BROADBAND COMMISSION
FOR DIGITAL DEVELOPMENT

Working Group on Broadband and Science
Final Report

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Foreword

The Broadband Commission for Digital Development (http://www.broadbandcommission.org/) believes that high-speed, high-capacity broadband connections to the Internet are an essential element in modern society, with wide social and economic benefits. Its mission is to promote the adoption of broadband-friendly practice and policies so that all the world's people can take advantage of the benefits of broadband.

The establishment of the Broadband Commission in 2010 came five years after the World Summit on the Information Society (WSIS), and ten years after the launch of the Millennium Development Goals. Expanding broadband access in every country is key to accelerating progress towards those goals by the target date of 2015.

At its second meeting in New York in September 2010, the Broadband Commission agreed to establish a number of Working Groups to focus on specific issues during 2011. The Working Group on Broadband and Science chaired by the European Commission acts as a collective think tank, brainstorming on several key issues in the field of Broadband and Science –with a particular emphasis in the developing world- in view of proposing forward thinking, practical solutions which may be conceptualized and marketed to the Broadband Commission for possible implementation.

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Executive Summary

Broadband connectivity has become a basic infrastructure of modern society, just like roads, electricity or water. Science and education communities depend on "e-Infrastructures" that build on broadband connectivity to provide online services supporting the communities' work. Not only have these services today become indispensable, they have also transformed the scientific process by enabling the instantaneous sharing of knowledge, virtual collaborations within and between continents, and remote access to scientific resources and instruments. Developing regions stand to benefit in particular because broadband networks reduce the barriers of distance and location.

Yet there are still many obstacles to overcome, with a clear scope for action by all stakeholders (e.g. governments, international organisations, regulators, research community, industry..). The Working Group on Broadband and Science urges the Broadband Commission to adopt the following recommendations and to defend them in the corresponding high level fora.

R1. **Sustainable, interoperable, efficient and accessible broadband infrastructures which can be used for Open Science, as well as for many other needed applications in fields such as health and education, should be an investment priority** all over the world, including in developing countries, especially in view of supporting the Millennium Development Goals.

R2. **Robust policies, legal and regulatory frameworks, as well as interoperability at national, regional and global levels are essential** in order to ensure seamless, competitive and affordable access to e-infrastructure services and to scientific material and data.

R3. **Broadband e-Infrastructures should be explicitly referred to in national research, innovation and education policies** and in development aid plans, with appropriate funding allocation.

R4. **Research and Education Networks (RENs),** the bodies set up in most countries -including developing countries– to manage and maintain e-Infrastructures, should be given **high political visibility** towards governments, regulators and academia given their role in the transformation of developing economies into knowledge societies.

R5. National authorities and the relevant international organizations should promote **affordable and fair access to broadband e-infrastructures via the establishment and consolidation of national, regional and global RENs**, fostering cooperative environments that bridge the Digital Divide (non-connected countries and regions) and the Geographical Divide (disadvantaged non-central areas).

R6. **RENs should spearhead technological and service innovation** in partnership with industry.

R7. **Broadband e-Infrastructures should be leveraged for public service,** fostering the engagement of RENs in other public sectors such as e-Health, e-Government, e-Learning, e-Innovation and "e-Capacity Building".

R8. Broadband e-Infrastructures should **support and encourage the involvement of citizens in science.**

R9. Funding authorities should **ensure Open Access to data and results emanating from publicly funded research**, enabling Open Science with major societal and economic benefits.

R10. **ICT capacity building initiatives require urgent support,** in particular for training computational scientists and telecom engineers, and for RENs to develop the adequate technical, management and administration skills to operate broadband infrastructures.

Short term targets by 2015 are to launch an international Task Force for scientific data access and interoperability (R2), to reflect e-Infrastructures in national policies (R3), to leverage e-Infrastructures for public service (R7), and to enable open access to scientific publications (R9).

1. Broadband and Science: the need for e-Infrastructures

1.1. Changing the scientific dynamics and landscape

Broadband networks are becoming a basic infrastructure in a modern society, just like roads, electricity or water. For science in particular, the introduction of Broadband and internet facilitates traditional science, allowing the communication, access and sharing of scientific results: for example, experiments at the Large Hadron Collider (LHC) can generate 27 Terabytes of raw data per day that can be accessed by more than 140 computing centres in 35 countries thanks to the Worldwide LHC Computing Grid (WLCG).

Moreover, the way we do research all around the world is being radically changed by advanced broadband infrastructures that make possible the sharing of powerful instruments and computational resources (hardware, software and content), remote access to massive datasets and research facilities, remote operation of research infrastructures and support of distributed infrastructures and use of digital platforms for research collaboration. This environment can be defined as ***e-Infrastructure***.

Particularly as scientific endeavours increasingly rely on data, simulation and models (computing is already named as the "third pillar" of science), e-infrastructures enable new ways of scientific collaboration and resource sharing, as well as wider availability of repositories of scientific data. Moreover, the term "e-Science" is used for large scale/intensive science that is carried out through an advanced communication environment, computing (e.g. grid or High Performance computing) and large data resources (e.g. massive datasets/databases) usually requiring distributed collaboration tools. Challenging tasks that need very large resources and a high degree of collaboration vary from the discovery of new drugs to modelling climate global changes, or from new elementary particle experiments in physics to pushing the limits of knowledge of the universe (see examples in Annex).

It is important to stress that large-scale scientific initiatives or experiments boost the need for better e-infrastructures (e.g. the LHC, the African VLBI network or the Square Kilometer Array (SKA)), and vice versa, better e-infrastructures make it possible to tackle bigger scientific challenges as well as the everyday needs of researchers across many disciplines.

1.2. Research and Education Networks (RENs)

E-infrastructures define a global cooperation model being developed by research and education network organisations[1] -usually on top of high-speed fiber optical backbone connections. Researchers and scientists can connect to each other and to the world thanks to national research and education networks (***NRENs***) such as Internet2 in USA, CERNET or CSTNET in China, AARNET in Australia, CANARIE in Canada, or TENET and SUNREN in South Africa -in some cases several Research and Education Networks co-exist in a country. Many countries have inter-connected their NRENs into regional RENs, such as the pan-European research network GEANT, RedCLARA in Latin America, EUMEDCONNECT in the Mediterranean, CAREN in Central Asia, HP-SEE in the Black Sea region or TEIN across the whole of Asia, or have developed connections to other individual NRENs through dedicated bilateral links. Finally, some national or regional

[1] An interactive "State of the Art" GeoMap of eInfrastructures by the CHAIN project is available online: http://www.chain-project.eu/infrastructure-geomap

initiatives enhancing general broadband connectivity are improving the communication capabilities of regional scientific communities where NRENs are non-existent or in a low development stage (e.g. TASIM -Trans-Eurasian Information Superhighway project).

Research and Education networks use a wide range of technologies, operational approaches and procedures that require constant evolution driven by the new technological and scientific needs. RENs act in this way both as a motor and as a "test bed" for new technologies, for example in new networking protocols that will be implemented a few years later in the commercial networks. In this sense, the collaboration with the private sector provides the opportunity for a rich technological environment to be built in RENs before going commercial. Complex and innovative features and ideas can be tested and later can potentially create massive opportunities for new business. Additionally, many developments that emerged from the work at universities and research labs have leveraged the availability of Research and Education network infrastructures, such as the World Wide Web, Skype, CISCO, SUN, Google, Facebook or Intune Networks. A stronger collaboration between RENs, governments, scientific and educational networks with the ICT sector research community would be positive in order to drive innovation from a technological perspective.

RENs are also moving "above" the network/e-infrastructures and are providing more complex services such as federated identity. They are starting to connect and engage with other public actors dealing with formal and informal education communities. These actors (e.g. public libraries or any other community anchor sector) are then provided with an opportunity to shape and utilize the content, services, and applications of the next generation Internet. As an example, the International Telecommunication Union's (ITU) initiative "Connect the School"[2] connects the community and promotes access to and use of ICTs by all people, including marginalized and vulnerable groups. Connected schools can be used as community ICT centres to meet the ICT needs of the local community in which they are located.

The particular "public good" nature and its non-commercial use is normally ensured by RENs with the compliance to Acceptable Use Policy (AUP). This avoids competition with the commercial sector and helps RENs to obtain special conditions from operators so that scientific activities can be increasingly protected or privileged from the fast business-oriented evolution of commercial Internet and its dominant noise such as spam, ads, security threats, etc.

1.3.e-infrastructures and the developing world

e-Infrastructures should not be just for rich countries. They are even more important for the developing world because they are key enablers to prevent “brain drain” by allowing local researchers to cooperate with world-wide peers and to remotely access scientific, computing and data resources. Researchers in remote or underdeveloped areas can also have access to the emerging markets of solving problems/scientific challenges posted by "customers" in the developed world.

E-infrastructures are also key to improve the visibility of the research made in less developed economies - today most African PhD theses will remain undiscovered on a shelf in a university library - and facilitate information exchange between researchers in the developing world. There is a polarity in research exchange: developing countries collaborate mainly with the developed world and favour North-North and North-South axes. The exchanges amongst developing countries are much rarer, and the vast majority of the South-South communication traffic travels via the Northern hemisphere, despite the assistance to developing countries to establish Internet Exchange Points (IXP) e.g. by ITU. On the other hand, there are plans for improving the South-South connectivity in

[2] http://www.itu.int/ITU-D/sis/Connect_a_school/index.html

the near future that can foster the research exchange and collaboration between developing countries (e.g. new direct fiber optic links between Brazil and Africa, AfricaConnect[3] in Sub-Saharan Africa interconnecting countries in the Ubuntunet Alliance, or future plans to connect West-African countries of the WACREN[4] association).

Finally, the research collaborators in developing countries/regions are frequently based on individual contacts (personal or institutions) and lack critical mass. The emerging National and Regional RENs have the potential to reach critical mass and take a leading role in the demand and use of e-infrastructures. These will in turn positively impact other sectors of society, illustrating the importance of research and education networks for the transformation of developing economies into knowledge societies.

1.4.Contributing to the Millennium Development Goals

Advanced communication networks are very important contributors for the Millennium Development Goals. In particular, e-infrastructures are key to *global partnerships for development* (Goal n. 8), peering research teams and enabling collaboration in any scientific domain, and affect directly target 8f ("*In cooperation with the private sector, make available the benefits of new technologies, especially information and communications*"). The advanced networks installed in many developing countries for research and education purposes (in many cases triggered by the demand of NRENs) use the same infrastructure to provide also capacity for many other services, generating additional added value in public and private activities in the surrounding society. E-infrastructures are a powerful enabler and can have an indirect effect in other Goals (e-Learning - *Goal n. 2 Universal Education*-, e-Health – *Goals 4, 5 and 6 Child Health, Maternal Health and Combat HIV/AIDS*), and in general terms, thanks to the generation of a huge demand for educated human resources created by ICT needs in all sectors of society in the entire value chain, can also contribute to reduce poverty (Goal n.1, *Eradicate Extreme Poverty and Hunger*).

The progress towards the Millennium Development Goals would be more efficient if the final users and consumers would be empowered to drive the demand side. Focus is mainly on the deployment of capacity and the "last mile" efforts done by commercial producers, but global infrastructures are also created by the connection of isolated local ones. These "first mile"[5] local broadband islands in rural areas can start consumer-driven first mile efforts as social businesses, creating opportunities and jobs, with a special focus on supporting progress towards the Millennium Development Goals. There is always local content (e.g. voice-video consultations between primary health centres and with district hospitals, reliable information about medical drugs, secure drug distribution and monitoring of the use of drugs, administrative tasks involving the district council offices, schools, healthcare units, local repositories of educational data imported physically and stored on local servers, local environment data, such as water quality, weather data, etc). Availability of local applications and content in vernacular languages would also increase interest of the local population in broadband and would be a key enabler for its uptake in particular in rural environments.

Local Broadband Islands are important even with no or only narrowband upstream connections to Internet, and can be a model to stimulate iterative pre-commercial procurements and public private partnerships.

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[3] http://www.africaconnect.eu/pages/home.aspx
[4] WACREN is the West and Central African Research and Education Network http://wacren.net/content/about-us
[5]See "A First Mile initiative" presented to the Broadband Commission, B.Pehrson et al, http://www.tslab.ssvl.kth.se/files/research/UNBC-FMI-2011-06-27.pdf

2. Global challenges and issues for global e-Infrastructures

The development of e-Infrastructures is increasing rapidly around the world. However, development may be held up by a number of issues.

2.1.Connectivity and Interoperability

As scientific endeavours are becoming increasingly global no single network operator can be responsible for end-to-end delivery of services across multiple domains. Failing to reach sufficient collaboration will lead to user dissatisfaction, an increased risk of losing time and money and a lower adoption rate of innovations. There may also be a duplication of investment of public funds if several different solutions are developed by different stakeholders for the same area and problem.

The biggest single cost element in a national, regional or international Research and Education telecommunications network is the cost of the connections that are used to transmit information. Even in an advanced competitive network such as GEANT, transmission represents well over 60 % of the total cost. It is therefore vital that these costs are carefully managed and competitive. However, the primary factors influencing the cost of transmission are not technological, as the technology used to build transmission is global and there is a competitive market for this technology. There are two key factors that are involved:

- The competitiveness of supply: Monopoly markets in transmission generally imply very high prices for connectivity. In these markets, prices and real costs can differ greatly. GEANT demonstrated that there is an inverse relation between the number of suppliers and the cost of connectivity. The experience of constructing the pan-European Research and Education network GÉANT has shown the importance of a competitive market place when it comes to gaining cost-effective access to broadband circuits. As a result of the liberalisation of the telecommunications market in Europe in the late 1990's, the cost of Broadband capacity, the 'raw material" for any network fell by a factor of at least 10,000 where competition was most effective.

  Historically, monopoly markets for telecommunications were the norm. De-regulation has done much to improve this situation but, de-regulation does not, of itself, guarantee a competitive market. It is crucial to have a benchmark for what constitutes a competitive cost. For example, the trans-Atlantic route between the any of the principal European and US landing points represents a good benchmark. It is a very competitive route with a large number of suppliers. It is also a long sub-marine route and therefore the costs are significant but not affected by complicating local circumstances.

- Geography -physical distance and geographic location-. The cost of building a transmission route will be closely related to its length -physical distance-, but the geographic location is a more complicated issue in which economies of scale strongly apply as far as transmission is concerned. The fixed costs of building a transmission route dominate over the incremental costs of providing transmission capacity. For any network there is an edge to the network and a centre. Traffic from the edge of the network will typically flow though the centre of the network, and edges will generate traffic for the centre. The converse is not true. As a consequence there are much larger traffic volumes in the centre than at the edge. This means that the economies of scale favor the central locations in a network, which as a consequence will always be cheaper – not the other way round.

Another factor is that the costs of building a network are typically ‘distance-dependant.’ Longer routes will incur greater construction costs. Again, this tends to be an issue affecting countries away from the geographic centre of gravity of a network. In a European context, Ireland, Portugal and Spain are obvious examples of this.

As a consequence there are issues of ‘Geographic divide,’ independent of questions of market competitiveness that also need to be addressed. Some form of regulatory intervention in the form of universal service obligation may be necessary to ensure that the benefits available to geographically advantaged locations are shared in a fair and equitable way. In Europe, the cost-sharing model employed in GEANT partly addresses this issue.

Research and Education networks are fundamentally about co-operation and access. There is an important challenge as to how the benefits of co-operation are paid for, particularly when recognising the issue of geographic disadvantage noted above. In public networks, the concept of universal service obligation is used to smooth out geographic disadvantage. For example in the GEANT network to date reliance has been placed on the approach to cost sharing and an assumption of voluntary solidarity among the members of the co-operation.

In general terms, the principles of solidarity (sharing the costs of the relative advantage of central countries) and mutuality (fair share of costs, not equal share of costs) are key. Costing models should be better understood and agreed, and more transparency should be provided about network costing/charging for end user communities. In this sense, ITU's Telecommunication Development Bureau (BDT) is currently preparing studies on cost modelling.

Other key issues that need to be tackled if end-to-end services across multiple domains are going to be quickly set up and reliably delivered and supported include: future network planning, operations and support of cross-country networking services. In particular:

- Planned capacity building (e.g. transatlantic services in the next five years are expected to move towards the provision of capacity in the order of 1 Terabit per second, deployment of new fiber optic cables between continents can dramatically change the situation for developing regions, increases of 3 orders of magnitude beyond the current LHC data situation to carry data from the future SKA (Square Kilometer Array) to astronomers from the telescope site, etc.)
- Planning end-to-end services (including issues such as performance monitoring, user support, trouble-ticketing etc.) requires strong cooperation and coordination between all stakeholders with a particular emphasis on user requirements in the planning process.
- Building resilient capacity by all stakeholders, agreeing about the choice of routes to ensure optimal diversity in order to achieve maximum resilience.
- The development and use of interoperable standards and services for dynamic allocation of bandwidth (e.g. short-term flexible capacity provision) as well as for security across multiple domains, e.g. in line with ITU Standardization (TSB) and Development (BDT) Bureaux works on standards and on Interoperability issues.
- Regional trans-border communication from a policy and regulatory point of view, in particular in regions where cross-border traffic for RENs (that are serving closed user groups for public good and strictly non-commercial) can be used by both the regulator and the operators to explore new solutions.

2.2. Access to scientific data and literature

Using e-Infrastructure, researchers in different domains or in geographically different locations can collaborate on the same data set, finding new insights. They can easily share a data set across the globe, but can also protect its integrity and ownership. They can also use, re-use and combine data, thereby increasing productivity. However, as pointed out by the report of the 'High Level Group on the future of scientific data'[6], the rising tide of enormous amounts of global, diverse, valuable and complex scientific data is both an opportunity and a challenge. The fragmentation in heterogeneous data repositories needs to be overcome in order to enable the research community to better manage, use, share and preserve data. This is a global problem and it makes no sense for one country or region to act alone on what should be a truly global infrastructure. An international framework for a collaborative data infrastructure (including global governance for data) should be put in place.

Global e-infrastructures are also changing the scientific landscape. They pave the way for global research collaborations and the creation of virtual research communities that benefit from an earlier and easier access to publications: researchers shorten the dissemination of their results by publishing in open repositories their working papers that have not yet gone through the traditional peer-review + publication process. The increasing costs of "traditional" publications and the need for faster access to research results amongst other factors create a huge demand on open access to research results. Initiatives like OpenAIRE (http://www.openaire.eu/) support researchers in depositing research publications and establish and operate an electronic infrastructure for handling peer-reviewed articles as well as other important forms of publications

Fulfilling the demand for scientific literature is even more urgent in developing countries, where thousands of students, researchers and academics struggle to gain access to current scientific information –either because of non-existing or poor connectivity (a simple article may take hours to be downloaded!) or because prices of prestigious journals are prohibitive. Current initiatives in collaboration with the publication industry (e.g. aRDi[7] or Research4Life[8]) have been very effective to start closing the knowledge gap. However, some of these programs are not sustainable: the publishers have the right to protect their business and may choose not to offer for free their journals to countries where they have significant sales or local sales agents, or if they see an emerging – or niche - market in a country in a growing path. This also happens in the context of the Western world where big subscription deals turn out to be too expensive for the average library.

In addition, researchers and academics in developing countries find difficulty in publishing their findings in peer-reviewed journals, updating their teaching curricula and identifying funding. The focus of scientific interest of the developing world also has to be taken into account. Many of the problems faced by the "global South" might not be considered interesting enough for the “international” journals, and will hence not be published in a journal with a high impact factor. Even if science to a large extent is global, there is a risk that scientific knowledge generated in the developing world will be measured following the same quality criteria as researchers in the "global North". A possible way to get around this issue is to introduce a new set of metrics for scientific impact - a set of metrics that goes beyond the current era of journal impact factors. Open Access

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[6] "Riding the Wave: How Europe can gain from the rising tide of scientific data" http://ec.europa.eu/information_society/newsroom/cf/document.cfm?action=display&doc_id=707

[7] http://www.wipo.int/ardi/en/about.html, the Access to Research for Development and Innovation (aRDi) program was launched in 2009 by the World Intellectual Property Organization (WIPO) in cooperation with 12 major publishers and provides free online access to major scientific and technical journals to local, not-for-profit institutions in least-developed countries and low-cost access to industrial property offices in developing countries across the world

[8] http://www.research4life.org/ gathers three scientific literature programmes (HINARI, AGORA, OARE) and provides developing countries with free or low cost access to academic and professional peer-reviewed content online

and Open Access Repositories open a whole new set of possibilities in this regard, and would make the global South more than just information *consumers*.

The developing world also has an enormous potential for data production (e.g. in biodiversity or climatology) that could be made available in local data repositories, encouraging the inception of local research data generation, storage and preservation. E-infrastructures have become a key element in making these data resources available and exploitable for researchers all over the world (see example NAPRECA - Natural products research in Africa in Annex I). More useful information can also be found in Action Line C3 of the World Summit on the Information Society (WSIS) dealing with access to information.

2.3.Computing, Software and Services

Scientific research for truly global challenges requires the use of increasingly complex and powerful computing resources. For example, modeling and understanding basic interaction between the oceans, the atmosphere and biodiversity in order to foresee climate changes or to anticipate natural catastrophes requires dedicated, extreme performance computers able to execute at least a million billion operations per second (a 'petaflop'), or the use of thousands of grid-enabled computers distributed across the world. Access to these computing resources and the necessary software, models and tools to harness and efficiently exploit them is a huge challenge. Solutions based on open source software and affordable, off the shelf hardware components, network components as well as grid and cloud computing components should also be explored.

In addition, access to large and expensive computing resources is hindered by the different geographical and economic conditions of scientific communities in different countries. Continental organizations can help to bridge the gap between these communities, facilitating the shared access to such resources. An example is the Partnership for Advanced Computing in Europe (PRACE)[9]. PRACE is a unique persistent pan-European Research Infrastructure for High Performance Computing which provides a large number of scientific communities in 21 European states access to world-class performance supercomputers for world-class science, in view of strengthening Europe's scientific and industrial competitiveness.

Complementing the access to computing and software, services and applications that support the end user and Virtual Research communities are critical aspects of research infrastructures, for example tools for collaboration (e.g. groupware) and data access (e.g. research papers, scientific databases, etc.). These services and tools should be built using standardised technological approaches –a sort of e-infrastructures "building blocks"- so that the end user communities are able to create their own research infrastructure environments and support and share their own applications using common standards and technology (e.g. using open application programming interfaces and cloud technologies). RENs are in a privileged position to aggregate application developers and the education sector at large, and these "application enablers" platforms can create an environment with the potential of boost innovation with respect to content and applications relevant to the education and research industry.

2.4.Impact in other areas of public services

The capabilities of e-infrastructures for enabling collaboration, resources sharing and providing access to information can have an effect in other areas of public interest not specifically related to

[9] http://www.prace-project.eu/

science such as e-Learning, e-Government and e-Health. Several projects and initiatives are on-going worldwide to provide low cost digital access for schools, hospitals and communities[10]. Countries and regions can benefit from leveraging broadband infrastructures for different purposes, rather than having several uncoordinated developments (in particular in regions or countries that cannot afford separate broadband infrastructures for different purposes).

The impact in e-Health has been radical. Rural areas suffering from geographic isolation have improved the health of their population and their overall living standard when given access to telemedicine, telehealth, on-line information on preventive health and support for self-management of chronic conditions, remote support for rural doctors, etc. A specific Broadband Commission working group on e-Health is providing more detailed information about the subject[11].

Broadband access allows e-Learning –e.g. distance education for pupils-, but also “e-Capacity-Building” for teachers and professors –e.g. audio- video-interaction supporting scientific learning or professional training. The systematic recording, storage and access to scientific conferences are effective mechanisms for researchers in remote areas or without many resources to acquire the latest scientific results. Even more, broad public access to internet resources and tools (including social networks) has favored informal education (from experienced-based activities to game-based learning) and the participation of amateur scientists in research activities ("citizen science"). The Broadband Commission working group on e-Learning is also providing more detailed information about these issues[12].

Broadband capabilities can also be adapted to enable “e-Innovation”, i.e. collaborations that would take open-innovation challenges into the field to address social problems of major importance, for example in support of living labs -Open innovation ecosystems in real-life settings in which user-driven innovation is fully integrated in the co-creative process of new services, products and societal infrastructures.

At a time when there is increased awareness of the cross-sectorial effects of broadband and the enabling effects on health, education, energy, transportation, commerce etc., REN authorities should work closely with other broader initiatives in view of improving the infrastructure for research and education. In particular, synergies between e-Government projects or other government driven broadband initiatives and Research and Education networks are not well exploited.

The use of e-Infrastructures can help research and higher education institutions promote the adoption of ICT in sectors such as public administration, education, health, etc., aiming at speeding up social and economical development, and vice versa: the economic development stimulates society's demand for better infrastructures and enables the access for more people in higher education, which in turn will increase the pressure on higher education institutions to provide better communication and ICT-based tools.

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[10] Example: Wireless broadband master plan in Asia/Pacific by ITU co-funded by the Korean Communication Commission (KCC) http://www.itu.int/ITU-D/asp/CMS/index.asp, with a next phase for similar assistance to Africa
[11] http://www.broadbandcommission.org/#wgroups
[12] http://www.broadbandcommission.org/#wgroups

3. Broadband and Science in developing countries

3.1. Challenges for developing countries

Thanks to the provision of international connectivity, scientific projects can be supported by peering the e-infrastructures, sharing computing and data resources so that local researchers in developing regions can collaborate with their world-wide peers. Brains cannot work in isolation – and it's of everybody's benefit that the best minds are connected, wherever they are, in order to tackle global challenges. Improved and affordable regional and international connectivity can enable these researchers to generate a proportionate amount of intellectual property (IP) to achieve parity with the rest of the world. Along with the development of local knowledge and technology, IP awareness is often weak or missing in these regions, so additional efforts in capacity building and technical assistance in innovation promotion and technology transfer are needed[13]. The regions with good connectivity can create "intellectual havens" that can reverse the flow of the brain drain and the use of advanced e-infrastructures (e.g. in universities connected to NRENs) stimulate demand by ensuring that people entering the job-market at all levels are internet-ready and thirsty for connectivity;

Naturally there are different models of e-Infrastructure for different regions at different stages of development, and these models evolve constantly. Africa, for example, has historically had to use low bandwidth solutions such as VSAT for connectivity, although with fiber-optic sea cables now available, along with the added connectivity offered by other players such as mobile operators there is an opportunity to make the change to higher bandwidth. In Latin America, some countries like Brazil invest in the expansion of fiber-optic infrastructure capable of supporting a wide range of private and public services that have a direct impact in the quality of life of remote regions. In countries where the operational benefit of a fiber-optic network was not evident, the construction of the regional research network RedClara[14] allowed the initial investments for operators (mainly monopolies or operating in quasi-monopolist environments) to provide broadband connectivity at affordable prices –after several tendering iterations and long negotiations.

Actors in some emerging economies and developing countries are still struggling to address challenges which have largely been already overcome in some other countries –many of these issues are already well identified for some regions[15]. These may include some or all of the following, and need a coordinated approach combined with strong political will to effectively address them:

- Connectivity prices are often extremely high, in particular in countries with poor communication infrastructures and less open telecommunication markets (e.g. universities can pay 7000$ per Mbps per month in Zambia). Access to essential broadband infrastructure for science is an issue in particular in those countries where incumbent operators are regarded as the only permissible owner of such facilities. For instance, stakeholders such as the UbuntuNet Alliance in Malawi or AfrISPA in Mauritius note that Africa needs to develop a low-cost high-volume telecom sector if it is to be able to effectively participate in e-Science. There may therefore be a need for accompanying regulatory measures and changes in the telecommunications market to make room

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[13] In line with the WIPO (World Intellectual Property Organization) efforts to developing a balanced and accessible international IP system, which rewards creativity, stimulates innovation and contributes to economic development while safeguarding the public interest. http://www.wipo.int/

[14] Cooperacion avanzada de Redes LatinoAmericanas http://www.redclara.net/

[15] See, for example, the results of FEAST: http://www.feast-project.org/documents/FEAST-Final-Report-2010-03-22.pdf, http://www.feast-project.org/documents/FEAST-D2D-2-final-african-workshop-report.pdf,

for not-for-profit, public-interest traffic at affordable prices. The problem is not about technology but about choice, competition and freedom from solutions locked to a particular set of protocols, technologies or service providers.

- The low awareness of the critical importance of high-quality e-Infrastructure: regional and national managers in education and research institutions and in public authorities in general are not well informed of its benefits and cannot adequately express their needs and requirements. There is not yet a clear understanding that research and higher education institutions cannot properly fulfill their academic missions, and most importantly, their role as key actors in the creation of a true knowledge society without a high-quality e-Infrastructure connected to the world. On their side, policy-makers, regulators and producers have a very limited knowledge about these needs and will not improve the situation unless there is a clear demand.

- The lack of local infrastructure to support and stimulate intra-regional traffic. African Internet users still spend many millions of dollars a year sending traffic outside Africa and then back in again because of the lack of local infrastructure, even though progress is being made with the establishment of further Internet Exchange Points.

- The issue of differing national regulatory regimes can be a problem when it comes to international circuits crossing national boundaries. This is particularly an issue if an international route has to be built in three separate sections, a national part, a cross-border interconnection and a separate second national part. Such fragmentation adds very considerably to the cost of a route, potentially more than doubling it. It also leads to a much poorer operational performance as it introduces additional points of failure and makes fault location and resolution more difficult. It is important that regulation should apply in a homogeneous way and that individual international routes can be provided by a single in a cost effective manner.

- The lack of harmonized policy, legal and regulatory frameworks at the regional and continental levels hinders the development of competitive telecommunication/ICT markets and infrastructures. Cross-border cable connectivity is still difficult to manage or even impossible, increasing the topology complexity and the costs of regional networks and in some cases aggravating the isolation of landlocked countries. Projects like HIPSSA[16] or HIPCAR[17] are working for the enhancement of the legislative/regulatory framework in this area.

- The high costs of accessing scientific information. Open access to data, scientific literature and libraries is a crucial issue for remote and underdeveloped research communities with scarce resources.

- In addition to the general shortage of ICT skills, there is an uneven technical capability of universities and research centres in different countries to sustain and manage the research and education networks. The need for training and funding of maintenance teams in order to ensure long-term sustainability may be underestimated by governments and institutions.

- Developing countries have to grapple with synergies of different donor schemes, rationalisation of interventions and harmonisation of policies at national and regional level.

[16] http://www.itu.int/ITU-D/projects/ITU_EC_ACP/hipssa/
[17] http://www.itu.int/ITU-D/projects/ITU_EC_ACP/hipcar/index.html

- The sustainability of research and education networks is crucial issue. It is important to understand the level of demand and commitment from African member states which are required to contribute funding towards the maintenance of the research networks.

3.2.The role of NRENs

Once deployed, e-Infrastructures will have a "Tsunami-like" impact in developing regions; the most evident example is on the need for capacity building for growth and sustainability. Quality education is needed to meet the huge demand for human resources created by ICT needs in all sectors of society.

Awareness and determination will be required to act on the increasing need for capacity building in the entire value chain. However, the level of awareness of policy makers and regulators in developing regions about what NRENs can contribute in this sense is very low. There are opportunities provided by the emerging NRENs in developing regions, for example:

- RENs can have a large transformational impact on the entire communication market since they will build more powerful networks than most commercial operators have today. RENs need to lease links, be it dark fiber, wavelengths or unmanaged capacity, and may use wireless technologies providing the initial connectivity to remote sites (the same infrastructure can separately serve NRENs and commercial services, so public good and private goals can be both satisfied). The link-market is a new market that needs to develop with competition in telecoms markets. RENs are important anchor customers in the development of such markets. Since they are serving closed user groups for public good and are strictly non-commercial, they can be used by both the regulator and the operators to explore new solutions (regulatory and technological) without risking competition or to be required to provide the same solutions commercially.

- Universities under the NREN umbrella can create critical mass and contribute to the market development by developing new services and applications that will drive the demand for commercial services. Universities can educate students that will be employed by different organisations in all sectors, either as demanding customers of communication networks and services or as competent network and service providers.

- Research networks could work in partnership and collaborate with existing private sector initiatives such as Internet Exchange Points (IXPs). NRENs can be an important non-traditional member for an IXP, contributing local traffic and local content through peering agreements, thereby helping to build critical mass of traffic volume and subsequent value for the IXP. As the IXP continues to evolve, efficient interconnections will contribute to increased resilience, lower latency, lower costs of access, and better end user experiences of the Internet. These are critical conditions for e-Infrastructures in helping scientists in developing regions to collaborate and to become more globally competitive.

4. Recommendations

Broadband connectivity facilities are basic infrastructure in a modern society, just like roads, electricity or water; it almost becomes a human right –even more so when it's used for science. E-infrastructures build on broadband to provide online services to science and education communities. Not only have these services become today indispensable, they have also transformed the scientific process by enabling the instantaneous sharing of knowledge, virtual collaborations spanning the globe, and remote access to scientific resources and instruments. E-infrastructures are today one of the main engines of scientific progress and its potential in other social and economic areas is enormous. Developing regions stand to benefit in particular because broadband networks dramatically reduce the barriers of distance and location. Yet there are still many issues and obstacles to overcome, and a clear role for all stakeholders to act (e.g. governments, international organisations, regulators, research community, industry..). The Working Group on Broadband and Science urges the Broadband Commission to support the recommendations listed below and to subscribe to these positions in the corresponding high level fora (e.g. international organisations, Ministerials Summits of ICT/Research and Education, etc.)

Regarding a time frame for implementationshort term targets by 2015 are to launch an international Task Force for scientific data access and interoperability (R2), to reflect e-Infrastructures in national policies (R3), to leverage e-Infrastructures for public service (R7), and to enable open access to scientific publications (R9).

R1. Sustainable, interoperable, efficient and accessible broadband infrastructures which can be used for Open Science, as well as for many other needed applications in fields such as health and education, should be an investment priority all over the world, including in developing countries, especially in view of supporting the Millennium Development Goals.

- Sustainable, interoperable, efficient and accessible broadband e-Infrastructures should become a world-wide investment priority as they are not only a main driver for Open Science but also are uniquely powerful tools for accelerating progress in many other areas – in particular in reducing the scientific knowledge gap between industrialized countries and the developing world and in supporting the Millennium Development Goals.

R2. Robust policies, legal and regulatory frameworks, as well as interoperability at national, regional and global levels are essential in order to ensure seamless, competitive and affordable access to e-infrastructure services and to scientific material and data.

- Robust policies and legal and regulatory frameworks at national, regional and continental levels need to be established in order to ensure a competitive Telecommunication/ICT market and remove barriers for cross-border traffic. In particular, Research and Education Networks should be able to own or get access (dedicated or shared) to broadband infrastructure at globally competitive prices, and should be able to have a sufficient technological and service choice not locked to particular providers, technologies or protocols.
- An international framework for a collaborative data infrastructure should be promoted in order to develop a fully functional global e-infrastructure for scientific data which

should become a flexible, reliable, efficient, cross-disciplinary and cross-border scientific vital asset[18].

R3. **Broadband e-Infrastructures should be explicitly referred to in national research, innovation and education policies** and in development aid plans, with appropriate funding allocation.

- The importance of dedicated research and education network broadband infrastructure in national policies and development aid efforts (just like any other infrastructure) should be reflected in terms of appropriate funding and budget allocation.

R4. **Research and Education Networks (RENs),** the bodies set up in most countries -including developing countries– to manage and maintain e-Infrastructures, should be given **high political visibility** towards governments, regulators and academia given their role in the transformation of developing economies into knowledge societies.

- A high political visibility of Research and Education Networks (RENs) towards governments, regulators and academia (and in particular in developing countries) is needed in order to increase awareness of the REN's key role in the transformation of developing economies into knowledge societies.

R5. National authorities and the relevant international organizations should promote **affordable and fair access to broadband e-infrastructures via the establishment and consolidation of national, regional and global RENs**, fostering cooperative environments that bridge the Digital Divide (non-connected countries and regions) and the Geographical Divide (disadvantaged non-central areas).

- National authorities should foster the establishment and consolidation of national and regional RENs. National RENs should be supported by local government, keeping and independent operation and a "public good", non-commercial nature and guaranteeing a minimum quality access to connectivity, computing, data and other resources for science.
- The access of global Research and Education Networks to global e-infrastructures should be affordable, fair, and at competitive market prices. Global RENs have the capability to bride the Digital Divide (non-connected countries and regions) and the Geographical Divide (disadvantaged non-central areas), fostering a cooperative environment where solidarity and mutuality of costs are key.

R6. **RENs should spearhead technological and service innovation** in partnership with industry.

- The role of RENs as public good/non-commercial spearheads to demonstrate technological and service innovation should be enhanced, in collaboration with the private sector and in particular with favorable conditions from the telecommunication operators.

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[18] In line with the conclusions of the High Level Expert Group on Scientific Data
http://ec.europa.eu/information_society/newsroom/cf/document.cfm?action=display&doc_id=707

- Closer collaboration of RENs with technology partners should be encouraged, in orderto better identify new emerging ICT technologies for the advancement of research. For example establishing cooperative platforms in which RENs, researchers and industry partners can bridge the understanding of research requirements and bring specific technological innovations to research activities.

R7. **Broadband e-Infrastructures should be leveraged for public service,** fostering the engagement of RENs in other public sectors such as e-Health, e-Government, e-Learning, e-Innovation and "e-Capacity Building".

- Broadband infrastructures should be leveraged for different public and private purposes, exploiting synergies and avoiding uncoordinated developments (in particular in regions or countries that cannot afford separate broadband infrastructures). Communication infrastructure should be regarded as a basic need utility, like e.g. roads or electricity, and should enjoy the corresponding shared access rights and appropriate trans-border links.
- The role of RENs in the public engagement with research and science in general, and in other public sectors as e-Health, e-Government, e-Learning, e-Innovation and "e-Capacity Building" should be promoted. RENs should become main actors in national broadband plans or wider government broadband driven initiatives.

R8. Broadband e-Infrastructures should **support and encourage the involvement of citizens in science.**

- The demand from citizens and the public and private sectors should be stimulated to access broadband networks and contents/results from the research networks. This demand should focus on key policy issues driven by national strategies, and should be accompanied by corresponding implementation plans. In developing countries, a special emphasis should be placed on technology reuse and renewable energies, and in general on the Millennium Development Goals.
- Policies should be supported to empower local communities to take first mile initiatives (e.g. creating first mile broadband islands in rural areas as social businesses) in cooperation with their research and higher education institutions as part of a research agenda. These policies can be implemented through pre-commercial procurements enabling the required innovations in technology and services necessary to meet the specific challenges, in particular in developing regions and rural areas.

R9. Funding authorities should **ensure Open Access to data and results emanating from publicly funded research**, enabling Open Science with major societal and economic benefits.

- Open Access Repositories and Open Access of research results emanating from publicly funded research should be ensured by funding authorities. In particular, support should be given to initiatives ensuring sustainability to access research results and for capacity building programs establishing document and data repositories where the research is carried out.

R10. ICT capacity building initiatives require urgent support, in particular for training computational scientists and telecom engineers, and for RENs to develop the adequate technical, management and administration skills to operate broadband infrastructures.

- ICT capacity building initiatives should be supported, and in particular for RENs to set-up the adequate technical, management and administration skills to operate broadband e-infrastructures. In particular in developing areas, the "Tsunami"-like demand for educated human resources created by ICT needs in all sectors of society, should be tackled by reinforced relevant academic curricula (e.g. master level in Communication systems and networks), and integrating student and researchers participation in development projects and learning in institutional partnerships.

Annex I: Some examples and initiatives related to broadband and science

To better understand what is involved in broadband and science, here are several examples of projects aimed at demonstrating the use of e-Infrastructures for different objectives.

Example 1: Virtual imaging laboratories for marker discovery in neurodegenerative diseases

The unprecedented growth, availability and accessibility of imaging data from people with neurodegenerative conditions has led to the development of computational infrastructures, which offer scientists access to large image databases and e-Science services such as sophisticated image analysis algorithm pipelines and powerful computational resources, as well as three-dimensional visualization and statistical tools. Scientific e-infrastructures have been and are being developed in Europe and North America that offer a suite of services for computational neuroscientists. The convergence of these initiatives represents a worldwide infrastructure that will constitute a global virtual imaging laboratory. This will provide computational neuroscientists with a virtual space that is accessible through an ordinary web browser, where image data sets and related clinical variables, algorithm pipelines, computational resources, and statistical and visualization tools will be transparently accessible to users irrespective of their physical location. Such an experimental environment will be instrumental to the success of ambitious scientific initiatives with high societal impact, such as the prevention of Alzheimer disease. In a recent article[19], authors provide an overview of the currently available e-infrastructures and consider how computational neuroscience in neurodegenerative disease might evolve in the future.

Example 2: Scientific collaboration to fight malaria

With malaria killing more than a million people each year, this is an important area of scientific concern that can illustrate the importance of local knowledge/exchange of local knowledge in the local region. But the development of new drugs takes an average of 12-15 years, with various research phases and trials needed both to ensure reliable results and to conform to stringent regulations. A European project called WISDOM[20] demonstrated the relevance of the Grid approach to address drug discovery for malaria. It gathered several partners around the world who used the Grid infrastructure to organise and accelerate their research. Partners from Africa, Asia, Europe and Latin America included experts in bio-informatics, chemo-informatics, biology and biochemistry. Combating malaria involves analysing a huge number of compounds, and looking for drug candidates to treat the disease is very time consuming. The WISDOM project offered a way to handle the massive amount of data involved by using the Grid e-Infrastructure available in the various regions. During the ten month "data challenge" phase of the project, researchers were able to analyse an average of 80,000 possible drug compounds every hour, and to process over 140 million possible docking arrangements between drug compounds and target proteins of the malaria parasite. Up to 5,000 computers were used simultaneously in 27 countries, generating a total of 2,000 GB of useful data. The project showed how Grid computing can be used to accelerate drug discovery research and reduce the cost of developing new drugs.

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[19] (Frisoni, G. B. et al. ***Nature Reviews Neurology***. advance online publication, http://www.egi.eu/export/sites/egi/about/press/Frisoni_etal2011_NatRev.pdf

[20] WISDOM (Worldwide In Silico Docking On Malaria), an EU 7th Framework Programme funded project, involving international partners. Address: www.wisdom.eu.egee.fr

Example 3: Analysis of earthquake data

As the recent disaster in Japan has shown, it is still impossible to predict when, where and how an earthquake will occur. Nevertheless, understanding the exact parameters of previous earthquakes brings experts closer to making more accurate predictions regarding location, timing, type and scale. This in turn facilitates the process of assessing the potential impact an earthquake can have on specific regions. Using Grids in Europe, the mechanism and coordinates of earthquakes measuring more than 5.5 on the Richter scale are monitored and data regarding spatial position and synthetic seismograms are computed, and the output is sent to those on the ground in the earthquake affected area. Such a process leads to a plethora of data which can however be analysed very quickly thanks to the distributed computing infrastructure. In this way, scientists at the Institut de Physique du Globe de Paris were able to perform a systematic determination of earthquake parameters within 24 hours of the December 2004 earthquake off the coast of Indonesia.

Example 4: The role of ICT in medical research in Malawi

The Malawi Liverpool Wellcome Trust[21] conducts biomedical research and also provides research training for clinical and laboratory scientists from Malawi and elsewhere. It focuses on six multidisciplinary research themes (malaria and brain diseases, therapeutics in the tropics, severe bacterial infection, mucosal and vaccine immunity, and health in the population). Its programme on clinical research involves human capacity building for local scientists and technical staff through collaboration with teams in another 21 countries. Topics include identification of genetic variants in malaria. Currently the clinical samples collected in Malawi are sent to the UK for analysis and the data is returned to Malawi where a huge dataset is being amassed. However, due to the lack of broadband connectivity this data has to be exchanged on discs or flash sticks which are both slow and inconvenient. The Malawi University has already lost research grants due to poor connectivity and consequent time-lags in obtaining and distributing results.

Example 5: Natural products research in Africa

NAPRECA[22] (Natural Products Research Network for East and Central Africa) is a non-profit making scientific body recognised by UNESCO (as one of its Network Programmes) whose task is the study, promotion and development of the science and other aspects of natural products, including their botany, chemistry, biological activity and economic exploitation, with a symposium organised every two years. It mobilises scientists in relevant fields in eleven East and Central Africa countries to research into medicinal plants and traditional medicine (more than 80% of the African population is estimated to be treated using traditional forms). Active substances are isolated, tested for their bioactivity and toxicity, and dosages are formulated. In addition to initiating and promoting research in natural products, it coordinates and maintains inter- and intra-regional links among different research groups. However, NAPRECA considers that its classical drug discovery methods are too long and too expensive. Its aim is to use Grid computing to speed up the drug discovery, so that knowledge can be shared, databases can be properly built based on Geographic Information Systems (GIS), and overlapping research can be avoided. For this, broadband connections between the universities and research centres in Africa are essential, together with links to other researchers in Europe, Latin America and elsewhere.

[21] http://www.mlw.medcol.mw/research.html
[22] http://www.napreca.net/

Example 6: ICTs for connecting global researchers to scarce localised data – the EVALSO project with Chile

The increasing cost of experimental facilities in many research fields leads to the concentration of such facilities in a few selected places, sometimes driven also by environmental conditions. This is the case for astronomical data being collected in Chile. The clear, steady skies without light pollution necessary to Astronomical Observatories are generally not easily found. In the Southern hemisphere the best observing facility for optical and infrared astronomy is widely acknowledged to be ESO (the European Southern Observatory in Chile). At the same time there are ever-increasing data volumes as detectors get bigger and more complex, and this raises a number of problems for the builders, the operators and the users. The remoteness of the facilities makes travelling from overseas institutions difficult and expensive. Thus EVALSO[23] creates a physical cable infrastructure (and the tools to exploit it) to efficiently connect the ESO and also the Cerro Armazones Observatories to Europe.

Example 7: e-infrastructures for Climate Modelling and Climate Change

The high social and political visibility and the increasing impact of the global warming require urgent actions at all levels, and e-infrastructures can be a crucial tool for scientist in this domain. As illustrated at the "Conference on the Role of e-Infrastructures for Climate Change Research 2011"[24] gathering Climatologists and Grid and Network Technologists communities, Climate Modelling and Climate Change have been identified as most promising applications drivers of e-Infrastructures: applications in this area have huge computational requirements that can fit both High Performance Computing and Grid-based systems, with high demanding access needs for large data repositories of the order of 10-100 PBytes. E-infrastructures can also provide the necessary collaborative tools in order to test several Climate models at global scale and downscale them to regional ones.

Example 8: African Great Lakes Rural Broadband Research Infrastructure

The Tanzania ICT for Rural Development programme[25] is a research effort on inclusive ubiquitous broadband access. The programme has launched first mile initiatives to explore strategies for the establishment of broadband markets in rural areas where there is demand but no supply due to high perceived risks. A successful strategy has been to attract investments by focusing on basic public services in healthcare, drug security, education and local government supporting progress towards the Millennium Development Goals, and then turn every stone to find customers to sustain the broadband network and services. The challenges include design of robust network components, dealing with poor or non-existent power supply, strengthening weak supply chains and development of sustainable business models. The planning of a next phase extending the programme in the African Great Lakes region is in progress.

Example 9: Somali universities as agents for change: Fibre for Peace

SomaliREN, the association of nine universities from all regions in Somalia, is more than a utility organisation for the establishment of the Somali National Research and Education Network. As one of the few functional national bodies, it is a framework for the universities to act as agents for change. The universities carry much of the school and healthcare systems on their shoulders and

[23] EVALSO is an EU Framework Programme 7 project: http://www.evalso.eu/evalso/
[24] http://www.egi.eu/about/news/news_0047_ICTP_conference.html
[25] ICT4RD is a Sida-supported programme in Tanzania http://www.ict4rd.ne.tz

cooperate with the Somali diaspora all over the world on the Fibre for Peace initiative[26]. The member institutions are also involved in SHERNET, an EU project supporting the reinforcement of their academic quality assurance procedures[27].

26 The Fiber for Peace initiative http://www.somalifiberoptic.com

27 SHERNET – Somali Higher Education and Reearch Networking (www.shernet.org)