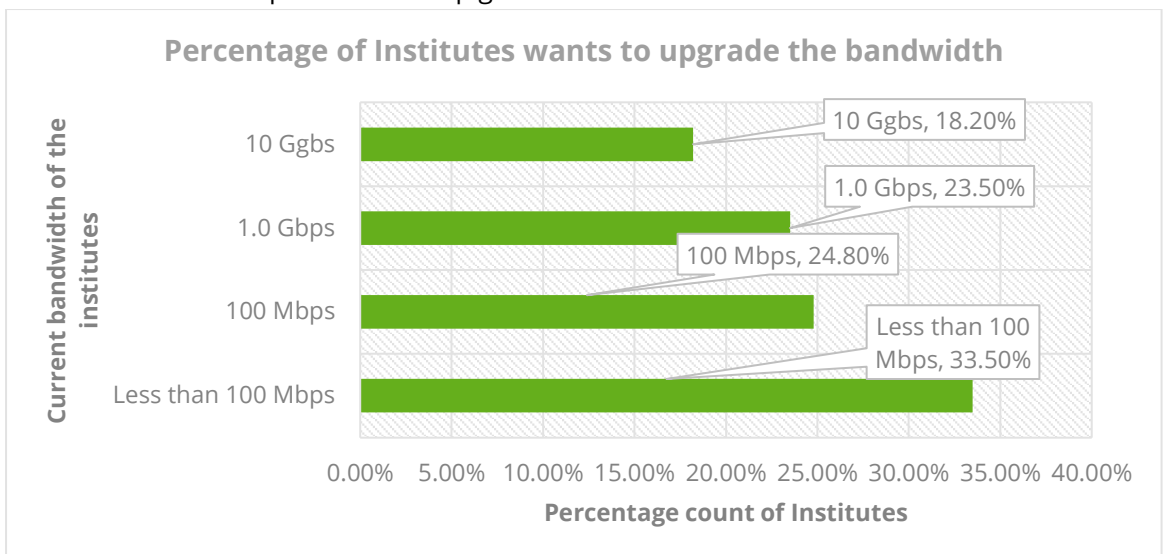


Figure 6.22 Bandwidth requirements by the institutes of different bandwidth bracket

2) User remarks on future requirements from NKN

Apart from an increase in bandwidth, institutes utilising the NKN network have several other expectations. The graph below illustrates the future needs in the coming years of these user institutes. They listed their needs in different areas where NKN can play an important role.

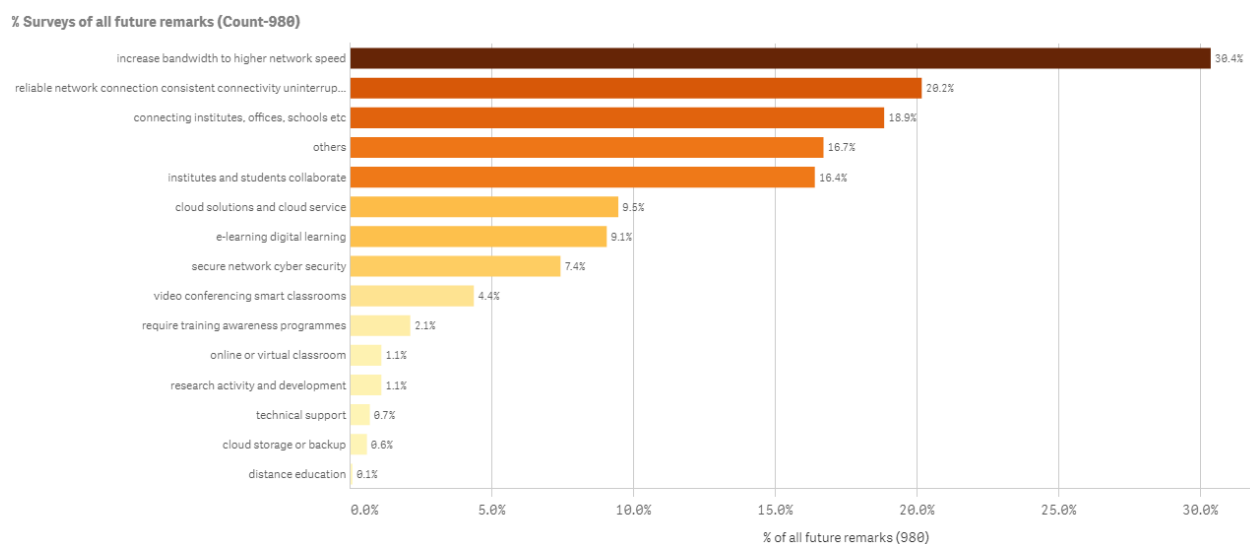


Figure 6.23 Future requirements from NKN by the institutes

6.7.3 SECTORIAL ANALYSIS

Understanding user institutes from different sector is achieved by analysing the responses sector wise. The graphical representation of this study has been presented in the subsequent pages for the following sectors:

1. Research
2. Education
3. Agriculture
4. Science and Technology
5. Space
6. Digital India
7. Healthcare

Research:

The research institutes using NKN have more than 75% connected users. In these institutions, the geographical area covered by NKN reaches up to 75%, which is quite high. The users have also shown high level of awareness about NKN. Almost 85% of the users of research institutions have shown awareness about NKN.

The users have also graded NKN high on reliability with cumulative score being 96%. These institutes have also been able to collaborate nationally as well as internationally for various projects because of NKN. The institutes also feel that NKN has played an important role in contributing to the capacity building. In terms of overall experience of using NKN, 95% of the institutes have cumulatively rated their overall experience of using NKN connectivity as good, very good or excellent.

Education:

The educational institutes using NKN have more than 75% connected users. In these institutions, the geographical area covered by NKN reaches up to 75%, which is quite high. The users have also shown high level of awareness about NKN. Almost 85% of the users of educational institutions have shown awareness about NKN.

The users have also graded NKN high on reliability with cumulative score being 87%. The institutes also consider NKN important for the various international and national collaborations that they undertake. The user institutes have also rated NKN highly in terms of connectivity with 98% of institutes cumulatively rating it as good, very good or excellent.

Agriculture:

The agriculture institutes using NKN have more than 75% connected users. In these institutions, the geographical area covered by NKN reaches up to 75%, which is quite high. The users have also shown high level of awareness about NKN.

The users have also graded NKN high on reliability with cumulative score being 95%. NKN has also facilitated national and international collaborations for these institutes which is also acknowledged by these institutes. Cumulatively, 95% of institutes have rated their overall experience of using NKN connectivity as good, very good or excellent.

Science and technology:

The S&T institutes using NKN have more than 75% connected users. In these institutions, the geographical area covered by NKN reaches up to 75%, which is quite high. The users have also shown high level of awareness about NKN. Almost 85% of the users of S&T institutions have shown awareness about NKN.

The users have also graded NKN high on reliability with cumulative score being 89%. These institutes have also acknowledged importance of NKN for international and international collaborations. Cumulatively, 98% of institutes have rated their overall experience of using NKN connectivity as good, very good or excellent.

Space:

The institutes conducting research in space technology using NKN have more than 75% connected users. In these institutions, the geographical area covered by NKN reaches up to 85%, which is quite high.

The users have also graded NKN high on reliability with cumulative score being 96%. These institutes have also acknowledged the importance of NKN for the various national and international collaborations and capacity building. Cumulatively, **all** of the science and technology institutes have rated their overall experience of using NKN connectivity as good, very good or excellent.

Digital India:

The institutes utilizing NKN for Digital India have more than 75% connected users. In these institutions, the geographical area covered by NKN reaches up to 75%, which is quite high. The users have also shown high level of awareness about NKN. Almost 85% of the users of Digital India institutions have shown awareness about NKN.

The users have also graded NKN high on reliability with cumulative score being 91%. Cumulatively, 95% of institutes have rated their overall experience of using NKN connectivity as good, very good or excellent.

Healthcare:

The institutes using NKN for healthcare have more than 75% connected users. In these institutions, the geographical area covered by NKN reaches up to 75%, which is quite high. The users have also shown high level of awareness about NKN. Almost 100% of the users of healthcare institutions have shown awareness about NKN.

The users have also graded NKN high on reliability with cumulative score being 95%. These institutes have also been able to collaborate nationally as well as internationally for various projects because of NKN. The institutes also feel that NKN has played an important role in contributing to the capacity building. Cumulatively, 75% of institutes have rated their overall experience of using NKN connectivity as good, very good or excellent.

6.8 SUMMARY

This assessment study used the framework that rests on the four pillars based attributes of the system, namely Outreach, Quality of Services, Knowledge Ecosystem and Value Proposition. These have been analysed through an exhaustive methodology and data collection from across NKN stakeholders. This survey tool comprised of open ended and close ended questions focused on the four pillars of the study. The study further explains the various aspects of NKN included in each of the four pillars and shows how each of these have created an impact to strengthen the network. A synopsis of the analysis is presented in this summary sheet and further details have been given in the preceding sections of this chapter.

Out of all the institutes to whom the survey was sent to, **1262 responded to the survey**, which is a good sample for analysis.

Under “Outreach” assessment pillar, four aspects were studied, namely, Number of Nodes, Number of Users, Percentage of Users and Geographical spread of NKN.

- It is observed, 38.5% of user institutes have less than 200 nodes, whereas 17.3% of the institutes have more than 1000 nodes connected. It was also found out that educational institutes have more nodes than others because of the high component of student usage.
- In regard to the number of users in each of the user institute, 39.4% of the institutes have 200-1000 users. At the same time 35% of the institutes have less than 200 users.
- 81% of the institutes have more than 75% of the users of NKN and 14% institutes have 50-75% users of NKN.
- On the geographical coverage of NKN within the institute, 75% of the institutes were well connected internally and 17% of the institutes had 50-75% range of coverage.

Under the “Quality of Service” assessment pillar, four aspects were studied, namely, Primary Connectivity, Reliability, Overall Experience of using NKN and NKN Awareness with the institute.

- The feedback and results received from most of the users have been very encouraging.
- 89.70% of the institute are using NKN for primary connectivity, while only 2.46% of institutes are using NKN for secondary connectivity.
- 65.85% of the institutes rated NKN reliability Very High, while 26.39% rated NKN's reliability as High.
- More than 99% of NKN user institutes are satisfied on their overall experience of using NKN. This can be seen in a positive light and is encouraging for NKN team.
- 77.7% of the institutes felt that the awareness about NKN was more than 75% in the institute users.

Under the “Knowledge Eco-system” assessment pillar, five aspects were studied, namely, Access of Information, NKN Usage in Institutes, Specific NKN Usage Areas, Digital Initiatives and Human Resources Development.

- 81% of the institutes agree that the both internal and external information availability has increased to more than 75%.

- 91% of the institutes are using it for research purposes, another 82% are using NKN for education, 73.1% for training, 68.2% are using NKN for their other technological interventions and only 21.6% are using NKN for e-Governance.
- Research has very high activity across sectors. The activity in agriculture, biotechnology, healthcare, labs, power, space and science & technology sectors is more than 95%. Educational activities are also very high across sectors. Training activity is more than 90% in defence and internal security and more than 80% in management.
- 97% of the institutes are using it for interconnectivity purpose. Biotechnology, Labs and Space are the largest users of video conferencing and Live Meetings with more than 90% use. Environment and Science and Technology use is also more than 80%.
- 85% of the institutes have chosen e-learning as the digital initiative, 55% have shown interest in synchronous learning or video conference and NKN has been able to fulfil both these needs.
- 43% are using NKN for Knowledge Portal as the digital initiative.
- NKN has also resulted in 10437 national institutional collaborations and 2661 international collaborations. Though, the actual value addition happening from these collaborations was out-of-scope of this assessment study, therefore this component could not be ascertained.

Under the fourth assessment pillar “Value Proposition”, three key aspects, namely, Cost-saving, increase in revenue and wealth creation for the country were the major focus of the study in this pillar.

- 99% of the users agree that NKN connectivity is helping them in adoption of emerging technologies.
- 81% of the institutes are planning a digital initiative in the future. This is a very healthy sign and definitely will impact the value proposition either in terms of revenue or expertise.
- Increase in the use of internet after NKN is recorded by 76% of the users to be more than 75% and 16% responded with 50 to 75% increase in Internet use.
- 92% of the users have marked the use of ICT increase by more than 50% after NKN.
- 72% of the users reported more than 75% and 21% reported 50-75% increase in HRD, another high impact area for NKN in this analysis.
- 99% of the users replied with a YES on increase in adoption of emerging technologies after NKN.
- Prior to NKN, 43% institutes were using less than 8 Mbps, 25% were using bandwidth ranging 8 to 20 Mbps and 31% Institutes had more than 20 Mbps bandwidth.

The survey also identified some general user feedback and some of the key future requirements of these user institutes are:

- The data indicates that a large percentage of institutes require to increase the available NKN bandwidth.
- Consistency in connectivity.
- Use of NKN for Cloud infrastructure and services.
- Explore connecting institutes, offices and schools.
- Enhance use of e-learning, Video Conference, Smart and Virtual Classrooms.
- Enhance institute and student collaboration.

- NKN related awareness and training.

Overall data and information collected from NKN teams and user institutes infers that the NKN project has been able to deliver and achieve the laid down objectives to a large extent. Keeping in view the NKN importance and it being a critical backbone for most of the user institutes, the projects needs another phase of push with a view to strengthen the existing services, an enlarged scope of implementation and increased services.

CHAPTER 7

Global Benchmarking with Similar Initiatives

7.1 CHAPTER OVERVIEW

National Knowledge Network (NKN) has collaborated with the world's leading National Research and Education Networks (NRENs) for development in the area of research and education. Understanding the importance that international peering has played, NKN has also collaborated with GÉANT, NORDUnet, Internet2 and Asi@Connect. This study, first, elaborates the need for such a global collaboration and then describes some of the major global initiatives with which NKN has collaborated. Thereafter a comparison has been made between the NRENs depicting various multi-dimensional distinctions between them.

7.2 NEED OF A GLOBAL KNOWLEDGE COLLABORATION

A global strategy of collaboration is crucial for the future of research and educational community. Establishing a joint presence secures unrestricted and unlimited access at the lowest possible cost. It is widely agreed that global peering is crucial to the future of NRENs. In a world where we see the growth of Internet of People, a lonely academic in his/her university is a thing of the past. That is why an increasing number of NRENs cooperate and directly collaborate with

each other at open exchange points all around the world. With growing number of activities in research and education requiring high quality access to the Internet, the need of the hour is to have one global commercial IP network.

To strengthen its international footprint, NKN has collaborated with several of the world's renowned NRENs (National Research and Education Networks). Such collaboration helps knowledge transfer in sectors like science, education, healthcare, weather, etc. These collaborations help in constant flow of discussions, learning outcomes and problem-solving tools and help in transcending barriers that earlier hampered such an exchange. The dedicated high-speed networks enable access to online resources for students and researchers, while also supporting content-level collaboration in research and education. Not only are the collaborations saving human labour hours and cutting costs, it is also enhancing content quality, expanding audience and bringing the very best content to more students. These are also enhancing the development of critical minds that are creative and can think outside the traditional box.

The above assertions are validated by a 2010 case, wherein, using robots based in Grenoble in France, Indian researchers in Mumbai could perform crystallography on HIV proteins. This group of researchers based out of Homi Bhabha National Institute (HBNI) in Mumbai, was able to carry out the, operating robots in a French laboratory almost 10,000 km away from their lab in Mumbai. This was possible due to remote control facilities supported by the EU India Grid connection. 180 frames were collected on crystals of drug-resistant M36I mutant HIV-1 protease and the structure could be refined to very low R-factors, a measure of the agreement between the model and the experimental data. More recently, data on HIV-1 protease substrate complexes have been collected. The diffraction data collected is stored temporarily on a local computer at ESRF, before it is transferred to HBNI computer through FTP(ScienceNode, 2011).

Experiments like these demonstrate how researchers increasingly require access to the top cutting-edge communication technologies. They are part of growth in e-Science which requires substantial bandwidth and computing power. This dimension can contribute to the development of a national knowledge base that can help close the digital divide, potentially countering the loss of highly qualified researchers and delivering research to benefit society more quickly and efficiently. The scientific community often uses leading-edge applications, requiring specific technological solutions and have demanding network requirements compared to both consumer and average business users. Collaboration among NRENs fulfils these needs by developing innovative technologies and constantly developing new services and applications which create synergies for the betterment of the society as a whole.

Study Methodology

Selection of global best practices

For comparison of NKN with the global leading practices of other NRENs, the first step was to select the global leading practices prevalent across the globe. Extensive review of literature along with several brainstorming sessions were done to decide these. The team settled on comparing four NRENs, namely Internet2, GÉANT, Asi@Connect and NORDUnet, based on the recent MoUs signed by NKN.

Understanding of NREN

The websites of each of the NREN were then critically studied to understand each of the initiative's history, network topology, etc. The discussions with the NKN team also helped in gaining an insight into each of the initiatives.

Comparison of NRENs

Post having a macro level understanding of each of the NRENs, **an unbiased classification of each of the platform was undertaken on select parameters based on secondary research, namely,**

1. year of inception
2. users
3. network spread
4. services provided
5. management and
6. funding

This unbiased comparison with international best practices helped not only to reveal insights about current achievements but also reflect on the scope for future NKN improvements.

7.3 DIFFERENT GLOBAL INITIATIVES

7.1.1 INTERNET2

Introduction

Internet2 is a collaborative effort by over 180 United States Universities to develop advanced Internet technology and applications vital to the research and educational missions of higher education. Internet2 is a project of the University Corporation for Advanced Internet Development (UCAID), a non-profit consortium led by university members working in partnership with industry and the government. The "community" of Internet2 also includes international participation through agreements with similar groups worldwide.

Internet2 operates the nation's largest and fastest, coast-to-coast research and education network to deliver advanced and customised services that are accessed and secured by the community-developed trust and identity framework. Internet2 serves 317 U.S. universities, 60 government agencies, 43 regional and state education networks and through them, supports more than 100,000 community anchor institutions, close to 1,000 In Common participants, 59 leading corporations working with the community and 70 national research and education network partners that represent more than 100 countries (Internet2, 2019).

Network

The Internet2 Network's (IEEE Communications Society, 2009) physical implementation is made up of several robust, logically different, but related networks, each on its own overlaid infrastructure. These networks include:

- Advanced IP network (provided by Juniper routers)
- Virtual Circuit network (provided by the multiservice switching capabilities of the Ciena Core Directors)
- Core optical network (provided by the Infinera platform)

Funding Model

Funding is mostly through membership fees. The members are divided into 4 Levels:

1. Non-connected Affiliate and Industry
2. Non-connected Affiliate
3. Research & Education Network
4. Industry

The membership fees are on a scale-based model with a cap. The fees are based on annual expenditure and annual research expenditure.

NKN Connection with Internet2

The Internet2 and NKN signed an MoU dated June 2015, for creation of a robust collaboration programme between the two National Research and Education Networks (NRENs). With active research projects in areas like energy, public health and earth sciences, the Internet2-NKN partnership provides a platform for the collaborative work. The Internet2-NKN partnership is based on a working group structure, composed of NKN collaborators and Internet2 members and is centred on the core cooperation themes of education, personalised medicine and harmonisation of research and education network infrastructure. With this collaboration, NKN's role has been enhanced in becoming the backbone of India's Knowledge Economy and the workforce for the Prime Minister's Digital India Programme.

7.1.2 GÉANT

Introduction

GÉANT is a pan-European high bandwidth, high performance data network for the research and educational community which connects NRENs across Europe. GÉANT is a fundamental element of Europe's e-infrastructure for scientific excellence, research, education and innovation. GÉANT has interconnections with over 40 NREN partners making it the largest and most advanced R&E network in the world. It connects over 50 million users at 10,000 institutions across Europe and supports all scientific disciplines while operating at speeds of up to 500Gbps with transfer of 1000 terabytes of data every day.

Network

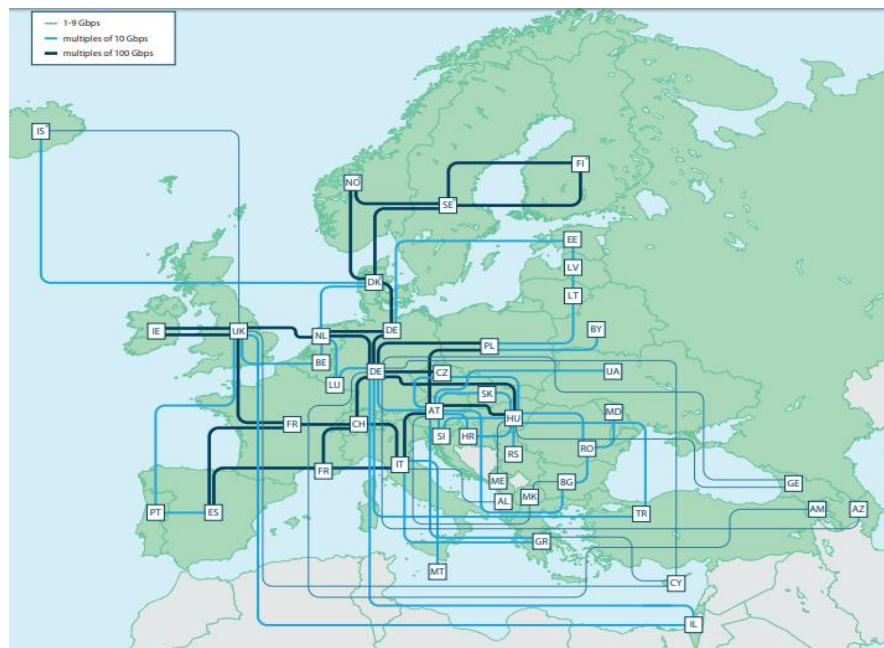


Figure 7.1 GÉANT's dual layer network

GÉANT network is one of the largest and most complex in the world supporting a diverse range of users and services from standard IP transit services to ultra-high capacity data centre interconnects. To cater to such diverse and complex range of users, GÉANT has built a dual layer network. This enables GÉANT to integrate service demands across a single core structure. The two layers of the GÉANT dual layer structure are transmission layer and packet layer.

Funding Model

GÉANT is an association of members with operations managed through its legal entities in the Netherlands and the United Kingdom. The funding of GÉANT comes primarily from the European Union (EU) via the European Commission (EC) for the management of networking and related projects, or to participate in them. Membership subscriptions (NRENs and Associates) also form part of GÉANT funding. Apart from these, earnings from the provision of administrative, consultancy and training services also fund GÉANT.

NKN Connection with GÉANT

A 10 Gbps of R&E connectivity was established between NKN and GÉANT. It became operational between India and Europe in 2016. It was inaugurated by Hon'ble Minister of Electronics and IT, Shri Ravi Shankar Prasad. The new capacity is provided over two diverse cable systems from Mumbai to Amsterdam where it interconnects with GÉANT via Netherlight. This was additional to the TEIN project's EU-India connection which was upgraded from 2.5 to 10 Gbps. The new link to GÉANT was welcomed by the high-energy physics community, as it was set to further support participation of Indian scientists in the LHC (large Hadron Collider) and other experiments at CERN. Additional R&E collaborations between Europe and India which are expected to benefit from the capacity boost include environmental monitoring, telemedicine, genomics, remote instrumentations and e-learning (GÉANT, 2016).

7.1.3 ASI@CONNECT

Introduction

Asi@Connect is a co-funded project by the European Union to provide a dedicated high capacity and high-quality internet network for research and educational communities across Asia-Pacific and Europe. It provides a large-scale research and education data-communications network for the Asia-Pacific region (Asi@Connect, 2018) . It connects Asian researchers to each other and with their counterparts in Europe via direct links to the pan-European GÉANT network, providing the Asia-Pacific countries with a gateway for global research collaboration. Operating at speeds of up to 10 Gbps, it currently connects twenty-four countries in the Asian and South Asian region. These countries are Afghanistan, Australia, Bangladesh, Bhutan, Cambodia, China, Chinese Taipei, Hong Kong, India, Indonesia, Japan, Korea, Laos, Malaysia, Mongolia, Myanmar, New Zealand, Nepal, Pakistan, Philippines, Singapore, Sri Lanka, Thailand and Vietnam. Through this network, collaborative programmes like Earth observation, disaster warning, climate research, food security, delivery of e-health and e-learning are supported.

Asi@connect is chaired by the project director of NKN.

Funding Model

The project receives funding from the European Union and participating Asian NRENs under the grant contract ACA 2016/376-562.

Activities Undertaken

NKN Connection with Asi@Connect

NKN has set up its own Internet links from Mumbai to Amsterdam and intends to allow Asi@Connect traffic to utilise these links. Furthermore, NKN provides international connectivity to the neighbouring countries of Bhutan, Bangladesh, Sri Lanka, etc. The connectivity with NKN brings efficient communication and dissemination of information/knowledge for over 50 million scientists, educationists, students and researchers in different disciplines. The connectivity also helps in collaborating with leading mission-oriented agencies in the fields of nuclear, space and defence research besides helping universities, libraries, healthcare and agricultural institutions. In India, Asi@Connect corresponds closely to the core project objective of digital connectivity and has linkages to both India's flagship project "Digital India" and the EU's "Digital Single Market"

7.1.4 NORDUNET

Introduction

NORDUnet is collaboration between the NRENs of the five Nordic countries namely

1. **Denmark** - Danish e-Infrastructure Cooperation (DeIC): supports Denmark as an e-Science nation through delivery of e-infrastructures like computing, storage and network.
2. **Iceland** - The Icelandic University Research Network (RHnet): it links together Icelandic universities and research institutions by means of high capacity computer network and supply services in the field of computer communications both domestically and internationally
3. **Norway** - Norwegian Research Network (Uninett): it is a high-capacity computer network interconnecting more than 300,000 users within research and education, as well as giving them access to international research networks.
4. **Sweden** - Swedish University Computer Network (SUNET): provides Swedish universities and colleges with access to well-developed and effective national and international data communication and related services that meet their needs, irrespective of their geographical location.
5. **Finland** - Finnish University and Research Network (Funet): it is a Finnish centre of expertise in ICT that provides excellent services for research, education, culture, public administration and enterprises, to help them thrive and benefit the society.

Funding Model

NORDUnet is not only a data network but also a non-profit organisation acting as a framework for Nordic collaboration in networking. As such, it represents the Nordic NRENs in international collaborations and organisations. NORDUnet is organised as a limited company, NORDUnet A/S. It is owned by the Nordic ministries of education and research or institutions under their control. Each of the Nordic NRENs has a seat on the board and share the base costs according to the country GDP. The five NRENs develop and operate the national research network infrastructures, connecting more than 400 research & education institutions with more than 1.2 million users.

Network

NORDUnet interconnects the Nordic NRENs and connects them to the worldwide network for research and education and to the general-purpose Internet. NORDUnet operates a global IP and MPLS backbone network that interconnects the research and education networks in the Nordic countries to the rest of the world. NORDUnet operates an optical network backbone interconnecting Oslo, Stockholm, Helsinki, Copenhagen, Hamburg, Amsterdam and London. This network forms the northern extension of the GÉANT footprint and through cross-border fibre, connects to Poznan, St. Petersburg and Tallinn. In Europe, the IP & MPLS network is built on top of the NORDUnet optical network and shares the same locations. In addition, it has a ring in central Europe, connecting Frankfurt and Geneva to Hamburg and Amsterdam. This ring is based on capacity obtained from partner European R&E networks SURFnet and PSNC. The IP network is dual stack IPv4 & IPv6. NORDUnet provides its services by a combination of leased lines and Internet services provided by other international operators. NORDUnet has peering in multiple important internet exchange sites outside the Nordics, such as Amsterdam, Chicago, Frankfurt, London, Miami and New York.

In addition to the basic Internet service, NORDUnet operates information services and provides USENET NetNews and Multicast connectivity to the Nordic national networks. NORDUnet also coordinates the national networks' Computer Emergency Response Team (CERT) activities and the Nordic national networks' IPv6 activities - area where NORDUnet has been active for years.

Connection with NKN

NKN and NORDUnet have set up direct peering with each other to improve the connectivity for users of both networks while providing researchers and students an access to global R&E community. A MoU was signed between the two parties to establish a direct peering between NKN and NORDUnet at the NetherLight open exchange point in Amsterdam. With leading scientists and researchers in both their constituencies, in fields as diverse as space exploration, high-energy physics and in medicine, there are lots of projects that will benefit from this direct peering.

7.4 GENERAL COMPARISON

After obtaining an understanding of various National Research and Education Networks (NRENs) around the world, a general comparison has been performed amongst them based on select parameters such as the year of inception, nature of users, network spread, services provided, management and funding.

7.1.5 FINDINGS

The comparison amongst the various NRENs was done and the same has been depicted in tabular form

Table 7.1 Comparison of various NRENs



Year Founded	1996	2000	1986-1992	2009	2000
Services available	Higher Education Affiliate (not for profit) Industry (for profit) R&E Network Member Network Connector Primary Participant	GÉANT and other international research and education network providers National and regional research and educational networks Commercial operators Individual research facilities	NRENs of the five Nordic countries • Denmark (DeIC) • Iceland (RHnet) • Norway (Uninett) • Sweden (SUNET) • Finland (Funet)	Government funded Research and Educational Institutes	National, International and regional research and educational networks Individual research facilities.

<i>Users</i>	<p>332 U.S. institutions of higher education</p> <p>65 leading corporations</p> <p>60 affiliate and federal affiliate members</p> <p>43 regional and state education networks</p> <p>More than 60 national research and education networking partners</p>	30 million	<p>400 research & educational institutions</p> <p>1.2 million users</p>	<p>50 Million Users</p> <p>1700 Research, Educational Institutes & Government Organisations</p>	15,000 research and academic centres
<i>Countries</i>	100	34 European Countries	<p>5 Main Nordic Countries</p> <p>Usage Patterns</p> <ul style="list-style-type: none"> • Europe (Non GÉANT): 36% • US: 27% • Peering and Content Providers: 18% • GÉANT: 9% • Asia – Pacific: 9% • Middle East and Africa: 1% 	<p>India</p> <p>Also provides International Peering</p>	24 Asian partners and Europe

<i>Services</i>	<p>Advanced Networking</p> <p>Cloud Services & Applications</p> <p>Trust & Identity</p> <p>Performance & Analytics</p> <p>Support</p>	<p>Connectivity & Network Management</p> <p>Trust, identity and security</p> <p>Cloud Services</p> <p>Real Time Communications</p> <p>Professional Services</p>	<p>Network Services</p> <p>Above-The-Net Services</p> <p>Logistics-Related Services</p>	<p>High-speed digital connectivity</p> <p>NKN Accounts/NKN One</p> <p>NKN LDAP Platform as a Service (PaaS)</p> <p>NKN Bitambulator</p> <p>Bandwidth monitoring service</p> <p>OSIR (Open Source IP Registrar)</p>	<p>Network procurement and management</p> <p>Capacity development of NRENs in developing countries</p> <p>Research and educational network design & operations and associated capacity development</p> <p>Deployment of specialised network products, services and applications and associated capacity development</p>
<i>Management</i>	<p>Governed by members of the Internet2 community</p> <p>The Board of Trustees—which includes four standing committees, as well as special</p>	<p>GÉANT’s highest governing body is the General Assembly (GA). The GA elects members to the Board of Directors (BoD), which manages and administers the organisation. Day-to-day operations are</p>	<p>NORDUnet Board is the managing body of NORDUnet A/S</p>	<p>Ministry of Electronics & Information Technology (MeitY), Government of India, is the Line Ministry.</p> <p>NIC is the implementing agency.</p>	<p>Asi@Connect Governors</p> <p>Discuss and reach consensus on the activities</p> <p>Asi@Connect Steering Committee</p> <p>Technical guidance</p>

	committees— provides strategic direction, leadership and oversight for Internet2	carried out by the association's staff			
<i>Funding</i>	<p>Funding is mostly through membership fees. The members are divided into 4 Levels:</p> <ul style="list-style-type: none"> •Non-connected Affiliate and Industry •Non-connected Affiliate •Research & Education Network •Industry <p>The membership fees are on a scale based model with a cap. The fees are based on annual expenditure and annual research expenditure.</p>	<p>The European Union (EU), via the European Commission (EC), for the management of networking and related projects.</p> <p>NREN network service subscriptions to co-fund the GÉANT Project</p> <p>Membership subscriptions.</p> <p>Earnings from the provision of administrative, consultancy and training services.</p> <p>Sponsorship for specific activities.</p>		Funded by Ministry of Electronics & Information Technology, Government of India	<p>European Union: 54.7% Funding</p> <p>NRENs: 45.3% Funding</p>

7.1.6 STUDY OBSERVATIONS

- It has been observed that NKN is the youngest initiative amongst all the NREN initiatives around the world. Despite being just a decade old, it has achieved a great feat of connecting 50 million users. Compared to this the number of users of other NRENs is quite small. The high number of users in case of the pre-existing NRENs can be attributed to the spread of their services to users like commercial operators, privately owned research facilities, commercial operators, industries, etc. The obvious factor behind this huge user base is the history of Internet2, where it can be observed that the NREN had industry partners since the beginning which was not in the case of NKN. The users of Internet2 include institutions of higher education, leading corporations, federal affiliate members, etc., while serving several regional and state education networks and NREN partners.
- Comparison of NRENs on the basis of services provided shows that all NRENs are providing several other services to its users besides acting as a network backbone. They all provide services to enhance the education and research community through Cloud, real time communication, etc. In case of other NRENs, these services are also provided to industries. In case of NKN, it was observed that the network has not restricted itself to just research and education but has gone ahead and empowered e-Governance. It is the network which carries traffic of research, government offices, e-Governance and internet on a single platform thereby creating an enabling platform for preparing digital citizens.
- The funding model also differs in case of each of the NREN. It has been observed that each of the NRENs has multiple sources of finance through which it receives its funding, for example, Internet2 has four types of members that provide membership fee. While in case of GÉANT, funding comes through management of networking, subscriptions for co-funding GÉANT projects, membership subscriptions, consultancies etc. Similarly, in case of NORDUnet, the funding is done by NRENs of all five countries and in Asi@Connect, the funding comes through European Union and participating Asian NRENs. In case of NKN, the funding agency is only Ministry of Electronics and Information Technology (MeitY, GoI). This helped NKN in its starting years where it received a complete support in managing the finances enabling NKN to focus on empowering the institutes in conducting path breaking research and improve processes. Connection of more than 1700 institutes of research and education, government organisations and processes in such short span of time was facilitated owing to this reason. In the second phase of NKN, self-sustainable models can be put into place in which institutions can pay for the network and services.

Feedback of Institutions regarding collaboration with NKN

The institutes were asked about the help they have received in their research work due to the international collaboration of NKN with other NRENs to assess the impact of such a collaboration. The following key observations are being highlighted here:

- The institutes considered the international collaboration quite important for conducting research work as they have been able to transfer huge amounts of data easily in real time which was not possible earlier.
- They have agreed to the fact that research on various aspects such as weather, health, agriculture, science etc., has been facilitated through the international collaboration.
- Exchange of knowledge and information at national and global level has been improved and made easier owing to the international collaborations with other NRENs.
- Not only the efficiency of data exchange has improved, it has become faster and more accurate.
- Institutes also feel that such collaboration paves way for Indian scientists to be a part of reputed research projects around the world which in turn improves their ability to conduct research in India. Some of the noted projects being undertaken through the collaboration are that of Large Hadron Collider, Mirror Regional Trans communication and GISC Centre, 30 m Telescope, meteorological data exchange, etc.

7.5 SUMMARY

NKN has played several roles besides providing network backbone to research and educational institutes of India. Not only has it established a high-speed backbone connectivity which enables knowledge and information sharing but also played an important role in enabling collaborative research, development and innovation. NKN besides providing services to institutes for performing these functions has tied up with several NRENs around the world. Some of these are GÉANT, NORDUnet, Internet2 and Asi@Connect, which have helped NKN in facilitating efficient communication and dissemination of information and knowledge between scientists, educationists, students and researchers and create innovative and stimulating work environment.

This chapter compared NKN with the major NRENs with which it has collaborated. It is understood that NKN being the youngest of all the network has been able to perform well in terms of connecting the research and educational institutes across India. Not only has it acted as a network backbone for academic institutions but is also facilitating an ultra-high-speed backbone for e-Governance.

The chapter assessed the feedback of institutions on how international collaborations between NKN and NRENs has helped them. It was found that the institutions have been able to tap their potential to much greater extent due to the facility they have been provided. The international collaboration has helped them in becoming part of reputed research projects and conduct path-breaking research by themselves. Such success of international collaboration has definitely paved way for one global commercial IP network i.e., a network for all.

Chapter 8

NKN: Empowering Digital India

8.1 INTRODUCTION

Ministry of Electronics and Information Technology (MeitY), has initiated Digital India Programme to transform India into a digitally empowered society and knowledge economy. e-Governance initiatives in India took a broader dimension in the mid-1990s for wider sectorial applications with emphasis on citizen-centric services. The major ICT initiatives of the government included, inter alia, some major projects such as railway computerisation and land record computerisation, which focused mainly on the development of information systems. Later, many states started ambitious individual e-Governance projects aimed at providing electronic services to citizens.

Though these e-Governance projects were citizen-centric, they could make less than the desired impact due to their limited features. The isolated and less interactive systems revealed major gaps that were thwarting the successful adoption of e-Governance along the entire spectrum of

governance. They clearly pointed towards the need for a more comprehensive planning and implementation for the infrastructure required to be put in place, interoperability issues to be addressed, etc., in order to establish a more connected government which was achieved through the launch and implementation of Digital India.

8.2 INDIA'S DIGITAL REVOLUTION⁸

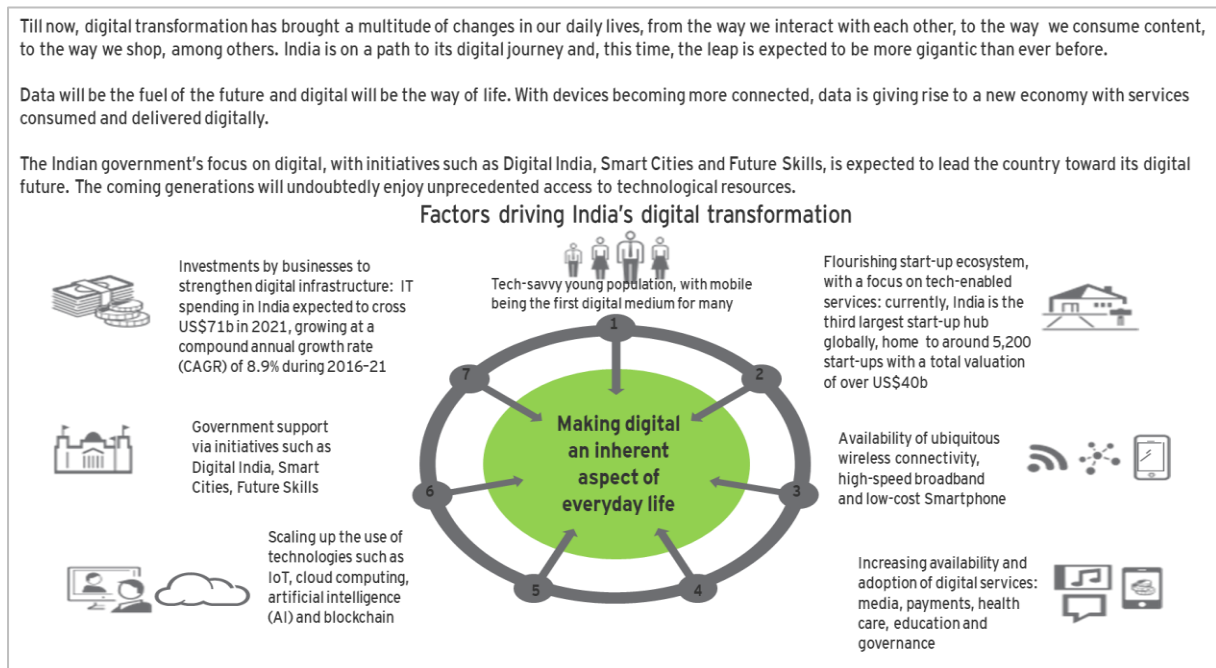


Figure 8.1 Factors driving India's digital transformation

"Today, India is the largest consumer of data globally, surpassing China, USA and Japan. Together, we consume over 2,360 Petabytes of data via mobile telephony every year, equivalent to data stored in 526 million DVDs! Nearly 82% of this data consumption is on 4G technology. 4G data has shown 135% growth and 3G data has shown 286% growth in CY17 vs CY16. India has also become the second largest market for smartphones in the world, with over 456 million smart phone users. The number of LTE capable devices have touched 218 million. Last year, 9 out of 10 smartphones sold were 4G capable. Over 100 major global smartphone brands are present in the Indian market. Commercial 5G launch targeting M2M/ IoT is expected in India by 2020. Connectivity has given rise to entirely new ways of delivering services to consumers. Industries like ed-tech, m-health, agri-tech, e-commerce and public transport are shining examples of this. Students in rural areas now have access to online course material and tuitions over digital devices, bridging the gap with their city counterparts. The market for online education is expected to grow to USD 1.96 billion by 2021."

By Secretary, Ministry of Electronics & Information Technology (MeitY), Government of India

⁸Sources: "Catalysing the Ecosystem for A Trillion Dollar Digital Economy," NASSCOM, February 2018; "India Semi-annual IT Spending Guide: Industry and Company Size," IDC, July 2017; news articles; EY analysis

NKN: A Digital Platform

National Knowledge Network (NKN) with its design philosophy to **Encourage, Enable, Enrich and Empower** the user community, is immensely helping in implementation of “Digital India” by supporting and providing connectivity to various endeavours of the Government of India in the field of e-Governance, Digital education, Security, Library, Space, Weather, e-Health and so forth. NKN bridges the gap of automation in the government sector which was initially lagging i.e., creating a complete digital ecosystem that connect all the dots.

NKN project was conceptualised by the Government of India 10 years ago with a mandate to provide connectivity to all major research and educational institutes. It has not only focused on achieving its mandate but becoming a Digital Backbone Internet Highway for the Government of India. Almost all the traffic of the digital initiatives rides on NKN.

National Knowledge Network has had an economic, social and environmental impact on India and has carved a path for a digitally empowered India. A digitally empowered India can mend social and economic condition of people through development of economic activities apart from providing access to education, health and financial services. It is important to note that ICT alone cannot directly lead to overall development of the nation. The inclusive growth and development can be realised by supporting and augmenting elements like literacy, basic infrastructure, overall business environment, regulatory environment, etc.

On 15th June 2018, the Prime Minister interacted with the beneficiaries of various Digital India Mission schemes from across the country, through video bridge. The Prime Minister also talked about the importance of National Knowledge Network (NKN) in building a strong Digital India.



8.3 PILLARS OF DIGITAL INDIA

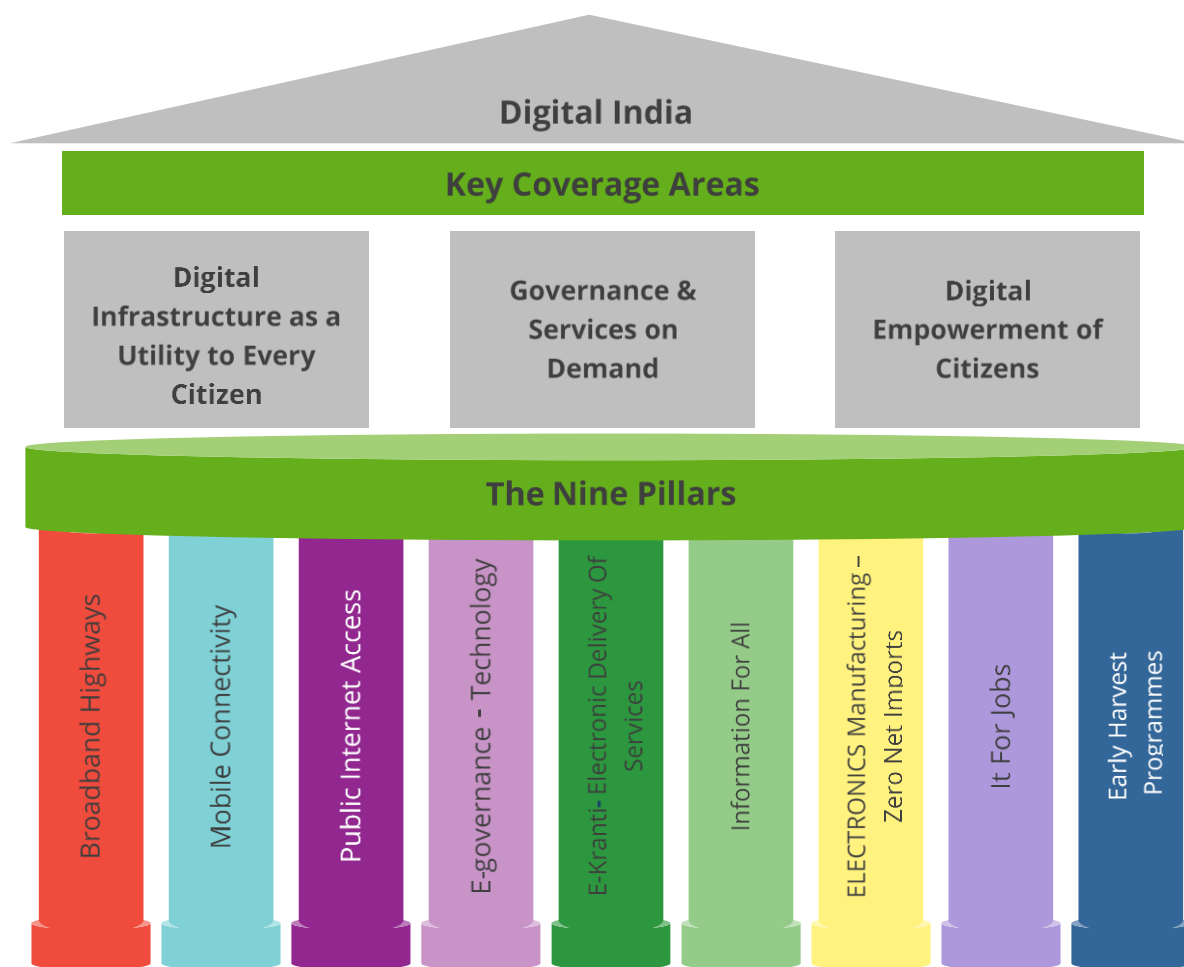


Figure 8.2 Pillars of Digital India

Some of the current Digital India initiatives that are empowered by NKN Platform are Open Government Data Platform, e-Taal , e-Samiksha, Service Plus , Plan-Plus , e-Office, e-Court, etc.

National Data Centres

National Data Centres offer a robust, highly available infrastructure with adequate redundancy to enable the government to render effectively the e-Governance services to the citizens. It provides services to the Government Ministries, departments, state governments, district administrations and block levels.

NDC hosts many e-Governance applications viz., e-Sahaj, e-Procurement, eLekha, e-Panchayat, Aadhaar Enabled Biometric Attendance System (AEBAS), IVFRT, PDS, Swachh Bharat Mission, National Portal of India, Jeevan Pramaan, NREGA, MyGOV, Digital Locker, JoSSA, & NEET (Counselling), ORS (e-hospital), National Scholarship, e-NAM, GeM, Cyber Swachhta Kendra, Digital India Portal, National Transport Project, Shram, Suvidha Portal, Prime Minister Office website, e-Vidhaan, Manav Sampada, Government Websites, etc. (Ministry of Electronics and Information Technology, 2019)

State Data Centres

State Data Centres act as a mediator & convergence point between open public domain and sensitive government environment. It enables various State departments to host their services/applications on a common infrastructure leading to ease of integration and efficient management, ensuring that computing resources and the support connectivity infrastructure (NKN/SWAN/NICNET) is adequately and optimally utilised.

- Creation of a shared secure resource for consolidation of Data, Services, Applications & Infrastructure at the State/UT level to enable electronic delivery of G2G, G2C & G2B services.
- Ensure better Operations, Standardisation of Systems & Management Control.
- Aggregate IT Infrastructure (Hardware, Storage, Networking and Software) and Management Resources leading to reduced costs of creating common Infrastructure and faster deployment.
- Optimally Utilisation by sharing of IT Infrastructure Resources to meet individual peak loads.

State Wide Area Network (SWAN)

State Wide Area Networks (SWAN) interconnect each State/UT Head Quarter with District Head Quarters and each District Head Quarter with the Block Head Quarters. The objective of SWAN is to create a secure Closed User Group (CUG) Government network for delivering G2G and G2C services.

Almost in all the states, Digital Initiatives are riding on NKN Platform. As far as the architecture is concerned, the super-core and core is the foundation of the District links/distribution layer (Please Refer Chapter 2 for Architecture). The number of such district links is 506.

SWAN connectivity model at State, District and Block level is shown in figure 8.3.



Figure 8.3 SWAN connectivity model at State, District and Block level

8.4 IMPACT OF NKN ON E-GOVERNANCE

The impact of NKN on various e-Governance initiatives has been studied in detail. The below study is performed on the impact of:

1. NDCs, SDCs, SWANs
2. Citizens
3. Education

Impact on NDCs, SDCs and SWAN

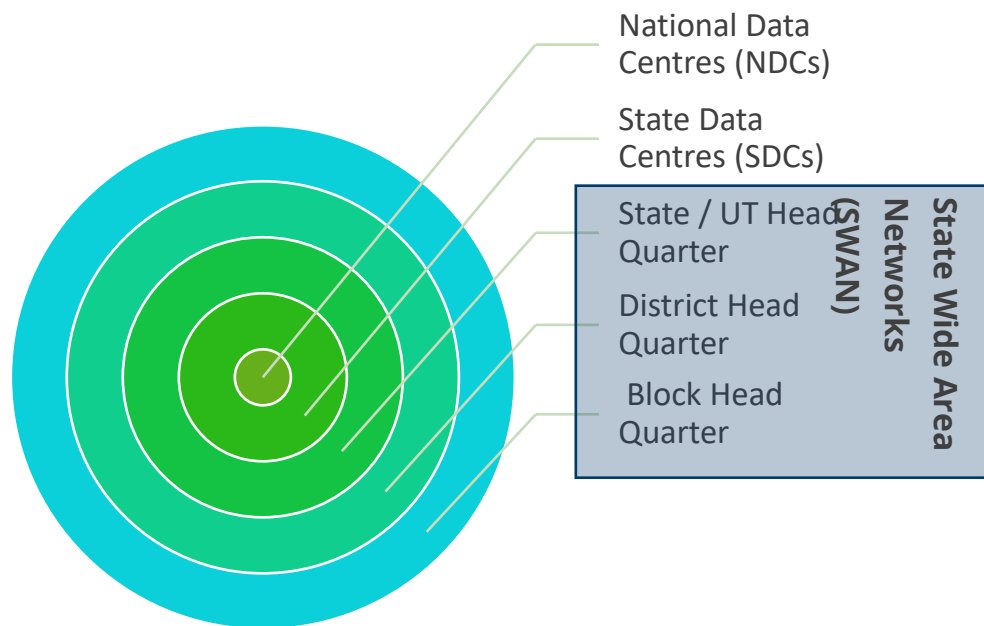


Figure 8.4 Impact of NKN on NDCs, SDCs and SWAN

NKN has connected all the NDCs and almost all SDCs & SWANs. The usage of e-Governance applications since on-boarding to NKN has risen multiple folds. e-Governance has thus become one of the strengths of NKN. If given the core up gradation to 100Gbps, usage of Digital Initiatives will rise exponentially and will affect the GDP of the nation.

NKN provides dedicated lease line connectivity, efficient manpower and redundancy for 24x7 service for a connected network which enables State Data Centres to provide many functionalities, such as Central Repository of the State, Secure Data Storage, Online Delivery of Services, Citizen Information/Services Portal, State Intranet Portal, Disaster Recovery, Remote Management and Service Integration. Some of the initiatives of NDCs, SDCs and SWANs running on NKN are Direct Benefit Transfer, e-Office, e-Procurement, Passport file updating, e-AWAS, Accommodation Management System, Mail Services, e-Governance, Virtual Classrooms, Video Conferencing and Web hosting.

The network enables many institutions to access high-performance bandwidth thereby helping to conduct advanced research in areas such as weather monitoring, earthquake engineering and other computationally intensive fields. NKN also provides various opportunities to test new hardware and software, vendor interoperability, etc. NKN acts as a super highway for integrating e-Governance infrastructure such as government data centres and networks. NKN provides bulk data transfer facility required for e-Governance applications. An institute just has to take a local leased line to be connected with all institutes across India which is provided by NKN. If there was no NKN, then each institute would have to take a national long distance (NLD) leased line for connecting with all the institutes, which would have considerably raised the cost of bandwidth. The government, by creating the NKN, also pays less for bandwidth for each institute, thereby saving costs.

Almost all the major applications of Government to Citizen (G2C) and Government to Government (G2G) services are hosted on NDCs and SDCs and the same are delivered/processed by the State/District/Block level administration using SWAN.

SWANs, NDCs and SDCs are the pillars of Digital India. Before the conceptualisation of NKN they were connected at 2/10/45 Mbps bandwidth and were having multiple issues with respect to funding, link down, bandwidth limitation, bottlenecks, etc. Since the inception of NKN, **SWANs, NDCs and SDCs** were on-boarded on NKN with the bandwidth availability of up to 1 Gbps. SHQs were given the connectivity of 10 Gbps and all the connected DHQ were connected with up to 1 Gbps bandwidth.

Post the connectivity with NKN, the usage pattern has changed drastically, where initially the maximum bandwidth utilisation was going up to 20/100 Mbps, in the current scenario, the bandwidth utilisation has risen to up to 12 Gbps. Going forward it is only bound to increase. Some of the SWANs, like Madhya Pradesh and Rajasthan, are having bandwidth utilisation above 10 Gbps. In case of Gujarat SWAN, NKN has provided 20 Gbps connectivity to cater to the enormous traffic.

Some of the direct benefits which are felt and appreciated since the on-boarding of SDCs and SWANs on NKN backbone are: -

- Connectivity of High Bandwidth with low latency
- Smooth traffic without any bottlenecks where earlier congestion was a major concern
- Fund issue has been eradicated as NKN is bearing the bandwidth cost

8.5 NKN IMPACT ON CITIZENS

NKN not only acts as a Digital Platform for the Government of India, but impacts the citizens of India as well, by bringing multiple online services that are currently being used in India.

Some of the online services are: -

1. Digital Library Consortium
2. Higher Education Information Services
3. User and Citizen Communication Services
4. New Mode Learning
5. Computerised University with High Speed Network
6. Telemedicine
7. Disaster Management

8. Multimedia Communications
9. Online Learning
10. University Credit Transfer
11. Effective Global Collaboration
12. The Virtual Medical Classroom
13. Network Enabled Medical diagnosis and Education in Skeletal Imaging using X-Rays.
14. Indian Integration with Global Imaging System via McGill Linkage, NBRC, Manesar
15. Network enabled online Casting Simulation System (e-Foundry), IIT, Bombay
16. NKN - a Gateway to Global classroom of the Amrita Vishwa Vidyapeetham, Coimbatore.

Broadband for All, a pillar of Digital India, covers three sub components, namely Broadband for All Rural, Broadband for All Urban and National Information Infrastructure.

NKN Contributes greatly in this pillar. Although it gives connectivity in both rural & urban areas, its users are members of the institutions and therefore NKN's contribution, is towards the third component i.e., National Information Infrastructure.

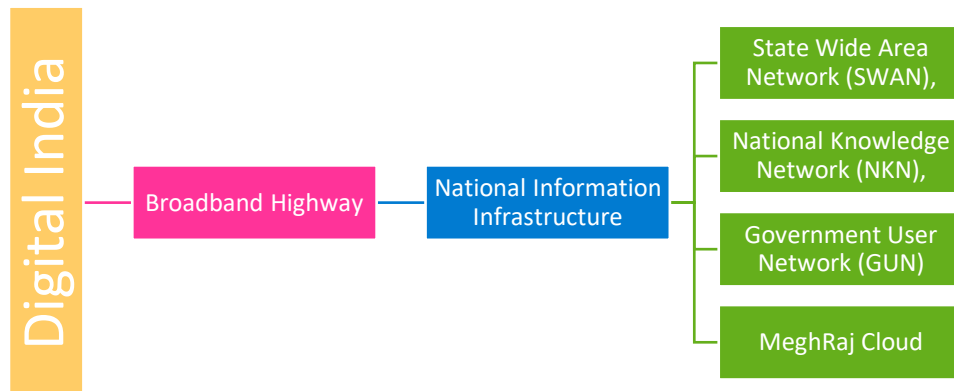


Figure 8.5 NKN's contribution in National Information Infrastructure

NII integrates the network and Cloud infrastructure in the country to provide high speed connectivity and Cloud platform to various government departments. These infrastructure components include networks such as State-Wide Area Network (SWAN), National Knowledge Network (NKN), National Optical Fibre Network (NOFN), Government User Network (GUN) and the MeghRaj Cloud. NKN is both a component and backbone of National Information Infrastructure.

This vision was achieved by providing a dedicated lease line of high speed internet bandwidth with low latency without any bottlenecks. Ministries/Departments of e-Governance (such as NDCs, SWANs, SDCs), have fully leveraged ICT in the form of NKN backbone. NKN has not only aligned itself with the Digital Pillars of India but has also provided opportunities for more initiatives. More than 75% of the institutes are leveraging NKN backbone for using Digital India initiatives whereas going forward more than 80% plan to increase its use.

e-Kranti is another pillar of Digital India. The project proposals in e-Kranti involve substantial transformation in the quality, quantity and manner of delivery of services and significant enhancement in productivity and competitiveness. There are 44 Mission Mode Projects under e-

Kranti programme. These mission mode projects are grouped into Central, State and Integrated projects. Multiple applications, for e.g., e-office, are hosted on SDCs/NDCs, SWANs, which are further riding on NKN.

NKN supports *Information for All* pillar indirectly by providing governance of the applications and the collaborations that are currently happening in institutes on NKN backbone. All the services which are running on NKN are helping the citizens of the nation. NKN has always been an enabler in supporting the e-Governance applications. The applications and the collaborations among institutes are not limited to the end users of the institutes, but also affects the citizens. Social media is one of the important aspects of society that has been one of the major achievements of NKN.

NKN provides a platform for the researchers and scholars of the nation that communicate with other researchers and scholars around the world, along with the collaborations of e-library, e-learning, etc.

NKN provides Internet connectivity in almost all major universities, thereby providing Internet which is not just limited to students but reaches various government offices.

8.6 OBSERVATION

NKN's high-speed network is the primary backbone for the entire government network which helps in making major digital resources universally accessible. It promotes collaborative digital platforms for government organisations. NKN has also helped in achieving the goal of Digital India by being the digital backbone of the nation with major digital initiatives riding on NKN platform. Since the inception of NKN, citizens of India have increased their usage on citizen centric applications, e-Governance initiatives, digitisation of land records, digital payments, etc. Through this knowledge portal, the gap in governance between the people and the government has now been bridged with greater transparency and accountability.

CHAPTER 9

Key Observations & Recommendations

9.1 CHAPTER OVERVIEW

This chapter summarises observations from the impact assessment along with recommendations on crucial aspects of NKN based on the four pillars of the proposed impact assessment framework of the study, *viz.*, Outreach, Quality of Service, Knowledge Ecosystem and Value Proposition (Section 1.5 titled 'Defining the Assessment Framework, Chapter 1), that may be taken into consideration in the next phase of NKN.

NKN has become an indispensable part of research, educational and other scientific institutes along with e-Governance initiatives whose traffic is riding on NKN. In line with this, respecting the intense academic intent of the study achieved through understanding of NKN reports and documents (chapter 2), management discussions (chapter 3) and through primary research of the institutes (chapter 6), this chapter strives to encapsulate its recommendations for optimising the usage and future needs for the next phase of NKN.

9.2 OBSERVATIONS AND RECOMMENDATIONS

After the analysis of current phase of NKN and understanding need for the continuation of the next phase of NKN, we have summarised some observations and recommendations. These points have been synopsised using the impact assessment framework (Chapter 1) that was being used for this study.

OBSERVATIONS

1. **With the aid of NKN, governance has become e-Governance**, thereby resulting in work getting done with enhanced speed along with better access to information. This results in effective implementation. e-Governance has ensured better functioning of all the government departments with appropriate coordination, thereby resulting in timely decision making which was one of the most eminent requirement for overall economic development of our country.
2. Prior to the conceptualisation of NKN, institutes used to independently pay for their network connectivity and value-added services. Since the implementation of NKN, respective institutions are being provided connectivity by an umbrella network which provides centrally implemented secure network connectivity along with a plethora of services (like network and community services). This has saved an enormous cost for the government/institutes and is still saving more. Developing these services or buying them from an open market would have had a much higher cost burden on the institutions. Institutions are focusing on their core expertise and NKN provides them with the required expertise for smooth and uninterrupted network and operations. **NKN becomes the single entity for all user institutes**, without them worrying about technology.
3. **Institutions have been availing high speed bandwidth at no cost**. By changing the financing model from OPEX to CAPEX for TSPs, a huge financial facilitation has also been achieved. On one hand this makes the on-boarding process easy. On the other hand, by infusing the CAPEX in NLDs, **NKN has helped in building network infrastructure companies in India**. If we compare the market equity of these companies from nine years back to now, we can see a significant contribution to the wealth of the country. NKN is a major CAPEX contributor and a major user of the network of these organisations. NKN has played the role of a strategic financial partner for these organisations.
4. Access to information, knowledge and collaboration among sectors has resulted in a scenario wherein many opportunities which could have been lost because of lack of knowledge at appropriate time, **have been encashed, thereby resulting in huge savings** in terms of opportunity loss. This saving in opportunity loss is humongous and is not quantifiable.
5. The research-based institutions which have been empowered through this network have helped India reach a stage of self-reliance in many segments (like space, weather, healthcare, research, etc.), thereby saving huge cost to the nation which the country earlier used to spend in the import of technology and high-end capital equipment. Similarly, high computing

power and the information available has helped us in strengthening our capability of predicting natural calamities through early warning mechanisms, thereby saving unimaginable quantum of money, lives of individuals, animals and property. **NKN has enabled special projects, such as Mission Mars and Weather Forecasting**, from the point of view of networking infrastructure and QoS support. These projects were executed at a fraction of cost in comparison to the global costs and NKN has had a **considerable contribution in cost savings on network, interconnectivity, bandwidth and QoS account.**

6. Observation of the **NKN's security system shows that it has a balanced, robust and secure network to provide a resilient backbone network** for its user community that can recover quickly from breakdowns and other cyber-attacks. It is also pertinent to mention that NKN is security compliant and has obtained necessary certifications for security. NKN ISO certification is also around security which builds up the right processes for the robustness of the network and applications. This instils trust in NKN for performing path-breaking research, spread knowledge and improve processes.

RECOMMENDATIONS

The recommendations on crucial aspects of NKN is based on the four pillars of the proposed impact assessment framework of the study viz., Outreach, Quality of Service, Knowledge Ecosystem and Value Proposition.

9.2.1 OUTREACH

As already indicated (chapter 1), first pillar of conceptual framework is 'Outreach' that had been evaluated by studying various components. The observations and the recommendations of the components of the 'Outreach' pillar is summarised herewith:

1. **On-Boarding Institutes:** The basic objective of NKN was to provide connectivity to all the major knowledge, educational & research institutions, e-Governance and all government offices including all major Indian mission critical agencies. NKN has achieved its target of connecting 1500 institutes by getting 1700 plus institutes on-board. This number can be further enhanced by not constraining its limits to institutions and reach to the lowest service delivery centres of government, like police stations, primary health centres, schools etc., in the next phase of NKN.

The continuation of NKN requires a two-pronged strategy: -

- a. There is an immediate need for financial and political support for the next phase of the project that will go a long way to strengthen the complete digital ecosystem of the nation.
- b. To ensure a complete digital ecosystem, various sectoral networks should be aggregated under NKN umbrella to ensure a productive utilisation of the NKN backbone by end users. NKN should evolve itself as a specialised "network of

networks” i.e., next generation network with ultra-high speed, redundancy, robust architecture and resiliency. This will create a Super Information Highway where each network responds to respective sectors under the main canopy of NKN i.e., creation of various sectorial networks by taking on-board various likeminded government organisations as aggregators.

For the successful integration of sectorial & remote networks it is recommended that Network to Network Interface (NNI) and multiple service providers should provide the connectivity. Further, these networks should align themselves technologically for smooth migration on NKN backbone in future. This will elevate the status of NKN which is both NREN (National research and education network) and NGN (Next Generation Network) of the nation.

2. **Augmentation of existing Infrastructure:** To successfully inculcate the above recommendations, there is a need of an integration of sectorial networks with multiple entities in the next phase of NKN leading to a quantum jump from the existing phase. This requires up gradation of the existing infrastructure and manpower. To support such a gigantic amount of traffic, there is a need of a strong core backbone. Dark Fibre is an option that has been in constant discussions by the makers of NKN since its inception. With the advancement of the telecom industry, the service providers now have the capability making this option viable for NKN and would support NKN to enhance its provisions to 100s of Gigabits and more.
3. **Knowledge Portal:** A majority of institutes are connected among each other through NKN to collaborate with one another. Though it is not in the current mandate of NKN, it is being recommended that NKN should have the access to monitor the applications and collaborations running inside institutes. This brings in the need for development of a Knowledge (*research and collaborative*) Portal with a strong visual interface (dashboard etc.) that would provide a platform to NKN connected institutes to exchange of information and knowledge.

This Knowledge portal will give the researchers a secure platform to showcase their achievements thereby helping in the utilisation of NKN for knowledge, research, education, e-Governance and collaboration.

NKN also proactively provides consultancy for NKN services to the institutes. Although, it is very important to insist that such kind of interconnectivity and collaboration needs equal emphasis on IPR related issues, IP Protection, management & commercialisation.

4. **Network Design as a Service for Internal Institute Network:** Inadequate LAN/Wi-Fi infrastructure and low penetration of ICT in some institutes inhibiting full utilisation of NKN services are few concerns raised by NKN. To address this concern, NKN has regularly conducted various national and regional workshops during the tenure of NKN, resulting in establishment of state-of-art LAN/Wi-Fi. Along with providing consultancy for NKN services, it is also suggested to provide technical consultancy for designing & implementation of the internal LAN architecture/infrastructure of the institute for the optimal utilisation of the full potential of NKN. Although this expertise has been

informally offered at some locations, a paid service can be provided *via the Government Procurement - Government e-Marketplace (GeM)*.

5. **Train the Trainers:** There is a need of Train the Trainers programmes for the NKN teams that would impart knowledge to the user institutes which will increase awareness and subsequently increase optimal utilisation of NKN and its value-added services. This knowledge can be further leveraged through training programmes at the user institute.

9.2.2 QUALITY OF SERVICE (QoS)

The observations and the recommendations of the second pillar 'Quality of Service', that had been studied on the parameters of 'bandwidth and latency', 'services', 'customer support', 'security' and 'awareness', has been encapsulated herewith. As already indicated (section 3.4 titled 'Quality of Service') the key objective of NKN was to have a strong core backbone with multiple of 10 Gigabits of connectivity with low latency and without any bottleneck. Based on the interactions with key stakeholders of NKN, the understanding of management perspective has shown that the NKN has performed exceedingly well on these objectives. The architectural design along with the technical innovations have been able to achieve this objective with considerable cost-saving and high user-satisfaction.

The primary study validates this assertion, wherein more than 90% of the respondent institutes have rated NKN to be "excellent/very high" on all QoS parameters. These respondents are also "highly satisfied" with NKN and they consider the network very reliable. Keeping pace with positive feedback of the partner institutes, it would be prudent for NKN to stay responsive to the needs and aspirations of its users by marching ahead of the technology curve. Therefore, the present research team of NKN could be augmented both in its number and skillset. Further, as the next phase NKN has wider coverage to attain, an enhanced research team could be envisaged that would help in exploring the emerging and futuristic technologies for enhancing its QoS and for staying ahead of times and in sync with increased user expectations. Presumably, it has already been envisaged to be implemented in the near future by NKN.

1. **Services:** Guided by NKN visionaries, NKN offers a plethora of value-added services to its institutes including DNS, Co-location services, VoIP, virtual classrooms, e-mail, SMS gateway, LDAP, video conferencing, Storage as a Service (SaaS) and so on (chapter 2, chapter 4).

Similarly, sector-wise advantages of these services are also getting defined in a better manner and hence it is being well received. For instance, healthcare sector is using telemedicine sessions clearly enabled with technology-based healthcare services. The primary survey indicates 'excellent/very high level of satisfaction' of NKN services by more than 90% of institutes (*chapter 6, section 6.5.3*). Currently, user institutes are primarily using only some of the NKN services which are Video Conferencing, e-Mail and LDAP. NKN should proactively take necessary steps in getting more user institutes on-

boarded to use these services by providing them proper awareness and timely information about these services to maximise their usage of NKN services. Further, analytics should be performed on Network Usage for critical users.

2. **Customer Support:** Timely response of NKN to any fault reported by the institute is its strength. An Escalation matrix is currently in place for customer grievance redress, which is an essential key performance indicators (KPI). NKN should continue with its pro-active approach of up scaling the customer support capabilities with its respective service providers and keep in pace for the next phase of NKN.
3. **Security:** It can be asserted that NKN is security compliant and has gone through all the required certifications for security. As a result, security of NKN is robust enough to provide a resilient backbone for its user community. At present, vouched by the case-studies (chapter 5), NKN can recover quickly from random breakdowns and other cyber-attacks. Though, this should not put NKN in any complacency-zone for its security matters as cyber security is a constant challenge which requires regular up gradation in the security system. This requires regular incorporation of the latest techniques and technologies to remain in constant sync (or may be a step ahead) with the changes in the cyber security ecosystem, in which NKN is already one step ahead of the curve.
4. **Content distribution network (CDN):** NKN has currently done peering and caching with multiple leading content providers, although it is recommended that NKN should increase the necessary infrastructure (Servers, Bandwidth etc.) to enhance peering/caching services. NKN should increase direct peering with NLDs and also with critical/high usage user institutes. To reduce the latency even further, major NKN POPs should have a direct link with critical organisations/institutes.
5. **Awareness:** Awareness forms the foundation of any good technical advent and upholding its spirit, NKN has already conducted four national and several regional workshops over the course of the current phase. These events have witnessed enthusiastic attendance of global NREN partners (Internet2, GEANT, NORDUNET, Asi@connect) and member nations of SAARC. There was also a substantial representation from NKN's partner institutes (chapter 3). Even the primary survey affirms that the awareness level of more than 85% of the institutes was "very high/high". (*Section 6.4.4*).

These awareness efforts by NKN can be further strengthened by emulating global leading practices such as that of Internet2, which globally showcases itself as an internationally competitive knowledge repository. This could be achieved by both, holding international workshops in India and sending NKN personnel for participating in international NREN events/workshops regularly. Some of the easiest awareness strategies that could be immediately imbued by NKN include declaring NKN as the 'default welcome portal' for all its connected institutes. This welcome portal could have a 'dashboard display of its optimistic feats'. Another step could be to encourage 'mutual collaboration amongst these institutes empowering them to share their respective success stories of using NKN'.

A 'branding and communication team' and a dedicated PR cell at NKN could help to implement, regulate and monitor awareness strategies which could be supported by chat bots. Appreciating 'awareness' to be the cornerstone of NKN's success, it is important that the respective NKN connected institutions should be kept updated. To this end, NKN can appoint an exclusive 'information coordinator' who could stay connected with the 'information and data in charge' of institutes for updating them about the emerging NKN services and its enormous potential. This could be effectively facilitated by creating a Knowledge Management System that could also include a repertoire of Leading Practices/Cases around the theme of "Success Stories of Institutes by using NKN". This would inspire and support others too to emulate. Activation of NKN services on its website should be one-step click end to end process.

6. **TEST BED PLATFORM:** NKN has already tested waters with test bed facility. The scope of the current initiative can be further expanded by building a dedicated facility centre that would help to test-bed nascent applications and/or hardware inventions on a pre-provided setup with beta-users. Obviously, such a centre would comprise of adequate number of and diverse range of equipment (machines, mobiles, computers with varied configurations) coupled with an array of user community that is willing to use and react to the innovations. This physical test facility could be accessed remotely by the users. Such a dedicated 'test bed platform' would help in testing applications for different environments and devices ensuring that the partner institutes don't have to invest individually for establishing such a facility. The start-ups can also use the facilities as it is very expensive to build such environments on individual basis.
7. **INNOVATION FRAMEWORK:** Innovations go waste in absence of a structured approach to manage them. Providing a structured framework and making it available for everybody will help in harnessing the innovation capital of India. In the case of NKN, its partner institutes have already done various experiments with R&D, collaboration and consulting frameworks (chapter 6). Several options are possible for implementing a structured approach towards successfully incubating innovations (section 6.5.4). The outcome data can be populated on knowledge dashboard and the intellectual property management portal as already describe in earlier passages.

9.2.3 KNOWLEDGE ECOSYSTEM


1. The third pillar *i.e.*, knowledge ecosystem, of the proposed conceptual framework intended to explore applications of NKN in various sectors such as research, learning and collaboration, education, health, agriculture, science, space, e-Governance, weather forecasting and so on (*section 6.5.2*). As envisaged in its vision, a large percentage of institutes are using NKN for spearheading research initiatives, capacity building, education and e-Governance, as summarised herewith.
 - a. **Research:** One of the major objectives of NKN was to connect all major knowledge institutions (Universities and Research Institutions) for knowledge creation, collection and dissemination of information linking to global networks

to collaborate with the research communities across the globe. With more than 90% of the institutes using NKN connectivity for research purposes, it fulfils its pre-conceived mandate (chapter 6). Space research on NKN backbone is pushing India in the global arena. Also, NKN connectivity ensures precise weather forecasting which is making life easier for the people of India (Section 3.5.4). Veterans of these fields have praised NKN again and again in their feedbacks (Chapter 3 case studies). We can successfully conclude that NKN has played its role in the growth of the knowledge economy of India. NKN provides a unique connectivity to the major universities and research institutes. To utilise its full potential, there is a need for providing an innovation platform i.e., an **Innovation Hub**, that caters to the Indian research and educational community for further collaboration with the national and international community, which would allow institutes of similar category to exchange knowledge on new technologies, research activities, etc.

- b. **Collaborations by the institutes:** Collaboration was another critical requirement of the NKN project. A lot of activity is happening on collaborations, both on domestic front and global associations. This we could gather from the survey results and remarks of the user institutes who are benefitting from the collaborations and interconnectivity. This emerged as a potential growth area in NKN. Further, to streamline the process, the need of a collaboration portal is felt very strongly. This collaboration portal will list the areas of collaborations, participating institutes, case studies, business cases, best practices, risks & mitigations, list of projects, products, services, processes worth collaboration, etc. The portal can have both secured and public access collaboration environment and data. The outcome data can be published on **Knowledge Dashboard** as well, as suggested earlier (**section 6.5.5**)
- c. **Knowledge Dashboard:** NKN could culminate the vision of its pioneers in an accelerated manner, if it aligns its approach to knowledge management. Taking a cue from the literature, such as the Knowledge Economy Framework (The World Bank, 2018), it insists on a four-pronged approach for building knowledge economy in a nation that comprises of 'education and training', 'information infrastructure', 'economic incentive and institutional regime' and 'innovation systems'.

Knowledge Economy Framework

The following pillars are four critical requisites for a country to be able to fully participate in the knowledge economy:



Education & Training
An educated and skilled population is needed to create, share and use knowledge.

Information Infrastructure
A dynamic information infrastructure-ranging from radio to the internet-is required to facilitate the effective communication, dissemination and processing of information.

Economic Incentive & Institutional Regime
A regulatory and economic environment that enables the free flow of knowledge, supports investment in Information and Communications Technology (ICT), and encourages entrepreneurship is central to the knowledge economy.

Innovation Systems
A network of research centres, universities, think tanks, private enterprises and community groups is necessary to tap into the growing stock of global knowledge, assimilate and adapt it to local needs, and create new knowledge

SOURCE: <http://web.worldbank.org>

This knowledge framework would be easiest to implement by building a knowledge dashboard that would track the changes in knowledge landscape garnered by the partner institutes (à la Ujala Dashboard). Knowledge parameters could be identified, defined, captured, analysed and displayed dynamically on the dashboard for various business deliveries of the institute and their respective outcome for the nation.

This information about these KPIs would help the strategists/policy makers to evaluate the contribution of each institute on the knowledge economy and nation's GDP and so on, by providing a holistic understanding of impact of NKN on varied sectors, both at the national and global level. For example, an agricultural innovation may have a direct impact on the earnings of the farmer and that fulfils PM's vision to double the earnings of the farmer that can directly be gleaned by studying the related KPIs on agriculture from the dashboard. This knowledge dashboard can be further supported by the innovation framework (explained subsequently) and collaboration sub-portal.

- d. **Capacity Building:** More than 70% of the institutes are currently using NKN for training purposes (chapter 6). This reassures that NKN is being used for capacity building and human capital development in various institutes are directly benefitting the end user. In addition, a good percentage (approx. 70%) of the institutes have technology-based consumption. The 'before and after' analysis shows that institutes have shown "more than 75%" increase in ICT use. Same kind of growing trends are seen in the sector-based analysis on capacity building. The outcome data demonstrates that the impact of NKN on capacity building is high.

- e. **Education:** NKN has setup 66 Virtual Classrooms that were demonstrated to the institutes by enabling successful sessions on the platform. Now the time is right to explore NKN ecosystem to achieve "One Class, One Nation" concept for the country that would be in accordance with the burgeoning knowledge needs of

the nation. It would also be aligned to NKN's own vision⁹ and help to assimilate the ever-evolving frontier technologies and stay ahead. For doing so, the present version of the NKN's Virtual Classroom could reboot with the latest technologies. For instance, mobile devices should be accepted as the essential front end for these classrooms for easier access. Chat bots could be the redeeming feature for aiding the learning process of its learners, irrespective of their entry behaviour. Mixed reality-based environments could make the learning process learner-friendly. Such features would help to create next generation learning platform on NKN. Such an ambitious (but achievable) national reality could be monitored by an 'education team'. A group should be constituted that takes the ownership of running this initiative. Targets should be given for one to five years. Complete system should be available through an easy to use portal and backend should have a defined dashboard with KPIs for the management to review the progress (section 3.5.1).

Even the primary survey reflected positive feedback of the partner institutes on these aspects (chapter 6). For example, it was communicated in the survey that usage of Virtual Classrooms was high and their effective implementation has created the need for more of such endeavours. This coupled with interest in e-learning, video conferencing and live-meeting, has again reinstated the need for technology enabled learning in these institutes.

9.2.4 VALUE PROPOSITION

NKN, with its provisions of high-speed, connectivity, collaboration, information availability and global interface with minimal financial encumbrances, is expected to render enhanced value to academic endeavours of an individual (researcher/scientist). It also augurs well for the national competitive environment of the partner institutes on NKN by morphing its governance into e-Governance resulting in better and timely decision making. The cumulative effect of enhanced institutional competitiveness further cements the knowledge economy of the country which further cascades as a positive factor to the entire world (figure 9. 1).

NKN for effective e-Governance: As affirmed by primary survey (chapter 6), application of NKN for e-Governance usage is comparatively low in the institutes, although this is understandable as the presently connected institutes are primarily research & educational institutes and not government organisations. The e-Governance usage is high at state level, at implementation points of SDCs, NDCs and SWANs, where the e-Governance initiatives are extensive as they are the pillars of the Digital India initiative. Internet connectivity and traffic management of government offices at the Centre/state, including *Bhavans* and offices, are connected through NICNET/NKN. Critical application

⁹ "One application, called Country-wide Classroom, alone will justify any amount of bandwidth and any amount of investment". High level data of this portal will also be published at the NKN website and at Knowledge Dashboard. (DPR, Page 18)

programmes include *Pragati* (Pro-Active Governance and Timely Implementation) which is one such system to encourage e-transparency and e-accountability under the chairmanship of the Prime Minister. Pragati enables real-time information exchange amongst its key stakeholders.

Also, there is a need to increase NKN coverage further to blocks and villages and so on. Therefore, such denser coverage of local government setups will supplement NKN's demand. This will directly increase e-Governance applications till the last mile.

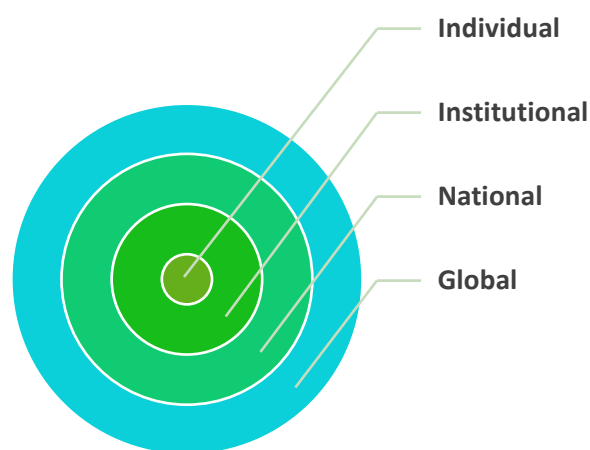


Figure 9.1 Impact from Individual to Global by NKN

Appreciating the tangible and intangible benefits rendered by NKN, it needs to position itself appropriately both within and outside the country. For doing so, it should not just explicitly account for the monetary aspects of NKN by calculating and reporting RoI (Return on Investment) but could also gauge and monitor the implicit advantages accrued by its partner institutes by piggy backing on NKN.

Respecting this, NKN could insist on its partner institutes to share their data on two aspects viz., revenue increase due to NKN and quantified values of innovation undertaken by them. Once such practice stabilises, NKN must initiate the practice for data analysis of the same using a dashboard. If NKN can put together the knowledge dashboard, the visibility of the initiatives will make their task much easier. For doing so, a systematic practice for data capturing, data analysis and reporting by the respective institutes must be institutionalised, which would prominently reflect the value accelerated by NKN both in the explicit and implicit manner.

Enhancement of NKN organisational structure: To assimilate the positive outcomes of the frameworks, such as creation of knowledge dashboard, innovation frameworks, test-bed platforms and so on, it is recommended to include additional manpower in the next phase of NKN in a systematic manner. This would help NKN to achieve its short term and long-term objectives in a more synergetic manner.

9.3 CONCLUDING REMARKS

Intellectual wealth is a matter of great pride for any country because the kind of power that comes with knowledge is long lasting and permanent in nature. Through NKN, India is striving rapidly to be accessible and connected for undertaking its research and development activities and implement effective e-Governance. Such a robust, scalable and redundant network goes a long way to successfully contribute to the country's economy.

For instance, the research-based institutions which have been empowered through this network have helped India in reaching a stage of self-reliance in many segments (like space research), thereby saving trillions of dollars which the country used to spend earlier in the import of technology and the high-end capital equipment. Similarly, high computing power and the information available through NKN has helped India in strengthening its capability of predicting natural calamities through early warning mechanisms, thereby saving unimaginable quantum of money in terms of savings in the lives of individuals, animals and the property.

NKN has also enabled special projects such as Missions Mars and Weather Forecasting which are one of the prestigious and revolutionary projects for the Government of India from the point of view of networking infrastructure and Quality of Service (QoS) support. These projects were executed at a fraction of the cost in comparison to the global costs. NKN has contributed considerably in cost savings on network, interconnectivity, bandwidth and Quality of Service

Effective management of a critical project like NKN is reliant on key areas like reliable and high-speed network with associated cost savings, empowering institutes to generate revenue by collaborations and research projects and creation of intellectual wealth. Therefore, apart from cost saving on the fronts that are being currently taken in account by NKN, it is equally pertinent for them to measure explicitly the increase in the revenue generation capacity of the institutes because of NKN's availability. The added parameter would explicitly reveal how research and collaboration have opened new doorways of opportunities for both the institutes and their researchers.

It is also important to take into account the emerging technology scenario. NKN is about to start the next journey having a new set of expectations that will be more dynamic in nature due to rapid technology changes. NKN has always been a front runner in technology in the past and to ensure that it maintains its rapid pace, it should focus on a rejuvenated goal statement that insists on its global expanse imbuing frontier technologies, resulting in refurbishing its offerings.

NKN should engage institutes and groups to have core capabilities in emerging technologies: Big Data, Artificial Intelligence (AI), Internet of Things (IoT), 3D Printing, Robotic Process Automation, Hardware Robotics, Block Chain, Augmented/Virtual/Mixed Reality, etc. New products, services and platforms can be built on these upcoming technologies.

Although NKN primarily comes across as a technology infrastructure initiative, its genesis and cultural mind set has always been centred around technology, whereas the fact stays that 'technology infrastructure' has been just one of the many aspects of NKN's impact since its establishment. After almost 10 years of its implementation and roll out, NKN is in a position to reorganise itself as a 'knowledge empowered organisation' where technology infrastructure would be one of many enablers it would provide. Such a redefined holistic approach would help

establish NKN in its next phase as the empowering platform for enhancing the knowledge economy of the nation

After this comprehensive and methodological evaluation, IIPA concludes that NKN has become an indispensable part to the government and R&D and educational community. Observing the vital contribution of NKN, IIPA lauds its potential and **recommends the continuation of NKN** and enhance its connectivity and scale to include smaller organisations along with other sectorial networks, thereby becoming a **Network of Networks**.

Glossary

A

1	ALICE (Advanced Linux Internet Communication Environment)	Allows multiple users on the network to access the internet using a Single Internet Service Provider (ISP) account.
2	AAA Service	Authentication Authorization and Accounting is a term that is used for a group of protocols that mediate network access.
3	ASEM	Asia-Europe Meeting is an Asian–European political dialogue forum to enhance relations and various forms of cooperation between its partners.
4	Asi@Connect	Unlike the telephone network, which for years in most countries was run by a single company, the global Internet consists of tens of thousands of interconnected networks run by service providers, individual companies, universities, governments and others. Open standards enable this network of networks to communicate. This makes it possible for anyone to create content, offer services and sell products without requiring permission from a central authority.

B

1	BARC	Bhabha Atomic Research Centre is India's premier nuclear research faculty, headquartered in Mumbai, Maharashtra.
2	BSNL (Bharat Sanchaar Nigam Limited)	State owned telecom service provider signed a contract with public sector org RailTel to execute various telecom related projects for national interest. NKN is one of the vital ones.

3	BitAmbulator	A cloud-based storage which provides a configurable amount of storage on the cloud to NKN members
C		
1	CISO	Chief Information Security Officer is the senior level executive responsible for establishing and maintaining the vision, strategy and program to ensure information assets and technologies are adequately protected.
2	CORE	The NKN comprises of an ultra-high-speed CORE (multiples of 10 Gbps), complimented with a distribution layer at appropriate speeds. It is Level 1 of NKN architectural design.
3	CDAC (Centre for Development of Advanced Computing)	It is an Autonomous Scientific Society of Department of Electronics and Information Technology.
4	CSIR (Council of Scientific & Industrial Research)	Known for its cutting-edge R&D knowledgebase in diverse S&T areas.
5	CollabCAD	A 3D CAD/CAM Software system for collaborative design & development of Industrial Designs
6	COLLABDDS	Collaborative Digital Diagnosis System provides an integral online environment to visualize medical images for diagnosis and treatment purpose.
7	CPSUs	The Community and Public Sector Union (more commonly known as the CPSU) is a national trade union in Australia. The union came into existence on 1 July 1994 with the amalgamation of the Public Sector, Professional, Scientific, Research, Technical, Communication, Aviation and Broadcasting Union ("PSU") with the State Public Service Federation ("SPSF"). The CPSU is one of the largest trade unions in Australia with 160,000 members.
8	CMS (Content Management System)	It is a software tool that allows you to create, edit and publish content.
9	CCI	The Common Client Interface (CCI) of the J2EE Connector Architecture provides a standard interface that allows developers to communicate with any number of Enterprise Information Systems (EISs) through their specific resource adapters, using a generic programming style.
10	CRL (Computational Research Laboratory)	It provides high performance computing (HPC) solutions and services.
11	CANARIE	Twelve provincial and territorial network partners, together with CANARIE, collectively form Canada's National Research and Education Network (NREN). This powerful digital infrastructure connects Canadians to national and global data, tools, colleagues and classrooms that fuel the engine of innovation in today's digital economy.
12	CRL (Certificate Revocation List)	A Certificate Revocation List (CRL) is a list of digital certificates that have been revoked by the issuing Certificate

		Authority (CA) before their scheduled expiration date and should no longer be trusted. CRLs are a type of blacklist and are used by various endpoints, including Web browsers, to verify whether a certificate is valid and trustworthy.
13	CUG (Close User Group)	It is created to offer a safe environment for sharing information within a group of people.
14	CERN (European Organization for Nuclear Research)	Physicists and engineers at CERN use the world's largest and most complex scientific instruments to study the basic constituents of matter – fundamental particles.
15	Commodity Infrastructure	Commodity servers are often considered disposable and, as such, are replaced rather than repaired.
16	Caching	Since Caching stores the visited web pages in cache memory, it reduces the number of requests on the content provider.
17	Collaborative e-Learning	The advantages of social and collaborative e-Learning. Collaborative learning is an e-learning approach where students are able to socially interact with other students, as well as instructors.
D		
1	DR	Disaster Recovery
2	DNS	Domain Name System is the system by which Internet domain names and addresses are tracked and regulated.
3	DRDO	The Defense Research and Development Organization (DRDO) is an agency of the Government of India, charged with the military's research and development.
4	DPR (Detail Project Report)	“Bring together all the stakeholders in Science, technology, Higher Education, Research & Development and Governance with speeds of the order of 10s of gigabits per second coupled with extremely low latencies. NKN will interconnect all institutions engaged in research, higher education and scientific development in the country, over a period of time.”
5	DDOS (Distributed Denial of Services)	DDoS (Distributed Denial of Service) is an attack where multiple compromised system are used to target a single system causing a DoS attack.
6	Dedicated Network	In computer networks and telecommunications, a dedicated line is a communications cable or other facility dedicated to a specific application, in contrast with a shared resource such as the telephone network or the Internet. It is a communication path between two points.
7	DEIC	Danish E-Infrastructure Cooperation
8	Dark Fibre	A dark fibre or unlit fibre is an unused optical fibre, available for use in fibre-optic communication. Dark fibre originally referred to the potential network capacity of telecommunication infrastructure. Dark fibre may be leased from a network service provider.

E

1	Edge Connectivity	Edge Connectivity. The minimum number of edges, whose deletion from a graph disconnects, also called the line connectivity. The edge connectivity of a disconnected graph is 0, while that of a connected graph with a graph bridge is 1.
2	EDUSAT	GSAT-3, known as EDUSAT is meant for distant class room education from school level to higher education. This was the first dedicated "Educational Satellite" that provide the country with satellite based two-way communication to class room for delivering educational materials.
3	ERNET	ERNET India is the National Research and Education Network dedicated to support the needs of the research and education community within the country.
4	e-Shikshak	e-Sikshak is the e-Learning framework developed by C-DAC, Hyderabad to offer on line course.
5	e-Governance	Electronic governance or e-Governance is the application of information and communication technology (ICT) for delivering government services, exchange of information, communication transactions, integration of various stand-alone systems and services between government-to-citizen (G2C), government-to-business (G2B), government-to-government (G2G), government-to-employees (G2E) as well as back-office processes and interactions within the entire government framework.
6	e-Infrastructure	Short term for Electronic Infrastructure, i.e., all ICT based resources (distributed networks, computers, storage devices, software etc.) and support operations which facilitate the collaboration among research communities by sharing resources, analysis tools and data.
7	e-Foundry	It empowers teachers in engineering and polytechnic institutes to enhance the interest and employability of students in metal casting, the mother industry in manufacturing sector.
8	EPILEPCY	Epilepsy is a central nervous system (neurological) disorder in which brain activity becomes abnormal, causing seizures or periods of unusual behavior, sensations and sometimes loss of awareness. The Centre of Excellence (CoE) for Epilepsy is a collaborative project of the National Brain Research Centre (NBRC), Manesar and the all India Institute of Medical Sciences (AIIMS), New Delhi supported by the Department of Biotechnology, Ministry of Sciences and Technology, Government of India.

G

1	Gbps	Gbps stands for billions of bits per second and is a measure of bandwidth on a digital data transmission medium such as optical fiber.
2	GigE	Gigabit Ethernet is the fastest growing interface for digital cameras in the field of industrial image processing.
3	GRID Computing	Grid computing is a processor architecture that combines computer resources from various domains to reach a main objective. In grid computing, the computers on the network can work on a task together, thus functioning as a supercomputer.
4	GARUDA (Global Access to Resource Using Distributed Architecture)	It is India's first Grid Computing initiative bringing together academic, scientific and research communities for developing their data
5	GEANT (pan European Network)	The GÉANT network continues to set the standard for speed, service availability, security and reach, delivering the high performance that rely on.
6	GLORIAD (Global Ring Network for Advanced Application Development)	GLORIAD is a high-speed computer network used to connect scientific organizations in Russia, China, United States, the Netherlands, Korea and Canada. India, Singapore, Vietnam and Egypt were added in 2009
7	GeM portal (Government e-Market Place)	GeM is hosted by DGS&D where common user goods and services can be procured. GeM is dynamic, self-sustaining and user friendly portal for making procurement by Government officers.
8	G2G (Government to Government)	Integration of various stand-alone systems and services between government-to-government (G2G).
9	G2C (Government to Citizen)	Integration of various stand-alone systems and services between government-to-citizen (G2C).
10	G2B (Government to Business)	Integration of various stand-alone systems and services between government-to-business (G2B).
H		
1	HBNI (Homi Bhabha National Institute)	HBNI is an Indian deemed university established by the Department of Atomic Energy, which unifies several of their constituent institutions.
2	HLC (High Level Committee)	This committee was formed to take up key decisions for implementing NKN.
3	Hops	In computer networking, a hop is one portion of the path between source and destination. Data packets pass through bridges, routers and gateways as they travel between source and destination. Each time packets are passed to the next network device, a hop occurs.
4	High Speed Net Connectivity	High-speed Internet is Internet access provided by a network of servers that transfers data via high-speed cable, satellite

		and wireless connections. Information is sent and received as bits of data, which move much faster than the traditional analog dial-up connections.
5	High Bandwidth	It is the capacity of a wired or wireless network communications link to transmit the maximum amount of data from one point to another over a computer network or internet connection in a given amount of time -- usually one second.
1	ICMP	Internet Control Message Protocol it is used by network devices, including routers, to send error messages and operational information.
2	IIT	The Indian Institutes of Technology (IITs) are autonomous public institutes of higher education, located in India.
3	Internet2 (US)	Internet2 is a member-driven advanced technology community founded by the nation's leading higher education institutions in 1996. Internet2 provides a collaborative environment where US research and education organizations can solve common technology challenges and develop innovative solutions in support of their educational, research and community service missions.
4	IP	An Internet Protocol address (IP address) is a numerical label assigned to each device connected to a computer network that uses the Internet Protocol for communication. An IP address serves two principal functions: host or network interface identification and location addressing.
5	IPv4	Internet Protocol version 4 (IPv4) is the fourth version of the Internet Protocol (IP). It is one of the core protocols of standards-based internetworking methods in the Internet
6	ISMS	Information Security Management System is a set of policies and procedures for systematically managing an organization's sensitive data.
7	ICRI (Institute of Clinical Research India)	ICRI is a leader in Clinical Research, Healthcare Management, Aviation Management, Logistics & Supply Chain Management.
8	IAM (Identity and Access Management)	It is the discipline for managing the access to enterprise resources. It is a foundational element of any information security program and one of the security areas that users interact with the most.
9	ICT (Information and Communication Technology)	ICT, or information and communications technology (or technologies), is the infrastructure and components that enable modern computing.

J

1	JIPMER (Jawahar Institute of Postgraduate Medical Education and Research)	JIPMER stands for Jawaharlal Institute of Postgraduate Medical Education and Research. It is a medical school situated in Pondicherry (southern India).
2	JRA	Joint Research Activities
3	JRM	Job Responsibility Matrix

K

1	Knowledge Eco System	The idea of a knowledge ecosystem is an approach to knowledge management which claims to foster the dynamic evolution of knowledge interactions between entities to improve decision-making and innovation through improved evolutionary networks of collaboration.
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L

1	LMS (Learning Management System)	Software that is installed to a server for tracking learning data and behavior of a learner community.
2	LHC	The Large Hadron Collider (LHC) is the world's largest and most powerful particle collider and the largest machine in the world.
3	LAN	A local area network (LAN) is a group of computers and associated devices that share a common communications line or wireless link to a server.
4	LDAP	Light Weight Directory Protocol which provides authentication and authorization to the users
5	LDCs	Least Developed Countries (LDCs) is a list of developing countries that, according to the United Nations, exhibit the lowest indicators of socioeconomic development, with the lowest Human Development Index ratings of all countries in the world.
6	Latency	Latency refers to time interval or delay when a system component is waiting for another system component to do something. This duration of time is called latency.
7	Large Hadron Collider	It is world's largest and most powerful particle accelerator.

M

1	MBSS	Minimum Baseline Security Standard allows organizations to deploy systems in an efficient and standardized manner.
2	MHRD	The Ministry of Human Resource Development, formerly Ministry of Education (until 25 September 1985), is responsible for the development of human resources in India. The Ministry is divided into two departments: the Department of School Education and Literacy, which deals

		with primary, secondary and higher secondary education, adult education and literacy and the Department of Higher Education, which deals with university education, technical education, scholarship etc.
3	MOOC	A massive open online course (MOOC) is a model for delivering learning content online to any person who wants to take a course, with no limit on attendance.
4	MTU (Maximum Transmission Unit)	A maximum transmission unit (MTU) is the largest size packet or frame, specified in octets (eight-bit bytes), that can be sent in a packet- or frame-based network such as the Internet.
5	Mesh	Mesh topology occurs when every node has a circuit connecting it to every other node in a network
6	MOM (Mars Orbiter Mission)	Mars Orbiter Mission (MOM), the maiden interplanetary mission of ISRO, launched on November 5, 2013 by PSLV-C25.
7	MPLS (Multiprotocol Label Switching)	It is a routing technique designed to speed up and shape traffic flows across the network. In MPLS routing of packets happen from one hop to other with the help of tags, thus avoiding complex routing table lookups.
8	MRTG Graph	It is being used to graph all sorts of network devices. It used for monitoring and measuring the traffic load on network links.

N

1	NKN (National Knowledge Network)	The NKN is a hierarchical network divided into three basic layers – ultra-high-speed CORE (multiples of 10 Gbit/s; Level 1), Distribution (Level 2) and Edge (speeds of 1 Gbit/s or higher; User Level).
2	NREN (National Research and Educational Network)	These are organizations that are specialized internet service providers dedicated to supporting the needs of research and education communities within their own country.
3	NICNET	NIC (National Informatic Centre) is an organization set up by the Government of India in 1977. NIC had set up a satellite based nationwide computer communication network called NICNET
4	NIS	Network Information System
5	National Informatics Centre – Computer Emergency Response Team (NIC-CERT)	NIC- CERT is the nodal arm of National Informatics Centre for managing the cyber security incidents in NIC. It acts as a single point of contact and co-ordinates with concerned stakeholders for cyber security incidents targeted at NIC Infrastructure.
6	NLD (National Long-Distance service providers)	National Long Distance (NLD) service refers to the carriage of switched-bearer telecommunications services over a long-distance network.
7	NLR Project	National Lambda Rail Project
8	NPTEL	NPTEL is an e-learning platform lectures and courses from 8

		different IITs.
9	NMEICT	The National Mission on Education through ICT is a Centrally sponsored Scheme to leverage the potential of ICT, in providing high quality personalized.
10	Next Generation Network (NGN)	The next-generation network (NGN) is a body of key architectural changes in telecommunication core and access networks. The general idea behind the NGN is that one network transports all information and services (voice, data and all sorts of media such as video) by encapsulating these into IP packets, similar to those used on the Internet.
11	NTRO	The National Technical Research Organization (NTRO) is a technical intelligence Agency under the National Security Advisor in the Prime Minister's Office, India.
12	NICSI	National Informatics Centre Services Inc. (NICSI) was established in 1995 as a section-8 (erstwhile section-25) company under National Informatics Centre, Ministry of Electronics & Information Technology, Government of India for providing and procuring IT solutions for multiple e-Governance projects undertaken by NIC, MeitY, Governments and Government Organizations (like Public Sector Undertakings).
13	NORDUNET	NORDUNET is an international collaboration between the National research and education networks in the Nordic countries.
14	Network Architecture	Network Architecture is the complete framework of an organization's computer network.
15	NTP (Network Time Protocol)	The Network Time Protocol (NTP) is a networking protocol for clock synchronization between computer systems over packet-switched, variable-latency data networks.
16	NPL (National Physical Laboratory)	The National Physical Laboratory of India, situated in New Delhi, is the measurement standards laboratory of India. It maintains standards of SI units in India and calibrates the national standards of weights and measures.
17	NDC	National Data Centers offer a robust, highly available infrastructure with adequate redundancy to enable government to render effectively the e-Governance services to the citizens. It provides services to the Government Ministries, departments, state governments, district administrations and block levels.
O		
1	Optical Fiber Cable (OFC)	An optical fiber cable is a type of cable that has a number of optical fibers bundled together, which are normally covered in their individual protective plastic.
2	OSDD	OPEN SOURCE DATA DISCOVERY is a CSIR-led Team India

		consortium with a global partnership. Its vision is to provide affordable healthcare to the developing world by providing a global platform.
3	OTR (Optical Trans Receivers)	An optical transceiver chip is an integrated circuit (IC) that transmits and receives data using optical fiber rather than electrical wire. Optical fiber, also called fiber optic, refers to the technology associated with the transfer of information in light beams or pulses along solid transparent fibers or cables.
4	Outreach	Taking an idea, service or product to the audience having needs of the same.
5	Overlay Network	A new network is created over an existing one.
6	OSIR	A cloud-based storage which provides a configurable amount of storage on the cloud to NKN members.
7	OWASP (Open Web Application Security Project)	It is a worldwide not-for-profit charitable organization focused on improving the security of software.
P		
1	PoPs	Point of presence (POP) is the point at which two or more different networks or communication devices build a connection with each other.
2	PerfSONAR	It is a collection of open source software for performing and sharing end-to-end network measurements.
3	PERF TOOL (iPerf)	PERF Tool is the performing monitoring tool which is used to test bandwidth speed of NKN network.
4	Peering	With peering NKN has more control over external paths and can easily adjust routing to avoid problem network segments.
5	PaaS	Platform as a service (PaaS) is a cloud computing model in which a third-party provider delivers hardware and software tools -- usually those needed for application development -- to users over the internet.
6	PGCIL	Power Grid Corporation of India Limited
Q		
1	QoS (Quality of Services)	It is one of the pillars that reviews NKN's network impact over last 9 years.
R		
1	Railtel	RailTel Corporation of India Ltd. is a "Miniratna" (public sector) enterprise of Government of India focusing on providing broadband and VPN services.
2	RFC	In information and communications technology, a Request for Comments (RFC) is a type of publication from the technology community. RFCs may come from many bodies including from the Internet Engineering Task Force (IETF),

		the Internet Research Task Force (IRTF), the Internet Architecture Board (IAB) or from independent authors.[1] The RFC system is supported by the Internet Society (ISOC).
3	ROADM	In fiber optics, a reconfigurable optical add-drop multiplexer (ROADM) is a form of optical add-drop multiplexer that adds the ability to remotely switch traffic from a wavelength-division multiplexing (WDM) system at the wavelength layer.
4	Redundancy	Network redundancy is a process through which additional or alternate instances of network devices, equipment and communication mediums are installed within network infrastructure. It is a method for ensuring network availability in case of a network device or path failure and unavailability.

S

1	SAARC	South Asian Association for Regional Cooperation.
2	SCPC	Single Channel per Carrier
3	SFC	Network service chaining, also known as service function chaining (SFC) is a capability that uses software-defined networking (SDN) capabilities to create a service chain of connected network services (such as L4-7 like firewalls, network address translation [NAT], intrusion protection) and connects them in a virtual chain.
4	SWAN (State Wide Area Network)	One of the core infrastructure components under the National e-Governance Plan of the Government of India.
5	SDC	SDC is a fully distributed protocol which requires only neighbor information and it can handle node dynamics locally with very small message overhead while keeping good quality of clustering.
6	SHQ (State Head Quarters)	SHQ means State Head quarter. All the 30 DHQ, 284 BHQ and 61 HO connected to SHQ.
7	SDN	Software-defined networking (SDN) is an architecture that aims to make networks agile and flexible. The goal of SDN is to improve network control by enabling enterprises and service providers to respond quickly to changing business requirements.
8	SDLC	Software Development Lifecycle is a framework defining tasks performed at each step in the software development process.
9	South Asian Sub Regional Economic Cooperation (SASEC)	The South Asia Sub Regional Economic Cooperation (SASEC) program brings together Bangladesh, Bhutan, India, Maldives, Myanmar, Nepal and Sri Lanka in a project-based partnership that aims to promote regional prosperity, improve economic opportunities and build a better quality of life for the people of the sub region.

10	SingAREN Singapore Advanced Research and Education Network.	It is Singapore's national research and education network.
11	STRATUM 0 and 1	A reference clock is a stratum-0 device that is assumed to be accurate and has little or no delay associated with it. Stratum-0 servers cannot be used on the network, instead, they are directly connected to computers which then operate as stratum-1 servers.
12	SSO (Single Sign-on)	It is a property of access control of multiple related, yet independent, software systems. With this property, a user logs in with a single ID and password to gain access to any of several related systems.
13	SUNET	Swedish University Computer Network
T		
1	Technical Advisory Committee (TAC)	The Technical Advisory Council (TAC) is a federal advisory committee of the Federal Communications Commission and the FCC's Office of Engineering and Technology (OET). Its mandate is to provide the FCC with technical advice in such rapidly growing fields as cable television, telephony and the Internet.
2	Terabit	A terabit is a multiple of the unit bit for digital information or computer storage.
3	TIFR (Tata Institute of Fundamental Research)	TIFR is a public research institution located in Mumbai, India that is dedicated to basic research in mathematics and the sciences.
4	TEIN4 (The Trans-Eurasia Information Network)	TEIN uses the ICT technologies to increase regional cooperation with Asian countries and to bridge the digital divide of less developed regions.
5	TCP (Transmission Control Protocol) Bandwidth Performance	Bandwidth-delay product (BDP) is a term primarily used in conjunction with TCP to refer to the number of bytes necessary to fill a TCP "path", i.e. it is equal to the maximum number of simultaneous bits in transit between the transmitter and the receiver. High performance networks have very large BDPs.
6	TACACS (Terminal Access Controller Access Control System)	An older authentication protocol common to UNIX networks that allows a remote access server to forward a user's logon password to an authentication server to determine whether access can be allowed to a given system.
U		
1	UCAID	University Corporation for Advanced Internet Development
2	UDP Bandwidth Performance	User Datagram Protocol (UDP) is a Transport Layer protocol. Since high performance is needed, UDP permits packets to be dropped instead of processing delayed packets. There is no error checking in UDP, so it also saves bandwidth.

User Datagram Protocol (UDP) is more efficient in terms of both latency and bandwidth.

V

1	VPN	A virtual private network (VPN) extends a private network across a public network and enables users to send and receive data across shared or public networks as if their computing devices were directly connected to the private network.
2	VSAT	A very small aperture terminal (VSAT) is a small telecommunication earth station that receives and transmits real-time data via satellite.
3	Value Proposition	A value proposition is a promise of value to be delivered, communicated and acknowledged. A value proposition is a statement which identifies clear, measurable and demonstrable benefits consumers get when buying a particular product.
4	Virtual Network	The main purpose of a virtual network is to enable a data center or service provider network to provision the most suitable and efficient networking structure for the applications it hosts – and to alter that structure as conditions warrant, using software rather than requiring physical changes in connections to hardware.

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