Connecting Africa's Universities to Affordable High-Speed Broadband Internet: *What Will it Take?*

prepared by

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- *More information on the Digital Economy for Africa initiative is available at https://www.worldbank.org/en/programs/all-africa-digital-transformation*

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- *More information on PASET is available at: https://www.worldbank.org/en/programs/paset*

Summary and Conclusions

Connecting African universities to affordable, high speed broadband internet is essential for attaining the goals of the Digital Economy for Africa Moonshot, which aims to ensure that all African individuals, businesses and governments are digitally enabled by 2030. Access to the Internet promotes economic growth, improvements to education and knowledge dissemination, and overall human development. The advanced digital skills of high quality, that are needed to adapt and exploit digital technologies, will need to be produced through reformed university programs and rapid skills development programs. Intermediate level digital skills that are needed on a broad scale for the diffusion of technologies will be produced on a large scale when all African tertiary level students (not just those in science and engineering courses) acquire adequate levels of digital competence. African universities need broadband in order to expand coverage, through blended and online learning; improve the quality of higher education; encourage the use of technology in higher education; and provide access to the enormous wealth of digital education resources available in the world and enable Africans to contribute their own digital content. High quality research, which is essential for finding solutions to Africa's pressing development challenges, also requires linking African researchers with their peers worldwide and encouraging intra-African and cross-continental collaboration, which is currently very weak. Connecting Africa's universities will also have spillover effects on the broader education system, especially secondary schools and technical-vocational institutions, where teachers and students need to acquire intermediate and basic digital skills.

Universities are among the key national institutions with the skills, equipment, personnel and mandate to generate new knowledge through research and education. In order for African universities to help serve the goals of national development, they require the mechanisms and resources to build bridges between academia and policy leaders, and to provide opportunities for African researchers, educators and students to collaborate locally and internationally via the Internet. Designing and building good university network infrastructure, with all of the campus segments and academic departments included, is vital for getting faculty and students in Africa connected from the laptop (or mobile device) to the cloud. As bandwidth to African universities increases, the bottlenecks shift to the campus network level, as most African university networks are inadequate to provide service to their large user communities. Without well-structured campus networks optimizing their use of bandwidth, uptake will be much slower. Solving last mile problems to increase widespread access and availability is also important to take advantage of the opportunities provided by the new international submarine cable systems now being deployed in both East and West Africa.

The spread of undersea and terrestrial fiber optic lines as well as the development of new mobile and satellite-based technologies creates tremendous opportunities for the continent's universities to leverage the deluge of data and wealth of digital resources and applications. Current levels of broadband connectivity, especially in much of Sub-Saharan Africa, are insufficient to support all but the most basic uses of digital technology. In terms of strategic opportunities that will change the landscape for Africa's participation in the global Internet fabric, the cable systems now make lambda level connectivity a real and affordable possibility between Africa, South Asia and

Europe, with benefits for the African research and education community by leveraging the existing investments in U.S.-European and U.S.-Asian R&E connectivity.

Across the world, the National Research and Education Networks (NRENs) in each country have enabled the university and research community to establish and continuously expand a dedicated network that provides high speed broadband access to universities, as well as other services. There has been a rapid expansion of NRENs in Africa (many supported by the World Bank's digital infrastructure projects); in addition, sub-regional RENs have also been created to support NRENs. The NRENs in Northern, Eastern and Southern Africa are more developed, while in many countries, especially in Central and Western Africa they are either non-existent or only minimally functional.

The European Union's Africa Connect program (three phases) has expanded connectivity between the GEANT network that connects European universities to the African regional RENs (UbuntuNet Alliance, WACREN and ASREN). The U.S. government's NEAAR project is funded by the National Science Foundation's International Research Network Connections (IRNC) program to also increase connectivity between the regional RENs of the USA, Europe and Africa. The Network Startup Resource Center (NSRC) at the University of Oregon is also funded by the NSF's IRNC program to help improve physical network connectivity and human resource capacity, with emphasis focused on collaborations with African NRENs and universities. The NSRC assists African universities to develop their campus network infrastructure in a manner that allows the university to connect to Internet Service Providers, local Internet Exchange Points, and National Research and Education Networks (NRENs). Enabling the networks with this capability helps each university to become opportunistic and react quickly to changes in pricing, available bandwidth or national policy and is a key to establishing effective interconnections with other universities and RENs.

This is an opportune time to leverage ongoing investments in Africa, thereby improving infrastructure (creating more supply), and delivering relevant platforms and services (to drive demand), which is good for the whole ecosystem. There is a clear need to scale rapidly so the current range of investments succeeds and provides pan-regional benefits.

The Bank can build on these ongoing programs and leverage the proposed financing under the Digital Economy for Africa Moonshot to rapidly scale up broadband connectivity for African universities. This could be done through a regional project (such as the proposed advanced digital skills project) or country level higher education or digital infrastructure projects. A distinct component focused on NREN development is essential as mobile network operators will not be able to address and solve the specific needs of many secondary and tertiary educational institutions to support NREN connectivity.

The following issues need to be addressed:

- Plan ahead and set benchmarks for broadband connectivity. The proposed benchmarks are 100 Mbps -1 Gbps for small universities, 2-5 Gbps for medium size universities, 5-10

Gbps for large universities. Research-intensive universities (limited to 1-2 per country) may need even higher levels of connectivity, between 25-50 Gbps in the coming years. The difference across the range of bandwidth needs depends on the cyber maturity of the institution. Bandwidth requirements depend on variables such as the size of computing labs on campus for students, utilization of course management software systems on campus, build-out of wireless infrastructure across the campus, and total number of users on the network.

- Strengthen NRENs where they exist or help to establish them where they do not. The governance and financing models for NRENs vary, but creating a business model for expansion and sustainability is essential. Governments can take a number of actions to support NRENs and NRENs can also learn from good practices in Africa. While at the basic level, NRENs provide connectivity, more advanced NRENs can provide more services, including cloud infrastructure.
- The policy and regulatory environment for development of digital infrastructure affects the cost over the "first mile", "middle mile" and "last mile". The affordability and availability of broadband for universities is linked to this broader policy regime, which differs across countries. Addressing the policy and regulatory bottlenecks are essential to help universities access cheap broadband.
- For the majority of countries in N. Africa, Eastern and Southern Africa, the main issue is last mile connectivity for remote universities, increasing speed and reliability and reducing broadband price for all universities. Price of distribution over the national network and especially at the last mile needs to be brought down further. Leasing of dark fibre and new technologies can be part of the solution.
- For countries in West Africa, the problem is of price and connectivity. Broadband prices in West Africa are among the highest in the world
- Investment in campus infrastructure is critical to make efficient use of greater broadband availability, as well investment in human resources and network engineering expertise to operate, maintain and grow the network facilities.
- Investing in the "soft capacity" of universities is critical to make full use of connectivity. This includes identification of digital applications and content, the courses that need to be upgraded; faculty training to use technology in teaching and research; training of students in digital skills, development of policies and guidelines, technical support and management capacity. These needs and their financing requirements tend to be systematically underestimated by universities and governments.
- Costs must take into account both capital costs (which would need to be financed by governments or donors) and operating costs (which should eventually be financed by universities, though there may need for support in the initial phases). Costs of internet services, operation of the campus infrastructure and use of digital resources, need to be included in the budgets of universities.
- Finally, computer science and engineering curricula need to be modernized in universities across Africa. Current curricula and teaching methods are too theoretical, teach outdated skills and do not employ modern teaching methods. This is the subject of another paper and not covered here. However, the full potential of broadband connectivity for African

universities can only be realized if young Africans are empowered and educated with advanced and relevant digital skills required by a rapidly changing environment.

1. Connecting Africa's universities to affordable high-speed broadband internet services is essential to reach the goals of the Digital Economy for Africa Moonshot initiative. It is also feasible.

The Digital Economy for Africa initiative of the World Bank has the goal of making "every individual, business and government to be digitally enabled by 2030. High speed internet connectivity for Africa's universities will drive the development of digital skills and capabilities that can help to strengthen the other pillars.

According to the United Nations Broadband Commission, " high speed, ubiquitous broadband internet connectivity is considered the critical enablers for digital ecosystems that are necessary components of programs aimed at development, economic transformation and income growth".[1] Specifically, in universities and tertiary level institutions, the availability of bandwidth determines:

- whether efforts to improve internet access through supplying devices (laptops, tablets) are successful
- the extent to which university faculty and students can access international knowledge (journals, papers, databases, courses, presentations on YouTube); collaborate with fellow academics worldwide (including uploading papers and large data sets) in research and teaching programs; access expensive instrumentation, such as supercomputers, virtual labs and so on
- what online content and applications can be used for teaching and learning; whether online and blended learning approaches can be introduced
- whether personalized and differentiated learning (such as adaptive learning) can be used for students and also for faculty professional development
- whether "cloud" services can be used for administrative and teaching purposes
- the ease of updating subscriptions, managing apps, maintaining content management, learning management and student information systems, as well as protection of the network by providing system updates and addressing vulnerabilities.

However, most African universities still do not have access to high speed broadband connectivity.[2] Although up to date data are not readily available, information obtained for 2016 from the National Research and Education Networks (NRENs) indicates that most universities get limited bandwidth, with speeds less than 100 Mbps (Megabits per second), and often less

[1] ITU/UNESCO Broadband Commission for Sustainable Development. (2019.) *The State of Broadband: Broadband as a Foundation for Sustainable Development*.

[2] The Broadband Commission notes that it "has not defined 'broadband' in terms of specific minimum transmission speeds, in recognition of the range of market definitions in different countries. Rather, the Commission views broadband as a cluster of concepts: always on, high-capacity connectivity enabling combined provision of multiple services simultaneously". Source: United Nations Broadband Commission. (2013.) *The State of Broadband 2013: Universalizing Broadband*. The requirements for universities will vary by size of the institution and the level of education, disciplines taught, whether it engages in research and so on. Some estimates of requirements are given later in the paper.

than 50 Mbps. (*Table 1*) Many of these universities have tens of thousands of students. Bandwidth is higher in the East and Southern African countries. More recent information provided by WACREN[3] seems to indicate that higher education institutions in the sub-region get bandwidth in the range of 100-1000 Mbps, whereas in West and Central Africa, the range is 10 to 100 Mbps. The University of Ouagadougou, for instance, which gets 10 Mbps for 60,000 students, effectively provides 0.16 Kbps per student; the University of Ghana is able to provide 25 Kbps per student.

By way of comparison, in the United States, the State Educational Technology Directors' Association (SEDTA) recommends *a target for schools in 2017-18 of 1 Gbps (Gigabits per second) per 1000 students*; for 2020-21, the suggested target is 3 Gbps per 1000 students.[4] These targets are based on using commonly available tools such as online videos and education resources. It is clear that the lack of affordable, high-speed broadband for African universities remains a significant hurdle for the use of technology in education and research and even more so for connecting African faculty and students to international teaching and research resources. Remedying this situation should be a strategic objective, especially as there can be significant spillovers for the school education system, especially secondary schools and technical/ vocational centres.

It is increasingly feasible to connect Africa's universities to affordable broadband. Undersea cables now connect all African countries on the two coasts and investments in terrestrial fiber is expanding (*Annex 1a*). Today, there are only a few countries in Africa, such as South Sudan or Eritrea, that do not now have a national fiber optic backbone. The terrestrial fiber backbone is also limited in many Central African countries and in the Sahel. At the other end, many countries in Eastern and Southern Africa, North Africa and parts of West Africa, have well-developed fiber networks. Further, while undersea and terrestrial fiber is critical for access to affordable broadband, new technologies, including satellite constellation systems can also increase access, especially in remote areas.

Ongoing multilateral and bilateral programs can be built upon to extend and scale up connectivity to African universities. Ongoing programs of the European Union (AfricaConnect Phases 1 and 2, and Phase 3 under preparation) and of the US government (Networks for European, American and African Research – NEARR) have already helped to connect African universities to international research and education networks. (*Annexes 1b and 1c*). These programs have leveraged the regional and National Research and Education Networks (see below).

[3] Boubacar Barry "WACREN – A catalyst for quality higher education and research". Presentation made in Ouagadougou, October 2018. (Received May 2019.)

[4] Fox, L. and Jones, R. (2016). The figures are for medium school district sizes (of about 3000 students).

Table 1: Status of bandwidths provided by NRENS across Africa[5]

Regional NRENs	*Country*	*NREN name*	*Number of Universities connected*	*% of universities connected*	*Range of bandwidth provided*
UbuntuNet Alliance (Eastern & Southern Africa)	Burundi	BERNET	13	-	38 Mbps
	Ethiopia [a]	EthERNet	36	-	100 Mbps
	Kenya	KENET	57	88%	-
	Madagascar	iRENALA	6	-	-
	Malawi	MAREN	3	-	-
	Mozambique	MoRENet	11	100%	34 – 155 Mbps
	Sudan	SudREN	35	100%	2 – 50 Mbps
	Tanzania	TERNET	7	-	8 – 15 Mbps
	Uganda	RENU	16	40%	5 – 200 Mbps
	Zambia	ZAMREN	7	60%	7.5 – 230 Mbps
WACREN (Western & Central Africa)	Côte d'Ivoire	RITER	5	-	100 Mbps
	Gabon	GabonREN	3	-	-
	Ghana	GARNET	25	28%	45 Mbps (Minimum)
	Niger	NigerREN	4	-	1 – 15 Mbps
	Nigeria	NgREN	27	100% (Almost)	155 Mbps basic in STM 1 increments
	Senegal	snRER	5	-	-
	Togo	SLREN	3	-	2 – 15 Mbps
ASREN (Middle East & North Africa)	Algeria	CERIST	63	-	10 – 100 Mbps
	Egypt	EUN	18	-	-

a. More recent data from the draft ICT Strategic Plan for Higher Education in Ethiopia 2018 indicates that bandwidth ranges from 45 to 800 Mbps in Ethiopian universities.

Source: Foley (2016).

[5] Bandwidth measures the rate at which data can be delivered to and from the Internet. It is measured in bits (unit of digital information) that can be transferred in a second. A 1 Kilobit per second (Kbps) connection can deliver a maximum of 1000 bits per second; 1 Megabit per second (Mbps) connection can deliver 1000 Kb in a second and 1 Gigabit per second (Gbps) can deliver 1000 Mb per second.

2. African governments and universities need to plan ahead and set benchmarks for broadband connectivity in order to benefit from the explosion of digital data and content for teaching and research

As the explosion of demand for mobile services on the African continent has shown, demand grows when the service demonstrates value to the user. Hence, in part, the service needs to become available for the user to recognize its value. The implication for African universities is that the use of internet based technologies for education and research will increase as they gain access to broadband (with corresponding investments in campus infrastructure, effective network management and faculty development).

Given the explosion of data, it is necessary to "future proof" the availability of broadband for African universities. The increase of students and data throughput, and the availability of new applications and technologies, will raise demand for bandwidth. Expansion of infrastructure (new buildings and renovations) should already take into account these requirements.

Table 2 provides some benchmarks for bandwidth for different types of universities. A minimum of 100 Mbps -1 Gbps should be available to all university campuses (i.e. taken as the lower bound for small university networks), taking into account the likely increase in data traffic and development of new applications over the next few years. When possible, universities should obtain access to fiber for their networks and their campus backbones. In countries and universities where this is possible, fiber optic access means starting at 1Gbps, and then growing their fiber optic backbones as bandwidth requirements increase. More detailed estimations should be undertaken at the country and institution level, and could be based on the requirements of bandwidth needed by the type of work, the information needs of students and faculty, and the types of remote facilities, shared scientific instruments and databases being accessed, such as supercomputing facilities, data analytics and visualization systems for weather, climate, genomics and agricultural data.

Table 2: *Bandwidth benchmarks for different types of universities*

Type of University	*Number of students*	*Bandwidth Benchmark*
Small campuses	<10,000	100 Mbps - 1 Gbps
Medium campuses	10,000-30,000	2 - 5 Gbps
Large campuses	>30,000	5 - 10 Gbps
Research universities		25 – 50 Gbps

Source: Author's estimates, based on inputs from Network Startup Resource Center (NSRC), University of Oregon. (https://nsrc.org/)

2.1 Broadband for collaborative and data-driven research

The quality of research in African universities, which is essential to solve the development challenges on the continent, will depend to a large degree on a collaborative approach between themselves and with other universities. Distributed access to very large databases, the sharing of computational resources, shared access to data analysis and visualization techniques, among others will require stable, reliable and cheap access to high speed broadband.

An emerging trend in university research is Open Science, the foundations of which are open data and distributed and parallel systems for carrying out analyses, and which will be increasingly integrated across disciplines and open to all. The Africa Open Science Platform proposes to introduce this in Africa and many countries are preparing to participate in it. [6]

Most universities in South Africa already have 10Gbps last mile connectivity. In more advanced countries, many of the advanced universities have 100Gbps connections. India's National Knowledge Network, which connects its education and research networks, aims to provide 100 Gbps connectivity.

While it will be impossible to upgrade all or even most African universities to these connection speeds, one strategy would to select about 1-2 research universities per country (especially in the more advanced sub-Saharan African countries, excluding South Africa) for these higher levels of connectivity.

2.2 Broadband for using technology in teaching

The use of technology in higher education can increase both access (online or blended courses) and quality. Greater use of technology and digital resources can enhance the learning experience of students (improvements in pedagogy, assessments, access to open education resources, online courses, etc.) and the professional development of faculty, which can be customized and personalized. *Table 3* provides an indication of the bandwidth requirements of some commonly used current technologies. This data also suggests that 1Gbps bandwidth should be considered the lower bound for broadband connectivity for universities.

[6] The Africa Open Science vision proposes the "creation of a federated network of existing and new facilities as the basis of an African network, and a research cloud offering state-of-the-art, flexible and economically efficient computational capacity, data stewardship and networking services to users".

***Table 3**: Bandwidth requirement for common educational technologies*

Type of technology usage	***Example***	***Bandwidth requirement per student/ device***	***Comments***
Instructional material (Open Education Resources - OER)	TESSA, African Virtual University	1 Mbps	Download speed
Learning Management System (LMS)	Canvas LMS	512 Kbps (min)	
	Schoology LMS	24 – 80 Kbps	
Online courses	Coursera	250 Kbps	
Online educational gaming	1-way simulation & gaming	1 Mbps	
	2-way gaming	2 Mbps	
Online testing	Multiple choice assessments online	60 Kbps	
	International Computer Driving Licence (ICDL) / Microsoft Digital Literacy Standard Curriculum Test	Light: 100 Kbps (min.)	
		Medium: 800 Kbps	
		Heavy: 1+ Mbps	
Remote instruction	Skype video / Google Hangouts	1+ Mbps	
Sharing cloud-based documents	Office 365 / Google Apps	50 Mbps	
Video conferencing	Light video conferencing	800 Kbps	
	Collaborating in video conference	1 Mbps	
	Collaborating in HD video conference	4 Mbps	
	Skype (group of 7-10 people)	8 Mbps	
	Zoom (1:1 video calling)	600 Kbps	Upload/ download speed
	Zoom (1:1 video calling - 720p HD video)	1.2 Mbps	Upload/ download speed
	Zoom (group conferencing - high quality video)	600 Kbps - 1.2 Mbps	
	Zoom (Gallery view - 720p HD)	1.5 Mbps	Upload/ download speed
Video streaming	Light video streaming	800 Kbps	
	Watching a video conference	1 Mbps	
	Khan Academy	1.5 Mbps	
	HD-quality	2 Mbps	
	University Lecture	4 Mbps	
	HD-quality	5 Mbps	
Voice calls	Skype	30 Kbps	
Web browsing	Chrome Devices	200 – 500 Kbps	
	Browsers (Google Chrome / Internet Explorer / Firefox)	Light: 100 Kbps	
		Medium: 500 Kbps	
		Heavy: 1 Mbps	
Webinar	Zoom (high quality)	600kbps	Webinar attendee
	Zoom (SD video)	1.2 Mbps	Download speed

Source: Constructed using data from Fox and Jones (2016); Brookings 2016 (https://www.brookings.edu); Arney, 2019 (consultant report)

3. Strengthening and establishing National Research and Education Networks (NRENs) are critical to providing sustainable and affordable access to broadband connectivity to universities

The approach to university connectivity worldwide is to develop a National Research and Education Network (NREN) mandated to connect all universities in a country and to link to international RENs (*Box 1*). In 2003, only 8 African countries had NRENs, and only 22 percent of institutions were members of the network. Since then, there has been a considerable growth in NRENs, although about 30 countries still do not have a functioning NREN. *Figure 1* shows African countries classified by the level of development of NRENs (also see *Annex 2*).[7] *Box 2* provides a summary of the development of KENET, one of the more successful NRENs on the continent, and the steps it can take to go to the next level.

Sub-regional networks have helped to connect NRENs and share resources amongst them. These are:

- West and Central African Research and Education Network – WACREN
- UbuntuNet Alliance – in East and Southern Africa
- Arab States Research and Education network – ASREN in North Africa

The EU's AfricaConnect program (now in Phase 3) is driving the program to connect country NRENs to each other and to global regional networks, such as GÉANT and Internet2 in the USA. In January 2017, the Networks for European, American and African Research (NEARR) project added a 100 Gbps connection between New York City and London. The regional African networks are the partners in this endeavor.

NRENs, especially those that are relatively more advanced, will increasingly need to play an important role in the provision of advanced research infrastructure and ICT services, in particular under the Open Science initiative.

Most NRENs have the mandate of connecting not only universities, research and tertiary education institutions, but also Technical Vocational Education and Training (TVET) institutes, Teacher Training Colleges, medical colleges, libraries, and even hospitals (*Annex 3*).

[7] This is an estimate. Figure 1 shows data as of 2016, according to which about 36 countries did not have a functioning NREN. However, since then, several countries have established NRENs, such as Ghana.

Box 1: The role of NRENs

"At the most basic level, NRENs act as a consortium of universities that organize themselves to aggregate demand and to get a better price from Internet service providers. But the primary role of the NREN to is to provide advanced services to its members. Its most visible service is to operate the national backbone that connects a country's university networks to each other and to other research and education networks globally. It runs its own Network Operations Centre to manage all traffic on the network , and it can provide technical support services and training to all of its members."

Source: Foley, Chapter 2

NRENs enable « identity and trust" (ie all those who are part of an institution that is a member of NRENs can be identified and have access to the education and research resources of all members as well as to global resources) and also foster platforms for collaboration between individual researchers and communities of researchers and educators.

NRENs typically lease the high speed backbone from private or national fibre networks. In some cases, they operate and own the last mile connections to member institutions.

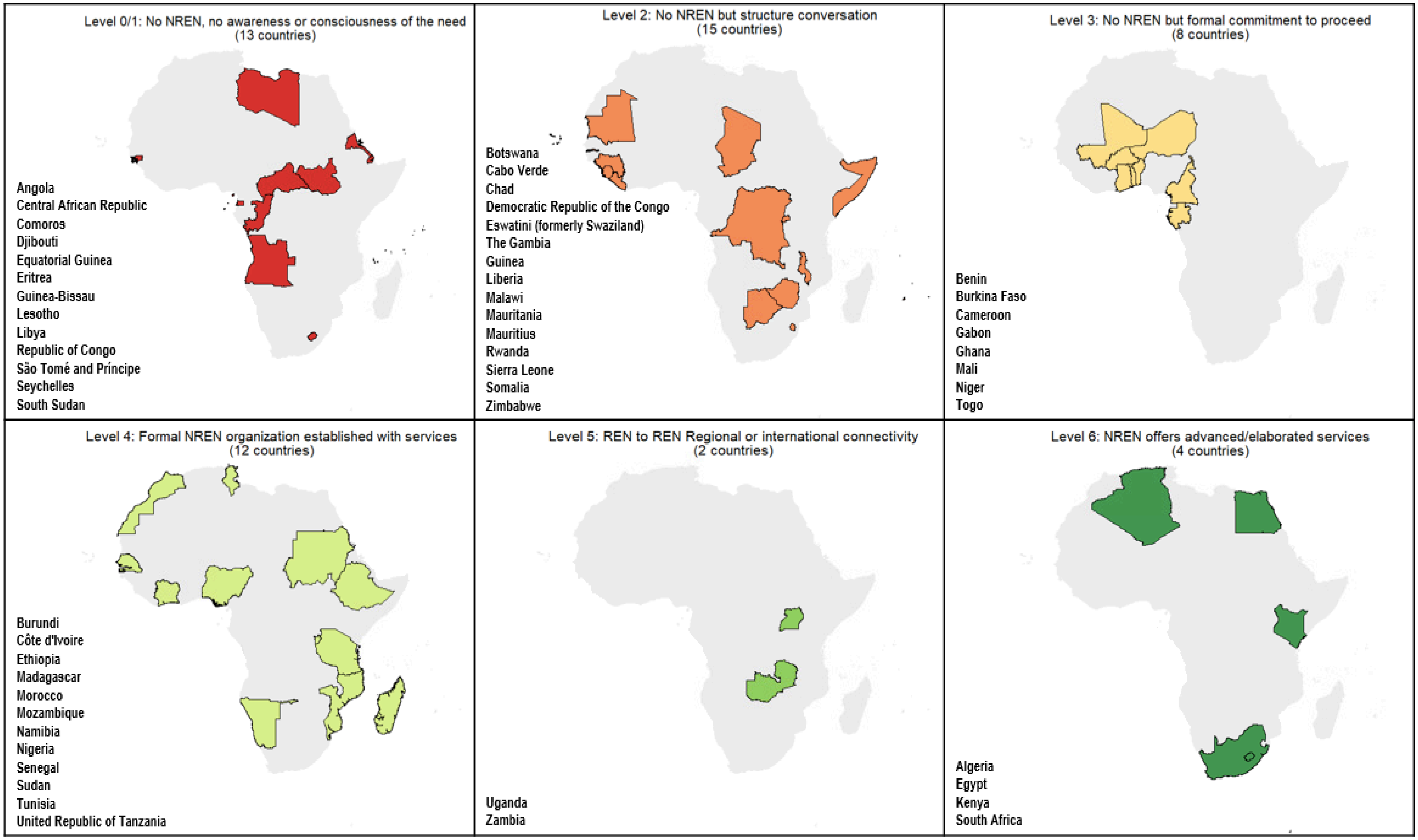
Many NRENs have grown "bottom-up" in Africa, as in other regions, based on the initiative and effort of universities and research institutions. These include South Africa, Kenya, Ghana and Uganda, which have distinct governance models with representation from their members. Other NRENs have been created by government initiatives, as in Ethiopia, Mozambique and Rwanda. The former tend to be more agile in decision-making and responsive to their member needs, because of the structure and composition of the governance structures.

NRENs are effective when universities have well managed data networks and encourage the use of technologies. The more mature NRENs have provided training and support to universities in these areas.

A summary of actions required to strengthen NRENs is given below

- Establish NRENs in countries that do not have them. This will require some donor financing and technical support.
- Recognition of NRENs in the country's respective ICT or education laws strengthens their role. Mozambique and South African NRENs are recognized as such.
- Support for NRENs by governments through waivers of operator license fees (as in Kenya, Uganda and Zambia), use of Universal Access Funds to connect institutions in remote areas, infrastructure grants (sometimes financed by donors) to strengthen the backbone that connects the university networks and income-tax exemptions.
- Development of business plans for NRENs to become sustainable, by offering enhanced services to their members, including capacity building in campus networks design and operations and cybersecurity.
- Investment to establish or upgrade infrastructure, bandwidth and provide enhanced services to members

Figure 1: Country-wise status and level of development of NRENs across Africa, circa 2016[8]



[8] Based on Foley (2016). Each level includes the competences/advances of the previous levels. For example, Leve 6 countries have the advances of Level 4 and Level 5 countries.

Box 2: KENET- Achievements and Next Steps

From very modest beginnings in 2000, initiated by enterprising academics who sought to establish links with the international university and research community, the Kenya Education Network (KENET) has grown to become a high-performing NREN in Africa, ranked amongst the top 5 along with South African, Egyptian, Zambian and Ugandan NRENs. KENET can now move to the next phase of development which could (i) further lower the cost of broadband to universities (ii) rapidly increase the use of technology in higher education to expand access and radically transform the higher education sector and (iii) offer high-end services to the university community in Kenya, including data repositories, support for deployment of technology and so on.

The roots of Internet access in Kenya began with the African Regional Centre for Computing (ARCC) and the NSRC in the early 1990s, which helped Kenya establish its first TCP/IP link to the Internet in 1995, and then assisted Kenyan colleagues in building out its first phase of KENET, starting in 1999.

The case of KENET shows that NRENS in countries with liberalized telecommunications sector tend to grow faster, as they can benefit from competitive leased line pricing, access to dark fiber provided by fiber operators (e.g., Liquid Telecom, Safaricom in Kenya and CSquare in Uganda), and access to content caches in their network (eg. Google, Akamai, and Facebook).

Selected achievements

The Kenya Transparency and Communications Infrastructure Project (KTCIP) funded by the World Bank in 2007-2013 helped to put KENET on a sustainable path: By the end of the project in 2013, the project supported KENET to connect 55 campuses of member institutions, established two Tier-2 data centers at two universities, created five Points of Presence in different parts of Kenya, procured 1200 Mb/s of international Indefeasible Rights of Use (IRU) circuits to London and set up a fully operational Network Operations Center (NOC) in Nairobi[9] Member institutions sustain KENET by **subscribing** to Internet bandwidth or community cloud services. A sustainability plan and an effective governance structure have been critical factors in strengthening the NREN.

Steep drop in unit price of broadband connectivity: Between 2010 and 2019, the average weighted price of internet paid by universities fell from about $ 1100 in 2009 to $ 27 per Mbps per month in April 2019. The price may fall further to $23 per Mbps per month in 2019-20. The ability to aggregate the Internet traffic of member institutions drives down the retail Internet prices to member institutions. Members sign a framework services agreement with prices reviewed on an annual basis.

Increase in bandwidth consumption: Over the same period, universities increased their consumption of broadband from less than 200 Mbps to over 29,000 Mbps.

Increase in number of connected institutions: A total of 270 campuses of universities, research institutions and tertiary colleges were connected as at April 2019, a sharp rise from 140 in 2013 and 55 in 2009.

Increased cloud services to universities: KENET provides services such as web hosting, co-location of servers (for disaster recovery), virtual servers, virtual labs, research cloud, and cloud-based web and video-conferencing. This is done through 3 data centers, which are still relatively small.

Domain name registry: KENET is recognized by the African Regional Registry of Internet Numbers (AFRINIC), as the custodian of the Internet address blocks allocated to the academic community of

[9] IRU is the long term lease of a part of an international cable; the lease is granted for periods varying between 15 to 25 years, which is effective ownership for that period.

Kenya. It is also one of the four shareholders of the not-for-profit company Kenya Network Information Center that maintains the .ke registry of Kenya.

Next Steps for KENET

Increase in bandwidth consumption: Projected increase of at least 100% mainly through increase in subscription of the medium to very large university campuses. Investments in upgrading and expanding campus networks and WiFi coverage by universities will help drive consumption.

Further reductions in price: Reducing the cost of distribution over the national network through long term leasing on the long haul fiber segments, and on the "last mile" connections through use of fiber to replace expensive radio lease lines and long term lease of dark fiber. Increased bandwidth consumption will also help to lower prices.

Technical services to universities: Creating the technical capacity to plan, procure and deploy, and secure digital assets in universities, research institutions and TVETs. Digital assets include research & educational technology infrastructures

Cloud based services: ERP services for universities, TVETs, and medical colleges; competency-based training materials for TVETs and medical colleges and universities; security services

Kenya Open Science Platform: Provision of advanced research infrastructure and ICT services. This would provide access to high performance computing, data storage and Open Data Repositories in different areas.

Note: Based on information in various documents supplied by KENET in 2019

4. NRENs are more successful where there is an enabling and competitive environment for digital infrastructure and services in the country

Providing affordable broadband connectivity to universities without reforms in the overall digital infrastructure landscape. The value chain of digital infrastructure networks can be broken down into *first mile* (where the internet enters the country), *middle mile* (where the internet passes through the country) and the *last mile* (where the internet reaches the end user). The network components and technology used across. In addition, it is useful to consider the *invisible mile,* where the network components are non-visible, including the spectrum, network databases, cybersecurity, etc. Table 4 outlines the network components and the technologies involved.

Competition in each segment of this market can help to reduce cost and increase bandwidth consumption. Broadly speaking, NRENs have been more successful in connecting universities to broadband where the market has been liberalized and prices in the first mile and middle mile have fallen. However, there still remain a lot of policy and regulatory issues that need to be addressed even in these countries. In West African countries, the lack of competition tends to keep prices high in the middle mile and even in the first mile, even when there is adequate fiber capacity. The cost of leasing fibre from companies that own the terrestrial links, and inability to make connections between landing stations, make it difficult to expand the network. In Central Africa and the Sahel, however, there is a problem of lack of terrestrial fibre.

Table 4: *Network components and technology characteristics of the internet value chain*

	First Mile	**Middle Mile**	**Last Mile**	**Invisible Mile**
Network components	International Internet access: submarine cables, landing stations, satellite dishes, crossborder microwave, domain name registration	National backbone and intercity networks, including the fiber backbone, microwave, Internet exchange points (IXPs), local hosting of content	Local access network, including the local loop, central office exchanges, and cellular wireless masts.	Radio spectrum, network databases (for example, for numbering), cybersecurity; international frontiers, multilayered taxation of activities, rights of way, and inefficient regulations.
Technology	Undersea fiber optic cables	Terrestrial fiber optic networks	Historically this been copper but is now increasingly fibre. New technologies include 5G fixed wireless access (FWA). New spectrum sharing techniques and TV whitespaces also allow the same bands to be used for multiple service allocations	
Note: Constructed based on World Bank documents and African Union. (2019). The Digital Transformation Strategy for Africa (2020-2030).				

5. Priorities for countries in North Africa, Eastern and Southern Africa: Last mile connectivity for remote universities, increasing speed and reliability and reducing price for all universities

Although there are significant variations between countries within North Africa and Eastern and Southern Africa, by and large, they have a high degree of international connectivity and also at least national fibre optic backbone, as well as a functional NREN (see *Figure 1*). One important challenge relates connecting universities in secondary cities or remote locations. Because the commercial returns are low (primarily because of low population density and/or purchasing power), commercial operators either do not serve remote locations or tend to charge high prices for leasing their lines to the NREN. Alternatively, this will require the NREN and/or the university to invest in the last mile connectivity.

However, the social costs of not serving these universities are high, as these universities serve poorer students and those in lagging regions of the country. There is a risk of a widening "digital divide" and greater inequality in access to quality higher education. At the national level, universal service access policies can help to remedy these inequalities.

In several North African countries, regulatory issues and the lack of competition also affect the price over the first mile and the distribution over the national network. These are similar to the conditions in West Africa.

Despite the advances made in these countries, more effort and investment is required to improve speed (to meet the suggested benchmarks) and reliability, as well as lowering the price of connectivity. *Box 3* documents the experience of KENET in bringing down the price of broadband for Kenyan Universities and the steps that could further lower them.

***Box 3:* Lowering Broadband Prices for Kenyan Universities**

The total weighted unit cost of broadband for Kenyan universities in 2018-19 was $ 27.4 per Mbs/ month, with 80 percent being contributed by national distribution costs. With a small margin used to pay for KENET administration and services to universities, the average unit price paid by universities was $ 31.8

"First" Mile Costs

Liberalization of the telecommunication sector in Kenya has helped KENET to access international connectivity at low cost. In the "first mile", three undersea cables land in Kenya - SEACOM, EASSy, and TEAMS. KENET has 17.2 Gb/s of international circuits to London/ Amsterdam, linking Kenyan universities to European Research and Education networks through the GEANT cloud. These circuits are on the SEACOM, EASSy and TEAMS undersea cables. About 70 percent of the international internet traffic for KENET is through peering or caches in Kenya. KENET peers with other networks in Kenya at the Kenya Internet Exchange Point, as well as privately with the large Internet Content Providers with a presence in Kenya (e.g., Google and Akamai).

KENET is able to purchase broadband at about $ 1/Mbps in London through the UbuntuNet Alliance (called the IP transit cost). It has also been to negotiate supplier-financing for procurement of additional 13 Gb/s

IRU capacity. There has also been a sharp drop in leased international circuits with the presence of global operators like Hurricane Electric in Nairobi.

The average cost of international bandwidth in Nairobi was about $5.7 per Mb/s per month in 2018-19, which includes the IP transit of $1 per Mb/s per month in London plus recurrent cost of international circuits of $4.7 per Mb/s per month. This represented about 21 percent of the total connectivity cost.

"Middle Mile" Costs

Over 80% of the 29 Gb/s internet bandwidth is being distributed over KENET-owned private network links, which has brought down the price over the national network. However, 20% of the distributed capacity is achieved using expensive managed lease line connections provided by commercial telecommunications operators in Kenya.

As a result, the cost of distribution over the national network is about $10.9 per Mbps per month and represents about 40 percent of the total cost. This cost can be brought down by:

1. Implementation of IRU leased wavelengths on the long haul fiber segments between KENET Points of Presence (Nairobi<>Mombasa, Nairobi<>Kisumu and Nairobi<>Eldoret)
2. Implementation of IRU dark fiber on existing leased dark fiber components

"Last Mile" Costs

A significant cost element for KENET is the last mile fiber and/or WiFi radio connectivity. At the end of the national backbone, KENET connects universities through last-mile leased lines providers (e.g., Liquid Telecom, Safaricom, JTL, or TKL).

Over the last mile, the weighted unit cost of distribution using managed leased lines is about $10.8 per Mbps per month, which represents 39 percent of the total cost. This is despite the fact that KENET is able to negotiate substantially lower cost and better quality of services than would be possible if each university negotiated individually. Lease line costs comprise about 40 percent of the last mile costs (compared to only 22 percent of the middle mile costs) This cost can be brought down by:

1. Implementation of last mile fiber to replace expensive WiFi radio lease lines
2. Implementation of high-speed KENET-owned last mile radio links in licensed or unlicensed bands
3. Implementation of long term IRU lease dark fiber for University main campuses, TVETs and large research institutions
4. Increase in bandwidth consumption of connected campuses through increase in WiFi coverage on campuses and upgrade of campus backbone networks.

Increase in bandwidth consumption in universities lowers costs

The "middle mile" network, in particular, has considerable idle capacity which could support more institutions or increased consumption without higher recurrent costs. Increased bandwidth consumption requires that universities are capable of utilizing technology in education. KENET's technical assistance and training for universities to set up campus networks and faculty development have helped to increase utilization and thus lower unit costs. Further investment in campus infrastructure and deployment of technology for teaching and research will help to drive consumption.

6. Priorities for countries in West Africa: Price and connectivity

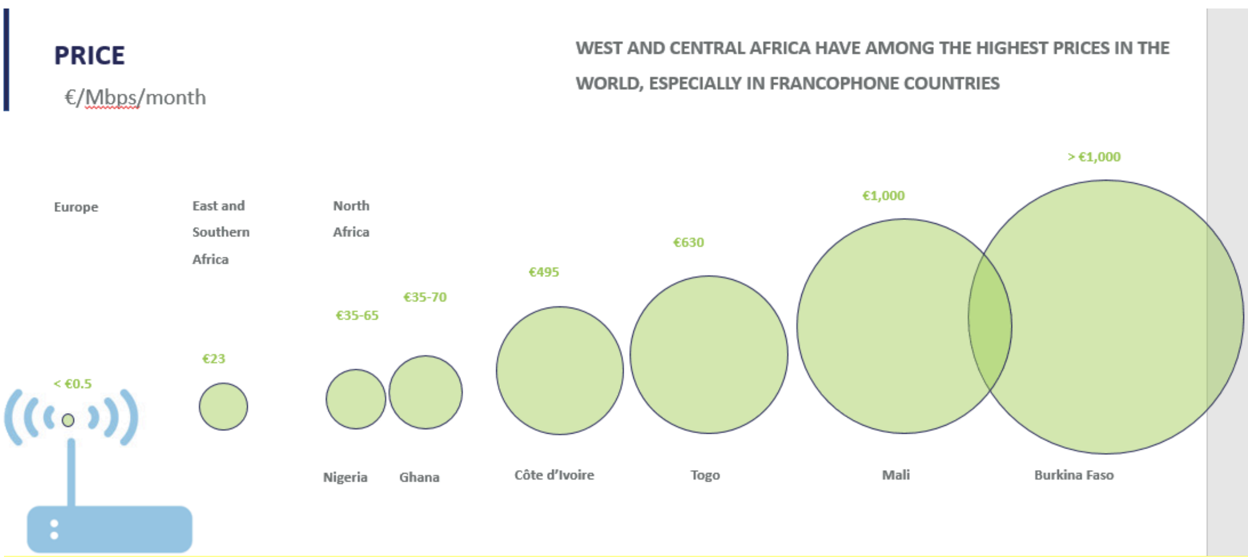
Although the first submarine cables reached the western coast of Africa as early as 2002, prices for internet in West African countries are among the highest in the world. Francophone countries are amongst the most affected. (*Figure 2*).

In these countries, the high price is often related to the "first mile". Monopoly control over the international gateway and the cable landing stations increases the price of internet at the point of entry. Further, the cost of distribution over the national network is relatively high, due to lack of sharing of network infrastructure owned by current private sector incumbents or public sector companies, which limits the supply of capacity and the lack of competitors to commercialize existing and new fiber.

In general, NRENs in these countries have been established only recently and do not have the capacity or services that are available in Eastern, Southern and Northern Africa.

Some countries have, however, gone ahead in improving connectivity. In Senegal, the initiative has been taken largely by the government and the networks are also managed by government agencies. *Box 4* highlights some of the features of university connectivity in Senegal and the differences across Africa.

Figure 2: Price Comparison between East and Southern Africa with Western & Central Africa



Source: Author's construction based on Boubakar Barry presentation on WACREN, October 2018. Received May 2019.

***Box 4*- Broadband connectivity for Universities in Senegal**

In Senegal, the government has taken the lead in providing connectivity to higher education institutions. Although Senegal has a NREN, it is still not a formal organization recognized by the Ministry. Internet connectivity for higher education universities is being funded out of the Telecommunications Universal Service Fund (Fonds de Développement du service universel de télécommunication – FDSUT). The first fiber-optic network in a university was started in Université Gaston Berger (UGB) in 2013. All universities have been equipped with a fiber-optic network which is linked directly to the national network operated by the government's ICT agency (ADIE) by optical fiber or through a AirFiber system donated by the NSRC (Internet technology which delivers a wireless gigabit performance with a long range). The national network of universities is managed by ADIE in collaboration with the Ministry of Higher Education and Scientific Research.

As a result of this increased connectivity, the Ministry signed an agreement with Elsevier and other publishers to provide access to journals and databases such as ScienceDirect, CAIRNINFO etc. Other innovations include the establishment of FabLabs and 3D printers in selected tertiary institutions. Other initiatives of the government which leverage broadband connectivity, include establishment of the Senegal Virtual University, the Knowledge City and Technology Park.

The government has also increased utilization by providing one laptop to each student in higher education, partly subsidized by the state and the rest paid by the student over a 12-month period. Internet access is free for students in all public universities. Outside campuses, student have access to 5 GB of data per month for $ 3.42, thanks to an agreement signed between the Ministry of Higher Education and SONATEL, the principal telecommunications operator.

However, as yet, there is no connection to international education and research networks such as GEANT. Senegal is not yet a member of WACREN.

7. Priorities for countries in Central Africa and in the Sahel: Digital infrastructure and basic connectivity at affordable prices

The majority of the population in these regions are still out of reach of even a mobile broadband signal and mobile prices are in general unaffordable (over 15 percent of GNI per capita).

Connecting universities to broadband can generate spillovers for skills development and secondary schools in the vicinity. This would ideally be undertaken as part of a national digital infrastructure project, which could utilize cross-sector infrastructure development such as roads and electricity in order to reduce the cost of laying the fiber optic backbone. Over the middle and last mile, other technologies, such as satellite technology, may be used due to the sparseness of the population and the high cost of traditional methods.

The level of broadband connectivity for universities in these countries would depend on the possibilities for current utilization and prospects for future growth. In particular, the possibility of using the university infrastructure and faculty to help connect secondary schools and/ or promote skills development for out-of-school youth should be factored in.

NRENs either do not exist or are barely functional in most of these countries. Supporting their establishment and building the capacity of the NREN in each country would be essential to enable the future growth of the network.

8. Priorities for network infrastructure

The previous sections covered requirements on a regional basis across Africa, accounting for the varying circumstances in each region.

Fundamentally today, physical network infrastructure is becoming greatly simplified, with legacy technologies become more and more rare with the roll out of fibre-optic technologies in many countries. NRENs being constructed or upgraded today are largely fibre-optic based, where:

- The NREN has access to dark fibre, either national dark fibre network as mandated by national Government, or where Government is facilitating access to fibre pairs or wavelengths from the private sector or incumbents
- Last mile physical access from the NREN backbone to the campus, where possible, is over fibre-optics, whether dedicated provision or a wavelength from the telecom operators
- Capacities provisioned are determined at the IP layer rather than the physical layer, as was the case in the past.

The advantage of this approach for the NREN is that capacity is upgradable by swapping fibre-optic infrastructure as required as bandwidth demands increase (1Gbps can become 10Gbps by swapping a transceiver, 10Gbps can become 40Gbps by swapping optics & electronics, 40Gbps can become 100Gbps, etc). This can apply to the NREN's backbone; it can equally apply to the access network from NREN to campus, as the campus bandwidth needs increase too.

As an example, a campus which identifies its bandwidth needs as 250Mbps (based on the earlier discussion) can now be provisioned with fibre optics (dark, or a wavelength) capable of being operated at 100Gbps using today's technologies – provisioning can start with 1Gbps interfaces and fibre optic transceivers, bandwidth on the router limited to 250Mbps, and upgrading by changing optics as the campus needs grow beyond 1Gbps. This provides a more flexible, scalable, and stable growth path than legacy access technologies did in the past.

9. Priorities for NREN infrastructure

Enhancing the campus infrastructure has a roll-on effect for the NREN supporting this improved connectivity. The model of Internet service provision in this decade have changed somewhat from those in the late 1990s and early 2000s when many of the existing networks were first in concept and early implementation stages. Today, a national REN in many countries around the world is **the** Internet services provider for the campus members connected to it. The NREN has the responsibility for providing not only transit to the global R&E network for high speed access, but also providing commodity Internet access, both at a local and international level. Practically, this means that the NREN connects to the local Internet Exchange Point (in-country) to peer with commodity Internet operators and content providers who are participating, as well as purchasing commodity Internet transit to the rest of the world, typically from a couple of commercial transit providers. A typical model for an NREN today is:

- The Internet services provider for the campus
- R&E transit from the Regional REN
- Connection to the local Internet Exchange Point to peer local traffic and content
- Commodity Internet transit from one or two commodity transit providers

This model optimizes the regional R&E infrastructure to carry R&E traffic, ensures that access to the many content caches and content distribution network is localized over high bandwidth local cross-connects (at IXPs or commodity providers), that staff and students can continue their high-speed access to campus and NREN hosted services whenever they are off campus, and that commodity Internet traffic is handled by the commercial providers.

10. Investment in campus infrastructure is critical to make efficient use of university connectivity

Bringing internet connectivity to universities is the first step. In addition, campus infrastructure needs to be upgraded to follow best practices in network design so that the university community can benefit from the access to increased broadband.

Specifically, the following areas should be considered for investment:

- Local Area Network and campus backbone linked to the NREN and regional networks
- Structured campus network design
- Campus network monitoring and management systems to enhance reliability and security of network services for the user community
- Wi-Fi which is accessible everywhere to support teaching-learning
- Commodity Internet access which is reliable
- Data Centre (on-campus or provided by the NREN, where applicable)
- High-performance computing (where applicable)
- Devices for students and faculty, to enable one-to-one computing
- Identity management and access systems
- Investment in local network engineers and IT staff to maintain and grow the campus network facilities and services

Without adequate infrastructure, monitoring and management at the campus/ university level, the quality of the service is seriously affected by bandwidth congestion, while actual utilization is affected by lack of devices, the lack of ability to monitor, mitigate and provide protection against viruses, spam and so on. Once a decision has been made about the universities that would be connected to high speed broadband, these universities should also receive additional investment for upgrading the campus infrastructure, augmenting the technical skills of campus IT staff, as well as the "soft capacity" to use and manage these resources effectively.

11. Investing in "soft capacity" -- digital content, faculty development and management capacity -- is critical to make full use of connectivity

In addition to the NREN infrastructure and campus infrastructure, universities need to invest in content, training and management in order to benefit from the "hard" infrastructure. Specific issues that need to be addressed are:

- Identification of the courses that will use digital applications, software and content for teaching and learning. The process of evaluating and selecting the appropriate technology needs to be developed, and this should primarily focus on the pedagogical needs and objectives rather than the technology per se. Training of faculty to use these applications and integrate them in teaching is essential to derive the maximum benefits from these investments. Prioritizing courses in engineering, science, mathematics and related areas, or the areas of focus of the university, may be a good way to proceed if the institution has limited capacity
- Reviewing and streamlining the procurement and purchase of appropriate software and content for teaching and learning. Many universities find this to be very difficult, especially if they follow the government procurement processes.
- Irrespective of the courses, all staff and students must acquire intermediate level proficiency in digital skills. This is required for faculty and students to be able to use digital tools and the internet for teaching, learning and research and for administrative and support staff to use learning management systems and so on
- Improved management of university's digital assets, including a properly staffed office, review and/or development of policies and guidelines, management of data privacy and security, management of network usage and data traffic, provision of adequate technical support to faculty and students, etc. A number of technical issues need to be addressed such as transfer of systems to the mobile or cloud environments and unified communications and document storage, among others.
- Proper budgeting for universities so that they have adequate funding for payment of internet services and the operational costs of the infrastructure

In countries with more mature NRENs, technical support for building university capacity can be provided by the NRENs. Irrespective of the approach that is used, financing technical assistance to enable universities to deploy, use and manage broadband services and associated infrastructure is as critical as provision of the middle mile and last mile connectivity.

However, the full potential of broadband connectivity for African universities can only be realized if young Africans are empowered and educated with advanced and relevant digital skills required by a rapidly changing environment. Computer science and engineering curricula need to be modernized in universities across Africa. Current curricula and teaching methods are too theoretical, teach outdated skills and do not employ modern teaching methods. This is the subject of another paper and not covered here.

12. Costs

This section identifies the main elements of cost for providing and utilizing broadband connectivity to African universities. Detailed costing exercises will need to be carried out at the individual university level.

The key elements of costs categorized by type of institution are given below. In practice, investment will need to take place in a holistic manner at the level of the NREN and university.

NREN

- Establishing/ developing NRENs where they do not exist or are currently non-functional
- Capital investment (covers long lease on national fiber optic backbone, Points of Presence, providing /upgrading last mile connectivity, especially for remote campuses; cloud infrastructure; access points etc.)
- Operational costs – these will generally be covered by subscription or user fees and some government subsidy (however, universities must have adequate funding to pay for the fees). Operational costs include national network and international connectivity costs, as well as delivery over the last mile.
- Technical assistance to NREN for developing a business plan and improving management capacity for managing the network and providing services to the user community

University level

- Capital investment: campus infrastructure covering LAN, Wi-Fi access, routers, data centre, etc. as well as computing facilities and devices. The cost of upgrading the campus infrastructure (excluding computers and devices) is estimated to be about $ 1 million for a small campus, and $ 3 and $ 5 million for a medium and large campus, respectively.
- Operational costs: subscription to NREN services and commodity internet; management costs; purchase of software and applications; training of faculty, staff and students;

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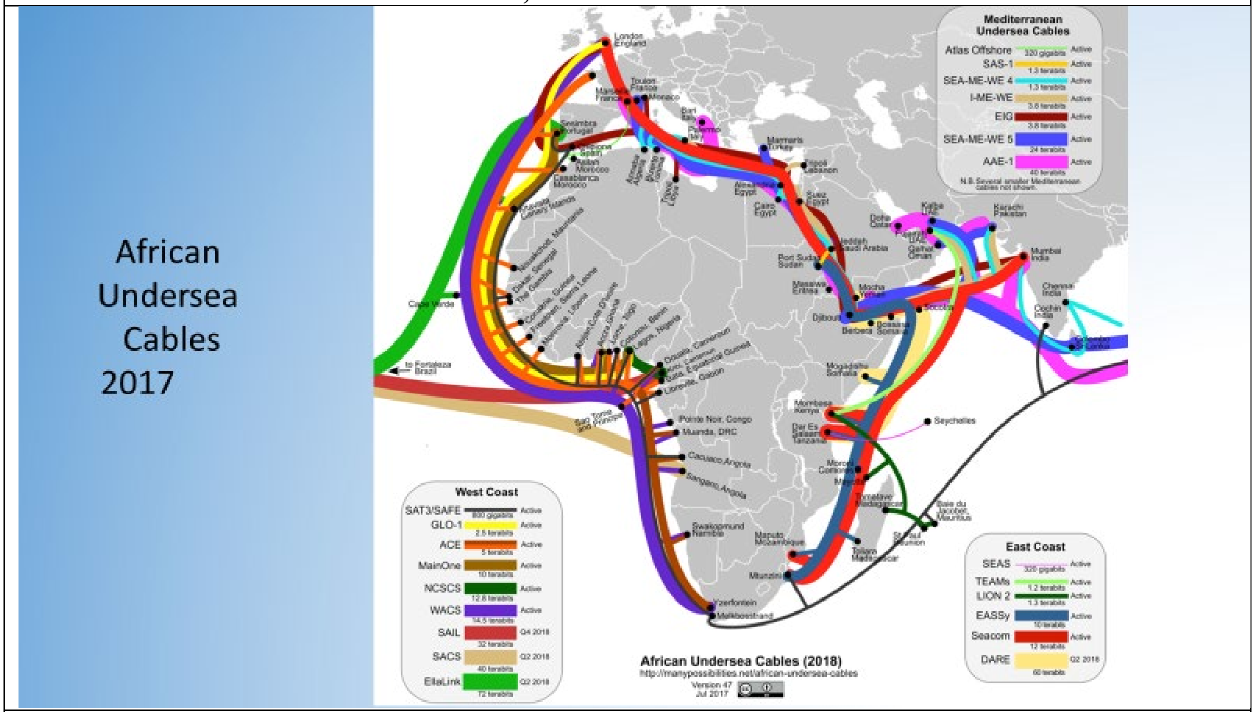
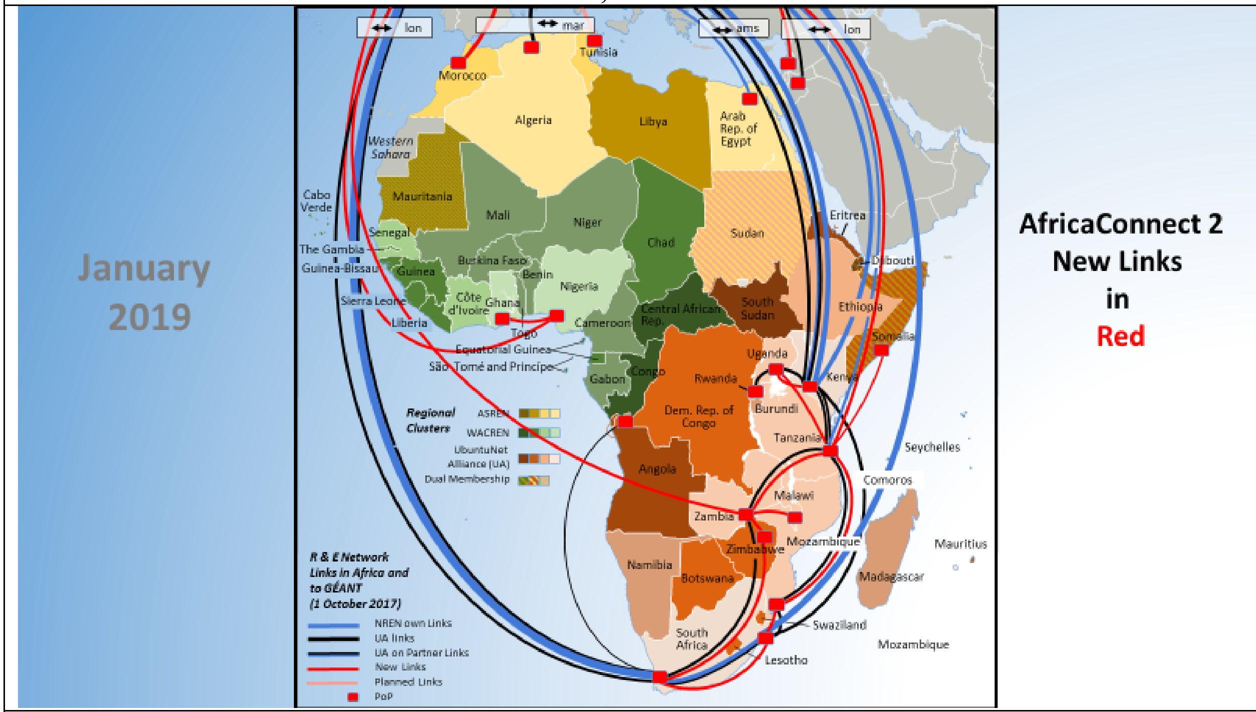
Annex 1

Annex 1a – African Undersea Cables, 2017



Source: Foley (2016)

Annex 1b - AfricaConnect Links to Africa , 2019



Source: Foley (2018). This slide from the presentation was updated as of January 2019. Personal communication.

Annex 1c - Networks for European, American, and African Research (NEAAR), transatlantic connection

Source: https://internationalnetworks.iu.edu/projects/NEAAR/index.html

Annex 2

***Annex 2:* Country-wise status and level of development of NRENs across Africa**

Country	*NREN*	*Region*	*Level*	
Algeria	ARN	ASREN	6	NREN begins to offer REN-specific advanced services.
Egypt	EUN	ASREN	6	
Kenya	KENET	UbuntuNet	6	
South Africa	TENET	UbuntuNet	6	
Uganda	RENU	UbuntuNet	5	First REN to REN international links are established.
Zambia	ZAMREN	UbuntuNet	5	
Ethiopia	EthERNet	UbuntuNet	4.5	A formal NREN organization with services is established.
Mozambique	MoRENET	UbuntuNet	4.5	
Sudan	SudREN	UbuntuNet/ASREN	4.5	
Tanzania	TERNET	UbuntuNet	4.5	
Morocco	MARWAN	ASREN	4.5	
Tunisia	RNU2	ASREN	4.5	
Burundi	BERNet	UbuntuNet	4	
Madagascar	iRENALA	UbuntuNet	4	
Namibia	XNet	UbuntuNet	4	
Côte d'Ivoire	RITER	WACREN	4	
Nigeria	NgREN	WACREN	4	
Senegal	snRER	WACREN	4	
Ghana	GARNET	WACREN	3.5	No actual NREN but a formal commitment to proceed is achieved.
Benin	RerBenin	WACREN	3	
Burkina Faso	FasoREN	WACREN	3	
Cameroon	RIC	WACREN	3	
Gabon	GabonREN	WACREN	3	
Mali	MaliREN	WACREN	3	
Niger	NigerREN	WACREN	3	
Togo	TogoREN	WACREN	3	
Democratic Republic of the Congo	Eb@le	UbuntuNet	2.5	No NREN but a more structured conversation regarding one.
Malawi	MAREN	UbuntuNet	2.5	
Rwanda	RwEDNet	UbuntuNet	2.5	
Botswana	-	UbuntuNet	2	
Mauritius	-	UbuntuNet	2	
Somalia	SomaliREN	UbuntuNet/ASREN	2	
Eswatini (formerly Swaziland)	-	UbuntuNet	2	
Zimbabwe	-	UbuntuNet	2	
Cape Verde	-	WACREN	2	
Chad	-	WACREN	2	
Gambia	-	WACREN	2	
Guinea	-	WACREN	2	
Liberia	-	WACREN	2	
Sierra Leone	-	WACREN	2	
Mauritania	-	ASREN	2	
Angola	-	UbuntuNet	1	No NREN but a diffused consciousness of
Comoros	-	UbuntuNet/ASREN	1	
Eritrea	-	UbuntuNet	1	
Seychelles	-	UbuntuNet	1	

South Sudan	-	UbuntuNet	1	the benefits of establishing one.
Equatorial Guinea	-	WACREN	1	
Guinea Bissau	-	WACREN	1	
São Tomé and Príncipe	-	WACREN	1	
Lesotho	-	UbuntuNet	0	No NREN and no awareness of the need.
Central African Republic	-	WACREN	0	
Republic of Congo	-	WACREN	0	
Djibouti	-	ASREN/ UbuntuNet	0	
Libya	-	ASREN	0	

Note: 'Levels of Development' describes the typical stages of development of NRENs based on a model adapted by Duncan Greaves of South Africa's NREN (TENET) Its values range from Level 0 (least developed) to Level 6 (most developed).
Source: Foley (2016)

Annex 3

Annex 3. **Communities Served by NRENs : Example of 10 NRENs in UbuntuNet Alliance (Information supplied from KENET**

UA NREN name / Country	Member Universities	Research Institutions	TVETs / Users	Teaching Hospitals + Medical colleges	Schools	Others	Total Bandwidth Subscriptions by members (Mb/s)
1. BERNET (Burundi)	14	-	-	-	-	-	Not available
2. KENET / Kenya	69	20	26	8	36	5	30,000
3. MoRENET / Mozambique	41	20	25	9	1	12	4,650
4. RwedNET	7						
5. SomaliREN / Somalia	8	1	-	-	-	-	260
6. TERNET / Tanzania	26	6	5	4		3	550
7. RENU / Uganda	28	14	9	-	-	4	4,000
8. XNET / Namibia	1	2	8	-	550	30	272
9. ZAMREN / Zambia	15	5	30	19	24	11	2,228
10. ZARnet / Zimbabwe	8	-	4		100	-	356