Satellite Connectivity

The Key to Africa's Digital Transformation?

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Contents

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1. Introduction

The COVID-19 pandemic has highlighted the ICT infrastructure challenges that most African countries face. As citizens from all over the world relied on internet connectivity to work, study, and communicate, many Africans struggled to make similar connections with limited, or even no access to the internet. The Alliance for Affordable Internet found that of the 45 African countries it monitors, only 10 meet its standard for "affordable internet,"[1] defined as 1 GB of data costing 2% or less than the average monthly income.

Addressing the digital divide is a priority for all African states. Connectivity is especially challenging in rural areas – despite African countries becoming more urbanized, 60% of Sub-Saharan Africans live in rural areas.[2] For example, in Cote D'Ivoire, 28% of the population live in areas without mobile broadband coverage, representing a digital divide of over 7 million people. Meanwhile in Ethiopia, roughly 15 % of the population live in areas without minimum 3G coverage, representing nearly 17 million people without access to mobile broadband. [3]

Improving connectivity and including more citizens in the digital economy is imperative for Africa's socio-economic transformation. According to the International Finance Corporation (IFC), a 10% increase in mobile internet penetration increases GDP per capita by 2.5%. This means that the digital economy has the potential to contribute USD 180 billion to Africa's economy by 2025.[4] Accelerating access to affordable and sustainable connectivity on the African continent will revolutionize how key productive and social sectors perform. Satellite connectivity can bridge the digital divide and provide affordable connectivity solutions in both rural and urban areas. The African continent has a land area of 30.37 million square kilometres, equivalent to that of the U.S., China, India, Japan, Mexico, and many European nations combined.[5]Consequently, the cost of rolling out terrestrial connectivity infrastructure would be exorbitant.

In fact, in rural areas, satellite connectivity is the only viable connectivity solution given challenging geographic terrains such as mountains, thick forests, and large water bodies. In addition, the rollout of terrestrial connectivity (fiber optic cables, telecom towers, microwave backhaul, etc.) involves very high capital and operational expenses, as well as long waiting times to install and maintain.

Economic growth and prosperity have already been advanced by increased connectivity. The use of mobile money has seen an exponential increase, as more Africans make use of the technology to make and receive payments, trade on e-commerce platforms and access a broader range of financial services, traditionally reserved for the few that have bank accounts. In light of the Africa Continental Free Trade Area, satellites are the only technology that has the potential of providing an instant platform for cross-border connectivity that is required to enable a single digital market across the continent.

This paper will explain how satellites enable internet connectivity in Africa, with a specific focus on Ghana, Kenya, Niger, Nigeria, Rwanda, South Africa, and Uganda. The socio-economic impact of increased connectivity on agriculture, education, job creation, youth and women empowerment, health care, service

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[1]South African Institute of International Affairs (2020) "Africa's ICT infrastructure: Its present and prospects." https://saiia.org.za/research/africas-ict-infrastructure-its-present-and-prospects/

[2] World Bank (2020) Rural population SS Africa (2020) https://data.worldbank.org/indicator/SP.RUR.TOTL.ZS?locations=ZG

[3] Broadband Commission (2020) "The role of geostationary satellite networks in meeting the rural connectivity challenge." https://broadbandcommission.org/insight/the-role-of-geostationary-satellite-networks-in-meeting-the-rural-connectivity-challenge/

[4] IFC(2020) "e-Conomy Africa 2020." https://www.ifc.org/wps/wcm/connect/6a940ebd-86c6-4a38-8cac-5eab2cad271a/e-Conomy-Africa-2020-Exe-Summary.pdf?MOD=AJPERES&CVID=nmPYAEV#:~:text=Internet%20penetration%20is%2040%25%20today,create%2044%20million%20new%20jobs.

[5] VisualCapitalist (2020) "True Size of Africa." https://www.visualcapitalist.com/map-true-size-of-africa/

delivery, and climate change will be explored. The African satellite industry is experiencing an exciting growth spurt. This paper explores some of these developments and concludes with policy recommendations, including creating a transparent, forward-looking regulatory framework and ensuring that there is more knowledge transfer between international satellite operators and African satellite operators and regulators.

2. How do Satellites Facilitate Connectivity in Africa?

2.1 Africa's Meaningful Connectivity Challenge

ICT infrastructure is one of Africa's most critical requirements for Africa's socio-economic transformation. Many Africans still lack access to mobile or broadband connectivity and if they do, the prices are unaffordable. Studies undertaken by the International Telecommunication Union (ITU), found that only 14.3% of households in Africa had internet access by the end of 2019, with those in urban areas four times more likely to have access to the internet than those who lived in rural areas. The cost of connecting the unconnected by 2030 is estimated to be USD 100 billion.[6]

In terms of defining meaningful connectivity, the Alliance for Affordable Internet's approach is referenced, whereby a framework for meaningful connectivity comprises 4G-like speeds and smartphone ownership, amongst others.[7] Perhaps consideration should be given to defining meaningful connectivity in a way more applicable to satellites. The World Telecommunication Development Conference (WTDC) attempted to address this. The WTDC 2022 Provisional Final Report stated that "meaningful connectivity is a level of connectivity that allows users to have a safe, satisfying, enriching and productive online experience at an affordable cost."[8]

While basic connectivity is still a challenge in many places, meaningful connectivity (use of the internet every day using an appropriate device with enough data and a fast connection) is a ubiquitous problem in Africa. In Kenya and Rwanda for example, while close to 50% and 22% of the population have basic access to the internet, only 11% and 1% respectively are meaningfully connected.[9] In addition, consumer readiness (knowledge and digital literacy skills) and relevant content (applications and digital content designed for local languages and cultures) continue to hinder the use of the internet. For the 750 million who live in areas without access to broadband connectivity, infrastructure is the primary challenge. This includes a lack of power (only 38% of Africa's population has access to electricity),[10] poor roadways and bridges, and the absence of terrestrial telecommunications infrastructure.[11]

2.2 How do Satellites Enable Connectivity?

Space-based networks are vital to today's global communications infrastructure. Billions of people around the world rely on satellite infrastructure to communicate, travel, access information, and for entertainment. Satellites provide unique and differentiating key capabilities for communications systems

[6] ITWeb (2020) "ITU study lifts the lid on ICT adoption in Africa." https://www.itweb.co.za/content/xnklOqzLDZO74Ymz
[7] Alliance for Affordable Internet (2022) "Advancing Meaningful Connectivity: Towards Active and Participatory Digital Societies." https://a4ai.org/research/advancing-meaningful-connectivity-towards-active-and-participatory-digital-societies/
[8] International Tellecommuncation Union (2022) "World Telecommunication Development Conference 2022." https://www.itu.int/dms_pub/itu-d/md/18/wtdc21/c/D18-WTDC21-C-0103!R1!PDF-E.pdf
[9] Alliance for Affordable Internet (2022) "Advancing Meaningful Connectivity: Towards Active and Participatory Digital Societies." https://a4ai.org/research/advancing-meaningful-connectivity-towards-active-and-participatory-digital-societies/
[10] Engineering News (2021) "Africa's rowing infrastructure needs and ensuing business opportunities." https://www.engineeringnews.co.za/article/africas-growing-infrastructure-needs-and-ensuing-business-opportunities-2021-05-06
[11] Broadband Commission (2020) "The role of geostationary satellite networks in meeting the rural connectivity challenge." https://broadbandcommission.org/insight/the-role-of-geostationary-satellite-networks-in-meeting-the-rural-connectivity-challenge/

and are being used to provide a variety of services worldwide. This section presents the general satellite network architecture.

- An Internet Service Provider (ISP)/ Network Operating Centre is connected to the internet via fiber optic cables.[12]
- A satellite that is orbiting the earth will receive radio transmissions from ISP gateways and transmit this signal to a small satellite dish on the ground (generally on the roof of a house or building).
- The satellite dish will then connect to a satellite router (similar to a wi-fi router).
- The satellite router will transmit a signal to any device that will enable internet connectivity (phone or laptop).[13]

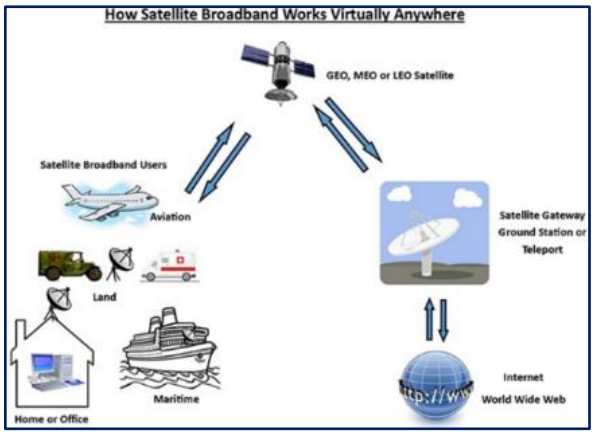

Figure 2: Explaining satellite connectivity.
Source:https://docs.google.com/document/d/1DMbWbzgyMHrGe4AdcRGLbwYvOeZNwnT6/edit

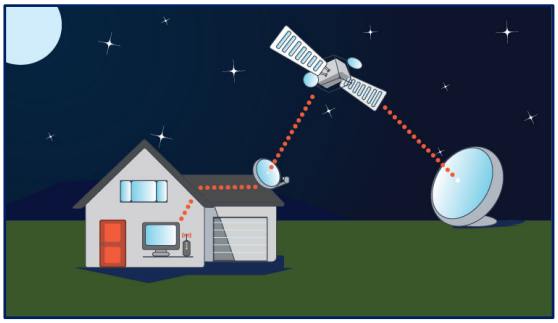

Figure 1: Explaining satellite connectivity. Source: https://www.reviews.org/internet-service/satellite-internet-work/

2.3 Satellite Backhaul

Satellite backhaul enables cellular services to be provided in areas where traditional terrestrial connectivity such as fiber, cable, or microwave are too expensive or impossible to install. Satellites, backhaul (backhaul facilitates data distribution over a network) cellular traffic allowing Mobile Network Operators to carry 2G, 3G, and 4G/LTE traffic.

Satellite backhaul is used where geographic challenges such as mountains and heavily forested areas make terrestrial backhaul (such as fiber optic cable or microwave links often referred to as last-mile connectivity) prohibitively expensive. In addition, given the lower population densities found in most rural areas, terrestrial backhaul becomes financially unsustainable.[14] Geostationary satellite networks provide ubiquitous coverage to 99% of the world's populated areas.

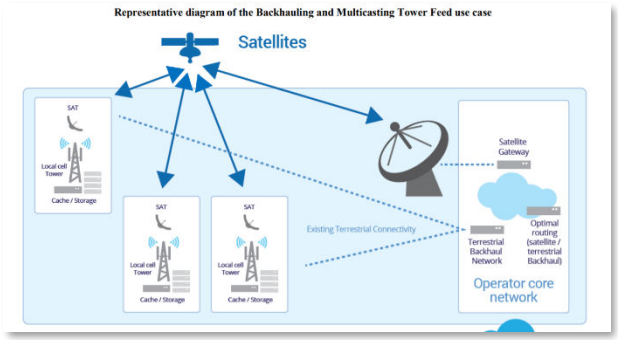

Figure 3: Satellite backhaul. Source: https://www.itu.int/dms_pub/itu-r/opb/rep/R-REP-M.2460-2019-PDF-E.pdf

Distance and topography are not constraints when providing backhaul connectivity to hard-to-reach areas. Also, because satellite coverage is everywhere, service providers can connect to any number of rural and remote wireless sites in far less time than if using fiber or microwave. Terrestrial connectivity struggles to

[12] International TelecommunicationUnion (2019)"Key elements for integration of satellite systems into Next Generation Access Technologies. https://www.itu.int/dms_pub/itu-r/opb/rep/R-REP-M.2460-2019-PDF-E.pdf
[13] Ground Control (2021) "How does satellite internet work." https://www.groundcontrol.com/how-does-satellite-internet-work/
[14] Intelsat (2020) Cell backhaul MNO Product Sheet https://www.intelsat.com/wp-content/uploads/2020/08/intelsat-cellbackhaul-MNOs-product-sheet.pdf

overcome geographic and economic challenges.[15] In 2019, Intelsat conducted a webinar hosted by GSMA, with mobile operators and industry verticals in attendance. During the webinar, two polls were conducted to better understand the challenges that mobile operators face when considering expanding broadband coverage into remote, hard-to-reach areas. In the first poll, the question posed was: "What is the biggest challenge to building mobile coverage in rural and remote areas?" The answers received indicated that high operating (installation and maintenance) costs, as well as a low return on investment, were the biggest obstacles.[16]

"Only satellite offers the means to connect hundreds even thousands of rural and remote sites, spread out geographically, to a provider's core network and the internet using a single pipe of satellite capacity, which is then distributed across the entire network of sites (cellular and or Wi-Fi) based on peak usage per site. Only by including satellite-based backhaul in a strategy to bring connectivity to rural areas and remote communities can the connectivity gap ever be closed."
Mr. S Spengler – CEO, Intelsat (2019)

Figure 4: Quote by Intelsat CEO. Source: https://broadbandcommission.org/insight/the-role-of-geostationary-satellite-networks-in-meeting-the-rural-connectivity-challenge

Satellite backhaul is also frequently used to back up critical sites served by a single fiber or by unreliable terrestrial connections, as well as in cases of emergency response. If there is an outage, traffic is instantly swapped over to the always-on satellite connection resulting in little or no traffic loss. Satellite companies are constantly upgrading their technology to improve the efficiency and efficacy of their backhaul connectivity solutions. Satellite backhaul is a critical component of the wireless terrestrial infrastructure today, and will continue to be vital for 5G as well.[17]

There have been several misconceptions around satellite backhaul, relating to the cost of satellite backhaul being too high or satellites being unable to support high-speed connections. These views, do not consider the continuous innovations in space platforms, such as high-throughput satellites, and satellite hubs and modems that incorporate new acceleration technologies. Today, users are ensured fiber-like experiences when connecting their devices to satellite-backhauled networks. Modern satellite systems, make use of smaller antennas, which are more readily transported across long distances, require less power to operate and are ideal for solar power supply.

New geostationary satellite networks allow bandwidth to be dynamically allocated to rural and remote network sites across regions using a single pool of satellite capacity. This means that capacity is efficiently utilized based on traffic patterns across the network of sites, ultimately reducing the cost of backhaul per site compared to fiber.

[15] Broadband Commission (2020) "The role of geostationary satellite networks in meeting the rural connectivity challenge." https://broadbandcommission.org/insight/the-role-of-geostationary-satellite-networks-in-meeting-the-rural-connectivity-challenge/
[16] Ibid
[17] EMEA Satellite Owners Association (ESOA) "Input Contribution to TG on Spectrum Recommendations for Rural Connectivity." https://docs.google.com/document/d/1DMbWbzgyMHrGe4AdcRGLbwYvOeZNwnT6/edit

2.4. Advancing Affordability Through Innovation

Africa has the most expensive internet in the world. The Alliance for Affordable Internet states that Africans pay on average 8,8% of their monthly income to purchase 1GB of data, compared to 3,6% in Latin America and 1,5% in Asia. In Chad, the DRC, and the Central African Republic, 1GB was found to cost as much as one-fifth of earnings. Beyond costs, there is also the challenge of coverage - one in four Africans are still not covered by any mobile broadband signal, and half of those who are covered do not use the internet.

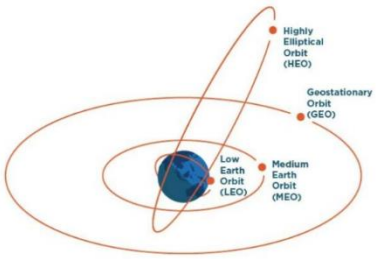

Figure 5 Satellites in geosynchronous and geostationary orbit match the Earth's rotation, thus staying "in synch" or "stationary" over the same point of the planet as the Earth turns

Technological developments in innovation related to low orbit satellites, geosynchronous orbit (GSOs) and non-geostationary orbit (NGSOs), and mega-constellations (groups of satellites that work together as a system), will make satellite connectivity more affordable and accessible. SpaceX's Starlink, Iridium, Boeing, Orbcomm, GlobalStar Amazon, OneWeb, and Telesat, are a few of the companies which are working on making satellite connectivity more accessible and affordable.[18] Intelsat through its fleet of EPIC GSO satellites has contributed to significant satellite connectivity cost reductions, further efficiencies are expected to be reached through forthcoming technological advancements and the launch of software-defined satellites(satellites can refresh and reconfigure themselves based on demand.)

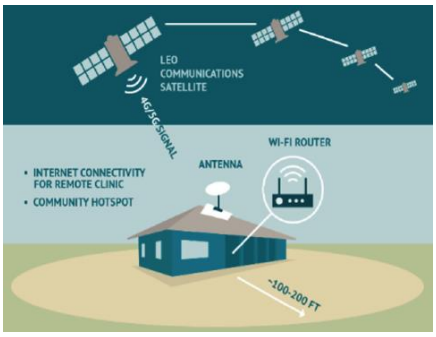

Figure 6 Notional deployment of satellite broadband to remote clinic, extended locally via wifi or mesh network.

Low Orbit Earth (LEO) satellites are only a few hundred kilometers away from the Earth compared to traditional geostationary satellites, which are generally 35 000 km away. Since LEO satellites are smaller and closer to Earth, they require less time and power to send through signals, thus significantly reducing the cost of satellite connectivity. Inmarsat has "hybrid" constellations of high elliptical orbit (HEO), GEO, and LEO satellites, resulting in a more affordable service offering. In Australia, two geostationary Sky Muster satellites are providing services to over 100,000 points in rural and remote areas.

Another approach is to eliminate the need for satellite-dedicated receivers and instead enable "satellite-to-cellphone" connectivity. Such projects, however, need to consider the international radio regulations, to make sure they comply with existing regulations for the provision of Mobile Satellite Services (MSS) in the same frequency bands already used for cellular communications.

Figure 7 Satellite to Mobile connectivity https://lynk.world/our-technology

[18]EngineeringNews "Low orbit satellites may improve banking for developing world." https://www.engineeringnews.co.za/article/low-orbit-satellites-may-improve-banking-for-developing-world-2022-01-13

Satellite technology is used not only by mobile operators but also by media broadcasters, governments and the maritime industry. For example, DSTV, Africa's largest broadcaster of satellite TV and entertainment, uses Intelsat satellites to stream its channels over the African continent[19]. Intelsat has also supported defense communication for numerous African governments. Intelsat provides broadband connectivity to ships and aircraft (inflight connectivity) that connect Africa to the rest of the world. In the event of a disaster or crisis, Intelsat satellites are used for emergency communication. Satellites are extensively used in the meteorological sector to monitor weather patterns and provide critical information to multiple sectors including agriculture, transport, and emergency responses.

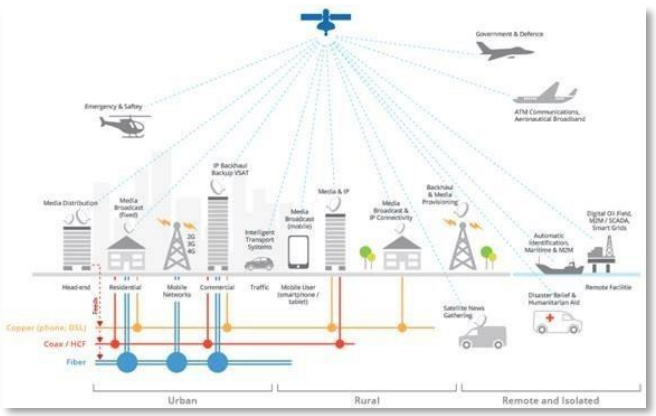

Figure 8: Connectivity solutions provided by satellites. Source: Maxar Blog

In addition, satellites can play a critical role in the provision of the Internet of Things (IoT), machine-to-machine (M2M), and Smart City communications. Intelsat satellites are used to enable communication between ATMs and banks. Satellites are uniquely suited to meet the demands of any time, anywhere communications for these services.[20]

3. The Socio-Economic Benefits of Satellite Connectivity

African governments are working hard to realize the demographic dividend by providing job opportunities to hundreds of millions of young people. This will spur sustainable economic growth and development, help eradicate poverty and reduce the income inequality the continent faces. The World Bank found that a 10% increase in broadband penetration would lead to a 2% to 3% increase in the employment rate.[21] Optimistically, a McKinsey report noted that the Covid-19 crisis "contains the seeds of a large-scale reimagination of Africa's economic structure, service delivery systems, and social contract."[22] The crisis is accelerating trends such as digitalization, market consolidation, and regional cooperation, and is creating important new opportunities. Similarly, the World Bank argues that reforms that address the digital infrastructure gaps and make the digital economy more inclusive not only ensure affordability but also build skills across all segments of society, which subsequently generates more jobs.[23] Access to connectivity is increasingly recognized as a human right[24] and an essential basic need for communities and enterprises. Shrinking the digital divide enables access to health care and emergency services, financial services, education, and employment opportunities.

In terms of the needs of the youth, more action is required to ensure that they have access to the internet. According to UNICEF, roughly 29% of the world's youth remain offline, limiting their ability to "fulfill their

[19] Satellite Today (2012) Multichoice moves DSTV to Intelsat "https://www.satellitetoday.com/broadcasting/2012/08/31/multichoice-moves-dstv-service-to-intelsat-20/

[20] International TelecommunicationUnion (2019) "Key elements for integration of satellite systems into Next Generation Access Technologies. https://www.itu.int/dms_pub/itu-r/opb/rep/R-REP-M.2460-2019-PDF-E.pdf

[21] Huawei (2020) "ICT Investments and Partnerships key to fueling Africa's digital growth ." https://www.huawei.com/br/technology-insights/industry-insights/outlook/mobile-broadband/wireless-for-sustainability/feature-stories/ict-investment-and-partnership-key-fuelling-africas-digital-growth

[22]United Nations (2021) Post-COVID-19 chance to leapfrog Africa's development through digitalization." https://www.un.org/africarenewal/magazine/march-2021/post-covid-19-chance-leapfrog-africas-development-through-digitalization

[23] World Bank (2021) "Amid recession SS Africa poised for recovery." https://www.worldbank.org/en/news/press-release/2021/03/31/amid-recession-sub-saharan-africa-poised-for-recovery

[24] Ann-Marie Grey (2020) "The Case for Connectivity, the New Human Right." https://www.un.org/en/un-chronicle/case-connectivity-new-human-right#:~:text=And%20make%20no%20mistake%20about,online%20counselling%20or%20health%20care.

potential and break intergenerational cycles of poverty." Broadband connectivity over satellite backhauled mobile and Wi-Fi networks give youth access to quality education and information that helps them improve their own lives and the communities they live in.[25]

3.1 Connecting Rural Areas – Bridging the Urban-Rural Digital Divide

In 2021, Eutelsat launched Konnect, its satellite broadband initiative in Africa. Konnect delivers easy, affordable, and fast internet, supporting social and economic development by creating new digital highways that terrestrial networks cannot reach. In Tanzania, Eutelsat Konnect partnered with Vodacom to extend internet access to businesses operating in rural areas. This partnership will enable Vodacom to provide 100% coverage throughout Tanzania, connecting previously unconnected areas in regions, districts, and villages within the country.[26] In Nigeria, Eutelsat undertook a similar partnership with Globacom (Glo), enabling Glo to provide connectivity in underserved areas throughout Nigeria.[27]

Figure 6: AMN base station in Benin. Source: VLN

Similarly, Gilat Satellite Networks, working with African Mobile Networks (AMN), has established Africa's largest satellite cellular backhaul network, extending coverage to several African countries. AMN works with telcos and builds mobile network base stations that serve rural communities in sub-Saharan Africa with no existing service.[28] Satellite company Intelsat is a shareholder of AMN, and both corporations are committed to creating Africa's largest cellular backhaul network.

In Benin, AMN installed a base station that utilizes a solar-based electrical power system and a satellite-based backhaul communication link to make the base station completely autonomous with no reliance on any local infrastructure. The base station can deliver service to a range of up to 7 km and covers approximately 150 sq. km.[29]

3.2 Connecting Rural Schools and Health Facilities

The COVID-19 pandemic has affected 1.5 billion children who were unable to attend school. Remote learning has assisted those in developed countries, however, in sub-Saharan Africa, about a third of the population remains out of reach of 3G networks. Satellite connectivity has provided a seamless solution to the challenges posed by remote learning. In Kenya, iManglo, an education technology program, facilitates high-quality training (for both parents and teachers) through satellite broadband connectivity. Avanti Communications Group provides satellite broadband connectivity via its HYLAS 2 Ka-band satellite. This satellite broadband, as opposed to terrestrial networks, which are almost

Figure 7: iMlango education programme that uses satellite broadband connectivity. Source: Avanti Communications Group.

[25] Broadband Commission (2020) "The role of geostationary satellite networks in meeting the rural connectivity challenge." https://broadbandcommission.org/insight/the-role-of-geostationary-satellite-networks-in-meeting-the-rural-connectivity-challenge/

[26] BusinessWire (2021)" Eutelsat's Konnect Africa and Vodacom Partner to Bring High-Speed Broadband to Unserved Regions of Tanzania." https://www.businesswire.com/news/home/20211202005455/en/Eutelsat%E2%80%99s-Konnect-Africa-and-Vodacom-Partner-to-Bring-High-Speed-Broadband-to-Unserved-Regions-of-Tanzania

[27] Africa.com (2021)"Eutelsat's Konnect Africa Selected by Globacom to bring satellite broadband to underserved regions of Nigeria." https://www.africa.com/eutelsats-konnect-africa-selected-by-globacom-to-bring-satellite-broadband-to-underserved-regions-of-nigeria/

[28] ViaSatellite(2021) "African satellite cellular bakhaul network expands coverage with Gilat Hubs." https://www.satellitetoday.com/telecom/2021/11/15/african-satellite-cellular-backhaul-network-expands-coverage-with-gilat-hubs/

[29] VNL(2021) "VLN teams up with Gilat for Africa Mobile Networks in Benin." http://staging.vnl.in/innovision/vnl-teams-up-with-gilat-for-africa-mobile-networks-amn-in-benin

non-existent in remote communities, connects primary schools to the internet for further access to the e-learning platform. The program runs in selected primary schools across four counties: Kilifi, Kajiado, Makueni, and Uasin Gishu. These schools were selected based on factors such as poverty rates, attendance statistics, access to electricity, and marginalization of female children.[30]

Access to quality primary and secondary education empowers citizens and provides them with numerous opportunities, such as furthering their studies at universities and TVETs[31] and entering the workforce with confidence. Similarly, lack of access to adequate education hinders opportunity and progress. In 2017, Intelsat collaborated with the United Nations High Commission for Refugees Ghana to build an ICT Center that provided free Wi-Fi for refugees in the Ampain refugee camp. The Ampain refugee camp was established in 2011, to shelter displaced citizens from Cote D'Ivoire, who had fled to escape the violence that ensued after the 2010 election.[32]

Intelsat has a 20-year partnership with Mindset Network (an organization that develops and delivers educational resources to students, teachers, health care professionals, and patients across Africa.) The Intelsat 17 enables Mindset to broadcasts its health and education channels to clinics and schools across the African continent. This has enabled Mindset to deliver educational materials to 1,607 schools, 1,025 health care facilities and 6 million homes.[33]

In recognition of the urgent need to connect the education sector to the internet, UNICEF and the ITU launched the GIGA[34] initiative to bring together a multi-stakeholder coalition to help map, finance and connect every school in the world. Satellites are expected to play a critical role in achieving this ambitious mission.

"I have plans of becoming an entrepreneur, so I have been focusing on trainings in the area of business development and how to manage a business. Hopefully when I'm done, I'll be able to use the knowledge and skills I've acquired to achieve my dream. I wouldn't know how life in the camp would have been like without this ICT Center"

Hama Virginie – Ampain Refugee Camp Ghana (2017)

Figure8, 9 and 10: Intelsat ICT Centre at Ampain Refugee Camp. Source: https://www.unhcr.org/gh/2019/06/16/e-learning-access-positively-impacts-refugees-in-ampain-refugee-camp/

[30] Space in Africa (2020) How satellite technology is supporting learning in Africa despite COVID-19." https://africanews.space/how-satellite-technology-is-supporting-learning-in-africa-despite-covid-19/

[31] Technical and Vocational Education Training

[32] UNHCR (2018) "Innovation and creativity in education for refugees." unhcr.org/gh/2018/10/31/innovation-and-creativity-in-education-for-refugees/

[33] Intelsat (2020) "Intelsat and Mindset Networks 18 year partnership expands access to high impact social economic education resources across Africa during COVID-19." https://www.intelsat.com/newsroom/intelsat-and-mindset-networks-18-year-partnership-expands-access-to-high-impact-social-economic-education-resources-across-africa-during-covid-19/

[34] GIGA Website (2022) https://giga.global/

3.3 Connectivity, Emergency Assistance and E-Governance

Satellite broadband networks are not susceptible to damage from disasters, because the primary repeaters are on board the spacecraft and not part of the ground infrastructure. Hand-held terminals, portable Very Small Aperture Terminal (VSAT) antennas and temporary fixed installations can all be introduced into a post-disaster environment to provide support to relief and recovery efforts. For example, satellite telecommunications equipment was deployed in Mozambique and Zimbabwe after the severe devastation caused by Hurricane Ida in 2019. The hurricane hit Mozambique, the city of Beira, before striking Zimbabwe and Malawi. Hurricane Ida caused devastating floods, killed and injured thousands of people and damaged crops, houses and roads. More than 2.6 million people were affected across the three countries, with most of the districts being almost completely cut off. All terrestrial communications infrastructure was destroyed. Satellite telecommunications equipment was sent to the devastated areas where telecommunications were most needed for the coordination of response efforts on the ground.[35]

E-government, which consists of automating and delivering government services to citizens and businesses online, is a powerful means to drive state services' efficiency, affordability, convenience and transparency. In Nigeria's Kaduna State, the government employed Yellow Line Services, a Kaduna-based IT company, to facilitate electronic voting during its 2018 local government elections, Nigeria's first and Africa's second electronic voting exercise.[36]

Education and healthcare are by far the largest social sectors that are supported by governments. COVID-19 has demonstrated how digital services can be used to track infection rates and assist with vaccine rollout. During the long months of lockdowns, innovative use of ICT – especially the internet – allowed governments to provide education to millions of children and students across the African continent. African governments have also partnered up with innovative start-ups to accelerate and simplify processes like medical supply delivery to rural areas. The Governments of Rwanda and Ghana partnered with Zipline to develop and deploy drones to deliver blood and medical supplies to rural areas. Orders can be made by phone call, SMS or WhatsApp, and delivery takes minutes instead of hours or days. When Zipline's flight operations began in 2016, the company had contracts with 21 hospitals in Rwanda and only delivered blood. It has since expanded to 160 different medical products including COVID-19 vaccines and is contracted to serve close to 2,500 hospitals and health facilities across Rwanda and Ghana.[37]

Satellite companies like Inmarsat, Intelsat, Iridium, and SES Satellites often work with governments, ensuring they remain connected and can undertake critical communications. Iridium worked with the Kenyan government and the South Rift Association of Landowners (SORALO – a land trust collectively owned by 16 Maasai communities), to improve communications and maintain the peaceful coexistence between people and wildlife. SORALO employs 35 community rangers who patrol the lands to monitor human-wildlife interactions, prevent illegal activities like poaching, and communicate with state authorities regarding emergencies. However, the rangers' old communication infrastructure used a patchy network of cell towers and basic analog radio, limiting their abilities to communicate reliably with each other or Kenyan security agencies. SORALO worked with Kinetic6, a UK-based

Figure 8: Game ranger in Rift Valley using satellite communication.
Source: Iridium.

[35] EMEA Satellite Owners Association (ESOA) "Input Contribution to TG on Spectrum Recommendations for Rural Connectivity." https://docs.google.com/document/d/1DMbWbzgyMHrGe4AdcRGLbwYvOeZNwnT6/edit
[36] TechPoint (2018) "Inside Nigeria's first ever exercise in Kaduna state." https://techpoint.africa/2018/05/14/kaduna-electronic-voting/
[37] Noah Lewis (2020) "A tech company engineered drones to deliver vital COVID-19 medical supplies to rural Ghana and Rwanda in minutes" https://www.businessinsider.com/zipline-drone-coronavirus-supplies-africa-rwanda-ghana-2020-5?r=US&IR=T

Iridium partner, to purchase Iridium Extreme PTT handheld devices, along with base station vehicle mounts, to allow for group communications on patrols. [38]

3.4 Connectivity and Financial Inclusion

Financial services for businesses and consumers are the foundation of economic growth and individual prosperity. Restricted access to loans, insurance and payment systems slows commercial activities. Historically, financial exclusion has been one of the major economic challenges facing Africa. In 2011, less than a quarter of African adults owned an account in a financial institution. By 2017, only 34% of Africans have access to a formal bank account.[39] However, the advent of mobile financial services dramatically changed the financial inclusion landscape with the number of mobile money accounts growing by more than 10-folds over the last 10 years to more than half a billion.[40]

Traditional banks, mobile money companies and fintech applications only function if they and their users have connectivity. SatADSL (a Belgian-based satellite operator) has designed a cost-effective ATM solution to enable financial institutions to roll out their networks in urban, suburban, or rural areas. The solution facilitates the secured execution on a real-time basis of every transaction from a large and scattered network of ATMs. Ecobank, the largest bank in Africa, has chosen SatADSL's solution to roll out its ATM network across Ghana.[41]

In 2017, MTN launched MTN Mobile Money (MoMo). MTN Mobile Money is a secure electronic service that enables MTN Mobile Money wallet holders to store funds, send and receive money, make payments and undertake many other transactions simply by using their mobile phones. Payment is simple, convenient and affordable. The service is offered by MTN in partnership with over 10 partner banks, in several countries across Africa.[42] In Uganda, MTN made use of Intelsat's satellite backhaul connectivity to provide mobile connectivity services to Ugandans in rural areas, thereby enabling them to receive and make payments via the MoMo application. Cross-border payments are also critical for the success of the Africa Continental Free Trade Area, which seeks to accelerate intra-Africa trade which sits at a paltry 2%.[43] Many fintech companies such as Opay and Wave have achieved remarkable success in this space, reaching the highly symbolic "unicorn" milestone in 2021.

3.5 Connectivity and Entrepreneurship

Technology innovation constitutes an avenue for engaging Africa's entrepreneurs in finding solutions to local and global problems, while creating jobs and wealth, and helping countries achieve the Sustainable Development Goals (SDGs). The number of innovation hubs, accelerators, incubators, and startup studios is growing rapidly, particularly in urban areas. In 2019, GSMA registered 618 active tech hubs, a 40% increase over the previous year.[44] In contrast, businesses in rural or remote areas often struggle with connectivity challenges, hampering their revenue and constraining their growth. The demand for closing the rural-urban digital divide to empower rural SMEs has however started attracting innovative solutions

[38] Iridium "Case studies: Iridium push to talk helps promote coexistence between communcities and wildlife in Kenya." https://www.iridium.com/case-studies/iridium-push-to-talk-helps-promote-coexistence-between-communities-and-wildlife-in-kenya/
[39] European Investment Bank (2017) Banking in SS Africa: Interim Report on Digital Financial Inclusion." https://www.eib.org/attachments/efs/economic_report_banking_africa_interim_2017_en.pdf
[40] Alexander Onukwue (2020) "How mobile money grew in sub-Saharan Africa in the last 10 years" https://qz.com/africa/2065566/mobile-money-has-grown-13-fold-in-sub-saharan-africa-since-2011/
[41] Tech Africa News (2021) "Ecobank chooses SatADSL ATM solution for a pan Ghana rollout." https://www.techafricanews.com/2021/11/01/ecobank-chooses-satadsls-atm-solution-for-a-pan-ghana-rollout/
[42] World Remit (2021) "Everything you need to know about MTN Mobile Money." https://www.worldremit.com/en/mtn-mobile-money
[43] World Economic Forum (2021) AfCFTA Free Trade Paytech." https://www.weforum.org/agenda/2021/08/afcfta-africa-free-trade-paytech/
[44] Brighter bridges (2019) "618 Active Tech Hubs in Africa". https://briterbridges.com/618-active-tech-hubs

such as community networks.[45] BeepTool, a Nigerian-based technology company, has launched a satellite that integrates TV Whitespaces with Wi-Fi hotspots. The solution can use backhaul for connectivity without barriers to offering faster and cheaper connectivity solutions that provide connectivity to an entire village. The integrated SuperWifi provides remote Wi-Fi hotspots, while the TV WhiteSpace technology covers long-distance. The device is designed to work with the following satellite operators: NigComSat, SES, ViaSat, Telesat, Avanti, Intelsat on C/Ku, Ka and S-Band, and in the pipeline to accept signals from SAS and OneWeb satellites.[46] BeepTool is used by entrepreneurs and small business owners in rural and underserviced areas in Nigeria – enabling them to provide free Wi-Fi for their customers and ensuring they can communicate with their service providers.

3.6 Connectivity, Agriculture, and Climate Change

In most African countries, the agricultural sector dominates economic output and employs the vast majority of the working-age population. The agriculture sector can contribute toward major continental priorities, such as eradicating poverty and hunger and boosting intra-Africa trade and investments.[47] In Uganda, agriculture constitutes 25% of GDP and employs 70% of the population. An agricultural application called m-Omulimisa uses mobile technology to empower small-hold farmers with access to loans, extension services, inputs, and market information, ultimately increasing their productivity and yield. In 2017, Uganda had a Fall Armyworm outbreak that damaged millions of hectares of maize crops. M-Omulimisa sent out a message informing farmers of which fertilizers and pesticides would protect their crops from the outbreak. Farmers that were illiterate or who did not speak English were connected to pre-identified partner farmers who spoke the local language and could relay this information.[48]

Connectivity can play a transformative role in improving the agricultural sector and enhancing efficiencies. According to the World Bank, half of the world's habitable land is used for agriculture, yet about half of the world's population remains unconnected. Satellite communications reach more than 99% of the globe's populated area and can play a key role in bridging this existential digital gap. As the above example illustrates, satellite communications allow farmers to access faster, reliable, accurate, and timely information for better decision-making and automated practices that directly impacts their output. With the economics of terrestrial broadband deployment for rural communities and areas of high agricultural production being prohibitive, the use of satellite communications for precision agriculture is critical to the future of agriculture operations.[49]

[45] APC (2019) "Community access networks: How to connect the next billion to the Internet". https://idl-bnc-idrc.dspacedirect.org/bitstream/handle/10625/59166/IDL-59166.pdf
[46]Space in Africa (2020) "Beeptool launches integrated satellite TV Whitespace wi-fi hotspot terminal." https://africanews.space/beeptool-launches-integrated-satellite-tv-whitespace-wi-fi-hotspot-terminal/
[47]NEPAD(2013) "Agriculture in Africa." https://www.tralac.org/images/docs/6460/agriculture-in-africa-transformation-and-outlook.pdf
[48]Africa Portal (2021) "Rooting Africa's COVID-19 recovery: the role of innovation, digital technologies and labour markets." https://www.africaportal.org/features/rooting-africas-covid-19-recovery-the-role-of-innovation-digital-technologies-and-labour-markets/
[49] ESOA (2020) "Satellite communication and the future of agriculture." https://esoa.net/reports_and_studies/nearly-a-billion-people-across-the-world-experience-the-effects-of-food-insecurity/

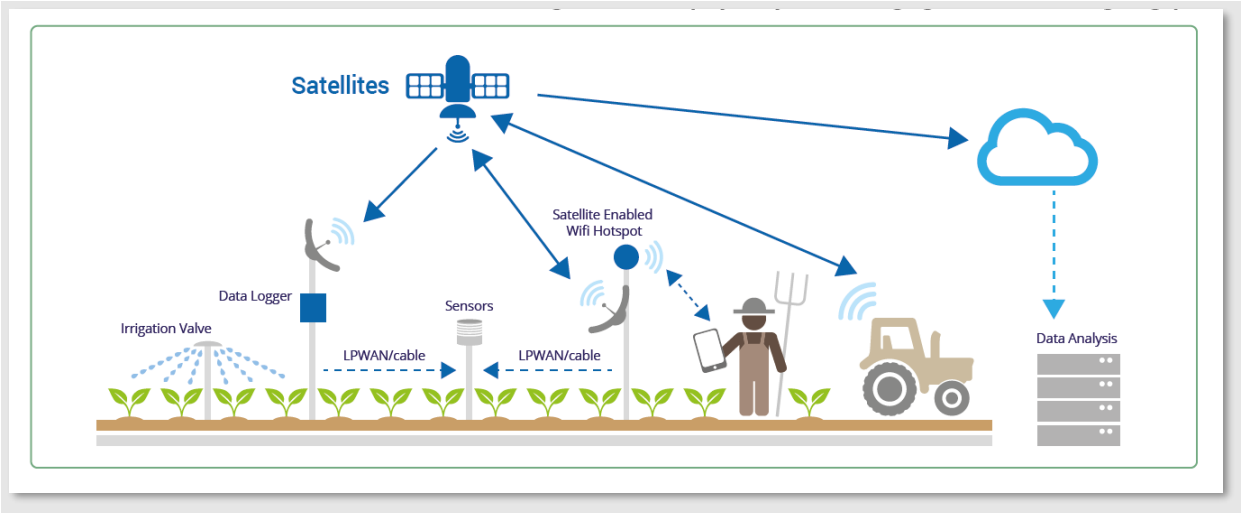

Figure 94 ESOA (2020) "Satellite communication and the future of agriculture." Source: https://esoa.net/reports_and_studies/nearly-a-billion-people-across-the-world-experience-the-effects-of-food-insecurity/

Satellites are also instrumental in addressing climate change. Satellite remote sensing allows for the collection of data and information about the earth's surface, oceans, and atmosphere. Satellite data helps scientists to understand the climate system by monitoring greenhouse gases, weather patterns, vegetation health, melting of glaciers and polar ice, bleaching of coral reefs, ocean acidification as well as wildlife migratory patterns. Satellites not only monitor the global environments, but its technological innovations such as miniaturization of sensors, high-speed data transfer, and upgraded storage capacity have also revolutionized climate science. [50]

In Africa, satellites are used to track deforestation (deforestation creates significant carbon emissions and is a major contributor to climate change). Whilst collecting and analyzing satellite imagery, scientists have found that deforestation has decreased significantly in 22 African countries. In these countries, organizations subscribed to a free service that sends out alerts about decreases in forest cover in the tropics from a news service that uses up-to-date satellite data. When there is a drop in forest cover, these automated warnings send high-resolution satellite data and alert messages to those in local governments and others interested in decreasing deforestation.[51]

3.7 Connecting the Health Sector

The use of digital health solutions exploded across the globe during the COVID-19 pandemic. Digital applications were used to perform complex surveillance and response tasks at an unprecedented scale. Telemedicine enabled continuity of care in situations where the provision of in-person care was not possible. Beyond the pandemic, digital health is expected to be an integral component of the universal health coverage strategies, aimed at providing accessible, affordable, and equitable care. In the context of Sub-Saharan Africa, where 13% of the world's population and only 2% of its doctors live, technology is expected to be a major enabler for addressing the 24% of the global disease burden that the continent suffers from.

Satellite-enabled connectivity solutions are therefore going to be critical to ensure that Africans, especially those in rural areas, are not left behind. Experts estimate that USD 25 to 30 billion in new investment will be needed in healthcare assets only, to meet Sub-Saharan Africa's growing healthcare demands. Investment efforts must consider the healthcare sector's connectivity needs, both at a facility and individual healthcare worker level. The possibilities presented by digital health will enable governments

[50] Earth.org (2021) "How satellites help tackle climate change." https://earth.org/data_visualization/how-satellites-help-tackle-climate-change/
[51] Space.com (2021) "How satellites are stopping deforestation in Africa." https://www.space.com/satellites-decreasing-deforestation-africa

and development partners of the health sector to address pressing issues, such as those created by rapid urbanization and the resulting urban/rural inequality in terms of access to healthcare, and the low ratio of health professionals to the population.[52]

As the world shifts gears from responding to COVID-19 to strengthening health systems and preparing for the next pandemic, ambitious projects such as the GIGA initiative should be created for meeting the connectivity needs of African health facilities and the healthcare workforce. Such connectivity would be useful to help quickly detect and efficiently respond to disease threats while providing a platform for educating the workforce and collecting the data that public health authorities need to make policy and operational decisions.

While there are no reliable sources of data on how many health centers have an internet connection in Africa, the school connectivity map produced by the GIGA initiative can provide a proxy for estimating the situation. In countries such as Niger and Benin, school connectivity is below 5% while Rwanda and Botswana have about 50% of their schools connected. Assuming a similar distribution, it is safe to assume that more than half of health facilities in Africa are not connected. In those circumstances, an internet connection to a health facility could serve the neighboring communities in ways that help spur the benefits of connectivity such as creating opportunities for digital skills development, innovation, entrepreneurship and job creation.

4. The Future of Satellite Connectivity in Africa.

According to the African Space Industry Annual Report 2021, the African space industry is set for significant growth. African governments are spending 9% more budget on their space industry, with several African governments developing national space programs. For example, Botswana launched a space program in December 2020, the Rwandan legislature approved the law establishing Rwanda Space Agency in March 2021, Namibia launched a National Space Science and Technology Policy in June 2021, and Burkina Faso, Djibouti, and Zambia are now developing new satellites that will launch their national space program. [53]

Through "Agenda 2063: Africa We Want" the African Union has identified space technologies as a critical tool that can boost Africa's economic growth and development and lead to the rapid transformation of the continent. [54]

5. Policy Recommendations

Due to the critical role played by satellites in connectivity across the African continent, African governments should actively promote the use of satellite technology, especially since satellite technology facilitates connectivity in rural and underserviced areas where terrestrial connectivity cannot be deployed and is extremely expensive.

This paper identifies three priority areas that government and private sector stakeholders should focus on:

[52] Virginia Economic Development Partnership (2021) Industry Report Africa – Healthcare / Life Sciences https://exportvirginia.org/sites/default/files/2021-07/Africa_Healthcare_Report_July_21.pdf
[53] Space in Africa (2021) "African Space Industry revenue to surpass USD 10.24 billion by 2024 despite COVID=19 setback." https://africanews.space/african-space-industry-revenue-to-surpass-usd-10-24-billion-by-2024-despite-covid-19-setback/
[54] *Ibid*

5.1 Dedicated Resources to Satellite Connectivity

Both private (financial institutions, industry bodies like GSOA) and public stakeholders (UN bodies like the ITU and national authorities) will need to prioritize funding for space programs in African countries. From a funding perspective, national authorities should ensure that infrastructure budgets have dedicated national space program allocations. International funding institutions like the World Bank and its private investment arm the International Financial Corporation can collaborate with governments, supplementing their space funding where possible.

All stakeholders "need to consider what investments should be made to maximize public benefits and mitigate risks of an increasingly space-based global telecommunications infrastructure. Leveraging these options could greatly reduce the cost and difficulty of connecting sparsely populated, dangerous, or geographically difficult places", especially in rural parts of Africa where terrestrial solutions are too expensive.[55]

5.2 Implementation of a Regulatory Framework that Encourages Satellite Connectivity

The World Radiocommunication Conference 2023, will review, and, if necessary, revise the Radio Regulations which govern the use of the spectrum and global policy for the use of the electromagnetic spectrum and the geostationary-satellite and NGSO satellite orbits. African administrations like the African Telecommunication Union (ATU), and regional associations like ECOWAS, SADC and EACO should ensure that regulations recognize the economic and social role that satellites play in Africa. Additionally, satellites usually have a lifespan of 15 years or more and require a large, up-front investment. Therefore, regulatory certainty, which provides business assurance to the industry, is critical.

To this end, all African administrations should publish and implement a transparent regulatory framework for satellite services, providing regulatory certainty to support long—term investment. Lastly, African administrations should aim toward harmonization of the frequency allocation and licensing process across African jurisdictions. A first step was taken by the ATU, that in 2021 established a Task Group (TG) to develop a satellite licensing framework for African Member States. The TG developed a Model Framework for satellite licensing among the ATU Member States. The Model Framework is not binding, but Member States will use it as guidelines when developing/implementing their regulatory framework.

Similarly, the ATU recommended that a separate TG should be established to adopt a harmonized approach to regional licensing and seamless movement of Earth Stations in Motion (ESIMs) among ATU Member States. ESIMs are earth stations that communicate with satellite systems operating in the fixed-satellite service - in essence, ESIMs provide reliable and high bandwidth internet services to mobile platforms such as ships, aircraft, and land vehicles.[56]

Demand for mobile data is rising rapidly, and requirements for spectrum may change over time. Mobile Network Operators (MNOs) and manufacturers are constantly pushing for additional spectrum to meet this increasing demand. Nevertheless, it is also necessary to consider the national, market, and MNO requirements when spectrum analysis and allocations are made. In terms of MNOs, 4G deployments need to continue before focus can shift to investments in 5G infrastructure.[57] The driving factors in the adoption of 5G services will depend on the cost of end-user devices and the development of the IoT and machine-

[55] https://www.cgdev.org/publication/space-and-development-preparing-affordable-space-based-telecommunications
[56] International Telecommunication Union (2020) "Earth stations in motion, satellite issues." https://www.itu.int/en/mediacentre/backgrounders/Pages/Earth-stations-in-motion-satellite-issues.aspx
[57] Wall Street Journal (2022) "What's Holding Back 5G rollout." https://www.wsj.com/articles/what-holding-back-5g-rollout-11647144776?mod=rss_Technology

to-machine services, which have not been adequately considered. GSMA's estimates indicate that 5G is anticipated to represent 12% of total connections by 2025 while 4G adoption is forecast to rise from 55% in 2020 to 67% in the same year.[58] Furthermore, Africa today has access to the 3.3-3.4 GHz band, this band has relatively low usage by the mobile service and could represent a less contentious sharing environment with existing services both in band and in adjacent band regimes.

A regulatory framework that encourages satellite connectivity should also consider the following:

- **Spectrum availability:** The retention of C-Band spectrum for satellite operators is critical to the success of the industry. There are currently over 200 satellite operators making use of C-Band spectrum. With its propagation characteristics and resilience to rain fade, the C-band spectrum is unique in its ability to provide robust wide-area coverage. Spectrum in the L, S, X, Ku, and Ka bands, among other bands, should also be available for use by satellite operators, considering that satellite operators do not have alternative frequency bands to which they can migrate to provide such services.
- **Spectrum fees:** Reasonable spectrum fees are an important input towards making satellite communications affordable and an effective solution to the digital divide. As a general principle and a matter of good economic governance, regulatory fees are best kept to a level that allows governments to recoup administrative costs covering, among others, costs on imports of equipment, technology, type approval, licensing charges and the functioning of the national authorities.
- **Regulatory framework for emerging satellite technologies:** As with all digital technology, the satellite industry is constantly upgrading its systems and technology to enhance its efficiency. Emerging technologies such as ESIM should be included in a country's regulatory framework. These emerging earth stations can operate, in the same frequency band, under similar technical and operational characteristics, allowing their licensing under a single blanket license regime. The introduction of a single blanket license also reduces the administrative burdens for both the national administrations and the applicants, in connection with the authorization of terminals.
- **Regulatory framework on terminal license should be clear:** Terminal type approval, identification, and authorization of terminals are fundamental features for the smooth operation of satellite systems, and the licensing process on terminal authorization and approval processes should be clearly articulated and harmonized as much as possible across the region.
- **Affordable tariffs:** Although satellite services can be available anywhere, at any time, the different architectures of systems bear differing cost elements. The identification and billing of calls made in different contexts could require technical and operational agreements to lower costs and ensure that they are affordable and can be utilized by as many citizens as possible. Regulators can drive the affordability of connectivity by taking the appropriate regulatory decisions regarding interconnection fees, government charges, and transit charges. The introduction of special rates for local communications inside a country or community telecommunications centers may assist regulators in promoting affordable services in rural areas.

5.3 Capacity Building and Knowledge Sharing between the International Satellite Industry and Domestic Satellite Operators and Regulators

The transfer of strategic, technical, and managerial knowledge is important for African governments and regulators. Depending on the prevailing local conditions, schemes, and programs, the transfer of know-

[58] GSMA (2022) "The Mobile Economy 2022" https://www.gsma.com/mobileeconomy/wp-content/uploads/2022/02/280222-The-Mobile-Economy-2022.pdf

how can be developed between satellite operators and the national authorities. Satellite entities should pledge, as part of the introduction of satellites in a country, that such transfers should take place. Knowledge transfer should cover such subjects as engineering, maintenance, operations, marketing, and billing. Satellite operators should adopt ways and means to transfer know-how effectively and efficiently. This can be facilitated at national ICT forums, special training programs, and capacity-building partnerships with regulators.

5.4 Effective use of Universal Service Funds (USF)

USF are funds collected from telecommunications operators which are to be directed towards ensuring that all citizens have access to affordable broadband connectivity, especially those that live in areas where it is not commercially viable to deploy networks. A strategic and efficient deployment of USF funds can fast-track the journey to universal connectivity. However, a 2014 GMSA report found that USFs are not functioning optimally.[59]

To ensure the USFs are used effectively, satellite connectivity should be made eligible for funding. In addition best practices in running USFs include the need to give USF autonomy and independence, a culture of stakeholder consultation, a clearly articulated mission and objectives, neutrality, transparency, and accountability in service deployment as well as a fair and objective project selection and resource allocation process.

6. Conclusion

Extending connectivity and bridging the digital divide is a challenge that African governments and the telecommunications industry should resolve together. Appropriate resources, therefore, must prioritize the deployment of universal meaningful connectivity in African countries. It is essential to ensure universal, *robust* and *affordable* access to the internet. Policy incentives should prioritize the rapid and wide deployment of affordable and scalable connectivity solutions, specifically responding to e-Government, e-Education, e-Health or e-Payment needs.[60]

Satellite connectivity can and will play a transformational role in enabling more Africans, in both rural and urban areas, to access the internet and unlock all the opportunities linked to the digital economy. As this paper has demonstrated, satellite connectivity can improve education, as school children can now watch quality educational content that is streamed via satellites. Satellite connectivity makes payments possible whether through mobile operators who make use of satellite backhaul technology or through connectivity they provide directly to ATMs and banks. Satellites also have a critical role to play in mitigating climate change – satellite imagery and data can track deforestation and alert governments of imminent danger. Governments are also making use of the internet to provide services to their citizens – satellite connectivity helps make this possible in rural areas where terrestrial infrastructure is both unfeasible and too expensive. Undoubtedly, satellite connectivity is the key to Africa's digital transformation.

African policymakers and regulators can support the satellite industry by creating a progressive regulatory framework that clearly articulates the compliance requirements and supports the satellite industry by ensuring they are provided with the required spectrum at a reasonable fee. Lastly, the industry needs to

[59] GMSA(2014) "SS Africa Universal Service Fund Study." https://www.gsma.com/publicpolicy/wp-content/uploads/2016/09/GSMA2014_Report_SubSaharanAfricaUniversalServiceFundStudy.pdf

[60] EMEA Satellite Owners Association (ESOA) "Input Contribution to TG on Spectrum Recommendations for Rural Connectivity." https://docs.google.com/document/d/1DMbWbzgyMHrGe4AdcRGLbwYvOeZNwnT6/edit

ensure that it transfers its knowledge and best practice to African satellite operators and regulators, ultimately promoting the growth of Africa's home-grown satellite industry.

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