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Role of the public ICT networks in facilitating innovation: Lessons from India

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Role of the Public ICT Networks in Facilitating Innovation¹: Lessons from India²

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Background

National competitiveness is largely driven by leadership position in Science and Technology. In a scenario of increasing competition intensity and a growing share of knowledge based economy, it is important that nations have the infrastructure and processes at the highest level that support technological innovation, the key driver for sustaining leadership in these areas. While earlier geographical clustering based on specialization of localized expertise in specific domains was a hotbed of innovation as exemplified by the software clusters in the Silicon Valley, this pattern is now changing (Asheim and Coenen, 2005; Huggins, 2008). Communities of interest linked by/on high speed networks working collaboratively to solve complex and large problems are the emerging scenario for future growth in science and technology. For example, significant scientific work is being done by large geographically dispersed teams, using equipment that is extremely expensive and localized but the data analysis is being done in distributed teams as in the Large Hadron Collider or the Human Genome Project³.

¹ I would like to thank UKIERI (UK-India Education and Research Initiative) for funding the research project.

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³Source: http://en.wikipedia.org/wiki/Big_Science, accessed on May 6, 2013

Increasingly, new knowledge and innovation is driven by sources both within and outside the organization and collaborative principles such as open source and open innovation have emerged to facilitate cross organization development of new knowledge and bring together a variety of perspectives in new knowledge creation and innovation.

However innovation and new knowledge creation would require going beyond the access and availability of knowledge. It would require support for tools for collaboration such as tools to structure and analyze knowledge. Since the structuring and analysis of knowledge is domain specific, this may require creation and dissemination of domain specific tools. Going one step further, the tools need to be verified and validated. Further, for groups that wish to adopt Open principles would require tools that support such collaboration.

Publicly provided national ICT infrastructure is seen as a key driver of supporting such innovation by providing high speed connectivity and access to high performance computing to the possibly geographically dispersed community of researchers. Several countries have such Research and Education networks, notably the Indian National Knowledge Network (NKN) and UK's Joint Academic Network (JANET). NKN provides high speed gigabit infrastructure support to geographically dispersed, publicly funded academic and research centres. NKN also provides connectivity to other such global networks such as GLORIAD (Global Ring Network for Advanced Applications Development)⁴ and GEANT⁵. JANET in UK is a high speed network that connects all further and higher education institutions. It not only provides support for high performance computing, it also provides advisory services for voice, video and multi-site connectivity⁶.

Objectives

Given the above characteristics of innovations in science and the role and features of a publicly funded national ICT infrastructure, this paper focuses on: a) what are the critical success factors in designing national ICT infrastructure to support innovation and b) How do the roles of various

⁴ Source: <http://www.gloriad.org/gloriaddrupal/>, accessed on May 6, 2013

⁵ Source: <http://www.geant.net/Pages/default.aspx>, accessed on May 6, 2013

⁶ Source: <https://www.ja.net/>, accessed on May 6, 2013

stakeholders change as the network evolves from supporting knowledge dissemination to include innovation?

Methodology

This paper adopts the case based approach advocated by Eisenhardt (1989) and Yin (2003). It adopts the specific context of one of the “model projects” of NKN - the Open Source Drug Discovery (OSDD) that is designed as a collaborative platform for drug discovery (Bhardwaj, et. al., 2011). The OSDD platform reduces risks and has the potential to dramatically lower the costs of drug discovery. We study OSDD application in relation to the infrastructure, facilities and services provided by NKN. The case study will focus on identifying a) the critical success factors in designing national ICT infrastructure to support innovation and b) how the roles of various stakeholders changed as the network evolved from supporting knowledge dissemination to include innovation. We use the learning from the OSDD project to generalize to future evolution of NKN.

We used primary and secondary sources of data for developing the case. Primary sources of data include interviews with key decision makers in NKN. These were supplemented by secondary data such as literature survey and media reports.

National Knowledge Network

We examine the background and the organizational structure of NKN and see how these dimensions influence the evolution of NKN towards supporting knowledge creation and innovation.

Background

The NKN is a public network that not only connects more than nearly 1000 institutions, it also envisages support for “model projects”. Such projects showcase the technical features of high bandwidth and shared computing resources for collaborative high-end scientific research and applications in nationally identified areas such as Health, Education, Science & Technology, Grid Computing, Bio informatics, and Agriculture. It is also envisaged that NKN will support e-

governance⁷. Appendix 1 gives an overview of NKN, model projects and the grids. Besides the model projects, NKN also aims to connect research groups working on cancer, brain, the Hadron Collider. The participants are not only connected by NKN, they are provided access to distributed high power grid computing facility, called GARUDA provided by another government agency - Centre for Development of Informatics under the Department of Information Technology. The Garuda grid is a project of the NKN that connects to it through 10Gbps link and has computing power of nearly 6000 CPUs. It provides tools for scheduling so that user submitted tasks may be seamlessly scheduled.

Organizational Structure

A government created High Level Committee (HLC) conceptualized the NKN. Another government agency, the National Informatics Centre (NIC) under the Department of Information Technology was designated as the implementing agency. The HLC created the Technical Advisory Committee to develop the action plan for NKN. Appendix 2 gives the organizational structure of NKN.

The Open Source Drug Discovery (OSDD) Project

Process of Drug Discovery

Drug discovery involves drug research, pre-clinical and clinical trials, evaluation and Phase IV studies. This may take about 10-15 years to develop one new drug from the time it is discovered to when it is available for treating patients. The probability of success in identifying molecules of interest is extremely low, as an extremely large number of molecules need to be examined and tested and eventually a very small number may go for pre-clinical and clinical trials. If the selected molecules meet the conditions of success in these trials, then they may go for manufacture. The cost of drug development includes the cost of failure at each of the above stages of identifying relevant molecules and going through the process of selecting the appropriate one. The average cost to develop research and develop each successful drug is estimated to be \$800 million to \$1 billion⁸. These costs vary with the type of drug and whether

⁷ Source: <http://www.nkn.in/>, accessed on May 6, 2013

⁸ Source: <http://www.innovation.org/index.cfm/insidedrugdiscovery>, September 20, 2013

the drug is a new molecular entity which has not been used before in any pharmaceutical product.

The high cost of doing all these steps in the lab, has led to a focus on in-silico models that use complex computational techniques for generating alternative drug molecules, screening and then taking them forward for experimental design.

A large part of the R&D for drug development is done in-house within large pharma companies with little sharing of results or issues. The patenting of drugs and the IPR associated with such R&D helps the companies to recoup their high investments and earn profits for shareholders. Therefore, there has been little focus on drug development for diseases such as tuberculosis (TB) and malaria as these occur mostly in developing countries where pharmaceutical companies do not find it profitable to operate. On the other hand, it is imperative that developing countries find a solution to these problems as the burden due to tropical diseases is very high (Sugumaran, 2012).

Details of OSDD

OSDD is led by government setup Council of Scientific and Industrial Research (CSIR). It is a global initiative with a vision to provide affordable healthcare to the developing world by bringing in openness and collaboration enabling researchers across the globe to work together to solve key challenges in drug discovery for neglected tropical diseases like malaria, tuberculosis, leishmaniasis, etc⁹.

The OSDD project aims to harness the power of high bandwidth ICT infrastructure platform to develop an open innovation model for drug discovery. This was driven by the long lead times and high expenses for identifying new drugs. It is through that open innovation and crowd sourcing that will bring down the cost of drug discovery. To date, the government of India has provided nearly \$12 million funding for the OSDD project.

⁹ Source: <http://www.osdd.net/about-us>, accessed on September 14, 2013

The OSDD ICT resources and the various partnering institutes and individuals contribute a knowledge cluster that works on the principles of open source development and crowd sourcing. The ubiquity of high bandwidth Internet and the resources on the World Wide Web have facilitated this. These principles have led to successful innovations as in the Human Genome Project, Hadron Collider Project, Linux, Android etc.

Drug development in the public sphere with the aim of making all research data publicly available is a novel approach to drug development. The Intellectual Property Regime associated with the project defines the constraints on how such public data may be leveraged for private benefit. The OSDD project allows sharing of “all data, methods, algorithms, for reuse and modifications as per the OSDD license. The information available online on the OSDD portal (<http://sysborg2.osdd.net/>) is regarded as ‘Protected Collective Information’ by the OSDD sign-in license”. The portal embeds algorithm for assigning credits to authors/researchers based on their contributions. All contributions are visualized as “nodes in a semantic network” whose value is determined by the links to the node (Bhardwaj, et. al., 2011).

The OSDD provides a common platform for drug discovery, development, and clinical trials by making biological, genetic and chemical information available to a varied group of researchers ranging from informaticians, wet lab scientists, contract research organizations, clinicians, hospitals and others. Besides databases, the OSDD project aims to make available computational tools and interfaces available for participants. The project aims to conduct clinical trials, one of the most expensive parts of drug discovery with the participation of public funded institutions. Since the project aims to achieve international standards in all aspects, the participating institutions are required to adopt appropriate processes and documentation but also internationally accepted best ethical processes. Those private pharmaceutical industries that are willing to make available the drug on a generic basis that is without IP encumbrances, and hence make it affordable, may participate in the process (Sugumaran, 2012).

The OSDD team recognized that to leverage the potential for collaboration, it would have to provide a common format for all data. This was done through the TBrowse interface and conversion of data to a standard format (Masum, et. al., 2011). To support the different stages of

drug discovery, a project management workflow software and tools and application for lab information management are provided. Members may contribute their own tools or use the existing tools. The OSDD ICT resources are provided in Appendix 3.

The Role of NKN in OSDD Project

The NKN is used by OSDD for connecting the various institutions, experts, students and volunteers across the country on a high bandwidth connectivity. With the high bandwidth connectivity it is possible to access centralized repositories of information maintained by the OSDD. Computational resources to be used in various phases of drug development are developed, maintained and used by the OSDD project are accessible through a common interface¹⁰. Another initiative related to OSDD was OSDDChem resource that aims to create a national repository of a large number of synthetic compounds for screening against TB and malaria. Thus NKN has provided the basic ICT infrastructure for the knowledge cluster associated with OSDD.

Despite the computational resources associated with OSDD, it requires significantly more. The additional computational resources are provided through the public infrastructure: GARUDA. The OSDD uses various tools on GARUDA for seamlessly scheduling jobs submitted across the grid. This grid has become a powerful tool for implementing the OSDD model, since by using it, those participants who did not have access to high power computing could access the same associated with the OSDD. Appendix 4 gives the architecture of OSDD vis-à-vis Garuda and NKN.

Achievements of OSDD

To provide a centralized repository on the Mycobacterium tuberculosis, a basic requirement for facilitating drug development for TB, it was necessary to re-annotate the entire gene sequence. Using open and crowd sourcing techniques, OSDD was able to do it within 4 months, a task that would have required 300 person years of efforts¹¹. By involving college level participants after some initial training and developing proper processes for submission and review of output,

¹⁰ Source: <http://sysborg2.osdd.net/web/guest>, accessed on September 14, 2013

¹¹ Source: <http://nkn.in/nkn-workshop2012/Document/slides/OSDD-NKN.pdf>, accessed on September 14, 2013

OSDD was able to use crowd sourcing and increase the pool of available resources. With an open source approach, the quality of the annotations was assured. A ranking system, based on the quality of uploaded output, ensured that participants submitted high quality output.

While the databases associated with OSDD contained relevant information, there was a need to also establish a framework for developing, storing and disseminating semantic relationships between various data elements using ontological tools. The OSDD project has taken the first step towards creation of domain specific ontologies by having standard formats and terminology for data representation across different sources as mentioned before.

The OSDD platform has been able to operationalize the access to key research findings in various stages from drug target identification to clinical trials. It has also been able to provide tools for computational analysis. So far, 54 molecules had been identified in the pipeline with two in the hit to lead phase. These were being optimized with private partners who would work with public hospitals for the trial phase (Ardal and Rottingen, 2012).

Analysis

OSDD had developed the process and systems infrastructure for development of TB drug which could be replicated for similar problems of neglected diseases in the developing countries. It had demonstrated the feasibility of using public institutions and publicly provided ICT infrastructure for solving complex problem of drug discovery that were traditionally done in the private sector.

Unlike some of the model projects of NKN which have not been deployed in a field situation in a significant way, OSDD has been able to show significant progress on the ground. Key critical success factors have been identification of high potential areas/individuals and support for high bandwidth connectivity. The OSDD project has been initiated in September 2008 which is led by strong vision for drug discovery in neglected diseases using ICT. The tools for sharing and scheduling resources have facilitated the open source collaborative approach. This accelerated the development of high quality tools and new knowledge creation as in the case of annotations of the Mycobacterium. Creation of an appropriate attribution regime has further facilitated contributions from various researchers.

In order to further leverage the ICT platforms, it will be necessary to develop deeper levels of ontologies. This would require collaboration between domain, ontologists and computer experts. Such ontologies have been developed in a number of areas of biological research such as cancer and the brain (Golbeck, et. al, 2003). For example, the National Cancer Institute, USA has developed comprehensive ontologies for cancer by integrating molecular and cancer related information. The thesaurus provides a common reference immunology for this (Sioutos, et. al, 2007). Ontologies help in creation of interoperable systems by providing a common or standard format for various terms and their classification and developing a conceptual model of the relationships among the real world objects (Gardner, 2005). This helps in creation and dissemination of knowledge and provides a semantic basis for analysis of data. While there are some “basic” or “foundation” ontologies, such as classes, objects and processes (ontologies), there are also domain specific ontologies (Gardner, 2005). Such ontologies create a platform for innovations and new knowledge creation by bringing a standardized mechanism for exchange of data, and providing scope for new relationships to emerge.

The rationale for OSDD to develop such ontologies for TB and malaria was that these diseases had received little focus in the developed world and such ontologies do not exist outside of OSDD. OSDD would have to expend significant resources developing such ontologies as it is a complex task. As we foresee, the evolution of OSDD into a global platform will hinge upon making the requisite ontologies robust in the domain of TB and malaria.

Evolutionary Phases in Knowledge Cluster Development

Literature analysis showed that there has been some work in the area of knowledge clusters primarily in the ICT sector. Since ICT development as well as OSDD rely heavily on technological developments and R&D we attempted to apply the life cycle model developed in the former case to the latter. The growth model of knowledge clusters in the context of ICT specifies four stages in the life cycle of knowledge clusters. These are: genesis, development, growth and renewal (demise). In the genesis phase there is expected to be an institutional trigger led by a specific institute and a set of individuals. This attracts the initial group of interested professionals, who probably have prior existing ties. In the development phase, the knowledge

cluster utilizes the informal networks and strong ties to push out entrepreneurs and firms to create new relationships and collaborations. This both broadens and deepens the network linkages. In the growth phase, entities attracted by the knowledge embedded in this network, both in terms of depth and breadth, such as venture capitalist and firms specialized in other services mutually beneficial to the entities in the network and they themselves become a part of the network. In this stage, the ties may become more formalized and may move away from the cluster. With changes in technology and markets, the initial core knowledge bases would need to change. In the demise or renewal phase, those clusters whose processes allow them to adopt newer technologies or product market spaces are strengthened and continue to survive while others may die. The role of continuous development of the human capital and the network's ability to forge new kinds of alliances and interactions are critical to its sustenance (Huggins, 2008).

We see that OSDD was started by CSIR by a team that felt strongly about drug development for neglected diseases as a priority. Using the above model, we see that the OSDD is in the “development” stage of this four stage model. Through the development of databases and tools, knowledge embedded in the initial team was being distributed to a variety of participants. The network also attracted a variety of participants through its crowd sourcing and open source approach. Driven by the outcomes and accelerated by the OSDD project tools, we see that some private companies have shown interest in collaborating for drug manufacture.

Implications for NKN vis-a-vis OSDD Life Cycle

We see that the growth model envisages different types of resource requirements for various phases. This analysis has implications for NKN support to OSDD project during the latter's life cycle. Also, this analysis will help the pave for evolution of NKN's role.

So far, NKN has focused on provision of infrastructure and support for OSDD through tools and applications. However, as the developments in OSDD show, NKN should move away from its current focus on infrastructure provision and support of generic applications for security and authentication to the service aspect and support tools and structures for domain specific knowledge creation and dissemination, such as development of ontologies. Semantic representation will accelerate the knowledge generation process when the “knowledge required

to support the use of an innovation is easily transferable across contexts” (Armstrong, et. al, 2006). Another dimension to consider when examining the growth of knowledge clusters vis-à-vis their scope is that there is increasing recognition that such networks need to be diverse as narrow scope leads to problems. Knowledge transfers in proximate clusters (not in terms of geographical distance but in terms of overlap of content) leads to greater innovation. This would greatly accelerate the development phase.

For the support during the growth phase, it would be important for NKN to evolve mechanisms to share domain specific solutions across various research areas to facilitate innovations by leveraging cross-field developments.

The recognition of the importance and emergence of a knowledge broker – “people or organizations that move knowledge around and create connections between researchers and their various audiences” (Meyer, 2010) is critical, more so in the growth phase, both for the creation of new knowledge and to the innovation process. Such knowledge brokers could also look at common tools and techniques that have been developed in a specific domain for their applicability to other domains. The knowledge brokers not only have cross domain knowledge (such as a person working on brain cancers, who understands the aspect of brain structure, physiology etc. and is associated say with the ontologies related to the brain as well as with those related to cancer) but also have a perspective on computational aspects of creating, storing, and maintaining such ontologies. For example, the China Knowledge Grid Research Group has developed semantic reasoning tools to link for different types of reasoning to describe “understandings of provided resources and background knowledge. The epistemology will accompany the resources, record different understandings, and continue to evolve as people’s understandings deepen” (Zhuge, 2004).

In order for NKN to facilitate the creation of different types of virtual domain specific networks, and create a niche for itself, it would need to focus on the needs of the Indian context. For those areas, where research is not India specific, as for example, in areas such as cancer and brain research, there are already global networks and organizations that have expended resources for the same. It would make sense for Indian researchers to be able to join such existing networks. In

this case, NKN's role would be to provide requisite bandwidth and computational tools for researchers. Those aspects of such research say in cancer, which arise because of the specificity of the Indian context, could be supported by NKN, not only through provision of high bandwidth and computational support across partnering institutions but also through sharing experience of successful projects and the processes adopted by them for maintaining workflow, databases and ontologies.

The above identified processes would lead to an evolution of communities across NKN. The governance structure of the future should reflect the requirements of its different communities. To some extent, the existing governance structure of NKN reflects this as the HLC has representation from the OSDD project. It also has representation from the domains of radio-physics, electronics and nuclear science. But this representation is not formalized as a part of the design. It is not clear that the HLC has a formal design or specified designated positions. For example, one of the objectives of NKN was to develop the brain and cancer grids, then, it should also ensure that there are designated positions for representing large user groups/model projects in the HLC. This organizational structure then must be represented in the Executive and Technical Advisory Committees as well.

Summary

This paper has identified the role of national ICT infrastructure – the NKN in the context of an innovatively design project for a knowledge cluster – OSDD. This may be generalized to and has implications for design and deployment of national ICT infrastructure in India and possibly in other countries.

We identified the critical success factors in the success of the OSDD project vis-à-vis the NKN. Using the life cycle approach to knowledge clusters, the study highlights how NKN would need to move away from an infrastructure provision to a service perspective and further to a knowledge enhancing and innovation outlook. The paper identifies the organizational and technical support requirements for different life cycle phases of knowledge clusters or domain specific networks. It identifies the role of a knowledge broker as critical in the growth phase. The analysis highlights the changes required in the governance and management structures as well.

In summary, the role of knowledge brokers in the NKN would need to be addressed as this aspect has not been deliberated on formally in NKN. The emergence of domain specific representation in higher level committees would need to be formalized.

Further Areas of Work

While literature provides insights on knowledge cluster life cycle in the case of commercial ICT, there is very little work in this area of knowledge networks driven by public and open source approaches. Also there is hardly any work in the area of processes that can contribute to successful transition from one phase to another. This is an area for further research.

References

1. Ardal, C., Rottingen J. A. (2012). “Open Source Drug Discovery in Practice: A Case Study”, *PLOS Neglected Tropical Diseases*, 6(9), e1827. doi: 10.1371/journal.pntd.0001827.
2. Armstrong, R., Waters, E., Roberts, H., Oliver, S., Popay, J. (2006). “The role and theoretical evolution of knowledge translation and exchange in public health”, *Journal of Public Health*, 28(4), 384–389. doi:10.1093/pubmed/fdl072.
3. Asheim, B. T., Coenen, L. (2005). “Knowledge bases and regional innovation systems: Comparing Nordic clusters”, *Research Policy*, 34, 1173–1190.
4. Bhardwaj, A., Scaria, V., Raghava, G. P., Lynn, A. M., Chandra, N., Banerjee, S., Raghunandan, M. V., Pandey, V., Taneja, B., Yadav, J., Dash, D., Bhattacharya, J., Misra, A., Kumar, A., Ramachandran, S., Thomas, Z. (2011). “Open source drug discovery - A new paradigm of collaborative research in tuberculosis drug development”, *Tuberculosis*, 91(5), 479-86. doi:10.1016/j.tube.2011.06.004.
5. Eisenhardt, K. M. (1989), “Building Theories from Case Study Research,” *Academy of Management Review*, 14(4), 532-550, October, 1989.
6. Gardner, S. (2005). “Ontologies and semantic data integration”, *Drug Discovery Today*, 10(14), 1001–1007, July 2005.
7. Golbeck, J., Fragoso, G., Hartel, F., Hendler, J., Oberthaler, J., Parsia, B. (2003). “The National Cancer Institute's Thésaurus and Ontology”, *Journal of Web Semantics: Preprint Server*, 1(1).
8. Huggins, R. (2008). “The Evolution of Knowledge Clusters: Progress and Policy”, *Economic Development Quarterly* 2008 22: 277, DOI: 10.1177/0891242408323196.
9. Masum, H., Schroeder, K., Khan, M., Daar, A. (2011). “Open Source Biotechnology Platforms for Global Health and Development: Two Case Studies”, *Information Technologies & International Development*, 7(1), 61–69, 2011.

10. Meyer, M. (2010). "The Rise of the Knowledge Broker", *Journal Science Communication*, 32(1), 118-127.
11. Sioutos, N., Coronado, S., Haber, M. W., Hartel, F. W., Shaiu, W., Wright, L. W. (2007). "NCI Thesaurus: A semantic model integrating cancer-related clinical and molecular information", *Journal of Biomedical Informatics*, 40(1), 30–43, February 2007.
12. Sugumaran, G. (2012). "Open Source Drug Discovery- redefining IPR through open source innovations", *Current Science*, 102(12). June 25, 2012.
13. Yin, R. (2003). "Case study research: Design and methods" (3rd ed). *Thousand Oaks, CA: Sage*.
14. Zhuge, H. (2004). "China's E-Science Knowledge Grid Environment", *IEEE Computer Society*, 19(1), Jan/Feb 2004.

Appendix 1: Overview of NKN, model projects and the grids

NKN has connected 1059 institutions and aims to connect over 1500 institutions/ organizations/laboratories under various categories throughout the country. The NKN enables collaboration among researchers from different entities like GLORIAD (Global Ring Network for Advanced Application Development), TEIN3 (Trans-Eurasia Information Network), GÉANT (The Pan-European Education and Research Network), CERN (European Organization for Nuclear Research) etc. To encourage the usage of the network among these institutes, NKN has come up with the concept of Model Project. NKN has funded almost 20 such projects out of which today seven projects have shown significant progress.

Key **Model Projects** are:

- 1) “**CollabCAD**¹²: It is a 3D CAD/CAM Software system for collaborative design and development of industrial designs. It provides a total solution from product design, numerical control, visualization, simulation, analysis to content management, workflow and office automation. CollabCAD is an initiative of NIC, DIT, Bhabha Atomic Research Centre (BARC, Department of Atomic Energy<<http://barc.gov.in/>>) and Vikram Sarabhai Space Centre (Department of Space, VSSC<<http://www.vssc.gov.in/internet/>>)”. It is open source software which is free to download and used by anyone.

- 2) “**CollabDDS**¹³: The project is “Network Enabled Medical Diagnosis and Education in Skeletal Imaging using X-Rays”. The primary objective is to connect Primary Health Centres with expert radiologists/ doctors and dentists at medical/ dental colleges and hospitals using suitable ICT tools and channel for real time radiological data transmission. This platform would enable physicians at remote level PHC’s to have real time radiological diagnosis for their patients. 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”.

¹² Source: Excerpted from <http://nkn.in/collabcad.php>, accessed on September 14, 2013

¹³ Source: Excerpted from <http://nkn.in/collabDDS.php>, accessed on September 14, 2013

- 3) **E-Foundry¹⁴**: It provides teachers, students and casting industry professionals free access to teaching content in casting design and simulation developed at IIT Bombay. The project aims to meet the technical human capital requirement of the metal casting industry, by freely providing the resources online like lesson videos, online simulation lab, reference material including papers, case studies, casting videos etc.
- 4) **eMedical Classroom**: The main objective of the project is to help the students from other medical colleges to have similar standard of teaching as available to students studying at nationally leading institutions.
- 5) **“Indian Integration with Global Imaging System via McGill Linkage, National Brain Research Centre (NBRC), Manesar**: This project is to develop a national imaging networking model between NBRC / its linked institutions and McGill University (MNI)/its linked institutions for using the Canadian and Global Brain facilities. It involves computational imaging analysis and telemedicine with special references to epilepsy, dementia and stroke which are the neurological dysfunction with maximal morbidity in India”.

Grids on NKN

- **“CANCER grid¹⁵**: Cancergrid is an initiative involving scientists at the Universities of Oxford and Cambridge, working together to reduce the cost of clinical research, and to increase its value through effective data sharing. Its build upon the success of a four-year project funded by the UK Medical Research Council to address a wider range of scientific goals, with support from Microsoft Research”.
- **“GARUDA grid¹⁶**: GARUDA is Grid Computing initiative of C-DAC to allow access for scientific and academic institutions to the aggregation of HPC clusters from various C-DAC centres and partners, comprising now over 6000 CPUs (~70 Terraflops) and

¹⁴ Source: Excerpted from <http://nkn.in/efoundry.php>, accessed on September 14, 2013

¹⁵ Source: Excerpted from <http://www.cancergrid.org/>, accessed on September 14, 2013

¹⁶ Source: Excerpted from <http://nkn.in/garudaoverview.php>, accessed on September 14, 2013

terabytes of mass storage to provide distributed data. Most of the partners of Grid GARUDA have already migrated to the NKN. Garuda Grid is now powered by NKN - a highly reliable and secure national optical fibre backbone”.

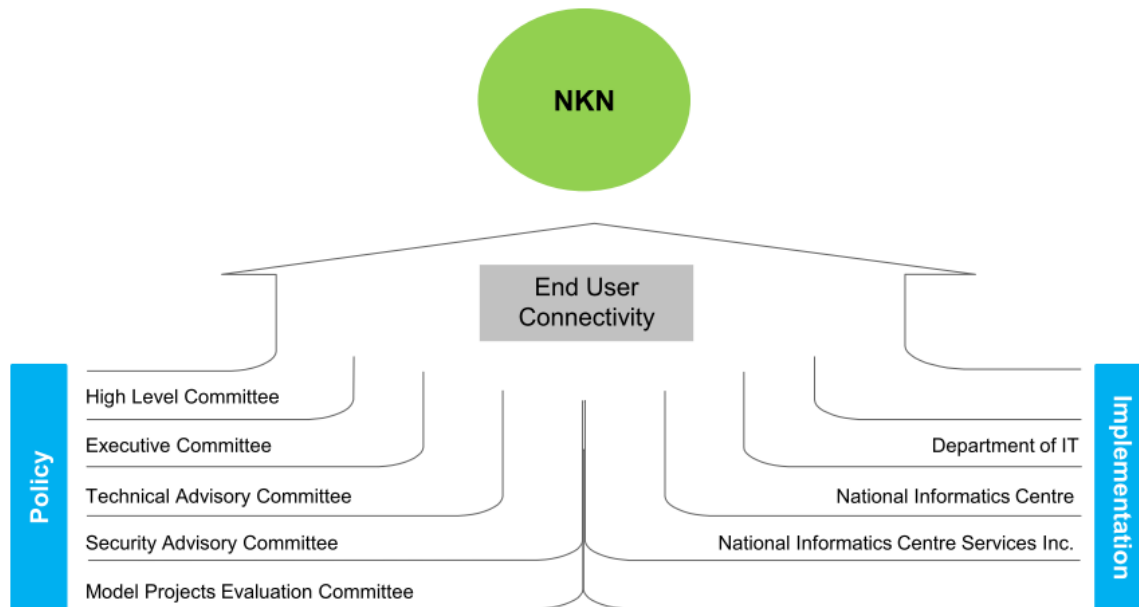
- **“WLCG (Worldwide LHC Computing Grid)¹⁷**: The Large Hadron Collider (LHC) is a large scientific instrument near Geneva, spanning the border between Switzerland and France about 100 m underground. It is a particle accelerator used by physicists to study the smallest known particles, the fundamental building blocks of all things. The Large Hadron Collider 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 analyse 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).

NKN currently connects two Tier-2 centres namely Variable Energy Cyclotron Centre (VECC) and Tata Institute of Fundamental Research (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. NKN also provides multi-gigabit connectivity to the European grid”.

¹⁷ Source: Excerpted from <http://nkn.in/lhc.php>, accessed on September 14, 2013

Appendix 2: Organizational Structure of NKN¹⁸

“The government of India has constituted a HLC for establishment of NKN. NIC has been designated as implementing agency for NKN. The vision of NKN has been translated into an action plan by the Technical Advisory Committee (TAC) set up by the HLC. The Executive Committee would be responsible for taking decisions on implementation issues”.



¹⁸ Source: Excerpted from <http://nkn.in/forcebehind.php>, accessed on September 14, 2013

Appendix 3: ICT infrastructure for OSDD¹⁹

“Sysborg 2.0 – Collaborative resource portal

Sysborg is a collaborative online platform for exchange of ideas, data and resources. The portal contains resources and tools to effectively organize collaborations, mine and analyze information”.

OSDD Chemistry Outreach Program: OSDDChem

OSDDChem is the open collaborative initiative to create a national repository by synthesizing large number of compounds for screening against TB and Malaria. OSDDChem aims at tapping in the potential of organic chemists in various academic and research institutes and universities in the country and training undergraduate and postgraduate students in modern synthetic reactions and encourage them to enter the field of research on neglected tropical diseases.

Large Scale Screening Project; 2 Molecules in Hit to Lead Phase

OSDD, besides encouraging the synthesis of novel molecules, also is involved in large scale screening of available databases to identify molecules with anti TB and anti-malarial activity. Under this, Indian Institute of Integrative Medicine (CSIR–IIIM) has screened 20,000 drugs like molecules to identify potential anti-TB molecules. Besides the screening of compounds submitted in OSDDChem, CSIR-CDRI is also involved in massive screening of in-house molecules to identify potential drugs.

Development of Computational Resources

Computational Resources for Drug Discovery (CRDD <http://crdd.osdd.net>.) is an important module of the in silico module of OSDD designed with the objective to provide computational resources related to drug discovery on a single platform. The community has developed a large number of computational tools that are available in open source mode for drug discovery and development.

¹⁹ Source: Excerpted from <http://www.osdd.net/publications-and-presentations>, accessed on September 9, 2013

Mtb Genome Re annotation

OSDD focus on the identification of novel drug targets in Mycobacterium tuberculosis. In this regard, over 800 student researchers of the OSDD community, contributed to the Phase I of the Connect2Decode programme in December 2009. They undertook the enormous task of re-annotating the genome of M.tb that involves the identification of elements in the genome and attaching biological information to these elements. This exercise helped the community gain more insight into the biology of the bacterium.

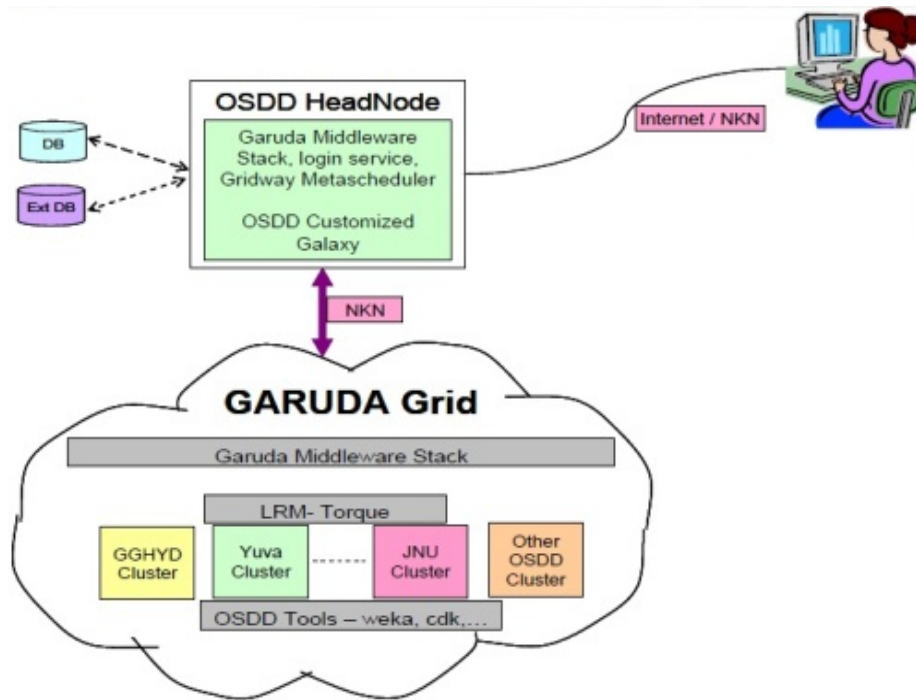
Open Access Clone Repository: A Crowd Sourcing Initiative

One of the objectives of OSDD is to establish a centralized repository of high-quality verified research clones of M. tuberculosis that can be distributed to OSDD scientists to aid in their research.

Cheminformatics and Chemical Data mining

This innovative research group with more than 400 registered members seeks to address the challenge of identifying molecules available in large online digital repositories with desired set of drug like properties, using computational tools”.

Appendix 4: OSDD vis-à-vis Garuda and NKN



(Source: Excerpted from <http://nkn.in/osdd.php>, accessed on September 9, 2013)