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ORIGINAL RESEARCH

E-Science infrastructure: National Knowledge Network (NKN) initiative

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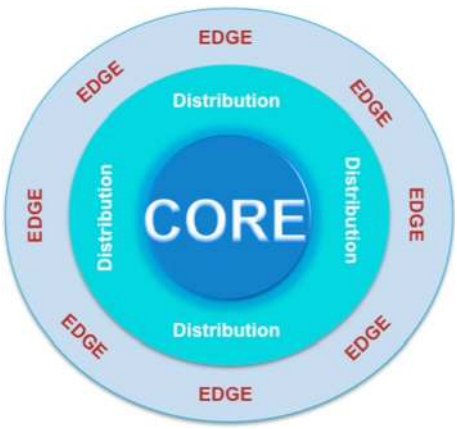
1 Background

The creation of an advanced cyber infrastructure has been recognized as a critical knowledge resource for further development of Science and Technology in India. Interaction among various interest groups and brainstorming sessions have converged naturally to the fact that several scientific departments and institutes for Higher Education and research benefit from this effort—that too immediately. E-Infrastructure seamlessly integrates heterogeneous partners and annihilates distance through Smart Ultra High Bandwidth networks.

2 NKN concept, design, architecture, and characteristics

The architecture of the National Knowledge Network (NKN) has been designed to be scalable and the network will consist of an ultra-high speed CORE (having an eventual speed of multi 10 gigabits per second), complimented with a distribution at appropriate speeds. The participating institutions at the edge would connect to the NKN seamlessly at speeds exceeding 1 gigabits per second or higher and the network architecture and governance structure shall allow the user institutions an option to connect to the distribution layer through a self arranged/procured last mile connectivity bandwidth. In addition, the NKN has been designed to support Overlay Networks and Dedicated Networks and to support applications in other sectors like health, bioinformatics, agriculture, e-governance, etc. NKN emerged as the most comprehensive network designed so far.



National Knowledge Network is an ultra high bandwidth network with a fully connected super core, multi-homed distribution as well as edges, that connects 1,500 institutions directly and 30,000 institutions indirectly at speeds exceeding 1 Gbps. National Knowledge Network core itself has capacity in multiples of 10 Gbps and will try and maintain dynamic equilibrium with technological opportunities and economic feasibilities as years pass by. National Knowledge Network is characterized by high bandwidth and low latency enabling *annihilation of distance* and *instantaneous observation of events*.

National Knowledge Network is present across India and is planned for a total of 650 points of presence. National Knowledge Network is also designed to connect globally. At present NKN is connected to European Research Network GEANT and TEIN4. Connection to INTERNET2 of United States is in advanced stages of planning. Work is under way for similar connections to

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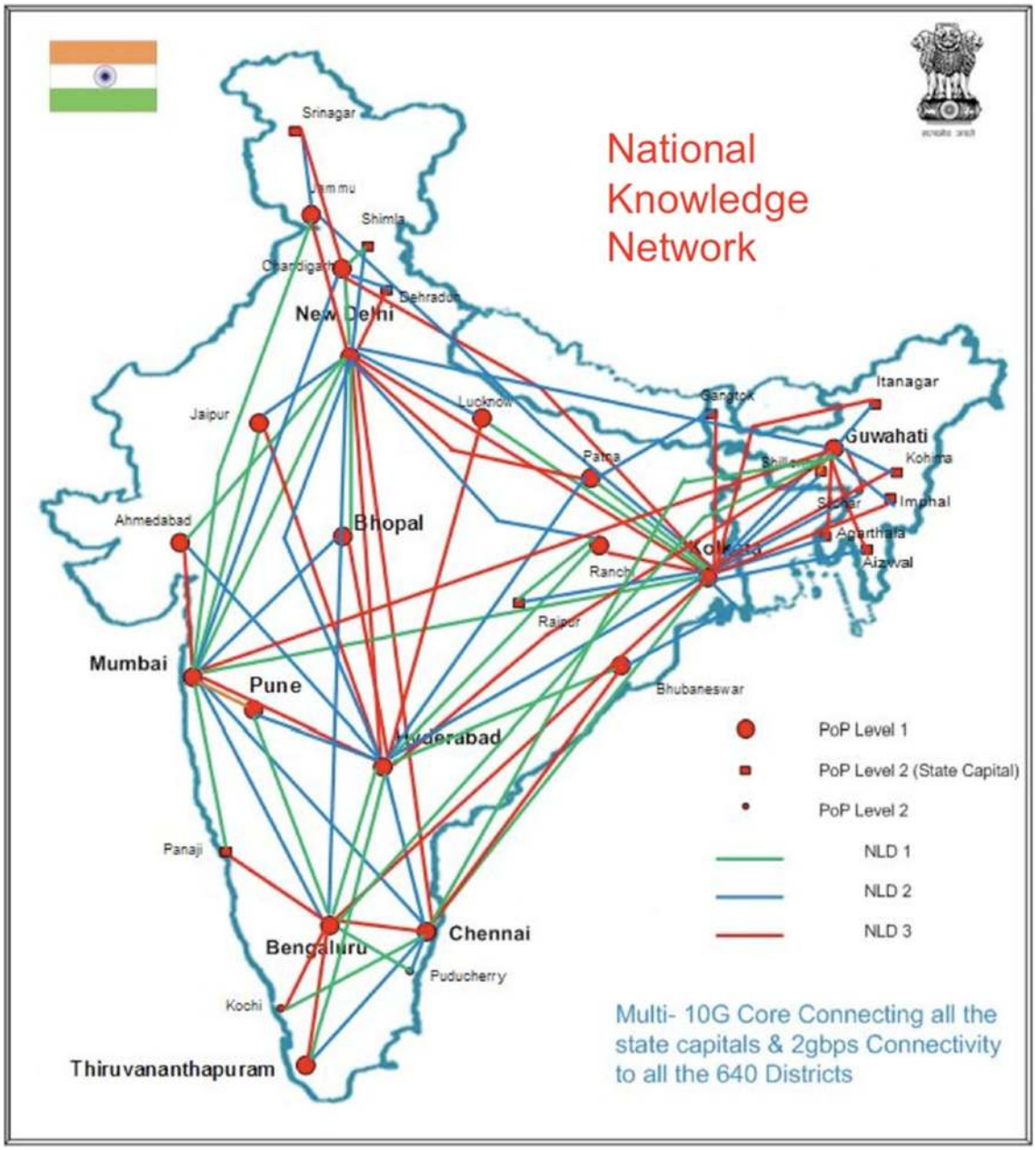
countries in Asia Pacific, Japan, and Australia. National Knowledge Network will have physical presence in New York, Amsterdam, Geneva, and Singapore soon. The international links will be operating at speeds equal to or higher than 10 Gbps.



National Knowledge Network enables Closed User Groups to be established on demand. As on date, Garuda (High Performance Computing Grid of CDAC) and WLHCG (High Energy Physics) are excellent examples of such collaboration. Both these grids are across India, across government departments, and across multi disciplinary institutions, including several universities. National Knowledge Network users access the beam line facility in Grenoble, France and University of California, Berkeley, USA.

National Knowledge Network has four different types of services; Special services, Community Services, Generic Services, and Commodity Services:

Special services focus on High end R&D interaction such as High Energy Physics, Climate Change, and

Global Collaboration on Emerging Science and Technology areas. They manifest as Virtual Private Network Stitching Services [VPN@L2 (Virtual Private Wire Service/Virtual Private LAN Service), VPN@L3] etc.

Community services enable synergistic collaborative education, research and development, which are domain specific and problem specific, but distributed across organizations in terms of resource and people. Virtual Classrooms, Virtual Laboratories, Cancer Grid, Brain Grid, are representative examples. They manifest as Virtual Private Network Stitching Services [VPN@L2 (Virtual Private Wire Service/Virtual Private LAN Service), VPN@L3] etc.

Generic Services focus on providing infrastructure services such as Domain Name Service (DNS), DHCP, Email Servers, Server Farms, Secure Filtering Services for Viruses, Commonly used Software, Internet, Intranet, Network Management Views, e-Mail, Messaging Gateways, Caching Gateways, Domain Name System, Web Hosting, Voice over IP, Multipoint Control Unit (MCU) Services, Video Portals, SMS Gateway, Co-Location Services, Video Streaming etc.

Commodity Services, on the other hand, provide traditional Email Access, Internet Access, and Access to worldwide resources, spanning a very broad spectrum.

National Knowledge Network design emphasizes quality of service (QoS) as the basis for defining and operating services as opposed to "Best Effort" services available through "internet like" technologies. By design NKN scales! NKN has a Super-Core, Core, Distribution, and Edges as an inside out concentric circle design. National Knowledge Network has the ability to be configured as Specialty E-Infrastructure, Community E-Infrastructure, and Commodity-Infrastructure.

2.1 NKN model projects

In order to demonstrate the capabilitisdes of NKN—high bandwidth and low latency—NKN launched a series of Model Projects to showcase the applicability across a spectrum of applications focusing on education and health, each one with a signature statement. Each project is carefully handcrafted to address a specific challenge. These projects are conceptualized, evolved, and facilitated for implementation.

1. In the area of medical education, NKN launched a model project with AIIMS as the Principal Investigator, to understand the ICT technology flavor that will match the pedagogy natural to medical education while using the high speed and low latency offered by NKN. Eight institutions joined AIIMS in this experiment and have come up with solutions after mutual consultations and actual field trials. They now have a template as to what combination is natural and acceptable to their community for skill transfer, knowledge transfer, and knowledge repository creation. It is interesting that they use high-end graphics coupled with animation for "routine" skills (Blood and urine Sample, Blood Pressure monitoring, etc.) transfer and direct video for classroom interaction, and a combination to share knowledge about surgical skills that are cardiac oriented.

   The USP of this project is, "Identification of appropriate match between ICT technology and Medical Application" for finding a solution to knowledge dissemination at a time when faculty are in short supply and rarest of the rare cases tend to be concentrated in certain parts of the country.

2. In the area of engineering education, there were several attempts in the past in creating and sharing course material, significant one being NPTEL—National Program on Technology Enhanced Learning. But the problem of continued knowledge accumulation by stakeholder community (consisting of Professors, Students, and Practitioners) using ICT remained a challenge hitherto in the absence of an infrastructure like NKN. With IIT Bombay, a model project was initiated in Metal Casting Education. This is an area where the community is small, spread out, and perhaps not that tech-savvy. Besides, the experimental facilities are challenges in Tier-2 and Tier-3 institutions. To do it well, requires high bandwidth and low latency. At the same time, many beneficiary institutions are connected through commodity networks using Internet as they are in private sector.

E-Foundry is a part of the NKN mission to empower teachers to enhance the interest and employability of engineering students in the manufacturing sector, mainly metal casting or foundry, considered the 'mother industry'. Users can freely access the teaching content developed in IIT-B, to update their knowledge in casting design and simulation. National Knowledge Network E-Foundry Resources include video lessons in five parts (introduction, science, engineering, technology, and application), online simulation laboratory (which accepts a 3D CAD model and generates solidification images), rich library of reference material (animations, presentation slides, paper abstracts, defects museum, industrial case studies, web links), quizzes and tutorials with answers for self-evaluation, a discussion hub for questions and answers, and a projects page with ideas for researchers.

The USP of this project is the establishment of a Web Based Portal that uses Computation (High Speed) and Interaction for Metal Solidification Simulation (Low Latency) to impart Casting Education along with novel experiments using indigenous equipment and set-ups. The E-Foundry Lab established at IIT Bombay has become an attractive model for others, and several institutes are already replicating the experimental and simulation facilities integrated with online learning resources. This approach ensures that the knowledge base will naturally grow with usage and participation, leading to better employability of students and wider penetration of simulation technology in the metal casting industry.

3. Inter-disciplinary research, three organizations were brought together to demonstrate the power of NKN in multi-institutional interaction. They are, NIC, CSIO, and AIIMS. The basic idea is to use engineering design solutions to solve medical requirements. CollabCAD platform—software capable of three-dimensional structural simulation with all the engineering nuances—was retargeted to solve a personalized dental imaging in 3-D. While NIC took care of the ICT part, CSIO concentrated on the imaging part, and AIIMS articulated the end-user requirements. It is in a stage where multiple 2-D images are used to creates 3-D virtual reality.

   The USP of this project is that all three organizations are suing the same image database on the same server for online and real-time manipulation of images, while discussing and annotating on the same image. Such a facility is not available even commercially, across the globe.

4. A program has been undertaken in the area of Brain imaging and integration of Indian medical imaging research with global programs, with National Brain Research Centre, Gurgaon as the lead organization. The endeavor is an initiative towards i-Brain (Indian Brain grid) that has been enabled as a research

infrastructure layer over NKN, and the institutions involved are from the four regional zones of the country. These institutions process and analyze their brain images online and in real-time, in consonance with international standards, such as that of C-Brain and G-Brain. These are the Canadian Brain grid and the Global Brain grid, the protocol development being facilitated by cooperation of McGill University and Canadian Advanced Research & Innovation Network (the Canadian counterpart of NKN). While the current team will focus on using the infra for studies like Neurodegenerative disorders, cerebral stroke, Alzheimer's dementia and cognitive impairment, ICMR is planning to use it as a general purpose infra for several brain related research projects that are multi-institutional.

The USP of this project is establishment of ICT infrastructure by medical community for a high end use, that too in an inter-actable and shareable form. The establishment is successfully under way, and the interact-ability and share-ability is under exploration.

5. Using videoconferencing for imparting education is a well-known application. But scaling it to be an Immersive Experience is a technology challenge even for a point-to-point interaction. With Amrita University in collaboration with IIT Bombay, SUNY, Buffalo, and MIT, Massachusetts, USA an immersive classroom that adapts itself to the mannerisms of a "teacher" is being attempted. Initially, video stitching of output from two cameras is being attempted. The idea is that, if one is addressing two sites simultaneously, it will appear as a single classroom at the "teaching" end. The solution requires use of a supercomputer for running the algorithms that decide the "sync" between two camera eyes. This project challenges the reliability and availability aspect of NKN significantly, as the high volume and high-speed computation is in real-time and a failure will directly "hit" the classroom experience.

   The USP of this project is automatic aligning of "teacher behavior" and "pedagogy" with the display structure at the receiving end—hitherto unaddressed issue, even by advanced countries in the world. This is expected to result in a paradigm shift in our perception of large-scale spread of quality education. This project is also likely to create "niche" technologies in several areas.

Each one of these Model Projects has a theme and a purpose. Success of each one of them will enhance the application potential of NKN in a demonstrable form. Besides, the CollabCAD project may become the technology platform for Brain infra. The immersive classroom may be integrated in medical education. The web based portal experience may be adopted by many other practice oriented engineering disciplines. There is definitely scope for *coherent synergy*, which is the underlying theme of the Office of PSA.

2.2 NKN applications

There are several initiatives undertaken by NKN connected institutions. Some of them are:

- Countrywide Virtual Classrooms
- Collaborative Research
- Collaborative Design in Engineering
- Collaborative Design in Medicine
- Open Source Drug Discovery
- Grid Computing
- GARUDA Grid
- Hosting NPTEL Courses (IITM)
- Training of Trainers Program (IITB)
- Virtual Laboratories (IITD)
- Linking Rural Training Institute to National Knowledge Network (IISER Pune)

2.2.1 Countrywide virtual classroom

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. The network enables co-sharing of information such as classroom lectures, presentations and handouts among different institutions.

2.2.2 Collaborative research

The NKN enables collaboration among researchers from different educational networks like GLORIAD, TEIN3, GARUDA, CERN etc. NKN also enables sharing of scientific databases and remote access to advanced research facilities. NKN is used extensively by Indian groups in CMS and ALICE experiments of the Large Hadron Collider (LHC) at CERN, Geneva.

The LHC is a large scientific instrument near Geneva, spanning the border between Switzerland and France about 100 m underground. It is a particle accelerator used by physicists to study the smallest known particles, the fundamental building blocks of all things. It will revolutionize our understanding, from the minuscule world deep within atoms to the vastness of the Universe. Two beams of subatomic particles called 'hadrons' either protons or lead ions will travel in opposite directions inside the circular accelerator, gaining energy with every lap. Physicists will use the LHC to recreate the conditions just after the Big Bang, by colliding the two beams head-on at very high energy. Teams of physicists from around the world will analyze the particles created in the collisions using special detectors in a number of experiments dedicated to the LHC.

The LHC will produce roughly 15 petabytes (15 million gigabytes) of data annually, enough to fill more than 1.7 million dual-layer DVDs a year! Thousands of scientists around the world want to access and analyze this data, so CERN is collaborating with institutions in 34 different countries to operate a distributed computing and data storage infrastructure: the Worldwide LHC Computing Grid (WLCG).

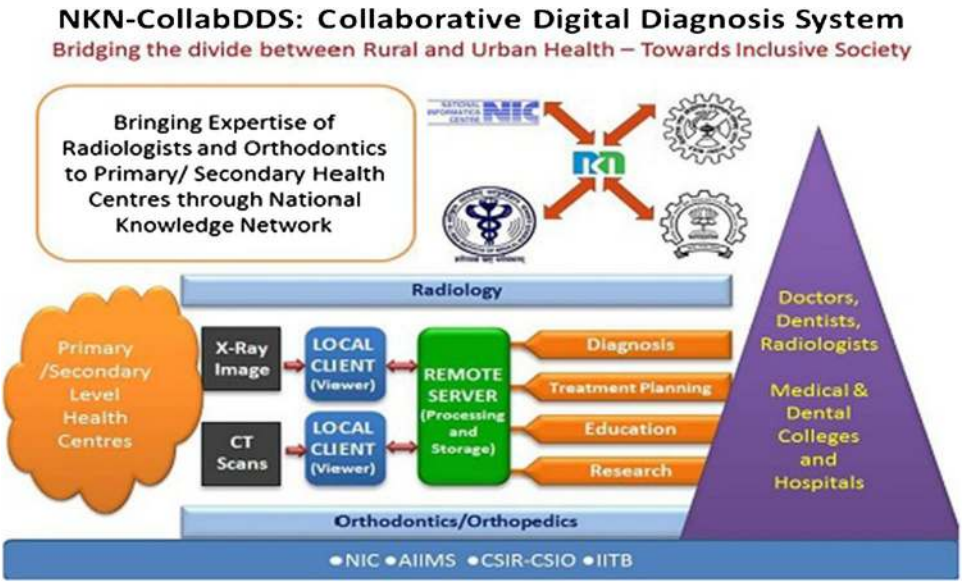
Data from the LHC experiments is distributed around the globe, with a primary backup recorded on tape at CERN. After initial processing, this data is distributed to eleven large computer centers in Canada, France, Germany, Italy, the Netherlands, the Nordic countries, Spain, Taipei, the UK, and two sites 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 centers make the data available to over 160 Tier-2 centers for specific analysis tasks. Individual scientists can then access the LHC data from their home country, using local computer clusters or even individual PCs.

National Knowledge Network currently connects two Tier-2 centers 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 desirous 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 date rates and low latency that real time applications require. National Knowledge Network also provides multi-gigabit connectivity to the European grid.

2.2.3 Collaborative design in medicine

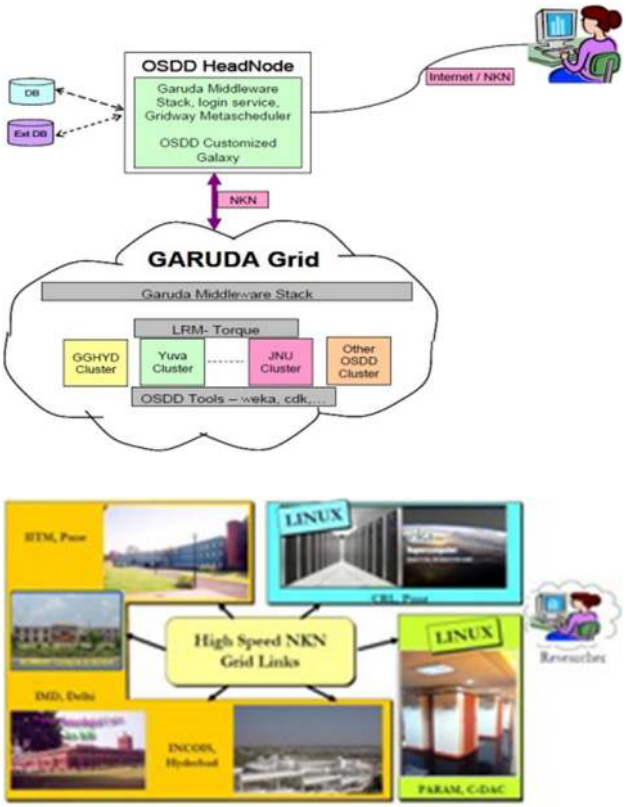
Organizations with expertise in different areas viz. National Informatics Centre, New Delhi, All India Institute of Medical Sciences, New Delhi, Indian Institute of Technology-Bombay, Mumbai and CSIR-Central Scientific Instruments Organization, Chandigarh joined in for effective development, implementation and roll-out of an application which could bring a shift in the way in which radiological diagnosis and teaching is carried out. The Model Project "Network Enabled Medical Diagnosis and Education in Skeletal Imaging using X-Rays" funded by

the NKN, was undertaken as a Proof of Concept to provide a network based system for radiological and orthodontic diagnosis using X-Rays. The area of study being complicated required expertise in varied domains such as but not limited to Orthodontics, Orthopedics, Radiology, Computational Methods, CAD/Rapid Prototyping, Image Processing and Pattern Recognition. Project was planned in two phases; first one being to develop an application, which could enable visualization, and processing of radiological data over a collaborative platform and second to effectively roll out and enhance the application as per the end user need. The project has been envisaged and is in progress keeping in view two goals. First one is to connect Primary Health Centers (PHC's) with expert radiologists/doctors & dentists at Medical/Dental colleges and Hospitals using suitable Information, Communication and Technology (ICT) tools and channel for real time radiological data transmission. The second objective is to use this platform to build a repository of rare clinical cases for teaching of medical and dental students thus providing these students with an opportunity to study cases which are currently limited to the centers of excellence in medical and dental field. With this vision an application CollabDDS - Collaborative Digital Diagnosis System—has been developed. The strength of CollabDDS over telemedicine/web based consultation lies in its real time collaborative environment where both the doctor and expert will view the same image simultaneously. The expert could interpret the image for diagnosis. This kind of a collaborative activity amongst PHC's with Medical/Dental Colleges & Hospitals and Centers of Excellence would help to provide improved diagnosis.



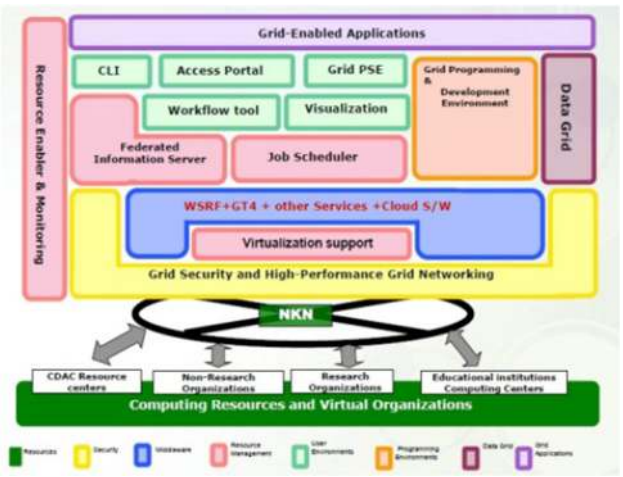
2.2.4 *Open source drug discovery using NKN*

Open source drug discovery (OSDD) 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 where the best minds can collaborate & collectively endeavor to solve the complex problems associated with discovering novel therapies for neglected tropical diseases like malaria, tuberculosis, leishmaniasis, etc. It is a concept to collaboratively aggregate the biological and genetic information available to scientists in order to hasten the discovery of drugs. This will provide a unique opportunity for scientists, doctors, technocrats, students and others with diverse expertise to work for a common cause. The Open Source Drug Discovery initiative will establish a novel open source platform for both computational and experimental technologies to make drug discovery for infectious/neglected diseases, cost effective and affordable to the people of the developing world. NKN connects OSDD partners such as IMTECH Chandigarh, IGIB, JNU, Institute Of Life Sciences, etc. With NKN as their backbone, they have the capacity to provide a distributed environment to all their computing partners. This allows them to provide a unified platform for Bio-Informatics and an open source platform for drug discovery.



2.2.5 *Grid computing*

The NKN has the capability to handle high bandwidth with low latency with a provision overlay grid computing. Some of the grid-based applications are climate change/global warming, science projects like LHC and ITER. The NKN can be the platform to realize many such innovative applications. The Garuda Grid has enhanced its power and stability by migrating to NKN.



2.2.6 *GRID initiative in India*

GARUDA is a collaboration of the Scientific, Engineering and Academic Community to carryout 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 Department of Information Technology (DIT) has funded the Center for Development of Advanced Computing (C-DAC) to deploy the nation-wide computational grid. 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. Currently the highly reliable and available NKN connects the resources of the Garuda grid with a bandwidth of 1 Gbps, with provisions of QoS and Security. In this collaborative grid project, various resources such as high performance computing systems (HPC) and satellite based communication systems have been committed by different centers of C-DAC and GARUDA partners. The total computational resources available today on Garuda are approximately 65 Teraflops.

A dedicated Grid monitoring and management center at C-DAC, Bangalore helps in managing and monitoring all the components in the Grid. State-of-the-art display walls and advanced software like Paryavekshanam developed at C-DAC help in effectively monitoring the health and utilization of various components of the Grid. Applications of national importance that require aggregation of geographically distributed resources have been operational on the GARUDA grid. Resource intensive applications from various domains of e-Science such as Bio-informatics, Astrophysics, Computer Aided Engineering, Weather modeling and Seismic data processing—have been provisioned on the operational grid.

2.2.7 *Linking rural training institute*

Zila Panchayat, Dantewada in the district head quarters Dantewada, has established a Rural Training Institute recently. Motive of this institute is to provide trainings related to skills, skill development and upgrading etc. to the rural youth, artisans and persons involved in the system. Pune based institution Indian Institute for Science Education and Research (IISER) Pune had come forward with different kinds of projects for the rural youth, children and artisans of the district, through which periodic training classes are to be conducted for the participants of the district through video-conferencing facility. Thus a videoconferencing set up to cater the training needs of not less than 100 persons a time is felt necessary. Zila Panchayat Dantewada came forward to

bare the expenditure that would involve insetting up in the VC facilities.

NIC district centre had provided a high-speed connection to this node from Zila Panchayat, which is already linked in LAN of NIC through OFC connection. NIC district centre had further coordinated with IISER Pune and Zila Panchayat in selecting the needed hardware and establishing the VC connectivity between RTI Dantewada and IISER Pune.

3 Concluding remarks

E-Infrastructure is a moving target. One can configure the technology platforms to be flexible to meet the common objectives. A process to define the eco-system for interaction on an on-going basis is perhaps the way to go. Such a process should obviously be adjustable to policy requirements dynamically. National Knowledge Network experience underscores this reality.

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