NRENs AS ICT INFRASTRUCTURE TO SUPPORT e-SERVICES AT UNIVERSITIES: A CASE OF WITS UNIVERSITY

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Abstract

The research report examined the value brought by NRENs, by investigating the utilization of the South African National Research Network (SANReN) at the University of the Witwatersrand (Wits). It explored the SANReN as the main international bandwidth service for the university and assessed how the university is able to efficiently provide a range of e-services in scientific research through the NREN.

Wits scientists engaged in data intensive research and international research collaboration shared the view that the SANReN infrastructure is critical to such work, however due to infrastructure limitations at university level, it is sometimes difficult to maximize the value of this dedicated network, where data storage capacity is low. A wide range of e-services, such as grid computing, use SANReN, but are limited by international bandwidth. A further problem is the high cost of international bandwidth, particularly as the demand for bandwidth increases with the amount of data required in scientific research. The biggest challenge is the growth of demand and the ability to meet this demand.

As scientific research relies on real time data, but experiences problems with data storage, advanced data infrastructure is needed in the form of a medium sized data centre, which would be used for storing and transferring large data sets and terabytes of data in and out of the country.

In conclusion, although SANReN makes it possible for big science projects to take place at universities, it is somewhat difficult to measure the value that SANReN brings, due to the many limitations mentioned. Therefore a matrix to measure outputs and value of SANReN is required, as proposed in Chapter 6 of this research report.

Declaration

I declare that this research report is my own unaided work. It is submitted for the MA in ICT Policy and Regulation at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any other degree or examination in any other university.

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Date

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This research is dedicated to my late father Pakishi Emmanuel and brother Mokone Justice.

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List of Abbreviations

APAN	Asian Pacific Advanced Network
CERN	European organization for Nuclear Research
CHPC	Centre for High Performance Computing
CNS	Central Network System
CSIR	Council for Scientific and Industrial Research
DANTE	Delivery of Advanced Technology to Europe
DHET	Department of Higher Education and Training
DIRISA	Data Intensive Research Initiative for South Africa
DST	Department of Science and Technology
EASSy	East Africa Submarine Cable System
eLSI	eLearning, Support and Innovation
e-VBLI	Very Long Baseline Interferometry
GEANT	Pan-European Research and Education Network
HEIST	Higher Education Internetworking Solution
ICT	Information and Communications Technology
KENET	Kenya Education Network
NICIS	National Integrated Cyberinfrastructure System
NREN	National Research and Education Network
NRF	National Research Foundation
RedCLARA	Latin American Advanced Networks Cooperation
SADC	Southern African Development Community
SALT	South African Large Telescope
SANReN	South African National Research and Education Network
SARUA	Southern African Regional Universities Assosiation
SEACOM	African Cable System
SKA	Square Kilometre Array
SNA	Systems Network Architecture
TENET	Tertiary Education and Research Network of South Africa
UbuntuNet Alliance	UbuntuNet Alliance for Research and Education Networking
UniNET	Universities Network
WACREN	West African Research and Education Network
WACS	West Africa Cable System
WIReDSpace	Wits Institutional Repository on Digital Space

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Chapter 1: NREN as ICT infrastructure and bandwidth provider for collaborative research

1. Introduction

National Research and Education Network (NREN) infrastructure brings connectivity to the communities of researchers, academics and students alike. The NRENs are high speed networks for the research community to collaborate with each other across countries and continents (Kotecha, 2009). The research collaboration with partner countries made possible by NRENs enables complex research initiatives to be undertaken (Abrahams, Burke, Gray, & Rens, 2008).

NREN plays a significant role of high-speed network connectivity to the universities, making it possible for the researchers, academics and students to connect and participate in collaborative research with their peers across the globe. University researchers and policy makers are able to make use of e-services supported by NREN to solve complex scientific problems in collaborative research and implement research-based responses to those problems. Therefore access to various e-services is a commodity for research and the requirement for data management in scientific research.

The NREN functions as a sophisticated network that makes it possible for high-speed Internet connectivity needed when conducting research projects, delivering lectures, conducting seminars, meetings and conferences. The objective of NREN thereof is provision of connectivity to multiple universities.

In South Africa, the South African National Research and Education Network (SANReN) is an ICT infrastructure that provides network connectivity to local universities (SANReN, 2013). The main drive for SANReN is to eliminate the digital divide thereby giving local universities the same access and opportunity to participate in international projects. SANReN connects to GEANT, the European and other regional research and education network (RREN) and the rest of the world (SANReN, 2013).

However the benefits of having NREN at the university have not been identified. In other words there has been little, if any, sustained research that aims to identify the benefits and value of NREN for South African universities once they are connected to SANReN.

1.1 SANReN, TENET, CHPC and key concepts pertaining to NRENs

SANReN plays a significant role in inter-institutional research collaboration through the provision of bandwidth infrastructure and the flow of terabytes and petabytes of data between multiple universities in South Africa (SANReN, 2013). SANReN "forms part of the comprehensive South African government approach to cyber infrastructure to enable successful participation of South African based researchers in the global knowledge production effort" (SANReN, 2013; p. 8).

According to the Centre for the Scientific and Industrial Research (CSIR, 2013), SANReN emerged as a high-speed high bandwidth network aiming to connect more than 200 research and tertiary sites around the country, as well as with international research and education organisations around the globe.

The SANReN initiative was conceptualized in 2003 in partnership with the then Department of Arts, Culture, Science and Technology (SANReN, 2010). SANReN and Centre for High Performance Computing (CHPC) were discussed and approved in Cabinet as part of the research infrastructure budget of the Department of Science and Technology (DST). The responsibility for planning and implementing the SANReN project was given to the Meraka Institute (CSIR, 2013) in 2007. The CSIR was involved with the process of establishing the CHPC to ensure a comprehensive and holistic approach to cyber-infrastructure development (SANReN, 2010).

Before SANReN and TENET, the international computer network FidoNet was used for cross-university communication in South Africa. Later in 1993 UniNet was established in South Africa (Lawrie, 1997), which started as an SNA[1]-based network(Lawrie, 1997, p. 3), linking some of the research universities in the country (Kemp, 1996, p. 26). In 1992, it was converted to TCP/IP[2] technology and has since then evolved into the

[1] Systems Network Architecture

[2] Transmission Control Protol/ Internet Protocol

academic and research network in the country. UniNet was funded by the National Research Foundation (NRF) (Lawrie, 1997) until such time the universities started an organization called Tertiary Education and Network of South Africa (TENET). The organization put all the needs of the universities together and bought connectivity from Telkom. TENET bandwidth funding came purely from the universities.

All the universities, technicians and many research institutions were linked through UniNet (Lawrie, 1997, p. 4).The vision of the UniNet Board was to transform the network into a South Africa National Research and Educational Network (SANReN), which would help in UniNet efforts to expand as a gateway to the Internet for neighbouring countries (Kemp, 1996, p. 26). Table 1 below highlights the chronology of SANReN infrastructure, connectivity, funding and services dating back from 1988 to 2014.

Table 1: Chronology of SANReN infrastructure, connectivity, funding and services

Year	Developments
1988	FidoNet system operational and was used by universities across the world including in South Africa
1991	UniNet was established, funded by the Foundation for Research and Development (FRD) now called the National Research Foundation (NRF)
1998	In 1998, NRF was established through the National Research Foundation Act No 23 of 1998. The main purpose is to support research through funding, human resource development and the provision of National Research Facilities in all fields of natural and social sciences, humanities and technology at higher institutions of learning
2000	TENET was established by universities to buy bandwidth from Telkom as a consortium.
2001	TENET and Telkom signed HEIST (the Higher Education Inter-Networking Solution) Agreement.
2004	New Second Generation Inter-networking Solution for Higher Education and Research Institutions- the GEN2 Agreement was signed between TENET and TELKOM replacing HEIST
2004	Submarine cable operator – Seacom(10gb/sec)

2009-	Connectivity of SALT (Southern African large Telescope) to SANReN backbone
2013	Connectivity of SKA (Square Kilometre Array) to SANReN backbone
	Science councils, higher education institutes (23) connected to 10Gb/sec SANReN backbone
	Managed bandwidth leased from Telkom for 10 years
	Implementation of dark fibre infrastructure in the metros for SANReN
	Establishment of SANReN PoPs in rural and urban area.173 sites connected across the country.
	Department of Higher Education (DHET) established and funded rural campus connectivity with initial investment of R28 million
	This program connected FET colleges and high schools.
	WACS-High Energy Physics Group (SA) participates in CERN project
2014	The following are e-services that are made possible through SANReN. -Eduroam -PerfSONAR -Light path services -Federated identity management -CA (certification authority),DIRISA -Mirror sites -SA Grid -CSIRT (Cyber Security)

Sources: Lawrie, 1997; Kemp, 1996; Wierenga & Florio, 2005; Mbale, Kadzamina, Martin, & Kyalo, 2012; SANReN, 2013

TENET operates the core network of SANReN. TENET was formed for “collaborative internetworking” of the universities, science councils and beneficiary institutions (TENET, 2013). It started as the “Section 21 Company”, with the amendment of the company’s act and reorganised as a non-profit organisation. It was never created for commercial purposes, its beneficiaries are solely the academic and research institutions.

While TENET bears the costs of operating SANReN, the cost of deploying and maintaining SANReN are borne by the DST through Meraka and not recovered from TENET or the institutions (TERENA, n.d.)

1.2 History of SANReN infrastructure

At the beginning of 2005 the Minister of Communications initiated a process regulating the information and communications technology sector whereby the Independent Communications Authority of South Africa (ICASA) issued new licenses to the new operators in the industry. At that point in time, the CSIR had been interacting with the DST to discuss the possibility of creating a network for TENET. The proposed network would effectively take away the cost burden on institutions to fund the infrastructure (SANReN, no date).

The CSIR and DST reached an agreement to create SANReN and the whole process allowed CSIR Meraka to buy infrastructure instead of leasing it (CSIR, 2013).

SANReN started off as a small project in CSIR Meraka and developed into the massive network project it is today. The network consists of a core network, procured and leased from Telkom on a 10-year basis and put in place by the CSIR Meraka team (CSIR, 2013). The network spans all the major metros though Pretoria, Johannesburg, to Bloemfontein, Cape Town, Port Elizabeth, East London and back up to Johannesburg. (CSIR, 2013).

1.3 Background to TENET

The first South African IP address was granted to Rhodes University in 1988(Lawrie, 1997, p. 5). On 12 November 1991, the first IP connection was made between Rhodes' computing centre and the home of Randy Bush in Portland, Oregon (Lawrie, 1997, p. 4). By November 1991, South African universities were connected through UNINET to the Internet. Commercial Internet access for businesses and private use began in June 1992 with the registration of the first .co.za subdomain (Lawrie, 1997, p. 4).

UniNET bought capacity for universities in South Africa through Telkom. UniNET existed up to late 1990’s and was under the control of the NRF. At that stage, the universities got a little more concerned because they needed the vehicle for capacity or else they had to buy the capacity individually. The discussions resulted in the creation of

TENET in early 2000. It is a non-profit company which has membership with all science councils and universities that are using their services.

TENET's primary goal was to do what UniNET was doing. They started buying capacity on behalf of institutions from Telkom. This was the case until 2004 at the time Neotel, the Second Network Operator, was entering the market and the network infrastructure, which was all leased by TENET moved from Telkom to Neotel. The infrastructure moved over to Neotel and named GEN2 (CSIR, 2013).

TENET's main purpose is "to secure, for the benefit of South African universities and associated research and support institution, Internet and information technology service, including the management of contracts with service providers; ancillary operational functions in support of service delivery; and the provision of other value-added services as may from time to time be needed in support of higher educational sector in South Africa" (TENET, 2010, p. 2). TENET is a service organisation and is committed to service excellence to services that are strongly aligned and consistent with the organisational requirements of the user community.

TENET operates the SANReN Network under the terms of a Collaboration Agreement with the CSIR. The network operated by TENET includes a 10 Gb/s circuit to London on the SEACOM cable system(Msangawale, Otaigo, & Koloseni, 2011), 10 Gbps on the WACS cable system, redundant backhaul circuits from the SEACOM landing station in Mtunzini, the SANReN 10 Gbps backbone, SANReN fibre rings in Johannesburg, Pretoria, Cape Town and Durban, the GEN3 MPLS[3] network and Metro-E circuits provided by Neotel, IP Connect bandwidth into the ADSL[4] cloud, and various optical fibre and wireless access circuits (Mutula & Mostert, 2010).

TENET operates transit and peering links in Cape Town, Johannesburg, London and Amsterdam, including a connection to the European research and education network,

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[3] Multicontrol Label Switching

[4] Asymmetric Digital Subscriber Line

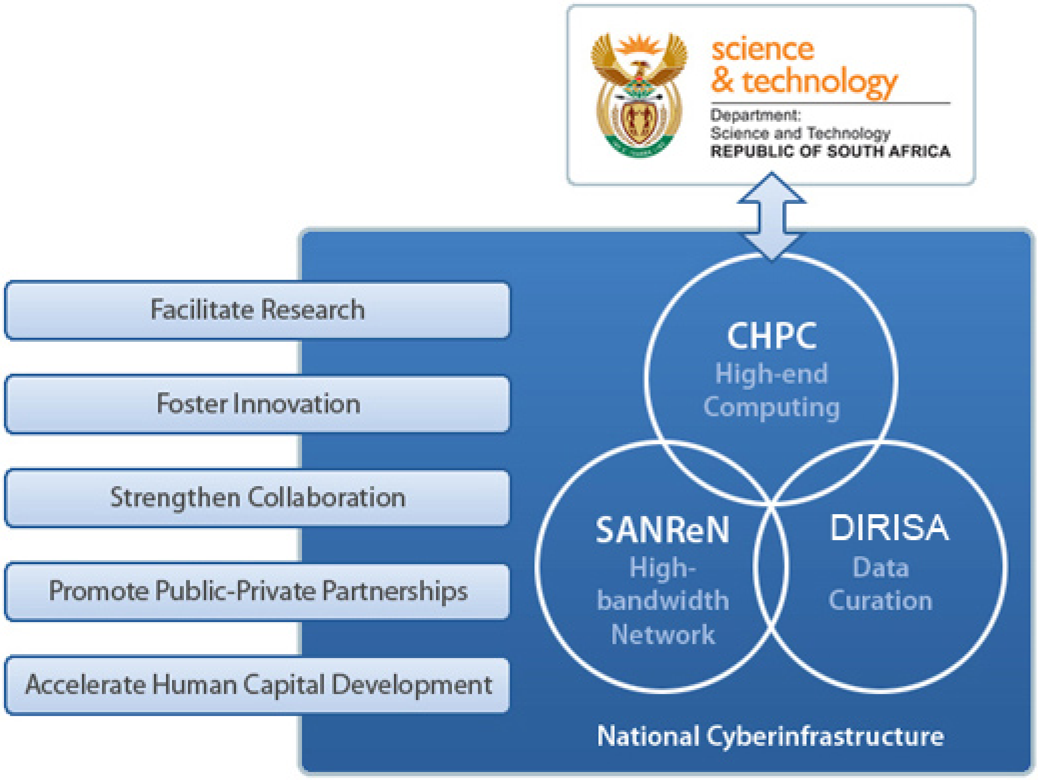
GÉANT. TENET also operates UbuntuNet gateways in Mtunzini, London and Amsterdam under contract to the UbuntuNet Alliance (Hotel, 2008).

1.4 Department of Science and Technology cyber initiative

The Department of Science and Technology (DST) established the cyber infrastructure initiative that complements the Centre for High Performance Computing (DST, 2013a). In 2012, the DST realised that they needed to build coherence in their cyber infrastructure and commissioned a review by an international panel and released a report of the International Committee for the Development of South Africa's National Integrated Cyber Infrastructure System (NICIS) at end of 2013.

One of the recommendations of NICIS was that there should be a structure for each entity and each of those entities should have a manager (DST, 2013a). The NICIS vision is to take a leadership position in the provision of a comprehensive cyber infrastructure which is essential to 21st century advances for South Africa in research, education and innovation (DST, 2013a). SANReN is part of the DST cyber structure portfolio together with the Centre for High Performance Computing (CHPC) and the Data Intensive Research Initiative for South Africa (DIRISA) (DST, 2013a) as per Figure 1.

Figure 1: National Cyber Infrastructure

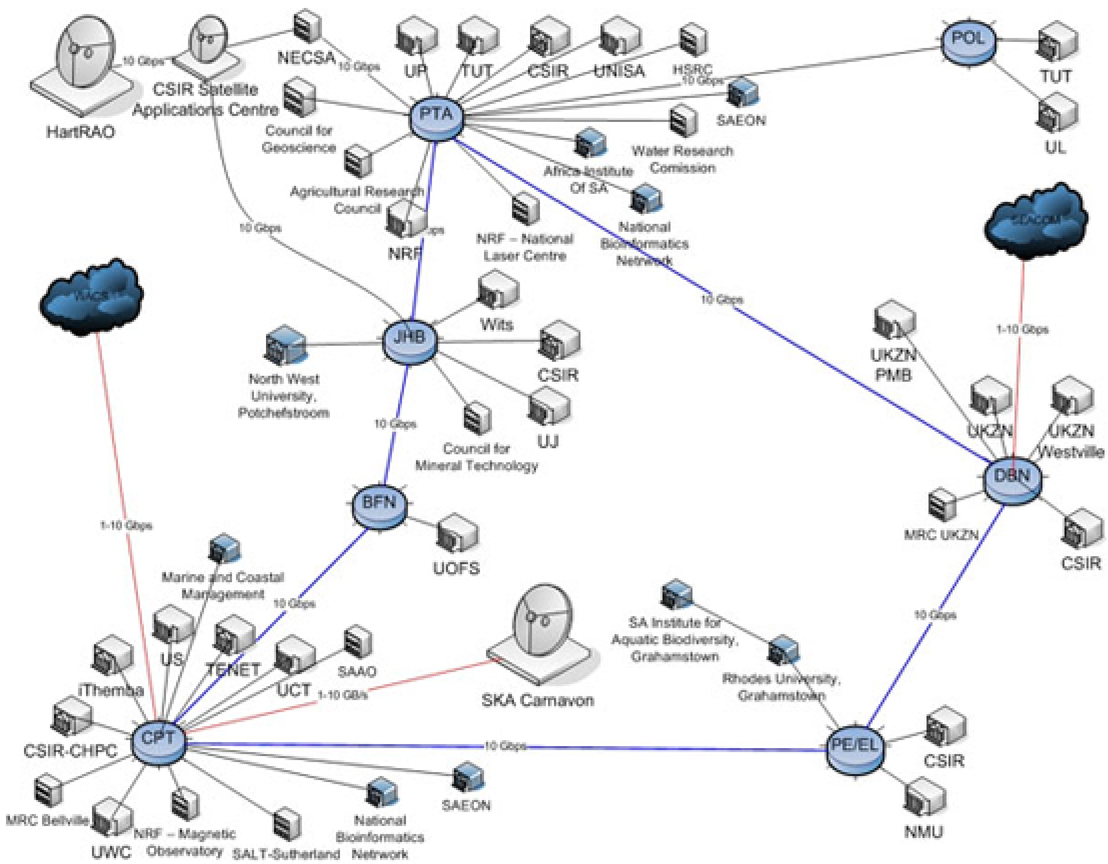


Source: Department of Science and Technology, 2013

1.5 SANReN connectivity

SANReN made priority on backbone extensions and 10GB connectivity. The map in figure 2 illustrate the SANReN prioritized backbone extensions to connect on the 10GB network and exting Point of Prescence and few still being constructed in Limpopo, Free State, Northern Cape and Western Cape provinces.

Figure 2: SANReN Points of Prescence



Source: SANReN, 2010

According to a Meraka Institute centre manager, SANReN high bandwidth network is important because as a national backbone it “gives institutions access to facilities such as Centre for High Computing Centre in Cape Town, enables the establishment of a national computing grid, and allow for a large volumes of data transfer among institutions- typically a requirement of the research community” (CSIR, 2009). The infrastructure is well developed and most universities have access to optical fibre links while others are connected via microwave links or remote areas still use VSAT.

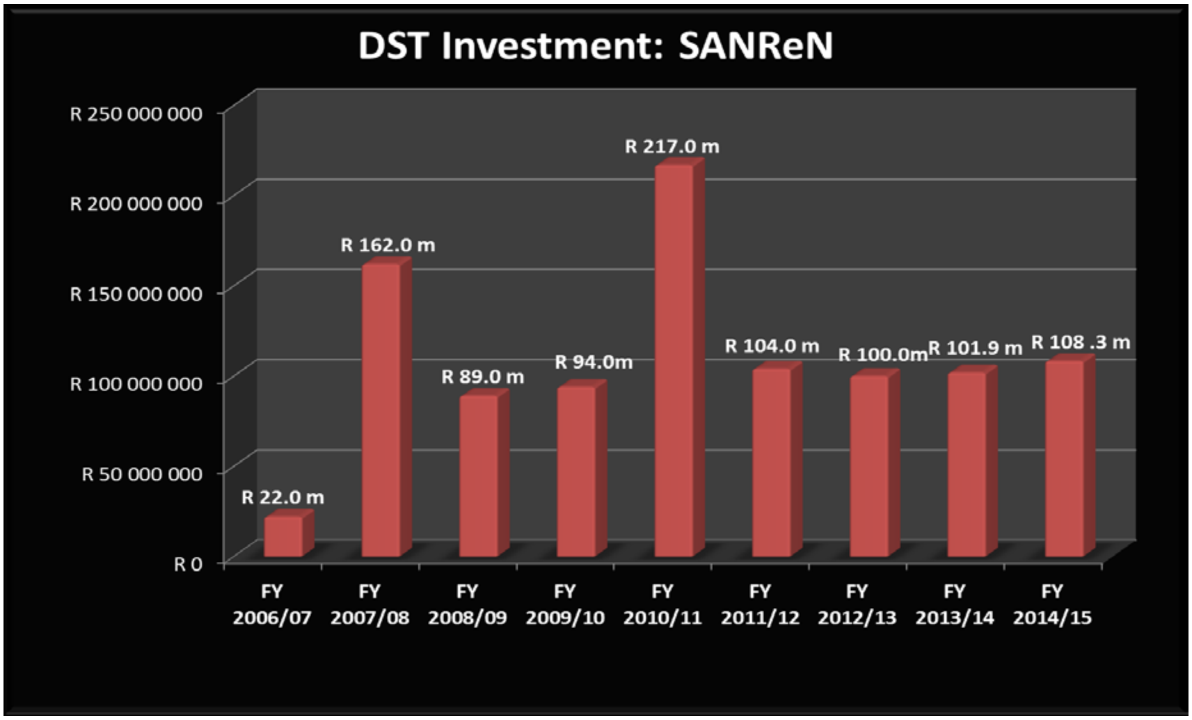
1.6 The SANReN funding

SANReN provides easy connectivity for researchers to produce research and form research partnerships nationally and internationally. As a result there has been an increase in investments value for SANReN.

The National Treasury provides funding to DST, which then signs a contract with CSIR to do the procurement for fibre. CSIR Meraka reports to DST on a quarterly and annual basis. A funding agreement to the value of R64 million (including VAT) was signed with the NRF. These funds were used to co-fund the installation of the 10Gbps telecommunications network (DST, 2013b). CSIR received an additional R55 million (including VAT) from the NRF specially to co-fund the installation of the network to remote areas (CSIR, 2013). Apart from the investment in national network, the DST also invested about R600 million in the acquisition of capacity on the West Coast Cable and on the East Coast Cable. The capacity is paid for by the universities. They went into contract among themselves using TENET to sign an agreement, which is about 10GB/sec to get capacity on the East coast. Below is the DST investment in SANReN between 2007 and 2014/15 financial year (Adams, 2014).

The value of investment in SANReN project is estimated to be above a R1 billion. Initially SANReN started in 2006 with R22 million, 2007 with R162 million,2008 with R89 million,2009 with R279 million and it was the same year DST invested in SALT and SKA site connectivity ,hence the spike, 2011 with R104 million. In 2012 an amount of R99.9 million was invested, R108 million in 2013 and R108 million in 2014/15. The investment is sustained at about R100 million a year on average. The funding for WACS international facility alone was R600 million. The R600 million is being invested for international activity (DST, 2014). Figure 3 below illustrates the DST investment in SANReN from 2006 until 2014.

Figure 3: DST investment in SANReN



Source: Department of Science and Technology, 2014

1.7 University of the Witwatersrand

Wits University (Wits) is made up of the East, West, Medical School, Business School and Education campuses in Parktown. Wits offers various post graduate qualifications including Masters and the PhD programmes in all five faculties and is known for its commitment to high quality research and therefore has a range of professionals, academics and scientists of high reputation in a variety of interdisciplinary fields. The university has faculties and schools, libraries and computer labs and 31125 registered students (Wits, 2013). The number of undergraduate and postgraduate students had steadily increased over the years as demonstrated in the table below.

Table 2: Total number of Wits students headcount enrollment

		2012		2013		2014	
UG/PG	Undergraduate	20 469	67.26%	20 960	67.34%	21 661	66.44%
	Postgraduate	9 619	31.61%	9 798	31.48%	10 607	32.54%
	Occasional	346	1.14%	367	1.18%	334	1.02%
Total		30 434	100%	31 125	100%	32 602	100%
Postgraduate Students	Doctoral Degree	1 424	14.80%	1 539	15.71%	1 640	15.46%
	Master's Degree	5 628	58.50%	5 566	56.81%	5 865	55.29%
	Honours Degree	1 315	13.71%	1 315	13.42%	1 526	14.39%
	Postgraduate Diploma/Certificate	1 378	12.97%	1 378	14.06%	1 576	14.86%
Total		9 619	100%	9 798	100%	10 607	100%
Faculty	Commerce, Law and Management	7 589	24.93%	7 923	25.45%	8 374	25.69%
	Engineering and the Built Environment	5 753	18.90%	6 077	19.52%	6 315	19.37%
	Health Sciences	5 095	16.74%	5 202	16.71%	5 438	16.68%
	Humanities	8 204	26.96%	7 813	25.10%	8 340	25.58%
	Science	3 794	12%	4 111	13%	4 135	13%
Total		30 434	100%	31 125	100%	32 602	100%

Source: University the Witwatersrand, 2014

The key focus areas for research that use SANReN are the High Energy Physics group, the Bioinformatics, Radio Astronomy and Geosciences field of study. As research institution Wits main focus is on conceptualisation of research centres that are focused on scholarly and intellectual work and many other various activities related to knowledge sharing. The Faculties and the Schools focus on teaching, supervision and the strategic research direction of the university, (Wits, no date).

Wits has more dedicated focus on journal articles and peer-reviewed work and do need to utilise the SANReN network in order to stay research active.

1.8 SANReN infrastructure at Wits

Through the SANReN backbone, Wits has access to 10Gbps bandwidth at the four campuses (SANReN, no date). SANReN is responsible for physical infrastructure and operation of the network as regulated through contractual arrangement with TENET. TENET is managing the facility that SANReN provides for Wits and surrounding institutions Wits (no date).

SANReN at Wits is made available through the user level agreement for the service between TENET and the university. The SANReN Points of Prescence (PoPs) are available at all campuses. These four PoPs are on a shared 10Gbps ring network that connects to a major gateway site operated by TENET and hosted by Internet Solutions in Johannesburg (CSIR, no date). There is one break away point for the network located at the Wits main campus, a TENET box where all campuses join the SANReN.

Students and staff are bound by the IT acceptable policy of use. There are two key proxies: the staff proxy and the student proxy. The Central Network Services (CNS) make an allocation of these proxies. Technically there is no distinction made with the allocation of proxy. Therefore the same allocation is made equal for everybody irrespective of their field of research. The researcher in the School of Paleontology, for example, transfers large amounts of data daily but has the same access as someone in the School of Education who would not be required to transfer a lot of data on a daily basis.

1.9 e-Services to enhance collaborative research at Wits University

The number of e-services provided by the NRENs at the universities vary widely for research, teaching and learning. Most of these services involve software development for Science, Engineering and Medicine. In the 1990's the e-services were very few as the Internet access was limited by accessibility and the affordability. Towards the end of the 90's the Internet was mainly used for surfing and emails. With the increasing provision of bandwidth the demand for new e-services to universities became more apparent.

Provision of e-services at the universities have been at the centre of major ICT reforms aimed at developing staff and students to make innovative use of the technology in teaching and learning. At Wits there is an application that is used mainly to facilitate ICT learning and course management, (Wits no, date). The eLearning, Support and Innovation (eLSI) Unit aims to assist staff and students to make excellent and innovative use of ICTs in their teaching and learning (Wits eLSI, no date). eLSI mandate is to ensure that Wits staff and students are supported in their academic activities.

The teaching and learning process is transmitted through an application called SAKAI, which is the interactive, online learning environment. The information available on SAKAI is related to the modules, course-specific and general announcements, course-specific calendars, etc. Depending on how the lecturers decide to use SAKAI, students may be given the opportunity to take part in online discussions, download additional reading material, submit assignments, complete self-assessment activities or even take class tests, semester tests or formal examinations in pre-booked computer labs (Wits, no date).

1.10 Electronic library services a valuable e-service to research

Wits has a wide range of electronic library services that are available to students and staff. (Wits, no date). The Wits library has many initiatives to innovate and improve library e-services (Wits, 2012). As such the digitization initiative includes a wide range of key research and learning resources. One of the areas is the 'Wits Institutional Repository on DSpace (WIREDSPace) collection which was developed over the years (Wits library AR, 2012).

Through SANReN the library is able to provide the e-service to allow students the best innovative experience in library e-services (Wits, 2012). The e-services offered include access to international journal and book databases such as Ebscohost, Science Direct which uses the SANReN capacity to gain access.

1.11 Bandwidth requirements for universities

Many activities that take place at the universities include conducting research, producing and sharing knowledge through formal lectures and library services. University research staff participate in international conferences and make presentations of their respective research projects. However the teaching and research environment brings many challenges, amongst those being bandwidth. University Vice-Chancellors from Higher Education Institutions (HEI's) in South Africa discussed the issues relating to access to high bandwidth and intercontinental collaboration and as Patel (2010) pointed out as higher education evolves in the 21st century, universities require new generation NRENs with capacity, networking, advocacy and managerial capability for the 21st century.

One of the key challenges faced by the universities is that they require resources to tip research collaboration into an era of greater productivity through access to high-speed, low cost bandwidth and dedicated networks (Kotecha, 2009). Even though the 2010 broadband policy for South Africa speaks of universal access to reliable, affordable and secure broadband infrastructure and services by 2020, they did not specify the needs of the universities.

Emerging REN's in Sub Saharan Africa (Kotecha, 2009), Ubuntu network provide universities and research institutions in Southern Africa with access to broadband services and the global Internet on the same level as peers in the developed parts of the world. Ubuntu alliance has been formed to organise the regional backbone for tertiary education and research, via backing from governments and SARUA (Kotecha, 2009), representing all 45 public universities in the SADC region (UbuntuNet, 2012).

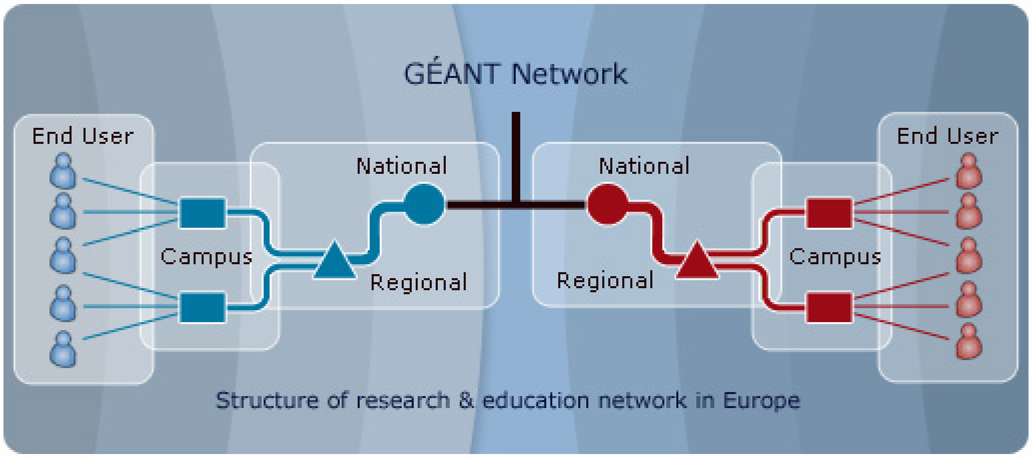
The Internet was incorporated for research and academia. Universities need the high capacity Internet to be able to adopt applications that would be used in the research by students and the lecturers. The challenges however relate to the need for overall funding, and the ability to make ICT services accessible. Universities around the globe are faced with demands for high speed Internet access. For them to cooperate effectively and be able to collaborate with one another there is an issue of capable network facilities.

There is also a need to increase the number of postgraduate research outputs, the issue of international research collaboration in line with practice for other research entities at the universities around the world. Universities in South Africa need SANReN to collaborate in comparative studies with their peers worldwide. The value of the NREN is seen where universities have the power to attract students, do quality research, and provide while remaining sustainable. Once a university enrolls a number of undergraduates and postgraduate students it has the responsibility to provide an environment where they can stay ahead of developments in their chosen areas of interest.

1.12 Global trends and models in national research and education networks (NRENs)

Emerging trends in Africa indicate that when universities drive NREN formation without government intervention, the tendency is to work together to address a common problem-usually the high cost of bandwidth- by pooling the resources like in the case of KENET (Kotecha, 2009). In the early 1990's research and education networking existed only as a small ad hoc arrangements to meet local needs (Roberts, 1992). These were the times of non-inter-working proprietary operating systems and communications protocols. Around the 1990's, some countries started to get more organised projects exploring how to integrate the existing ad hoc facilities into a common set of standard ways of working that could be used on a national or even international basis (GEANT, 2013). The underlying technology that supported these networks was copper wire, owned and operated by monopoly suppliers willing to lease circuits. The cost of leasing a circuit seemed directly linked to the amount of revenue that the line might generate if it were used for telephone calls, and consequently was very expensive. Below is the illustration of how the NREN in Europe is organized.

Figure 4: Cross domain supply of data communications



Source: GEANT, 2010

Most governments recognised the importance of providing their academic communities with good data network services and were willing to provide some funding towards the development. Due to an increase in demand for high-speed Internet connectivity starting as early as the 80's, institutions of higher learning started collaborating on the improved ICT networks. American universities were heavily involved in the development and planning of the NRENs (Roberts, 1992). The high-performance computers and computer networks became the subject of federal research sponsorship in the U.S. for more than 20 years. The broadband connection to the Internet became an essential element in a society with wide economic and social benefit. In every nation, not just the richest, these networks had the same fundamental importance as transport, power or water networks.

According to Patel (2010) through research collaboration using NREN infrastructure universities are able to have increased capacity and lower bandwidth costs. NREN infrastructure serves both research and education to improve research activity of any country. In Latin America, NRENs date back to 2005. The collaboration initiative between several universities led to the formation of continent wide research and education network, RedCLARA, which was made up of the NRENs of Argentina, Brazil, Chile, Costa Rica, Mexico, Uruguay and Venezuela.

1.13 The regional research and education networks, RRENs

Regional research and education networks (RRENs) are designed to operate advanced networks for research and academic collaboration across the world (Kotecha, 2009). They provide the connectivity between the local networks of research and NRENs with higher-education institutions in a country. RRENs provide a unique platform for the development of regional and intercontinental collaborations(Kotecha, 2009).

The RRENs of Europe are more advanced and they have become "the role models for collaborative networking among universities and research institutions of Africa" (UbuntuNet, 2012, p.1). The table below illustrates the RRENs and when they began operating.

Table 3: RRENs

Regional Research and Education Network	**Starting Year**
Delivery of Advanced Technology to Europe (DANTE)	1993
Trans-European Research And Networking Association (TERENA)	1994
Pan-European Research And Education Network (GEANT)	2000
Asia Pacific Advanced Network (APAN)	1997
UbuntuNet Alliance for Research and Education Networking (UbuntuNet Alliance)	2006

Source: DANTE, TERENA, GEANT and UbuntuNet Alliance

According to UbuntuNet report (2012), few RRENs are government bodies, but most are structured as non-governmental associations of member's institutions, with government officials participating in, but not controlling the governance processes.

One of the European RRENs, Delivery of Advanced Network Technology to Europe (DANTE), plans, builds and operates advanced networks for pan-European research and education (Dante, no date). DANTE works in partnership with Europe's national research and education networks and the European Commission. DANTE was established in 1993 and is based in Cambridge (Dante, no date).

Europe's first international network of networks was formed and named GEANT, (Davies, 2003). These networks gradually evolved over the years, enabling large amount of data transmission and enhanced applications adoption. Currently the networks connect universities in other countries across the world.

The RedCLARA vision is to serve as a Latin American collaboration system by means of telecommunications advanced networks for research, innovation and education (Stöver, 2005). On November 15 2004, Latin American RedCLARA began providing connectivity to the region, linking national research and education networks in Latin America via the Points of Presence (PoPs) established in Argentina, Brazil, Chile, Panama and Mexico(Stover, 2005). By encouraging the regional cooperation, the promotion of scientific and technological development and the direct integration of the world scientific communities, RedCLARA is fundamental for research and education in Latin America. It links 12 countries and 729 universities (more than 671.986 academics, 104.607 researchers and 3.763.142 students) throughout the continent, and connecting them to GEANT2 at 622 Mbps via the link between Sao Paulo (Brazil) and Madrid (Spain)(Stover, 2012). In 2007, RedCLARA added to its backbone a sixth note (PoP) in Miami (USA), to which the Central American network works (DANTE, no date).

As one of the biggest RRENs across Latin America Red CLARA offers a high capacity link. Red CLARA develops and operates the only Latin American advanced Internet network that was established for regional interconnection and linked to GEANT2 via ALICE project in 2004.

Like most RRENs, Red CLARA is a non-profit International Law Organisation, whose legal existence is dated on 23 December 2003, when it was acknowledged as such by the legislation of Uruguay. RedCLARA interconnects the national advanced academic networks from Latin America among themselves and with networks in Europe (GEANT 2), the United States (Internet2) Asia (APAN) and the rest of the world, providing scientists, academics and researchers in the region with an infrastructure that allows them to effectively collaborate with the global scientific community.

The RREN of East and Southern Africa is called UbuntuNet Alliance for research and education networking. It was incorporated in 2006 in the Netherlands. Tertiary Education and Research Networking of South Africa, TENET is a founder member of the UbuntuNet Alliance for Research and Education Networking. UbuntuNet is a non-profit association, with the head office in Lilongwe, Malawi.

UbuntuNet interconnects the NRENs in the east and southern region and connects them with the NRENs across the world. The Alliance provides TENET (and other African NRENs) with connectivity in London and Amsterdam to other research and education networks of the world and to the Internet worldwide. UbuntuNet Alliance provides the network infrastructure to connect Africa's education and research organizations to each other and to the world (Ngwira, Martin, & Banda, 2008). UbuntuNet Alliance provides the network infrastructure to connect Africa's education and research organizations to each other and to the world (Hotel, 2008).

According to the UbuntuNet report, there are 13 NREN members and NRENs in development in East and Southern Africa, while WACREN reports 2 NREN members and 9 NRENs in development. Ubuntu Net and WACREN are regional RENs for their respective regions.

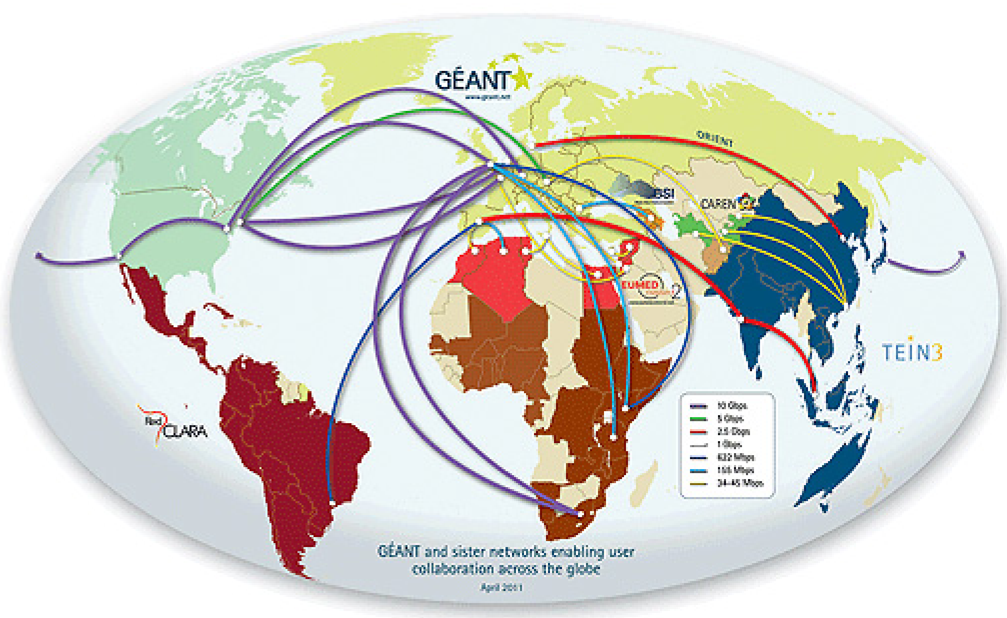
The European RRENs receive substantial funding from their national governments (Dossett, 1993). In many ways the NRENs of Europe are the role models for collaborative networking among universities and research institutions of Africa. Most European NRENs receive substantial funding from their national governments. A few are government bodies, but most are structured as non-governmental associations of member's institutions, with government officials participating in, but not controlling the governance processes.

1.14 The UbuntuNet Alliance thrust to connect the NRENs of Africa to GEANT

The UbuntuNet Alliance thrust offers those African countries which have NRENs connectivity to GEANT using the NRENs existing Internet access service contracts and infrastructures, including both terrestrial and satellite-based infrastructures (Ngwira et al., 2008). The thrust focuses on IP routing arrangements, and establishes institutions' connectivity to UbuntuNet and via UbuntuNet to GEANT without waiting for broadband transport infrastructures to become affordable or available (Martin, 2012).

The bandwidth of the connectivity is determined by the institutions' and NRENs existing infrastructure, and, in many cases, would not be at broadband speeds (Geant, 2012). GEANT enables users to collaborate across the globe. Below is an illustration of GEANT connectivity in Europe and across the world.

Figure 5: GEANT Connectivity

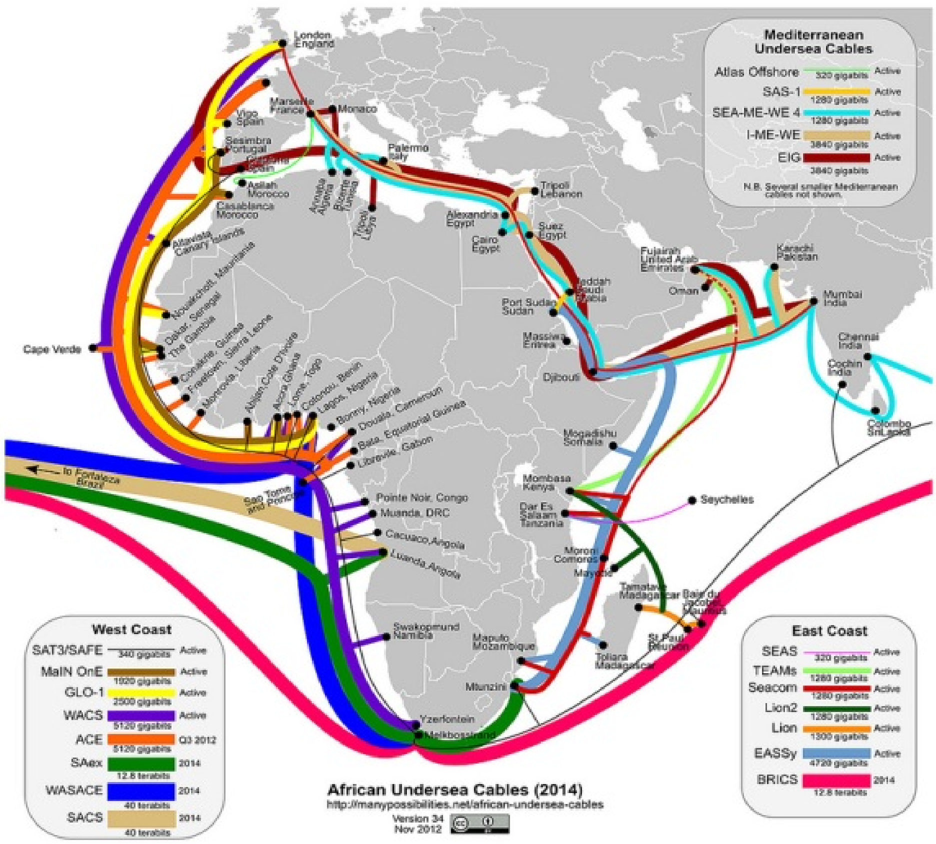


Source: GEANT (Davies, 2003)

GEANT is the de facto central hump of the inter-connected RENs of the world because of the vision and commitment of the European Commission in building the GEANT network and in establishing high-speed inter-continental links between the GEANT network in Europe and RENs all over the world. For this reason, the UbuntuNet Alliance launched its "Thrust to connect to GEANT", which enables the first useful service that the UbuntuNet Alliance offers to participating NRENs – connectivity to GEANT and hence to the NRENs of the world (Martin, 2007).

The figure below shows the intercontinental connectivity available via several submarine cables, including SAT-3/WASC/SAFE and soon SEACOM and EASSy.

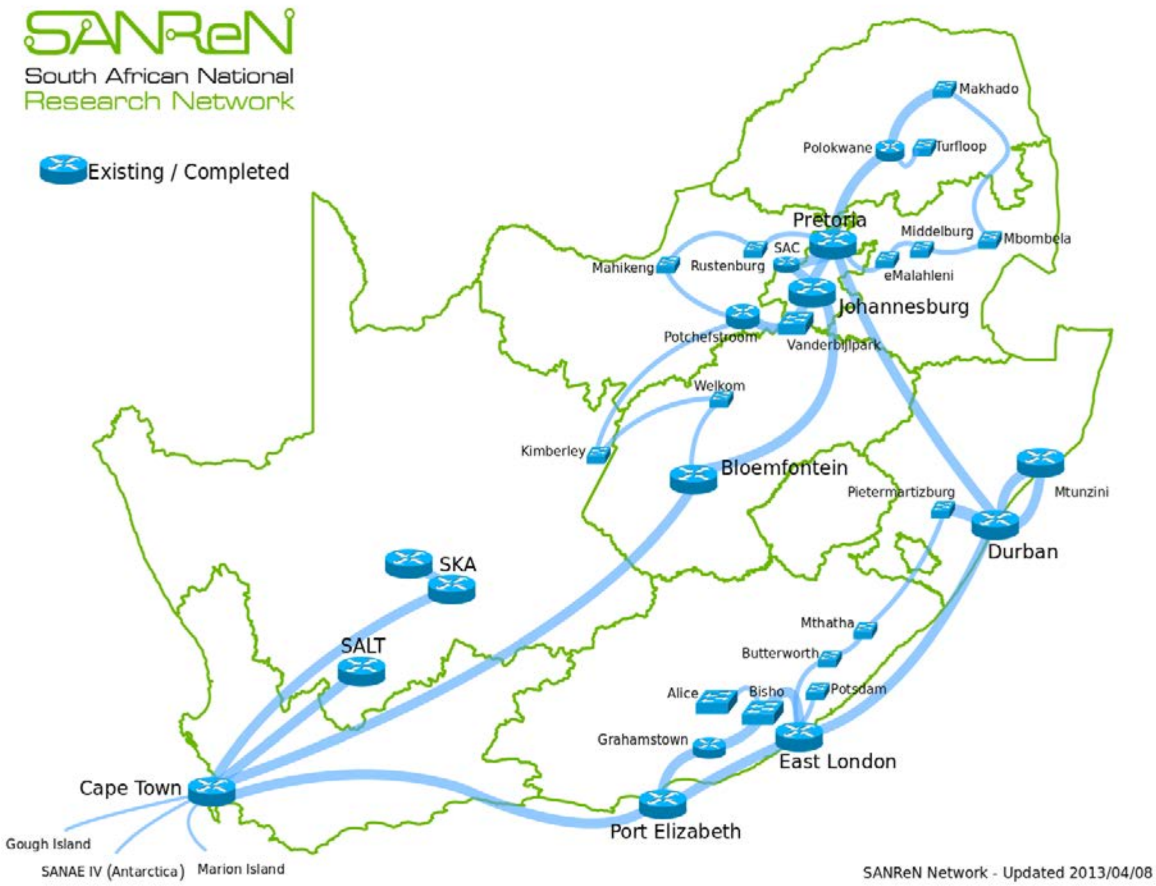
Figure 6: International Connectivity: Submarine cable servicing African continent



Source: Song, 2013

SANReN comprises a national backbone, several metropolitan rings, and some dedicated long haul circuits to reach important research installations. The SANReN national backbone was provided to Meraka by Telkom SA commissioned in December 2009. It comprises a 10Gbps backbone ring interconnecting nodes at Pretoria, Johannesburg, Bloemfontein, Cape Town, Port Elizabeth, East London and Durban and back to Pretoria. Below is the map of SANReN backbone available in most of the major cities.

Figure 7: South African National Research Network



Source: SANREN, 2013

The SANReN network includes access circuits that TENET itself provides for many campuses. These include optical fibre access circuits that connect six campuses, each to its nearest SANReN node, including the main campuses of MINTEK, Monash SA and the University of Zululand, and major satellite campuses of Wits Soweto, UNISA Florida and Wits Baragwanath.

Dark Fibre Africa supplies SANReN optical fibre ring networks in Johannesburg, Pretoria, Cape Town, and Durban that were commissioned during 2010. In aggregate they connect some 90 urban campuses to the backbone (CSIR, 2013). There are additional campus access circuits. While TENET bears the costs of operating SANReN, the cost of deploying and maintaining SANReN are borne by the DST through Meraka and are not recovered from TENET or the institutions. TENET recovers the full cost of service delivery through service charges that its Board sets from time to time. (Adams, 2014)

Where funding is well structured, the survival of NRENs means the success to the universities that use the NREN service. Universities need the infrastructure that is well developed to get easy connectivity for researchers to do high powered research, universities to provide high level e-services for students and for academics to deliver world class education through NRENs high performance networks.

1.15 Research problem statement

The SANReN provides high speed bandwidth for universities to undertake collaborative research and to carry on with day to day university business. Investment has been made in the SANReN by the Department of Science and Technology, but little is known with regard to SANReN value to universities once they are connected on to the network (Patel, 2010).

While the universities have NREN infrastructure and e-services most universities including Wits face demands that require a strengthening of their ability to contribute to global knowledge in scientific endeavors.

This research is dedicated to finding out about the value brought by the SANReN network to e-research, using a case study of Wits. Therefore the research problem to be investigated is how SANReN encourages the creation of value for collaborative research at the university.

Chapter 2: Conceptual framework applicable to NRENs

2.1 Introduction

The literature on the NREN provides the foundation knowledge and concepts from which to conduct research. It details the value of NREN infrastructure which is relevant for the study. The chapter highlights the value that NREN bring to institutions of higher learning. It looks at the conceptual framework by studying the value of NREN to the university. Subsequent to that the argument that NREN could bring value creation for the end user. Where funding is well structured, the survival of NREN is relevant on the success of the universities that use the service.

The aim of this research is to understand how the SANReN has brought value to universities, using Wits as a case study, in order to consider future issues for ICT policy, science and technology policy or higher education policy.

2.2 NREN usage at the university in the 21st century

One of the most significant developments of 21st century for universities across the world has been the emergence of research and education networks. The digitalization of telecom networks, the new network capacity from the supply of communication and information services, and the information sharing culture of the academic research community have been major driving forces behind the networks development

Universities use high performance networks for research collaboration, and access to services such as video conferencing and wireless network infrastructure. These are the advanced ICT infrastructures of the twenty first century (Martin, 2010). The growth and usage of the Internet increased with the growth in student numbers registered. However there is no framework that addresses the future of ICT needs for the universities. There is limited focus on the future ICT needs for the universities.

Ndiwalana (2011) is of the view that there are many opportunities for the universities to work together through NRENs. The important goal of the NRENs is the dedication to strengthening academic research amongst universities. Patel (2010) notes the relationship between NRENs and the changing role of the universities in context of globalisation.

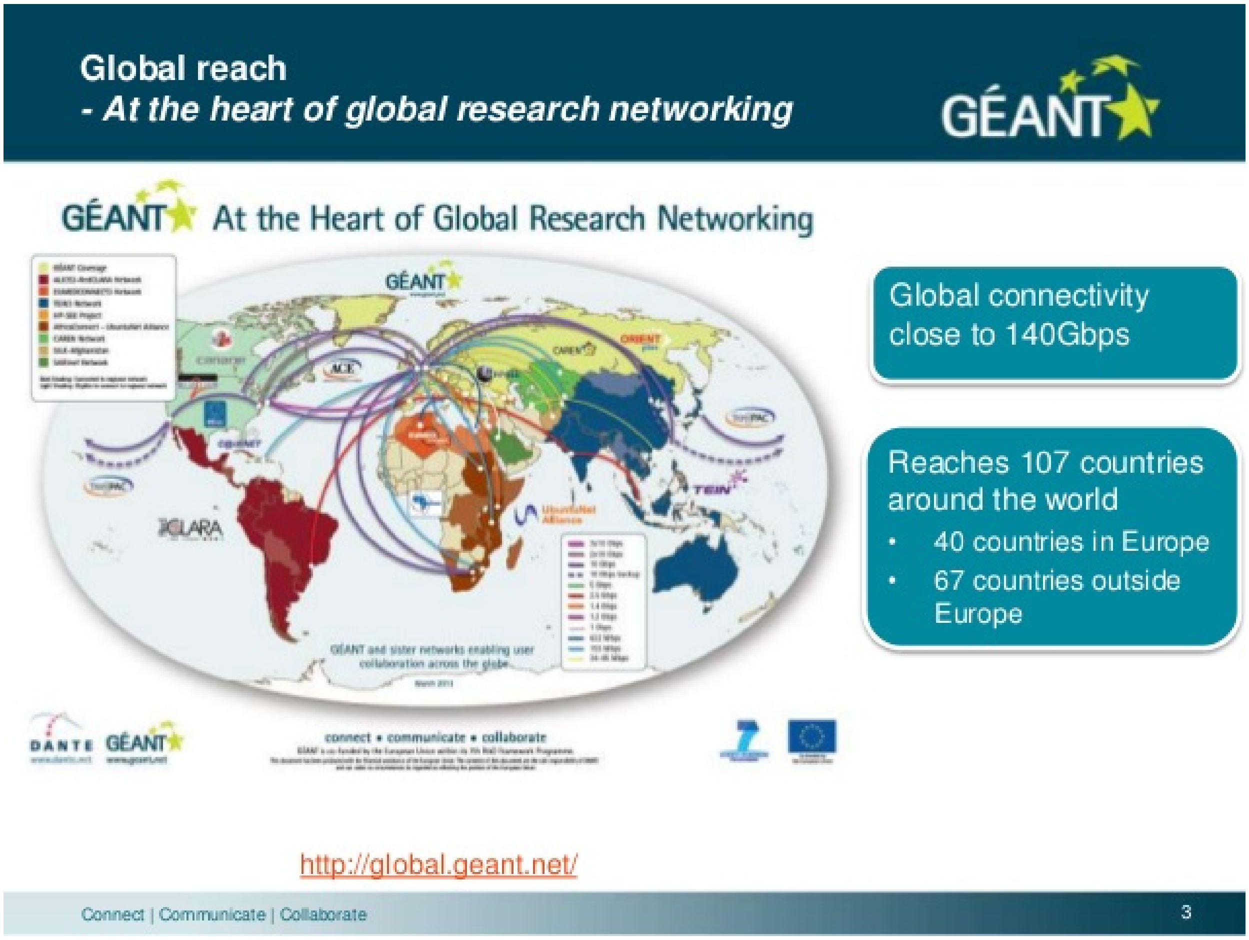
2.3 Trends in NRENs

The 2013 TERENA Compendium outlines the NRENs functions for each country and it is often used as a reference tool to the progress and development of the NREN. Trans-European Research and Networking Association (TERENA) is informative with updates on emerging global trends in NRENs (TERENA, 2013). TERENA emphasises that the technological innovation is at the heart of what NRENs are about (TERENA, 2013). As of 2013 most of NRENs were "deploying the next generation of high-capacity networks with innovative network architectures"(Rena, 2008). The most advanced country was Germany which had "100Gb/s capacity on its core network and several NRENs are planning to install similar capacities" (TERENA Compendium, 2013, pg 6). Another key innovation by the NRENs is the "spread of dark fibre networks" (TERENA, 2013, pg. 6).

While attention is given to accelerated provision of undersea cabling and national backbone fibre networks, the importance of establishing basic infrastructure inside universities cannot be forgotten, and remains an unmet need in many institutions. A major constraint to be dealt with on the way to high-speed connectivity has long been evident in lack of campus-level infrastructure and facilities for bandwidth management (Brownstein, 1990).

The typical core capacity for the NRENs in most GEANT partner countries is 10Gb/s with lowest capacity being 1Gb/s for countries that have joined GEANT in 2013 (TERENA, 2013, pg. 31).

Figure 8 below demonstrate the global connectivity, which is at 140 GB/s



Source: GEANT, 2013

Patel (2010) points out that through NREN collaboration, universities are developing corporate models of management function seen in new research and development capacity and increased post-graduate students. He is of the view that when universities drive NREN formation because without government intervention, the tendency is to work together to address a common problem which usually involve the high cost of bandwidth.

2.4 Value of NREN Infrastructure for collaborative research

The literature concerned with key concepts relating to the NRENs is categorised as the infrastructure (Ndiwalana, 2011) bandwidth capacity (Savory, 2012a; 2012b), funding models (Patel, 2010), value of e-services (Greaves, n.d.), applications and usage (Daniel, 2012).

The advent of infrastructure especially the undersea cables has in many ways led to what Patel (2010) calls “broadband abundance” (Patel, 2010, p. 1). This is driven by the universities requirements for high-speed access networks beyond just surfing the Internet amongst other factors. The NREN infrastructure support e-services that promote access to quality research publications and use technology for collaborative research (Kotecha, 2009).

The campus level infrastructure enables students and academics multiple-access to electronic services, be it electronic journals, content on lectures or any e-services that is available at the university. NRENs are the key driver of educational organization collaboration and support various e-services such as video conferencing, VOIP, Eduroam and many others that are useful for academic purposes (Osazuwa, 2011).

The literature on ICT infrastructure attempts to describe structures. Adam (2007) speaks of the fact the NREN infrastructure can be conceived as a ‘layer cake’ or pyramidal set of building blocks. The content and applications adoption available through the NRENs add the campus-level to these layers and as a result enables particular uses of the network.

Raj (2011) is of view that the universities in the context of NREN infrastructure can utilise the NREN. He sees   NRENs playing both supportive role for research delivery by enabling data transfer and communication, and direct facilitation role in that they enable research teams to construct virtual platforms for experimental design and research collaboration.

Significantly more fibre infrastructure (Chege, 2011) is not only being planned and discussed but also being rolled out. The fibre infrastructure change rapidly. The optical fibre is already available to build a regional as well as national research and educational networks with reasonable coverage of institutions, except in a few countries that have plans under discussion (Van der Ham, Grosso, Van der Pol, Toonk, & De Laat, 2007). Physical infrastructure (Campanella-GARR, 2008) is not a backbone bottleneck.

According to Dyer (2010) there is already optical fibre available to connect most of the key research and higher education institutions and to interconnect them to other continents.

The Department of Science and Technology set up SANReN with the major focus to set up major infrastructure. DST invested in cyber infrastructure to support research universities and research councils. SANReN connects all the universities in the country and research councils. Initially SANReN targeted centres where research was being conducted in Johannesburg and Cape Town. DST /CSIR entered into a contract with TENET to acquire bandwidth, and then the network was linking research centres, universities and so on. TENET is a consortium of the universities. TENET operates the SANReN network and then there is a contractual agreement between TENET and SANReN on how that bandwidth can be used.

2.5 NREN usage for collaborative research

NRENs are publicly-funded (Brennan, 2010) interconnecting fibre backbone networks that are designed to operate for the higher education institutions and the research communities, often in the context of the development of national innovation systems (Kotecha, 2009, p. 54).The NRENs are meant to bring faster Internet access and the opportunities for the research community to collaborate with each other across the world (Comstedt, Martin, & Muchanga, n.d.). Data transfer across electronic networks occurs at high speeds and enables knowledge sharing and online communication among research teams, post-graduate research students, linking academic communities irrespective of their geographic location (Martin, 2008).

The existence of NREN is dependent on the economic status of the region. Efforts are made by the host government for NREN in that particular government to achieve the intended goals. In order for South Africa to successfully bid for the SKA telescope mega project, it was important to demonstrate that the country has the capability to host, therefore the presence of SANReN was key in SA being successful at the bid.

In Europe, the interconnection of computer networks was initially developed mainly for the use of emails. As the network technologies evolved in the 80's and early 90's, the European national research and education networks were established.

2.6 Value of e-services for e-research

There are a number of electronic services that NRENs provide to the university communities. The NRENs create a platform for an interactive and engaging environment through the innovative services it brings to the universities. Universities play key role in providing higher education, learning, teaching and research. It is important that these services are accessible and available to the staff and the students.

Eduroam is one of the most common e-services that involve many national research and education network organization (Wierenga & Florio, 2005). It is a secure global wireless connection which provides automatic guest provisioning system and encryption and authentication using WPA2-Enterprise standards (Florio & Wierenga, 2005). The e-service enables students, researchers and academic staff to obtain secure and fast Internet connectivity across participating organizations in 54 countries. The service is set up for use by visiting students, researchers, academic and support staff from participating organizations only (Wierenga & Florio, 2005).

Universities cater for new needs in education and training which stem from the knowledge-based economy and society. These include an increasing need for scientific and technical education, horizontal skills, and opportunities for lifelong learning, which require greater permeability between the components and the levels of the education and training systems.

2.7 e-Services usage and value arising from NRENs

Provision of e-services at the university is facilitated by the highly capable networks of international bandwidth (Bishop, 1990). When speaking about the universities, it is critically important to understand that their business is all about generating quality research and dissemination of knowledge. Universities do not merely exist to teach students and prepare them for the future as most have visions of being world-class and attracting and raising the number of post graduate students.

NRENs offer opportunities for collaborative research practices and linkages to regional and international RENs. Kotecha (2010) is of view that networks at universities be funded and managed properly. She emphasizes that good Internet connectivity is vital for a country to fully participate in the global knowledge economy. Therefore research and education institutions need to use bandwidth for the facilitation of academic peering between universities, nationally, regionally and globally.

One of the examples of services NRENs provide are outlined by the Swiss National Research and Education Network (SWITCH) (Plattner, 1988) To this day, universities are able to provide the e-services that go beyond reading materials. It is possible to access You-tube, mark papers and get students to interact with one another online prompting the belief that a brick and mortar classroom is slowly becoming obsolete.

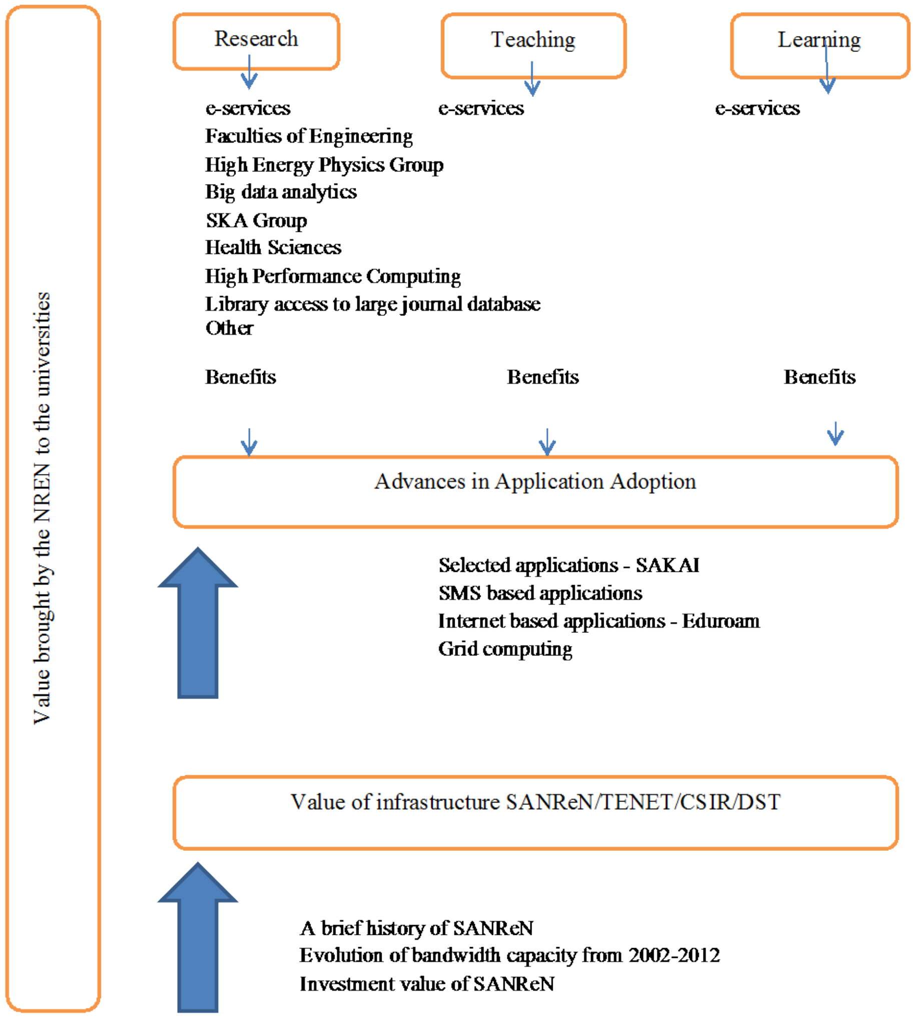
NRENs offers universities with many options for e-services. There has been a growth in a number of e-services used at the universities for research and educational services.

2.8 Conceptual framework

The framework established in this research takes as its point of departure that the NREN infrastructure should bring value to research, teaching and learning. The current limitations in Internet usage for educational and research purpose can be addressed through a number of measures, in particular through the introduction of dedicated national research and education networks (NRENs) and regional RENs (Kotecha, 2009).

The conceptual framework below demonstrate the requirements of dedicated NREN infrastructure to enhance e-research and allow for the analytical relationships and propositions regarding the concept of NREN infrastructure and value of e-services at the universities. The diagram illustrates the key concepts that shape NREN; in particular, the infrastructure, which provides dedicated high speed bandwidth to transfer terabytes and petabytes of data, applications adoption and value created by the NRENs to research collaboration.

Figure 9 Conceptual framework: NREN infrastructure and e-services at universities



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Chapter 3: Qualitative research methodology

3.1 Introduction

The aim of the research is to examine SANReN infrastructure to support constantly evolving university e-services for collaborative research. The nature of the research is purely qualitative and therefore the qualitative methodology approach was used to collect and analyse data. The major part of this research utilised descriptive technique complemented by a literature review. The detailed literature review provided a better understanding of value of SANReN at universities in South Africa. The conceptual clarity was sought on e-research, NREN infrastructure for e-research, applications adoption and e-services. Particular attention was paid to value of infrastructure of e-research.

The choice of Wits as a case study provided for a broader investigation where a case is studied in detail over time. The case had elements of both representivity (suitable research projects) and unique description (data from interviews).

3.2 Research approach: Qualitative research methodology

Qualitative research is a method of inquiry employed in many different academic disciplines, traditionally in the social sciences (Mouton & Babbie, 2012). The researcher aimed to gather a detailed understanding of particular characteristics, events, institutional processes, policy processes and outcomes and the reasons behind particular outcomes with respect to SANReN within Wits.

Babbie and Mouton (2012) give an in-depth analysis of the qualitative research methodology in social research. The empirical information that addressed the research topic was mainly qualitative. The mode of enquiry for this research "attempt to study human action from the perspective of the social actors" and the primary goal for using such approach "is defined as describing and understanding" (Babbie & Mouton.2012, p 270).

The research aimed to make a contribution to a study of user experiences and of the value of NREN and user perspectives of issues relating to NREN infrastructure at universities, therefore took the form of written or spoken language and qualitative methods that was in sync with each concept. The qualitative methods generally related to generating the descriptions (Hamel, 1993).

3.3 Main research question

How does SANReN infrastructure support constantly evolving university e-research?

Sub-questions

1. How do the applications adoption and e-services functions contribute to collaborative research for end users?
2. How have the trends in NREN usage impacted on collaborative research at the universities?
3. What value is brought by SANReN to Wits students and academics?

3.4 Overview of the research design and data collection

The data gathered for the research was collected from the beginning of 2014 until October of the same year. The data was gathered from the main users and beneficiaries of SANReN. The researcher preferred to collect data from within and outside of the university in order to investigate a case in detail over time.

The data was analyzed so as to produce comprehensive answers to the research question. The researcher would have liked to use phenomenology, which in Husserl's (2003) conception, is concerned with the experiential underpinning of knowledge, in that the researcher becomes immersed for the period of the research in the activities related to the research problem. However the phenomenology approach would be the ideal approach for the case study because it would have enabled even greater depth to the observations made, however, it was not possible for the researcher to immerse herself in the many activities and events of the selected research projects that would have been required by a phenomenological approach.

3.5 Outline of the case study qualitative research methodology

The case study, which is an in-depth analysis of concepts, and involves user experience of value was used in this research. The main advantage for using the case study as a research method is that it offers a chance to get a picture of real life. The choice of case study method depends largely on the nature of research questions (Yin, 2013). The main research question in this research sought to explain the "how" and "what" questions, which made the choice of descriptive case study more relevant to the research. The method is most appropriate for dealing with a subject that is context dependent.

The case study approach was chosen as it allows the researcher to concentrate on a single case in an in-depth process unlike if it was more than one case. It was used in describing a situation of phenomenon occurring in the present, where an in-depth description is useful and where the researcher does not need to manipulate events. Dul and Hak (2008, p.4) defined a case study as "a study in which one case or a small number of comparative cases in their real context are selected and scores obtained from these cases are analysed in a qualitative manner". Case study method is best applied when the research addresses descriptive or explanatory questions.

Yin (2012) has identified three types of case studies. The explanatory case study is used to define questions and hypotheses or to test out a research procedure. A descriptive case study is the one used to describe a particular phenomenon within its context. It is "a case whose purpose is to describe a phenomenon (the case) in its real world context (Yin, 2012). The exploratory case study explores the cause-effect relationships and how the events happened. According to Yin (2012) a case study design should be considered when: (a) the focus of the study is to answer "how" and "why" questions; (b) you cannot manipulate the behaviour of those involved in the study; (c) you want to cover contextual conditions because you believe they are relevant to the phenomenon under study; or (d) the boundaries are not clear between the phenomenon and context.

Case studies generate useful perspectives of organisational practice and process and enable the researcher to understand the dimensions of such practices and processes. The discussion of case study methodology centres on its most useful definition by Yin (2012) and thus defines a case study as “an empirical enquiry that investigates a contemporary phenomenon within its real life context, when the boundaries between phenomenon and context are not clearly evident, and in which multiple sources of evidence are used”.

3.5.1 Determining the unit of analysis

The approach for the Wits case study is descriptive because the researcher both describe and explain the institutional processes and policy issues. The main advantage for using the case study as a research method is that it offers a chance to get a picture of the real world. The method is most appropriate for dealing with a subject that is context dependent, as is the case with NREN infrastructure in universities.

As Yin (2012) has alluded, the case study approach will provide the research an in-depth understanding of a single case study, in a concentrated manner. The reason this method is selected is because the value of SANReN will be investigated to a certain level of depth of insight, in relation to teaching, research and learning, funding model, applications adoption and e-services approach which engages both academics and students.

In order to determine what data may be required an important consideration is the unit analysis. The unit of analysis will strongly influence the type of data required for the research. In this case study research the units of analysis would be Wits University, NREN value; applications adoption; e-services; experience of value; research, teaching and learning.

The case study methodology has been selected due to various reasons. It is chosen because one is able to focus the research and concentrate on a single case. This approach provides a research space to understand in-depth processes within the single case study. According to Remenyi (2012: pg. 2) “case study research allows challenging research questions to be addressed using multiple sources of data or evidence”. An overarching perspective, which brings together the various elements of methodology, is that this is a constructivist case study, which uses an explanatory approach

3.5.2 Data collection methods: Document analysis and key informant interviews

The data collection methods relevant to this research are document analysis and semi-structured interviews. The two data collection methods allow the researcher to study selected research problems in depth and to draw generalizations. They were appropriate to address in detail the research categories of infrastructure, the advances in applications adoption and the value of infrastructure brought by the SANReN, as identified in the problem statement.

In case study research, the collection and analysis of data can be challenging as it requires the researcher to be actively involved, asking the right questions which link to those that are central to study (Neumann, 2011). Case study research uses multiple sources, as these provide a researcher with the ability to check on the consistencies or inconsistencies in the data. The research collection methods used in this study seek to unravel and explore the ICT infrastructure used in support of e-services.

3.5.3 Semi structured interviews

The interviews were conducted with the selected users of the SANReN within the university. The interviews were structured in such a way that created a confession by the researchers of the experiences and usage, value and also what they thought of as areas of constraints on SANReN network to the data intensive field of research. The interviews were asked in a way that made the interviewees share the knowledge they had on SANReN and the value they saw in these sophisticated networks and also allowing them to share their views, both negative and positive about the SANReN infrastructure.

This descriptive research was based on a series of semi-structured in-depth interviews that allowed for the collection of data in order to offer researcher the chance to explore topic in-depth and to gain appreciation of the subject area. The semi-structured interviews allowed for a clear list of issues to be addressed. The one-on-one interviews were used, these are open-ended enough to allow exploration and fact-finding of views to be collected in a reasonable space of time. The disadvantages of interviews may be that the whole interview process can be time consuming or the issue of confidentiality or ensuring that all interviews are conducted in the same way and access to appropriate.

An interview schedule contained all the questions required to elicit the required information for research. The schedule was used as the basis for conducting the individual interviews and allowed the researcher and the participant to have full discussions and explanations of the questions and answers.

The interviews involved the main users of SANReN within the University of the Witwatersrand, who are senior researchers in the High Energy Physics Group, Bioinformatics, JSCE and SKA as detailed in Table 4 below.

Table 4: List of the respondents

SANReN user	**Interview method**	**Interview Date**	**Identifiers**
Bioinformatics-Wits	Face-to-face, recorded	3 March 2014	BIO1
Wits CNS	Face-to-face, recorded	6 March 2014	CNS1
Wits CNS Director	Face-to-face, recorded	18 June 2014	CNS2
High Energy Physics Group	Face-to-face, recorded	11 August 2014	HEPG1
Centre for Maths and Computational Studies	Face-to-face, recorded	16 September 2014	CMCAS1
Joburg Centre for Software Engineering	Face-to-face, recorded	12 October 2014	JCSE1
SKA Wits	Face-to-face, recorded	19 September 2014	SKA1
Department of Science and Technology	Face-to-face, recorded	8 September 2014	DST-SANReN-1
Cyberinfrastructure SANReN Meraka	Face-to-face, recorded	17 September 2014	DST-SANReN-2
SANReN Meraka CSIR	Face-to-face, recorded	30 October 2014	DST-SANReN-3
Patent Application Wits	Face-to-face, recorded	15 September 2014	Patent 1

3.5.4 Sampling

Sampling is mainly about the selection of subjects to be interviewed. It is important for the sample to be representative of the population. The limitations to the researcher are time and resources therefore one end up involving only subject who will give different perspectives relevant to the research. A researcher need to understand that with qualitative research paper it is the relevance to the research topic which assist the researcher to pinpoint people who are knowledgeable in with the NRENs and also those who actively participate in the collaborative research.

According to Neumann (2000), qualitative researchers use a non-probability sampling technique which means that they are unable to determine the sample size. The snowball technique was used in order to achieve the objectives of the research. The snowballing is often most appropriate approach of sampling for the qualitative research.

The respondents in the case study research are specifically chosen for their knowledge and expertise as users, custodians, funders and beneficiaries of SANReN. The interviews were conducted with the people involved with the decision makers who play an active role within SANReN.

The respondents who were selected within Wits are those who participate in data intensive projects and those who have a clear knowledge of SANReN and the potential for it to facilitate their work within the faculty

Their roles in the university are those of senior researcher, professor and highly knowledgeable academics in their respective fields. The difference with those whom were selected to participate in the research and those who were not, is the fact that the latter usage for bandwidth is purely limited to Internet surfing and emails and doing day to day research. Those in scientific research need SANReN to transfer terabytes and petabytes of data, which made them specifically relevant to this research.

The university of the Witwatersrand was a preferred choice for the researcher as it was an institution familiar to the researcher and also because it was a previous employer. Wits is accessible and offered a range of faculties which has international research collaboration research in complex fields of, engineering, science, physics, astronomy and medicine. The idea to do a case study was influenced by the researcher's experience of having been at Wits in the past unlike any other university which the researcher will not be quite familiar with.

3.5.5 Document analysis

Document analysis is a form of qualitative research in which the data that is relevant to the research problem is extracted from a wide range of documents, both printed and electronic, followed by interpretation of the data to give meaning to and an assessment of the topic under investigation (Bowen, 2009). The documents are reviewed and systematically analyzed in order to elicit and develop empirical knowledge (Bowen, 2009). Documents serve a variety of purposes in research. According to Bowen one of the key functions of the documents is to "provide data on the context within which research participants operate- a case of text providing context" Bowen (2009, p 29).

This research was about the value brought by the NREN for students and academics at the University of the Witwatersrand and the e-services that impact on teaching and learning processes. Therefore the primary documents that were useful for Wits case study included the official university archives from 2012 until 2014 such as the university annual reports, university website and the enrollment reports. The documents provided background information and historical analysis to supplement research data for this research.

3.5.6 Data analysis methods

The analytical approach covers the various techniques applicable in the data analysis based on data from interviews and secondary sources. The analytical approach used favours a descriptive case study, or reasonable insight into cause and effect. The research explained the substantial value added by each technique at the same time pointing out on the strengths and weaknesses.

One of the strengths of selecting a case study is that one could use multiple sources and have enough space to check and recheck any consistencies and inconsistencies in the data. In order to deepen the understanding of SANReN infrastructure the research used interviews and secondary sources.

One of the most desirable techniques for case study analysis is to use a pattern-matching logic. Such logic (Trochim, 1989) compares an empirically based pattern with a predicted one or with several alternative predictions. If the patterns coincide, the results can help a case study to strengthen its internal validity. However in this research pattern matching is not possible, because the researcher is not able to predict a pattern. Therefore, the researcher identified the categories and any sub-categories from the data that relate to the identified themes and analyses cause and effect within and between these themes, categories and sub-categories. If the case study is an explanatory one, the patterns may be related to the dependent or the independent variables of the study or both. However if the case study is a descriptive one, pattern matching is still relevant, as long as the predicted pattern of specific variables is defined prior to data collection (Neumann, 2011).

3.5.7 Significance of the research

This research is significant for the contribution it makes to the future ICT policy for the South African universities using the NReN. It captures the picture of national research and education networks infrastructure and provides an approach that other universities can learn from. It addresses the ways in which universities which participate in international collaborative research and those with data intensive scientific research can appropriate the value and usage of SANReN to facilitate their research. Most could learn from the experiences of Bioinformatics, Physics group and the Square Kilometer Array at Wits

3.5.8 Limitations of the research

There are possible limitations to this research, which are both methodological or those of the researcher. These difficulties could arise from the number of units of analysis to be investigated, the lack of available or reliable data, and lack of prior research done on the topic. The limitation for the researcher could depend on the ability to access documents, people and organization.

Chapter 4: Advances in international research collaboration using SANReN

4.1 Introduction

This chapter presented the results based on the qualitative approach to data collection. The data is gathered from SANReN, TENET, the High Energy Physics Group, and the SKA Research Chair at Wits, the Centre for Maths and Computational Studies, Joburg Centre for Software Engineering and the Bioinformatics group. The chapter presents different perspectives on SANReN usage, SANReN infrastructure, application adoption and e-services.

It discussed the cases of particular experiments including the ATLAS particle detector experiment, the Square Kilometer Array radio-telescope mega-project and international research collaboration made possible by the utilization of SANReN. The characteristics used in this chapter were derived from the conceptual framework found in Chapter 2.

4.2 Themes and issues emerging from the data collection

The main themes were identified as international research collaboration at Wits University, data management and SANReN infrastructure, SANReN usage, e-services, applications and investment value of SANReN. Once the main themes were identified, the researcher identified the next process in the data collection, which was the review of the primary data, made up of semi-structured interviews with the main users of NREN within the university, i.e. the High Energy Physics Group, the Radio Astronomy, Bioinformatics, Joburg Centre for Software Engineering and Mathematics and Computational Sciences and the representatives from the Department of Science and Technology, SANReN, CSIR Meraka. Table 5 below illustrates the main themes and sub-themes to be discussed in this chapter.

Table 5: Themes and issues emerging from the data collection

Themes	**Emerging Issues**
4.3 International research collaboration at Wits University	4.3.1 Data intensive research collaboration 4.3.2 International bandwidth for research collaboration 4.3.3 E-Services and applications adoption 4.3.4 Experiences of SANReN usage in scientific research
4.4 Data management and SANReN infrastructure	4.4.1 Cyber Infrastructure 4.4.2 Data Centre for Scientific research 4.4.3 Grid Technology 4.4.4 Patents application and Intellectual property
4.5 Constraints of SANReN usage	4.5.1 Risks associated with SANReN failure 4.5.2 SANReN redundancy
4.6 Investment value of SANReN capacity	4.6.1 Size of investment and total capacity 4.6.2 Value of investment in SANReN 4.6.3 Is SANReN core capacity and connectivity sufficient for scientific research?

4.3 International research collaboration at Wits University

There are a number of data intensive research projects at Wits University such as High Energy Physics group, SKA group, the Bioinformatics and Centre for Maths and Computational studies who are the main SANReN users within the university. The scientific researchers in mathematics, engineering and science fields of study are heavy users of the bandwidth provided at the university.

4.3.1 Data intensive research collaboration

Data intensive research collaboration is conducted with a number of universities or research partners worldwide. It is a complex interdisciplinary research which involves high volumes of data transfer and analysis of data. The collaboration is made possible by advanced infrastructure with a high level of sophistication to equip scientists with the necessary tools for data analysis, management and transfer so that the universities can continuously contribute to new innovations and scientific discoveries. Respondent Bio1 named two big international projects that fall into this category, ATLAS and ALICE, in which South African universities collaborate. Example of collaborative research include projects that interviewees are involved in and which are devoted to research in the fields of physics and medicine, and astrology at an infinitely bigger scale. The theme of data intensive research collaboration sought views from those respondents who are users of advanced computing for big data projects.

4.3.1.1 High Energy Physics Group

At the University of the Witwatersrand, the High Energy Physics Group (HEPG) is a collaborator in the data intensive project known as “A Toroidal LHC Apparatus” (ATLAS) experiment (Wits High Energy Physics Group, 2013). ATLAS is a particle detector that works with the Large Hadron Collider (LHC), a particle accelerator at the European Organization for Nuclear Research (CERN) based in Switzerland (ATLAS, no date). It studies the basic forces that shaped the universe since the beginning of time (ATLAS Collaboration, 1999). Among the possible unknowns are the origin of mass, extra dimensions of space, microscopic black holes, and evidence for dark matter candidates in the universe (ATLAS, no date). Following the discovery of the Higgs boson, data allows in-depth investigation of the boson's properties and the origin of mass (ATLAS, 2014).

In this experiment, sub-atomic particles produced during high-energy proton-proton collisions are detected, analysed and shared with the world (Wits High Energy Physics

Group, 2013). As science becomes more sophisticated the ATLAS particle detector searches for new discoveries in the head-on collisions of protons of extraordinarily high energy (ATLAS, no date). It becomes clear that SANReN connectivity is critical for HEPG to be able to host data.

From the discussion with respondent it was noted that HEPG plays a primary role in conducting advanced experiments at ATLAS. During the discussions it became clear that the existence of advanced infrastructure would make it possible for further development of scientific research projects with experiments done all the time. Currently the HEPG make use of the Centre for High Performance Computing (CHPC) in Cape Town.

According to HEPG1 the South African university contributions to the ATLAS experiment are significant. The project has several members and the group aims to be at the forefront of the field of high-throughput supercomputing in South Africa. ATLAS is about 45 meters long, more than 25 meters high, and weighs about 7,000 tons (ATLAS, 2014). The data rate is equivalent to 50 billion telephone calls occurring at the same time. ATLAS actually only records a fraction of the data (those that may show signs of new physics) at a rate equivalent to 27 CDs per minute (ATLAS, 2014).

The research collaboration in ATLAS involves 3,000 scientific authors at 174 institutions in 38 countries. South Africa and Morocco are the only countries on the African continent participating in this cutting-edge project (CERN, 2014). Multiple funding sources for this science project include the Department of Science and Technology (DST), the National Research Foundation (NRF), the University Research Council (URC), the Science Faculty Research Committee (FRC) and the School of Physics (HEPG, Interview date 11 August 2014).

4.3.1.2 Bioinformatics

Interviewee Bio1 has two projects that use the SANReN network. The projects involve the effective software development in applied bioinformatics and the Computational Molecular Biology Research Programme, which has a strong algorithm and data structure design focus. The key project is EST clustering which looks at the design of a key algorithm in genome or DNA sequence assembly. Such work has strong theoretical and engineering components. The Bioinformatics Group works with biologists who use EST clustering as part of their work.

The interviewee gave an example of one project where, together with collaborators at the Wits Medical School, investigations are done on population surveillance in Soweto to look at various health related issues such as the genotypes of individuals. The DNA data is sent to sequencing centres in the USA and gets genotyped and transferred back to South Africa.

The respondent's view is that exploring complex problems as big as genotyping is very expensive particularly taking into account large data sets. Technically SANReN brought substantial improvement in network performance needed for large data transfer for this collaborative research (Bio1, Interview date 3 March 2014).

Bioinformatics projects deal mainly in collaborative work with local and international universities. This is where SANReN is key to the requirements of huge data transfers (Bio1, Interview date 3 March 2014).

International collaborative research that the respondent is involved with is called "A Large Ion Collider Experiment" (ALICE). The ALICE Experiment goes in search of answers to fundamental questions, using the tools provided by the LHC trying to find answers to questions such as (i) what happens to matter when it is heated to 100,000 times the temperature at the centre of the sun and (ii) why do protons and neutrons weigh 100 times more than the quarks they are made of (Bio1, Interview date 3 March 2014).

ALICE is one of the largest experiments in the world devoted to research in the physics of matter at an infinitely small scale. Hosted at CERN, the European Laboratory for Nuclear Research, it involves an international collaboration of more than 1200 physicists, engineers and technicians, including around 200 graduate students, from 132 physics institutes in 36 countries across the world.

4.3.1.3 Centre for Maths and Computational Science

The Centre for Maths and Computational Science and Centre of Excellence for Mathematics and Statistics provide support for large data projects. The Centre for Mathematical and Computational Sciences (CMACS) was established by the University of the Witwatersrand as a direct response to the report "Review of Mathematical Sciences Research at South African Higher Education Institutions" of the International Review Panel Committee constituted by the National Research Foundation. The most significant recommendation of the report was for South Africa to invest in a National Centre of the Mathematical Sciences that would serve the South African mathematical community at all South African universities (CMACS-Data Science 1, Interview date 16 September 2014).

The Panel found evidence of world-class research conducted by South African mathematicians in pure and applied mathematics, statistics, mathematics education and (theoretical) computer science. It also identified issues that need to be addressed at the systemic level, including the academic, intellectual and geographic isolation of South African mathematics research from international centres of research. It also highlighted the under-representation or absence of some contemporary and mainstream sub-fields and disconnection of the research conducted from areas of contemporary interest (Wits, no date).

One of the major areas that respondent CMACS-Data Science 1 is pursuing is big data in mathematical tools of data mining. There is a group within Wits, led by the current DVC Research considering formation of a data science institute and one of the sub groups is the curriculum development group which CMACS-Data Science 1 is currently leading (CMACS-Data Science 1, Interview date 16 September 2014).

Respondent CMACS-Data Science 1 is of view that the SANReN network will facilitate the traffic of big data in a way that would have been impossible without the SANReN investment. Respondent CMACS-Data Science 1 addressed the question of skills development in data science. There is a need to train people to be competent in manipulating big data and mathematics is fundamental to collaborative research.

CMACS is funded by the university through a startup grant as it is an emerging area and does not qualify to apply to the research committees.

4.3.1.4 Radio-telescope project

The semi-structured interview generated feedback on Wits international research collaboration in the Square Kilometre Array (SKA) Radio-telescope Project. This major international research collaboration involves the effort to build the world's largest radio telescope with a square kilometer (one million square meters) collection area (SKA, Interview date 19 September 2014). It deploys thousands of radio telescopes, in three unique configurations, to enable astronomers to monitor and survey the entire sky at a high level of detail and is thousands of times faster than any telescope currently in existence (SKA, Interview date 19 September 2014).

According to respondent SKA1 it is a worldwide cutting-edge project, the biggest astronomical project, one of the largest astronomical collaborations with partners in many countries: "A big science, big data project, big human endeavor, deeply rooted in astronomy". The project was awarded by an international panel of the science community. In May 2012 the decision was made that the majority of SKA projects be located in Africa, with the core project located in South Africa and the core antennae built in the Karoo. The other part of the SKA project is located in Australia and has the technical frequency within a range of 100 megahertz to 10 gigahertz. There are possible plans to increase to 125 gigahertz, and to microwave frequency (SKA, Interview date 19 September 2014).

SKA has two basic precursors called Australian SKA Pathfinder (ASKAP) and Murchison Widefield Array (MWA), both based in Australia and both are mid frequency. In South Africa the prototype is called the MeerKAT, which is in the range of lower to higher frequency from a few megahertz to 15 gigahertz. MeerKAT started in 2014 and constituted 64 dishes and by the first semester of 2014 the construction of the first dishes in the Karoo were completed. South Africa has designed and built the MeerKAT telescope as a pathfinder to the SKA. The technology being developed for MeerKAT is cutting-edge and the project is creating a large group of young scientists and engineers with world-class expertise in the technologies which will be crucial in the next 10 to 20 years. These technologies are very fast computing, very fast data transport, and large networks of sensors, software radios and imaging algorithms (SKA, Interview date 19 September 2014).

The KAT-7 prototype has been conceived as a necessary step to MeerKAT and MeerKAT is a final step to the SKA. KAT-7 is an engineering prototype to MeerKAT. KAT-7 is real data and not predictions of theory. In 3 years' time, scientists will be using MeerKAT data to get ready to use SKA data. The level of complexity in the process is higher and they are ready to go from MeerKAT to 64 dishes (SKA, Interview date 19 September 2014).

MeerKAT needs a more complicated and intense process of data management and transmission. The SKA team has already produced papers and publications from the first phase of the project. SKA1 had submitted an article to a professional journal for referee purposes (SKA, Interview date 19 September 2014).

The idea for an SKA research Chair was to use experiences to grow a research group that would consist of Masters, PhD and post-doctoral students from South Africa and other countries committed to the project. The present work is done with South African students and other collaborators provide direction on how to use the future data of MeerKAT SKA based on actual data from KAT-7. The group consists of 10 to 15 students dealing with certain aspects of the projects, all related in some way to MeerKAT and SKA (SKA, Interview date 19 September 2014).

4.3.1.5 Joburg Centre for Software Engineering

Respondent JSCE1 used Wits as an example of a big institution which can use the smart grid to measure the peak electricity usage and build models that predict in of electricity usage. The JSCE intends to adopt this strategy on the Wits Campus. It is called a smart switch strategy which can save the university millions per year. In the US there is a presidential task team on smart grids putting hundreds of millions of dollars into smart grids research for the reason that it can save huge amounts of money in energy use. JSCE research has the potential to have high value in real terms, to Wits and to South

Africa as they collaborate with international power utilities. The requirement to do all that is a dedicated NREN infrastructure to enhance research.

The respondent reported that the amount of research in the past mainly derived from assumptions. This was a project that effectively was not possible because researchers couldn't move data abroad from South Africa to abroad due to the absence of data infrastructure. The data depended on real time, "so you couldn't put it on disk and transport it that way and in the past we couldn't have even considered this research but now its opening up possibilities that JSCE couldn't even think of" (Respondent JCSE1).

"For this work it's a form of database called no sequel data bases, the tool used is called Hadoop, which is a kind of open source non sequel database, it's very technical, it works with unstructured data. It's one of the tools used and JSCE has a team working with a project from Oxford and we develop the software ourselves. JSCE is work with existing software, but for many of our projects we develop our own software" (JSCE1, Interview date 12 October 2014).

4.3.2 International bandwidth for research collaboration at Wits

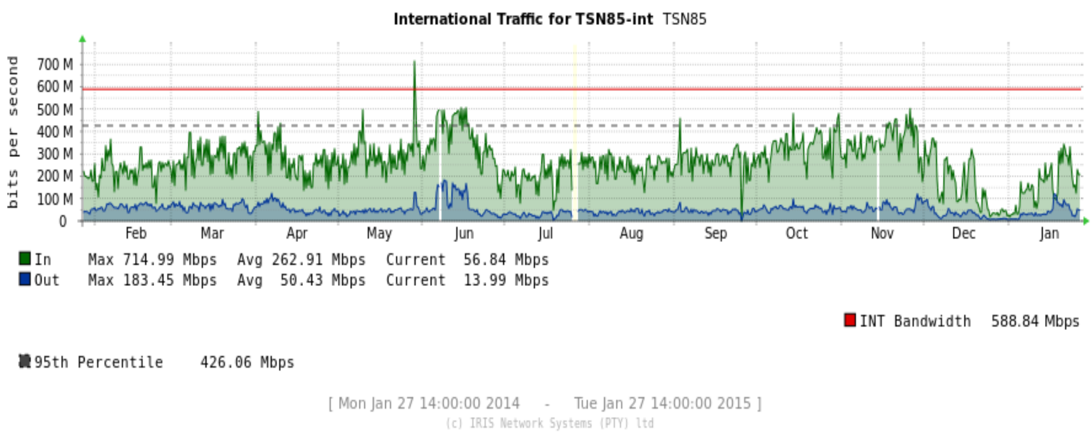
SANReN is the capacity that the Department of Science and Technology (DST) has invested in to connect the universities locally and to provide access to international bandwidth. Universities pay for the international bandwidth through TENET and both are important because without SANReN there will not be international bandwidth.

Prior to SANReN, Wits had very limited bandwidth. There was a restricted international bandwidth and backbone infrastructure provided by TENET. Since SANReN, there was a huge growth in bandwidth access and Wits went from megabytes to gigabytes of capacity (CNS1, Interview date 6 March 2014).

The university started off with 400 Mbps because of unrestricted multi gigabyte connectivity on the Seacom cable. The 500 Mbps is the line speed, the amount the university purchased is downloaded on the Seacom cable (CNS1, Interview date 6 March 2014). In 2014 a proxy of 150 was assigned to students and 90 to staff. The Central Network Services (CNS) does not have restrictions on national cable therefore has multi-gigabytes going out on the national links to other institutions in the country. The restrictions are only on the international side, where Wits purchases through TENET, for example, international bandwidth on the Seacom cable (CNS1, Interview date 6 March 2014). The graph below illustrates peak international traffic going in and out of the university.

The graph illustrates the international traffic at Wits between January 2014 and January 2015. The usage fluctuates on a daily basis depending on the amount of incoming and outgoing traffic (CNS 2, Interview date 18 June 2014).

Figure 10: International bandwidth for research collaboration at Wits



Source: TENET

CNS' biggest challenge in terms of the SANReN network is the growth in and ability to meet the demands. "It is a challenge every university has" (CNS1, Interview date 6 March 2014). There is a demand for additional bandwidth and currently Wits spends about R990,000 a month on international bandwidth. CNS established an extensive wireless network which saw Wits connecting residences and new buildings on the West campus. Due to the demand CNS had to increase the international bandwidth and purchased an additional 100 Mbps. "The capacity of 500 Mbps is fine for now but will not be enough in the next few years" (CNS1, Interview date 6 March 2014). CNS1's view is that bandwidth is never enough and the demand will always be high because the Internet is in demand: "a lot more is now done on the Internet" (CNS1, Interview date 6 March 2014).

On the question of any policy or guidelines in terms of SANReN network usage at Wits, CNS1 response was that Wits has an acceptable use policy for guidelines on usage for its own network and infrastructure, but not for the SANReN network. The Acceptable Use Policy (AUP) document is available online (CNS1, Interview date 6 March 2014).

Regarding the web based applications available for students and staff, CNS1 referred to the new e-learning tools available within the university. Some of the applications are available on virtual private network (CNS1, Interview date 6 March 2014).

The respondent's view regarding the question on demand and supply of the bandwidth is that it depends on the requirements of the user and the pipes cannot be dedicated specifically for a certain department because of the number of students and staff who use it. "There are no dedicated links, so it will depend on the amount of people using bandwidth at that particular moment" (CNS1, Interview date 6 March 2014). "CNS never runs out bandwidth, because TENET allows them to burst and sometimes it runs up to 600 Mbps. "That is not sustainable because Wits cannot consume more than they buy. In some faculties there is terabyte usage of data and even the presence of SANReN and the current bandwidth of 500 Mbps cannot be effective enough for those departments at Wits" (CNS1, Interview date 6 March 2014).

CNS1's response to the question of whether the SANReN network is effectively used at Wits was that the academics would answer the question better. For Internet purposes the network meets the requirements. However there has been a lot more failures in the past. The SANReN network is more reliable now, since it has a lot more of redundancy built into the network, although Wits can always do with a little bit more (CNS1, Interview date 6 March 2014).

Management of international bandwidth is done at various levels. Wits pays for a certain amount of international bandwidth from TENET and the university is only entitled to the amount purchased. It is a policy decision by the university to decide on how much bandwidth they get, a decision made by CNS and partly by the university ICT committee (Bio1, Interview date 3 March 2014).

TENET manages international traffic, with bandwidth acquired through higher education funding. Current capacity is 10Gbps and it is already over utilized. “DST managed to fund R600 million for connectivity on WACS to support SKA and now have 20 Gbps on the West Coast and that can grow to 40 Gbps in five years” (CNS1, Interview date 6 March 2014). TENET acts as an interface between higher education and SANREN. It looks after backbone connectivity, last mile of SANREN backbone and international connectivity.

The view from the discussion with interviewees is that shipping data to the CHPC is very expensive due to the costs of international bandwidth. A respondent mentioned the difference the international bandwidth would make to bioinformatics work. According to the interviewee, “we are at the level now where we can carry the research although it is sometimes a challenge. If you compare the bandwidth that we have to our counterpart’s facilities in Europe, we are talking of four to five times faster than what we are getting” (Bio1, Interview date 3 March 2014). For example the large data sets the respondent downloaded in the beginning of 2014 when hardly anyone was around at the university was adequate as there was enough bandwidth available. It took a day or two to download the data. “However in that period if something went wrong, a minor hitch, you have to start again, but it was okay” (Bio1, Interview date 3 March 2014).

Respondent Bio1 stressed that that there is always going to be a demand for bandwidth, but right now the supply needs to be managed very carefully. “Back to the datasets we mentioned earlier, due to technical challenges of supply of bandwidth, we had to download the data rather than request students to do it. So in a different network environment, students would have done it rather than us downloading data for students” (Bio1, Interview date 3 March 2014).

The network is able to carry the high volume of data traffic but by international standards it is not good. CNS has the firewall to filter the usage of bandwidth and to make sure the network is used for what is meant for. “The firewall is more for protecting the network and it blocks anything malicious from the network. There is some traffic on the firewall that CNS does not allow such as sites for downloading movies, music etc.” (CNS1, Interview date 6 March 2014).

4.3.3 e-Services and applications adoption

There is a wide range of e-services and applications that NREN users benefit from. “There is set of system software called grid middleware which makes all this work. This is one of the e-services applicable in research. It makes it possible for scientists across the world to transfer terabytes and to process this data” (Bio1, Interview date 3 March 2014)

According to DST-SANReN2, TENET and SANREN are all about research and it is frustrating when staff at the university does not know anything about these services. TENET provides connectivity services to Wits CNS. When it comes to international connectivity it is slightly different, SANReN does not charge universities for national connectivity, they only charge a connection fee. Universities pay for international connectivity towards bandwidth expenses.

The students are the first beneficiaries of the services that are brought by the SANReN. SANReN enables students and researchers to perform data analysis. Currently SANReN provides the capacity of 10 Gbps nationally and soon there will be a need of international bandwidth at 40 Gbps. When DIRISA and CHPC comes in, this will be introduce a huge volume of cyber infrastructure and these projects will have an important component that enables multimedia, conferencing and others. Other value added e-services that use or would use SANReN are discussed below.

4.3.3.1 Eduroam

Eduroam enables students, researchers, academics and support staff at Wits to obtain secure and fast Internet connectivity across participating organizations in 54 countries. The service is set up for use by visiting students, researchers, academics and support staff from participating organizations only. In South Africa, Eduroam partnered with SANReN, connects directly to the SANReN and users at Wits can access this network through their laptops and smart phones or other mobile devices. It is due to the capacity of SANReN that the e-service is accessible. According to one interviewee the Eduroam has hotspots free of data-roaming charges and benefits staff travelling for conferences and those doing collaborative work. “There is no need to sign on to the ICT policy on campus as connectivity can be done anywhere where there is an Eduroam hotspot. Eduroam is accessible at any Wits Campus" (DST-SANReN 2, September 2014)

4.3.3.2 PerfSONAR

PerfSONAR is a toolkit deployed on stand-alone servers for network performance measurement and monitoring. It encapsulates best practice tools for measuring available throughput, loss and latency (amongst other performance parameters) (SANReN, 2013). It is a performance focused service orientated network monitoring architecture that helps SANReN to monitor or measure the capacity that reaches the end-user. For example, if the end user is given 10 Gbps capacity, SANReN can use perfSONAR to monitor and to ensure the end user gets what they pay for. From the university side the software ensures that they receive the capacity they paid for, but problems arise when universities have inadequate or incompatible infrastructure (DST-SANReN 2, September 2014).

4.3.3.3 Light path service

Gole Light Path is currently not available in the country but will soon be running on WACS (West African Cable System). "Gole Light Path is like a telephone exchange. If somebody needs to transmit large quantities of data, they can use software to dial in between GOLE links. For example, with satellite dishes one can collect a vast quantity of data" (DST-SANReN 2, September).

4.3.3.4 Federated identity management

FIDM amounts to having common sets of policies, practices and protocols in place to manage the identity and trust for IT users and devices across organizations. At universities the system is used to overcome the problem of research equipment and access to data sets sitting in different places, when researchers need access to those data sets. "Instead of having to phone people in different places to allow one access to data, the researchers have to start by signing the agreement of collaboration and everybody who is registered will have access to that university and use a university staff or student number to log on. Researchers can use it to share research information" (DST-SANReN 2, September).

4.3.3.5 Certification Authority

Certification authority is an electronic certificate which certifies that the database is trustworthy and reliable and satisfies a set of international standards in terms of the way data is looked after. “There will be a set of criteria that satisfy international standards and in this country DIRISA is a certification authority used to certify databases” (DST-SANReN 2, September).

4.3.3.6 Cyber Security

Cyber security is the protection of information systems from theft or damage to the hardware, the software, and to the information stored, as well as protection from disruption or misdirection of the services provided. “Protection of information from theft is one of the critical areas” (DST-SANReN 2, September).

4.3.3.7 Grid computing

According to an interviewee “a grid works on various tasks within a network, but it is also capable of working on specialized applications (DST-SANReN 2, September 2014). “It is designed to solve problems that are too big for a supercomputer while maintaining the flexibility to process numerous smaller problems. In grid computing, the computers on the network can work on a task together, thus functioning as a supercomputer. Computing grids deliver a multi-user infrastructure that accommodates the discontinuous demands of large information processing. At Wits HEPG and bioinformatics grid computing is critical and overlaps with cloud computing” (DST-SANReN 2, September 2014).

4.3.3.8 Applications adoption

ICT applications adoption at the university since SANReN includes Eduroam (CNS1, Interview date 6 March 2014). Bio1 mentioned that there is no web based applications usage in his research, but they use software and programmes that specifically designed for bioinformatics research. Bio1 uses Google applications “but it is not a major part of what we do…An application that uses SANReN is Adobe Connect and we use that very extensively during meetings” (Bio1, Interview date 3 March 2014).

4.3.4 Experiences of SANReN usage in scientific research

Respondent Bio1 explained that it made a big difference when SANReN came on stream and bandwidth improved dramatically, both local and international (Bio1, Interview date 3 March 2014): “There has been substantial improvement in network performance. The SANReN network facilitates research collaboration, but one must differentiate between the different bandwidths you are getting. SANReN is the national infrastructure” (Bio1, Interview date 3 March 2014).

As an academic and senior researcher, Bio1 felt that SANReN has been used more for knowledge sharing and sometimes it is used as a vehicle to share knowledge with other researchers in the country (Bio1, Interview date 3 March 2014). Bio1’s view is that SANReN is sometimes being effectively used. There is always international traffic coming in during working weeks. Wits is using the entire bandwidth allocation paid for, in that sense it is using the entire capacity that is paid to use for 24 hours and that means some of the data transfer can be scheduled for after hours (Bio1, Interview date 3 March 2014).

The general connectivity to SANReN is reliable although there have been times when there were challenges since the beginning of 2013 (Bio1, Interview date 3 March 2014). At other times the network is faster. There is a huge difference if transferring data of 500 Mb or 5000 Mb, the difference between the two is that it takes two days to transfer 500 Mb and twenty days for 5000 Mb, and that is not practical (Bio1, Interview date 3 March 2014).

The various faculties and schools that do data intensive projects and transfer terabytes of data sometimes get limited access due to slow Internet. Sometimes it takes several days for their data to be transferred to overseas. Therefore CNS has been in consultation with the Physics Department to resolve the data transfer situation (CNS1, Interview date 6 March 2014).

In response to the question on the biggest data transfer done in numbers Bio 1 responded that they upgraded sites, populated data and transferred about 5 terabytes within a few days, but regularly transfer data in the 10 to100 gigabytes range once a month. The

School of Electrical Engineering pays for network infrastructure, cable, modem etc. within the department. The scientists use Centre for High Performance Computing facilities from time to time and there is one Masters student who uses their specialised equipment in Cape Town. DST is establishing a bioinformatics support platform which will be based in high performance computing and Bio1 has been involved in setting this up (Bio1, Interview date 3 March 2014).

On the question of SANREN being of any value, CMACS-Data Science answer was "no". "How many people know of SANREN, or even TENET? There are services that are there that people at the university are not even aware of. One good example is Eduroam. It's a service agreement internationally which is such that if you are a user of it and you are at UCT, you can log into the UCT network as if you are at Wits. SANREN is a physical infrastructure and the services are there and we not making use of them. So my subjective view is that there are many areas of SANREN that we not using" (CMACS-Data Science 1, Interview date 16 September 2014).

4.4 Data management and SANReN infrastructure

SANReN provides easy connectivity for researchers to share data, produce collaborative research and publish co-authored journal articles in highly cited academic journals. "Whenever science becomes more sophisticated it generates more data. There is a correlation between progress in science and the generation of more data. The logic is that with complicated devices one needs to know how to store and how to move data. Without SANReN there would not be talk of serious science in this country" (HEPG1, Interview date 11 August 2014).

"The High Energy Physics Group generates tremendous amounts of data from CERN tier 1 and tier 2 centres. With SANReN it will be possible to push data from Wits to the rest of the country, about 100Tb (terabytes) of data for paleo-science data, SKA and radio astronomy, and high-energy physics. The SKA data centre cannot be built without SANReN" (HEPG, Interview date 11 August 2014).

HEPG1 stated that NRENs are the backbone of the ability to lead research in particular fields in the world. HEPG is expanding on its competiveness and the SANReN infrastructure makes that possible (HEPG, Interview date 11 August 2014). According to SKA1, processing the vast quantities of data produced by the Square Kilometre Array radio-telescope in South Africa will require very high performance central supercomputers capable of 100 petaflops per second processing power (SKA, Interview date 19 September 2014). "This is about 50 times more powerful than the current most powerful supercomputer and equivalent to the processing power of about one hundred million PCs" (Wits High Energy Physics Group, 2013).

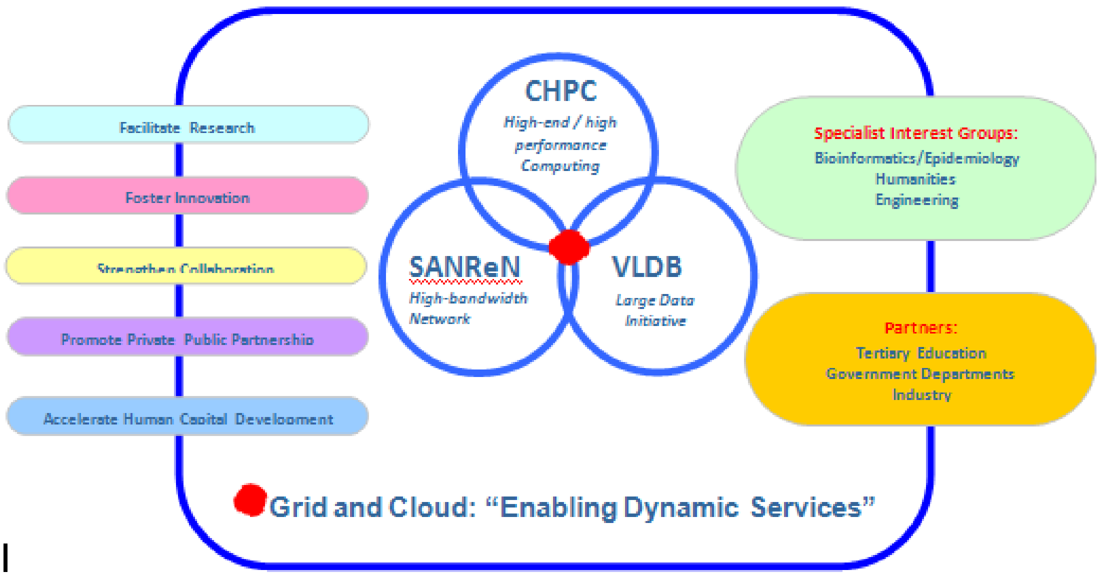
4.4.1 Cyber infrastructure

The cyber infrastructure is as important as the question of leadership because science is all about generating large amounts of data. HEPG1 pointed out that scientific research is becoming more detailed therefore "scientists are not happy with just observing in the microscope or inspecting fossils by hand" (HEPG, Interview date 11 August 2014). HEPG1 elaborated "scientists want to see what is inside the fossil and therefore have to run 3D recognition by looking inside the fossil. In other words the smaller distances you probe the more you have to dig out, but you don't need an intrusive procedure to destroy the fossil, just look inside with x-ray and capture the data for analysis" (HEPG, Interview date 11 August 2014).

CMACS-Data Science 1 highlighted the National Initiative for Cyber Infrastructure-(NICIS), the national DST project. In the NICIS report DST envisage skills development, services, and physical infrastructure. The South African National Research Network (SANReN) and the Very Large Databases (VLDB) complement the CHPC through the provision of high-speed, high-bandwidth connectivity, and the effective curation of a variety of notably large databases. "The cyber infrastructure activities are complemented by that of the SAGrid. Therefore people must be taught parallel computing, cloud computing, in order to develop the local skills" (CMACS-Data Science 1, Interview date 16 September 2014).

The cyber infrastructure consists of the three pillars, SANReN which is a physical infrastructure, the Centre for High Performance Computing, and the SA-VLDB, the large data sets or big data initiative. The CHPC is one of three primary pillars of the national cyber infrastructure intervention supported by the (DST). Figure 11 below illustrates the national cyber infrastructure that would facilitate the grid and cloud computing as outlined in the national integrated cyber infrastructure systems.

Figure 11: South Africa's cyber infrastructure in 2011: An overview



Source: CSIR, 2013

HEGP1 highlighted that the cyber infrastructure is necessary to science in South Africa and gave an example of the constraints of sophisticated network capabilities. "It may sound dramatic, but at a meeting in the video-conference room in the Physics building with other convenors of cyber infrastructure at Wits, the paleontology scientists mentioned something that was frightening. The data for 3D analysis of fossils is shared with the world while hosted in the US and what was frightening is that Wits is a leading institution in paleo-sciences but is not able to host paleo-science data due to physical infrastructure constraints, namely the need for servers hosting terabytes of data" (HEPG, Interview date 11 August 2014).

According to CMACS-Data Science 1 the weakness in South Africa is that there is no discussion with the private sector in terms of needs for connectivity and available infrastructure. "As the NICIS report has stated, the cyber infrastructure is about research, but the private sector can also make use of it. It is not conceived of as a space where only the university can do research" (CMACS-Data Science 1, Interview date 16 September 2014).

4.4.2 Data centre for support of scientific research

The findings from the data collection reveal that there is a high demand for a service in the form of a data centre. There are three aspects to storing data, namely data transfer, data management and data archival. The findings highlight a need for relatively small data centres at institutional level, to be connected to other points, such as the main data centre near the telescopes in the Karoo or somewhere close. According to SKA1 "good connectivity is required between these centres and that is where SANReN infrastructure plays a role" (SKA, Interview date 19 September 2014).

In response to the SANReN network as a facilitator for storing data, SKA1's view is that the SANReN network is essential for the SKA project. "SANReN enables communication at the highest possible speed. Imagine having to communicate and share data in Cape Town, North West University etc., with a very reliable and high efficiency tool for data uploading and downloading" (SKA, Interview date 19 September 2014).

SKA1 held the view that SANReN is a network and a service for the SKA work. SKA scientists have a small size data centre with at least 100 terabyte storage capacities in house, at the physics department. The computing capacity, fast computing, Internet, and the capacity to work with data are still required. "The 100 terabytes is sufficient at the moment but will be insufficient in two years' time when dealing with MeerKAT and there will be a need for another factor of 5 or more" (SKA1, Interview date 19 September 2014).

SKA1 explained that already the MeerKAT archival is managed at a different level of complexity. "One level of complexity is the in-house capacity to store and analyse data but that is an internal problem at institutional level. With KAT-7, the SKA team can still manage a data archive as it should be relatively small" (SKA, Interview date 19 September 2014). SKA1's opinion is that SANReN is supposed to provide the support and should connect users and once it provides the capacity it is a matter of a user developing in-house management of the data. There are plans to put a data archive in the

Karoo as a storage facility and analysis centre. The centre will facilitate transfer and management of data and possibly the digital interaction.

As this respondent has alluded “For SKA to be successful there has to be good investment in data management, data science related to SKA. SKA will be a machine manufacturing data. They have to think about data science in a new approach. SKA needs to have infrastructure at the level of SANReN. There is a need to produce a new generation of technicians and researchers in the country” (SKA1 interview). “If I don’t have a technician, I can’t do anything. If I don’t have good administrators, good project managers I cannot bring the country along with SKA and we will regress” (SKA1 interview). There is a high level of complexity of issues and in this respect the interviewee believes there is an opportunity for South Africa to break down this wall of competiveness. “Scientists need to ask more from the resources that they have, in terms of the role they play on big projects and in terms of the attention our country will give to education by asking the right questions and using the right tools” (SKA, Interview date 19 September 2014).

SKA1 has plans to improve data facilities but this will require funding resources to develop. “It is important to have a very good and fast and high capacity centre for analysis. Once the data comes in at a fast speed, if you don’t have a fast computing system, you can’t do much. So in order to exploit the full capacity of the data, there is a need for a highly efficient computing system” (SKA, Interview date 19 September 2014).

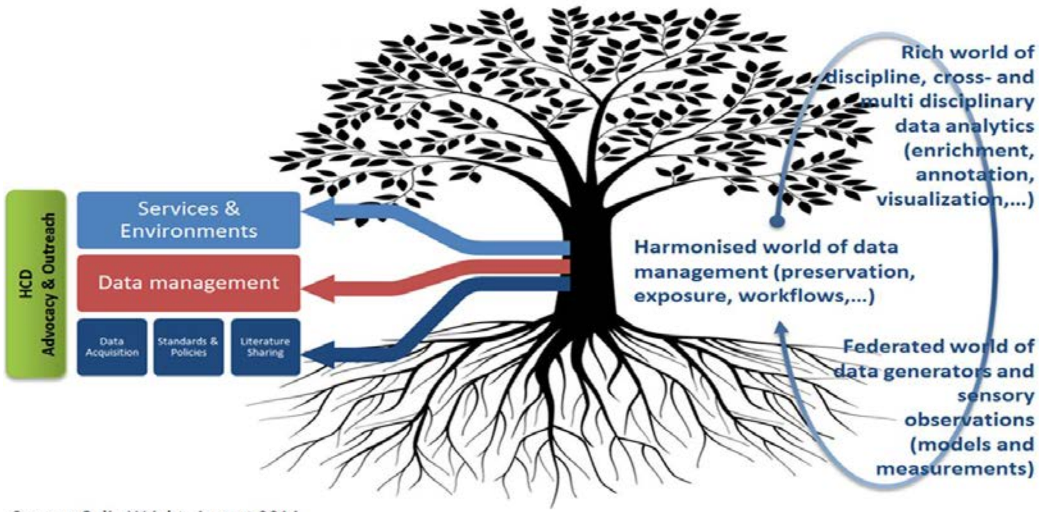
Currently SKA1 is asking for funds to upgrade the data storage system to plan ahead “because in two years’ time we cannot wake up and ask for 200 terabytes. It is not only funds that are needed but new ideas too. The money is important, but we want people to come up with new ideas. Those good ideas will produce innovation as the country needs continuous innovation. It is the challenge and SKA requires innovation at a higher level. In the street, in the rural areas, in the ocean, we need innovation and SKA is one project that needs innovation” (SKA, Interview date 19 September 2014).

SKA1 highlighted that SKA is "an opportunity for all scientists, an opportunity for the country. SKA is a complex big science project, it's impossible to even think we can manage a project like that. The project needs first class researchers, otherwise South Africa will not be able to exploit the data from the SKA" (SKA, Interview date 19 September 2014).

The SKA being such a complex machine, it necessitates precursors to probe technology and develop the data analysis system and transmission. The SKA will create clusters of dishes and three spiral arms of about of 100 km radius (SKA, Interview date 19 September 2014). The SKA Phase 2 project deals with the three basic detector systems which are the mid frequency arrays, a combination of detectors and dishes and high frequency dishes to start the operation in MeerKAT.

DST-SANReN 3 is of the view that each of the science projects has different storage needs, but the role of SANReN has nothing to do with storage. The Centre for High Performance Computing (CHPC), SANReN's sister unit, and the Data Intensive Research Initiative of South Africa (DIRISA) have storage capabilities and may have to store data for the SKA (SKA, Interview date 19 September 2014). However according to the respondent, expansion in this data–intensive portfolio requires infrastructural support. See the diagram below for a proposed data infrastructure service.

Figure 12: Data Infrastructure



Source: Colin Wright, August 2014

With regard to the question on data infrastructure, DST-SANReN 3's response is that it is not clear whether the actual setup of the CHPC centre is suitable to provide the growing demands of the data management service. However SKA1 emphasised that there is a need for a very high performance computing centre that is able to store the data and provide pre-analysis of that data. "For example a typical scientist would want to use the data to write a paper and will not want to deal with the old process of acquisition and first qualification of the data. Data cannot be used straight away as there is a need for pre-management to make data available in a specific format that can be applied in computer software that every scientist can understand. In the case of SKA the process of data management should be done closer to the telescope to avoid unnecessary replications which takes up a huge amount of time, energy and resources" (SKA1, Interview date 19 September 2014).

HEPG1 spoke about Wits' need for a data analytics centre to boost scientific research. HEPG1 is writing a proposal for this and has formulated the specifications and budget for the centre. The hardware needed for the centre is relatively inexpensive for the mid-size data centre he is proposing. "The proposal would be for a couple of hundred terabytes of data with proper ratio of hardware to technical support for sustainable effort to look at Tier 2's in the US and China, in the context of the CERN computing model. Tier 3 data centres serve the needs of a group, it could be as small as a laptop to serve the needs of a particular research group" (HEPG, Interview date 11 August 2014).

"The Wits CNS service needs high end computing and video-conference facilities, but the way CNS is structured today is that it is not able to provide the service required. The researchers need to link supply and demand across the system e.g. students and research objectives, but researchers are building the capacity to generate demand, and students would write the algorithms, etc." (HEPG, Interview date 11 August 2014).

At the moment Wits is planning to build a data science research institute as discussed at the University Research Committee (URC). The process to establish a proposed Centre of Excellence (CoE) has already started and data science curriculum meetings commenced in August with the aim to build capacity for data analytics (HEPG, Interview date 11 August 2014).

4.4.3 Grid technology

Grid technology is important for two reasons: one is that researchers rely on raw bandwidth and secondly SANReN provides the network to coordinate grid sites locally for the ALICE experiment. An interviewee uses the CHPC which itself utilizes the SANReN infrastructure.

The Worldwide LHC Computing Grid (WLCG) is composed of four levels, or "Tiers", called 0, 1, 2 and 3. Each Tier is made up of several computer centres and provides a specific set of services. Between them the tiers process, store and analyse all the data from the Large Hadron Collider (LHC) (CERN, 2014). "Tier 1 Centre concepts come from the CERN computing model, which would need to be modified to South Africa. South Africa has various projects. A Tier 1 data analytics centre has to be dedicated to a number of big sciences. It must have excellent throughput capabilities to SANReN. It is within the ranges of 10 – 40Gbps throughput to SANReN but can store and process significant amounts of data which the HEPG is working on" (HEPG, Interview date 11 August 2014).

Tier 2s are typically universities and other scientific institutes that can store sufficient data and provide adequate computing power for specific analysis tasks. They handle a proportional share of the production and reconstruction of simulated events. There are around 155 Tier 2 sites around the world (CERN, 2014). Individual scientists can access the Grid through local (or Tier 3) computing resources, which can consist of local clusters in a university department or even an individual PC. There is no formal engagement between WLCG and Tier 3 resources (CERN, 2014).

The ALICE and ATLAS projects share computer facilities at Wits and Bio1 runs that computer facility. ALICE uses a computing system called grid technology. "The way it works is that data gets generated and distributed to computers across the world. The data produces a signal that physicists are interested in" (Bio1, Interview date 3 March 2014)

The SANReN hub in Cape Town and the CHPC plays an important role, "it could be a Tier 1 centre hosting thousands of petabytes, and some data could be resident in the CHPC. CHPC is primary storage to store data that universities cannot afford to store or to analyse. Wits can build capacity for the data centre, but having the rest of South Africa in mind including those universities who do not have capacity and therefore would need to collaborate in order to enhance Wits' ability to collaborate with others in South Africa. It is critical to Wits' ability to lead science in South Africa and the world" (HEPG, Interview date 11 August 2014).

4.4.4 Patents application and intellectual property

A patent is an exclusive right granted for an invention, which is a product or a process that provides a new way of doing something, or offers a new technical solution to a problem. The patent provides protection for the invention to the owner of the patent. The protection is granted for a limited period, generally 20 years. Patent protection means that the invention cannot be commercially made, used, distributed or sold without the owner's consent.

Patents are intellectual property which cover invention, trademarks, trade secrets, and all aspects created by the human mind. Certain intellectual property such as creative arts can be protected by copyright of which patents are one aspect. Everything except copyright is geographical, which means registration of a patent has to take place in the country where one needs protection. However there are also international treaties that give protection for patents.

"Patent protection is given for inventions. The whole philosophy is that you disclose your invention to the world and you get 20 years monopoly. For trademarks you get at least 10 years, and you lose them if you don't use them. Patent philosophy is to speed up technology development by making your invention available to the public, and the state gives you the monopoly for 20 years. So you get patent letters, which is a letter between an inventor/applicant and the state. The applicant can be the inventor, the company, the university" (Patents 1, Interview date 15 September 2014).

4.4.4.1 HEPG patent application

The HEPG applied for a patent for a system for handling data in South Africa. The specification has a section called the summary of the invention where description of scientific invention is outlined. The HEPG filed the application in the United Kingdom, "…the reason being that once they get a search report it allows them a year from the priority date not to develop the invention further. After a year, they will file a complete application which will be published. After the first year, they can let it lapse, or they can re-file or even move the priority date a year ahead to complete it for protection" (Patents 1, Interview date 15 September 2014).

Due to the need for technologies to process terabytes of data per second (Tbps) and since data is too large to be stored scientists have to process and generate knowledge immediately, so the devices and techniques Wits scientists are developing will be useful to other scientists.

4.4.4.2 Steps followed in patents

To satisfy a patent, the invention needs to satisfy three criteria, it has to be novel, inventive, meaning it's not normal to a man skilled in the art and it has to be useful. Hence discoveries are not patentable because they are in nature already patented. Software is not patentable, only the application is patentable. "There is the Treaty of

Paris, which means that to start the protection route, which is what HEPG has done, one has to file the first application and the date of filing the application is called the priority date. It doesn't give you protection, but it gives you a priority date. When the patent is examined, anything before that date can affect the novelty and inventiveness" (Patents 1, Interview date 15 September 2014).

4.5 Constraints of SANReN usage

In response to the question on the constraints of SANREN usage respondent SKA1 explained that it is not a SANREN problem but internal university problems. "At the moment the big constraint could be the fact that the university is not able to use the capacity of the SANReN. It might be that part of the problem is the internal infrastructure which is old and not compatible to SANReN or there might be other reasons, but to be fair, the problem is complicated. Other constraints might depend on technical and infrastructure aspects. The technical problem relates to management" (SKA, Interview date 19 September 2014).

This interviewee thinks the current capacity should be improved at the level of the final user and this would facilitate scientific work. "We would like to have more bandwidth from SANReN and SANReN must extend the capacity country wide. Currently it is not enough to cope with MeerKAT data" (SKA, Interview date 19 September 2014).

"Then the broader issues are that the type of technology used to manage SANReN is not always used to manage scientific data. There is a big difference, SANReN provides bandwidth to a lot of people and they do a lot of things. The normal production use of the network, what each is doing is relatively small. There are thousands of requests over the Internet at Wits, and each request is different and small, but with scientific data there is relatively few people with requests for big data. So there might be gigabyte data sets when ATLAS runs, there are relatively few, but huge amounts of data are transferred. The type of data needed to supply general university staff and students is different from data for scientific use" (Bio1, Interview date 3 March 2014).

4.5.1 Risks associated with SANReN failure

Some of the risks of SANReN failing relates to sustainable electricity flow, power cuts, and downtime. Respondent HEPG1 felt that if the whole system halted it would create backlogs which would be very difficult to catch up. The risks include data transfer through switches and intermediate points between users, and end-users have to have a risk assessment and feasibility study for failure rate of each single point, to minimize system and single point failures to avoid breakdowns. That leads to the thinking of SANREN as being a scientific agency, but also a potential bottleneck.

"There have been people trying to hack into the system every day and it becomes a bottleneck and that is a trade-off. The configuration of the network system is a challenge, for example when SANReN came on stream which was about three years ago, there was 10 Gbps from SANReN and the gateway router was capable of only receiving 1 Gbps, and it was only resolved last year, and in the campus there is still have so much of that. If I had to receive data here on the desktop, I would only get about 100 Mbps, so there might be a high quality backbone at Wits, this fantastic SANReN, but actually to get data to the machine it is only 100 Mbps" (Bio1, Interview date 3 March 2014). This is not only a Wits problem but is true for all universities. "With both TENET and SANReN, there are significant challenges, one already alluded to is how does the university support research and teaching with this network and prevent people from downloading inappropriate content from it? So that is a real problem, security is a challenge" (Bio1, Interview date 3 March 2014).

4.5.2 SANReN redundancy

On the question of SANREN redundancy DST-SANReN 1 explained that the initial project was to get everybody connected in a linear fashion, "and at the moment it is like a one-way network. There is a need for redundancy which is in action in second phase of the project. The next phase of the project is to upgrade the network to bring in redundancy on the network at national level and at international level with the DST" (DST-SANReN 1, Interview date 8 September 2014).

According to DST-SANReN 2 redundancy is important. When the SANReN connection is 30 to 40 Gbps full, the CSIR starts increasing capacity. “The idea is that when someone is doing research and would like to move big piles of data around, they don’t want traffic to delay” (DST-SANReN 2, Interview date 17 September 2014). According to this interviewee, the DST bought redundant routes deliberately “as they want a situation where if traffic cannot go through those routes, then it can go through alternative routes or vice-versa” (DST-SANReN 2, Interview date 17 September 2014).

The DST through Broadband Infraco acquired capacity on the West Coast cable which will then provide redundancy at the international level. The redundancy at national level is what Meraka is working on now and that will be made possible by the ongoing support to SANReN.

4.6 Investment value of SANReN capacity

DST-SANReN 1 explained that the DST is the funding agency of SANReN and the CSIR is the implementing agency but the project itself sits in one of the units at CSIR called the Meraka Institute. “The CSIR is one of the entities that report to DST. The parliamentary grant to CSIR comes to DST but this is a separate contract, they get the funds, and do the oversight and make sure the strategic imperatives are met” (DST-SANReN 2, Interview date 17 September 2014).

DST-SANReN 1 explained that most of the investment today was in establishment of the national network: “All 23 universities main campuses, the science councils, the six national facilities of the National Research Foundation (NRF) and other public research performing institutions and some museums, Baragwanath Hospital and some further education and training (FET) colleges have been connected. Apart from the national backbone, what DST got out of this investment today is the connectivity of the two main national projects, the SKA radio-telescope and the SALT optical telescope and within particular metropolitan municipalities, various sites were connected because some universities have satellite campuses”.

Off the backbone, there are points of presence (PoP’s), where SANReN go to a particular point and provide presence where other entities like future schools or other research facilities can connect to. Some of the PoP's offer 1 GBps but the national backbone is 10 Gbps. In total there are 173 sites connected across the country. Apart from providing the funding DST realized that it was going to be very expensive to connect some remotely located campuses so they entered into a partnership with the Department of Higher Education and Training (DHET) to establish the Rural Campus Connectivity Programme. The DHET made funding available to accelerate the roll out of the SANREN to the rural campuses (DST-SANReN 1 Interview).

4.6.1 Size of investment and total capacity

South Africa has invested large sums in ICT infrastructure. "In 2012 DST reported a total figure of R1.5 billion and this financial year, the national treasury gave DST R660 million to connect to WACS. TENET was finalizing a contract with CSIR around WACS and where TENET comes in is that it will operate that in conjunction with Seacom" (CMACS-Data Science 1, Interview date 16 September 2014). The interview revealed that the first investment was about R28 million with the focus to support work with the rural campuses to get them connected onto the network on a wireless radio link. A case in point is a fibre link running into Makhado, 30 km from Venda.

4.6.2 Value of investment in SANReN

DST-SANReN 1 explained that the initial reason why the DST invested in this particular project was to provide high-speed broadband connectivity to the universities: "So initially it was a very narrow project to provide connectivity to research performing universities such as Wits and UCT. But they soon realized that there is a need across the entire system for these capabilities because they wanted universities to undertake more research to enable them to participate in international projects and even participate locally with each other. Good connectivity is key to doing good research. The concept or the plan was to have a national project to include all the universities in the country, national facilities of NRF and science councils and all other public research performing institutions".

4.6.3 SANReN core capacity and connectivity for scientific research

There are discussions underway to upgrade the network. The core capacity is sufficient for now but SANReN is fast approaching the limit of this capacity. There will be a need to increase the bandwidth to 40 Gbps by 2015. The SANReN 10 Gbps core capacity is believed to be almost at its peak and will not be adequate when mega projects such as the SKA come fully on board.

The SANReN system has been designed in such a way that the network could be upgraded without ripping up the existing cables. The network is designed in such a way that its capacity can be increased but this will depend on the needs and will be demand driven. The network can go up to 100 Gbps depending on the demands and needs of the usage. It will allow an upgrade in case capacity is needed for major projects like the ATLAS experiment and the work with CERN and the SKA.

4.7 Conclusion

Chapter 4 has outlined the data collected based on the qualitative research approach. The data was collected from SANReN, TENET, the High Energy Physics Group, and the SKA project at Wits, the Centre for Maths and Computational Studies, Joburg Centre for Software Engineering and the Bioinformatics group. The chapter presented different perspectives on SANReN usage, SANReN infrastructure, application adoption, e-services and value.

Chapter 5: Discussions and reflections on characteristics of NReNs as ICT infrastructure to support e-research

5.1 Introduction

The chapter provides an analysis of research findings in relation to the literature review and research questions and the characteristics of SANReN as ICT infrastructure to support e-research. The aim of this chapter is to gain an understanding of ICT infrastructure required to carry out international research collaboration at the university and to efficiently provide a range of e-services through the SANReN.

5.2 SANReN policy for ICT at universities

There has been sustained effort to improve computing abilities as science is constantly expanding therefore more international bandwidth will be needed in future. The analysis points to lack of clear policy for SANReN to address the future needs of the universities.

The SANReN policy would advance on the ICT Infrastructure at the universities to support e-services, applications adoption and to the people using SANReN for research collaboration.

5.3 Data intensive research collaboration using SANReN

Observations from the analysis reveal that SANReN is mandated to work on projects of national interests in the science space with the SKA being one, and the High Energy Physics Group which are members of the ATLAS experiment at CERN in Geneva. ATLAS experiments requires SANReN network as it involves collection of massive data of protons colliding at very high energy leaving a lot of debris measured at very high speeds. After a complicated process of collecting the large amount of data, of about 100 exabytes (10^6 terabytes), it is then captured on disc and sent to participating members at CERN.

It is observed from analysis that Wits High Energy Physics Group is interested in Higgs boson and need to use automated software from CERN for a summary of data relevant to Higgs boson. The requirement thereof is of reliable international bandwidth and capacity. The process of SANReN has enhanced HEPG data processing capacity by 10%. It has further been revealed that in order for the group to achieve success the group needs a stable system that can sustain a continuous stream of data going back and forth to Europe, US and China through the high use of bandwidth. SANReN has made progress in the ability to connect and quality of communication. Video conferencing and Skype would not be possible without the bandwidth provided by SANReN at the university. HEPG receive good quality video conferencing and audio from CERN which means that SANReN is beneficial.

5.4 SANReN/TENET connectivity and university infrastructure

The issues emerging from the discussion with SANReN users highlights the internal capacity, e-services such as the data Centre to be able to host international research collaboration projects. Although SANReN provides connectivity the researchers doing work for the SKA and those involved with CERN experiment need the data centre for data storage, curation, analysis and management. The data centre will ensure long term sustainability, availability and security and assist scientific researchers with sustainable tools, models and algorithms to help drive discovery (NSF, 2012). Such functions are connected in a recurring life of data, as research generates new data, old data are revisited and new theories are advanced.

5.5 SANReN as a vehicle for data intensive research collaboration

SANReN has brought the data intensive research projects such as the SKA and High Energy Physics Group together. Lack of seamless computing ability in scientific environment can hamper the growth of these collaborative research. The bandwidth provided by SANReN is a critical element to the success of these scientific research projects. However, bringing the data from the SANReN has been challenging as bandwidth constraints limit the capacity to move large data sets to CERN data Centre.

The findings from the semi structured interviews revealed that although SANReN makes it possible for research collaboration amongst multiple universities there are still major constraints that limit usage of SANReN at institutional level.

The respondents involved in data intensive research collaboration shared the similar view that the advanced network is capable of making a substantial impact however due to the infrastructural limitations at the university level, the high speed broadband sometimes does not enable rapid transfer of high data volumes.

5.6 SANReN infrastructure evolution

Observations from analysis reveal that DST emphasise the need for more managed infrastructure for SANReN. The infrastructure itself cannot be a means to an end, but it is an enabler to do collaborative research and make an impact in science.

SANReN itself does not have infrastructure. The current model is that they lease it from Telkom for certain number of years. Dark Fibre Africa supplied SANReN optical fibre ring networks in Johannesburg, Pretoria, Cape Town and Durban that were fully commissioned by 2010. In aggregate they connect some 90 urban campuses to the backbone. Dedicated access circuits include 10 Gbps long-haul circuits to the radio astronomy and space operations centres at Hartebeeshoek; the astronomical observatory at Sutherland and the developing radio astronomy site at Carnarvon, TENET (2014, no date).

5.7 The cyber infrastructure

The cyber infrastructure addresses key issues in data management and data curation both of which are critical to research in engineering, science and physics. The report of the Ministerial Review Committee on the Science, Technology and Innovation Landscape of South Africa (2012) made a specific reference to the development of a cyber infrastructure roadmap for the country (DST, 2013a). The landscape is changing somehow as SANReN is becoming more of a vehicle to acquire international bandwidth (DST, 2013a).

Like the physical infrastructure of roads, bridges, power grids, telephone lines, and water systems that support modern society, cyber infrastructure refers to the distributed computer, information and communications technologies combined with the personnel and integrating components that provide a long-term platform to empower the modern scientific research endeavor (National Science Foundation, 2013).

5.8 Developing an e-service in the form of a data centre

A data centre is critical to support complex problems and issues addressed by scientific research at Wits. The findings reveal that advanced computing and a science data institute where Wits scientists can use for data storage and management from SKA data centre in the Karoo to the CERN data centre is required.

Figure 13 below depicts how the scientific data will travel if there is data centre at Wits. Observation from analysis reveal that South Africa Science is still not big enough, due to limited Data Centre capacity. Wits can build Tier 2 Centre in order to build internal capacity, a data centre that belongs to an institution offering multi- and interdisciplinary services for scientific research so that local researchers do not depend on CERN infrastructure. A dedicated data Centre in Sutherland, Northern Cape and high throughput computing at Wits Main campus that is able to transfer data to CERN in Geneva as per below diagram.

Figure 13: Data Centre

Source: Researcher

5.9 Grid Technology development

Sharing resources by the Grid technology like the CERN, South Africa scientists can share data across the world using grid computing. The grid system and advanced computing, networks, databases and scientific instruments which will provide collaboration for universities to take part in video conferences and subscribing to international databases and secure resource sharing where everybody can access the journal databases.

5.10 SANReN connectivity to the universities

Observations reveal that the Southern Africa Large Telescope (SALT) project started with little bandwidth to cope with the demand of data collected and sent overseas. When TENET bought 10 per cent of the Seacom cable, there were a number of institutions that were off the national backbone, like Limpopo and Rhodes universities. This meant that although they invested in Seacom cable, still they did not benefit since they were off the national backbone.

Observations reveal that from the beginning SANReN was meant to increase connectivity for research universities and councils. The vice chancellors of the universities were concerned that they contributed to the international cable but were not benefitting from it. Institutions were connected to SANReN infrastructure but those that were not conducting research were not connected. SANReN benefited institutions until there was some funding from the DST and Department of Higher Education and Training (DHET). The vice chancellors lobbied the DST and DHET to make funds available to connect those institutions. In total R80 million and R28 million were channeled through Wits.

Observations from analysis reveal that Wits need SANReN connectivity to work. If Wits does come with advanced state of capacity in form of data centre their scientists will have 90% of the work done. Currently the incompatibility of infrastructure presents a major problem for the future of scientific research in South Africa because it will not able to host the data critical to everybody in the field as far as science is concerned.

Observations from the analysis reveal that SANReN is a vehicle for broadband to the universities. SANReN infrastructure is critical to the work of researchers in large scientific projects because without the SANReN they will not be able to develop the international collaboration. The ongoing projects show the value of the SANReN. The transfer of data is critical to the work of researchers. CERN Physics project, ATLAS is one the largest research group in the country that is data intensive. However the ability to participate effectively in high profile experiments like ALICE and ATLAS depend on significant computing infrastructure (DST, 2013a, p.29).

CNS biggest challenge in terms of the SANReN network is the growth and ability to meet the demands. It is a challenge every university has and from Wits perspective it always been able to meet the demand

5.11 SANReN redundancy

Observation from analysis reveal that SANREN deliberately build in redundancy. The idea is that no site must be at the end of a single network in case if something goes wrong the technicians could always find alternative ways to get to a site.

Analysis reveal that redundancy is built where national networks link up with two international networks. The one is on the East Coast, the Seacom cable which provides the international connectivity on the East Coast. On the West Coast WACS, West Africa Cable System, SANReN network links up with the East Coast in KwaZulu-Natal and in Cape Town. The process enables South Africa to host of the large hydrogen collider (CERN) project.

5.12 Value of applications adoption and e-services that contribute to teaching, research and learning for end users

From the observations the DST, Meraka and CSIR agree that SANReN is meant to support evolving e services at the universities but most of the users at the universities are unaware of those e-services that are supported by SANReN.

The e-services mentioned in the research are used in data intensive research. Most of them are not well known amongst the university staff. It is only a few researchers who make use of the e- services brought by SANReN to the university. In the HEPG the students, Masters, PhD and Post docs are the first beneficiaries of the services that are brought by the SANReN.

5.13 International bandwidth is expensive

From the observations the biggest challenge is cost. If it was possible to get a cheaper bandwidth and bigger pipes the cost of bandwidth would come down. Observation from analysis reveal that Wits pays on average about R9 million per annum. International bandwidth is limited by the budget allocation. The data traffic increases on a day to day basis as there is always a demand for bandwidth. There is potential in data intensive research if the international bandwidth can be available in high capacity. Already there is indirect and direct benefits, according to DST in that the cost of connectivity could possibly come down by a factor of 10. The number of SANReN users is estimated to be a million. UNISA alone has almost 400,000 students.

5.14 Value brought by SANReN to universities

Observations from the analysis reveal that publication of research articles and research data will be of value to scientific research. At the very high level SANReN provides equal opportunities and access to the university students and researchers. Academics at university of Venda can do experiment participating at the same level as the one at University of Cape Town, thus making it possible for researchers and students to participate in big science projects. The other value added services is that the SANReN infrastructure made Eduroam possible. Eduroam is a free Internet access for researchers worldwide and SANReN subscribes to the services (Wierenga & Florio, 2005). When a researcher or an academic travels overseas for a conference or exchange programme they can have access to the Internet through Eduroam.

DST, Meraka and CSIR acknowledged that it is difficult to measure the impact of the value of SANReN since there is no accurate matrix to measure the value. At the university, there are no people to manage the capability and the infrastructure. SANReN is a dedicated infrastructure sometimes incompatible with the university older infrastructure. The universities have to revamp the infrastructure to get more benefits of SANReN as currently, bringing the data from the SANReN has been sometimes found to be slower.

There were plans to bring DHET on board and the terms of releasing funds available to alleviate the challenges. Although Eduroam is well known e-service, not all universities have subscribed.

5.15 The matrix to measure the impact of SANReN

Observations reveal that the challenge for going forward is well defined matrix to measure the output in terms of number of sites connected. DST can measure the average bandwidth per SANReN sites, but they cannot measure the number of users of the network. A good matrix can be the number of sites connected to SANReN. Another measure could be the number of students connected. At the moment there is almost 900 000 university and FET colleges students in the whole country. The two new universities, Sefako Makgatho Health Sciences University and University of Mpumalanga, have already been connected to SANReN PoP's.

More connectivity can be given by upgrading the network for universities to use the cyber infrastructure. The real challenge is to get the matrix that measures the impact. The investment to date is at about R1.3 billion. TENET brings in funding to the table. It works on cost recovery from the institutions and any given financial year TENET bring about R230-R240 million per year. Therefore calculating the return on investment is very difficult.

At the simplest level it could mean that any student who received a degree from the university in the past few years has somehow benefitted from SANReN. CSIR produces a lot of publications through SANReN. SANReN is sitting under CSIR and owned by DST. With TENET in the picture it is a challenge from an operational perspective because the two organisations need to work on one network.

5.16 Conclusion

The analysis was made in the form of qualitative research in which characteristics were interpreted by the researcher to give voice and meaning around an assessment topic. The discussion was on emerging issues from Chapter 4. The analysis was on the value brought by the NREN at the University of the Witwatersrand and the e-services that impact on collaborative research.

The chapter outlined the process followed by the researcher in analysing the primary data findings from semi-structured interviews with the main users of SANReN within the university, i.e. The High Energy Physics Group, the Radio Astronomy, Bioinformatics and Mathematics and Computational Sciences and the representatives from the Department of Science and Technology, SANReN, CSIR Meraka. The approach for the Wits case study is descriptive and has described a phenomenon of NREN within the context of research collaboration.

Chapter 6: Conclusion and recommendations: NRENs as ICT infrastructure for e-services at universities

6.1 Introduction

The main purpose of this research was to examine the NREN infrastructure needed to support e-services needed for research collaboration at the universities, using a case study of University of the Witwatersrand (Wits). The research report examined the value brought by the South African National Research and Education Network at the University of the Witwatersrand, the main bandwidth provider for the university. The explored the NREN infrastructure value to research collaboration, applications and e-services and paid close attention to e-research which utilize the NREN at the university and investigated how these bring value to the collaborative research environment at Wits.

The key findings in Chapter 4 were significant and unexpected. The qualitative methodological approach allowed a presentation of the contours and nuances of SANReN infrastructure at the universities. The analysis in Chapter 5 was framed to focus on dedicated SANReN infrastructure to support collaborative research.

Key observation from the research findings is that DST has invested a lot of funds in national cyber infrastructure of which SANReN is part. The Bioinformatics, HEPG, CERN Project, THE SKA are some of the largest data intensive research collaboration in the country that use SANReN infrastructure. Through SANReN the university aimed to promote and advance continuous collaboration, knowledge creation for the benefit of the scientific research. Wits is driven mainly by the need to obtain more bandwidth for the scientific collaborators to share data across the world.

There is evidence that SANReN makes it possible for research collaboration amongst multiple universities however the infrastructure at the campus level does not complement the very high speed broadband. While there are many interrelated factors, the connectivity brought by SANReN impacts on how researchers share data, produce collaborative research and publish journal articles. It is necessary to acknowledge that it is difficult to measure the impact of the value of SANReN since there is no accurate matrix to measure the value.

6.2 Matrix to measure value of SANReN

The impact in value of SANReN is shown where data intensive scientific research thrives within the university. There is a need for a matrix of measuring output and value of the SANReN. A future matrix is needed to dig deeper into what universities use for the cyber infrastructure. Projects like SKA have already formed complex research partnerships nationally and internationally. A 3x3 matrix could be useful for measuring value of SANReN at universities. The research value for the university will increase with capacity of allocated bandwidth. Therefore the availability of SANReN bandwidth will have an impact on how the universities conduct research. The creation of a data centre will contribute to meeting the high computing demands of the university and transform the publications output and financial value to the university. Below is the illustration of the proposed SANReN value matrix.

Figure 14: SANReN matrix

Output / Value	Research value	Publications value	Financial value
Capacity/Connectivity			
Data Centres			
Services and applications			

Source: Researcher

6.3 SANReN capacity

A major highlight to the research is that the SANReN infrastructure is critical to the work of researchers in large scientific projects because without the SANReN it will be difficult to develop the international collaboration. The ongoing science projects show the value of the SANReN which is the requirement for transfer of data, critical to the work of scientific researchers.

The SANReN infrastructure is firmly in place. The system will in future have to be upgraded to meet collaborative projects needs at the institutions. The 10GB/sec is sufficient for now, but projects like the SKA will need 40GB/sec in future. The upgrades on the system need to be strengthened. There has to be discussion on how universities can get maximum benefits out of SANReN, including funding of data centre.

SANReN need to strengthen synergy with universities to improve on data management and storage. One of the recommendation of the NICIS Framework Report (DST, 2013a) is where to keep data. DIRISA is part of that infrastructure but DIRISA is about storing the data, data management only at national level. There is a need for data services and clear policies relating to data management, computing, visualization and training (DST, 2013a). Lastly there is issue of human capacity development as the country needs skilled people who can handle huge amounts of data and do data analytics.

6.4 Summary

The research made it clear that despite complex problems relating to infrastructure, the SANReN is being effectively used at Wits. The scientific researchers are heavy users of the bandwidth provided although they need more capacity. The scientific research in fields of Engineering Science and Medicine benefit from the services that are brought by the SANReN.

The research has also considered the issues such as the allocation of international bandwidth, to boost the research. It is clear that there is a need to improve the existing infrastructure and to try to decouple the research by meeting infrastructure needs like a dedicated data centre at the university. There are fundamental goals for data in Science and Engineering, amongst others there is a provision of national repository with a national data infrastructure that enables the capture, management, curation, analysis, interpretation, archiving, and sharing of data at unprecedented scale and complexity in a manner that will stimulate discovery in all areas of enquiry and from all facilities, ranging from campus to the national level (National Science Foundation, 2013, p.2).

One of the recommendations for the University could be to emulate the similar model as the National Science Foundation as the need for the data centre at university level is critical. The university could make a commitment to high end ICT based infrastructure or cyber infrastructure for the provision of high performance computing capability and data management systems.

Appendices: Interview Guide and Participant Information Sheet

Participation information sheet 18th June 2014

Dear Participant

My name is Eugenia Sekgobela and I am a student at the University of Witwatersrand. I am studying towards a Masters of Management in ICT Policy and Regulation. I am working on the research report as part of the requirements to complete the degree and need to conduct interviews for data collection for my research. I would appreciate your participation in the questionnaire.

The research is about the use of SANReN at the University of the Witwatersrand. The main purpose of this research is to examine the ICT infrastructure needed to carry out collaborative research at universities, using a case study of University of the Witwatersrand (Wits) in the view of challenges faced with the delivery of higher education.

It is estimated that this interview will take an hour to complete. Participation in this research is voluntary, and you may refuse to answer questions which might make you uncomfortable and may withdraw from the study at any time without explanation. The data we collect do not contain any personal information about you. The ethical clearance is not required as this research is not about human subjects. The information gathered will be used solely for the research purposes.

If you need any further information about this research, you may contact my supervisor, Lucienne Abrahams.

Regards
Eugenia Sekgobela
0823486992

Title of the Research: NREN as ICT infrastructure to support e-services at Universities

My name is Eugenia Sekgobela and I am a student at the University of Witwatersrand. I am studying towards a Masters of Management in ICT Policy and Regulation. I am working on the research report as part of the requirements to complete the degree and need to conduct interviews for data collection for my research. I would appreciate your participation in this questionnaire.

This interview instrument is sent to you before the actual interview to allow you sufficient time to complete it electronically and submit it to the interviewer before the interview. This allows the interviewer and interviewee to engage with the responses and documents submitted. The advantage of this is to allow for deeper introspection so as to elicit responses that will allow for accurate and valuable research. It also allows for you to complete the document at your leisure and not be pressurized into providing instant answers.

I may request your permission to record the interview and to consult with you in future for clarification on any point you make. Please have the documents that you have consulted to complete the questionnaire in case it is necessary to check any figures. It is estimated that this questionnaire will take one to two hours to complete if the information is readily available.

Date of interview		Name of interviewee	
Position of interviewee		Period in this position in years	
Contact number land line		Contact number cellular	

INTERVIEW QUESTIONS

EXISTING AND FUTURE ICT POLICY AT WITS UNIVERSITY

Does Wits have an ICT policy regarding the use of SANReN? If not are there future plans to formulate one?

To what extent is the SANReN infrastructure improving on the research collaboration at the university?

Is there any potential e-services that may be brought by SANReN network at Wits?

In your opinion what are the benefits that SANReN bring to Wits research community?

INFRACTRUCTURE AND APPLICATIONS ADOPTION

Would you mention the role of SANReN network infrastructure at Wits and what it entails?

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How has SANReN infrastructure been of benefit to your research?

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Which are the applications used in your research that are on the SANReN network? Please specify.

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Would you mention any capacity and technical related issues that affect connectivity of Wits to SANReN network?

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Are there any issues regarding internal ICT infrastructure that might make it difficult for connectivity to SANReN?

SUPPLY AND DEMAND

How has the demand and supply for bandwidth evolved at the University of the Witwatersrand and to what extend does the supply exceed demands?

How has the SANReN network capacity facilitated research collaboration at Wits?

How much bandwidth does the university community use on average annual and monthly basis? What is it mostly used for?

USAGE AND VALUE OF NREN

What are the e-services available at Wits and which ones did the university recently introduce as a result of being connected to the high-speed network?

What has been the experience of postgraduate students at Wits using SANReN and how has the use of this cyber infrastructure contributed to the success of research, teaching and learning?

In your opinion, is SANReN network effectively utilized at Wits?

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