

Regional Strategy for C@ribNET: Provision of Blueprints for the Development and Implementation of National Research and Education Networks (NRENs)

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NREN Blueprint for Barbados



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List of Acronyms

AUP	Acceptable Use Policy
BBREN	Barbados Research and Education Network
CARICOM	Caribbean Community
CARNET	Croatian Research and Education Network
CDRC	Chronic Disease Research Center
CEO	Chief Executive Officer
CKLN	Caribbean Knowledge and Learning Network
CLARA	Latin American Cooperation of Advanced Networks
DANTE	Delivery of Advanced Networking Through Europe
ECFS	East Caribbean Fibre System
HEDU	Higher Education Division Unit
ICT	Information and Communications Technology
IP	Internet Protocol
IRU	Indefeasible Right of Use
Mbps	Mega bits per second
MPLS	Multi-Protocol Label Switching
NOC	Network Operation Center
NREN	National Research and Education Network
RREN	Regional Research and Education Network
SLA	Service Level Agreement
SCMR	School of Clinical Medicine and Research
TERENA	Trans-European Research and Education Networks Association
WAN	Wide Area Network

1. Rationale for National Research and Education Network in Barbados

1.1. Introduction

A high performance national network connecting academic and research institutions and popularly termed a National Research and Education Network (NREN) is increasingly viewed as a vital component of modern teaching, research and learning. About a hundred countries in the world have adopted the NREN as the centerpiece of their information and communication technology (ICT) plan for tertiary education institutions and for connecting research institutes and other institutions such as schools and hospitals. A list of Research and Education Networks with hyperlinks to their websites is provided in Annex III.

The one NREN per country model that has evolved in Europe proved to be one of the most successful mechanisms forging collaboration among researchers and educators at national and regional levels and enabling the creation of a family of inter-connected research and academic communities around the globe. The NRENs link through Regional Research and Education Network (RREN) backbones and connect- internationally via high speed networks. The building blocks are the fiber-based campus networks in individual institutions that connect to a centrally operated high capacity national fiber backbone connecting NREN, links to other countries' NRENs and then to regional networks like **GÉANT** in Europe or **Internet2** in the United States. Figure 1 shows the building blocks of research and education networks.

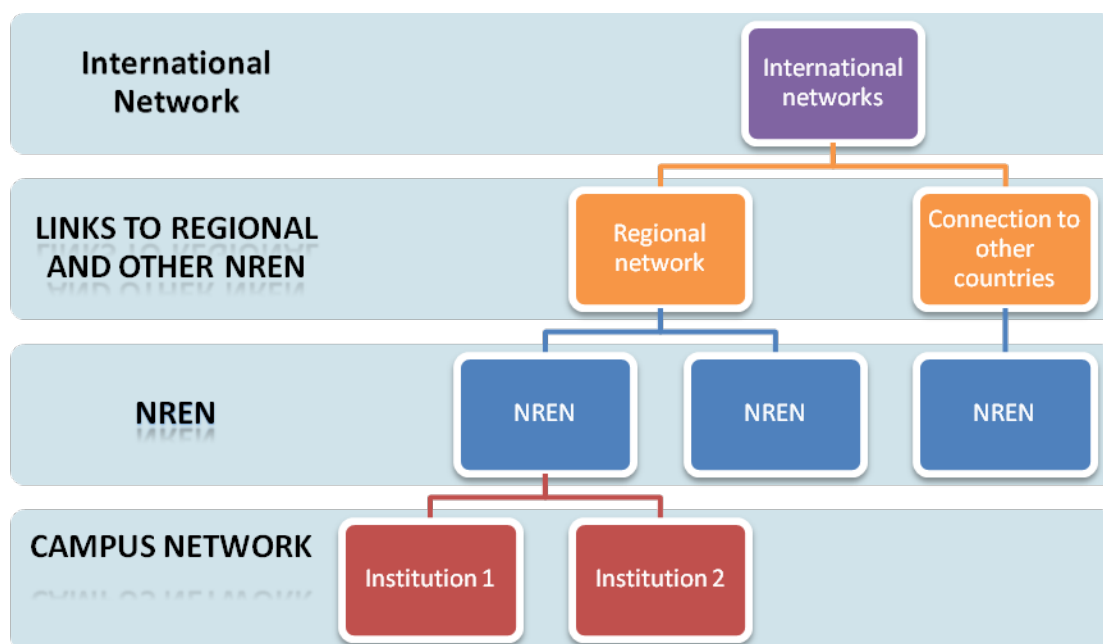


Figure 1: Building Blocks of Research and Education Network Connectivity

The NREN is essential to create economies of scale for building and sharing high speed networks and expensive research equipment and to host applications for advanced collaborative scientific research. Scale is the primary motivation for creating NREN. The more the number of universities and other institutions that participate in the NREN, the better the sustainability, the lower the cost per institution and the higher the negotiating strength of participating institutions. For example, the Academic and Research Network of Slovenia (ARNES)¹ - connects universities, institutes, research laboratories, museums, schools, databases and digital libraries in the country. The network connects over a thousand Slovenian organizations and makes ARNES' services available to nearly 200,000 people.

The Caribbean region, including Barbados, has largely been excluded from the development of such networks. Noting this gap, the Caribbean Knowledge and Learning Network (CKLN) has been supporting the development of NRENs at national level and establishment of a Caribbean Research and Education Network (C@ribNET) that connects Caribbean institutions to each other and to other international networks such as Internet 2², Red³ CLARA and GÉANT⁴.

¹ <http://www.arnes.si/en/about-arnes.html>

² www.internet2.org

³ www.redclara.net

⁴ www.dante.net

CKLN realizes that NRENs are primarily human networks and the accompanying organizational structures and infrastructure for production, distribution, management, sharing and utilization of knowledge and for promoting a continuous research agenda.

The formation NRENs generally is comprised of two major elements:

- The institutional and governance framework that binds the membership together and
- The underlying physical connectivity.

The NREN governance framework provides the human networking element while the infrastructure provides dedicated, high-performance communications network capabilities not only within a country, but between research and educational institutions located in different parts of the world.

The development of a Barbados NREN (BBREN) and its subsequent link to C@ribNET and then to Internet 2, redCLARA and GÉANT therefore requires collaboration between local stakeholders, affordable access to infrastructure, the sharing of applications and other network resources and governance mechanisms that drives the evolution of the physical and human networking in the island. The purpose of this Blueprint is to outline the network infrastructure, application and services, governance, human resource, management capacity and skills, as well as a proto-implementation plan for NREN development in Barbados.

1.2. Benefits of Barbados National Research and Education Network

Education, cutting-edge research, science and technology are the key ingredients of sustainable social and economic development. Building a strong education and research community is a cornerstone for prosperity, societal development, stability and regional integration. Information and communication technologies underpin research and education and the creation of an innovative and life-long learning society, which possesses a community of scholars, researchers, engineers, technicians and firms engaged in production of knowledge goods and services. Academic and research networking is now regarded as an essential national infrastructure, 'public goods' comparable to roads, water, ports and energy services due to its implications on learning, teaching, research and many other scientific endeavors that have positive impact on the knowledge economy, general economic development and social cohesion.

NRENs design, build or lease, operate, maintain, support and manage a physical telecommunications network for the benefit of the education and research community. They

provide national-scale networks that interconnect universities and other knowledge-generating institutions and research centers separately from the commercial Internet, providing uncongested, high-speed, advanced communications capabilities. One such example is the Croatian Academic Network (CARNet)⁵ which built a private network of Croatian academic, scientific and research community, as well as of institutions in the elementary and high school system. The network infrastructure is owned by CARNet institution, but cables are rented from various telecommunication providers. CARNet network is an example of a WAN network (Wide Area Network – a network distributed over large distances), which enables CARNet members throughout Croatia to connect into a compact information and communication system. In the same vein, the development of a Barbados National Research and Education Network would provide access to more affordable high capacity bandwidth to institutions in Barbados.

National and Regional Research and Education Networks connect the academic and research community to each other and access to educational resources, complex data sets and computing facilities (i.e. supercomputers and scientific instruments like optical and radio telescopes) and host advanced applications. Scientific applications in physics, environmental science, oceanographic and atmospheric research demand high network capacities and put heavy demands on network availability and end-to-end performance. These applications usually require a communications network dedicated for these purposes.

The establishment of a NREN in Barbados opens doors for scientific and research collaboration, underpin the exchange of international and regional e-learning content, optimizes the use of networked educational resources and fosters collaboration between domestic academic and research institutions. The NREN initiative could also be used for facilitating connectivity to schools and public institutions, enabling digital inclusion and improving everyday life of citizens by promoting telemedicine and e-government. It would serve as a problem solving and collaborative platform in the region; thereby positively affecting democracy and equity in the Caribbean.

The establishment of National Research and Education Networks in Barbados will:

- Provide a high-speed and low cost broadband network for research organizations to link up to each other and carry out collaborative research,
- Create economies of scale for building and sharing high speed networks, expensive research equipment, applications and other resources,
- Facilitates the negotiation of favorable pricing for Internet access and software license on behalf of all participating institutions,
- Promotes joint institutional content development, access to large databases and sharing of research results,

⁵ <http://www.carnet.hr/infrastructure>

- Promotes distance learning and additional services such as Domain Name Services, network security, bandwidth management, web caching and hosting, IP telephony, traffic shaping and authentication, e-mail and authorization and accounting services for the entire national education and research community,
- Provides centralized training, capacity building and advisory services to their member institutions and others such as local secondary schools,
- Promotes linkages between the academic and research community, industry, government and other international research and educational networks,
- Promotes Caribbean level and international collaboration between communities of practice,
- Allows for the hosting and execution of data-intensive applications (e.g. bio-modeling and computation) and sharing of high end computing assets thereby facilitating better research outcomes and problem solving,
- Provides the experimental platform for researchers to investigate, develop and test new network and internet technologies and applications prior to deployment within the public sector or for commercial use.

In sum, the NREN provides platform for accessing digital resources, instrumentation, computation essential for international collaborative research between researchers in Barbados and others around the world. NREN will also serve as a springboard for innovation with spin offs to industry, education, healthcare and governance. NREN is critical for building a network-literate population that will serve as the foundation for the knowledge based economy in Barbados. Indeed, it will enhance the success of EduTech 2000 that strives to promote learner-centred pedagogies.

1.3. Positioning Barbados NREN within the Context of Regional and Global Network

Barbados has a good communications infrastructure. All academic institutions including primary and secondary schools have good connectivity to the Internet. However, the emphasis so far has been in providing individual connection to the Internet to access to servers in Europe and the Americas, rather than the establishment of national and intra-Caribbean connectivity as the basis for academic and research collaboration and for resource and knowledge sharing.

The development of National Research and Education Network in Barbados will create an opportunity for collaboration between academic and research institutions including the University of West Indies (Cave Hill), Barbados Community college, Samuel Jackman Prescod Polytechnic, Barbados Institute of Management and Productivity and Erdiston's Teachers College and their onward connectivity to the Caribbean Network (C@ribNET) and to other global networks, thereby fostering academic collaboration worldwide as shown in Fig 2. This

interconnection of schools, colleges and research institutions will provide an opportunity to mobilize and use local resources to solve local problems by aggregating resources and local researchers.

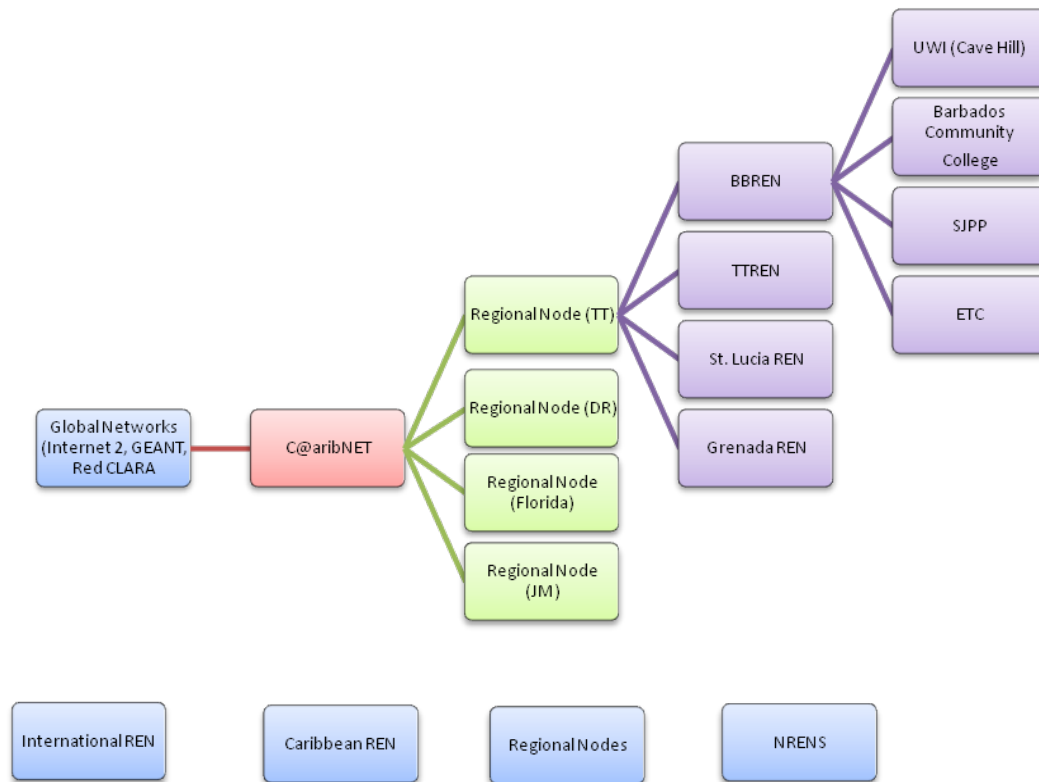


Figure 2. Positioning Barbados NREN Within the Global Context

The development of NREN in Barbados will strengthen Caribbean level networking that is spearheaded by the Caribbean Knowledge and Learning Network (CKLN). CKLN is an inter-governmental agency established by CARICOM with the mission to build capacity in the areas of education and training through initiatives that will enhance and grow the regional human resource outputs⁶. CKLN has been working towards the design and implementation of a Caribbean regional research and education network for connecting all Caribbean universities and other tertiary level institutions to support collaboration on the development of education and research activities in the region and connect to knowledge networks in Europe, North America and Latin America. The major objective of CKLN⁷ is:

⁶ www.ckln.org

⁷ CKLN, **C@aribNET: The Regional Research and Education Network – Regional Public Good, September 2010**

- Coordinate the development of an advanced networking environment for research and education (R&E) communities in the Caribbean region under C@ribNET and enable regional and transnational cooperation,
- Enable digital inclusion, promote local content development as well as connectivity for knowledge creation and information sharing,
- Offer ICT infrastructure to support functional cooperation between CARICOM states and development of the human resource ,
- Foster development of national research and education networks in support of these objectives

C@ribNET is a two-tier network - the backbone level to be hosted by points of presence in Trinidad and Tobago, Jamaica, Dominican Republic and the United States (Miami) and the access levels connecting directly to NRENs in member States as shown in Figure 3.

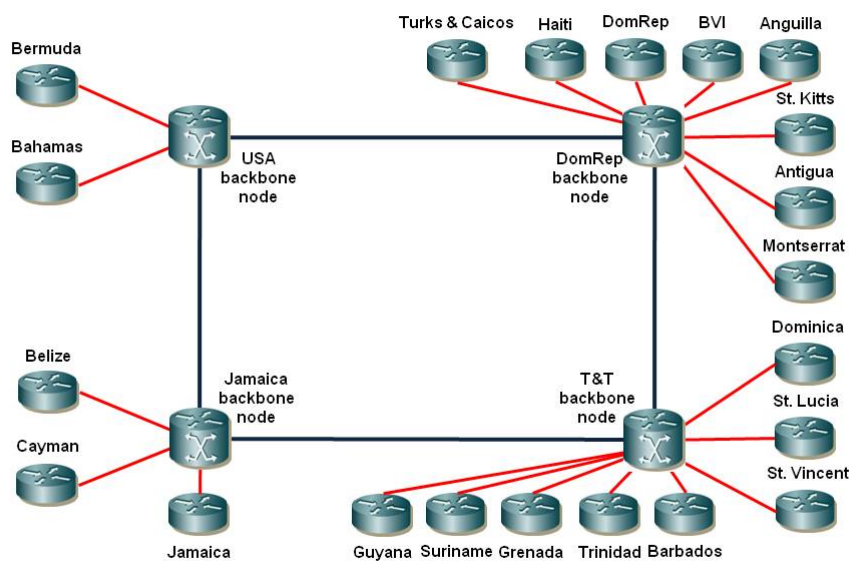


Figure 3. Proposed Connectivity Between NREN in the Caribbean

Source: Paper, **C@ribNET: The Regional Research and Education Network – Regional Public Good, September 2010**

It is evident from Figure 3 that Barbados will connect to other countries and international networks through a backbone node to be established in Trinidad and Tobago.

The development of a NREN in Barbados will also serve as a conduit for connecting colleges, schools and research institutions to the global academic and research networks in Africa such as UbuntuNet Alliance, the West and Central African Research and Education Network (WACREN), the Asia Pacific Academic Network (APAN), GÉANT and Internet 2, and the Latin American research network Red CLARA to provide access to global network and resources. There is already a massive pool of valuable world class resources available freely to the non-profit world of research and education networks. An example would be the New England Journal of Medicine which is free to the developing world.

1.4. Overview of the Needs and Gaps for Connecting the Education Sector in Barbados

Barbados, situated just east of the Caribbean Sea, is a West Indian continental island-nation in the western Atlantic Ocean with an estimated population of 284,589. The country's terrain that covers 431 square Kilometer is largely flat but rises gently to central highland region. Its nearest Caribbean neighbors are St. Vincent and St. Lucia. Barbados is approximately 1,600 miles south-east of Miami, Florida. The capital, Bridgetown, is located in the south-west of the island in the parish of St. Michael, which is the most populated of the eleven parishes⁸.

Barbados is one of the more populous and prosperous Caribbean islands with GDP of about US\$3.9 billion in 2009 and GDP per capita of US\$11,900⁹. The economy was originally dependent on sugarcane cultivation and related activities. However, in recent years the economy has diversified into light industry and tourism with about three-quarters of its GDP and 80% of exports being attributed to services.

The four main foreign exchange earning sectors are tourism, international business services, manufacturing and agriculture. The focus on the development of tourism, business and service sector has prompted the importance of highly skilled human resources and state of the art communications infrastructure. Barbados allocates a high share of GDP to education (7.9 percent in 2001). This level of expenditure has led to significant achievements, including universal enrollment in primary and secondary education, free primary and secondary education, and support for some costs of textbooks, transportation, and meals.

⁸ <http://www.britannica.com/EBchecked/topic/52655/Barbados>

⁹ Invest Barbados, Guide to Doing Business in Barbados, www.investbarbados.org/docs/Doing%20Business%20in%20Barbados.pdf

¹⁰ <http://www.ccentre.wa.gov.au/ForSchools/CHOGM/WhobelongstotheCommonwealth/Pages/Barbados.aspx>

The government's 1995 white paper on education targeted development of a twenty-first century workforce, and led to the Education Sector Enhancement Program (EduTech 2000) that was launched in 2000, strongly focused on curriculum change supported by the integration of ICT into both primary and secondary instruction¹¹.

While EduTech 2000 has led to increased learner-centered instruction, improved planning for ICT integration, increased interaction between teachers and students and greater student interest and motivation, there has been low level of usage and problems with hardware maintenance and networking. This implies that in spite of a significant progress, Barbados needs to upgrade human resources capacity for the knowledge economy and increase computer usage at primary, secondary and tertiary levels¹².

Moreover there is a limited integration of colleges and universities in the country into the global research and education networks. The key institutions such as University of West Indies (Cave Hill campus), Barbados Community College, Samuel Jackman Prescod Polytechnic, Barbados Institute of Management and Productivity and Erdiston's Teachers College do not have direct connection to regional and international research networks. This implies that the focus has been largely in carrying "commodity" internet traffic rather than research traffic.

The disconnection from the global network has resulted in:

- Inadequate flow of educational and research content to schools, colleges and universities,
- Inadequate research activities and an underdeveloped research infrastructure,
- Lack of technical expertise and visionary capability that has curtailed competitiveness of the country,
- Limited interaction between academic and research community, industry and government,
- Limited regional cooperation and collaboration in sharing knowledge between researchers, teachers and educators that have a negative impact on overall competitiveness of the Caribbean.

The absence of National Research and Education Network in Barbados has also been the key constraint to the country's ability to learn from the global experience in the development of research networks.

2. International Best Practices in the Development of NREN

2.1. International NREN Best Practices

¹¹ Brief Description of EduTechn2000,
<http://unpan1.un.org/intradoc/groups/public/documents/caricad/unpan009517.pdf>

¹² See InfoDev Report on ICT in Education in Barbados, www.infodev.org/en/Document.596.pdf

There has been a significant building of National Research and Education Networks around the world. Europe hosts the biggest and most influential regional education and research network known as GÉANT. This network is managed by DANTE,¹³ a non-profit company based in Cambridge in the United Kingdom and supported by the Trans-European Research and Education Network Association (TERENA),¹⁴ based in Netherlands. GÉANT connects national research and academic institutions in thirty European countries and provides international connections to regional networks beyond Europe, delivering levels of network bandwidth and services unobtainable from the commercial sector. The United States and Canada along with most of the Asian countries including Australia have also developed the most advanced and influential research and education networks. Internet 2¹⁵, of the United States has a significant international support programme to strengthen NREN development in Africa, Asia, Latin America and the Caribbean.

There has also been NREN built out in Latin America over the last two decades. Focus has also been shifting to the development of NRENS in Africa in recent years.

¹³ www.dante.net

¹⁴ www.terena.org

¹⁵ www.internet2.org

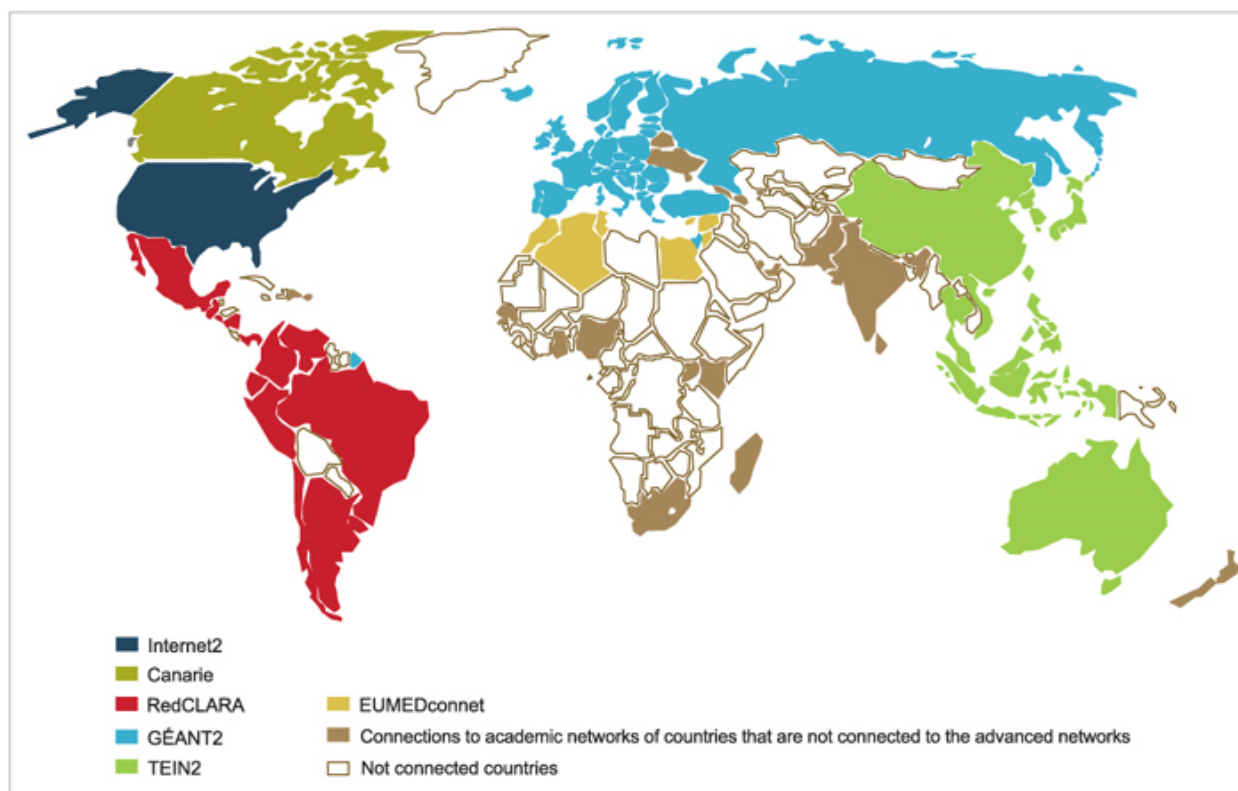


Figure 4. NRENs around the World

Europe has been the key source for NREN development around the globe. The European research network - GÉANT 3 is the latest iteration - provides a high-performance, state-of-the-art network infrastructure and is co-funded by Europe's NRENs and the European Commission (EC). It connects 40 million users in over 8,000 institutions across 40 countries. Local campus networks link to national research networks that span specific countries, and these then interconnect via the GÉANT backbone. The network offers data transfer speeds of up to 10Gbps across 50,000 km of network infrastructure, of which 12,000 km is based on its own fibre. There are 25 Points of Presence (PoPs), forty-four (44) routes, including eighteen (18) dark fibre routes¹⁶.

¹⁶ http://www.geant.net/About_GEANT/Partners/pages/home.aspx

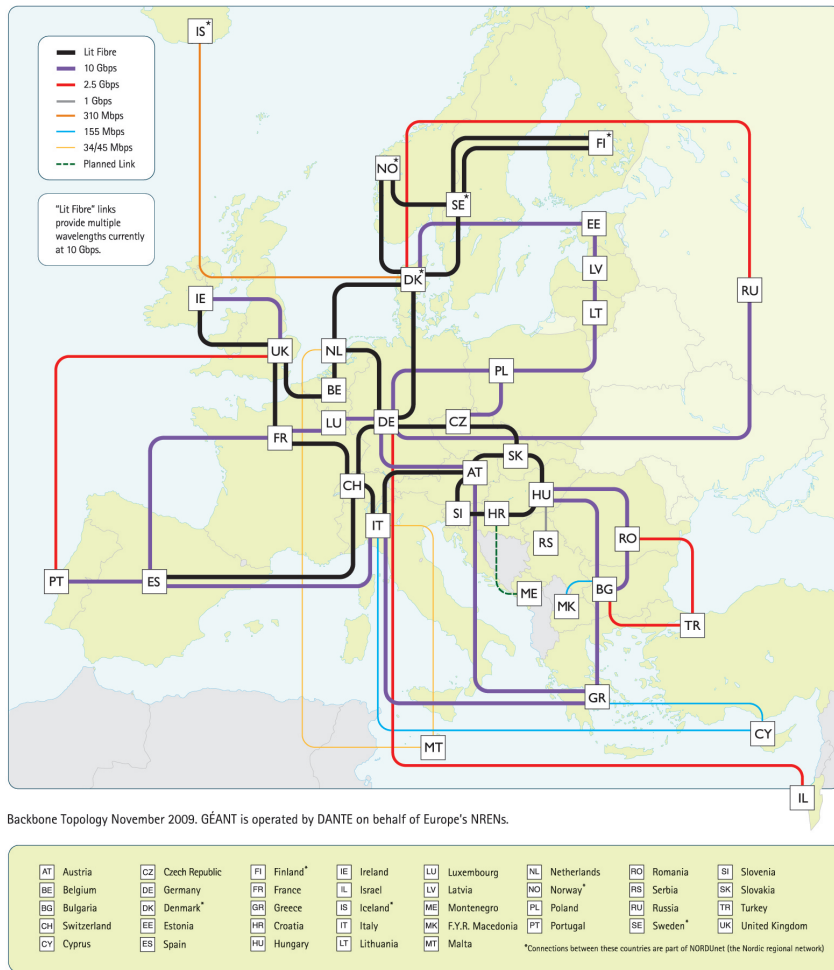


Figure 5. The GÉANT Network

The European enlargement programme in the last decade has also seen progress on the connection of South Eastern European countries such as Albania, Bosnia-Herzegovina, Bulgaria, Former Yugoslav Republic of Macedonia , Federal Republic of Yugoslavia - Serbia and Montenegro , Greece, Hungary and Romania to the major GÉANT Points of Presence and their incorporation in the Pan-European research network community (TERENA, DANTE). This has provided a significant boost to these countries and their integration into the global economy:¹⁷.

- At the **political level**, the connectivity of Eastern European countries promoted common cultural ties through applications that enabled publishing, access and sharing of cultural assets among users and possibly educated various social and ethnic communities.

¹⁷ www.seeren.org

- At an **educational level**, it created conditions for growth throughout South East Europe, enabling the exchange of ideas, launching of joint experiments and projects, disseminating research and technological development results, and activating market forces, all substantial elements in the process of regional development.
- At a **social level**, the networking environment was used as a working paradigm towards improving the everyday lives of the citizens of the region. This was accomplished by designing and running advanced applications such as telemedicine, tele-teaching etc.
- At a **business level**, the process of the development of research and education networks enacted a communication channel between South East Europe's scientific community and the European industry (liaisons to major Information and Communication Technology vendors), thus resulting in an increase in the demand for specialized services provided by the highly skilled academics and researchers of the region.

Through DANTE and TERENA, the European Union has forged links with Asia, Africa, the Middle East and Latin America over the last decade, creating a significant boost to academic and research networking in these regions and providing support for their onward connectivity to GÉANT. The support includes financing national and regional links, connecting these networks to GÉANT and exchange of experience and expertise on network administration, bandwidth management procedures, international networking and cost modelling.

The Europe and Latin American Connectivity (ALICE)¹⁸ project was one of such initiatives coordinated by DANTE and financed by the EU. This led to the establishment of the Latin American Co-operation of Advanced Networks (Red CLARA) and the implementation and growth of National Education and Research Networks in South and Central America. The EU and Red CLARA¹⁹ were instrumental in the development of National Research and Education Networks in 17 Latin American countries, including InnovaRed (Argentina), ADSIB (Bolivia), RNP (Brazil), REUNA (Chile), RENATA (Colombia), CR2net (Costa Rica), RedUniv (Cuba), CEDIA (Ecuador), RAICES (El Salvador), RAGIE (Guatemala), UNITEC (Honduras), CUDI (Mexico), RENIA (Nicaragua), RedCyT (Panama), ARANDU (Paraguay), RAAP (Peru), RAU (Uruguay) and REACCIUN (Venezuela) and their onward connection to GÉANT.

¹⁸ <http://alice.dante.net/?PHPSESSID=7e2dfc9363bf1461ec182a9f8993b4d5>

¹⁹ www.redclara.net

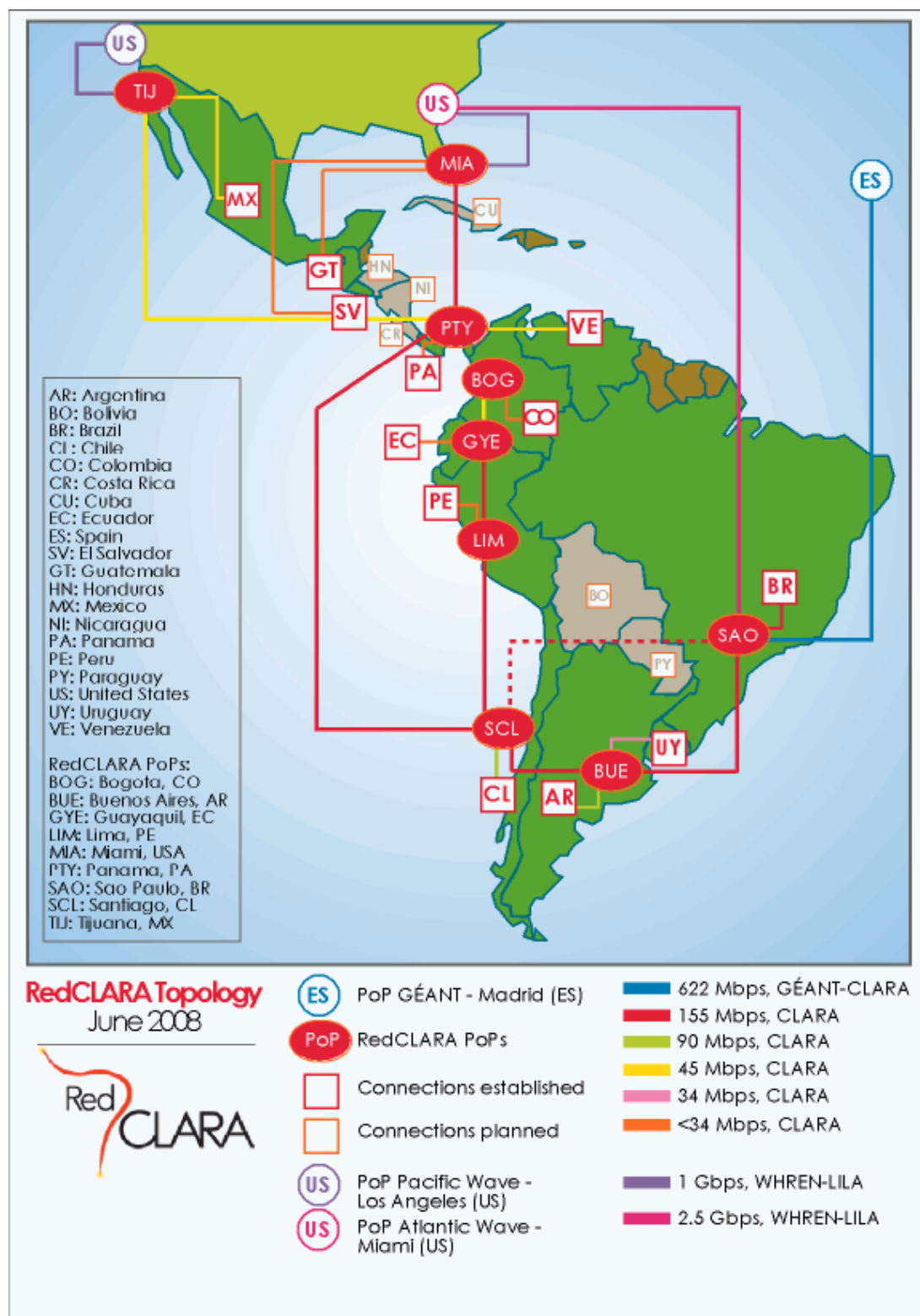


Figure 6. Latin American Network

North African countries including Algeria, Egypt, Morocco and Tunisia were the other beneficiaries from the EU and DANTE support. The EUMEDCONNECT²⁰ project that was financed by the European Union did not only provide academic institutions in North Africa with state of the art international connectivity that shifted academic traffic from commercial providers, but also allowed for transfer of experience and best practices in the hosting of databases, the use of bandwidth-intensive real-time applications (tele-medicine, video-conferencing) and the introduction of IPv6 to the region.

In Asia the Trans-Eurasia Information Network (TIEN) connects research and education network for the Asia-Pacific region to GÉANT, providing the Asia-Pacific countries with a gateway for global research collaboration. The current and third generation of the Trans-Eurasia Information Network (TEIN3)²¹ provides a dedicated high-capacity Internet network for research and education communities in 19 countries in the Asia Pacific region, including Bangladesh, Bhutan, Cambodia, China, India, Indonesia, Japan, Korea, Laos, Malaysia, Nepal, Pakistan, the Philippines, Singapore, Sri Lanka, Taiwan, Thailand and Vietnam. Australia is also actively participating in the Trans-Eurasian Information Network.



Figure 7. Asia Pacific Connection to the Rest of the World

²⁰ <http://www.eumedconnect2.net/?PHPSESSID=7e2dfc9363bf1461ec182a9f8993b4d5>

²¹ www.tein3.net

The last five years have seen a focus on the African RENs driven by the availability of undersea cables in the eastern and western coasts of Africa²². The academic and research community in Africa has been savvy in exploiting available national broadband network through the formation of the National and Regional Research and Education Networks (NRENs/RRENs). North African Research and Educational institutions have been utilizing available bandwidth through a regional network - EUMEDCONNECT since 2002. Eastern and Southern Africa where UbuntuNet Alliance for Research and Education Networking²³ was formed in 2005, has established a partial network that was boosted by support from the European Union. The latter aim was to establish links to the European Research and Education Network, GÉANT. There are several NRENs under formation in West and Central Africa²⁴ where the process of establishing a regional network – WACREN –to spearhead connectivity in those regions is ongoing.

2.2. Experience of NREN Development

The building of NREN in about 100 countries around the globe provides an invaluable experience and some best practices for Barbados to adopt. Every NREN development is a unique process influenced by historical and local processes. However, the recurring themes are useful for NREN development in Barbados. The experiences of three National Research and Education Networks are described below.

Estonia – Estonia is one of the fastest growing and smaller countries in Europe where NREN development is more inclusive. The Estonian Educational and Research Network (EENet)²⁵ is a governmental non-profit organization established in August 1993 by the Ministry of Education of Estonia with the task of managing, coordinating and developing the computer network of science, education and culture. Since 1997 EENet operates as a state agency administered by the Estonian Ministry of Education and Research.

- The mission of EENet is to provide a high-quality national network infrastructure for Estonia's research, educational and cultural communities. Its services include a permanent Internet connection as well as webhosting, e-mail, ftp, DNS and consultations in the event of security problems. Development projects are being carried out in cooperation with universities and institutes, among them the *Estonian GRID* project launched in 2004. The EENet network is the most inclusive. Its backbone network connects most of its counties. Its extensive customer base include:
 - Members of the Estonian Academy of Science

²² See many possibilities –<http://manypossibilities.net/african-undersea-cables/>

²³ www.ubuntunet.net

²⁴ www.wcaren.org

²⁵ http://www.eenet.ee/EENet/EENet_en

- Research and methodology institutions providing services to educational institutions;
- Universities defined by the Universities Act;
- Vocational education institutions
- Primary and secondary schools
- Pre-school institutions
- Continuing education and lifelong learning institutions
- State and municipal museums
- Public archives;
- Public libraries and subject libraries
- Structural units of county governments and local governments supervising education;
- The Ministry of Education and Research and its subordinate units;
- Publishers specialising in educational and scientific literature;
- Children and youth organisations whose activities support the educational sphere;
- Social institutions and organisations providing support training to disabled persons in the scope of specific support services;
- Theatres that are supported from the state budget

The Kiwi Advanced Research and Education Network (KAREN)²⁶ is another high-capacity, ultra high-speed national research and education network connecting New Zealand's tertiary institutions, research organisations, libraries, schools and museums to each other and the rest of the world. The network is owned and operated by the Research and Education Advanced Network New Zealand Ltd (REANNZ), a not-for-profit company.

The purpose of KAREN is to:

- Enable leading-edge e-research
- Facilitate universal connectivity throughout the New Zealand and international research and education communities
- Encourage broad participation by the research and education sector in New Zealand through accessible technology and reasonable pricing
- Connect the research and education sector to the broader innovation community for pre-commercial research and development-based collaboration
- Facilitate participation by multiple telecommunications-sector partners to ensure the greatest possible flexibility for ongoing evolution

KAREN emphasizes the promotion of e-research, therefore scientists in New Zealand can participate in exchanging large volumes of data quickly, gain access to large scale national and international science and network infrastructure and collaborate on research and education

²⁶ www.karen.net.nz/

projects at distance. KAREN consists of a high-speed optical network connecting points of presence (PoPs) throughout New Zealand. A PoP provides an interconnection point between member sites around the network. Members may connect at one or more POPs. KAREN links universities and research Institutes within New Zealand via Telstra Clear fibre-optic cable, at speeds of 10 gigabits per second.

International links to Australia and United States (Pacific Northwest Gigapop) via the Southern Cross Cable connect KAREN to other national research and education networks in Australia and the United States, and through them to Asia and Europe. The speeds are 155 megabits per second to Australia and 620 megabits per second to Seattle, Washington, USA. As of June 2010, 99 organisations at 144 sites across New Zealand had connections to KAREN.

The Lithuanian Research and Education Network LITNET²⁷ provides another useful example of NREN development. It was established in 1991 as an association of academic research and other non-profit organizations. LITNET gets financial support from the Lithuanian Ministry of Science and Education. Its organizational structure mirrors the experience of other National Research and Education Networks. The highest governing body of LITNET is the LITNET Board whose structure and regulations are confirmed by the Ministry of Science and Education in Lithuania. The LITNET Board coordinates the development and the management of the network. The NREN operates a Network Operation Center (NOC) located in the Kaunas University of Technology and provides support network services to its members. It has a technical expert group that designs, implements and guides the operation of its connectivity and network services.

The LITNET national network is extensive with high speed connection to the various research and education institutions throughout the country as shown in Fig 8.

²⁷ <http://www.litnet.lt>

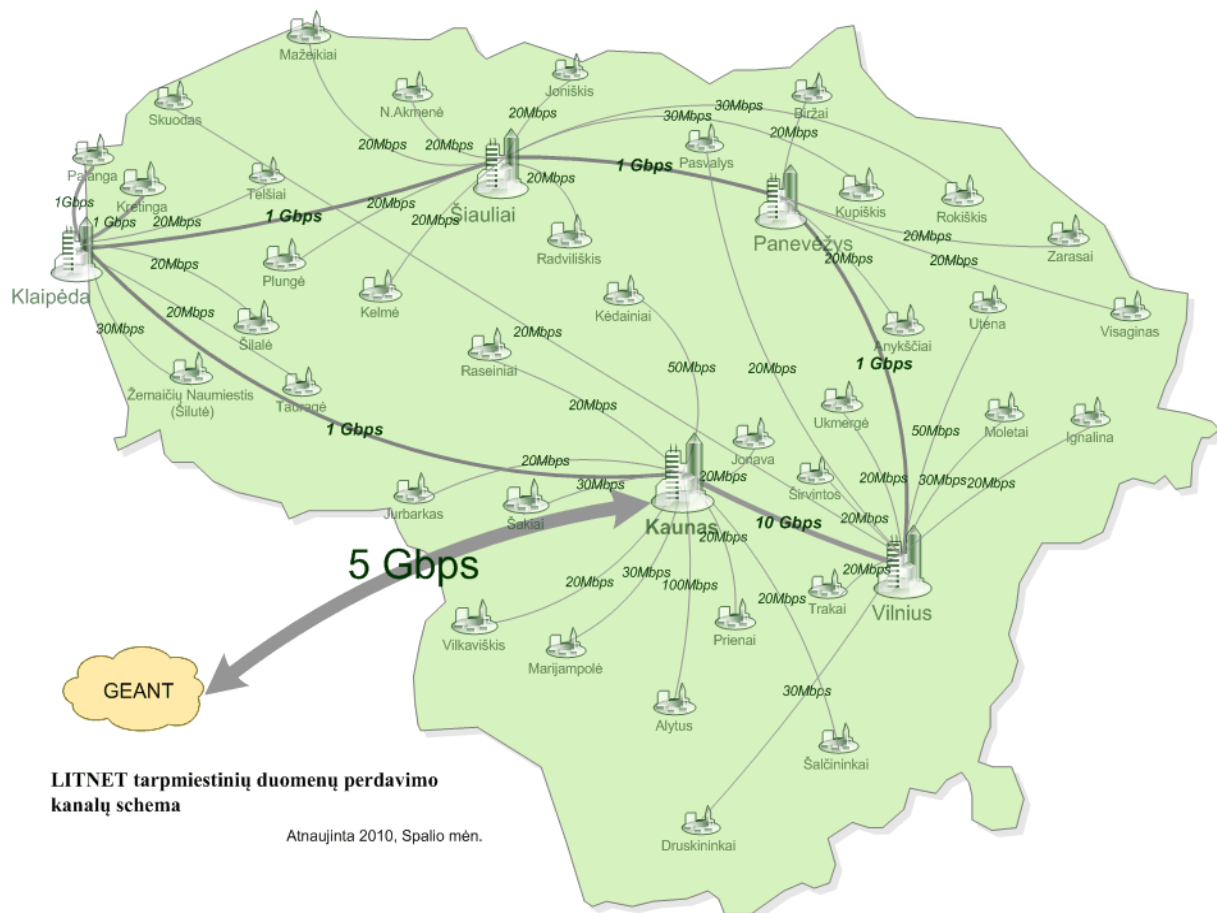


Figure 8. LITNET Reach Throughout Lithuania and Connection to GEANT

The other major lessons that can be used for the development of Barbados Research and Education Network include:

- **NREN start up:** A lead institution or government often initiate NREN and backstop its formation. In South Africa, the Tertiary Education Network was started by the National Research Foundation. Canada's CANARIE was conceptualized and born out of Industry Canada discussions. Singapore's NREN, SingAREN, was directly funded by the government. The UK Computer Board was behind the formation of JaNET, the research and education network in the United Kingdom.
- **Operational model:** National Research and Education Networks are membership-based not-for-profit limited liability companies whose roles are to provide state of the art interconnection, stimulate sharing of application and services and support continued growth and development of the networks and the provisioning of federated, communal services. NRENs are rooted in the research and education agenda. This implies that beyond providing the necessary physical connectivity among universities and to

international backbones, NRENs must play a key role in serving the research, teaching, learning and special needs of different academic departments.

- **Governance issues:** Experience also shows that the prerequisites for the creation and existence of research and education networks are not limited to the use of physical networks. They are influenced by policy-making, management, legal and financial issues.
- **Membership models:** Memberships of NRENs vary from place to place but they tend to reflect groupings of institutions based on one or more of common organizational attributes. Most models recognize full members, associates and affiliates. The membership of NRENs can be regarded as broad based or restricted to academic and research institutions. In most countries both private and public universities participate in NREN. Countries such as Estonia and Vietnam include secondary education institutions. The membership of Malaysia NREN (MYREN) is open to any research-oriented organizations including publicly-funded universities, privately-funded universities & colleges, government sponsored research institutions, National Centre of Excellence and research laboratories.²⁸ The Academic and Research Network of Slovenia (ARNES)²⁹ links over 1000 Slovenian organizations including universities, institutes, research laboratories, museums, schools, databases and digital libraries and makes ARNES' services available to nearly 200,000 people.
- **Build and Operate Infrastructure:** The primary motivation of NREN is to provide the latest and fastest communication services and comprehensive access to state-of-the-art applications and resources required for highest quality learning and research. There are various options for NREN to acquire the necessary infrastructure depending on the policy and regulatory environment and available infrastructure³⁰:
 - **Build to own infrastructure:** In countries where the regulation allows, NRENs can build their own physical networks. This would involve laying their own fibre and provisioning necessary transmission equipment or deploying wireless systems such as microwave links. The NREN can operate and manage this infrastructure itself or outsource operation and management to service providers.
 - **Lease infrastructure:** NRENs lease existing but unused infrastructure e.g. dark fibre from telecommunications providers or other entities such as electricity, gas or rail companies. In this case, the NREN would provide its own transmission equipment.

²⁸ <http://www.myren.net.my/membership/membership-type>

²⁹ <http://www.arnes.si/en/about-arnes.html>

³⁰ Alex Twinomugisha, National Research and Education Networking, Understanding NRENs and Key Consideration in Establishing them, Global E-school and Communities Initiative, January 2007

The leased infrastructure can be operated by the NREN or outsourced to an independent manager.

- **Purchase managed services:** The NREN would lease fibre or microwave and satellite links from the telecommunications providers owning all transmission equipment.
- **Purchase capacity:** NRENs would purchase capacity or bandwidth from service providers between two or more points. In this case, the NREN network is usually a Virtual Private Network.

Leasing of fibre is generally preferred to the NREN laying their own fibre, therefore, there has been a significant shift towards leasing fibre capacity and managing the network by NREN institutions around the globe. The Belgium Research and Education Network (Belnet)³¹ laid down a 1,650 km fibre network that combines a traditional IP network with an optical layer. The Canadian Advanced Research and Innovation Network (CANARIE) has deployed one of the world's largest and fastest networks dedicated to cutting-edge research, education and innovation covering over 19,000 km of fibre optic cable linking Canada's academic and research institutions³². The Bangladesh NREN leases dark fibre from a local telecom operator³³.

Services – NREN services vary from one country to the other. In addition to network and connectivity, NREN provide a platform for testing various tools and future technologies. The National Lambda Rail network (NLR)³⁴ in the United States is capable of hosting both experimental and production networks simultaneously, allowing easy and broad-based access by researchers to the multitude of networks running over NLR. This facilitates migration of promising technologies from experimental to production networks, provides real-world production network data for study and enables research and development that transcends or interconnects different network layers. Applications such as online video conferencing, tele-medicine, distance learning, e-business, online environment monitoring system, early warning system for disaster mitigation often run on the NREN.

Governance - Experience of NRENs around the globe shows that NRENs need to be governed by an independent “board of directors” or “board of trustees” guided by a charter, constitution, articles of association or other governing instruments. The board of directors of the NREN should be selected on the basis of their experience and contacts that are directly beneficial to the NREN or on what they are able to offer the NREN. Leatt and Duncan³⁵ suggest that, the

³¹ www.belnet.be

³² http://www.canarie.ca/templates/news/docs/CANARIE_101_both_E.pdf

³³ www.bdren.net.bd/

³⁴ www.nlr.net

³⁵ Leatt, J.V and Martin, D.H 2000, Reflections on collaboration within SA Higher Education by two bloodied but unbowed participants, <http://tenet.ac.za/>

board should be an expert rather than a representative one, meaning that the IT director of different universities should be customers to the NREN than becoming managers of the NREN. The Board of Directors decides on taking new members, making contracts, creating new nodes, upgrade lines, business trips, and participation on international and national projects and address further important questions. Therefore, making individual universities to sit on the board would complicate the decision of some of these issues due to self interest.

NREN members should meet in General Assembly that elects a Board of Directors of NREN and decides on prices for the provided services. The General Assembly is the ultimate decision making organ for most established Research and Education Networks. NRENs could also have various committees that are entrusted with operation of the certain aspects, such as networking technologies, auditing, etc. The Nepal Research and Education Network is one of the recent NRENs that is governed by its General Assembly. The Organizational Framework for NREN³⁶ includes General Assembly, a board (Executive Committee) and Chief Executive Officer and various departments as shown in Figure. 9.



Figure 9. Organizational Framework of the Nepal Research and Education Network (NREN)

Financing: NREN operation is heavily supported by public resources, typically in an 80:20 ratio formulation; 80% of operational costs supported by public funding resources, including donor funding and 20% often arising from members and revenue of value added services. In almost all cases, the primary initiative and funding for NREN has been initiated by governments such as

³⁶ <http://www.nren.net.np/>

through their national science foundation, (USA, China), education and technology ministry (Vietnam), or university grants commission (Pakistan, India, Sri Lanka). NREN through its non-profit nature generally ensures Internet access and digital services at lesser cost and at better quality for its members.

It is evident from global experience that NRENs occupy a special position outside the commercial Internet market. They operate as not-for-profit organizations serving a closed user group and consequently there is a case for them to be designated as non-public networks. NRENs create a platform for information exchange and serve as the source of much Internet innovation, much of which will spill-over into the commercial Internet for the benefit of society in general. The government should, therefore, regard NRENs as national assets to be fostered and supported by central contributions in a hybrid funding model.

2.3. A Gap Analysis of the Situation in Barbados

Barbados sits closer to most of the activities of NREN in Latin America, United States and Canada. The proximity to the United States and Latin America creates a significant opportunity for Barbados institutions to benefit from research network, data and research resources. The relatively small number of research and academic institutions also makes it easier to establish and finance NREN particularly in extending connectivity to schools, libraries, museums and other public institutions. The focus on connecting schools and colleges individually has been the major drawback so far. There is a need for fostering collaboration between the academic and research institutions and government programmes in order to encourage collaboration and sharing of services, content and applications.

3. The Research, Education, Policy and Regulatory Landscape

3.1. The Education Landscape

Barbados is a leader in education in the Caribbean, with compulsory education to age 16 and a literacy rate of close to 100%. This can be attributed in large measure to a committed government which has stipulated that education is mandatory up to the age of sixteen, and has continued to subsidize the cost of education at the primary, secondary and tertiary levels. There are a few tertiary level institutions in Barbados namely the University of West Indies Cave Hill Campus, Barbados Community College, the Samuel Jackman Prescod Polytechnic and the Erdiston Teacher Training College. These institutions will form the foundation for a National Research and Education Network. Barbados has twenty-three (23) government and six (6) private secondary schools. There are seventy-one (71) government primary schools and eleven

(11) private assisted primary schools that can potentially be NREN members. In addition there are libraries, museums, and academies which can be potentially major contributors of digital information invaluable for the higher education and research communities.

The major institutions that can be immediate members of NREN include:

- The University of West Indies (Cave Hill) and affiliate institutions such as the Chronic Disease Research Center (CDRC), and the School of Clinical Medical and Research (SLMR)
- Barbados Community College
- Barbados Hospitality Institute
- Samuel Jackman Prescod Polytechnic
- Barbados Institute of Management and Productivity
- Erdiston's Teachers College
- Secondary Schools

Other public institutions that will become potential institutions include:

- Higher Education Development Unit
- The Center for International Metrology and Hydrology

3.2. Institutional Networks

The main tertiary institutions such as the University of West Indies (Cave Hill campus) have made considerable investments in linking faculty and students to the Internet. The University of West Indies holds an aggregate capacity of 163 Mbps link to the commercial Internet and 55 Mbps link to Internet 2 through Florida in the United States. The Interent2 link is a high capacity leased line to Puerto Rico (STM-1), which splits there to respectively provide additional Internet services (commercial Internet, 100 Mbps) and a link to Internet 2 in Miami (55 Mbps). The Cave Hill campus is host to the Open Campus administration that includes UWI Distance Education Centre (UWIDEC), the Office of the Board for Non-Campus Countries & Distance Education (BNNCDE), the School of Continuing Studies (SCS) and the Tertiary Level Institutions Unit (TLIU). Access to the Internet is fundamental for multi-modal form of learning adopted by the Open Campus, blending distance learning and face to face teaching and learning process. The Open Campus unit has two video conference rooms.

UWI has two research centers offsite the main campus; dedicated redundant broadband links connects the Chronic Disease Research Center (CDRC), and the School of Clinical Medical and Research (SLMR). Both them are duplicated MetroEthernet links, respectively leased from LIME (5 Mbps) and Telebarbados (1 Mbps).

The Cave Hill campus IT infrastructure possesses a fully redundant structure with two datacenters connected to each other via a 4 Gbps internal optical link. Each datacenter has their own core switches, firewalls and load balancers, UPS and power supply backup systems. The older of the two datacenters is being completely refurbished, with significant changes to the fibre cable plant and in the security infrastructure.

The Center for International Meteorology and Hydrology (CIMH) that carries out regional modeling of climate data has an Internet link to transfer climate data of 3 to 4 Tbps range with daily data traffic of about 80 Gbps. The ICT applications used by the institute include other low-latency services for call conferencing, whiteboard applications and videoconferencing (mainly with UWI Mona Campus in Jamaica, and also with institutions in Mexico, Germany and elsewhere).

The Barbados Community College is located within close proximity of the Higher Education Division Unit (HEDU) of the Ministry of Education. The BCC and HEDU are connected and there are shared resources and a good environment of collaboration between the two institutions. The Barbados Community College campus has a 2 Mbps dedicated MetroEthernet links provided by a long-term contract with LIME Barbados and some 4 Mbps capacity provided by Telebarbados that is shared with the HEDU network.

The Samuel Jackman Prescod Polytechnic, Barbados Institute of Management and Productivity and the Eridston Teachers College have also Local Area Networks that connect to high speed internet provided by Telebarbados and LIME. The use of wireless broadband is being exploited by the Government of Barbados to link three separate campuses that are being merged (Barbados Community College, Samuel Jackman Prescod Polytechnic and Eridston Teachers' training College) to form a national university.

Barbados has also made significant progress in bringing connectivity to secondary and primary schools. The Ministry of Education's Wide Area Network (WAN) links the ministry to secondary schools while Net-schools provide connectivity to both secondary and primary schools.

3.3. Research and Education Network Initiatives

The Education Sector Enhancement Programme (EduTech) is the key initiative that has paved the way for the development of NREN in Barbados. EduTech, a programme began in the late 1990s, includes both curriculum reform and the phased-in introduction of computers in all primary and secondary (both public and private) school classrooms, so that the use of computers and the Internet becomes an integral part of the teaching and learning process. EduTech has four components:

- Curriculum Reform
- Developing Human Resources
- Physical renovations
- Technological Infrastructure

The technology component of the project has the following objectives: (i) supporting access to computers and Internet in the schools, (ii) building computer skills for teachers and students, (iii) creating e-learning platforms for distance learning students and (iv) the development of an Education Management Information System (EMIS).

3.4. The ICT Human Resource in Barbados

Barbados boasts one of the more sophisticated information technology infrastructures in the region which is largely due to the skilled and internationally accredited Information Communication Technology (ICT) providers which operate on the island.

Given the focus on standards and accreditation, coupled with a sound education system, the market provides a diverse range of services including software design and development, IT consulting, data management services, database training, systems integration, network administration and support. MIS auditing, security solutions, VoIP/IT hardware, graphic design and web support services are some of the more advanced offerings.

Although the ICT sector is characterized by presence of small to medium sized enterprises, it provides quality business process outsourcing solutions to a large number of international entities, particularly in the areas of financial services, customer service, medical transcription, accounts receivables and insurance claims processing.

3.5. The Regulatory Environment

The telecommunications market in Barbados is fully privatized and competition is allowed in all markets. LIME (Cable and Wireless Barbados) continues to be the sole domestic fixed line provider. The mobile market is served by LIME, Digicel and Sunbeach Communications. There are six Internet Service Providers (ISPs) including LIME and Caribsurf which are the largest. Based on the latest ITU statistics, broadband penetration in Barbados is 21.77 per 100 inhabitants, one of the highest in the region.

The market is regulated under the Telecommunications Act 2000. A carrier license is required to own and operate a public telecommunications network and a service provider license for providing public telecommunications services. Sections 22(1a) and (1b) of the Telecommunications Act stipulates that licenses are required for owning and operating a private telecommunications network³⁷ and for offering a private telecommunications service. This includes licensing for Very Small Aperture Terminal (VSAT) and other specialized equipment, the use of spectrum, and for providing private network services. Application is made on a prescribed form. There is an application fee as well as an annual fee payable to the authorities. A licensee with a private network or service provider license is not allowed to offer services to the public. This implies the formation of NREN as a closed user group should begin with a license from the regulator.

3.6. The ICT Policy Environment

ICT has been identified as an important component of various national development objectives in Barbados. Information and Communication Technology is one of the key features of the National Strategic Plan of Barbados 2005-2025. The ICT sector objectives of the National Strategy are:

- To create the information architecture, infrastructure and human resources capacity for the information economy.
- To ensure the information services sector (public and private) is knowledge driven, and has an improved capacity to identify and analyze global opportunities for, and threats to, the information economy in Barbados.
- To establish the legislative, fiscal and training framework to stimulate the development of information industries.
- To integrate modern information and communication technologies into the operations of government to facilitate maximum operational efficiency. To continue the educational initiatives of the educational enhancement programme (EduTech) to ensure that everyone enjoys the right to be educated to his or her full potential.
- To increase access to and enrolment in tertiary education using distance and e-learning modalities.

³⁷ Network used by person or affiliated group of persons and not interconnected with the public telecommunications network.

- To encourage the use of public libraries and community technology centers as avenues to access distance education and web-based learning.

Barbados has developed various documents with strong emphasis on the role of ICT for its competitiveness. These include:

- The Green Paper on Telecommunications Sector Policy prepared in 2000 by the Ministry of Industry and International Business.
- The draft National ICT Strategic Plan prepared by consultants for the Ministry of Commerce, Consumer Affairs and Business Development.
- The Review of the Status of ICTs in Barbados: Designing a Networked Nation prepared in 2004 for the Ministry of Commerce Consumer Affairs and Business Development.

The draft e-Government Strategy prepared by the Civil Service Division, Ministry of Labor and Civil Service.

Barbados's National ICT Strategic Plan (Draft) includes in its objectives:

- Support of human development in sectors
- Development of online content at various levels.

The government has taken several steps towards promoting the development of a thriving local ICT sector by:

- Liberalization of the telecommunications sector (2001)
- Enactment of a solid and early legal and regulatory framework to enable secure on-line transactions, e-commerce and cyber crime accountability and prosecution (2001).
- Publication of "Guidelines for Electronic Banking" by the Central Bank (2002).
- Removal of all customs duties from computers and peripheral devices (2003).
- Invitation of local financial institutions to provide electronic merchant services to enable citizens to pay for public services through the e-government portal under development (2006).

4. Network Infrastructure and Connectivity

4.1. Introduction

Network infrastructure and connectivity is one of the major aspects of NREN development, the other three (3) ingredients being network application and services, the governance framework and financing. There are three major infrastructure components of NREN. These include – campus network including connectivity to the nearest national education and research backbone and international connectivity to regional networks. Figure 10 shows the major ingredients of NREN development.

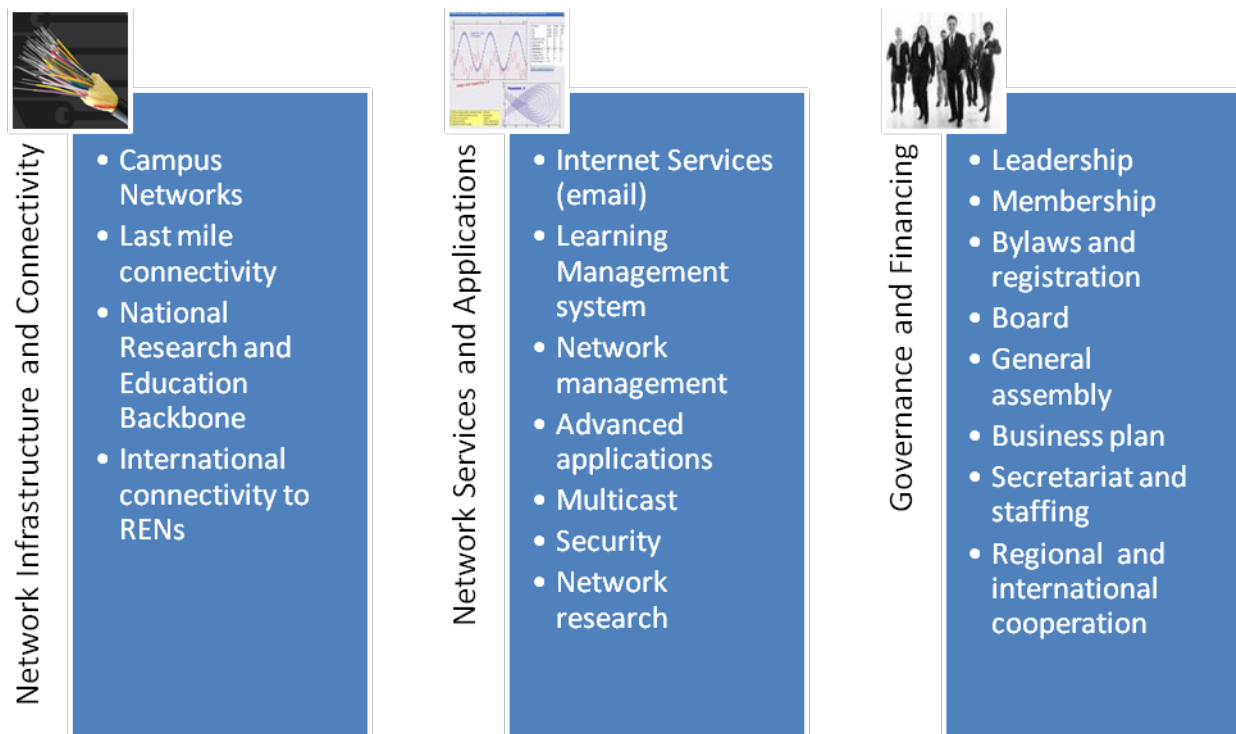


Figure 10. Ingredients of Research and Education Networks

The design and upgrade of campus network and last mile connectivity to the nearest national point of presence (POP) switch is often the responsibility of individual universities and research intuitions. NRENs operate national backbone that connects campus networks to each other and to other RENs globally, with its own routers, switches and servers. Therefore the focus of NRENs is generally in bringing connectivity to academic institutions and linking them up to international networks. There are various options for building NREN backbone including:

- **Building own infrastructure:** Some NRENs build their own networks from the ground up. This often involves laying their own fiber and provisioning necessary transmission equipment or deploying wireless systems such as microwave links. The building of the network can be done in partnerships with service providers and private sector enterprises. Such NRENs may choose to either operate or manage this infrastructure by themselves or outsource the operation and management to service providers.
- **Leasing the infrastructure:** NRENs can lease existing but unused infrastructure, like dark fiber, from telecommunications providers or other entities such as electricity companies. In this case, an NREN could provide its own transmission equipment. Again, the leased infrastructure can be operated by the NREN or outsourced to an independent operator.
- **Purchasing managed services:** The NREN can lease fiber or microwave and satellite links from a telecommunications provider which owns all the transmission equipment.
- **Purchasing capacity:** The NREN can purchase capacity or bandwidth from service providers between two or more points. In this case, the NREN network acts as a Virtual Private Network.

Leasing infrastructure has become an increasingly preferred option for the deployment of NREN national backbone and building international connectivity. This implies the Barbados NREN should work closely with operators such as Telebarbados and LIME to secure the NREN backbone network. Initial international and regional connectivity will be provided by C@ribNET.

4.2. Broadband Provision in Barbados

Barbados has established a modern, world class telecommunications infrastructure. International connectivity is provided with full redundancy via fibre optic systems and the Digital Eastern Caribbean Microwave System. Mobile telephone service is available island wide and includes international roaming features. The main communications service providers include:

- LIME – the main provider of domestic fixed line services. In addition LIME provides mobile, high speed Internet, broadband, leased line, metro ethernet and Multi-Protocol Label Switching (MPLS) services
- TeleBarbados – started operations in Barbados in May 2005 and is owned jointly by Light & Power Holdings in Barbados and Leucadia National Corporation of the United

States. The services include dedicated Internet access, Island-wide broadband network, lease line and fixed line services

- Digicel – officially launched its services in February 2004 and offers mobile services only.

Barbados is a landing point for the East Caribbean Fibre System (ECFS) submarine cable with links to 13 other islands in the Eastern Caribbean extending from the British Virgin Islands south to Trinidad and Tobago as shown in Figure 11. The East Caribbean Fibre System is operated by LIME.

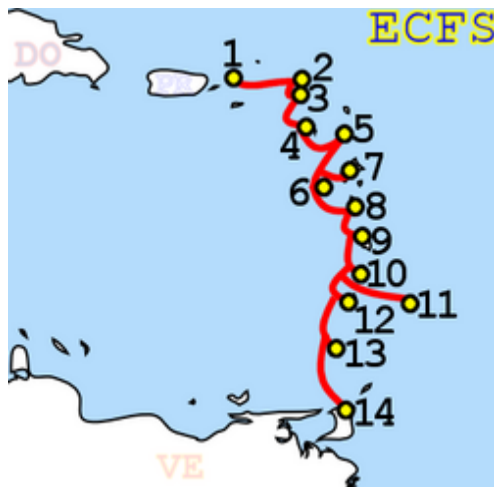


Figure 11. East Caribbean Fibre System

Barbados also hosts a landing station for Antilles Crossing submarine cable that operates at 20 Gbps. Antilles Crossing was built by a consortium that includes TeleBarbados interests, and is one of the newer important network connections to the Internet for Caribbean countries. Telebarbados is a joint venture between Leucadia National Corporation and Barbados Light & Power Holdings Limited. The Antilles Crossing submarine system currently extends from Needham's Point, Saint Michael, Barbados to Saint Croix in the U.S. Virgin Islands where it interconnects with Global Crossing's world-wide telecommunications network.



Figure 12. The Antilles Crossing

4.3. Partnership between BBREN and Service Providers

NRENs generally operate as a network for a closed group of users who have advanced requirements to support their research and education users. These requirements are not generally satisfied by commercial offerings from ISPs, therefore NRENs often operate their own network by leasing capacity from providers. The NRENs do not compete with the service providers such as Telebarbados and LIME, but offer a different level of service in parallel with them. The NREN often operates as the centre of a research and education consortium, acting on behalf of its constituency to organize joint purchases of services. This does not bring any distortion of the market, but is merely good practice on behalf of the community.

The development of BBREN will provide an opportunity for partnership in buying the capacity from Telebarbados and LIME either leasing a managed service or acquiring an Indefeasible Right of Use (IRU) for existing cable plant. An Indefeasible Right of Use is a contractual arrangement with which an “IRU user” can unconditionally and exclusively use one or more fibres of the “IRU grantor’s” fibre network for a long time period (typically 10 to 25 years). The partnership between the provider to be stipulated in the SLA contract or the IRU contract could include research cooperation such as evaluation of some new usage possibilities, etc.).

The partnership between Telebarbados, LIME and BBREN will be essential to improve connectivity by building backbones where they are non-existent and secure discounted domestic and international broadband tariffs for research and education networking.

4.4. Proposed Network Architecture

Considering the number of institutions to be linked to BBREN and the further link to C@ribNET, it is proposed that BBREN constituents be from the following:

- All secondary schools connected to BBREN using fiber. Other alternative such as wireless broadband explored where fiber is not available to schools
- Network should be designed to connect fifty (50) nodes comprising tertiary and secondary institutions and research centers without major upgrade for the next five years,
- Consider implementing a MPLS-based network for network resiliency, traffic shaping, quality of service (QoS) as well as the possibility for Layer2 and Layer3 VPN creation among research partners and special interest groups,
- A data center and NOC will be established to house the NREN's specific contents and applications.

4.5. Design of the Barbados Research and Education Network

The network design of Barbados Research and Education Network will constitute an iterative process that involves:

- The design of the physical topology for connecting institutions in different areas of Barbados along with clustering of institutions into routing areas,
- Design of the logical topology of BBREN based on IP/MPLS platform and the identification of core backbone and network access levels,
- Specification of the Quality of Service, and

- Design of external connection and peering arrangements with C@ribNET and other international networks.

It is generally assumed that:

- The campus network design is the responsibility of individual institutions.
- International connectivity will be provided by C@ribNET.

Considering the number of institutions to be linked to BBREN and the link to C@ribNET and other international and regional networks such as Internet 2 and Red CLARA, it is proposed that BBREN consider the following in the design of its various networks and clusters:

- All uplinks should be based on fibre in order to facilitate scalable bandwidth, connections. The use of wireless broadband and satellite connections should only be made in extreme cases where fibre is not available.
- A national node hosting C@ribNET should be established at a suitable location, preferably at the University of West Indies (Cave Hill campus).
- Establish linkage to the Barbados Community College, the Eridston Teachers College and the Samuel Jackman Prescod Polytechnique through Leased Fibre. Optic cables.
- A Network Operation Center (NOC) and data center to house the content and applications of BBREN should be established at a suitable location,
- Network should be designed to connect all tertiary and secondary institutions, research centers, archive, hospitals and other relevant institutions without major upgrade for the next five years,
- BBREN should consider IP/MPLS platform in order to facilitate network resiliency, traffic shaping and quality of service (QoS).

4.5.1. Design of a Physical Topology of BBREN

A typical physical topology involves main nodes, Point of Presence (PoPs), the actual bandwidth, termination points in different areas of the country and points of international connection. It is based on the number of nodes, the available infrastructure from service providers and other considerations such as costs. The network may employ leased pairs of optical fibres or wireless or leased circuits at the beginning. A case in point is the evolution of CESNET network in the Czech Republic. Figure 13 shows a physical network topology of CESNET the Czech Republic's NREN in 2004³⁸.

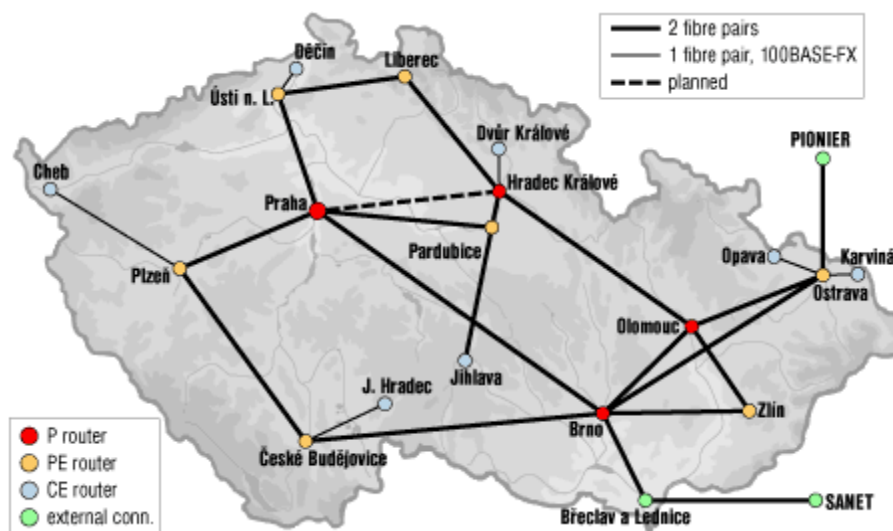


Figure 11. CESNET Topology 2004

Source: <http://www.ces.net/doc/2005/research/nren.html>

The experience of CESNET and other NRENs shows that the physical network will evolve based on improved national fibre infrastructure and the experience gained in design of the NREN. Figure 14 shows the evolution of the physical topology of CESNET in 2010³⁹.

³⁸ <http://www.ces.net/doc/2005/research/nren.html>

³⁹ <http://www.ces.net/network/>

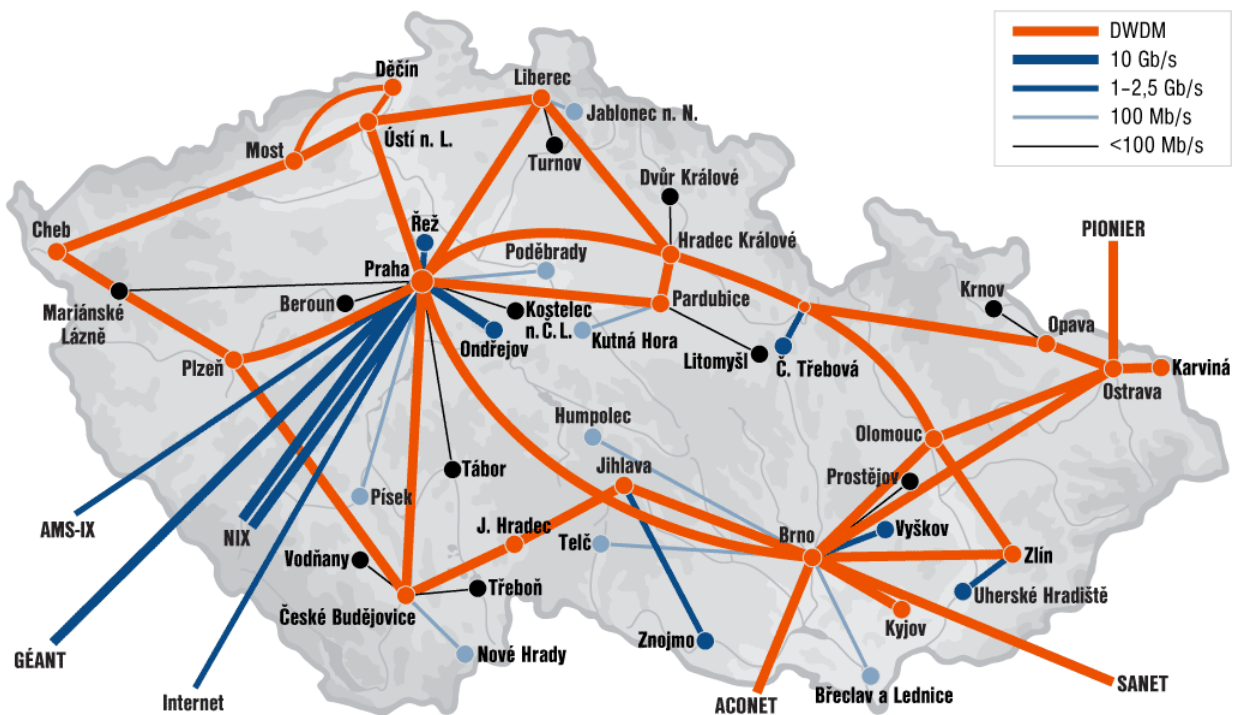


Figure 12. Evolution of CESNET Backbone 2010

Source: www.ces.net

The choice of transmission technology depends on what is available from operators at a given point of time. NREN should be built on the premises that the network traffic is bursty and optimum and scalable broadband capacity is required to execute scientific and research work. NRENs traditionally run a best-effort IP service over circuits leased from telecommunications carriers based on SDH/SONET that are designed to carry voice traffic and not optimized for handling bursty traffic such as IP.

Therefore, it has become increasingly important for research and education networking organizations to lease dark fiber that allows for the implementation of their own transmission systems; in particular, equipment that takes advantage of DWDM encoding techniques. DWDM allows for multiple optical channels to operate within a single leased fiber. Among other things, this offers the flexibility to configure network topologies on demand and upgrade capacity as necessary without having to renegotiate prices. It is, therefore, recommended that BBREN network be built on the latest fiber transmission technology.

4.5.2. Designing Logical Topology for BBREN

The IP Multi-label Protocol Switching (MPLS) is the preferred transfer protocol employed within established backbone networks today and, therefore, it constitutes the underlying platform for the logical topology. IP/MPLS provides a protocol agnostic, highly scalable data delivery mechanism that can bring the diverse network environments together. IP/MPLS enables

targeted service delivery over the network by enabling Class of Service and Quality of Service options as needed for real-time services such as voice and video specific to the needs of the end user. It provides flexibility by enabling Layer 3 and Layer 2 service delivery as well as point to point and point to multipoint connectivity between institutions as required. Based on the limited availability of bandwidth in the backbone, MPLS maximizes the utilization of the available resources as customers contend for services.

IP/MPLS network logical topology is often divided into two functional levels – the core router (Provider Edge) and access router levels (Customer Edge). The backbone network topology design, in compliance with development of the DWDM network, preserves core routers only in the main metro network circuit that act as an aggregation site, where customer sites are most likely to connect to. Based on the packets that arrive, the core router performs a swap, push or pop function; i.e.; it swaps the labels depending on the destination of the packet, or performs a push function by adding a label as the packet enters the MPLS network or performs a pop function by removing the label as the packet leaves the MPLS core.

The Access level devices function as the handoff point or demarcation from where services to the customer network will be extended. Any number of customer edge devices can be connected to the Provider Edge device based on the port density at the Providers Edge site. These routers provide connected participants with all functions and services of the backbone network (MPLS, MPLS VPN, QoS, IPv4/IPv6 routing, IPv4 multicast, NetFlow statistics export, access filters, etc.). A prototype of a logical design is shown in Figure 15.

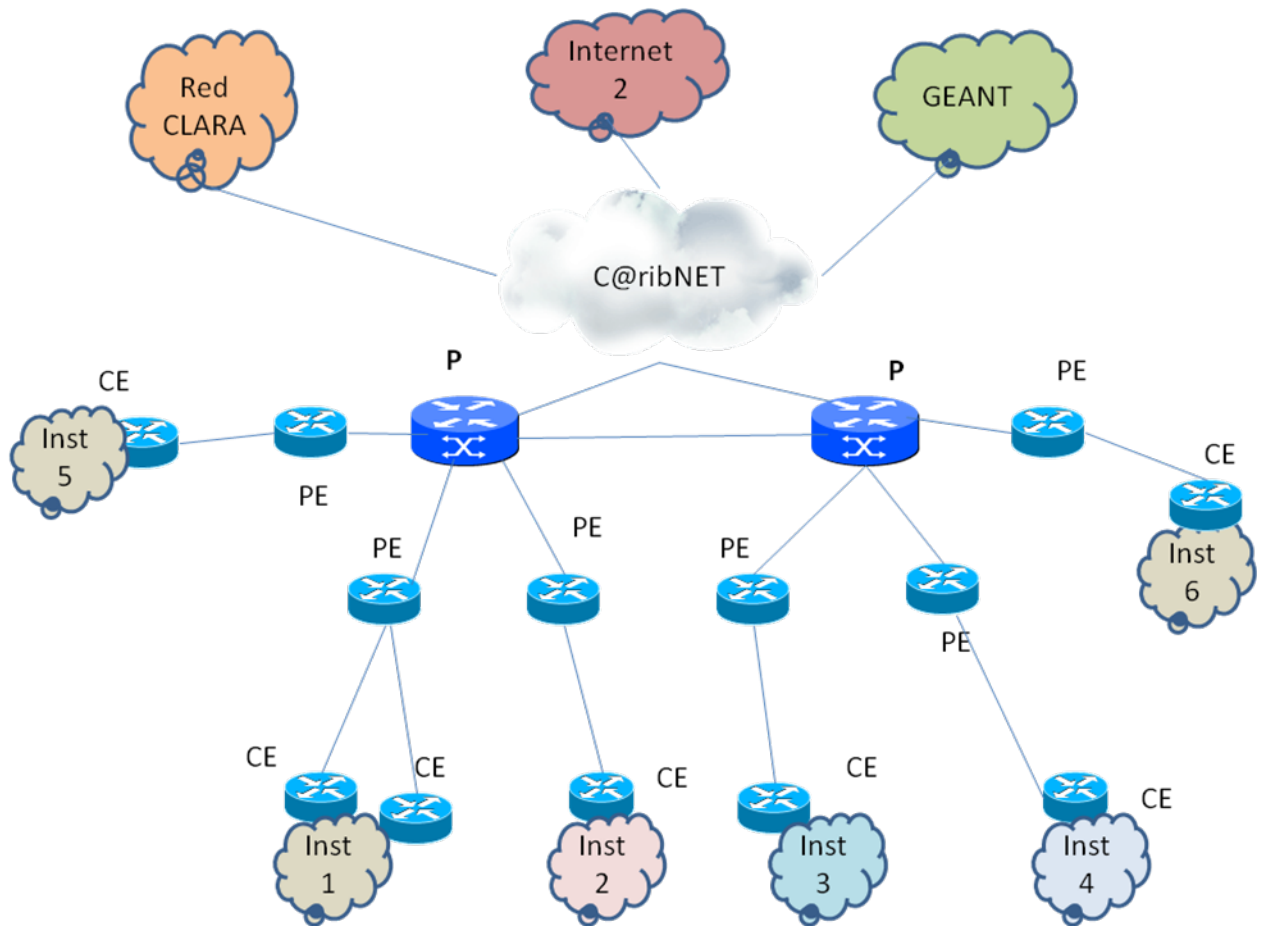


Figure 13. A Prototype MPLS Topology

The Provider (or P) routers that form the core of the MPLS network should be located at a secure facility that is capable of providing continuous power with backup generators. The P routers function as transit routers for label switched packets and, therefore, its functions are less complex than the corresponding PE routers but they provide the essential connectivity to the backbone. The second P router shown in figure 15 is not necessary but recommended to ensure high availability on the network.

The P and PE routers should support the following specifications:

- Protocol support: Should support CEF, BGP, modular QoS policies, encryption, multicasting
- High density: Aggregation of 10GE & 1GE at the core
- Flexibility: Ability to support TDM, Ethernet, WDM interfaces

- Scalability: Scalable up to 400 Gbps of bandwidth per slot
- Support for video delivery
- Longevity: Power and cooling
- Modular: I/O port density corresponds to wattage consumed
- NEBS + OSHA compliance
- Load-Balanced: Traffic load-balanced across both fabrics simultaneously at all times

Additional routers can be added to connect multiple campuses as shown in Figure 16.

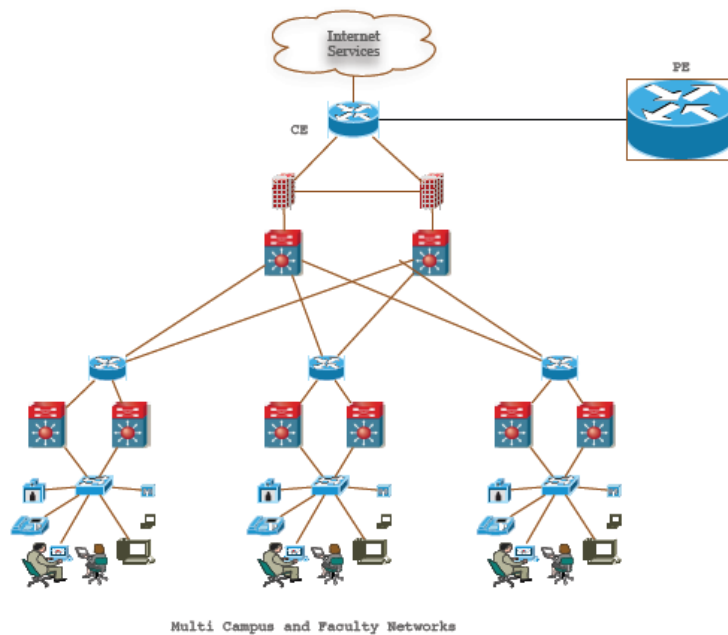


Figure 14. A prototype multi campus and faculty network

It is evident from the CESNET logical network topology shown in Figure 17 that the core networks provide an aggregation point and generally equipped with better and powerful routers⁴⁰.

⁴⁰ <http://www.ces.net/doc/2005/research/nren.html>

- Peering with regional network such as C@ribNET and Internet 2
- Peering with a national exchange point
- Peering with neighbouring country or other countries
- Connection to a commodity traffic (Internet)

A prototype peering design is shown in Figure 18. The CESNET Peering includes connection to GEANT, access to the exchange point (NiX1 and 2), access to commodity internet (Telia 1 and Telia 2) and connection to other networks (PIONIER and SANET)⁴¹.

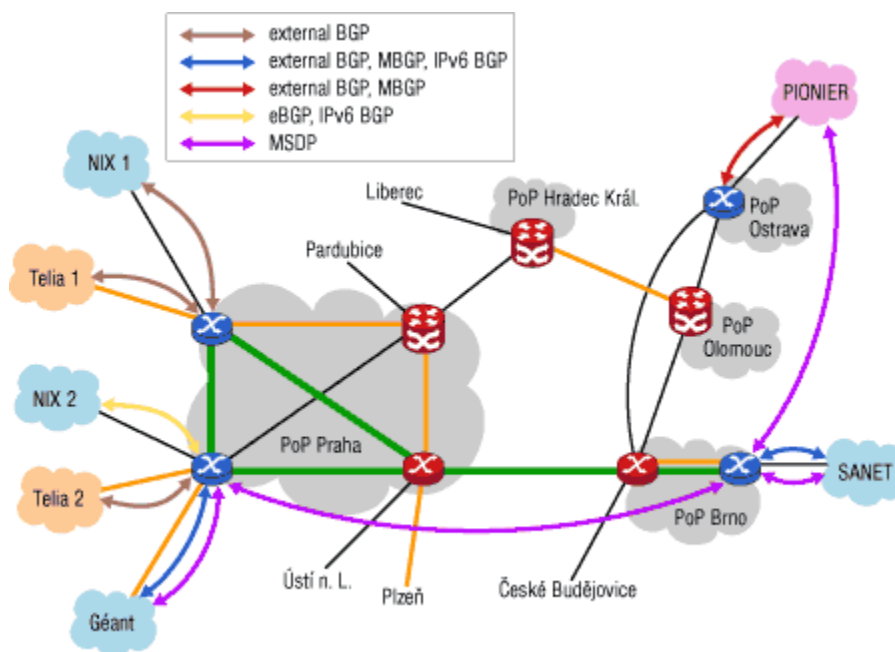


Figure 18. An Example of External Peering Topology

Source: <http://www.ces.net/doc/2005/research/nren.html>

In addition the network needs to be designed to meet the following criteria:

⁴¹ <http://www.ces.net/doc/2005/research/nren.html>

- **Scalability** – the network should be scalable to growth and change without requiring significant redesign or change to the fundamental network topology or the technology employed. A modular design approach is a suggested option for building the overall network.
- **Service availability** – The network should be designed to meet the mission critical nature of academic networking. The design should take the tariffs, expertise and other factors that constrain service availability. The most cost effective option that is sustainable and conforms to Service Level Agreement should be selected.
- **Reliability** – the national, metro and campus network needs to be designed taking into consideration the 24/7 operation. It is essential that the design takes account of the resilience requirements at all layers, and that the impacts of hardware and path failures are determined so that appropriate resilience is correctly reflected in the component designs. The design must be as simple and highly structured as possible to aid effective troubleshooting. In addition, recovery mechanisms must be considered as part of the design process.
- **Coherence** - the network should conform to a set of minimum interoperability standards that will be agreed to, by consensus, by all stakeholders to achieve the desired interconnectivity. In particular, the network should conform to the government interoperability framework.
- **Security** - The network should be designed to achieve ultimate security. Only authorized users to access approved content and applications. The security of the NREN is an essential aspect of its design. Internal and external security considerations are equally important and both must be considered.

4.6. Phase Implementation of BBREN Physical Network

The development of the Barbados Research and Education Network require an extensive network design activity and integration to the Caribbean Research and Education Network (C@ribNET) followed by connectivity of all national research and education institutions, including primary and secondary schools. A tentative schedule is provided in table 1:

Item		
1	Carryout a comprehensive design of the physical and logical topology and peering of the Network	December 2011

2	Establish link to C@ribNET	March 2012
3	Establish a data center and network operation center	March 2012
4	Connect all the tertiary institutions, hospitals, museums, libraries , archives and research organization to the national node	September 2012
5	Establish links to all schools	December 2012

Table 1. Schedule for BBREN Connectivity

5. Application and Services of BBREN

5.1. Introduction to NREN Services

The major benefit of REN is simply not to establish physical network but rather the benefits it bring to research and academic community. Universities and colleges, schools and research institutions in Barbados should take a full advantage of the infrastructure once it is put in place by running a whole new range of services and applications. Major services can range from email to digital library, multimedia communication, courseware and content management, scholarly publishing, computerized university, to Grid supercomputing. Typical NREN applications and services are classified into:

- Network services (network operation, service provision maintenance and support)
- Networking services (management, outreach, user support)
- Other service offerings (e.g. connectivity to schools, e-government, etc.)

NREN operates the national backbone that connects campus networks to each other and to other RENs globally, with its own routers, switches, servers etc. They connect researchers and educators globally using dedicated and private high speed links (not at mercy of commercial Internet traffic). In addition NREN:

- Runs its own Network Operations Center (NOC) to monitor the network and manage all traffic on it
- Provides access to high cost instrumentation and laboratories,

- Customizes connectivity solutions for research teams, collaborating globally, and
- Allocates official IP addressing space which can be grouped together according to requirements.

NRENs also provide access to the commodity Internet. They run e-mail service for member organizations, host a local Digital Library (saves international bandwidth) and host local mirror sites of international databases. In addition they create a platform for new Internet protocols and services (inventing the Internet of the future – commercial spin-offs). The key services include:

- Operating Videoconferencing bridging and providing access to the MBone virtual network for videoconferencing and video transmission on the Internet, using IP multicasting to supply streams of audio and video data
- Hosting Higher Education Management Information System
- Hosting Learning Management Systems (LMS)
- Hosting of digital libraries
- Facilitating e-Learning, and Virtual Classrooms
- Providing Web hosting, as necessary
- Providing technical support services such as equipment sourcing, tender development, etc. to its members if needed

The full range of NREN services are provided in Table 2.

Category of services	Service types	Details
Network operation services	Backbone and network transmission services	DWDM, MPLS, Ethernet, TCP/IP
	Network applications	Access to research networks including advanced labs, Access to the Internet Access to Internet Exchanges

		Access to Regional Networks
	IP multicasting services	Video conferencing Virtual learning
	Domain Name Services and IP services	Autonomous Systems Domain Name Services IP allocation services
	Web hosting and mirroring services	Caching and mirroring Database hosting and mirroring service Virtualization services
	Email services	
	Network monitoring and accounting services	
Information services	Directory services	X.500 and other directory services such as Whois, web page lists, white pages
	Web content services	Access to library catalogues, publication databases, online scientific catalogues, wikis, social network (Web 2.0)
	Search and indexing services	Open access to indexed searchable digital content
	Learning Management systems services	Moodle, Blackboard, WebCT, virtual classrooms
Security	Security monitoring and response	Emergency Response services
User support service	Customer support	Help desk services
	Document provision	User documentation, FAQ, knowledge base
	Training and capacity building	Workshops conferences, training courses
	Technical assistance	Local capacity-building, technical design, technology boot camp
	Concluding licensing agreements with hardware/software suppliers	Discounts, campus licenses, preparation of tendering documents

Table 2. NREN Services

Based on the assessment of typical application the following services and applications are recommended for BBREN to be launched in two phases:

5.2. BBREN Phase 1 Applications and services (2011-2012)

- Commodity Internet access
- Hosting of Network Operation Center, traffic monitoring and shaping
- Hosting of Learning Management Systems
- Full featured e-Learning platform, tools and portals for collaboration in course and program development between Barbados tertiary institutions
- A Multiparty video conferencing
- Online security tools
- Hosting of digital library resources
- Software licensing
- Catalogue systems and document delivery
- Community web tools such as wikis

The operation of a network operation service is one of the key application and task during phase I. The Network Operation Center will serve as a one-stop centre facility for BBREN users. It will:

- Managed helpdesk service to address and manage technical enquiries and issues
- Monitor traffic health status and utilization rate
- Manage faults and incidents - single trouble ticket centre
- Provide technical assistance including application and services support to BBREN users
- Multipoint Video Conferencing service for BBREN users
- Manage and host web applications including BBREN website
- Assistance and Coordination of Programs, Meetings, Distance Learning

5.3. BBREN Phase 2 Applications and Services (2012 – onward)

- Provides access to high cost instrumentation and laboratories
- Customizes connectivity solutions for research teams collaborating globally
- Cloud applications such as high-capacity storage and remote computing power
- Streaming video

- Online web-shops for a range of academic services

BBREN needs to consider specific application that will benefit the society as whole such as connectivity to secondary and primary schools, e-health programmes for the hospitals and medical establishments. During the second phase BBREN needs to facilitate specific applications.

- Natural Disaster systems –hurricane, flood, tsunami and earthquake warning, prediction and monitoring
- Climate change research, meteorology, environmental monitoring and data sharing
- Telemedicine and remote diagnostics
- Link with Grid initiatives, computing and data repository sharing
- Monitor emerging pandemics
- Bio-informatics, Agro-informatics, Astronomy, eVLBI (grid of radio telescopes)
- Host a node of the Caribbean Digital Heritage Exchange

6. Institutional Design for BBREN

Experience of other NRENs indicates that the governance framework of BBREN should be constituted of the General Assembly, the Board of Management and a Secretariat. A General Assembly for member institutions should be a key facility for ensuring accountability to participating organizations, research and education communities and any other important strategic users of the NREN's infrastructure and services.

The Barbados Research and Education Network will be established as an association of academic research and others such as schools and research entities. The objectives of BBREN are to:

- Develop the data communication network connecting Barbados educational, research and cultural institutions and organize its connection to the Internet;
- Create the necessary technical platform and infrastructure, and ensure its functioning and development;
- Manage and coordinate data communication of educational and research institutions;
- Represent educational, research and cultural institutions in the field of data communication in the national and international level;
- Procure and administer software licenses for universities and research and development institutions for joint use;
- Participate in international projects and cooperation;
- Organize the joint use of computing capacities ;
- Maintain Learning Management System, digital libraries and other content of institutions
- Develop monitoring, data security and other digital services;
- Organize training and conferences, provide consultations and carry out expert analyses in the field of data communication, and provide other data communication services;

The highest governing body of BBREN will be a Board whose structure and regulations are confirmed by the Ministry of Education or the authoritative governmental authority. The Board coordinates the development and the management of the network. The organizational structure of BBREN is shown in figure 17.

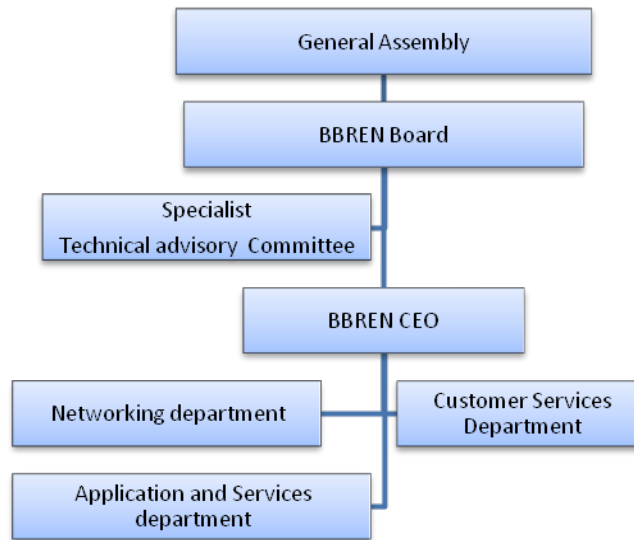


Figure 19. Organizational Framework of BBREN

The BBREN Board will comprise major champions of NREN drawn from university vice chancellors, college leaders, ministry of education and others that could play a key role in the establishment and development NREN. **The Board should not be based on membership of the directors of ICT at the colleges to avoid conflict of interest.**

The Board should comprise 7 to 9 members. The members of the Board shall be recommended to the Minister for appointment and, where necessary, removed by the Minister of Education on ratification of the General Assembly. The major functions of the Board include:

- Leading the strategy and development directions of BBREN;
- Assessing the implementation of the budget and action plan of BBREN;
- Recommending to the Minister of Education the candidate for the position of Chief Executive Officer;
- Approve the procedure for providing paid services of BBREN and the respective price list;
- Approving the procedure and conditions for qualification as an BBREN customer
- Performing other duties assigned by the Minister of Education.

The Chairman of the Board will organize the activities and convene and chair meetings of the Board. In the absence of the Chairman, meetings shall be chaired by a person designated by the Chairman. The meetings of the Board shall be held as necessary, but not less frequently than four times a year. Advance notice of at least ten (10) days shall be given to the members of the Board of the holding of a meeting and of its agenda. A meeting of the Board has a quorum if more than one-half of the members of the Supervisory Board participate.

6.1. BBREN Secretariat and CEO

A Secretariat should be established to implement the decisions of the Board of Directors and the General Assembly and to manage the day to day operations of the BBREN. The major role of the Secretariat is to develop and implement a financial and business plan for BBREN.

BBREN should be represented and its activity shall be managed by the Chief Executive Officer who will enter contract with the Board. The major functions of the BBREN CEO would include:

- Organizing the preparation of the strategic plan, draft budget and action plan of BBREN and present them to the Board of BBREN for approval;
- Organizing and deciding on matters within the authority of BBREN;
- Planning and analyzing the activities of BBREN;
- Undertaking effective performance of the functions of BBREN and ensuring the conduct of internal audits;
- Determining the duties, obligations and responsibilities of the employees of BBREN;
- Issuing directives for the management and organization of the activities of BBREN;
- Approving the internal rules of procedure and the operations procedure of BBREN;
- Providing the Ministry of Education and the Board of BBREN with an overview of performance of the functions by submission of activity reports and annual reports;
- Ensuring the servicing of the Board of BBREN;
- Establishing committees and working groups and project groups for the performance of its statutory functions;
- Representing BBREN at Caribbean and International levels

6.2. Departments of BBREN

BBREN will have the following departments:

Network Department to:

- Operate of the Network Operation Center and management of the entire network
- Ensure the flawless operation, extension and monitoring of the backbone network connecting all institutions
- Ensure the speedy recovery from network connection failures,
- Organize the operation of the services necessary for the use of the network,
- Provide the possibilities for connecting users to the network.

Applications and Services Department to:

- Ensure the operation and development of content services,
- Maintain video conferencing, digital libraries, email and web services
- Promote, launch and maintain applications that support research and development
- Organize the solution and prevention of security incidents,

- Organize the preparation and distribution of information and training materials,
- Ensure the up-to-date development of the BBREN information system.
- Customer Service Department to:
 - Provide speedy and friendly services to customers,
 - Ensure the correctness of operations,
 - Organize the provision of information to the public regarding the services and activities of BBREN,
 - Monitor and study changes in the needs of network and service users.

The Customer Service Department is also responsible for the dissemination of information about the activities of BBREN through its web site, periodicals, press reports and newspapers.

6.3. Location of BBREN

BBREN offices will be established at suitable location that is agreed by stakeholders, including the Ministry of Education. The offices will host the data center, staff offices, the Network Operation Center, training and capacity building hall as well as board room.

6.4. Human Resources, Staffing and Financing

The staff of the BBREN should be kept small in order to maintain low operational overhead. A CEO, two network engineers, one application and service specialist, a finance and administrative officer and two support staff are required at the beginning. BBREN will encourage Interns to participate in its activities to facilitate knowledge transfer and reduce costs.

BBREN will follow the predominant model of financing research and education networks; 80% of the cost of BBREN will be financed by the government either directly or through donor support while the remaining 20% will be borne by the participating institutions.

6.5. Membership Rules and Membership Criteria

Membership of BBREN will be open to non-tertiary education institutions such as schools. There will be primary members and other institutions that will be accepted as associate members. Primary NREN members are voting members and associate members non-voting members. The details of membership will be established in the bylaws/constitution of BBREN. Members should generally need to abide by the BBREN Acceptable Use Policy, constitution, articles of association, or other governing statute. Members of BBREN are expected to:

- Contribute to the purchase of bandwidth
- Adhere to payment procedures established by the BBREN
- Establish a well functioning campus network and ICT and networking unit that connect to the BBREN
- Participate in regional and international activities pertaining to BBREN.

7. Implementation Plan for BBREN

7.1. Major Tasks for Implementation of BBREN

The development of a high performance national research and education network in Barbados requires a concerted effort by all government entities spearheaded by the Ministry of Education and tertiary institutions. The implementation of BBREN needs to follow the next steps:

Task 1: Establish an NREN Taskforce and Recruit Champions

At the beginning the founding members need to establish a task team and an operational vehicle to oversee the take-off of BBREN activities. The task team and operational vehicle can begin the process of bringing the targeted academic institutions together and set up the network. Thereafter, BBREN should be formed as an independent non-profit limited liability company. Members through the General Assembly must agree with price, access conditions, the statute, rules of the usage of the network and Acceptable Use Policy (AUP). The initial BBREN taskforce need to be drawn from champions of the leading tertiary institutions, the Ministries responsible for higher education, communication, finance, the telecommunications regulator and tertiary-level educational institutions. .

Task 2: Register BBREN as a non-profit Limited Liability Company

The registration of BBREN as a non-profit limited liability company is a key step to ensure the legal status of BBREN. The registration can be done by the taskforce and champions.

Task 3: Create awareness on the importance of BBREN and secure consensus on its operations

The Task team coordinated by the ministry responsible for higher education needs to organize awareness-raising workshops in order to secure buy-in from all stakeholders including government, donor agencies, regulators, operators and their user community. Government buy-in is critical especially at early stages where investment in NREN infrastructure and operation demands public financing and support. NREN buy-in requires extensive awareness raising, lobbying and campaigning, TV shows, holding national workshops and producing promotional tools like posters, newsletters and video clips. It is important to note that all the stakeholders have a key role to play at one point or the other. Involving top leadership (inclusive of the Prime Minister) is important to secure higher level political support. The key stakeholders that participate in the awareness creation workshops at national levels include:

- Politicians, government officials, regulators and other key decision-makers involved in policies and funding research and education networks
- University and research institutions leaders
- Scientific users who will benefit from a better networking infrastructure and will be able to have more means to perform research and to participate in projects demanding high bandwidth.
- Potential new users such as research institutions, schools, museums and hospitals
- Service providers and equipment vendors

Task 4: Build the Capacity of Network Engineers

The Task team needs to organize various workshops aimed at improving the capacity of network engineers in the area of internetworking technologies. The workshop will provide opportunities for technical personnel to exchange experience and design the national network.

Task 5: Design the Physical, Logical and Peering Network for BBREN

A first comprehensive design of the physical and logical network of BBREN along with international peering arrangement should be carried out immediately after the workshop of the network engineers by involving all the communications service providers and network experts. It would also be useful to engage external an expert with a hands-on NREN network design to facilitate the process of designing the network architecture for BBREN.

Task 6: Launch Demonstrative Initiative

The taskforce and champions should identify some of the areas that will bring maximum benefits through the formation of BBREN and those applications that can demonstrate the benefit of NREN. The lighthouse applications demonstrating the return on investment are important for motivating a second phase. Direct connection to C@ribNET and Red CLARA or capacity building for participating institutions could demonstrate some of the key areas that help to bring immediate benefits of BBREN. It is also essential to seek discipline-based champions (early adopters), that will demonstrate the benefit of BBREN as well as to participate in the demonstration of the impact of the network.

Task 7: Seek initial financing of the BBREN Secretariat

The taskforce needs to come up with initial funding for setting up an NREN Secretariat.

Task 8: Put a Governance Framework in Place

Experience to date shows NRENs need to be governed by an independent “board of directors” guided by a charter, constitution, articles of association or other governing statutes. Board directors of BBREN should be selected on the basis of their experience and contacts that are directly beneficial to the network or on what they are able to offer the NREN. The ICT Directors should not be Board members in view of the conflict of interest. The Board of Directors decides on taking new members, making contracts, creating new nodes, upgrade lines, business trips, participation in international and national projects and address further important questions. Therefore, making individual universities’ technical personnel as board members would tend to complicate the decision-making on some of these issues due to self interest.

BBREN members will form a General Assembly that elects or approves a Board of Directors of BBREN and ratify prices for the provided services. BBREN could also have various committees that are entrusted with operation of the certain aspects such as networking technologies, auditing, etc.

Task 9: Set up BBREN Secretariat

Once the Board is in place BBREN needs to establish a Secretariat and recruit the key staff including the Chief Executive Officer. The CEO and staff will focus all their energies on getting BBREN going and building it up as a community, review its infrastructure needs and options on an ongoing basis, acquire or lease the necessary infrastructure from broadband providers on behalf of members, operate and maintain the telecommunications systems, support users and provide additional services as may be required by the user community. Running an NREN is a full time affair and cannot be achieved with part time staff seconded from member institutions. However, the BBREN should not be built as a bureaucracy of its own. The staff and its management should be lean and dedicated to achieving its strategic goals.

The core staff of the NREN would include a Chief Executive Officer and Network Engineers, Applications and Service Specialists that operates and maintains the network and applications on behalf of member institutions. BBRENs also need experts with proven managerial and administrative skills that handle the financial transaction in a more efficient way. Since NRENs derive the bulk of their revenues from institutions as payment of services rendered based on agreed pricing structure, a considerable amount of financial and user management expertise is required.

Task 10: Develop a Business and Financial Plan

A strategic plan for the implementation of NREN that covers bandwidth and network upgrade, staffing, funding should be developed by the BBREN staff in collaboration with its Board members and through external support in order to put the necessary infrastructure and

network services in place within a specified period. While much of the planning can take place during the course of NREN formation, it is essential to have an integrated approach towards bandwidth procurement, pricing, staffing and capacity building. The plan would cover BBREN services to be provided to users, price baskets for different services including subscription fees, management structure for operation of NREN, physical network projection, operational plan including networking activities, network services, running of the Network Operation Center and business models for financing and sustainable operation of NRENs. It also includes a detail network design (national, metro and campus levels) and connectivity plan.

The strategic and business plans need to cover a minimum of three years and should be developed as Rolling Strategic Plan to be revised annually based on changes in technology, users' requirements and market forces.

Task 11: Cultivate Partnerships for Resource Mobilization

Resource mobilization is an essential component of NREN Development. NRENs are generally subject to a wide range of costs including:

- Bandwidth costs- the cost of leasing infrastructure and purchasing capacity
- Equipment costs- the cost of providing transmission equipment, switches and routers and any servers for applications such as billing and monitoring
- Salaries- all salaries and benefits of the NRENs staff
- Travel costs – funds are required for national and international travel
- Organization costs –resources needed for organization of conferences and workshops.

NRENs will usually also have other expenses such as:

- Legal costs- for setting up and registering the NREN and for drafting and reviewing contracts and policies
- Rent and utilities costs.

There are three main sources of NREN funding to cover these costs: Government, Donors and NREN member institutions.

- Government funding is usually provided through one or more ministries, departments or other such bodies responsible for education, science, technology, telecommunications or research.
- Donor funding includes funding from bi-lateral and multi-lateral development organization, public and private foundations, Non Governmental Organizations (NGOs) and private industry. Government and donor funding is critical in the initial phase for

acquiring the physical network. Funding is also required to continuously upgrade and extend the physical network and develop new services.

- Member fees, on the other hand, are critical for operating and sustaining the NREN. These fees come in the form of annual contributions or “membership fees” and payments for services such as training and consulting.

Experience shows that NRENs need to mix central government and donor funding and membership fees based on circumstances and capacity of the institutions to pay for services. It is also important to position NREN as public goods so that they benefit from universal access funds.

Task 12: Establish National Connectivity

BBREN needs to deploy the necessary backbone infrastructure that connects universities, research centers and other tertiary institutions based on the lease or build decision that will be agreed between operators and BBREN. A Service Level Agreement needs to be signed between BBREN and operators. A sample SLA is provided in Annex II.

Task 13: Link to C@ribNET and other International Network

BBREN should also establish direct link to C@ribNET through it or directly to Internet 2, Red CLARA and GEANT to participate fully in international research, teaching, learning and knowledge exchange.

Task 14: Building Human Resource Capacity

Staffing and skills-development are other important aspect that needs to be considered by the BBREN. The establishment of BBREN will lead to a considerable skill requirement especially at the beginning both at individual academic institution and at the BBREN coordinating center. A peer-to-peer training programme where staff from one college and research institution attached to other campuses with relative skills in network management would be important. Universities can also forge alliance with communications service providers and IT companies for on-the-job training on network deployment and management. More crucially short term intensive courses are important for technical and administrative staff from universities and for BBREN coordinating center staff on network and bandwidth management, resource sharing, policy development and information resources management and use.

BBREN needs to forge collaboration through C@ribNET with capacity building institutions such as the Network Start-up Resource Center (NSRC), Internet Society and other NRENs such as CANARIE in Canada to improve the human capacity in networking technology. Staff from participating institutions and those working for BBREN should also be encouraged to participate in international NREN meetings. These meetings not only expand the knowledge of NREN experts, but also serve as forums for sharing experiences and best practices knowledge within

their level. Participants have the opportunity to learn about real-life problems, describing similar situations occurring in different environments, to gain a better understanding of the problems that arise in front of them and how to resolve them.

Task 15: Promote the Exchange of Applications and Services

A key outcome of the successful NREN is its ability to meet the content and application needs of its consumers- researchers, students, academic and administrative staff. NREN users need access to email and web, databases, scientific instruments and advanced computing and storage capabilities. Different NREN users require different connectivity, application and content options. In general there are three groups of content and application users:

- Group I - low level content and application users who are involved in browsing the net, e-learning and email applications. The majority of students and academic staff and students belong to this group.
- Group II – high bandwidth users that require specific applications, multi-cast, video streaming and other bandwidth intensive applications. These include researchers in engineering, earth sciences, economic modelling.
- Group III- very high bandwidth intensive application users who work on special scientific application such as astronomy, high energy physics, and meteorology.

While the focus of NREN is generally on group I users, it is essential to optimize the network for high-end users in Group II and III that often are involved in cutting edge-research in medicine, engineering, sciences, economics relevant to social and economic development.

7.2. Phased Implementation of Tasks 1-15

The implementation of the above initiatives will take place in three phases as shown in Figure 20.

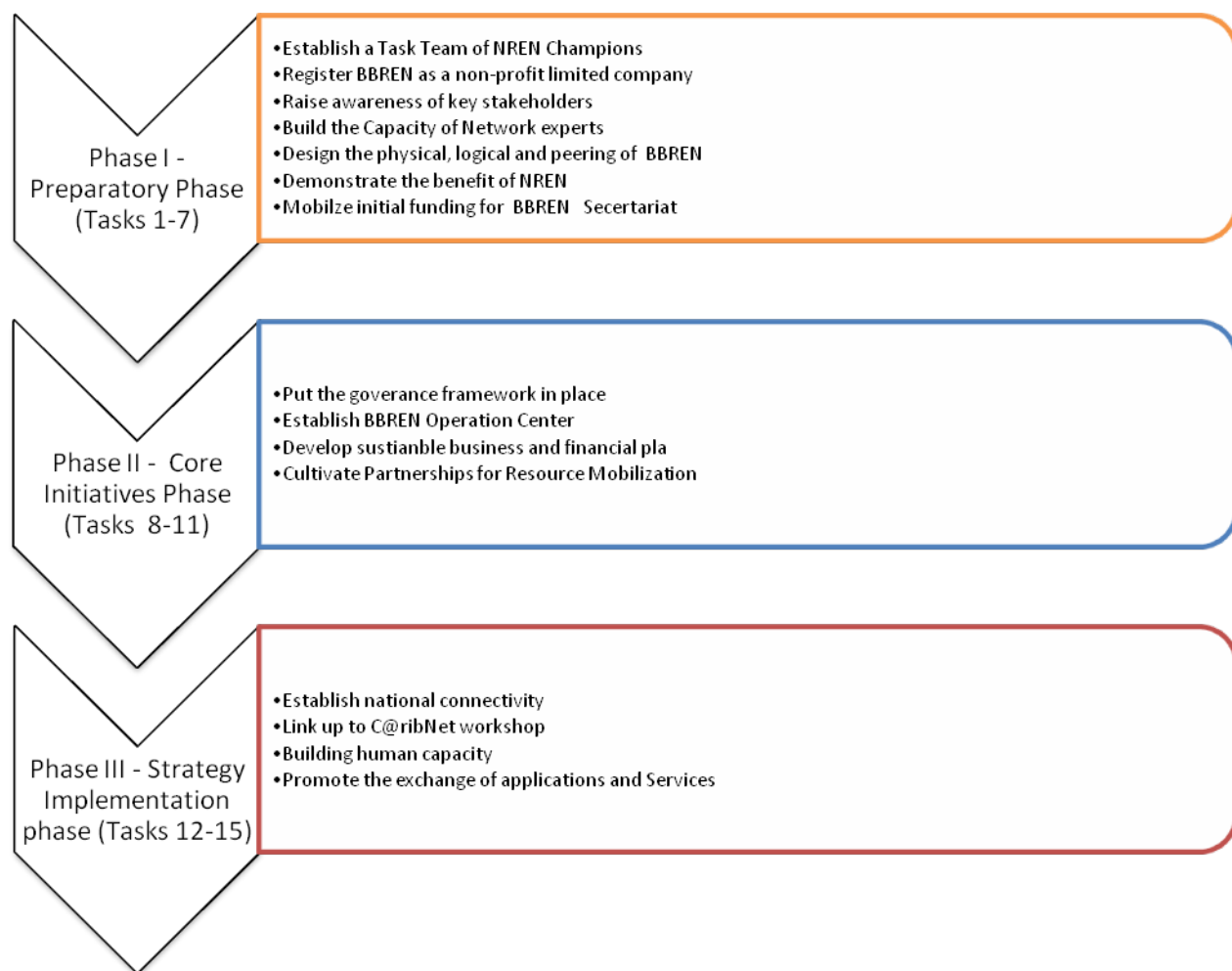


Figure 16. Phased Implementation of BBREN

Phase I – Tasks 1-7

Phase I covers all the preparatory activities for launching BBREN and is expected to be completed by December 2011. The key tasks during this phase include:

- Establish a Task Team of NREN Champions
- Register BBREN as a non-profit limited company
- Raise awareness of key stakeholders
- Build the Capacity of Network experts
- Design the physical and logical network

- Demonstrate the benefits of BBREN
- Mobilize initial funding for BBREN Secretariat

Phase II involves the core activities of BBREN. This involves:

- Putting the governance framework in place including the set up of the Board
- Establish BBREN Operation Center and recruiting the staff
- Develop a sustainable business and financial plan
- Cultivate Partnerships for Resource Mobilization including the development of a financial proposal for the operation of BBREN based on the business strategy and financial plan

Phase II is expected to be completed six months after the preparatory phase by June 2012.

Activities of the third phase are expected to begin immediately after Phase I at the end of December 2011 but continue throughout the year. At the end of 2012, BBREN is expected to:

- Expand links to other between academic and research institutions including connection of secondary schools to the network
- Upgrade the regional and international connectivity.
- Build a critical mass of human resources for its operation and that of participating institutions
- Promote the exchange of content and launch further innovative applications.

7.3. Estimated cost of the Priority Initiatives

Table 3 provides ball park cost of priority initiatives during phase I. The actual cost of BBREN over the next five years is expected to be available following a thorough analysis during the design of a five year business and financial plan.

Activity	Detail Tasks	Estimated cost	Remark on Financing
Establish a Task Team of NREN	Task team meeting, venue, consulting to	US\$100,000	Ministry of Education

Champions	support task team Experience exchange with other NRENs		
Register BBREN as a non-profit limited company	Logistics cost, registration fee,	US\$5000	Ministry of Education
Raise awareness of key stakeholders	National Workshop for key stakeholders	US\$20,000	CKLN
Build the Capacity of Network experts	National workshop for network engineers	US\$45,000	CKLN, Ministry of Education
Design the physical and logical network	Network engineers in collaboration with providers and external consultant	US\$50,000	CKLN, Ministry of Education
Launch activities that demonstrate the benefit of BBREN	Connection to C@ribNET Demonstrative application	US\$50,000	Ministry of Education
Mobilize initial funding for BBREN Secretariat	Concept paper and lobbying	US\$10,000	Ministry of Education
Total cost		US\$280,000	

Table 3. Phase I Cost

The financing of the priority initiative should be covered by the Government of Barbados.

7.4. Risks and Mitigation

There are a number of risks and dependencies which may impact on the evolution of BBREN. These include limited commitment from senior decision makers including tertiary education leaders, senior government policy makers from the Ministry of Education and Ministry of Finance, insufficient budget, lack of adequate or technically skilled staff and low level of cooperation and service delivery by service providers.

The support of policy makers is crucial for successful deployment of BBREN. An adequate financial resource is also needed to support preparatory activities during phase 1 and the implementation of the BBREN business and financial plan over the course of five years. The major risks and mitigation strategies are listed in Table 4.

Risks	Factor	Mitigation measures
Limited commitment of senior decision makers in design and development of BBREN	Individual institutions may be reluctant to join the club of REN Competition to lead the process Mistrust among different institutions	Organize workshop on the role of NREN. Support consensus building process
Insufficient / unsuitable Human Resources made available to BBREN	Lack of staff with the necessary skill to deploy BBREN applications and services	Ensure that newly recruited staff has industry recognized competence Advertise widely to attract the best talent Provide opportunity for training and interaction
Insufficient budget made to BBREN	Institutional budget remain insufficient Inadequate annual allocation by the Ministry of Education for the formation of NREN	Improve the ICT budget taking BBREN into the account, Seek donor support and funding

Inadequate cooperation from service providers (LIME and Telebarbados)	Completion of BBREN with the services of the operators	NREN should operate as a closed user group with acceptable use policy
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Table 4. Risk and Risk Mitigation Strategies

8. Conclusion

The creation of BBREN will bring a coherent connectivity to academic and research institutions in Barbados. The relatively small number of tertiary institutions will make it easier for the development of BBREN and connection of other entities such as hospitals, schools and government institutions that have research and education orientation. The development of BBREN involves building the physical network that connects all these institutions and putting in place the governance framework, staffing, capacity building and financing for the evolution of the network.

The following key actions should be taken in order to establish and operate BBREN:

- Set up a Task Team to spearhead the registration of BBREN, carryout capacity building, design its network and make calls for the General Assembly for establishing its governance framework
- Set up a governance framework for BBREN including its Secretariat
- Adopt a five year business plan
- Mobilize resources using a hybrid model combining government allocations, donor funding and usage fees
- Secure the bandwidth by leasing from service providers
- Establish international connection through C@ribNET

NRENs have been able to bring the benefits of collective buying power to universities and tertiary-level educational institutions by procuring networks and services on a national basis. This provides savings for the community of researchers, students and academics. Individual institutions or indeed countries are finding it difficult to become a serious player on the international stage without the establishment of a robust NREN. Being affiliated to the NREN community and representing it on the international level gives credibility and enhances the ability to actively participate in global research efforts. NRENs are invaluable assets on linking researchers, promoting collaboration and in the implementation of national policy on education, research and ICT. They are invaluable sources of regional cooperation. The development of BBREN will, therefore, be critical not only for improved access to research knowledge but also to forge the competitiveness of Barbados and the Caribbean Region.

Annex I: Guidelines for Operation of NREN

1. Operating Principles

- 1.1. NREN should be regarded as a public good.
- 1.2. NREN should be designed as a closed user group whose purpose is to carry research traffic and support the exchange of learning and research content and applications.
- 1.3. NREN members should abide to Acceptable Use Policy that restricts the use of network for commercial purposes.
- 1.4. NREN should be organized as a non-profit consortium of institutions engaged in teaching, learning and research activities.
- 1.5. NRENs should have organization, bylaws and Acceptable Use Policies to which members sign to.
- 1.6. The NREN should be configured so that its overhead costs are kept relatively low.
- 1.7. NREN development should involve policy and decision makers since government support is important at all stages. Government will be a key financier of NREN infrastructure and operation. Extensive awareness raising, lobbying and campaigning, holding national workshops and producing promotional tools like TV shows, posters, newsletters and video clips should be used to increase awareness on NREN development.

2. NREN External stakeholders

- 2.1. NREN involves a wide range of stakeholders including the ultimate decision makers such as the Prime Minister. National Research and Education Networks need to forge good relations with government, donor agencies, regulators, operators and their user community.
- 2.2. it is critical to secure maximum support from the Ministry of Education and the higher education units.
- 2.3. The Communications Ministry is important as it is responsible for enacting overall telecommunications policy and influencing the planning and building of the national infrastructure.
- 2.4. The telecommunications regulator is responsible for overseeing and implementing telecommunications policy, introduction of competition and for granting critical licenses to the NREN. Regulators are becoming increasingly supportive to NREN development and providing them with the necessary funding through universal access funds. INDOTEL is the leader in the development NREN (RADEI) in the Dominican Republic. Such leadership should be emulated by other countries.

2.5. The Ministry of Finance is another key stakeholder that needs to be convinced. It does not only allocate the budget to education and research networking but has a lot of influence over donor funding and their allocations to research networking. Recent move in many countries away from donor project financing to direct budget support makes the Ministry of Finance even more critical.

2.6. Development aid agencies have always been the key supporters of NREN, however it is preferable that connectivity is funded by governments directly or by raising resources from donor agencies. There is a need for ongoing lobbying of officials of donor agencies in order to secure start up and operational funding. Donors could also play a key role in influencing the allocation of public budget to NRENs.

3. Objective of NREN.

3.1. The first order of business of the new NREN Board will be to develop the objectives of the NREN. The objective of NREN should be to promote coherent access to advanced network infrastructure to improve the conduct of teaching, learning and research. Other goals of the NREN may include:

- Providing a stable high-speed transport network that meets the expected end-user demand
- Establishing a community for education and research networking
- Design and develop network services such as video conferencing, digital libraries, e-learning content and encourage broad participation of member institutions in sharing content such as learning materials
- Promoting research into high performance technologies in networks and exploring new strategies, techniques for the effective use of network infrastructure
- Promoting research and development based collaboration especially in the subject areas that require constant connectivity and sharing advanced networking resources
- Providing users support
- Training and capacity building
- Promote participation in regional network (C@ribNET) and other networks
- Transfer knowledge to other institutions such as schools
- Contribute to national ICT and education strategies with the ultimate aim of bridging the digital divide.

4. Organizational Design

- 4.1. The NREN should have a competent Board. The Board of Directors decides on taking new members, making contracts, creating new nodes, upgrade lines, business trips, participation on international and national projects, and address further important questions. Therefore making individual universities sit on the Board would complicate the decision of some of these issues due to self interest. The Board should be drawn from major sponsors and owners of NREN including ministers, vice chancellors, heads of institutes, donors and others that will bring value to the development and smooth operation of BBREN.
- 4.2. The Board can be appointed by Minister of Education. NREN should have a General Assembly that elects a Board of Directors of NREN and decides on prices for the provided services.
- 4.3. NRENs could also have various committees that are entrusted with operation of the certain aspects such as networking technologies, auditing, etc. The members of the technical committee should not be representative to avoid conflict of interest. The technical committee should address the following issues:
- Design of network to be used for NREN connectivity
 - Network monitoring
 - Network security oversight
 - Technical training planning
 - Technical problem escalation support
 - Technical budgets
 - SLA requirements for both vendors and clients
 - NREN portal development and operations
 - NOC Operations
 - Helpdesk and support issues
 - Network security and disaster recovery
- 4.4. The core staff of the NREN may include a competent CEO and networking, applications and services specialists that operates and maintains the network, services and applications for academic institutions. The different specialist will be responsible for

management of the network, running the Network Operation center and the various applications as well as procurement processes, billing and financial reporting, and other non-technical operational processes. NRENs also need proven managerial and administrative (financial or accounting) staff that handles the financial transaction in a more efficient way. Since NRENs derive the bulk of their revenues from institutions as payment of services rendered based on agreed pricing structure, a considerable amount of financial and user management expertise is required.

5. Business Plan

- 5.1. NREN should establish a business plan and phased financial plan that will serve as a basis for resource mobilization.
- 5.2. The business plan should cover services to be provided to users, price baskets for different services including subscription fees, management structure for operation of NREN, operational plan including networking activities, network services, running of the Network Operation Center and business models for financing and sustainable operation of NRENs.
- 5.3. The business and financial plan should spell out roles and responsibilities of different actors
- 5.4. The business plan should be accompanied by an implementation strategy

6. Membership

- 6.1. Membership of the NREN should be agreed on by the General Assembly. All tertiary institutions should be members of the NREN.
- 6.2. NREN should be able to add additional classes of non-voting membership such as associate or affiliate membership including industrial and international partners.

7. Procedure for NREN startup

- 7.1. The responsible ministry or higher education institution should take the lead and convene and organize a **non-profit consortium for NREN** by inviting all the universities, colleges and research institutions.
- 7.2. A task team needs to be established to foster the initial establishment of NREN.
- 7.3. A proposal should be prepared and submitted to government and International organizations for requesting capital funding.

8. Financing NREN Operation

- 8.1. Public resources should be sought to cover the bulk of the NREN cost
- 8.2. NREN should be financed from universal access fund and Research and Development fund and other grants and donor resources

- 8.3. NREN should explore the three sources of financing (government, donor and membership fees) to generate adequate revenue for operation.
- 8.4. Infrastructure and associated investments are largely addressed by funding from public sources, including donor funding. Operating overhead costs are borne via membership and service-related fees. Some services are delivered as common to membership while others are on an “opt-in” basis
- 8.5. A funding proposal that draws on the business and financial plan is important to mobilize resources.

9. Function of NREN Secretariat

- 9.1. Establishment and management of the Network Operation Center
- 9.2. Provision of enterprise services such as digital library, content hosting, electronic mail, director and information services
- 9.3. Establish NREN Web Site
- 9.4. Coordinating research in networking
- 9.5. Build a compendium of networking and service covering status of connectivity in campuses of academic and research institutions (hardware, software, platforms, application, bandwidth, campus network configuration, international bandwidth, human resource capacity and skills, applications in use, etc.) and the various connectivity options (fibre, wireless network, dark fibre) including contact lists

10. Skills development and capacity building

- 10.1. NREN will lead to a considerable skill requirement especially at the beginning both at individual academic institution and at the NREN coordinating body levels.
- 10.2. A peer to peer training programme where staff from one university and research institution attached to other campuses with relative skills in network management would be important.
- 10.3. More crucially, short term intensive courses are important for technical and administrative staff from universities and the NERN coordinating center on network and bandwidth management, resource sharing, policy development and information resources management and use.

Annex II: Draft Service Level Agreement

SERVICE LEVEL AGREEMENT Nr.

GENERAL PROVISIONS

February 2011

Telebarbados

Represented by

Position

And

Barbados National Research and Education Network (BBREN)

Represented by

Position

Hereinafter referred to as Parties define the service level agreed to be provided by Telebarbados to BBREN users.

ARTICLE 1- PURPOSE AND GOALS OF THE SLA

The purpose of this SLA is to establish a partnership between Telbarbados and the Barbados National Research and Education Network (BBREN) in order to provide high quality communication services to users.

The goals of this Agreement are:

- to express mutual understanding of the principles of cooperation between parties;
- to define responsibilities of each party;
- to set procedures for monitoring activities;
- to define network requirements;
- To establish problem reporting procedure and problem response procedures and time.

ARTICLE 2-DEFINITIONS

Network requirements – collection of parameters that have to be implemented in order to guarantee successful operation of the applications within this network;

Fair and Reasonable use – the use of the network that corresponds to the goals of the Barbados National Research and Education Network, policies defined in this Agreement, netiquette, and acceptable usage practice of .

ART-management – Quality of Service according to Amber, Rock and Timber levels;

Users – researchers that run their applications;

NRR – Network Resources Request;

Monitoring activities – activities performed by and participants that measure the actual status of the networking processes and their correspondence to the network requirements defined in this Agreement.

ARTICLE 3 - TERM OF AGREEMENT

The period for the agreement shall be effective by 30 June 2011. Periodically, according to clauses in The ARTICLES 6 and 7, both Parties will review the benefits of continuing the SLA and take one of the following actions:

1. Terminate the SLA,
2. Modify the General provisions of the SLA, or
3. Modify the Specific Provisions of the SLA.

ARTICLE 4 – DUTIES AND RESPONSIBILITIES OF PARTIES

TELEBARBADOS: CHARACTERISTIC DUTIES AND RESPONSIBILITIES

1. Ensures service availability and best possible network performance
2. Responds to BBREN information requests necessary for accomplishment of this Agreement in due time but not later than 5 (five) working days. Urgent requests (specified so by BBREN) shall be answered as soon as possible but not later than in 2 (two) working days.
3. Ensures that Telebarbados staff is available 24/7 to make the necessary installments and configuration of the BBREN network and smooth operation.
4. Responds to and resolves problems reported by Telebarbados Technical contact person by e-mail in due time:
 - a) **Breakdown:** more than 90% BBREN users are not able to use the infrastructure of Telebarbados. Response time (high priority): 2 hours;
 - b) **Broken international connection:** BBREN users are not able to exchange data via international link. Response time (Medium priority): 4 hours;
 - c) **Broken link:** BBREN users at the specific institutions are not able to use the infrastructure of NREN. Response time (Medium-Low priority): 8 hours.

5. Telebarbados contact persons:

Administrative contact person: _____

Technical contact person: _____

BBREN: CHARACTERISTIC DUTIES AND RESPONSIBILITIES

Provides all necessary help to BBREN in order to ensure service availability to its

1. Provides all necessary help to users to ensure service availability to its network
2. Ensures that the network is only used for academic and research purpose and users are guided by acceptable user policy for NREns

3. BBREN contact persons:

Administrative contact person: _____

Technical contact person: _____

DEMARICATION POINTS

Name of Demarcation point

Address, Floor, Room, Rack number

Type of interface

Planned capacity of the connection

(e.g. 1Gbps interface might have been planned for use up to 622Mbps due to uplink restrictions, other users etc.)

Name of Demarcation point

Address, Floor, Room, Rack number

Type of interface

Planned capacity of the connection

...

ARTICLE 5 – MONITORING SLA ADHERENCE

Both BBREN and Telebarbados will monitor the compliance of actual network resources to the network requirements defined in the Specific provisions of this Agreement.

Results are collected and analyzed on a monthly basis. Results might serve as a proof to the need to modify the SLA.

ARTICLE 6 – TERMINATION OF THE SLA

Either party may terminate this agreement provided that the terminating party first notifies the other party in writing of the exact nature of such decision giving the other party ten (10) days in which to cure the cause for such an action if it is caused by its actions. Agreement is considered terminated if other party does not reply or expresses an acceptance of the termination.

If a party which receives a termination notice from the other party does not agree to terminate the agreement, it notifies the other party and proposes amendments or modifications of the agreement or a new agreement.

If a consensus between parties is not reached in 2 (two) months, the agreement is considered to be terminated.

ARTICLE 7 – MODIFICATION OF THE SLA

Modification of the agreement might be initiated if BBREN considers changing Specific provisions of the Agreement from ART-management to Over-provisioning.

Modification of the agreement is to be made if TeleBarbados does not meet network requirements defined in Specific provisions of the Agreement for Over-provisioning. In this case Specific provisions must be changed to ART-management.

Either party may invoke modification procedure by sending fully phrased amendment of a clause in writing to the other party. The party receiving a written proposal of modification, within 10 (ten) days accepts, alters or rejects modifications notifying the other party in written. Modifications are in force when both parties sign an amendment to the Agreement.

ARTICLE 8 – DISPUTE RESOLUTION

All disputes arising under this Agreement shall be discussed the Parties within 30 working days after the issue has arisen or been identified.

If the dispute cannot be resolved within the said period, the Agreement shall be terminated or modified.

SPECIFIC PROVISIONS (Over-provisioning)

1. Under this Agreement Telebarbados will provide the following connectivity to BBREN.

- Packet loss: < 0.1%
- One-way delay will be in the range of 20-50ms, but does not exceed 150 ms under any conditions.

- MTU of at least 1500 bytes all along the traffic path.
- Minimal jitter by avoiding extra routing/buffering hops on the path.
- Traffic load does not exceed 75% of available bandwidth for more than 10% a month.
- Available bandwidth should be increased so that traffic load does not exceed 50%.

2. In the case of non-compliance to the specified network requirements, Telebarbados shall increase the capacity of their international connection or support ART-management.

SPECIFIC PROVISIONS (ART-management)

1. Under this Agreement Telebarbados will provide Quality of Service management for the following levels:

Amber.

- Corresponds to C@ribNET Premium IP.
- Does not exceed 10% of total C@ribNET connection capacity
- One-way delay does not exceed 100ms (distance delay + 50ms)
- Jitter does not exceed 25ms.
- No packet loss.

Rock

- Corresponds to C@ribNET traffic class.
- One-way delay does not exceed 200ms.
- Packet loss < 1%.

Timber

- Uses capacity unused by Amber and Rock traffic classes.
- Might be rate-limited.
- Packet loss: unspecified

2. The request for the specific level is to be submitted by BBREN not later than 3 (three) working days before the level has to be implemented.

3. Telebarbados may propose to change the Specific provisions to Over-provisioning if monitoring results provide enough evidence.

Annex III. Research and Education Networks

Research and Education Networks in Europe:

Belgium	BELNET	http://www.belnet.be/
Denmark	Forskningsnettet	http://www.forskningsnettet.dk/eng
	NORDUnet	http://www.nordu.net
Germany	DFN	http://www.dfn.de/en/
Estonia	EENet	http://www.eenet.ee/EENet/
Finland	FUNET via NORDUnet	http://www.csc.fi/suomi/funet/index.html.en
		www.nordu.net
France	RENATER	http://www.renater.fr/
Greece	GRNET	http://www.grnet.gr/default.asp?pid=1&1a=2
Great Britain	JANET	http://www.ukerna.ac.uk/
Ireland	HEAnet	http://www.heanet.ie/
Iceland	RHnet über NORDUnet	http://www.rhnet.is/english/
		www.nordu.net
Israel	IUCC	http://www.iucc.ac.il/
Italy	GARR	http://www.garr.it/eng/
Croatia	CARNET	http://www.carnet.hr/english
Latvia	SigmaNet	http://www.sigmanet.lv/?lang=en
Lithuania	LITNET	http://www.litnet.lt
Luxembourg	RESTENA	http://www.restena.lu/restena/en/EN-Index.html
Malta	University of Malta	http://www.um.edu.mt/
The Netherlands	SURFnet	http://www.surfnet.nl/en/
Norway	UNINETT über NORDUnet	http://www.uninett.no/index.en.html
		www.nordu.net
Austria	ACOnet	http://www.aco.net/
Poland	PSNC	http://www.man.poznan.pl/pcss/public/main/index.html?lang=en
Portugal	FCCN	http://www.fccn.pt/

Romania	RoEduNet	http://www.roedu.net/en/node/43
Russia	JSCC	http://www.jscc.ru/
Sweden	SUNET über NORDUnet	http://www.sunet.se/www.nordu.net
Switzerland	SWITCH	http://www.switch.ch/
Slovakia	SANET	http://www.sanet.sk/english.html
Slovenia	ARNES	http://www.arnes.si/english/
Spain	RedIRIS	http://www.rediris.es/
Czechia	CESNET	http://www.ces.net/
Turkey	ULAKBIM	http://www.ulakbim.gov.tr/eng/
Hungary	NIIF	http://www.niif.hu/en
Cyprus	CYNET	http://www.cynet.ac.cy/english/CyNet_Home.htm

Research and Education networks in North America:

Canada	Canarie Inc.	http://www.canarie.ca/
USA	UCAID	http://www.internet2.edu/

Research and Education networks in Latin America

LATIN AMERICA		
Argentina	INNOVA RED	www.innova-red.net
Bolivia	ADSIB	www.adsib.gob.bo
Brazil	RNP	www.rnp.br
Colombia	RENATA	www.renata.edu.co
Costa Rica	CONARE	www.conare.ac.cr
Cuba	RedUniv	www.mes.edu.cu
Chile	REUNA	www.reuna.cl
Ecuador	CEDIA	www.cedia.org.ec
El Salvador	RAICES	www.raices.org.sv

Guatemala	RAGIE	www.ragie.org.gt
Honduras	UNITEC	www.unitec.edu
Mexico	CUDI	www.cudi.edu.mx
Panama	RedCyT	www.redcyt.org.pa
Paraguay	Arandu	www.arandu.net.py
Peru	RAAP	www.raap.org.pe
Uruguay	RAU2	www.rau.edu/uy/redavanzada
Venezuela	CENIT & REACCIUN	www.cenit.gob.ve

Research and Education Networks in the Asia-Pacific region (selection):

Australia	AARNet	www.aarnet.edu.au
Armenia	ARENA	www.arena.am
Azerbaijan	ANAS	www.ict.az/en
Bangladesh	BdREN	www.bdren.net.bd
China	CERNET	www.cernet.edu.cn
Hong Kong	HARNET	www.polyu.edu.hk
Japan	SINET	www.sinet.ad.jp
India	ERNET	www.eis.ernet.in
Indonesia	INHERENT	www.itb.ac.id
Israel	IUCC	www.iucc.ac.il
Jordan	JUNet	www.junet.edu.jo
South Korea	KERIS
Lebanon	CNRS	www.cnrs.edu.lb
Malaysia	MYREN	www.myren.net.my
Nepal	NREN	www.nren.net.np
New Zealand	REANNZ	www.reannz.co.nz
Pakistan	PERN	www.hec.gov.pk
Palestinian Territory	PADI2	www.padi2.ps
Philippines	PREGINET	www.dost.gov.ph
Qatar	Qatar Foundation	www.qf.org.qa
Saudi Arabia	KAUST	www.kaust.edu.sa
Singapore	SingAREN	www.singaren.net.sg
Sri Lanka	LEARN	www.learn.ac.lk
Syria	HIAST & SHERN	www.hiast.edu.sy

Taiwan	NCHC	www.nchc.org.tw/en
Tajikistan	TARENA	www.tarena.tj
Thailand	ThaiREN	www.thairen.net.th
Turkmenistan	TuRENA	www.science.gov.tm
United Arab Emirates	ANKABUT	www.kustar.ac.ae/ankabut
Uzbekistan	UzSciNet	www.uzsci.net
Vietnam	VinaREN	www.vinaren.vn

Research and Education Networks in Africa

Algeria	CERIST	www.arn.dz
Democratic Republic of Congo	Eb@le	www.ebale.cd
Egypt	EUN	www.eun.eg
Ethiopia	EthERNet	
Kenya	KENET	www.kenet.or.ke
Malawi	MAREN	www.maren.ac.mw
Morocco	MARWAN	www.marwan.ma
Mozambique	MoRENet	www.morenet.mct.gov.mz
Rwanda	RwEdNet	
Senegal	RENER	
Somalia	SomaliREN	www.somaliren.org
South Africa	TENET	www.tenet.ac.za
Sudan	SUIN	www.suin.edu.sd
Tanzania	TERNET	www.ternet.or.tz
Tunisia	TUREN	www.mu.tn
Uganda	RENU	www.renu.ac.ug
Zambia	ZAMREN	