The Senegal Model of Open Internet Technical Infrastructure

The Open Internet as cornerstone of digitalisation

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Abbreviations list

ADIE	Agence De l'Informatique de l'Etat
AFRINIC	African Network Information Centre
ARE	Autorité de Regulation
ARTP	Autorité de Régulation des Télécommunications et des Postes
ccTLDs	Country code TLDs Top Level Domains
CDNs	Content Delivery Networks
CEO	Chief Executive Officer
CII	Critical Information Infrastructure Protection
CNC	Commission Nationale de Cryptologie
DNS	Internet's Domain Name System
DNSSEC	Domain Name System Security Extensions
ENO	Open Digital Space
EU	European Union
FOSS	Free and Open-Source Software
GDP	Gross domestic product
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GSMA	Global System for Mobile Communications Association
gTLD	Generic Top Level Domains
HTTPs	Hypertext Transfer Protocol Secure
ICANN	Internet Corporation for Assigned Names and Numbers
ICT	Information and communication technology
IDNs	Internationalised Domain Names
IMRS	ICANN-Managed Root Server
ISOC	Internet Society Chapitre Sénégalais
ISP	Internet Service Provider
ITU	International Telecommunications Union
IXPs	Internet Exchange Points
MCTEN	Ministry of Communication, Telecommunications and Digital Economy
NIC	Network Information Center
NTP	Network Time Protocol
OECD	Organisation for Economic Co-operation and Development
POS	Point-of-sale
PPP	Public-private partnerships
QUIC	Quick UDP Internet Connection
TLDs	Top Level Domains
UNESCO	United Nations Educational, Scientific and Cultural Organization
USD	United States Dollar
USO	Universal Service Obligations
UVS	Université Virtuelle du Sénégal

Executive Summary

Open Internet connectivity is recognised as a promotor of human centric development. Digital technologies and the Open Internet are two distinct concepts that, if blended into a consistent policy approach, create a digitisation process that maximises the opportunities for social and economic growth.

Key to the success of the Open Internet is its decentralised architecture built on open standards and protocols, underpinned by a multi-stakeholder internet governance model that involves government and non-government actors in open consensus-driven internet policy dialogues. At the application level closest to the internet user, democratically developed principles, regulations, and policies can be put in place regionally and nationally, to ensure fundamental rights and locally driven development.

The realisation of the Open Internet's potential for locally driven growth requires a comprehensive approach, separate from the investment in technology and connectivity, and focused on the deployment of Open Internet digital infrastructure, enabling policy and regulatory environments for Open Internet, investment in Open Internet skills and competences, the creation of an Open Internet economy and participation in Open Internet governance.

This roadmap elaborates on the Open Internet technical infrastructure and explores Senegal's experience and successful practices to serve as a model that can inspire other African and Global South countries.

58.1% of Senegalese is online - 10.19 million active users – which is considerably higher than the average of 33% for the African continent, while 40% are not connected[1]. Providing good quality connectivity at a reasonable price comes first. To allow everyone to participate in the data-intensive world requires investments in the traditional backbone infrastructure as well as novel solutions for remote or sparsely populated regions.

Digital infrastructure, however, is largely agnostic when it comes to the type of internet it supports. Supplying quality, affordable connectivity does not guarantee the technological development of the Open Internet where local communities can maximise the benefits of digital development and internet connectivity. Open Internet infrastructure empowers the end user to take part in the online world and use the internet as a tool for his wellbeing and development.

The Open Internet infrastructure that intrinsically strengthens and develops the technical

1 DataReportal. Digital 2023: Senegal, https://datareportal.com/reports/digital-2023-senegal

dimension of the Open Internet includes:

- **Internet Exchange Points (IXPs)** that reduce the cost of internet connectivity while increasing its stability, resilience, and robustness because local data no longer travels long distance over expensive international and intercontinental transfers (and back).
- **Local carrier-neutral data centres** that offer cheaper, more reliable, safer options for data storage for organisations, business, e-entrepreneurs, or government institutions while enhancing competition between internet connectivity providers resulting in better offers for their clients.
- **Deployment of recent versions of Open Internet Standards and Protocols,** such as IPv6, Domain Name System Security Extensions (DNSSEC), Hypertext Transfer Protocol Secure (HTTPS), Quick UDP Internet Connection (QUIC). New standards and updates to existing ones may have a direct security or performance impact on the internet, its performance or security.
- Strengthen the global infrastructure underpinning the **Internet's Domain Name System (DNS)** to improve its performance and resilience and stimulate the local DNS ecosystem as it contributes to the development of a locally driven internet.
- Stimulate and support the development and use of **digital commons** including open-source software and knowledges resources e.g., wikis. They empower local internet entrepreneurs, developers, and users to become internet prosumers, allow innovations tailored to local needs, and lay the basis for a digital economy that may reach far across the country's borders.

Senegal's model for the promotion of the Open Internet encompasses various initiatives and strategies to foster a more open, inclusive, and secure digital ecosystem for the country. Its effectiveness shows through concrete interventions and proposals that reinforce Senegal's position as a leader in promoting the Open Internet.

This report incorporates insights from interviews with key actors in Senegal's digital ecosystem, giving information on how to build a resilient, inclusive, sovereign, and digitally advanced e-society based on Open Internet digitalisation while bridging the digital divide.

1. The Open Internet as Cornerstone of Digitalisation

While digitisation is an unstoppable process, the Open Internet which maximises the opportunities provided by digital development, is not and should not be taken for granted.[2]

Digital technologies and the **Open Internet** are two distinct concepts that are often confused. Ensuring that the two go intrinsically together in the digitisation processes of countries and regions is an important policy and investment choice, which has an impact on all key drivers for social and economic growth. Communities that embrace Open Internet digitisation are better placed to reap the full benefits of digital development.

The key to the success of the Open Internet is its **decentralised architecture** built on open standards and protocols[3] and underpinned by **multistakeholder internet governance**. The multistakeholder model involves both government and non-governmental actors in dialogues at global, regional, and national level, and goes beyond the management of the technical and logical infrastructure.[4] At the application level **democratically developed principles, regulations and policies** ensure respect for fundamental rights and empower a locally driven development.[5]

The realisation of the Open Internet requires a comprehensive approach from policy makers and stakeholders that goes further than investing in technology and connectivity. To take the necessary steps, actions and investments must focus on five areas: the deployment of Open Internet digital infrastructure[6]; the development of enabling policy and regulatory environments

2 The report 'The Open Internet as cornerstone for digitalisation' demonstrates that the Internet's unpredicted spectacular growth and its ability to promote human centric development is underpinned by the current Open Internet model. Digital connectivity technologies as such, while essential, are largely agnostic of what type of Internet they support. If the Internet further develops into more closed networks, this risks to lead to a cascade of negative consequences tempering the Internet's growth and missing opportunities to drive innovation, investment, socio-political, economic, and cultural development around the world.
Degezelle, W., et al. (2022). "The Open Internet as cornerstone for digitalisation. The Global Gateway Partnership Opportunities between the European Union and Africa." Stantec.

3 The internet is constructed as one global network of individual networks that exchange data and information, without a centralised authority. Transfer of data between networks, and as such the exchange of information over the internet is possible because of the use of commonly agreed standards and protocols.
Ibid p. 20-30.

4 The Open Internet's multistakeholder governance model, its venues, processes, and actors are described in the project's report. Ibid p. 31-34.

5 Examples of Internet-related policy, regulation, and e-government initiatives in Africa and Europa are compiled in the report.
Ibid p. 57-65.

6 Ibid p. 38-57.

for Open Internet[7]; investment in Open Internet skills and competences[8]; support for the creation of an Open Internet economy[9]; and participation in Open Internet governance[10]. These five pillars form clusters of investment priorities and partnership opportunities to be refined and scoped in response to national, regional, and subnational contexts, local demand, and existing initiatives. A dialogue with local stakeholders on priorities will contribute to a more effective cooperation to create growth and socio-economic development driven by the Open Internet.

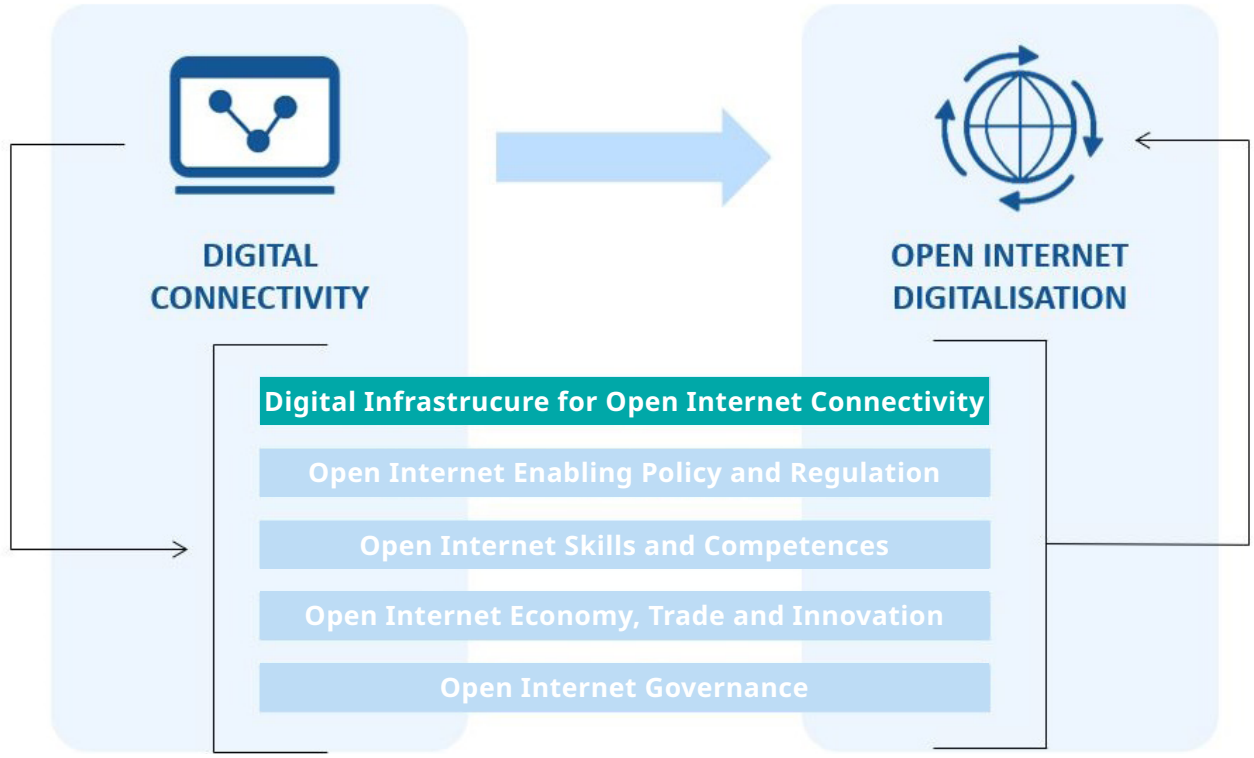

Figure 1. From Digital Connectivity to Open Internet Digitalisation

This document further explores the dimension Open Internet technical infrastructure.

7 Ibid p. 57-68.
8 Ibid p. 68-74.
9 Ibid p. 74-82.
10 Ibid p. 82-87.

2. Open Internet Technical Infrastructure

2.1 OPEN INTERNET CONNECTIVITY

Internet connectivity is expanding rapidly, experiencing an added boost during the pandemic. According to the 2022 figures published by the International Telecommunications Union (ITU)[11] 66 % of the global population had internet access, 5.3 billion users in total. However, internet access is not equally spread across the world. Internet use on the African continent for example, has dramatically increased over the past two decades[12] but is still lagging with only 40% of the African population using the internet, particularly concentrated among the young and people living in urban areas.

The physical buildout of the internet infrastructure is the inevitable first step for digital connectivity. However, defining connectivity only by number of people connected and ignoring its quality misses an important part of the picture. Internet users need a meaningful[13] and affordable connectivity that allows them to use the internet every day with a suitable device, sufficient data, and a fast connection.[14] Ignoring the need for meaningful connectivity creates and worsens digital divides 'between the poorly connected (those who use a single application or website once a month) and the hyper connected (those watching movies and working remotely every day).[15]

The modern, data-intensive applications and services require investments in broadband infrastructure – the traditional backbone infrastructure as well novel solutions for remote or sparsely populated regions – to supply basic connectivity that is reliable, of good quality and affordable.

Digital infrastructure, however, is largely agnostic when it comes to the type of internet it supports. Supplying qualitative, affordable connectivity does not guarantee the technological development of the **Open Internet** where local communities can maximise the benefits of digital

11 ITU. (2022). "Measuring digital development. Fact and Figures 2022."

12 Between 2000 and 2020, internet access on the African continent increased from 4.5 to 590 million (Internet World Stats. "Internet User Statistics for Africa" https://www.internetworldstats.com/stats1.htm)

13 According to the Alliance for Affordable Internet (A4AI) the following four requirements define meaningful connectivity: an appropriate device, regular internet access, a fast connection, enough data.

14 A4AI. "Meaningful Connectivity – unlocking the full power of internet access." Alliance for Affordable Internet. https://a4ai.org/meaningful-connectivity/

15 Thakur, D., Woodhouse, T., Jorge, S. (2020). "Meaningful Connectivity: Advancing the Open Internet during COVID 19". p.37-40

development. The Open Internet embodies opportunities for those connected to not only be passive consumers of content and services but "prosumers", potential producers of content, applications and services that meet local needs to be shared easily at a low cost to compete freely with established market players.[16]

As stated by the Coalition for Digital Africa, 'the power of the internet comes from being a single, open and interoperable internet that is easily accessible globally and locally, to anybody, anywhere, at any time.'[17] Limiting Open Internet connectivity and creating closed systems comes with considerable opportunity costs that result in breaking or straying away from 'the internet that has become the backbone of the world economy and our lives'.[18]

'The full benefits of connectivity can be reaped in an Open Internet environment, with an internet which is accessible, secure, robust, and interoperable.'[19] Open Internet connectivity connects to global and open markets, to shared knowledge and other resources, and ensures the long-term development of digital societies.

2.2 BUILDING BLOCKS OF THE OPEN INTERNET INFRASTRUCTURE

For a proper digital transition, the efforts to supply qualitative and affordable broadband internet, affordable devices to connect and support infrastructure such as reliable electricity must be complemented with a buildout of **Open Internet infrastructure** and investments in Open Internet connectivity.

The design of the internet based on the Open Internet architecture and its open protocols, empowers end users and allows them to take an active role, 'independently deciding how to use and create apps, services and any kind of content'.[20] Connectivity investments that intrinsically strengthen and further the develop of the technical dimension of the Open Internet, such as IXPs, IPv6 deployment and a robust DNS are necessary to allow this human-centric internet to develop as an enabling tool in the hands of active end users and their communities.[21]

IXPs are fundamental Open Internet infrastructures[22] that allow to exchange internet traffic between networks locally without sending domestic traffic back and forth to other countries or continents over expensive intercontinental transfers. IXPs make local networks less dependent on third parties. Peering[23] at the local IXPs

16 Belli, L., Baca, C., Huerta, E., Velasco, K. (2020). "Community Network in Latin America: Unleashing Openness through Self-determination". p. 114

17 Coalition for Digital Africa, Guiding Principles. https://www.coalitionfordigitalafrica.africa/our-story#guiding-principles (accessed November 2023)

18 York, D. (2022)." What is the Splinternet? And why you should be paying attention. "The Internet Society.

19 The European Telecommunications Network Operators' Association (ETNO). (2022)." Internet connectivity empowering today's communities." In: Degezelle, W., et al. (2022). p. 57.

20 Belli, L., Manzar, O., Farooqui, S. (2020.) "COVID-19: A Harsh Reminder that Open Internet Access and Meaningful Connectivity are Essential". p.27-29.

21 Degezelle, W., et all. (2022). p. 40.

22 IXPs serve as 'physical locations where different networks connect to exchange internet traffic via common switching infrastructures. They contribute to increasing the affordability and quality of connectivity in local communities, largely by eliminating the need to exchange local traffic via international routes. Source: Internet Society. (2015, 30 October). "Internet Exchange Points. An Internet Society Public Policy Briefing".

23 Peering is a process by which two Internet networks connect and exchange traffic. It allows them to directly hand off traffic between each other's customers, without having to pay a third party to carry that traffic across the Internet for them. Peering is distinct from transit, the more usual way of connecting to the Internet, in which an end user or network operator pays another, usually larger, network operator to carry all their traffic for them.'
Netnod. "What is peering?" https://www.netnod.se/ix/what-is-peering

means that internet traffic is routed more directly, making internet connectivity faster, cheaper and of better quality while increasing the stability, resilience, and robustness of the local internet. There are currently 51 active IXPs located in 47 cities in 36 countries in Africa[24]. The most successful among them exchange 70 to 80% of the local internet traffic, saving millions of United States Dollar (USD)[25] [26] by avoiding international transfer cost.[27]

IXPs are at the centre of vibrant local internet ecosystems. In addition to cost savings and quality improvements, IXPs strengthen the capacity and partnerships among internet service providers and other internet-based businesses and academic networks. They enable competition by facilitating the entry of new service providers, local data centres, DNS root server mirrors, hosting providers and Content Delivery Networks (CDNs)[28] in a cost-effective[29] way.[30]

For an IXP to flourish, an enabling legal framework and the creation of the IXP community are of equal importance as the investment in the IXP's infrastructure. Modern IXPs can cost little[31] to set up and run but require key utilities such as reliable and redundant power supply and access to terrestrial cable infrastructure.[32]

Local carrier-neutral data centres create the capacity to store data locally, without being tied to a single service provider (for example telco or Internet Service Provider (ISP))[33]. They can offer the same connectivity as a single carrier data centre with better flexibility, reliability, and a lower cost.[34] Renting storage at a carrier neutral data centre is for most organisations, business, e-entrepreneurs, or government institutions a cheaper, more reliable, and safer option than depending on inhouse storage or a single carrier data centre.[35]

In addition, carrier neutral data centres introduce choice and flexibility as one can choose the carrier that best fits the client's needs e.g., bandwidth capacity or price, and allows to easily

24 The African IXP Association: www.af-ix.net/ixps-list/

25 For example, the Kenya Internet Exchange Point (KIXP) grew from carrying peak traffic of 1 Gigabit per second (Gbps) in 2012 to 19 Gbps in 2020, with cost savings quadrupling to USD 6 million per year. The Internet Exchange Point of Nigeria (IXPN) grew from carrying just 300 Megabits per second (Mbps) to peak traffic of 125 Gbps in 2020, and cost savings increased 40 times to USD 40 million per year.

26 Costs and Savings per IXP in US$ 2020 (ISOC)

Country/City	IXP	Yearly IP Transit Savings	Yearly Savings per connected Network
Angola/Luanda	Angonix	US$ 4,320,000	US$ 228,350
DRC/Kinshasa	KINIX	US$ 3,780,000	US$ 163,233
Egypt/Cairo	CAIX	US$ 2,040,000	US$ 240,000
Burkina Faso/Ouagadougou	BFIX	US$ 1,440,000	US$ 115,800

Adapted table from Kende, M. (2021). "Moving Toward an Interconnected Africa: The 80/20 initiative." Internet Society. p. 36.

27 Kende, M. (2021). p. 36.

28 A CDN refers to a geographically distributed group of servers which work together to provide fast delivery of internet content, by storing copies of the content (caches) closer to the user, allowing for faster access.

29 New entrants do not have to build out their networks to all the other networks that are exchanging traffic at the IXP. The IXP generally provides a neutral traffic exchange point, whereas bilateral interconnection can be expensive and include other barriers to entry.

30 IGF, Best Practice Forum on IXPs. (2017). "Contributing to the success and continued development of internet exchange points". Internet Governance Forum. p.12.

31 The 2015 IGF Best Practice Forum on IXPs noted that 'Establishment and operational estimates range from 5,000 – 8,000 USD or less (low-end) to a maximum of 50,000 USD.'
IGF, Best Practice Forum on IXPs. (2015). "Enabling Environments to Establish Successful IXPs." Internet Governance Forum. p. 22.

32 IGF, Best Practice Forum on IXPs. (2015). "Enabling Environments to Establish Successful IXPs." Internet Governance Forum. p. 22.

33 A carrier-neutral data centre, also known as a network-neutral data centre, is a facility that provides hosting and colocation services to multiple telecommunications carriers and network service providers. Unlike data centres operated by specific carriers or providers, carrier-neutral data centres do not have ownership ties or exclusive partnerships with any particular network or telecommunications company.

34 Isberto, M. (2021, 24 February). "What is Carrier Neutral Colocation?" Colocation America.

35 For example, the cost of security (both cyber and physical) and redundancy measures of state-of-the-art data centres can be shared by the clients.

switch providers while physically keeping the data in the same data centre and server space. This increases cost efficiency as carriers compete on price and customer service. Direct connections at the data centre reduce the number of hops between carriers, which reduces latency and supplies faster connectivity.[36] When the carrier-neutral data centre is in the country, no costly international or intercontinental transfer via the undersea cable system is needed. The benefits of local carrier-neutral data centres are optimised when the data centre can connect to and peer at a local IXP.

While the data centre capacity on the African continent has doubled since 2016, it is predicted that five to six time the current capacity will be needed by 2030.[37] African data centre development can 'be split into five main hubs: South Africa, Nigeria, Egypt, Morocco and Kenya' but investors and operators are looking to enter new emerging markets.[38] Most of Africa's data is still stored in data centres outside the continent. Multiple initiatives are underway to boost the capacity on the continent. Several however, are driven by the demand of external actors who want to create local capacity for their applications and content, while the bigger opportunity comes from Africa generated data itself. Today, most government, healthcare, defence, and even financial data in Africa is kept in analogue, manual fashion (file cabinets with paper folders). Inevitably, this massive cache of data will eventually be digitised and stored in cloud services. Furthermore, African content creators have been busy – with youth rich populations creating music, video and novel applications that are driving tremendous levels of digital traffic.[39] Finally, as is the case with IXPs, data centres require adequate support infrastructures such as access to connectivity infrastructure and reliable power supply.

Internet Standards Deployment is an important building block of the Open Internet infrastructure. The deployment of the most recent versions of the Open Internet's main technical protocols and standards has a major impact on the quality, security, resilience, and openness of internet connectivity. Key examples of open standards and protocols are IPv6, DNSSEC, HTTPS, QUIC.

IPv6 (internet protocol version 6) brings along efficiency and assures the long-term development of the internet. While transition to IPv6 is vital for supporting the internet's evolution, adoption in Africa is lagging compared to other continents. Telecommunications and ISP industries are leading but more needs to be done to prepare public institutions, school networks, smaller ISPs, and businesses.[40] DNSSEC adds an extra layer of security to the DNS by adding digital signatures to DNS queries and responses. This prevents hackers from intercepting and changing data and reduces the risk of DNS cache poisoning and other types of attacks. Africa recently marked the greatest growth globally in DNSSEC validation[41] 'growing from a low of 17% at the start of 2022 up to 31% at the start of

36 Smith, J., (2022, 2 April). "How Carrier Neutral Data Centres Prevent Downtime." Host Dime Blog.

37 Kampala. (2021, 4 December). "Data centres are taking root in Africa". the Economist.

38 DCByte. (2023). "Africa's Key Data Centre Markets. South Africa, Nigeria, Kenya, Egypt, and Morocco." DCByte Market Spotlight.

39 Amoo, F., Kumbhani, R. (2022, 4 October). "The Appetite for African Data Centres: Can Investment Keep Up?" Forbes. https://www.forbes.com/sites/franklinamoo/2022/10/04/the-appetite-for-african-data-centers-can-investment-keep-up

40 Degezelle, W., et all. (2022). p. 50.

41 'There are two sides to DNSSEC: signing and validating. On the one side, DNS operators sign domain names cryptographically. On the other side, when you do anything online that uses domain names, the DNS resolver you use, often at your Internet Service Provider (ISP), performs DNSSEC validation to check whether DNSSEC signatures are correct.
For DNSSEC to provide its extra layer of security globally, we need both: domain names to be signed, and local DNS resolvers to be checking for those DNSSEC signatures.'
York, D. (2023, 16 March). "DNSSEC Validation in 2022: Africa Leads with Amazing Growth." Internet Society.

2023'.[42] Similarly the use of HTTPs[43], when properly configured, provides a fast, secure connection that offers privacy and reliability, while QUIC is a new low-latency transport protocol that is being deployed by large global players for its performance and other benefits and also relevant for local African developers to keep up with the latest technology.[44]

The Open Internet protocols and standards, including the above-mentioned examples, remain under the scrutiny of open processes where they are evaluated, updated, and complemented with new protocols to address changing challenges and new demands. Hence, using the latest standards has a direct impact on the performance of the internet. Governments can lead by example and use the latest versions in their networks and applications, while taking initiatives to stimulate and support business and network operators to follow suit.

The Internet's **DNS** facilitates internet use as it allows the use of domain names to access information online instead of the complex (alpha) numeric IP addresses computers and devices use to communicate[45]. The global DNS infrastructure is based on a root server system that, to date, consists of more than 1750 instances[46] operated by 12 independent root server operators[47]. Investments in the robustness of the DNS infrastructure, by increasing the number of local DNS Root server instances on the African continent brings immediate benefits for everyday internet users as they help to mitigate the impact of potential cyber-attacks[48] and reduce the time it takes for a website to load, particularly when there are spikes in internet usage.[49]

The domain name space itself is structured in Top Level Domains (TLDs). The managers of generic TLDs (gTLDs such as .com or .org) and country code TLDs (ccTLDs such as .ke for Kenya, .sn for Senegal) handle the registration and administration of domain names under their TLD. The African DNS address space consists of 56 top level country code ccTLDs,[50] five Internationalised Domain Names (IDNs) — Egypt (مصر), Algeria (الجزائر), Tunisia (تونس), Sudan (سودان) and Morocco (المغرب) – and four geographic TLDs (.africa, .capetown, .durban, .joburg).[51] A comprehensive study of the DNS market in 2016 found links between the development of the domain name market and the presence of hosting and web developers: 'Domain name registration by African entities takes place mainly in countries where the local hosting industry and web development sector has developed sufficiently to create demand for local domains'.[52] This leads to conclusions that strengthening the local TLDs and stimulating a vibrant DNS sector contributes to the development a locally driven internet eco-

42 York, D. 2023. "DNSSEC Validation in 2022: Africa Leads with Amazing Growth." Internet Society. 16 March 2023. https://pulse.internetsociety.org/blog/dnssec-validation-in-2022-africa-leads-with-amazing-growth

43 https://internet.nl/faqs/https/

44 Degezelle, W., et all. (2022). p. 51

45 For an introduction to the DNS for Non-Experts: Karrenberg, D. (2004, 1 March). "The Internet Domain Name System Explained for Non-Experts". Internet Society.

46 Number as of 16 September 2023: https://root-servers.org/

47 IANA. List of Root Servers. https://www.iana.org/domains/root/servers

48 In particular DDoS (Distributed Denial-of-Service) cyberattacks which work by overwhelming servers with floods of queries.

49 ICANN. (2022, 28 February). "ICANN-Managed Root Server Clusters to Strengthen Africa's Internet Infrastructure".

50 .ao (Angola), .bf (Burkina Faso), .bi (Burundi), .bj (Benin), .bw (Botswana), .cd (Congo DRC), .cf (Central African Republic), .cg (Congo Rep.), .ci (Cote d'Ivoire), .cm (Cameroon), .cv (Cape Verde), .dj (Djibouti), .dz (Algeria), .eg (Egypt), .er (Eritrea), .et (Ethiopia), .ga (Gabon), .gh (Ghana), .gm (Gambia), .gn (Guinea), .gq (Equatorial Guinea), .gw (Guinea-Bissau), .ke (Kenya), .km (Comoros), .lr (Liberia), .ls (Lesotho), .ly (Libya), .ma (Morocco), .mg (Madagascar), .ml (Mali), .mr (Mauritania), .mu (Mauritius), .mw (Malawi), .mz (Mozambique), .na (Namibia), .ne (Niger), .ng (Nigeria), .re (Réunion), .rw (Rwanda), .sc (Seychelles), .sd (Sudan), .sl (Sierra Leone), .sn (Senegal), .so (Somalia), .ss (South Sudan), .st (Sao Tome and Principe), .sz (Swaziland), .td (Chad), .tg (Togo), .tn (Tunisia), .tz (Tanzania), .ug (Uganda), .yt (Mayotte), .za (South Africa), .zm (Zambia), .zw (Zimbabwe).

51 IANA Root Zone Database.

52 Stucke, W. (2017). "The 2016 African Domain Name System Market Study". South African Communication Forum. p.13-14.

system based on Open Internet connectivity.

Digital Commons and Open Source are Open Internet building blocks that empower local internet entrepreneurs, developers, and users. Digital commons are 'information and knowledge resources that are collectively created and owned or shared between or among a community'[53]. They include wikis, open-source software, and open-source licensing. Digital commons have two main characteristics: the resource is non-rival – the use of the resource by some does not limit the use by others, and the resource is non-exclusive – the right to use it is not restricted but (generally freely) available to third parties which counterweights dependence of and imbalances between local players and global giants. The creation of digital commons makes it easier to locally develop and provide applications, services and information that are tailored to local needs.[54] There is a direct positive impact as local e-jobs are created to develop and maintain software, applications, and resources as well as progress in other sectors. Parts of society can use new technologies to improve their processes and knowledge.

53 Fuster Morell, M. (2010). "Dissertation: Governance of online creation communities: Provision of infrastructure for the building of digital commons." p. 5.

54 Alais, O. (2021). "Internet and Africa: what cyberspace for tomorrow?". iD4D. 10 March, updated on 17 June.

3. The Senegal Model of Open Internet Infrastructure

3.1 SENEGAL'S DIGITAL CONNECTIVITY AND THE OPEN INTERNET

Senegal is on course to becoming a leading hub for digital transformation in West Africa[55]. Over the past decade the government has developed a multiannual digital strategy, Sénégal Numérique 2025 (SN2025), which aims to bring the share of the digital economy up to 10% of Senegal□s Gross domestic product (GDP) by 2025 while creating 54,000 direct and 162,000 indirect jobs[56]. This strategy for the internet and the digital economy is based on the principles of trust, accessibility, inclusiveness, and innovation. The plan has prioritized investments in digital backbone infrastructure, connections to the global submarine fibre optic cable network[57], in-country broadband connectivity[58], and the creation of new data centres.

While Senegal has made considerable progress in deploying critical internet infrastructure, including fibre optic backbone and wireless connectivity, the country also recognizes that investments in Open Internet infrastructure, such as IXPs, local carrier-neutral data centres, internet standards, and digital commons are equally important. Although the latter have only been prioritized recently, there is understanding that only by developing a holistic digital strategy in favour of the Open Internet the country can consolidate its digital infrastructure fostering local content development and trusted interconnections with the global digital ecosystem as the conditions for a prosperous digital future.

Table 1 Internet Use in Senegal: Key Indicators

Internet Users	• 10.19 million active users. 58.1% of the pop. (46.0% in Jan '21) • +255K (+2.6%) between 2022 and 2023
Internet Connections	• 20.13 million mobile connections (2023) • +378K (+1.9%) between 2022 and 2023 • Number of mobile connections as % of population: 114.8%
Internet connection speed	• Median mobile internet connection speed via cellular networks: 23.10 Mbps (+29% in 12 months) • Median fixed internet connection speed: 21.77 Mbps (+5% in 12 months)
Share of web traffic by device	• Mobile phone: 76.05% • Fixed / Desktop: 23.16%

Source: DataReportal. Digital 2023: Senegal

55 Muller, A. (2018, 6 March). "Digital Economy in Senegal: Envisioning the Future." World Bank Blogs.

56 Ministère des Postes et des Télécommunications, République du Sénégal. (2016). □Stratégie Sénégal Numérique 2016 □ 2025□.

57 Senegal connects to more than 40 countries through four submarine fibre optic cables: Main One, Atlantis-2, SAT-3, and the Africa Coast to Europe (ACE) cable.

58 Broadband coverage reaches 97.12% of the population. (31 March 2023). Data : Observatoire sur les Systèmes d□Information, les Réseaux et les Inforoutes au Sénégal. http://www.osiris.sn/Internet.html

SN2025 National Digital Strategy

The country's key policy framework calls for 'digital for all and for all uses by 2025, with a dynamic and innovative private sector in an efficient ecosystem'[59]. It has been a catalyst for consolidating and building the country's digital infrastructure and digitising the economy.

At its core SN2025 focuses on reinforcing and extending backbone infrastructure through public-private partnerships (PPPs) [60] to support the creation of high-speed internet services and accelerate the adoption of digital technologies across all sectors of the economy.[61], [62]

The government has also prioritised attracting foreign direct investments in digital infrastructure projects (fibre optic networks, 4G and 5G, new data centres, and reinforced data processing capacities). It has encouraged the sharing of ICT infrastructure assets among different operators to improve the quality, affordability, and availability of internet services[63].

This has resulted in a favourable environment for the development of the country's digital economy; a sound basis for the creation of new digital tools and services including a rapid growth in the number of e-government services across key sectors of the economy.

Backbone infrastructure

Senegal's internet backbone consists of a mix of terrestrial fibre-optic cables and connections to international, ultra-high-capacity undersea cables[64], connecting the main cities and regions with Dakar.[65], [66] The national backbone extends to its borders with Mauritania, The Gambia, Mali, and Guinea, allowing these countries to access international bandwidth via the submarine cables that land in Senegal.

Broadband Connectivity

Data from Global System for Mobile Communications Association (GSMA) Intelligence shows that there were 20.13 million cellular mobile connections in Senegal at the start of 2023. This was equivalent to 114.8 percent of the total population (a level that can be explained by the fact that many individuals have more than one mobile connection). According to data compiled by Datatreportal[67], in 2023 Senegal had an advertised average download speed of 23.10 Mbps for mobile broadband (+29.3% since 2022), and 21.77

59 Ministère des Postes et des Télécommunications, République du Sénégal. (2016). Stratégie Sénégal Numérique 2016 2025.

60 PPP projects that have been implemented or are under development include the Dakar Digital Technology Park, which already hosts data centres, the Senegal internet exchange point (SENIX), and innovation hubs.
The mission of the Parc des Technologies Numériques du Sénégal (www.ptn.sn) are 1) Establishment of a world-class infrastructure to attract international and regional companies in the ICT, research and innovation sector; 2) Establishment of an attractive framework for investors (regulatory framework and taxation); 3) Creation of a platform for innovative e-government solutions in development sectors such as health, education, agriculture, etc; 4) Improving research and development and entrepreneurship in the field of ICT

61 Amadou Hott, Minister of Economy, Planning, and International Cooperation (2021) in Cruz, M., Dutz, M., Rodríguez-Castelán, C. (2021). Digital Senegal for Digital Growth.

62 Freehills, H. S. (2021). "Adoption d'une nouvelle loi sur les partenariats public-privé (PPP) au Sénégal."
In 2021, a new PPP law was adopted with a view to simplifying and streamlining the legal and institutional framework for PPPs and attracting more private investment and expertise in the sector.

63 Ministère de Postes et des Télécommunications, République du Sénégal. (2019). "Etude sur le partage des infrastructures des télécommunications et des TIC au Sénégal."

64 Senegal is the landing point for an exceptionally large number of undersea cables with connections to the Africa Coast to Europe (ACE), 2Africa, MainOne, SAT3/WASC and Senegal Horn of Africa Regional Express cables (Source : Submarine Cable Map : www.submarinecablemap.com)

65 The country's backbone infrastructure is managed by a combination of public and private entities. The Ministry of Digital Economy and Telecommunications, and the country's Regulatory Authority for Telecommunications and Posts (ARTP) have overall responsibility for planning, investments, and regulatory aspects. Terrestrial fibre-optic networks have, to a large extent, been deployed and maintained by telecommunications operators Sonatel and Orange, and internet service providers (ISPs). Connections to undersea cables are managed by the government in coordination with consortia of international partners.

66 Ministère de la Communication et de lEconomie Numérique, République du Sénégal. (2019). "Plan National Haut Débit du Sénégal."

67 OECD Broadband Statistics Update, 13 July 2023. https://www.oecd.org/digital/broadband/broadband-statistics-update.htm

Mbps for fixed broadband (+5% since 2022). These speeds are above the average for Africa but remain below the average for Organisation for Economic Co-operation and Development (OECD) countries. The number of mobile connections increased by 378 thousand (+1.9 percent) between 2022 and 2023[68].

Data storage and Computing capacity

Senegal has successfully combined investments in digital infrastructure with efforts to strengthen its ability to handle, store and process locally generated data. This commitment to developing domestic capabilities and harnessing the advantages of digitalization while prioritizing national interests, data privacy, and security was emphasized by Cheikh Bakhoum, Chief Executive Officer (CEO) of Senegal Numérique (formerly Agence De l'Informatique de l'Etat (ADIE)). He highlighted this commitment in June 2021 at the inauguration of the national data centre in Diamniado – built with the support of Huawei – underscoring Senegal's dedication to safeguarding its data and using digitalisation for its benefit.

"With this data center, the Senegalese state will be sovereign in terms of data storage. It is a tool that will preserve our informational heritage and benefit the public administration and private companies. Until now, the majority of our data has been stored outside, in the United States and in Asia in particular[69]"

The pursuit of digital sovereignty in Senegal is legitimate, driven by the desire to protect national interests, data privacy, and ensure control over critical digital infrastructure. However, while 'this may help the country process and draw value from its own data, the reliance on foreign entities to build such critical infrastructure places data sovereignty in potential jeopardy.'[70] Some, for example, have raised concerns about the ability of local engineers to maintain the infrastructure, governance, and data management practices.

National Data Centre

In 2021, the launch of Senegal's new "national data centre", was viewed by the government as a critical piece of internet infrastructure that will reinforce the country's sovereignty over its digital assets.

The facility, located in Diamniadio Tech Park, built with financial backing from Huawei, is intended to serve as a national hub for storing, processing, and managing data generated by the government, private companies, and citizens. The government views this new data centre as a key element in its strategy to reinforce the country's digital infrastructure and increase its capacity to securely collect and analyse data.

While it is widely hoped that the data centre will enhance the government's ability to manage the country's digital assets, protect data sovereignty and security, and promote the development of the digital economy, some experts (some of whom were interviewed as part of this report) have expressed concern about the governance of this facility, calling for tighter regulation.

Senegal has also reinforced its in-country data processing capacity with the introduction of a **supercomputer** with a computing capacity of 500 teraflops. This supercomputer will be used for a range of applications from weather forecasting to climate change modelling, and tracking the spread of infectious diseases, and will be available for new applications in key sectors of

68 DataReportal (2023, 14 February). "Digital 2023: Senegal."

69 van der Made, J. (2021, 25 June). "Senegal to move all government data to Huawei-run data centre." RFI.

70 Maswabi, G., Nkala, S. (2022, 12 July). "How Africa Can Achieve Data Sovereignity." The African.

the economy, primarily agriculture, health, education, and research[71].

During interviews with local stakeholders the expectation was raised that the supercomputer will support the development of new digital services and solutions including digital platforms for e-government, e-learning, e-health, and e-commerce. It can foster collaboration and knowledge sharing among researchers, academics, entrepreneurs, and policymakers across sectors and disciplines. However, additional training of local engineers and maintenance technicians is needed before the country can fully exploit and benefit from this piece of technology.

In early 2023 Onix announced that it will be building a new data centre in Dakar at the landing station of the 2Africa submarine cable. Driven by a desire for improved latency performance and data sovereignty concerns, this carrier neutral data centre is due to start operations in the first quarter of 2024[72].

Digital Skills

The creation of digital capacity-building programmes in schools and adult education centres is further driving the process of digital transformation. The government is focused on reinforcing local expertise and upskilling the wider workforce in the exploitation and maintenance of national ICT installations, networks, and telecoms infrastructure; the secure management of the state's digital assets; and the development of data management platforms across the country[73].

Founded in 2014, the **Université Virtuelle du Sénégal** (UVS) is a public digital university based in Dakar. The UVS offers online courses, making it the first entirely digital public university in Francophone Sub-Saharan Africa and the second largest university in Senegal in terms of student numbers. The UVS has a network of "open digital spaces[74]" spread across Senegal to increase digital skills among students and the wider population.

3.2 THE SENEGAL MODEL OF OPEN INTERNET TECHNICAL INFRASTRUCTURE

To achieve a full and effective digital transition in line with the technical standards, governance, and regulatory practices associated with the Open Internet, expanding core internet infrastructure, and ensuring quality access is not enough. While core internet infrastructure remains neutral to the type of internet model it supports, the deployment of Open Internet infrastructure supports an internet where local communities can maximise the benefits of digital development and internet connectivity.

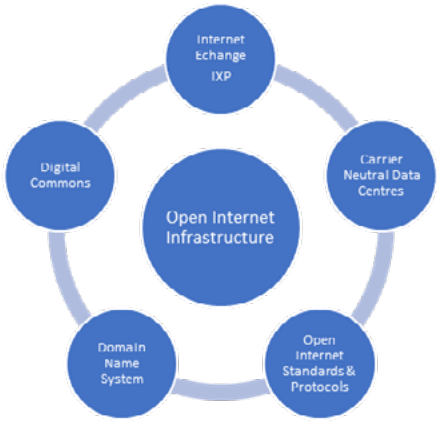

Figure 2. Components of Open Internet Infrastructure

71 Clémençot, J. (2020, 18 November). "Avec son "supercalculateur" le Sénégal veut peser dans la course à l'innovation." Jeune Afrique.

72 Bains, L. (2023, 11 May). "Africa's Data Centre Boom." Construct Africa

73 Sénégal Numérique : Infrastructure. https://www.adie.sn/expertise/infrastructure

74 Open Digital Spaces - Espace Numérique Ouvert (ENO) - are spaces created in connection with the Université Virtuelle du Sénégal, designed to facilitate training in digital skills for the population at large.

Key infrastructure elements that are essential for strengthening the potential of Senegal's Open Internet digitization are:

- IXPs
- Local carrier neutral data centres
- DNS
- Standards of the Open Internet
- Digital commons (including open-source)

3.2.1 Internet Exchange Points

Preparations to build an internet exchange in Senegal as promoted by the African Union started in 2012 by a group of stakeholders including government, civil society, and the private sector, led by the Ministry of Post and Communications. Earlier attempts to establish an IXP were unsuccessful, among others because of the historic monopoly[75] of the telecom operator.[76]

In August 2017, Senegal inaugurated SENIX[77] with as mission[78] to:

- Allow the direct exchange of local traffic to encourage the emergence of local services and optimise the use of bandwidth and the cost of international traffic.
- Offer a place where SENIX members can permanently exchange traffic on a transparent and non-discriminatory basis ('*peering*').
- Offer a space for hosting content services.

SENIX offers several advantages for the country's digital economy. By keeping local traffic within Senegal, it generates significant savings on international traffic. It provides critical basic services such as a Network Time Protocol (NTP) time server, a root server mirror, a routing server, content hosting, unicast and multicast services, and cache servers. These services make SENIX a valuable component of Senegal's Open Internet infrastructure. The creation of SENIX represented an important step towards greater digital independence with Senegal no longer at the mercy of international traffic, which opens new prospects to build a sustainable domestic internet ecosystem.[79]

3.2.2 Carrier Neutral Data Centres

There is a growing awareness in Senegal of the function and crucial role of carrier neutral data centres for the development of the local digital ecosystem. In February 2023, the launch of a carrier-neutral data centre developed and run by Onix was announced in Dakar, at the landing point of the 2Africa, ACE and MainOne undersea cables[80]. This was hailed as an important step forward in the provision of neutral colocation and connectivity services to digital enterprises in Senegal and the West African region. Meanwhile, Morocco-based N+ONE has announced plans for the construction of three more data centres located in the Diamniado Tech Park[81].

3.2.3 Domain Name System

The DNS, the addressing system for the worldwide web which allows machine-readable IP addresses to be translated to human-readable domain names, relies on a globally distributed and hierarchical infrastructure. The DNS is an essential component of Open Internet technology on which web browsers rely to load online resources quickly and efficiently.

Technically, the DNS is organised in a hierar-

75 While the historic monopoly of the incumbent operator (Sonatel) officially ended in 2004, only in 2007 the first competing operator (Sundanese Sudatel) received the authorisation to offer ADSL and mobile phone services.
Mendy, G. (2021, 12 October). "Une histoire de l'Internet au Sénégal." Internet Society.

76 https://senix.sn/historique.html

77 SENIX Website: https://senix.sn

78 https://senix.sn/missions.html

79 France IX. (2018, 5 April). "Back to the creation of SENIX, the first Senegalese exchange point."

80 AITN. (2023, 22 February). "Onix Data Centers s'étend à Dakar, au Sénégal." AfriqueITNews.com.

81 Oxford Business Group. (2021). "Data Centres in Africa Focus Report."

chical structure with country code top-level domains (ccTLDs) (e.g. .sn, .uk., .fr) and generic TLDs (gTLDs) (e.g. .com, .org) at the top. 'Dot-SN' (.sn), the ccTLD for Senegal is one of the 54 ccTLDs in Africa.

Senegal Network Information Centre (NIC) and the delegation of .SN

.SN, the ccTLD for Senegal, was delegated (added to the DNS root zone) in 1991 and has been in operation since 1996. NIC Senegal[82], the entity responsible for managing the registration of .SN domain names, operates under the supervision of a National Orientation Committee chaired by the ARTP (Autorité de Régulation des Télécommunications et des Postes du Sénégal). At the end or 2022 NIC Senegal reported 9,000 actives .sn domain names.[83]

Domain Name Registrars

Domain Name Registrars manage the registration of internet domain names, acting as intermediaries between domain name users and the Registry Operator (NIC Senegal). One of the eleven African Internet Corporation for Assigned Names and Numbers (ICANN)-accredited registrars is based in Senegal[84]. In addition, the country counts some thirty-eight non-ICANN-accredited domain name registrars, largely concentrated in Dakar, for the registration of domain names under the .sn TLD[85]. This is a relatively high number compared to other African countries.

Instance of DNS L-Root Server

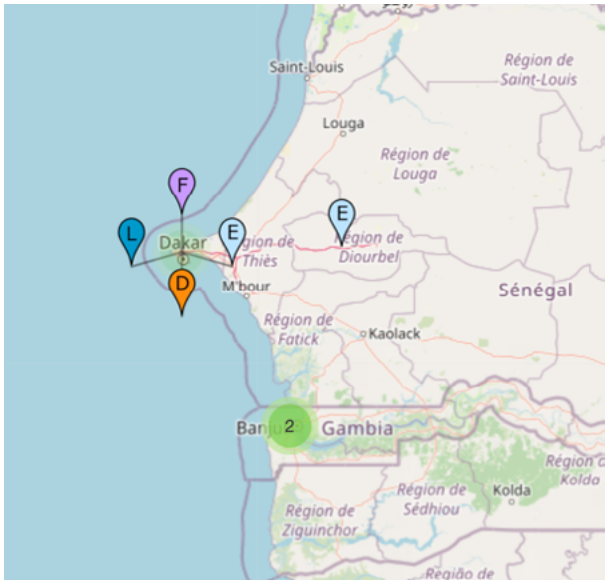

Figure 3: Instances of Root Servers located in Senegal.

In 2013 the deployment of an instance (copy) of the L-root server in Senegal was viewed as a significant measure to boost Africa's Open Internet infrastructure[86]. Carried out by ICANN in collaboration with African Network Information Centre (AfriNIC), the creation of DNS Root server instances in Africa makes the DNS more secure, reliable, and faster. Root-Servers.org indicates that there are also instances of the D, E and F root servers in Dakar, and another L-Root server at another location in Senegal.

Further enhancing the security, resiliency, and latency of the DNS system in Africa with the creation of dedicated Root-server for the continent is viewed by certain key actors of the DNS ecosystem as a strategic priority. While the creation of an

82 NIC Senegal: www.nicsenegal.sn.

83 NIC Senegal homepage.

84 Compared to other regions, Africa has a small number of ICANN-accredited registrars: 11 in total with 4 in South Africa, 2 in Morocco, and one each in Burundi, Ghana, Nigeria, Senegal and Tunisia (ICANN African DNS Market Study, 2016).

85 NIC Senegal: https://www.nicsenegal.sn/bureaux-nationaux/

86 DNS root servers are a critical part of the Internet infrastructure as they enable the resolution of domain names to Internet Protocol (IP) addresses, the numbering system which allows communication between devices on the Internet. There are currently 13 DNS root servers, mostly located in the US and Europe, identified by the letters A through M. Instances (copies) of these servers are distributed geographically around the world. There are no root servers on the African continent.
Instances of the L-root server, operated by ICANN, have been set up in Senegal, Kenya, South Africa, Ivory Coast, Mauritius, and Mozambique.

additional root server seems unlikely[87], through its Coalition for Digital Africa, ICANN has recently focused on the creation of ICANN-Managed Root Server (IMRS) Clusters across the continent[88]. These clusters are intended to ensure that *"Internet queries from Africa can be answered within the region, and not be dependent on networks and servers in other parts of the world, thus reducing latency and improving internet user experience in the entire region."*[89] One such cluster was inaugurated in Kenya in November 2022, and Senegal would be a strong candidate to host a similar cluster for the West Africa region.

3.2.4 Promotion of Internet standards deployment

Open Internet standards can be seen as cornerstones of the Open Internet. Broad, multi-stakeholder participation in internet standards processes, with balanced representation from stakeholders from around the world, and the recognition of open standards by governmental and regulatory bodies are essential for the continued growth and development of the internet.

Frontrunner in the deployment of DNSSEC

Senegal was one of the first African countries to deploy DNSSEC, the domain name system security extension that adds digital signatures to DNS queries and responses to help prevent DNS spoofing and other types of attacks. The root zone for .SN, the Senegal ccTLD has been signed since 2016[90]. While broader deployment of DNSSEC has been slow, in recent years, the Senegalese Network Information Center (NIC) has been keen to promote DNSSEC adoption among domain name registrars and hosting providers. The government has also made a commitment to deploy DNSSEC across e-gov services which should help drive greater adoption.

Promotion of IPv6

With a 3.85% IPv6 Capable and 3.82% IPv6 Preferred rate, IPv6 adoption in Senegal scores slightly better than the regional average for Western Africa (1.42% IPv6 Capable, 1.39% IPv6 Preferred) and the African continent (2.02% IPv6 Capable, 1.97 IPv6 Preferred). Senegal ranks in top 12th position compared to all other African countries. Nevertheless, these figures lag far behind the global average of 35,46% IPv6 Capable and 34.55 % IPv6 preferred.[91]

The transition from the original internet protocol (IPv4) to IPv6, which offers significantly expanded address space, is viewed as strategic priority by Senegal's Cybersecurity Strategy (SNC2022)[92] to accommodate the growing number of internet-connected devices and ensure the continued growth of the digital ecosystem.

The Government of Senegal in coordination with AfriNIC and the telecommunications regulator, ARTP, have been actively encouraging Internet Service Providers (ISPs) to adopt IPv6. Workshops and awareness raising campaigns on IPv6 adoption and deployment have been organized, targeted at ISPs and other network operators.

Among the challenges for IPv6 deployment in Senegal, as in other countries, is the significant reliance on "legacy" IPv4 infrastructure and the need for investments to upgrade networks and equipment to support IPv6. Limited awareness and technical expertise regarding IPv6 among

87 The issue of the creation of a dedicated Root Server for Africa was raised during interviews carried out as part of this report. The last DNS root server to be put into service was root server "M," in 2008. This was the first new root server to be added since 1999.

88 ICANN. (2022, 15 November) "ICANN Investment in Africa Enables Safer, Faster Internet Access Across the Continent."

89 ICANN. (2022, 28 February).

90 ICANN African DNSSEC Roadshow: https://dnssec-africa.org/index.html

91 Measurements for September 2023, based on https://stats.labs.apnic.net/ipv6 .

92 Ministry of Communications, Telecommunications, Post and the Digital Economy, Republic of Senegal. (2017). "Stratégie National de Cybersécurité du Sénégal - SNC2022." (Senegalese Cybersecurity Strategy)

network operators and digital service providers is also an issue.

3.2.5 Stimulation of the use of Digital Commons and Open Source

A recent study by the World Bank Group[93] highlighted that a broader use and adoption of productivity-enhancing digital and complementary technologies by formal and informal enterprises, and households in Senegal 'can generate better and more jobs, including for lower-skilled people, and support both the short-term objective of economic recovery and the government's long-term vision of economic transformation with more inclusive growth.' Also, informal micro-enterprises benefit from the use of management software tools or inventory control/point-of-sale (POS) software or use the internet to better understand their customers for marketing and sales. The creation and uptake of 'easy-to-use apps that respond to the needs of lower-income, lower-skilled workers and other vulnerable and excluded groups' is said to further stimulate inclusive economic growth.

These and other observations make clear that there are opportunities for local developers, e-entrepreneurs to create applications and services to support the Senegalese enterprises and economy using open-source software. They can be tailored to the local market and needs, and help informal enterprises to professionalise, and offered to the global market.

The website www.madeinsenegal.dev, for example, offers a space where Senegalese developers can present the tools they built. The project is driven by the Galsen DEV initiative that creates 'a **community that brings together Senegalese developers** with the aim of creating an ecosystem conductive to creation and sharing as a developer and popularizing programming throughout Senegal.'[94]

In 2006 the government publicly acknowledged the importance of open-source software when the state's IT agency (AIDE) switched to open software solutions for payroll, accounting and budgeting and started to **promote the use of Free and Open-Source Software** (FOSS) in public institutions, including schools and government agencies, to cut software costs, enhance digital literacy, and encourage collaboration and knowledge sharing.[95] The Ministry of Health and Social Action for example uses iHRIS Manage[96], a free open-source software solution to design and manage a comprehensive human resources strategy.[97]

Internet Society Chapitre Sénégalais (ISOC) Senegal has focused on the **development of Local Content**. on developing local digital content, including in local languages, to address the needs of the population.[98]

The government in cooperation with United Nations Educational, Scientific and Cultural Organization (UNESCO) has set up **Community Technology Centres (Centres Multimédia Communautaires)** across the country. These centres give access to computers, internet connectivity and training programs, aimed at bridging the digital divide, promoting digital literacy, and allowing remote communities to benefit from digital technologies.[99]

Information and communication technology (ICT) Education and Training: The government

93 Cruz, M., Dutz, M., Rodríguez-Castelán, C., (2022). "Digital Senegal for Inclusive Growth. Technological Transformation for Better and More Jobs." World Bank Group.

94 https://galsen.dev/en/about

95 Niccolai, J. (2006, 31 January). "Senegal goes open source to cut software costs." NetworkWorld

96 https://www.ihris.org/ihris-manage

97 http://www.grh.sante.gouv.sn/index.php/login

98 UNESCO (2020). Evaluation du Développement de l'Internet au Sénégal.

99 https://cursus.edu/fr/3040/senegal-creation-de-cinquante-centres-multimedia-communautaires

has prioritized ICT education and training programs to enhance digital skills and knowledge. Initiatives such as Orange Digital Centres, with financial backing from Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ)[100], have been launched to train teachers and students in ICT usage, programming, and digital literacy, empowering individuals with the necessary skills to participate in the digital world.[101]

Open Data Initiatives. The country has indicated that it favours the promotion of open data and transparency, notably by joining the Open Government Partnership, and with the creation of **Senegal Data Portal** to publish and share government statistical data.[102]

These initiatives show Senegal's proactive approach reinforcing secure online exchanges, enhancing the reliability of domain name management, and fostering a robust and trusted digital ecosystem in Senegal.

3.3 RESULTS OF THE SENEGAL MODEL OF OPEN INTERNET TECHNICAL INFRASTRUCTURE

Senegal's efforts to develop a robust, reliable, and accessible core internet infrastructure, coupled with targeted investments in Open Internet infrastructure, have had a positive impact on the digital economy. There is a climate of innovation with the creation of new job opportunities and improved accessibility to digital services for its citizens.

Below are of some key economic, social, and technical results that Senegal has achieved through its Open Internet technical infrastructure model approach.

Enhanced Connectivity and meaningful access

Recent studies have shown that mobile broadband internet coverage in Senegal has been associated with higher household consumption and lower poverty rates.[103] They point to the potential benefits that access to mobile broadband internet has had on increasing consumption and reducing poverty in Senegal, with estimates indicating that consumption rates in households covered by 3G is 14 percent higher than that of households without coverage.[104]

Moreover, the government's efforts to expand and upgrade the country's telecommunications and internet infrastructure have paid off in terms of increased access to the internet via fixed and mobile devices. A combination of government and private sector investments in digital infrastructure projects have resulted in the creation of new services and technologies.[105] These have been assessed to have had a positive impact in many sectors, including education, healthcare, and commerce.

Improved Economic Development

Senegal's digital transformation has led to the creation of new e-government services, the emergence of new enterprises notably in the areas of e-commerce, fintech and digital services, and increasing employment opportunities.

100 https://www.giz.de/

101 GIZ (2021, 25 February). "Digital Skills and Support for Young People in the Tech Sector."

102 Senegal Data Portal: https://senegal.opendataforafrica.org/

103 Masaki, T., Granguillhome Ochoa, R., Rodriguez Castelan, C. (2020). "Broadband Internet and Household Welfare in Senegal." World Bank Group.
The study examines the relationship between access to broadband internet and household welfare between 2011 and 2018. The results show that 3G coverage is associated with a 14 percent increase in total consumption and a 10 percent decline in extreme poverty.

104 Vargas Da Cruz, M. J., Dutz, M. A., Rodriguez Castelan, C. (2021) "Digital Senegal for Inclusive Growth: Technological Transformation for Better and More Jobs." World Bank Group.

105 Chango, M., Sadio, I. (2020), "Evaluation du développement de l'Internet au Sénégal : utilisation des indicateurs ROAM-X de l'universalité de l'Internet de l'UNESCO."

Table 2: Creation of E-Gov & E-Commerce services

E-Gov Services	E-Government Development Index: 0.4479 (Global rank 143 / 193)
E-Participation	E-Participation Index: 0.3409 (Global rank: 110 / 193)
E-Commerce	Revenue in the eCommerce market is projected to reach €208.39m in 2023. Revenue is expected to show an annual growth rate (CAGR 2023-2027) of 10.77%, resulting in a projected market volume of €313.76m by 2027. With a projected market volume of €1,450.74bn in 2023, most revenue is generated in China. In the eCommerce market, the number of users is expected to amount to 8.82m users by 2027. User penetration will be 33.5% in 2023 and is expected to hit 42.0% by 2027.

Enhanced Digital Skills

Senegal has invested in digital skills, notably through the creation of a UVS[106], a "digital public university" that uses an innovative pedagogical model based on ICTs. This network of "open digital spaces" across Senegal, the UVS system aims to introduce digital tools provide training to all population categories. There are plans for the construction of at least one Open Digital Space (ENO)[107] per department. The UVS system is a key component of Senegal's digital transformation strategy, aiming to improve access to education and has contributed to the development of a skilled workforce and subject matter experts.

Improved Innovation and Entrepreneurship

Senegal is emerging as a regional start-up hub with a growing reputation as one of the most mature start-up ecosystems in Francophone Africa.[108] Digital transformation has led to an environment that is conducive to innovation and entrepreneurship by providing access to resources including funding, mentorship, and market access.

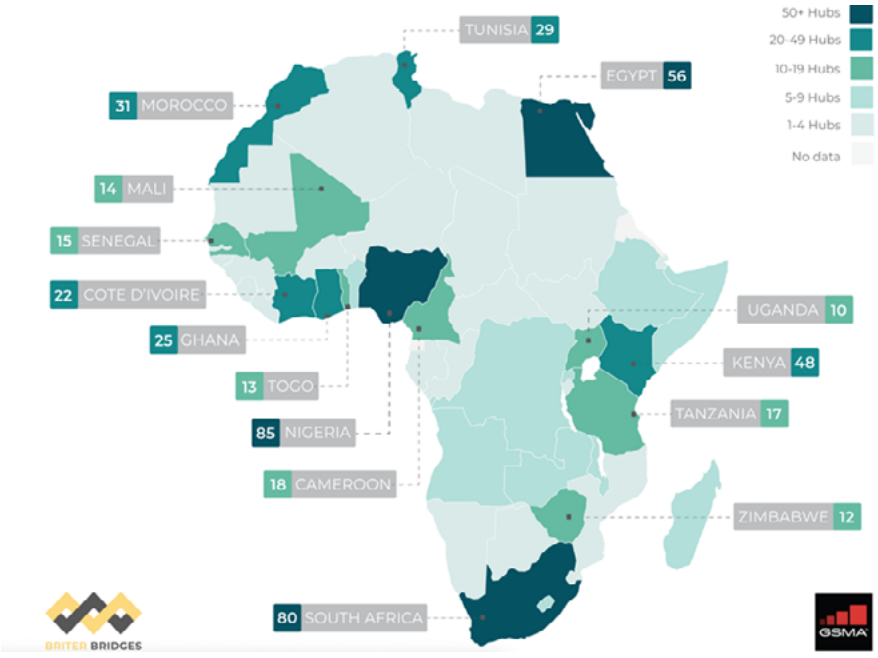

Figure 4. Mapping of Tech Hubs in Africa. Senegal has emerged as a leading Tech Hub in West Africa, with Côte d'Ivoire, Ghana and, more recently, Mali. Source: GSMA (2019)

106 Université Virtuelle du Sénégal : https://www.unchk.sn/

107 Open Digital Spaces - Espace Numérique Ouvert (ENO) - are spaces created in connection with the Université Virtuelle du Sénégal, designed to facilitate training in digital skills for the population at large.

108 VC4A. (2019, 7 May)." VC4A launching Senegal research report: startup ecosystem starting to pick up the pace again."

Improved Public Services

Digital transformation has helped in the delivery of more efficient, accessible, and cost-effective public services such as in healthcare, education, and e-government services. For example, the Sénégal Services[109] platform was put in place to manage administrative procedures with the aim to allow users to consult a geolocated map of the network of Senegal Services Spaces and to for a public service or contact. At present, the website provides information on administrative procedures and the European Union (EU) is working to promote a pilot action providing real services to users by government services. For improved competition, Senegal still needs to open the market to have more competition, cover more of country white zones, and reduce internet price for white zone inhabitants.

Increased investment through favourable Policy and Regulatory Frameworks

Senegal has introduced a clear, transparent, and favourable regulatory framework that promotes competition, reduces barriers to entry, and ensures fair pricing while ensuring consumer protection and fair market practices. Senegal established the Telecommunications and Postal Regulatory Authority[110] (Autorité de Régulation des Télécommunications et des Postes ARTP) as an independent regulatory authority, placed under the President of the Republic, to oversee and enforce regulatory policies and coordinate regulatory practices with neighbouring countries to facilitate cross-border internet services. ARTP has legal personality and financial and management autonomy. Law No. 2011-01 of February 24, on the Telecommunications Code assigned ARTP's missions[111], responsibilities[112], and prerogatives.[113] For example, in early November 2023, ARTP and the Regulatory Authority of Mauritania (Autorité de Regulation, ARE) signed a cooperation agreement[114] relating to cross-border frequency management in order to reduce cross-border interference and improve the quality of telecoms services in regions along the 742km border between Senegal and Mauritania.

The establishment of ARTP has led to an increase in national, regional, and international investment in internet infrastructure in Senegal, from fiber-optic and last-mile connectivity to local neutral data centres.

Increased Internet access and coverage

Senegal invested in the development of a robust Open Internet infrastructure. It expanded its core fibre optic network infrastructure coverage, connected it to international gateways, and improved middle and last-mile connectivity to urban and rural areas. This has significantly improved internet access and connectivity, online services, the digital economy, and digital inclusion.

Risk-shared Public-Private Partnership (PPP) initiatives

Senegal has achieved strong collaboration between government entities, private sector companies, and civil society organizations by investing in the development of a robust Open Internet infrastructure. Senegal facilitated collaboration between public and private sectors through PPP initiatives. Senegal has encouraged private sector participation in internet infrastructure development by creating clear and transparent guidelines and regulations favourable for investment in the key areas of internet infrastructure. For example, through PPP initiatives, Senegal has better leveraged resources, exper-

109 Sénégal Services : https//senegalservices.sn
110 https://artp.sn/lartp
111 https://artp.sn/lartp/nos-missions
112 https://artp.sn/lartp/nos-attributions
113 https://artp.sn/lartp/nos-prerogatives
114 Senegal and Mauritania commit to cross-border frequency management (commsupdate.com)

tise, and funding to improve high-speed internet access to urban and rural areas and improve its Internet technical infrastructure.

Some additional examples of regulations and guidelines, that were considered favourable, in clarity and transparency, to investment in internet infrastructure in Senegal, include:

- Senegal established ARTP as the regulatory authority responsible for overseeing the telecom and internet sector in Senegal. ARTP presence has improved investor confidence by ensuring that Senegal's regulations are more reliable and enforceable.
- Senegal facilitated licensing for investors - such as by telecom companies and ISPs and allocated radio spectrum in a transparent and competitive manner, allowing operators to acquire spectrum licenses through auctions and competitive processes.
- Senegal implemented data protection and privacy regulations, to ensure the security and privacy of user data, which are considered crucial for investor and consumer confidence.
- Senegal's policy aimed at expanding user access to internet services and reaching out to new users and communities. For example,
  - Senegal imposed Universal Service Obligations (USO) requirements on operators to extend their services to rural and underserved areas.
  - Senegal regulations also encouraged infrastructure sharing, making it more cost-effective for businesses to invest in and expand internet infrastructure.

Enhanced skills development and capacity building

The Senegal Model emphasizes capacity-building and training programmes to develop local technical expertise in internet infrastructure management. In fact, Senegal encouraged investment in training and skill development programmes to build a local workforce capable of maintaining and expanding internet infrastructure. This includes training network engineers, technicians, and support staff.

Improved performance services at reduced cost through local neutral data centres and IXPs

Senegal has encouraged the establishment of local neutral data centres and Internet Exchange Points (IXPs)IXPs. This has enhanced internet performance, reduced network latency, and lowered costs by keeping local traffic within the country rather than routing it through international networks and service providers. It has also improved colocation, hosting, and online services.

Reduced digital divide and increased digital inclusion

Senegal expanded its network and last-mile connectivity, and implemented initiatives to connect marginalized communities, schools, and remote businesses by giving wider and more affordable access to the internet. Senegal has also engaged with a wide range of stakeholders, including local communities, businesses, and civil society, to ensure that the internet infrastructure meets the diverse needs of the population. This has reduced the digital divide by expanding access to underserved areas and promoting digital literacy while introducing more affordable prices through key infrastructure local solutions.

Improved e-Government Services

Senegal has used the internet to deliver government online services to improve the efficiency and accessibility of public sector online offers to the public and the private sector alike. This included online services related to public financial management, taxation, health, education, etc. Moreover, Senegal implemented cybersecurity measures to protect critical internet infrastructure and user data which has increased trust in the use of the internet and encouraged investment. For example, Senegal's

cybersecurity strategy[115], "Stratégie Nationale de Cybersécurité du Sénégal (SNC2022)", approved in 2017, was part of the wider ICT strategy of the country ("Sénégal Numérique 2025"). SNC2022 supported five main strategic objectives:

- Improve the legal and institutional framework,
- Promote Critical Information Infrastructure Protection (CII),
- Promote a culture of cybersecurity in Senegal,
- Increase (technical) capacities in all sectors of the economy, and
- Participate in relevant regional and international efforts aimed at improving cybercrime protection.

SNC2022 mentions an index of critical infrastructures and measures (section 4.2) and leaves the identification and protection of critical information infrastructures (CII) in the hands of three disparate authorities:

a. The Telecommunications and Postal Authority (ARTP).
b. The National Cryptography Commission (Commission Nationale de Cryptologie, CNC); and
c. The Agency for State informatic (ADIE).

The strategy was annexed by a budget and action plan noting specific objectives and actions as well as the responsible agencies and ministries. The ministry in charge is the Ministry of Communication, Telecommunications and Digital Economy (MCTEN), where a special committee oversees the implementation measures.

Moreover, the establishment of a directory of CIIs and information systems in Senegal was scheduled for September 2018, under the joint responsibility of the abovementioned authorities according to the priority projects listed in Annex B of the SNC2022. However, the state of implementation of the rudimentary CII policy is not public. Moreover, a single entity/agency for cybersecurity has not been formed yet.

115 Ministry of Communications, Telecommunications, Post and the Digital Economy, Republic of Senegal. (2017). "Stratégie National de Cybersécurité du Sénégal - SNC2022."

4. Conclusion: Is the Senegal Model of Open Internet Technical Infrastructure applicable in other countries?

Senegal's model for the deployment and promotion of Open Internet technical infrastructure offers insights and lessons that can undoubtedly inspire similar approaches across West Africa and the wider continent.

Despite the myriad political, economic, environmental, and technological challenges faced by different countries in Africa, the Senegalese example calls for attention to the way it has been planned and implemented, the governance practices which underpin it, and the impact it has had on connectivity rates and economic development. The conditions to replicate Senegal's successful implementation experience in Open Internet technical infrastructure will inevitably vary on the country and the consideration of local conditions such as:

- **Political will and support:** Governments should understand the implications and opportunities of the Open Internet and be willing to create an enabling national and regional environment for its growth.
- **Investment in Open Internet digital infrastructure:** Countries should be committed to investing in and building up their Open Internet digital infrastructure and secure support for and identify optimal locations for IXPs based on population centres, traffic patterns, and connectivity gaps.
- **Development of digital skills**: Countries should be committed to develop the digital skills of the public and private sectors and the overall country population. This should enable the different societal groups to fully participate in and reap the benefits from the Open Internet. Countries should offer adequate specialised training programmes, by collaborating with educational institutions and industry experts, to provide the needed training and certification to build local expertise in Internet infrastructure management, cybersecurity, and digital literacy. It will be advisable to include certification to confirm, benchmark, and exchange skills, knowledge, and expertise at the national, regional, and international levels.
- **Collaboration with stakeholders:** Governments should be supportive of the multi-stakeholder approach to the development of the Open Internet, and committed to working with stakeholders including businesses, civil society organisations, and international partners to develop and implement common strategies. In addition, the Internet Service Providers should be ready and willing to peer locally in each country to improve connectivity and outreach to rural and underserved groups and remote areas.
- **Adoption of supportive policies and regulations:** Countries should be committed to the adoption of policies, regulations, and governance practices that support the growth of the

Open Internet, promote competition, protect consumers, ensure fair market practices, and promote net neutrality, data protection, and cybersecurity. Moreover, the enacted laws and regulations should support the establishing of independent oversight regulatory authorities to oversee and enforce regulatory policies and encourage the coordination of regulatory practices with neighbouring countries to facilitate cross-border internet services.

- **Support to digital inclusion:** Countries should be willing to develop policies to reduce the cost of internet access, such as subsidies or tax incentives, implement initiatives to extend internet access to rural and underserved areas, and launch digital skills training programmes, targeting both urban and rural populations and disfranchised populations or groups in the society.

Is the Senegal Model of Open Internet Technical Infrastructure replicable?

While replication will necessarily require customization to fit the unique context of each country, Senegal's model in support of the development of Open Internet Technical infrastructure can serve as guidance for other countries in the Global South.

Senegal's collaboration with the European Union is based on a vision that is largely shared for advancing and fostering the Open Internet. With its commitment and potential, it is our view that the country is well-positioned to take on a more prominent role in the West Africa region and within Pan-African organizations such as the African Union, the International Telecommunication Union, and Smart Africa, to further the promotion of an Open Internet and digital inclusion.

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