ITUPublications

International Telecommunication Union
Development Sector

Strategy for 5G adoption and uptake in Uganda

THE REPUBLIC OF UGANDA
MINISTRY OF ICT & NATIONAL GUIDANCE

Strategy for 5G adoption and uptake in Uganda

Acknowledgements

This report was developed by the Ministry of ICT and National Guidance and the International Telecommunication Union (ITU), with the support of Divisions and Services in ITU Headquarters and ITU Regional Office for Africa under the Technical Assistance and Training to Uganda on National ICT Development Strategy' (2021-2024) project. The project is a collaboration between the Government of Uganda and ITU, supported by the Global Development and South-South Cooperation Fund (GDSSCF) and the ITU ICT Development Fund (ICT-DF).

The research was undertaken by Technology Solutions Africa Ltd under the framework of the project and its deliverables. Technical input, feedback and guidance have been provided by ITU and the Ministry of ICT and National Guidance project team members and experts in government ministries, agencies, institutions, and across Uganda's digital ecosystem.

Disclaimer

The designations employed and the presentation of the material in this publication do not imply the expression of any opinion whatsoever on the part of the International Telecommunication Union (ITU) or of the ITU secretariat concerning the legal status of any country, territory, city or area, or of its authorities, or concerning the delimitation of its frontiers or boundaries.

The mention of specific companies or of certain manufacturers' products does not imply that they are endorsed or recommended by ITU in preference to others of a similar nature that are not mentioned. Errors and omissions excepted, the names of proprietary products are distinguished by initial capital letters.

All reasonable precautions have been taken by ITU to verify the information contained in this publication. However, the published material is being distributed without warranty of any kind, either expressed or implied. The responsibility for the interpretation and use of the material lies with the reader.

The opinions, findings and conclusions expressed in this publication do not necessarily reflect the views of ITU or its membership.

ISBN

978-92-61-40001-9 (Electronic version)
978-92-61-40041-5 (EPUB version)

Please consider the environment before printing this report.

Foreword

The **Strategy for 5G adoption and uptake in Uganda** represents a pivotal moment in our country's journey towards achieving the aspirations of the Digital Uganda Vision. The potential of 5G technology to transform our economy, enhance service delivery, and foster innovation cannot be overstated. As we stand on the brink of a new era of connectivity, this strategy provides a comprehensive roadmap for addressing challenges, seizing opportunities, and ensuring that 5G becomes a driver of inclusive growth and national development.

The adoption of 5G technology is not merely a technological milestone but a strategic imperative for Uganda's future. It symbolizes our commitment to creating a digital society that bridges the gap between rural and urban areas, enhances productivity in key sectors such as manufacturing and agro-processing, and empowers our citizens with opportunities for economic and social advancement. This strategy addresses critical gaps in our ICT ecosystem, including affordable broadband access, digital literacy, and regulatory readiness, ensuring that no one is left behind in the transition to 5G.

The strategy also aligns with our national goals under the Third National Development Plan (NDPIII) and Uganda's Vision 2040, emphasizing the importance of technology in driving industrialization and economic diversification. By integrating international best practices and focusing on capacity building, the strategy positions Uganda to compete in the global digital economy while safeguarding our national interests through enhanced cybersecurity and regulatory compliance with global standards.

This is not merely a strategy for technological advancement but a commitment to building a more equitable and connected future for all Ugandans. I call upon all stakeholders—government agencies, the private sector, development partners, and the broader community—to rally behind this initiative and play their part in ensuring its success. Together, we can unlock the transformative potential of 5G and propel Uganda into a new era of innovation and prosperity.

Hon. Dr. Chris Baryomunsi
Minister of ICT and National Guidance

Foreword

It is my pleasure to present this report under the project 'Technical Assistance and Training to Uganda on National ICT Development Strategy', a collaboration between the Government of Uganda and the International Telecommunication Union, supported by the Global Development and South-South Cooperation Fund and ITU's ICT Development Fund.

Through carefully co-crafted interventions in support of the country's vision to transform Uganda into a digitally enabled society that is innovative, productive and competitive, the project has applied a three-pronged approach focusing on the development of policy recommendations, enabling capacity development, and the implementation of pilot projects.

In recent years, Uganda has witnessed tremendous growth in its digital economy, reflecting broader trends across the Africa region and globally. The increased access to digital technologies, new opportunities that connectivity has brought, and the surge in digital services are fueling rapid advancements on how citizens engage with one another and with vital government services. These developments also bring new challenges, requiring policy-makers and regulators to rethink strategically and build enabling policy and regulatory frameworks that are future-ready and adaptable to this ever-changing landscape. Moreover, digital skills remain essential for citizens to meaningfully participate in the digital space and for professionals to fully leverage the potential of digital technologies in addressing socio-economic challenges. This has been a critical aspect of the implementation of the policy interventions within this project.

Co-created and initiated in support of Uganda's ambitious digital transformation journey, this project stands as an example of how focused and meaningful partnerships can lead to impactful change. We have witnessed the results of the policy interventions and the impact of the significant capacity development in the country. I believe the efforts will continue to impact Uganda's transformation for years to come.

I encourage ITU Member States across Africa and globally as well as development partners to join forces and invest in digital transformation for social and economic growth. The Telecommunication Development Bureau stands ready to continue supporting countries on their digital transformation journeys with impactful project implementation and partnerships that are essential for achieving universal and meaningful connectivity and digital transformation for all.

Dr Cosmas Luckyson Zavazava
Director of the Telecommunication Development Bureau
International Telecommunication Union

Foreword

The development of **Strategy for 5G adoption and uptake in Uganda** is a significant achievement, reflecting the collaborative efforts and dedication of multiple stakeholders. This strategy provides a clear and actionable framework for the adoption and deployment of 5G technology in Uganda, addressing technical, regulatory, and capacity building needs to ensure that this transformative technology benefits all Ugandans.

I extend my heartfelt appreciation to the International Telecommunication Union (ITU) for their unwavering support, both technically and financially, in the preparation of this strategy. Their expertise and insights have been instrumental in shaping a document that aligns with international best practices and Uganda's unique needs. I also acknowledge the Global Development and South-South Cooperation Fund (GDSSCF) for the financial contribution which made this work possible.

A special recognition is due to the technical team at the Ministry of ICT and National Guidance, whose dedication and expertise were critical in every stage of this process. The team's efforts in coordinating stakeholders, analyzing complex technical issues, and ensuring that the strategy is both practical and forward-looking cannot be overstated.

Additionally, I wish to thank our partners from the private sector, academia, and civil society, who provided valuable insights and perspectives during the stakeholder consultations. Their input enriched this strategy, ensuring that it is comprehensive and responsive to the needs of various sectors.

This strategy underscores the importance of investing in infrastructure, workforce development, and regulatory reforms to ensure that Uganda is ready for 5G adoption. By prioritizing capacity building, cybersecurity, and pilot projects, the strategy provides a robust foundation for the successful implementation of 5G technology.

As we move towards implementation, I urge all stakeholders to remain actively engaged. The deployment of 5G is not just a technological upgrade; it is a catalyst for socio-economic transformation. Together, we can ensure that Uganda reaps the full benefits of 5G, driving innovation, efficiency, and growth across all sectors of the economy.

Dr. Amina Zawedde (PhD)
Permanent Secretary
Ministry of ICT and National Guidance
Government of Uganda

Table of contents

List of tables and figures

Tables

Figures

Abbreviations

AI	Artificial Intelligence
DUV	Digital Uganda Vision
FDD	frequency division duplex
eMBB	enhanced mobile broadband
GDP	gross domestic product
ICT	information and communication technology
IoT	Internet of Things
ISP	Internet service provider
ITU	International Telecommunication Union
KPI	key performance indicator
LTE	Long-Term Evolution
M&E	monitoring and evaluation
MCS	mission critical services
MIMO	multiple input–multiple output
MIoT	massive Internet of Things
NBI	national backbone infrastructure
NDP III	Third National Development Plan
NESAS	Network Equipment Security Assurance Scheme
NITA-U	National Information Technology Authority Uganda
NSA	non-standalone
PPP	public–private partnership
SMS	short message service
TDD	time division duplex
UCC	Uganda Communications Commission
USF	universal service fund

Executive summary

The 5G adoption strategy for Uganda initiative aligns the broader objectives of the Digital Uganda Vision (DUV), the Third National Development Plan (NDP III) and the Uganda Digital Transformation Roadmap (3). Within the wider context of broadband development and investment in Uganda, this strategy is designed to propel Uganda into a digitally empowered society, where the transformative potential of 5G technology drives innovation, economic growth and social inclusion. The primary goal of this initiative is to create a supportive policy and regulatory environment for broadband, enhance Uganda's information and communication technology (ICT) infrastructure, and ensure that the benefits of digital transformation are accessible to all people living in Uganda.

This strategy stems from the need to address key challenges identified in Uganda's current wireless networks. Although Uganda has made significant progress in expanding 3G and 4G networks, these resources remain underutilized, primarily due to low demand restrained by limited digital literacy, affordability issues and insufficient access to broadband services. This underutilization presents a substantial challenge to the economic viability of 5G investments, as the lack of a robust user base makes it difficult to justify the high costs associated with 5G deployment.

In addition to infrastructure and demand challenges, some gaps in Uganda's existing regulatory framework need to be addressed to facilitate the smooth roll-out of 5G. These include the need for updated policies on spectrum management, infrastructure sharing and cybersecurity, which are essential for creating a conducive environment for 5G adoption.

Moreover, the 5G adoption strategy identifies critical sectors such as agriculture, health care, education and urban development, where 5G can have the most transformative impact. However, the services offered in these sectors rely heavily on 3G and 4G networks and other broadband access technologies, highlighting the urgent need to enhance demand and build a solid foundation for the future deployment of 5G. The 5G adoption strategy emphasizes the importance of stimulating demand for existing broadband services to overcome these challenges and capitalize on the opportunities presented by 5G. This can be achieved through targeted public awareness campaigns, expanding digital literacy programmes, and providing affordable broadband solutions and devices, particularly in underserved areas. By boosting demand, Uganda can lay a strong foundation for 5G, ensuring that investments in this new technology are economically viable and socially beneficial.

The 5G adoption strategy also calls for leveraging 5G to drive industrial automation and economic diversification, particularly in the manufacturing and agro-processing sectors. This will require significant investments in Internet of Things (IoT) infrastructure and workforce development, to ensure that these sectors can fully utilize 5G technology. Additionally, the strategy advocates for updating Uganda's ICT regulatory framework to address current gaps and align with international best practices. This includes revising policies on spectrum management, establishing standards for infrastructure sharing, enhancing cybersecurity measures to protect Uganda's digital infrastructure, and ensuring compliance with 5G global standards such as the Network Equipment Security Assurance Scheme (NESAS).

Capacity development and knowledge transfer are also critical components of this strategy. Building local expertise and facilitating knowledge transfer through comprehensive training programmes and partnerships with international experts will ensure that Ugandan stakeholders are well prepared to manage and operate 5G networks. To demonstrate the practical benefits of 5G, the strategy proposes pilot projects in key sectors. These projects will serve as proof of concept, showcasing the potential of 5G to improve service delivery, enhance efficiency and drive economic growth.

In conclusion, the successful implementation of this 5G adoption strategy will require coordinated efforts across government, industry and the broader community. By focusing on increasing demand for broadband services, addressing regulatory gaps, building local capacity and ensuring compliance with international standards such as NESAS, Uganda can ensure that 5G technology is deployed effectively and equitably, driving the country towards the goals of the DUV. This strategy is not just a roadmap for technological advancement; it is a commitment to building a more connected, innovative and prosperous future for all Ugandans.

1 Introduction

As Uganda embarks on a journey towards enhanced connectivity and technological progress, adopting fifth generation (5G) technology becomes critical to this transformation. 5G wireless networks promise to revolutionize how Ugandans live, work and interact by delivering unparalleled speeds, reduced latency and expanded connectivity. The potential economic and societal benefits of 5G adoption are immense, from catalysing economic growth and creating new industries to improving public services such as health care and education.

The review of broadband adoption, including the consideration of 5G among other technologies as per the national connectivity objectives, was one of the areas for further study within the Government of Uganda and ITU "Technical Assistance and Training to Uganda on National ICT Development Strategy" (2021-24) project. This initiative aims to bolster the ICT sector, fostering economic development, reducing poverty and supporting various poverty alleviation activities. Rooted in the DUV framework and aligned with NDP III and Uganda's Digital Transformation Roadmap (3), the overall Government of Uganda-ITU project, supported by the Global Development and South-South Cooperation Fund (GDF) adopts a three-pronged approach focused on developing policy and strategy recommendations, enhancing capacity and implementing pilot projects. These efforts aim to establish a digitally empowered society and knowledge economy, ultimately transforming Uganda into a digitally enabled, innovative, productive and competitive nation.

Central to the success of this transformation is the development of robust broadband infrastructure, which is essential for driving economic growth and improving the livelihoods of Ugandans. The project seeks to enhance Internet connectivity and network resilience, boosting sustainable social and economic development opportunities. It also aims to support the Ugandan Government in creating an enabling ICT policy and regulatory environment, making ICT services more affordable and accessible for all.

In this context, considering the adoption of different types of wired and wireless technologies, including 5G technology in Uganda represents a significant milestone. Building on the successes of 3G and 4G technologies, 5G is expected to meet the growing demands for faster data transmission and more reliable Internet access. According to Cervell (1), 5G offers significantly higher data speeds, greater network capacity, and lower latency, enabling a wide array of new applications and services, from virtual and augmented reality to autonomous vehicles and IoT (ibid.).

While 5G adoption in Uganda is still in its early stages, the potential for transformative impact on the economy and community life is substantial. Recognizing these opportunities, the Ugandan Government has proactively begun to lay the groundwork for 5G adoption. Through recent Ministry of Information and Communications Technology and National Guidance initiatives – such as the Digital Transformation Roadmap 2023/24–2027/28 (3), and the National Broadband Baseline Survey and Infrastructure Blueprint (4) – and the development of this strategy document with the support of international partners, the government is showing its commitment to the digital future of Uganda. One of the DUV 2040 pillars is enhancing digital infrastructure and connectivity; deploying 5G networks is a critical step in this direction.

The strategy for 5G adoption in Uganda not only addresses the technical aspects of deploying 5G, but also considers its potential to drive sustainable development and improve the quality of life for all Ugandans. The following sections will explore the existing technologies, players in the

market, demand and supply. The aim is to establish the gaps, challenges, drivers, enablers and strategic actions for 5G adoption in Uganda. Ultimately, the strategy will provide an assessment of ongoing 5G implementation in Uganda, documentation of international lessons learned from benchmarking, and an institutional framework that defines functions and the roles of the different stakeholders in Uganda's 5G adoption.

2 Situation analysis: Existing wireless networks in Uganda

2.1 Introduction

The Uganda telecommunication landscape is at a critical juncture, where the adoption of 5G technology can act as a catalyst for broad-based socio-economic transformation. To lay the foundation for this transition, it is essential to comprehensively analyse the current state of existing wireless networks, the market environment and the key stakeholders involved. This situation analysis will explore the network infrastructure, technologies, demand and supply dynamics, as well as the gaps and challenges that must be addressed to facilitate the successful deployment of 5G networks in Uganda.

2.2 Current infrastructure and technologies

The Uganda telecommunication infrastructure has evolved significantly over the past two decades, transitioning from 2G to 4G Long-Term Evolution (LTE) networks. As of June 2023, the country had approximately 34.9 million mobile subscriptions, indicating a penetration rate of 77 lines per 100 Ugandans (2). The mobile networks remain the predominant mode of Internet access, with mobile broadband accounting for over 99 per cent of Internet subscriptions (2).

2.2.1 Existing networks: 2G, 3G, and 4G

The existing network coverage data from the Uganda Communications Commission (UCC) in Table 1 shows a robust foundation, with 99 per cent 2G, 87 per cent 3G, and 61 per cent 4G population coverage in the country.

Table 1. Network coverage by technology (2)

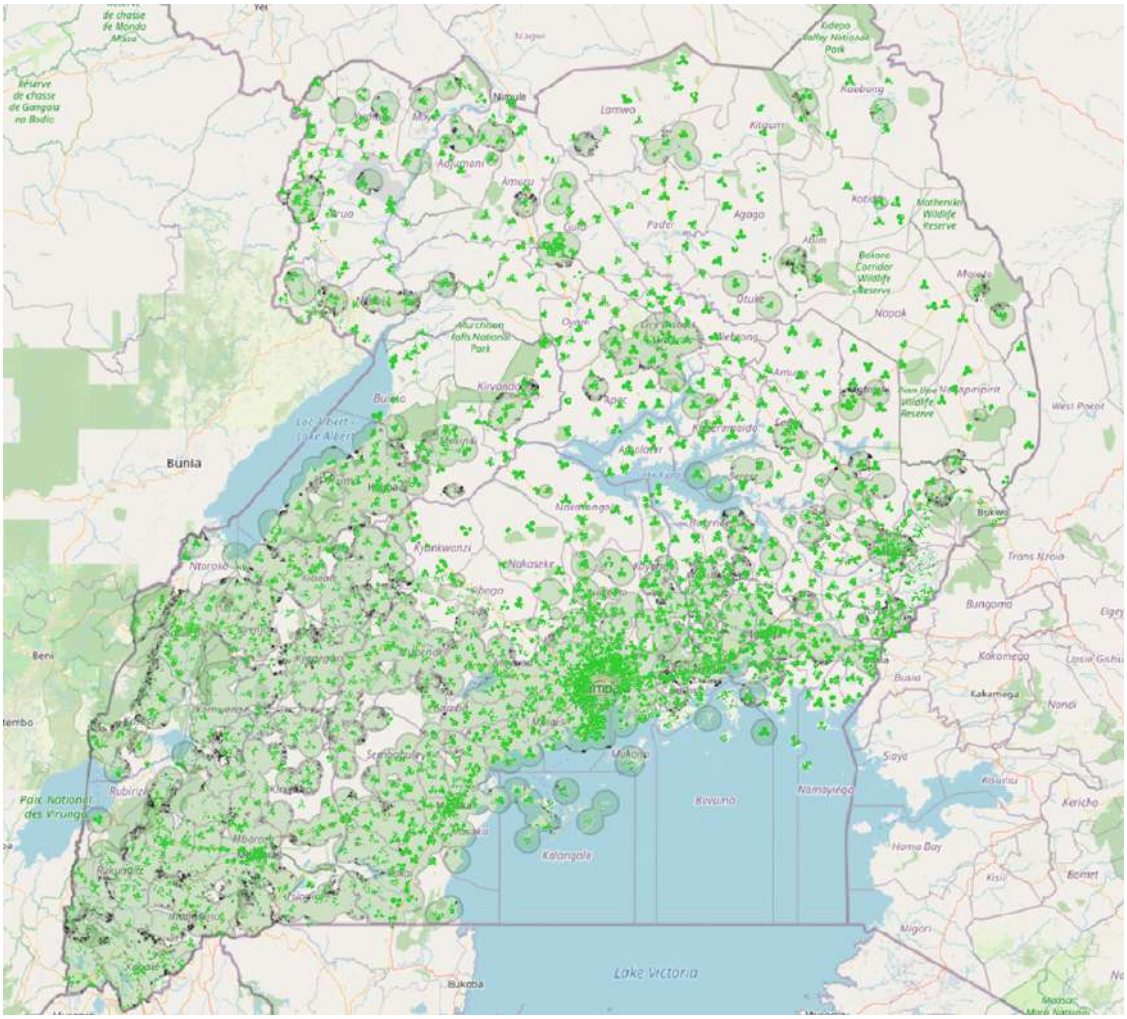
Technology (generation)	Combined population coverage (percentage)
2G	99
3G	87
4G	61

- 2G networks: Still in operation primarily for voice calls and basic messaging (Unstructured Supplementary Service Data (USSD) services). These networks are prevalent in rural areas where higher-generation networks have yet to fully penetrate.
- 3G networks: These networks have supported the expansion of mobile Internet across Uganda, enabling services such as e-mail, basic browsing and social media access. However, the data speeds and reliability are limited compared to more advanced technologies available in the market.

- 4G LTE networks: Uganda has seen steady growth in 4G LTE deployment, with major telecommunication operators such as MTN, Airtel and Lycamobile providing nationwide services. The availability of 4G is more pronounced and utilized in urban areas, while utilization in rural areas remains limited. The 4G networks have facilitated the growth of data-intensive services such as video streaming, online gaming and mobile payments, but spectrum allocation and infrastructure sharing challenges persist (2) (3).

According to the 2022 National Broadband Baseline Survey and Infrastructure Blueprint (4), while Uganda has expanded 4G coverage, there are still significant gaps, especially in rural areas where 3G remains the primary connectivity mode. The survey indicates that "approximately 45 per cent of the population is covered by 4G networks, with rural areas predominantly relying on 3G, and in some cases, 2G" (ibid.). Figure 1 shows the current 4G wireless national coverage in Uganda.

Figure 1. 4G wireless national coverage in Uganda



Source: UCC
Note: The designations employed and presentation of material in this publication, including maps, do not imply the expression of any opinion whatsoever on the part of ITU concerning the legal status of any country, territory, city or area, or concerning the delimitations of its frontiers or boundaries.

2.2.2 National Backbone Infrastructure

The National Backbone Infrastructure (NBI) is a critical component of Uganda's digital infrastructure. The NBI project, overseen by the National Information Technology Authority

– Uganda (NITA-U), aims to extend high-speed Internet access across the country, including rural areas. Despite the progress, gaps remain in middle-mile and last-mile connectivity, particularly in remote regions. The NBI has been pivotal in connecting government institutions and providing backbone support for Internet service providers (ISPs), but the need for last-mile connectivity solutions is still significant.

According to the 2022 National Information Technology Survey Final Report (5), "the NBI has reached all major towns and cities, but the challenge remains in extending this infrastructure to less populated, rural areas where the economic return on investment is less clear". The survey also highlights that "only 22 per cent of rural households have access to broadband Internet, compared to 68 per cent in urban areas", underscoring the need for continued investment in rural broadband initiatives (ibid.).

2.2.3 Satellite and fixed broadband

While mobile networks dominate, satellite and fixed broadband solutions provide alternative connectivity, particularly in remote areas. However, these services are often more expensive and less accessible to the average Ugandan, limiting their impact on broader digital inclusion efforts. The National Broadband Baseline Survey and Infrastructure Blueprint noted that "satellite broadband is currently used by less than 5 per cent of the population, primarily in remote areas where other forms of connectivity are unavailable" (4).

2.3 Market players and ecosystem

A few key players – including MTN Uganda, Airtel Uganda, Lycamobile and Uganda Telecom – primarily drive the telecommunications market in Uganda. These operators are responsible for most mobile subscriptions and Internet services in the country.

2.3.1 MTN Uganda

As the largest telecommunication operator, MTN Uganda has played a significant role in the country's digital landscape. With a substantial market share, MTN has been at the forefront of deploying 4G LTE networks and exploring opportunities for 5G deployment. The company infrastructure investments have focused on urban areas, though there are ongoing efforts to expand coverage to rural regions (2).

2.3.2 Airtel Uganda

Airtel Uganda is the second-largest operator and a key competitor to MTN. The company has made significant strides in expanding its 4G network, offering competitive data packages and mobile money services. Given its extensive customer base and existing infrastructure, Airtel will have a crucial role in the 5G roll-out (2).

2.3.3 Uganda Telecom

Although its market share is smaller, Uganda Telecom remains a vital player, especially in providing services to government agencies and public institutions. Their involvement in the 5G roll-out could hinge on partnerships and government support (2).

2.3.4 Internet service providers

Beyond mobile operators, a range of ISPs operate in Uganda and provide fixed broadband services. These providers cater primarily to corporate clients and high-income households in urban centres. The ISP market is competitive, with companies such as Zuku Fiber, Simba Fiber, Roke Telecom and Liquid Telecom playing significant roles (2).

2.4 Demand and supply dynamics

The demand for Internet and digital services in Uganda has grown exponentially, driven by the proliferation of smartphones and the expansion of mobile broadband. However, the supply side faces challenges, including the high cost of infrastructure deployment, spectrum management issues and the need for significant capital investment (2).

2.4.1 Demand drivers

Demand drivers include:

- Smartphone adoption: The increase in affordable smartphones has been a significant driver of Internet adoption. With over 13.3 million smartphones in use as of June 2023, the demand for high-speed Internet services continues to rise (2).
- Mobile money services: Uganda's mobile money ecosystem is among the most developed in Africa, with over 39.4 million registered accounts. Integrating mobile money with other digital services has fuelled the demand for reliable Internet connectivity (2).
- Digital content consumption: The rise in digital content consumption, particularly in urban areas, has increased demand for faster and more reliable Internet services. This trend is expected to continue with the advent of streaming services, online gaming and remote working (2).

2.4.2 Supply-side constraints

- Infrastructure costs: Deploying telecommunications infrastructure remains a significant barrier, especially in rural and hard-to-reach areas. The need for investment in new technologies such as 5G compounds this challenge (2).
- Spectrum management: Efficient spectrum management is critical for successfully deploying 5G networks. Uganda faces challenges in optimizing spectrum use, which could delay the roll-out of 5G services (2).
- Energy supply: Reliable energy supply is essential for maintaining telecommunications infrastructure. However, frequent power outages in Uganda challenge the consistent operation of network services. According to the Digital Transformation Roadmap 2023/2024–2027/2028, energy supply issues are a significant barrier, with 60 per cent of telecommunications infrastructure relying on diesel generators in off-grid areas (3).

2.5 Gaps and challenges

Several gaps and challenges must be addressed to create a conducive environment for 5G adoption in Uganda.

2.5.1 Coverage gaps

- Rural–urban divide: There is a significant disparity in Internet and mobile coverage between urban and rural areas. Urban centres benefit from better infrastructure and higher network speeds, while rural areas lag, with many regions still relying on 2G or 3G networks. The National Broadband Baseline Survey and Infrastructure Blueprint reports that "rural areas account for 80 per cent of the population but receive only 40 per cent of the broadband infrastructure investment" (4).
- Last-mile connectivity: The last-mile connectivity gap remains a critical challenge, particularly in remote areas. Without addressing this, the benefits of 5G will be limited to a small segment of the population.

2.5.2 Regulatory and policy challenges

- Spectrum allocation: The current spectrum allocation process must be streamlined to support the efficient deployment of 5G networks. This includes ensuring adequate spectrum availability and a transparent and competitive process.
- ICT policy coordination: Better coordination among government agencies responsible for ICT policy and regulation is needed. This will ensure that policies align with the broader goals of digital transformation and economic development (3).

2.5.3 Supply-side challenges

- Limited demand for 5G services: Operators (MTN and Airtel) report that the demand for 5G services is limited, with most customers in the urban areas opting for fibre-to-the-home services, which are faster and more affordable. Furthermore, the operators emphasized the underutilization of the already existing technology of 3G and 4G infrastructure; therefore, a case for nationwide deployment of 5G is not yet justifiable.
- High costs of 5G devices and services: Despite the increase in affordable smartphones highlighted as a driver, the high cost of 5G-compatible devices and data bundles deters widespread adoption. There are only 180 000 5G-capable devices in the country of 46 million people. The 5G-capable devices on the market cost at least USD 300 per device. The target price for an affordable 5G-capable smartphone for the mass population should be about USD 30 (UGX 80 000–100 000). This price is only achievable if the Government supports local manufacturing of such a phone and intentionally waives the import taxes on the raw materials required. The current local manufacturing effort is focused on producing 2G phones, which should shift to making smartphones to support the digital transformation in the country. Concerns about phone theft, particularly high-end smartphones, exacerbate these challenges.
- Lack of public awareness and use cases: More public awareness campaigns are needed to educate citizens on the benefits of 5G. Moreover, developing more 5G use cases across different sectors is crucial to creating demand and justifying further investment.

2.6 Enablers and current status of 5G adoption in Uganda

Despite the challenges associated with 5G deployment, several factors drive its adoption in Uganda. These enablers include government initiatives, public–private partnerships (PPPs), technological innovation, and recent regulatory and infrastructure developments.

2.6.1 Government initiatives

- Digital Uganda Vision (DUV): The DUV framework provides a strategic roadmap for the country's digital transformation. As outlined in the Digital Transformation Roadmap

2023/2024–2027/2028, the government commitment to enhancing digital infrastructure is a crucial enabler for 5G adoption (3).

- Public–private partnerships (PPPs): Leveraging PPPs can help mobilize the necessary resources and expertise for 5G deployment. These partnerships can be crucial in addressing infrastructure gaps, particularly in rural areas.

2.6.2 Technological innovation

- Infrastructure sharing: Encouraging infrastructure sharing among telecommunication operators can reduce the cost of 5G deployment. This approach is particularly relevant in areas where the economic case for standalone infrastructure is weak (2).
- Emerging technologies: Integrating emerging technologies such as IoT, Artificial Intelligence (AI) and cloud computing with 5G networks can create new business models and revenue streams, driving investment in 5G infrastructure (3).

UCC has played a pivotal role by developing a technology-neutral spectrum band policy, which supports various technologies, including 5G. In 2023, UCC allocated spectrum authorization for 5G deployment to leading market players, Airtel Uganda and MTN Uganda. This allocation is critical for 5G services, although some spectrum blocks, particularly in the 700 MHz and 3.5 GHz bands, remained unallocated, as shown in Table 2. The two players account for 68 per cent of the available 5G spectrum.

Table 2. Details of allocated 5G spectrum by UCC

Band	Available blocks	Block Size (MHz)	Awarded to MTN (MHz)	Awarded to Airtel (MHz)	Remaining blocks
700 MHz frequency division duplex (FDD)	4	2x5	2(2x5)	0	2
800 MHz (FDD)	2	2x5	0	2(2x5)	0
2 300 MHz time division duplex (TDD)	10	1x10	1x100	0	0
3 500 MHz (TDD)	20	1x10	0	1x100	10
2 600 MHz (FDD)	1	2x10	2x10	0	0

2.7 Regulatory framework and 5G readiness

UCC established stringent spectrum authorization conditions following the spectrum allocation to ensure the 5G roll-out meets national development goals. These conditions include coverage and data rate targets for reducing data costs by 2025. Despite these efforts, challenges remain:

- Current infrastructure and 5G readiness: As of February 2024, Uganda's 5G infrastructure shows promise, particularly in urban centres. Airtel has 50 while MTN has 500 5G sites in Kampala. Additionally, MTN Uganda has signed a strategic partnership with Huawei, focusing on a 5G-capable core network modernization project over five years (2023–2028).

However, despite the operators having 5G-ready networks, customer adoption is low, with less than 3 000 subscribers on the MTN 5G network as of mid-2023 across its 500 sites.

- Non-standalone (NSA) 5G deployments: The current 5G networks are non-standalone, utilizing shared 4G-LTE core networks. Operators are concerned about the slow demand for 5G, which poses a risk to further investment in expanding the network. There is no business justification for standalone 5G networks at this time.

3 Evolution of network technologies and the road to 5G

3.1 Evolution of networks: From 1G to 5G

The current state of 5G readiness in Uganda is the culmination of decades of technological evolution. The evolution of mobile network technologies has been marked by significant advancements over the past few decades. Each generation of mobile technology has brought speed, capacity and capabilities improvements, laying the groundwork for the next wave of innovation. This section will provide an overview of the evolution from 1G to 5G wireless networks, highlighting the key milestones and technological advancements that have shaped the telecommunications landscape. Understanding this evolution is crucial to appreciating the significance of 5G and the opportunities and challenges it presents.

3.1.1 1G to 4G: The journey so far

Mobile network technologies have evolved quickly from the first generation (1G) to the fifth generation (5G), the standard currently under specification, as shown in Table 3:

- 1G networks: The first generation of mobile networks, introduced in the 1980s, was analogue and primarily focused on voice communication. These networks were limited in capacity and coverage, and offered poor voice quality.
- 2G networks: Launched in the 1990s, 2G networks were digital, providing improved voice quality and the introduction of SMS (Short Message Service). Although at very low speeds, these networks laid the foundation for mobile data services.
- 3G networks: The early 2000s saw the deployment of 3G networks, which significantly improved mobile data capabilities. The 3G networks allowed for faster Internet access, enabling mobile e-mail, basic web browsing and video calling services.
- 4G LTE networks: The introduction of 4G LTE in the late 2000s and early 2010s revolutionized mobile data speeds. The 4G networks enabled high-definition video streaming, online gaming and other data-intensive applications, making mobile Internet an integral part of daily life. However, 4G networks, while robust, have limitations in handling the explosion of connected devices, real-time applications and the demand for ultra-high-definition content.

3.1.2 The transition and promise of 5G

The fifth generation of mobile networks, or 5G, represents a significant leap forward in mobile technology. It is designed to overcome the limitations of the previous generations, as 5G promises ultra-fast data speeds, significantly reduced latency and the ability to connect a vast number of devices simultaneously. This makes 5G an evolution and a revolution, enabling new applications such as autonomous vehicles, smart cities, advanced IoT networks and more.

These advancements are expected to drive innovations in various sectors, including health care, education, transportation and entertainment.

Table 3. Evolution of mobile network technologies standards

Standard	1G	2G	2.5G	3G	3.5G	4G	5G
Launch	1981	1991	2001	2001	2006	2009	2020
Encoding		Digital	Digital	Digital	Digital	Digital	Digital
Service	Voice-only	Digital voice, SMS	Voice, SMS, Multi-media Messag-ing Service (MMS)	Inte-grated audio, video and data	Inte-grated audio, video and data	Dynamic data access, IoT, Voice over LTE	Broadband access every-where, massive IoT, extreme real-time communication, ultra-reliable communication
Switching	Circuit	Circuit, packet	Packet	Packet	All packet	All packet	All packet

3.2 5G Network: Evolution and technical aspects

The 5G network is not just an evolution of 4G, but a transformative technology enabling new use cases and applications. This section will delve into the technical aspects of 5G, including its deployment, architecture, frequency bands and the technological innovations that set it apart from previous generations.

3.2.1 5G network deployment

There are three ways in which 5G networks can be deployed:

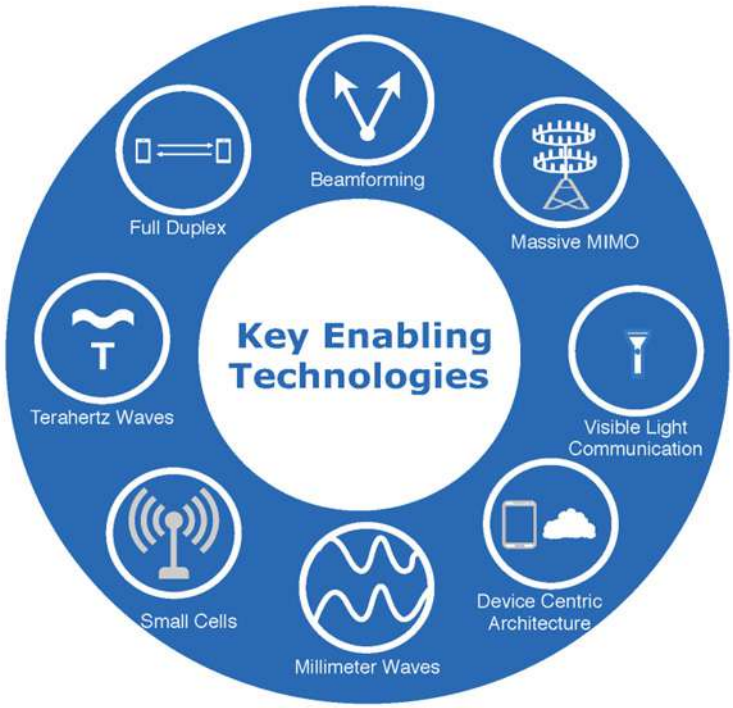
1. Non-standalone (NSA) 5G networks: These rely on sharing existing telecommunications infrastructure, such as the 4G-LTE Core network, to improve bandwidth, capacity and reliability of wireless broadband services. Most initial 5G deployments are of the NSA type.
2. Standalone (SA) 5G networks: SA networks do not depend on existing infrastructure and allow end users to realize the full potential of 5G. This includes enabling applications that require connectivity for tens of billions of devices over large areas, providing ultra-low latency for critical near-real-time communications, and delivering enhanced speeds.
3. Hybrid of both NSA and SA networks: This approach combines the strengths of NSA and SA deployments, allowing for versatile applications and a phased adoption strategy, depending on customer needs.

The flexibility of 5G allows for a gradual adoption strategy, starting with small-scale implementations to test use cases and then scaling to broader applications that can improve operational efficiency, reduce costs, and accelerate time to market. Given the progressive nature of 5G, businesses should adopt a "crawl, walk, run" approach: starting small (crawl); expanding to more significant projects (walk); and ultimately pursuing bold, broad strategic initiatives over the longer term (run).

3.2.2 Architecture and key features

As Uganda prepares to adopt 5G and beyond, the key features shown in Figure 2 have been identified as pivotal to realizing the potential of these next-generation networks.

Figure 2. Key enabling technologies for 5G (6)



Source: R. Chataut and R. Akl (6)

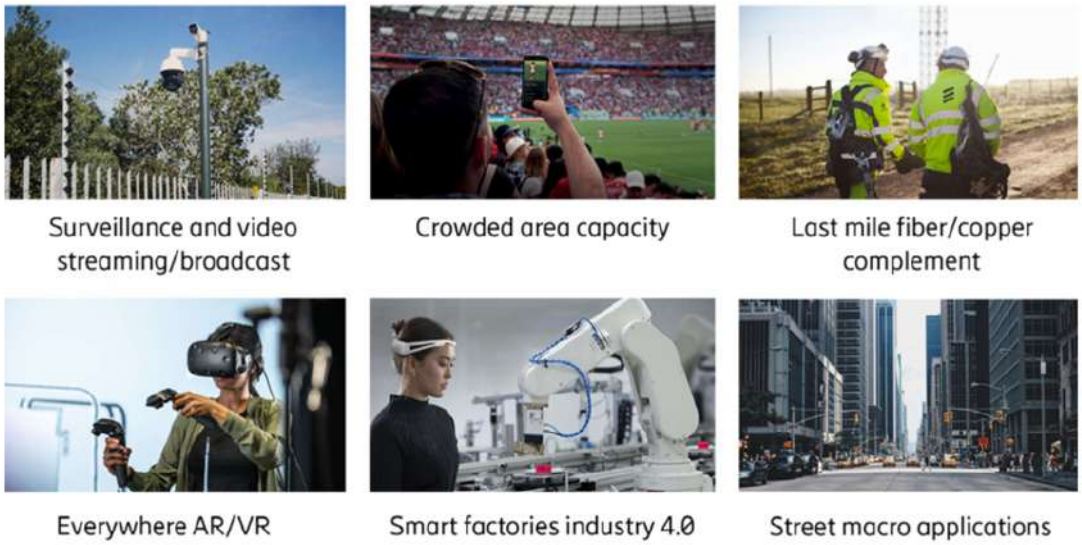
The key technologies that will underpin the architecture of 5G and potentially 6G systems include the following.

3.2.2.1 Millimetre Waves (mmWave)

Traditionally, frequencies below 6 GHz have been utilized for cellular communications, with higher frequencies reserved for other applications such as medical imaging and radio astronomy. However, the escalation in data traffic demands has congested these lower frequency bands, leading to limited bandwidth and reduced reliability. To address this, frequencies above 6 GHz, specifically in the 30 GHz to 300 GHz range known as millimetre waves (mmWave), are being explored for their potential to provide significantly higher bandwidth. These waves offer a potential tenfold increase in bandwidth over the entire 4G cellular band, but are challenged by their inability to penetrate buildings and susceptibility to absorption by rain. Additionally, because they have a short range, more base stations are required to provide coverage.

Use cases include solutions such as the Ericsson mmWave portfolio for macro and street macro levels, which offer service providers the opportunity to seamlessly bring high-capacity connectivity to urban dwellers and professionals. These include popular, crowded areas and hotspots with large numbers of smartphone users, such as stadiums or other large indoor events.

Figure 3. Applications and use cases for 5G mmWave (7)

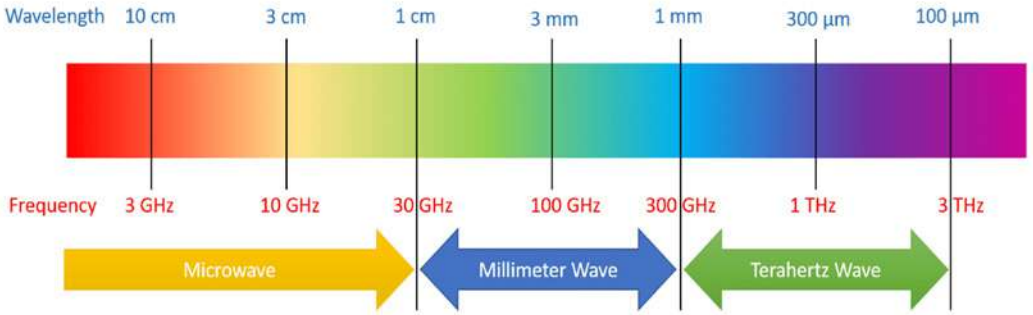


Source: Ericsson

3.2.2.2 Terahertz band

Looking beyond even mmWaves, the terahertz band (300 GHz to 3 THz) offers promising prospects for future wireless communications, supporting the increasing demand for ultra-high-speed data. This band is advantageous for its minimal interference and scalability, suitable for applications in imaging, holographic telepresence and industry 4.0. However, challenges such as high propagation losses and the need for complex antenna designs remain significant areas of ongoing research. The millimetre wave and terahertz wave bands are shown in Figure 4.

Figure 4. Millimetre and terahertz wave band



Source: R. Chataut and R. Akl (6)

3.2.2.3 Small cells

Small cells are compact base stations designed to augment network coverage and capacity, particularly in densely populated areas. These stations, which can be as small as a pizza box, are crucial for delivering high-speed mobile broadband and ultra-low latency necessary for 5G services. Based on their coverage area and capacity, they are categorized into microcells, femtocells and picocells. Small cells are often deployed in residential (Home Base Station (BS)), enterprise (Local Area BS), and urban and rural environments (Medium Range BS). When connected to multiple antennae, the small cell deployments are also termed distributed

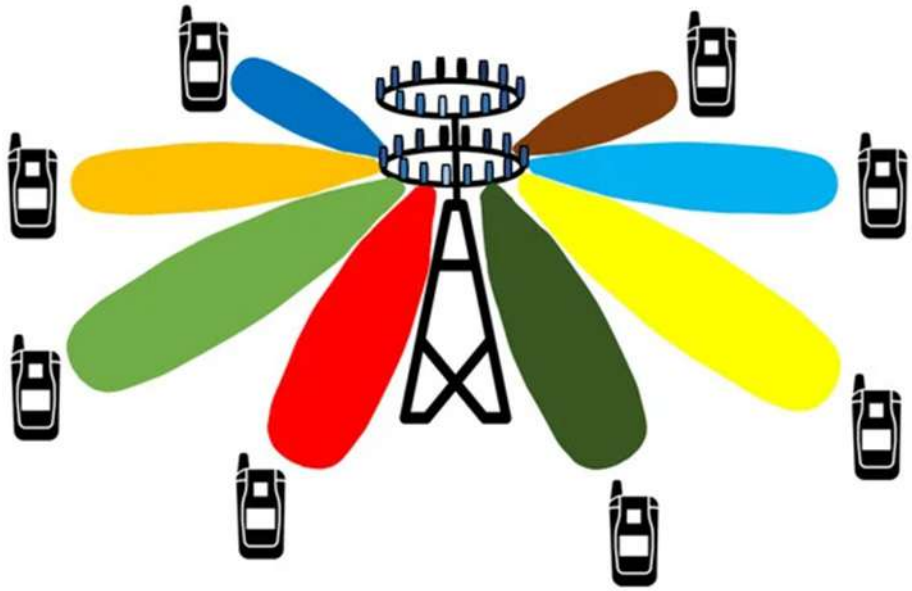
antenna systems (DAS) or in-building systems (IBS), where they provide service within an existing structure.

While economies such as Hong Kong (China), Japan, Singapore and the United States have made significant progress in this area, regulatory hurdles, right-of-way permissions and infrastructure limitations continue to hinder deployment efforts in other regions, such as India. Addressing these challenges through streamlined regulations, uniform policies and improved access to infrastructure will be crucial in ensuring the widespread deployment of small cells, paving the way for the full realization of 5G technology globally (8).

3.2.2.4 Beamforming

This antenna technology enhances the directionality and effectiveness of the network by focusing signals towards intended users while minimizing interference, making it invaluable for both millimetre wave-based and massive Multiple Input–Multiple Output (MIMO) technologies, as shown in Figure 5. Beamforming optimizes the radiation pattern of antennas to improve communication quality and network capacity.

Figure 5. Massive multiple input–multiple output (MIMO) beamforming

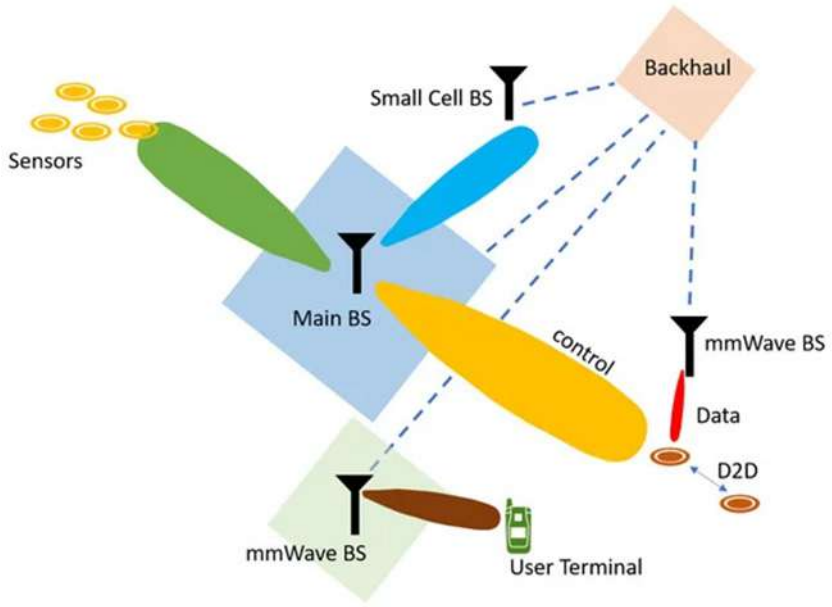


Source: R. Chataut and R. Akl (6)

3.2.2.5 Device-centric architecture

As network demands evolve, shifting from traditional base station-centric to device-centric architectures is necessary. This change supports increased network densification and the integration of various frequency bands, enhancing user experience by facilitating seamless device communication across heterogeneous network nodes. Figure 6 shows a typical device-centric architecture.

Figure 6. Device-centric architecture

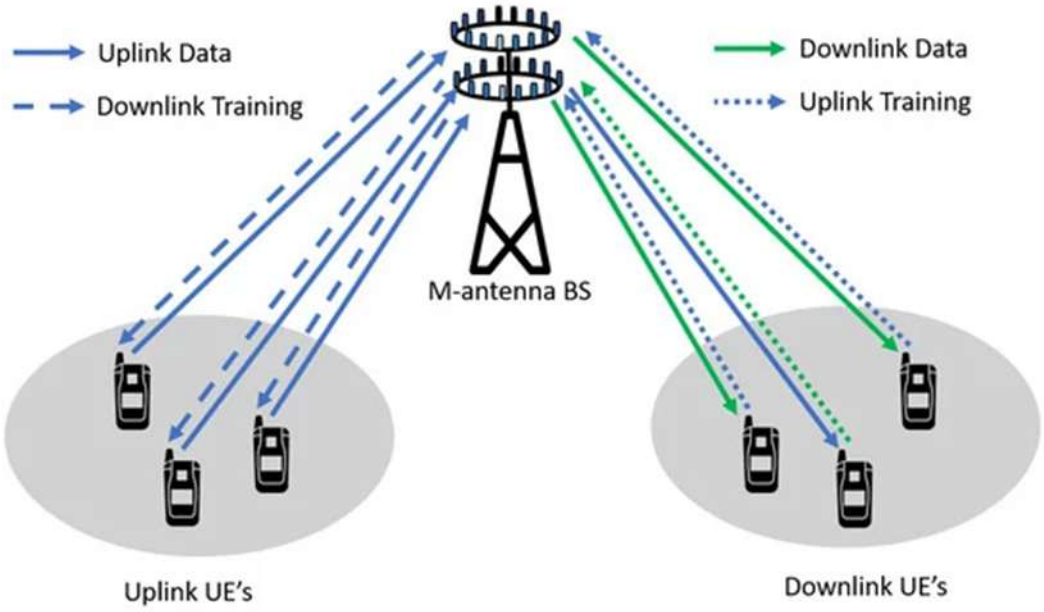


Source: R. Chataut and R. Akl (6)

3.2.2.6 Full duplex technology

This antenna technology allows simultaneous transmission and reception of signals on the same frequency, potentially doubling network capacity, as shown in Figure 7. Full duplex systems, however, require sophisticated echo cancellation techniques to manage the increased potential for interference.

Figure 7. Full duplex technology



Source: R. Chataut and R. Akl (6)

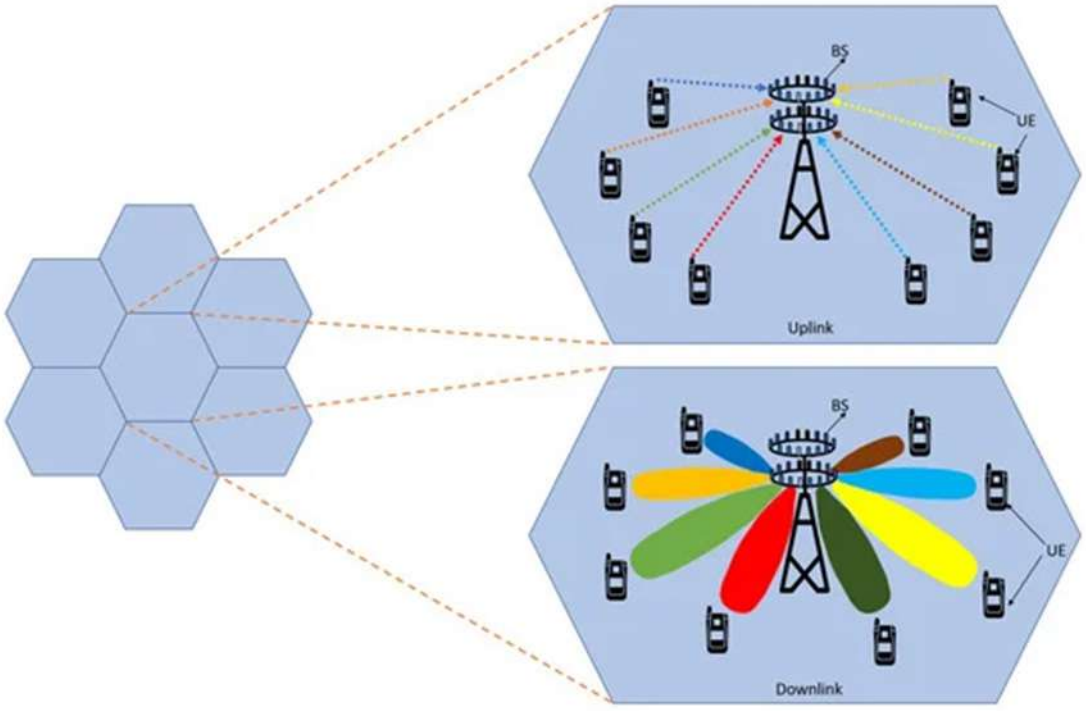
3.2.2.7 Visible Light Communication

Visible Light Communication (VLC) uses the visible light spectrum to transmit data, offering an alternative to radio frequencies with benefits such as high bandwidth and minimal electromagnetic interference. Primarily suitable for indoor environments, VLC is recognized as a potential cornerstone for smart city applications.

3.2.2.8 Massive MIMO

Massive MIMO technologies represent a quantum leap in capacity for wireless networks. Massive MIMO dramatically enhances network efficiency, capacity and user tracking accuracy by employing hundreds or even thousands of antennas at a single base station to serve multiple users simultaneously. Benefits include significantly higher data rates and spectral efficiency, robustness against interference, and enhanced link reliability due to antenna diversity. Figure 8 shows the massive MIMO downlink and the uplink system.

Figure 8. Massive MIMO uplink and downlink



Source: R. Chataut and R. Akl (6)

Table 4 summarizes the core components that constitute the architecture of 5G networks, including some of the critical technologies detailed above. These components include advancements in frequency range capabilities, network architecture innovations, access technologies, and the implementation of complex systems such as MIMO technology, network slicing and edge computing. Each element is critical in ensuring that 5G networks meet modern digital services' diverse and demanding requirements.

Table 4. Technical description of 5G network (9)

Technicalities	Description
Frequency range	5G networks use a range of frequency bands, including low-band FDD (1 GHz–2.6 GHz), mid-band TDD (2.3 GHz-6 GHz), and high-band (mmWave) (24 GHz–48 GHz) (7).
Network architecture	5G networks employ a cloud-native, software-defined network design that makes the network more adaptable, scalable and efficient.
Multiple access technologies	5G networks include a variety of access technologies, including Orthogonal Frequency-Division Multiple Access (OFDMA) for downlink communication, and Single Carrier Frequency Division Multiple Access (SC–FDMA) for uplink communication.
MIMO technology	5G networks employ advanced MIMO antenna technology, such as massive MIMO and beamforming, to boost network capacity and coverage.
Network slicing	Network slicing is a technology used in 5G networks that allows the network to be partitioned into many virtual networks, each optimized for a unique use case or application.
Edge computing	Edge computing is supported by 5G networks, which allow data to be processed and analysed closer to the source, lowering latency and enhancing network performance.
Security	5G networks include enhanced security features such as encryption and authentication to safeguard the confidentiality and integrity of data transmitted across the network.

3.2.3 Comparison of 5G with other networks

Compared to its predecessors – 3G and 4G – 5G networks significantly improve data rate, latency and spectral efficiency. According to the Ericsson analysis[1] 5G networks would deliver up to 20 times faster data transmission rates than 4G/LTE networks. It will have latency as low as 1 millisecond (1) (10), starting with small-scale implementations to test use cases and Open Radio Access Network (ORAN), and support for a broader range of frequency bands, including sub-6 GHz and mmWave bands. Furthermore, 5G employs the Non-Orthogonal Multiple Access (NOMA) multiple access technique, which allows multiple users to share the same spectrum resources and increases spectral efficiency (6) (7). With its technological advancements, 5G technology is predicted to have a substantial economic impact by stimulating innovation; creating new jobs in various industries – including health care, education and entertainment; and creating new applications and services that require high-speed, low-latency communication (10). Table 5 provides a side-by-side comparison of technical specifications between 3G, 4G and 5G.

[1] Ericsson (2019), 5G for business: a 2030 market compass, https://d110erj175o600.cloudfront.net/wp-content/uploads/2019/10/the-5g-for-business-a-2030-compass-report-2019.pdf

Table 5. Comparative features of 3G, 4G and 5G networks (11) (12)

Technical specification	3G	4G	5G
Data rate (peak)	2 Mbit/s	100 Mbit/s	20 Gbit/s
Latency	100–500 ms	10–50 ms	< 1 ms
Spectral efficiency	0.2–1 bit/s-Hz	2–4 bit/s-Hz	30–40 bit/s-Hz
Network architecture	Code Division Multiple Access (CDMA)	orthogonal frequency-division multiplexing (OFDMA)	Open Radio Access Network (ORAN)
Frequency bands	1.9 GHz	2.5–2.7 GHz	24–40 GHz, sub-6 GHz
Multiple access techniques	CDMA, wideband CDMA (WCDMA)	OFDMA	Non-Orthogonal Multiple Access (NOMA)

3.2.4 Categorizing 5G use cases

As countries globally progress in deploying 5G technologies, they tailor their use cases to align with national priorities which, despite their diversity, can generally be categorized into three primary groups: enhanced mobile broadband (eMBB), massive Internet of Things (MIoT), and mission critical services (MCS). Each category harnesses unique attributes of 5G to serve different strategic purposes, from boosting consumer connectivity to enabling industrial automation and supporting critical communications.

3.2.4.1 Enhanced mobile broadband

The eMBB technology focuses on delivering vastly improved data speeds and network reliability in densely populated areas and across extensive regions. This facet of 5G facilitates high-definition video streaming, seamless mobile browsing and the connectivity demands of complex virtual and augmented reality applications. By enhancing mobile broadband, eMBB not only caters to growing consumer data demands, but also supports burgeoning business applications that rely on rapid, reliable data transfer.

3.2.4.2 Massive Internet of Things

MIoT extends the capability of 5G beyond individual consumer devices to encompass vast networks of interconnected sensors and machines. This use case is pivotal for industries such as agriculture for smart farming techniques, logistics for enhanced supply chain management, and smart cities for everything from traffic control to environmental monitoring. The MIoT potential to connect millions of devices within a network while maintaining low power consumption and high data throughput is critical for scaling IoT solutions economically and efficiently.

3.2.4.3 Mission critical services

MCS exploits 5G ultra-reliable and low-latency communications (URLLC) to support services where real-time network performance is crucial. Applications include remote surgery,

autonomous driving and emergency response systems, where milliseconds can determine an operation outcome or individuals' safety. MCS ensures that critical data are transmitted without delays, making it a cornerstone of future safety and security infrastructures.

3.2.4.4 Summary and integration

Table 6 summarizes these categories and describes their key features and implications for various sectors.

Table 6. Categorization of 5G use cases (13)

Category	Description	Key applications
eMBB	eMBB enhances broadband access in dense areas and improves network capacity, facilitating advanced consumer and business applications. It lowers the cost-per-bit for data transmission, essential for the broad adoption of mobile broadband.	High-definition video streaming, virtual/augmented reality, enhanced mobile Internet browsing
MIoT	MIoT enables extensive machine-to-machine communications with improved power efficiency and coverage, transforming agriculture, logistics and urban management sectors.	Smart farming, efficient supply chain management, smart city infrastructure
MCS	MCS leverages 5G low latency and high reliability for mission-critical applications – including autonomous vehicles, health care and public safety – ensuring immediate and reliable data transmission.	Remote surgery, autonomous driving, emergency response systems

3.2.5 Recommended deployment steps

To effectively harness these capabilities of 5G networks, stakeholders in the 5G ecosystem must:

1. Assess and prioritize 5G use cases that offer immediate business value.
2. Align strategic objectives between business units and IT/networking teams.
3. Identify critical locations and user groups that will benefit most from 5G upgrades.
4. Evaluate public and private 5G network solutions tailored to specific business needs.
5. Address skills gaps and ensure the availability of knowledgeable teams for deployment.
6. Set clear deployment objectives, establish a realistic timeline, and define milestones for success.

3.2.6 Economic benefits of adopting 5G

The deployment of 5G technology is poised to bring transformative benefits to various sectors, significantly enhancing the quality and efficiency of Internet connectivity. Recognized as a

catalyst for economic growth, 5G networks offer three foundational advantages that are critical for modernizing today's industries and infrastructure:

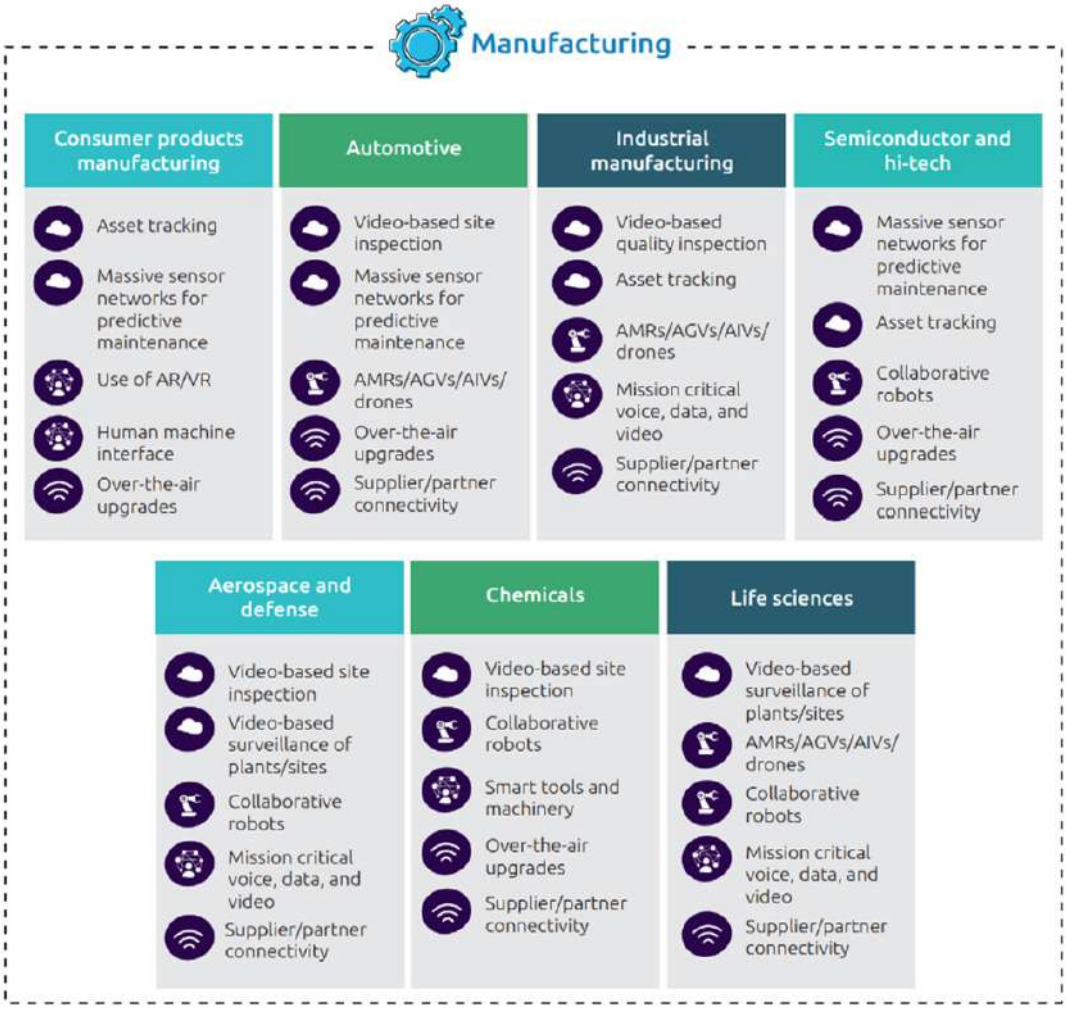
- Higher data rates: 5G will facilitate advanced consumer and business applications with speeds over 100 times faster than 4G, enabling high-speed data services and content delivery, which are essential for businesses and consumer satisfaction.
- Ultra-low latency: This feature is crucial for MCS, providing near real-time interactivity that is significantly faster than previous technologies. This low latency is essential for applications such as autonomous driving and remote medical surgeries, where every millisecond counts.
- Increased network capacity: 5G technology will support a significantly larger number of connected devices simultaneously. This scalability is vital for MIoT, allowing for the expansive growth of interconnected devices in smart cities, industrial automation and beyond.

According to a report by IHS Markit titled "The 5G Economy", implementing 5G networks is expected to generate an impressive $3.6 trillion in economic output and support 22.3 million jobs by 2035. The expansive roll-out of 5G will not only enable the development of new applications and services, such as smart cities and autonomous vehicles, but also foster significant business opportunities that fuel further economic expansion (13).

Furthermore, 5G is set to drive innovation and boost productivity across multiple industries, including health care, education and entertainment. By providing an enhanced infrastructure, 5G will allow businesses to explore new avenues for growth and efficiency, paving the way for transformative business models and services that were previously unattainable. As 5G networks continue to develop and spread, their economic impact is expected to be substantial, stimulating innovation, creating new jobs, and enabling the creation of new products and services. These developments underscore the potential of 5G to serve as a backbone for the future economy.

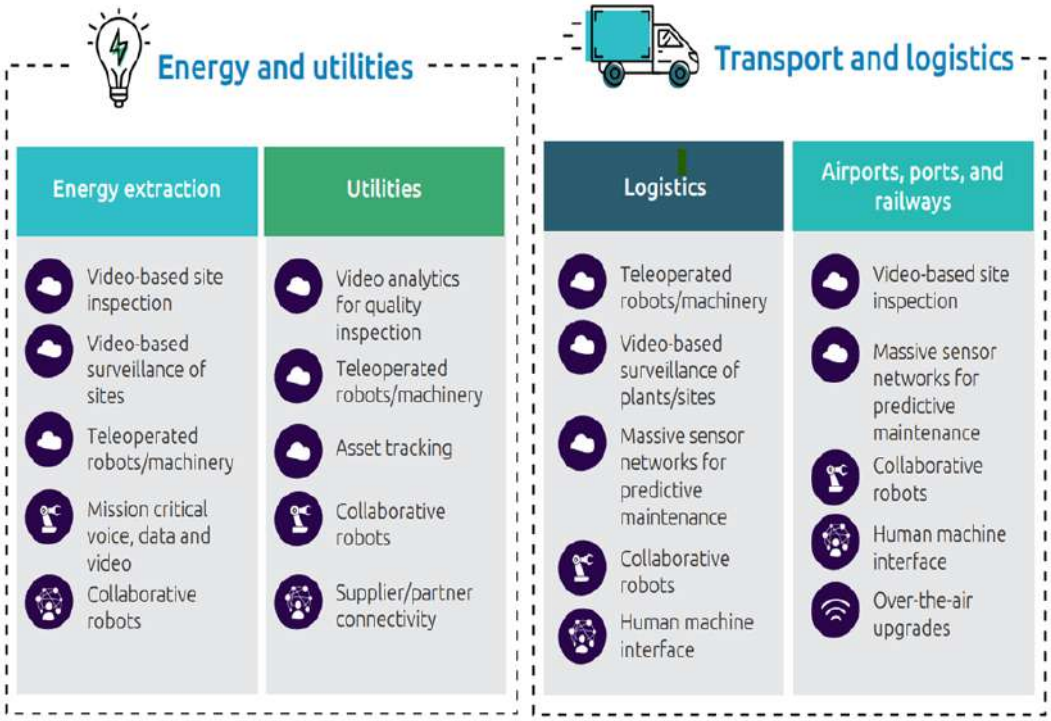
The Capgemini Research Institute survey on "Industrial Revolution Accelerating the 5G State of 5G and edge in industrial operations", conducted in February–March 2021, highlights the top five use cases by business impact in each sector. The detailed infographics in Figures 9 and 10 visually represent the data and insights from the survey and illustrate how 5G capabilities are harnessed across different industries to drive economic and operational benefits (14).

Figure 9. Top five use cases by business impact in the manufacturing sector



Source: R. Capgemini (14)

Figure 10. Top five use cases by business impact in the energy and transport sectors



Source: R. Capgemini (14)

4 5G and the Sustainable Development Goals

The exploration of diverse 5G use cases reveals the technological prowess of this next-generation network and its potential to catalyse significant social and economic transformations. As we delve deeper into the specific capabilities of 5G – from enhancing connectivity in urban and rural areas to supporting real-time data-driven decisions in health care, agriculture and industry – the broader implications for achieving the Sustainable Development Goals (SDGs) become increasingly apparent.

The role of 5G technology extends beyond conventional telecommunications, touching upon every aspect of sustainable development. The enhanced connectivity and innovative applications enabled by 5G are instrumental in driving progress across all 17 Goals, from improving health and education outcomes to enabling smart energy grids and fostering inclusive economic growth. As such, the transition from discussing use cases to analysing the impacts on SDGs reflects a natural progression: from understanding "how" 5G works to exploring "what" it can achieve in the broader context of global sustainability efforts.

This section of the report builds on the foundation of 5G use cases to provide a detailed analysis of how this technology will impact each SDG.

Table 7. Impact of 5G on the Sustainable Development Goals

Sustainable Development Goal	How 5G could contribute to achieve the specific goal
1. No Poverty	The deployment of 5G network-based technologies has the potential to bridge the digital divide and reduce inequality by providing high-speed Internet access in underserved rural and urban areas to support applications such as efficient access to credit, crowdsourcing and lending and financial traceability.
2. Zero hunger	With IoT sensors connected over 5G networks, farmers can closely monitor factors such as humidity, temperature, soil moisture and crop health, and deploy automated irrigation systems to maximize crop yield and reduce waste. Autonomous machines – including tractors, ground robots and imaging drones – can also help increase the efficiency of food production.
3. Good health and well-being	Health care, which has lagged far behind in many developing countries, could see massive reforms as part of 5G Internet access. New AI and IoT devices could revolutionize the industry through crowdsourcing health systems, AI-enabled wearable devices for diagnostics, and drones for remote delivery of medicines.
4. Quality education	Inclusive and equitable education for all can be achieved by connecting unreachable locations to online teaching resources and remote learning opportunities. The speed of 5G Internet could allow students to tune in live to classrooms globally, with AI-designed digital curriculums and access to learning content across devices.
5. Gender equality	The deployment of 5G can help narrow the digital divide and improve women's access to technology and microcredits, use AI to identify unbiased selection to support inclusivity, use AI-enabled remote work platforms targeted at women, and support novel governance structures.
6. Clean water and sanitation	The 5G networks can support novel and emerging technologies to facilitate smart water and sanitation management. Intelligent water systems with predictive maintenance capabilities can reduce supply outages, and advanced materials for desalination technology and general water quality analysis can help the 2.2 billion people worldwide who still lack safely managed drinking water.
7. Affordable and clean energy	Compared to 4G networks, 5G can reduce energy consumption by 50 per cent to 90 per cent per traffic unit (W/Mbit/s). Its energy efficiency, low latency and high fidelity promise to unlock the full potential of the IoT and expand the reach of AI, which will transform countless industries. This will lead to better use of energy and natural resources, reduced waste products and lower greenhouse gas emissions.
8. Decent work and economic growth	The introduction of 5G is expected to continue this revolution – by 2035, IHS economics and technology has determined that 5G Internet will enable USD 13.2 trillion in global economic output. In addition, it should allow the creation of 22 million jobs by stimulating ICT-centric innovative entrepreneurship and fostering vibrant small and medium-sized enterprises.
9. Industry, innovation and infrastructure	The deployment of 5G is more affordable and sustainable. This implies reducing the barrier to investment for telecommunication providers in bringing broadband infrastructure to rural and underserved areas. Delivering 5G connectivity to these populations opens them to new educational, work and commerce opportunities.

Table 7. Impact of 5G on the Sustainable Development Goals (continued)

Sustainable Development Goal	How 5G could contribute to achieve the specific goal
10. Reduced inequalities	The deployment of 5G network-based technologies has the potential to bridge the digital divide and reduce inequality by providing high-speed Internet access in underserved rural areas. It would also reduce social inequalities through online access to democratic participation, information and expression tools.
11. Sustainable cities and communities	The 5G network and its associated technologies, such as IoT, will also improve citizens' quality of life and security. Smart cities will offer services that adapt in real time to traffic conditions and optimize mobility. Smart homes will also automatically regulate optimal comfort conditions.
12. Responsible production and consumption	The 5G networks will interconnect machines, robots, processes, self-guided vehicles, goods and remote workers in real time. This will allow better integration of production components, the realization of more precise predictive analysis, and the automation of certain decisions – all aiming to improve the performance of industrial processes, reduce costs, and improve the safety of work environments.
13. Climate action	A 2020 5G energy efficiency study from Nokia and Telefonica found that a fast roll-out of 5G could cut the global CO_2 output from mobile network operations by 0.5 billion metric tons over this decade – the equivalent of more than one year of greenhouse gas emissions from all aviation globally.
14. Life below water	The 5G technology can measure and monitor the environment more quickly and efficiently than humans and existing technology. It has been used to promptly identify toxic algae in the ocean, supporting preventative action.
15. Life on land	The new 5G technology is being used to identify, monitor, photograph and track wildlife populations to protect endangered animals, and to learn more about their migratory patterns and needs for protection. Its connectivity, combined with AI, has helped uncover illegal logging in Costa Rican rainforests in real time, giving rangers a better chance to catch the culprits.
16. Peace, justice and strong institutions	The 5G technology can foster the development of e-government – that is, the use of technology to bring public services closer to citizens. This, along with the population's greater access to the Internet, would increase citizen participation in political affairs and strengthen democratic mechanisms.
17. Partnership for the Goals	The 5G technology is intended to create a digital ecosystem in which billions of different devices interact in real time, with enhanced speed and connection reliability. This means information can be exchanged in real time across boundaries. The 5G technology has the potential to embed a fact-based culture through partnerships.

5 Benchmarking 5G adoption in seven countries with common aspects to Uganda

Different countries have adopted 5G technology at varying rates. Understanding the varied landscape of 5G implementation across different nations becomes crucial. This next-generation technology promises to redefine connectivity, enhance industrial productivity and revolutionize consumer experiences. However, implementing 5G comes with unique challenges and

opportunities that differ significantly from country to country due to economic, geographic and regulatory landscape variations.

5.1 Benchmarked case studies

A comparative analysis of 5G adaptations in several vital nations – People's Republic of China, the Republic of Korea, India, Thailand, South Africa, Nigeria and Kenya – each at different stages of 5G deployment, is provided below. These nations have been selected for benchmarking because they represent diverse economic backgrounds, regulatory environments and technological infrastructures. This diversity offers valuable insights into different approaches to 5G deployment, which can be particularly instructive for Uganda as it formulates its own 5G strategy. The following cases encapsulate a detailed comparative study, showcasing how each country navigates the transition to 5G, the specific applications driving adoption, and the strategic considerations shaping their 5G landscapes. By examining these nations, Uganda can learn from their successes and challenges, tailoring international best practices to local conditions.

5.1.1 People's Republic of China

Table 8. Accelerating innovation and economic growth: An analysis of China's comprehensive 5G deployment strategy and its global implications (15)

Aspect	Details
Coverage	As of early 2024, China has established widespread 5G coverage, with major cities and many rural areas accessing 5G services. The country has deployed hundreds of thousands of 5G base stations, aiming for almost full national coverage by 2025.
Key use cases	1. Industrial automation: The Huawei smart factory in Dongguan uses 5G, significantly increasing production efficiency. 2. Smart cities: Hangzhou City Brain project uses 5G to improve traffic management and emergency responses.
Challenges	1. High costs: Significant investment required for infrastructure development. 2. Technical issues: Interoperability with existing networks and international standards. 3. Regulatory hurdles: Spectrum allocation, data privacy and security regulations. 4. Geopolitical issues: Tensions with other countries impacting technology sharing and procurement.
Opportunities	1. Economic growth: Boosting gross domestic product (GDP) from improved network efficiencies and new business opportunities. 2. Innovation hub: IoT, AI and smart technologies advancements. 3. Export of technology: Potential to lead in global 5G solutions and infrastructure. 4. Rural development: Bridging the digital divide with improved access in remote areas.

Table 8. Accelerating innovation and economic growth: An analysis of China's comprehensive 5G deployment strategy and its global implications (15) (continued)

Aspect	Details
Key considerations	1. Adoption Strategy: Phased roll-out focusing on high-demand urban areas and expansion to rural regions. 2. Collaboration: Partnerships with global tech firms despite geopolitical challenges. 3. Public perception: Addressing public concerns about 5G health implications and surveillance. 4. Innovation ecosystem: Encouraging start-ups and established firms to develop new applications and services tailored for the 5G network.

5.1.2 Republic of Korea

Table 9. Pioneering 5G: Republic of Korea's early adoption and the impact on urban connectivity and technology sectors (16, 17)

Aspect	Details
Coverage	The Republic of Korea achieved rapid nationwide 5G coverage shortly after its initial roll-out in April 2019. The coverage extends to over 90 per cent of the country, including major urban areas and significant portions of rural areas.
Key use cases	1. Consumer applications: Deployment of ultra-HD video streaming and cloud gaming services by major telecommunication companies. 2. Smart cities: Seoul's smart city initiative integrating 5G to manage traffic flows and public safety systems.
Challenges	1. Network density: The high density of base stations needed to ensure comprehensive coverage and performance. 2. Device availability: Early on, the limited availability of 5G-capable devices, which hindered consumer adoption rates. 3. Cost: The significant expense of deploying and maintaining a robust 5G infrastructure. 4. Security concerns: Enhancing cybersecurity measures to protect an increasingly networked society.
Opportunities	1. Technological leadership: Establishing a global benchmark in 5G technologies. 2. Economic boost: Creating new business models and industries, enhancing productivity in existing industries. 3. Cultural export: Leveraging 5G to enhance K-pop and K-drama streaming services globally. 4. Education and training: Using 5G to transform educational methods through immersive technologies.

Table 9. Pioneering 5G: Republic of Korea's early adoption and the impact on urban connectivity and technology sectors (16, 17) (continued)

Aspect	Details
Key considerations	1. Consumer education: Educating the public on the benefits and uses of 5G to enhance adoption rates. 2. Innovation encouragement: Supporting start-ups and businesses in developing 5G-dependent technologies and services. 3. Policy and regulation: Streamlining policies to support rapid deployment and integration of 5G technologies. 4. International collaboration: Engaging in global partnerships to share knowledge, standards and technology.

5.1.3 Thailand

Table 10. Leveraging 5G for tourism and smart agriculture: Thailand's strategic approach to digital transformation (18)

Aspect	Details
Coverage	Thailand began rolling out 5G in 2020 and has since expanded coverage, primarily in major cities such as Bangkok, Chiang Mai and Pattaya. Plans are to extend further into rural areas to achieve nationwide coverage.
Key use cases	1. Tourism: Implementation of 5G-supported augmented reality (AR) and virtual reality (VR) experiences at major tourist sites such as the Grand Palace and historical parks. 2. Agriculture: Pilot projects in Chiang Mai using 5G for real-time monitoring and management of agricultural environments.
Challenges	1. Infrastructure investment: High costs associated with upgrading infrastructure to support widespread 5G deployment. 2. Geographic and demographic diversity: Challenges in reaching extensive rural areas with reliable services. 3. Regulatory framework: Development of a supportive regulatory environment for 5G technologies and spectrum allocation. 4. Digital divide: Ensuring that advancements in 5G do not widen the gap between urban and rural populations.
Opportunities	1. Economic growth: Potential for 5G to stimulate economic development, particularly in the emerging economies community. 2. Innovation in key sectors: Opportunities for significant agriculture, tourism and healthcare advancements. 3. Export of services: Potential for Thailand to become a hub for digital services in South-east Asia. 4. Enhanced connectivity: Improvements in national and regional connectivity that can foster greater integration of the Association of South-East Asian Nations (ASEAN) economies.

Table 10. Leveraging 5G for tourism and smart agriculture: Thailand's strategic approach to digital transformation (18) (continued)

Aspect	Details
Key considerations	1. Collaboration with operators: Partnerships between the Government and telecommunication operators, which are crucial for efficient roll-out and management. 2. Public awareness and engagement: Informing the public about the benefits of 5G and involving them in the transition process. 3. Sustainability considerations: Implementing 5G in a way that supports the Sustainable Development Goals. 4. Technological preparedness: Preparing the existing tech infrastructure to be 5G-ready through updates and upgrades.

5.1.4 India

Table 11. Bridging the digital divide: India's 5G roll-out as a catalyst for rural development and enhanced public services (19)

Aspect	Details
Coverage	India has already achieved over 90 per cent 5G geographical coverage; that is, all states have been covered: https://dot.gov.in/5g-bts-deployed.
Key use cases	1. Health care: Partnership between telecommunication providers and hospitals to deploy 5G-enabled telemedicine services across rural areas. 2. Education: Pilot programmes for 5G-enabled virtual classrooms in technology institutes for immersive learning experiences.
Challenges	1. Infrastructure development: High cost and logistical challenges in deploying 5G infrastructure across diverse geographic and urban landscapes. 2. Regulatory hurdles: Delays in spectrum allocation, pricing and regulatory clearances. 3. Digital divide: Addressing disparities in access between urban and rural populations to prevent widening the digital divide. 4. Skilled workforce: Developing a skilled workforce to support the advanced technologies associated with 5G.
Opportunities	1. Economic growth: Boosting GDP from new services and efficiencies in existing sectors. 2. Innovation hub: Establishing India as a leader in South Asia for 5G technology innovation and services. 3. Job creation: New job opportunities in tech and related sectors. 4. Enhanced global competitiveness: Improved infrastructure that boosts India's standing in the global economy.

Table 11. Bridging the digital divide: India's 5G roll-out as a catalyst for rural development and enhanced public services (19) (continued)

Aspect	Details
Key considerations	1. Public–private partnerships (PPPs): Collaborations are essential to overcome investment and expertise barriers. 2. Policy support: Need for supportive policies that encourage 5G deployment and adoption. 3. Consumer education and outreach: Engaging with the public to educate people on the benefits of 5G and address any concerns. 4. Sustainability focus: Ensuring that 5G deployment aligns with environmental and sustainability goals.

5.1.5 South Africa

Table 12. Enhancing connectivity across diverse landscapes: South Africa's 5G implementation challenges and sector-specific opportunities (20)

Aspect	Details
Coverage	South Africa began rolling out 5G in 2020, initially focusing on major urban areas such as Johannesburg, Cape Town and Pretoria. Plans are to gradually expand coverage to include smaller cities and rural areas.
Key use cases	1. Industrial applications: 5G trials in mining operations to enable remote operations and real-time data analysis. 2. Smart cities: Johannesburg's efforts to incorporate 5G into its urban safety initiatives through connected closed-circuit television (CCTV) solutions.
Challenges	1. Infrastructure costs: Significant investment required for 5G infrastructure, especially in rural and underdeveloped areas. 2. Spectrum availability: Delays in spectrum allocation impeding more rapid deployment of 5G services. 3. Economic disparities: Addressing the digital divide, ensuring equitable access to 5G across different socio-economic groups. 4. Energy constraints: Dependence on reliable electricity supply, which can be inconsistent, particularly in less urbanized areas.
Opportunities	1. Economic development: Potential for 5G to drive economic growth and innovation across multiple sectors. 2. Job creation: New opportunities in the tech sector and industries transformed by 5G. 3. Tourism enhancement: Improved connectivity, which can enhance the tourist experience, promoting growth in the sector. 4. Agricultural efficiency: Potential for smart farming techniques to increase productivity and sustainability.

Table 12. Enhancing connectivity across diverse landscapes: South Africa's 5G implementation challenges and sector-specific opportunities (20) (continued)

Aspect	Details
Key considerations	1. Regulatory support: Ensuring the Government provides adequate support and swift regulatory processes for spectrum and infrastructure deployment. 2. PPPs: Collaboration between the Government and private sector to facilitate rollout and adoption. 3. Consumer awareness: Educating the public on the benefits of 5G to foster acceptance and increase uptake. 4. Sustainability practices: Incorporating environmentally sustainable practices in the deployment and operation of 5G networks.

5.1.6 Nigeria

Table 13. Driving economic diversification through 5G: Nigeria's focus on industrial automation and improved financial services (21)

Aspect	Details
Coverage	Nigeria has initiated the roll-out of 5G in select major cities, including Lagos and Abuja, with plans to progressively extend coverage to other parts of the country. Due to higher demand and economic feasibility, the focus is initially on urban centres.
Key use cases	1. Financial services: Development of 5G-powered mobile banking services to enhance financial inclusion in rural areas. 2. Agriculture: Launch of smart farming solutions that utilize IoT over 5G to increase yield and efficiency.
Challenges	1. Infrastructure investment: High costs associated with building out 5G infrastructure in a geographically and economically diverse landscape. 2. Power supply: Reliable power supply remains a critical challenge for continuous network operations. 3. Regulatory framework: Need for clear policies regarding spectrum allocation, data privacy and network security. 4. Digital literacy: Enhancing the digital skills of the population to maximize the benefits of 5G technology.
Opportunities	1. Economic growth: Boost to various sectors such as technology, health care and education through enhanced connectivity. 2. Job creation: New opportunities in tech development, network maintenance and content creation. 3. Innovation drive: 5G catalysing local start-ups and businesses in developing innovative applications and services. 4. Enhanced connectivity: Bridging the urban–rural divide by extending advanced network services to underserved areas.

Table 13. Driving economic diversification through 5G: Nigeria's focus on industrial automation and improved financial services (21) (continued)

Aspect	Details
Key considerations	1. PPPs: Essential for funding and expertise in rolling out 5G networks. 2. Community engagement: Involving communities in the planning and deployment process to address local needs and concerns. 3. Scalable implementation: Phased roll-out to test technologies and gauge user acceptance and demand. 4. Sustainability: Integrating 5G deployment with efforts to improve national power infrastructure and promote sustainable practices.

5.1.7 Kenya

Table 14. Kenya's 5G vision: Empowering sustainable development and inclusive growth through enhanced mobile technology

Aspect	Details
Coverage	Kenya began piloting 5G in select urban areas, including Nairobi, with plans to expand to other major cities and, eventually, rural regions. The roll-out strategy focuses on gradually increasing coverage based on demand and economic viability.
Key use cases	1. Transportation and logistics: Nairobi's implementation of 5G to streamline logistics and supply chain management in the industrial sector. 2. Health care: Initiatives to provide 5G-enabled telemedicine services in remote regions to improve accessibility and response times.
Challenges	1. Infrastructure costs: Significant investment required to develop 5G infrastructure, which is particularly challenging given the rural expanses. 2. Power reliability: Dependence on a stable power supply to ensure continuous network service, which can be problematic in off-grid areas. 3. Regulatory environment: Navigating the complexities of spectrum allocation and ensuring compliance with international standards. 4. Digital divide: Balancing network expansion to avoid widening the gap between urban and rural connectivity.
Opportunities	1. Economic impact: Potential for 5G to stimulate economic activity across multiple sectors, contributing to GDP growth. 2. Innovation and entrepreneurship: Enabling local start-ups and businesses to innovate with new technologies and services tailored for a 5G network. 3. Enhanced global connectivity: Positioning Kenya as a technology leader in East Africa, attracting international investment and partnerships. 4. Social benefits: Better connectivity to improve access to education and healthcare services.

Table 14. Kenya's 5G vision: Empowering sustainable development and inclusive growth through enhanced mobile technology (continued)

Aspect	Details
Key considerations	1. Stakeholder collaboration: Collaborative efforts between the Government, the private sector and international partners to fund and execute 5G projects. 2. Public awareness: Educating the public on the benefits and potential of 5G to drive adoption and acceptance. 3. Infrastructure synergy: Leveraging existing telecommunications infrastructure to optimize costs and expedite roll-out. 4. Policy adaptation: Developing policies that foster a conducive environment for 5G adoption while addressing concerns such as cybersecurity and privacy.

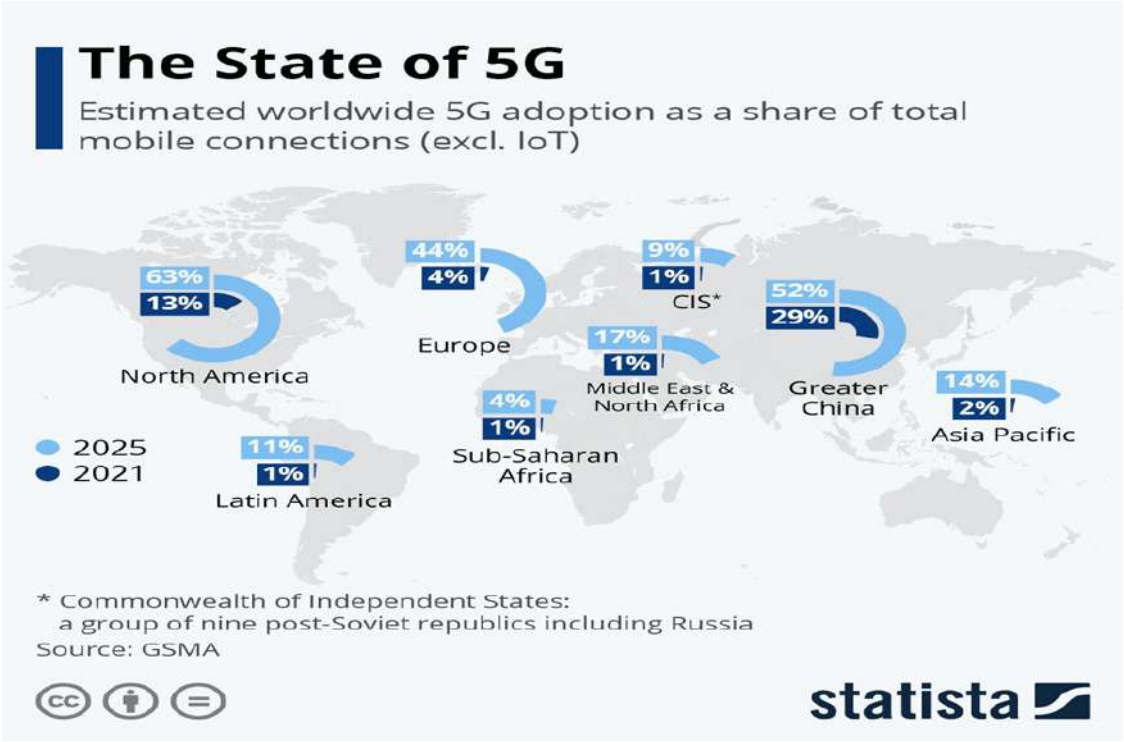
5.2 Chapter summary

The comparative analysis of 5G adaptations across People's Republic of China, the Republic of Korea, India, Thailand, South Africa, Nigeria and Kenya underscore the transformative impact of 5G technologies across diverse economic and cultural landscapes. Each country's approach to deployment, from urban centres to rural expanses, highlights a spectrum of strategies tailored to local needs and capacities.

The opportunities presented by 5G are vast, ranging from enhanced industrial productivity to improved public services, and are set to revolutionize sectors such as health care, education and transportation through increased efficiency and accessibility. However, challenges such as regulatory hurdles, infrastructure costs and technological readiness remain common barriers that must be navigated carefully.

This global perspective informs and equips stakeholders with a broader understanding of how 5G can be effectively implemented, taking cues from the successes and lessons learned internationally. Figure 11 shows the estimated worldwide adoption of 5G as a share of total mobile connections to visualize this dynamic better.

Figure 11. 5G adoption globally



Source: GSMA

6 5G use cases relevant to Uganda

The benchmarked cases showcase different approaches and focus areas, as each country attempts to maximize the benefits of the 5G technology. As Uganda considers adopting 5G technology, it is crucial to identify the use cases that will significantly impact the country's socio-economic development. This section will explore the potential 5G applications that are particularly relevant to Uganda, focusing on areas such as agriculture, health care, education and urbanization.

6.1 Agriculture

Agriculture remains the cornerstone of Uganda's economy, with over 70 per cent of the population relying on it for their livelihoods and a significant portion of GDP stemming from agricultural activities (23). As the country considers adopting 5G technology to modernize its agricultural sector, evaluating whether existing 3G and 4G networks can meet current needs and where 5G might offer unique advantages is crucial. This analysis will examine realistic applications of 5G in Uganda's agriculture, while also considering the extent to which 3G and 4G can be leveraged.

6.1.1 Current state of 3G and 4G networks in agriculture

Before making the case for 5G, it is essential to recognize the capabilities of the existing 3G and 4G networks, which have already been deployed across much of Uganda.

6.1.2 3G and 4G capabilities

- 3G networks: These networks support essential mobile Internet services, sufficient for many agricultural applications such as mobile banking, essential weather updates and market information. For many rural farmers, these services meet their immediate needs and have significantly improved agricultural practices.
- 4G networks: With higher data speeds and lower latency, 4G networks enable more advanced applications, including video-based training, access to detailed weather forecasts and mobile-based agricultural advisory services. However, reports indicate that the existing 4G infrastructure in Uganda is underutilized, with only a fraction of its capacity being used (2).

Given these points, it is evident that 3G and 4G networks already provide valuable support to agricultural activities, particularly in regions where high-tech solutions are not yet feasible or necessary. However, their capabilities are not without limitations, primarily as Uganda aims to transition towards more data-intensive and precision-driven agricultural practices.

6.1.3 Where 5G brings unique advantages

While 3G and 4G networks are sufficient for many current agricultural needs, 5G offers several unique advantages that could be crucial for Uganda's next phase of agricultural development.

6.1.3.1 Enhanced connectivity and data management

One of the significant advantages of 5G is its ability to support a massive number of devices with consistent, high-speed connectivity. This is particularly relevant for large-scale agricultural operations (commercial farms) relying on real-time data from multiple sensors, automated systems and even smart irrigation systems. In countries such as India, 5G is being explored for its potential to handle large datasets that inform precision agriculture, a capability that exceeds what 3G and 4G can offer.

6.1.3.2 Support for emerging technologies

While Uganda might not yet be ready for widespread drone use in agriculture, as seen in more advanced markets, 5G could lay the groundwork for future innovations. Technologies such as IoT devices for soil monitoring, automated weather stations and advanced crop management systems require the low latency and high reliability that 5G provides. These systems can help improve agricultural productivity and resource management, which is vital as Uganda faces challenges with climate change and water scarcity.

6.1.4 Future-proofing the agricultural sector

The demand for more sophisticated technologies will grow as the agricultural sector evolves. Investing in 5G infrastructure now ensures that Uganda's agricultural sector is future-proofed and can adopt new technologies as they become viable. This strategic foresight can prevent Uganda from falling behind as neighbouring countries and global markets continue to modernize their agricultural practices.

6.1.5 Strategic considerations

Given the underutilization of 4G networks in the country today, it is important to consider a phased approach to 5G adoption, where its deployment targets areas that would benefit most from its capabilities.

6.1.5.1 Complementary use of 3G, 4G and 5G

Rather than viewing 5G as a replacement for existing networks, it should be seen as complementary. The 3G and 4G networks can continue to serve most farmers, mainly smallholders in rural areas. In contrast, 5G can be selectively deployed in regions with higher potential for technology adoption, such as commercial farms and areas with the necessary infrastructure to support more advanced agricultural practices.

6.1.5.2 Cost–benefit analysis

For 5G to be justified, there needs to be a precise cost–benefit analysis that demonstrates its value over 4G. This includes assessing the potential increase in agricultural productivity, improved resource management and enhanced market access that 5G could bring. PPPs could be vital in funding and implementing 5G in the agricultural sector, ensuring that farmers' costs are not prohibitive.

6.1.6 Addressing infrastructure gaps

To make the most of 5G, Uganda must first address existing infrastructure gaps limiting the use of 4G. This includes expanding network coverage to underserved areas, ensuring farmers can access affordable 4G devices, and improving digital literacy among the farming population. By strengthening the foundation, Uganda can better prepare for the gradual introduction of 5G.

6.1.7 Conclusion: A balanced approach to 5G adoption

Deploying 5G technology in Uganda's agricultural sector presents exciting opportunities, but must be approached cautiously and strategically. The existing 3G and 4G networks already provide a robust foundation for many agricultural applications, and efforts should be made to maximize their use before fully committing to 5G. However, for specific high-impact applications, and to future-proof the agricultural sector, targeted 5G deployment could offer substantial benefits. A balanced approach that leverages the strengths of all available technologies will be essential for achieving sustainable agricultural growth in Uganda.

6.2 Healthcare sector

The healthcare sector in Uganda, as in many developing countries, faces significant challenges, including limited access to services, inadequate infrastructure and a shortage of healthcare professionals (24). As Uganda explores the adoption of 5G technology, it is essential to assess how this technology can realistically address these challenges, especially in comparison to the capabilities of existing 3G and 4G networks. By drawing on global examples and tailoring solutions to Uganda's unique situation, we can determine where 5G offers real value and where existing technologies may suffice.

6.2.1 Current state of healthcare and technology integration in Uganda

According to the Annual Health Sector Performance Report (Fiscal Year 2022/2023), Uganda's healthcare system is under significant strain due to factors such as limited healthcare facilities in rural areas, high patient-to-doctor ratios, and insufficient medical supplies (24). While 3G and 4G networks have supported basic telemedicine and mobile health (mHealth) applications, they have limitations in supporting more advanced healthcare services that require high bandwidth and low latency.

6.2.2 Utilization of 3G and 4G in health care

- Telemedicine: Current telemedicine services in Uganda, supported by 3G and 4G, have enabled remote consultations and essential diagnostic services, particularly in rural areas where healthcare access is limited. However, these services often suffer from connectivity issues, such as lag and poor video quality, impeding effective communication between patients and healthcare providers.
- Health information systems: 3G and 4G networks have facilitated the digitization of health records and the deployment of health information systems, allowing for better patient data management. Yet the use of these networks for this purpose remains rudimentary, and their ability to handle large volumes of data, especially in real-time applications, remains limited.

6.2.3 Where 5G can make a difference

While 3G and 4G networks provide foundational support for many healthcare applications, 5G's advanced capabilities could significantly enhance the quality and scope of healthcare services in Uganda.

6.2.3.1 Real-time remote diagnostics and telemedicine

Global examples from countries such as the Republic of Korea (25) (26) and the United States (27) (28) demonstrate that 5G enables ultra-high-definition video consultations and real-time remote diagnostics, which are critical for timely and accurate medical assessments. For Uganda, this could mean more effective telemedicine services, particularly in diagnosing and managing chronic diseases such as diabetes and hypertension, where continuous monitoring and timely intervention are essential.

With 5G, healthcare providers could use high-definition imaging tools and share real-time data with local, regional and global specialists, improving diagnostic accuracy and patient outcomes. For example, a remote village health centre in Uganda could leverage 5G to connect with specialists in Kampala or even internationally for complex cases, something current networks struggle to support reliably.

6.2.3.2 Mobile health applications and wearable devices

In countries such as Japan (26), 5G is being used to support advanced mobile health applications and wearable devices that monitor patient health in real time, providing continuous data that can alert healthcare providers to potential issues before they become critical. In Uganda, where monitoring and managing communicable and non-communicable diseases are major health priorities (24), 5G could enable the widespread use of such technologies, particularly for vulnerable populations who might not have regular access to healthcare facilities.

For instance, wearable devices that monitor heart rates, blood pressure or glucose levels could transmit data in real time to healthcare providers, allowing for immediate intervention when necessary. This would be especially beneficial in rural Uganda, where reaching a healthcare facility quickly in an emergency is often not feasible.

6.2.4 Enhancing public health and epidemic response

The 5G technology can also enhance public health initiatives by enabling faster data collection and analysis during epidemics. In China (29) (30), 5G networks have been used to support large-scale health monitoring and real-time data analysis during the COVID-19 pandemic, enabling quicker responses to outbreaks. With its history of dealing with epidemics such as Ebola, Uganda could benefit from similar 5G-enabled capabilities, improving the efficiency and effectiveness of public health responses.

By using 5G, health authorities in Uganda could monitor health trends in real time, deploy resources more effectively, and communicate quickly with both the public and healthcare workers in the field. This would be a significant improvement over the current systems, which often rely on slower, less reliable networks.

6.2.5 Strategic considerations

While the potential of 5G in transforming Uganda's healthcare sector is significant, there are important considerations to ensure its successful implementation.

6.2.5.1 Complementary use of 4G and 5G

Similar to agriculture, a complementary approach is advisable. The 4G networks, which are already underutilized, can continue to support basic telemedicine and mHealth services, particularly in less resource-intensive applications. Meanwhile, 5G can be reserved for more critical applications where high-speed, low-latency connectivity is essential.

6.2.5.2 Cost-effectiveness and infrastructure development

The deployment of 5G in the healthcare sector must be cost-effective. Investments should prioritize areas where 5G will have the most significant impact, such as tertiary hospitals, specialized care centres and public health agencies. PPPs will be crucial in funding the necessary infrastructure, especially in rural areas where the economic return on investment might be less immediate.

6.2.6 Training and capacity building

Healthcare workers will require training to utilize 5G-enabled technologies effectively. This includes understanding how to operate advanced diagnostic tools, use wearable technology for patient monitoring and interpret real-time data. Capacity-building efforts should be vital to any 5G healthcare initiative in Uganda.

6.2.7 Conclusion: Balancing needs with technology

Integrating 5G technology into Uganda's healthcare sector offers promising possibilities, particularly in enhancing telemedicine, remote diagnostics and public health management. However, it is essential to balance these possibilities with the realities of the current infrastructure and healthcare needs. By strategically deploying 5G where it is most needed, and utilizing 3G and 4G where they are sufficient, Uganda can make significant strides in improving healthcare outcomes nationwide.

6.3 Education

The education sector in Uganda faces numerous challenges, including limited access to quality education, particularly in rural areas, inadequate infrastructure, and the significant disruptions caused by the COVID-19 pandemic. While 3G and 4G technologies have facilitated some progress, the potential of 5G to transform education in Uganda is substantial. By drawing on international examples, we assess how 5G technology could enhance educational outcomes in Uganda while also considering where existing technologies might suffice.

6.3.1 Current state of education and ICT integration in Uganda

The Annual Education and Sports Sector Performance Report (ESSAPR) highlights the significant progress in integrating ICT into Uganda's education system, especially during the COVID-19 pandemic, when digital learning became a critical tool for continuity. However, there are still substantial gaps in infrastructure, particularly in rural and underserved areas, where access to reliable Internet is limited (31). The Ministry of Education and Sports Uganda report further emphasizes the gender-related impacts of the pandemic on education, revealing how the lack of robust digital infrastructure has exacerbated educational inequalities (32).

6.3.2 The potential of 5G in transforming education in Uganda

While 3G and 4G networks have enabled some level of digital learning, their limitations – especially in speed, reliability and capacity – are apparent. The 5G technology offers several advantages that could significantly improve education delivery in Uganda.

6.3.2.1 Enhanced e-learning and virtual classrooms

Countries such as the Republic of Korea have leveraged 5G to enable immersive e-learning experiences, including virtual classrooms, allowing real-time interaction between students and teachers, regardless of location (33). This has proven particularly beneficial during the COVID-19 pandemic, where traditional classrooms were disrupted. In Uganda, where teacher shortages and overcrowded classrooms are prevalent issues (31), 5G could support more interactive and effective virtual learning environments.

6.3.2.2 Expanding access to education in rural areas

India provides a relevant example of how 5G technology can bridge the educational divide between urban and rural areas. By deploying 5G-enabled devices and platforms, India has delivered high-quality educational content to remote areas, overcoming barriers such as a lack of infrastructure and qualified teachers (34) (35) (36). For Uganda, where many rural schools

still lack access to quality teaching resources, 5G could facilitate the delivery of digital content, remote teaching and real-time student assessments.

6.3.2.3 Supporting inclusive education

Japan's approach to inclusive education provides another example where 5G can be instrumental. The country has utilized 5G technology to support students with disabilities through personalized learning tools and assistive technologies that enhance accessibility and participation in the classroom (37) (38) (39). In Uganda, where inclusive education is still developing, 5G could provide the necessary infrastructure to support students with special needs and ensure they receive the same education as their peers.

6.3.3 Addressing challenges and making the case for 5G

While the potential benefits of 5G in education are clear, it is also important to address the challenges and consider where 3G and 4G technologies might still play a role. The key challenges include the high cost of 5G infrastructure, the need for substantial educational training and development investments, and the potential for digital divides to widen if 5G is not deployed equitably.

However, 5G scalability, speed and reliability make it a critical investment for the future of education in Uganda. By strategically implementing 5G alongside existing technologies, Uganda can build a more resilient and inclusive education system that meets the needs of all learners.

6.3.4 Conclusion

Integrating 5G technology into Uganda's education sector presents a significant opportunity to overcome existing challenges and enhance educational outcomes. By learning from international examples and addressing the unique needs of Uganda's education system, 5G can be a transformative tool that supports equitable access to quality education across the country. However, this must be done with careful planning, and considering existing infrastructure and resources to ensure no learner is left behind.

6.4 Urbanization

As Uganda continues to urbanize rapidly, integrating advanced technologies such as 5G into urban development plans could significantly enhance infrastructure, service delivery and economic growth. However, it is crucial to consider how the existing 3G and 4G networks can be effectively utilized alongside the deployment of 5G. This balanced approach, which we strongly advocate, ensures that Uganda maximizes the potential of its current technological infrastructure while strategically integrating 5G, where it can make the most impact.

6.4.1 Urbanization trends and the role of ICT

Uganda's urban population is proliferating, with significant urbanization challenges such as overcrowding, inadequate infrastructure and the need for improved public services. The Uganda State of Urbanization Report (2022) highlights these challenges, noting that urban

areas such as Kampala are already under pressure from high population density and insufficient infrastructure (40).

ICTs, particularly mobile networks, are crucial in addressing these challenges by enabling smarter, more efficient urban management. Uganda's urban areas primarily rely on 3G and 4G networks, which support a range of services from mobile banking to basic Internet access. However, as metropolitan areas grow and the demand for more sophisticated services increases, the limitations of these networks become apparent.

6.4.2 Leveraging 3G and 4G for urban development

Before exploring the potential of 5G, it's important to acknowledge the significant role that 3G and 4G networks already play in Uganda's urbanization.

6.4.2.1 Supporting essential services

The 3G and 4G networks currently provide the backbone for many essential services in Uganda's urban areas. These include mobile financial services, access to government services through mobile platforms, and basic Internet access for education and business. These networks are sufficient for many current applications, particularly in areas where high-speed, low-latency connections are not yet critical.

6.4.2.2 Enhancing public safety and traffic management

The 4G networks can also support smart city initiatives such as improved traffic management and public safety systems. For instance, real-time traffic updates, mobile-based reporting of incidents and emergency response coordination can all be effectively managed using 4G technology. In Johannesburg, South Africa, 4G networks have been utilized to support the city traffic management systems, which include real-time updates and mobile alerts for road users. Uganda can leverage 4G in Kampala and other cities to improve traffic flow and reduce congestion.

6.4.3 The case for 5G in Uganda's urbanization

While 3G and 4G networks provide a solid foundation, adopting 5G can address more complex urban challenges and drive future growth. The capabilities of 5G go beyond those of 4G, offering ultra-high-speed connections, low latency and the ability to connect a vast number of devices simultaneously.

6.4.3.1 Supporting smart city infrastructure

The 5G network is critical for developing smart cities, which rely on interconnected systems to manage urban resources efficiently. These systems include smart grids for energy management, intelligent transportation systems, and real-time environmental monitoring. The low latency and high capacity of 5G make it ideal for supporting these complex, data-intensive applications. In the Republic of Korea, 5G is the backbone of smart city projects in cities such as Seoul, where the technology supports everything from autonomous vehicles to real-time pollution monitoring. For Uganda, 5G could enable similar advancements, particularly in rapidly growing urban areas such as Kampala, where managing traffic congestion and pollution are pressing concerns (41).

6.4.3.2 Enhancing urban mobility

The deployment of 5G could revolutionize urban mobility in Uganda by enabling connected and autonomous vehicles, which require reliable, real-time data transmission. While 4G can support basic traffic management, 5G is necessary for more advanced applications such as vehicle-to-everything (V2X) communication, which is crucial for the safe operation of autonomous vehicles and intelligent traffic systems. For example, Singapore is using 5G to develop its autonomous vehicle ecosystem, which includes real-time communication between vehicles, infrastructure and pedestrians. In Uganda, 5G could support similar developments, improving urban mobility and reducing traffic accidents.

6.4.3.3 Improving public health and safety

In the context of public health, 5G can enhance urban healthcare services by enabling telemedicine, real-time health monitoring, and rapid data sharing among healthcare providers. This is particularly important in densely populated urban areas, where healthcare facilities are often overwhelmed. China has used 5G during the COVID-19 pandemic to support telemedicine and real-time health monitoring in cities such as Wuhan. For Uganda, 5G could similarly enhance the capacity of urban healthcare systems, improving service delivery in cities where healthcare demand is high.

6.4.4 Strategic integration of 5G with existing networks

To maximize the benefits of 5G, Uganda should adopt a phased approach that integrates 5G with existing 3G and 4G networks. This strategy would involve:

- Targeted deployment: Focusing 5G deployment in areas where it can make the most significant impact, such as in central business districts, industrial zones and healthcare facilities, while continuing to rely on 4G in less data-intensive applications;
- Infrastructure investment: Investing in the necessary infrastructure to support 5G, including fibre-optic networks and data centres, while upgrading 4G networks to fill coverage gaps and improve service reliability;
- PPPs: Engaging private sector partners to share the costs and benefits of 5G deployment, as has been successfully done for infrastructure projects in countries such as Rwanda and Ethiopia.

6.4.5 Conclusion

Uganda's urbanization presents challenges and opportunities, and the strategic integration of 5G technology can play a crucial role in addressing these challenges while driving future growth. By leveraging existing 3G and 4G networks to their fullest potential and strategically deploying 5G, where it offers the most value, Uganda can create smarter, more efficient urban spaces that improve the quality of life for all residents. Drawing on lessons from other African and Asian countries, Uganda can ensure that its urbanization efforts are sustainable and forward-looking.

6.5 Chapter conclusion

The exploration of the potential of 5G in Uganda's key sectors – agriculture, health care, education and urbanization – has highlighted the transformative possibilities that this next-generation technology offers. By drawing on global examples from countries such as the

Republic of Korea, India, Rwanda and China, it is evident that 5G can significantly enhance productivity, service delivery and quality of life when strategically implemented. However, it is equally crucial to acknowledge the role existing 3G and 4G networks continue to play, providing a solid foundation upon which 5G can be gradually introduced.

As Uganda moves towards embracing 5G, it is clear that a balanced approach, leveraging current infrastructure while strategically deploying 5G in areas of most significant impact, will be vital in maximizing the benefits of this technology. This chapter has comprehensively analysed how 5G can drive Uganda's development goals across these sectors, laying the groundwork for formulating strategic objectives that will guide the nation's 5G adoption.

7 Strategic objectives for 5G adoption

Building on the comprehensive analysis of the potential impact of 5G on agriculture, health care, education and urbanization, it is evident that this technology can play a pivotal role in achieving Uganda's Digital Uganda Vision (DUV) and supporting the objectives outlined in the Third National Development Plan (NDP III) for fiscal years 2020/21–2024/25. DUV aims to create a digitally empowered society and knowledge economy, and the adoption of 5G is a critical component in realizing this vision.

The strategic objectives for 5G adoption in Uganda are formulated to address the challenges identified across these critical sectors and capitalize on its transformative capabilities. These objectives will ensure that Uganda leverages 5G technology to enhance economic growth, improve public services and promote inclusive digital access nationwide. Furthermore, these objectives align with the broader goals of the DUV, emphasizing innovation, productivity and competitiveness.

7.1 Increasing demand for broadband services

Objective: Drive widespread adoption and utilization of broadband services across Uganda to create a sustainable market for future 5G investments.

Actionable strategies:

- Digital literacy campaigns: Implement nationwide digital literacy programmes that educate citizens on the benefits and uses of broadband services. These programmes should target both urban and rural areas, focusing on empowering women and youth, as outlined in the Ministry of Education and Sports Programmatic approaches to the gender-related impacts of COVID-19 on education: Lessons from 2020 Case study: Ministry of Education and Sports Uganda (32).
- Subsidized access to broadband devices: Partner with telecommunication operators and device manufacturers to provide affordable smartphones and tablets, particularly in underserved areas. This strategy will help bridge the digital divide and stimulate demand for 4G and 5G services.
- Enhance content and services: Develop and promote locally relevant digital content and services – such as e-government services, online education platforms and telemedicine – which require broadband access. This approach aligns with the objectives in the Annual Health Sector Performance Report (FY 2022/2023) and the Annual Performance Report (FY 2019/20) (24) (31).

- PPPs: Leverage PPPs to roll out community Wi-Fi in public spaces such as markets, schools and healthcare centres. These initiatives will increase Internet penetration and demonstrate the benefits of broadband, leading to higher demand for 3G and 4G services.

Rationale: As telecommunication operators have highlighted, Uganda's existing 3G and 4G networks are underutilized. By increasing demand for broadband services, Uganda can ensure a higher return on investment for these networks, making the case for 5G deployment more compelling.

7.2 Boosting economic diversification through industrial automation

Objective: Leverage 5G capabilities to enhance the manufacturing and agro-processing sectors, thereby driving economic diversification and productivity.

Actionable strategies:

- IoT integration in agriculture: Promote the use of IoT devices in agriculture to optimize irrigation, soil monitoring and crop management, particularly in regions where industrial-scale farming is feasible. This aligns with the use cases discussed for 5G in agriculture, drawing on examples from India and Thailand (23).
- Smart manufacturing hubs: Establish 5G-enabled smart manufacturing hubs in key industrial areas, starting with pilot projects in Kampala and other urban centres. As seen in Ethiopia's industrial parks, these hubs would utilize automation, real-time data analytics and IoT to increase production efficiency and product quality (40).
- Skills development for Industry 4.0: Collaborate with educational institutions and industry stakeholders to develop training programmes focused on Industry 4.0 skills, including IoT, AI and robotics. This will ensure that Uganda's workforce is prepared to engage with the new technologies that 5G will bring.

Rationale: By enhancing the capabilities of the manufacturing and agro-processing sectors, Uganda can diversify its economy, reduce reliance on agriculture and create new jobs. This aligns with regional goals, such as those of the East African Community, which emphasize industrial growth.

7.3 Improving healthcare and education outcomes

Objective: Utilize 5G technology to improve access to quality health care and education, particularly in underserved areas.

Actionable strategies:

- Telemedicine expansion: Deploy 5G in major hospitals and healthcare facilities to support real-time telemedicine services, enabling remote diagnostics and consultations. This strategy builds on the successful use cases from the Republic of Korea and China, where 5G has significantly enhanced healthcare delivery (24).
- Remote learning platforms: Develop and support 5G-enabled remote learning platforms that offer interactive, real-time educational content to students in rural and urban areas. These platforms should also provide resources for teacher training and support, as seen in Japan's use of 5G for inclusive education (31) (32) (37) (39).
- Health and education infrastructure investment: Prioritize investment in 5G infrastructure in areas with high potential impact, such as urban hospitals and educational institutions. This

aligns with the strategic goals outlined in the Annual Health Sector Performance Report (FY 2022/2023) and the Annual Performance Report (FY 2019/20) (24) (31)

Rationale: Leveraging 5G for health care and education can address critical service delivery gaps, particularly in remote areas with insufficient infrastructure. This approach ensures that Uganda meets its development goals by improving health outcomes and educational access.

7.4 Fostering smart urban development

Objective: Deploy 5G-enabled smart city technologies to enhance urban planning, management and the overall quality of life in Uganda's rapidly growing cities.

Actionable strategies:

- Smart traffic management: Implement 5G-powered intelligent traffic systems in Kampala and other major cities to reduce congestion and improve road safety. This strategy draws on successful models from Singapore and the Republic of Korea, where 5G has been integral to managing urban mobility (40) (41).
- Public safety and environmental monitoring: Utilize 5G for real-time monitoring of environmental conditions and public safety, including air quality sensors and connected surveillance systems. These systems can provide critical data for city planners and help mitigate the challenges of rapid urbanization.
- Affordable smart housing: Develop 5G-enabled smart housing projects that offer affordable, energy-efficient homes equipped with smart utilities. This initiative can be modelled after Rwanda's integrated urban planning efforts that focus on sustainability and inclusivity (4).

Rationale: As Uganda's cities continue to grow, the challenges of urbanization – such as congestion, pollution and housing shortages – can be addressed through intelligent, data-driven solutions supported by 5G. This ensures that urbanization contributes positively to Uganda's economic and social development.

7.5 Enhancing cybersecurity

Objective: Strengthen cybersecurity measures to secure the expanding digital infrastructure and ensure the safe and reliable deployment and operation of 5G networks in Uganda.

Actionable strategies:

1. Adopt the Network Equipment Security Assurance Scheme (NESAS) Standards for Network Security:
    - Uganda should adopt NESAS, developed by the GSMA and 3GPP, as a baseline for assessing the security of 5G network equipment. NESAS provides a globally recognized security assurance framework that improves the security level across the mobile industry.
    - Why NESAS? NESAS offers a uniform approach to security audits, helping to avoid fragmentation and conflicting security assurance requirements across different markets. By implementing NESAS, Uganda can ensure that 5G network equipment from various vendors meets rigorous security standards, thereby protecting the network from potential vulnerabilities (42).
2. Develop a national 5G cybersecurity framework:

- Uganda should develop a comprehensive 5G cybersecurity framework with stakeholders, including telecommunication operators, government agencies and international partners. This framework should be aligned with global best practices, such as the GSMA 5G Cybersecurity Knowledge Base, which provides detailed threat maps, mitigation strategies and standards for managing 5G security risks.
- Global examples: Countries such as China and Germany have recognized and adopted NESAS as part of their national 5G security frameworks, ensuring that all 5G equipment and operations meet stringent security requirements. Uganda can learn from these examples to create a robust cybersecurity framework that protects its digital infrastructure from emerging threats.

3. Capacity building and awareness programmes:
    - Invest in cybersecurity training programmes for telecommunications sector professionals, focusing on 5G technologies and the specific security challenges they present. This initiative should also include public awareness campaigns to educate businesses and consumers on best practices for cybersecurity.
    - Importance of capacity building: As Uganda transitions to 5G, there is a critical need for skilled cybersecurity professionals to manage and mitigate the risks associated with this advanced technology. Building local expertise will be essential in maintaining the security and integrity of Uganda's 5G networks.
4. Implement regular security audits and assessments:
    - Establish a regime of regular security audits and assessments for 5G networks based on the standards set by NESAS and the GSMA 5G Cybersecurity Knowledge Base. Accredited third-party organizations should conduct these audits to ensure objectivity and adherence to international security standards.
    - Rationale: Continuous monitoring and network security assessments are vital in identifying vulnerabilities and ensuring that security measures are up-to-date with the evolving threat landscape. This proactive approach will help safeguard Uganda's 5G infrastructure from cyberattacks and unauthorized access.
5. Foster international collaboration on cybersecurity:
    - Engage with international cybersecurity initiatives and organizations, such as ITU and GSMA, to stay informed about the latest developments in 5G security standards and participate in global efforts to enhance cybersecurity.
    - Global engagement: Participation in international cybersecurity forums will enable Uganda to benefit from shared knowledge, tools and resources, strengthening its cybersecurity framework and ensuring alignment with global best practices.

Rationale: As Uganda advances towards the deployment of 5G technology, securing its digital infrastructure is crucial to maintaining public trust, protecting sensitive data and ensuring the overall reliability of its telecommunications networks. By adopting global standards such as NESAS and implementing a comprehensive national cybersecurity framework, Uganda can effectively mitigate the risks associated with 5G, enabling a secure and resilient digital environment.

8 Guiding principles for 5G implementation

The strategic objectives outlined above – from increasing broadband demand to enhancing cybersecurity – are ambitious and necessary for Uganda's digital transformation. However, to

achieve these objectives, the implementation process must be guided by clear, actionable principles that align with national priorities and global best practices. These guiding principles will ensure that the 5G roll-out is conducted in a manner that maximizes benefits, minimizes risks and addresses the needs of all Ugandans.

8.1 Inclusivity

Goal: Ensure that 5G benefits all regions and communities, including rural and underserved areas.

Method: Implement policies that mandate coverage benchmarks and incentivize private sector investment in less profitable areas.

Justification: Inclusivity must be at the forefront of increasing broadband demand and extending digital services to all Ugandans. This principle ensures that the digital divide is bridged and that 5G contributes to equitable development across the country.

8.2 Sustainability

Goal: Develop 5G infrastructure that is sustainable and minimizes environmental impact.

Method: Promote the use of green technologies where feasible and energy-efficient equipment in the 5G roll-out.

Justification: Sustainability is critical in ensuring that the infrastructure built today does not harm future generations. By integrating green technologies, Uganda can lead by example in creating a more sustainable digital economy.

8.3 Scalability

Goal: Build a 5G network that can scale as demand increases and technology advances.

Method: Use modular infrastructure and cloud-based technologies for easy expansion and updates.

Justification: Scalability is essential to meet the growing demand for broadband services and ensure that the 5G network remains relevant as technology evolves. This principle supports the objective of boosting economic diversification through technology-driven growth.

8.4 Security

Goal: Ensure the security and integrity of the 5G network to protect users and data.

Method: Implement robust cybersecurity measures, regular audits and compliance with international security standards.

Justification: Security is a non-negotiable aspect of the 5G roll-out. By adopting frameworks such as NESAS and conducting regular security audits, Uganda can protect its digital infrastructure, aligning with the objective of enhancing cybersecurity as detailed in the strategy.

8.5 Partnerships

Goal: Leverage expertise and investment from both the public and private sectors.

Method: Establish partnerships with global tech companies, local businesses and other governments for technology transfer and funding.

Justification: Strong partnerships are crucial for mobilizing the resources and expertise needed for a successful 5G roll-out. This principle ensures that Uganda benefits from global best practices and innovation, supporting objectives across all sectors, including health care, education and urbanization.

8.6 Regulatory compliance

Goal: Align 5G implementation with national laws and international guidelines.

Method: Regularly update regulations and standards to keep pace with technological advancements and industry practices.

Justification: Regulatory compliance is essential for maintaining a stable and predictable environment for 5G deployment. This principle ensures that all actions align with national and international standards, supporting a smooth and lawful implementation process.

8.7 Innovation

Goal: Foster a climate of innovation around 5G technologies and their applications.

Method: Support research and development through grants, subsidies and establishing innovation hubs.

Justification: Innovation drives the long-term success of 5G by enabling new applications and services. Uganda can maximize the benefits of 5G technology by fostering an environment that encourages creativity and experimentation.

8.8 Transparency

Goal: Maintain public trust through transparent practices in deploying and operating 5G networks.

Method: Engage with communities, disclose plans and progress, and respond actively to public concerns.

Justification: Transparency is critical to building and maintaining public trust. This principle ensures that the 5G roll-out is conducted openly and in an accountable manner, which is essential for securing public support and cooperation.

To ensure that these guiding principles are effectively integrated into the strategic objectives, a visualization matrix (Table 15) will be used to illustrate their alignment. This matrix categorizes each guiding principle alongside every strategic objective to show how implementing each principle affects various goals within the 5G strategy. Each cell in the matrix represents the influence a particular principle has on an objective, graded by impact level – high, medium or

low. This visual representation aids in identifying focus areas that require strengthened efforts or adjustments to maximize strategy effectiveness.

Table 15. Guiding principles and strategic objectives impact matrix for Uganda's 5G adoption

	Enhancing connectivity	Economic diversification	Health care and education	Smart urban development	Enhancing cybersecurity
Inclusivity					
Sustainability					
Scalability					
Security					
Partnerships					
Regulatory compliance					
Innovation					
Transparency					

Colour coding scheme:

- High impact
- Medium impact
- Low impact

9 Roadmaps and theories of change for Uganda's 5G adoption

As Uganda embarks on the journey of 5G adoption, the need for a clear, strategic approach that translates vision into actionable steps is paramount. This chapter presents the detailed five-year roadmaps and theories of change for each of the key strategic objectives. These roadmaps provide a comprehensive plan for the phased deployment of 5G technology across different sectors, ensuring that Uganda maximizes the benefits of 5G while laying a solid foundation through the existing 3G and 4G networks.

The theories of change for each strategic objective outline the pathways through which 5G will drive transformative outcomes in Uganda's agriculture, health care, education, urban development and cybersecurity. These theories are grounded in the realities of Uganda's current technological landscape and the lessons learned from global best practices. They emphasize the importance of leveraging existing resources to create a robust demand for broadband services, which is critical for the successful transition to 5G.

In alignment with the Digital Uganda Vision (DUV), this chapter emphasizes that the transition to 5G is not just about technology, but about empowering Ugandans with the tools and opportunities to thrive in a digital economy. By linking the roadmaps and theories of change to

the DUV, this chapter underscores the strategic importance of 5G in driving Uganda's economic growth, enhancing public services and fostering inclusive development.

9.1 Five-year roadmap for increasing demand for broadband services

The five-year roadmap for increasing demand for broadband services is a critical foundation for Uganda's transition to 5G. This roadmap outlines strategic actions aimed at expanding digital literacy, improving access to affordable devices, and enhancing the availability of locally relevant digital content. By driving demand for existing 4G networks, this roadmap supports the DUV objective of creating a digitally empowered society. The successful implementation of this roadmap will not only build the user base necessary for the economic viability of 5G, but also ensure that all people in Uganda can benefit from the digital revolution.

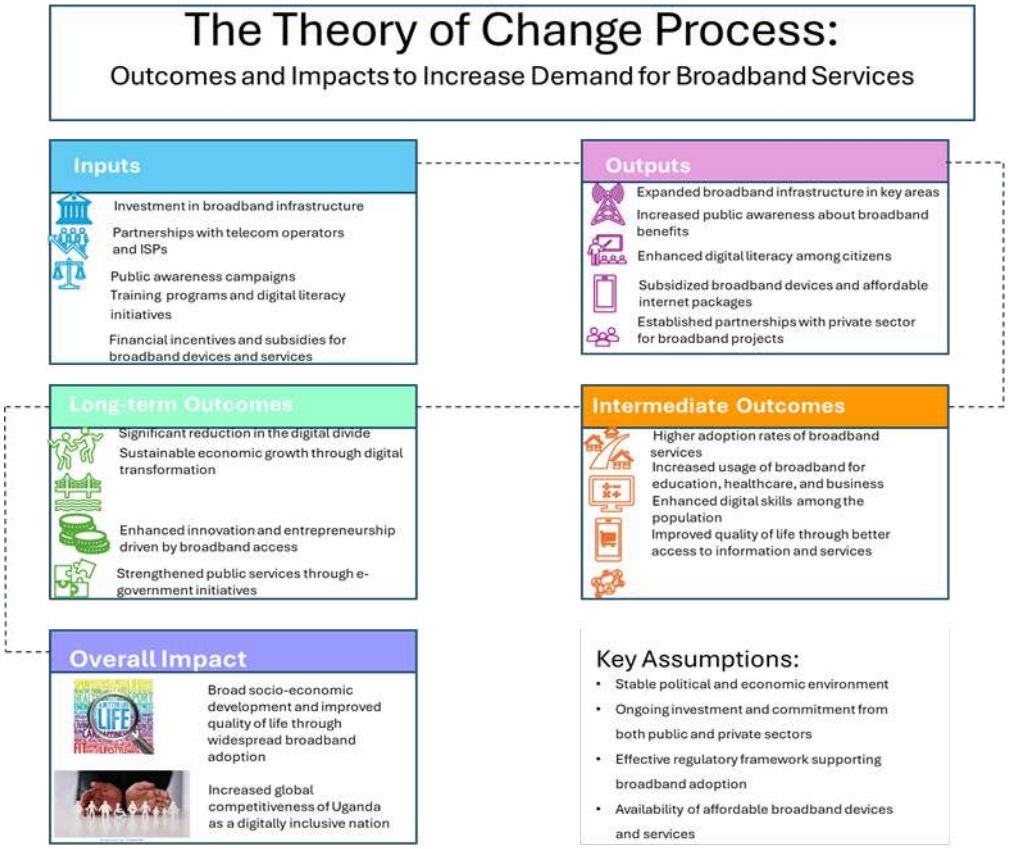
Figure 12. Five-year plan for enhancing connectivity in underserved areas

Source: ITU

9.1.1 Theory of change

The theory of change for increasing broadband demand posits that – if Uganda can significantly expand digital literacy, improve access to broadband devices and enhance the value of digital services – then the demand for broadband will rise, thereby justifying further investment in 5G. This change is expected to lead to more equitable access to information, services and opportunities across the country, which is aligned with the DUV goals. By focusing on the full utilization of existing 4G networks, this strategy ensures a smoother transition to 5G, as the market will be primed for the enhanced capabilities that 5G offers.

Figure 13. The theory of change process: Outcomes and impacts to increase demand for broadband services

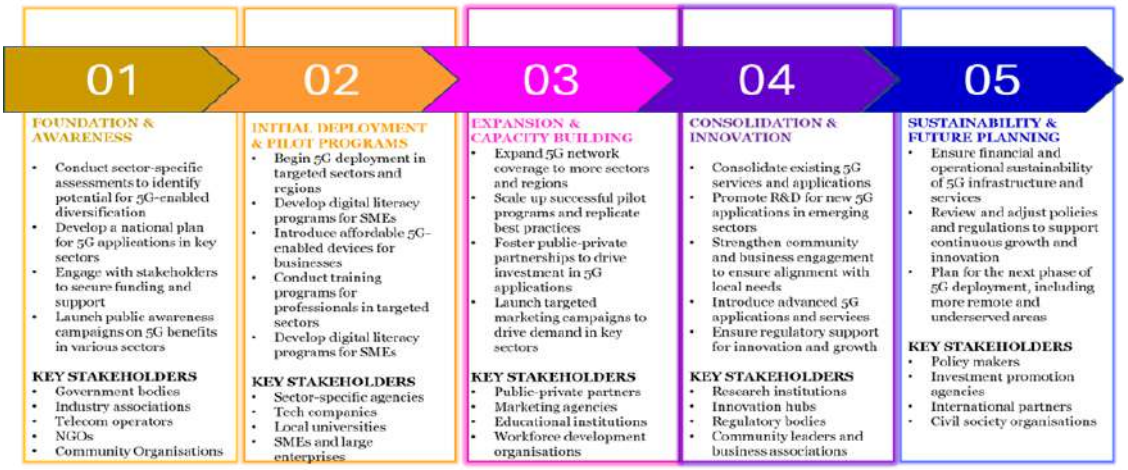


Source: ITU

9.2 Five-year roadmap for economic diversification

The five-year roadmap for boosting economic diversification through industrial automation focuses on integrating 5G technology into Uganda's manufacturing and agro-processing sectors. This roadmap includes initiatives such as establishing smart manufacturing hubs, promoting IoT in agriculture, and developing a skilled workforce for Industry 4.0. By leveraging 4G networks to kickstart these initiatives, Uganda can build the necessary infrastructure and expertise to fully exploit 5G capabilities in the future. This approach supports the DUV emphasis on innovation and competitiveness, driving economic growth and diversification.

Figure 14. Five-year plan for economic diversification

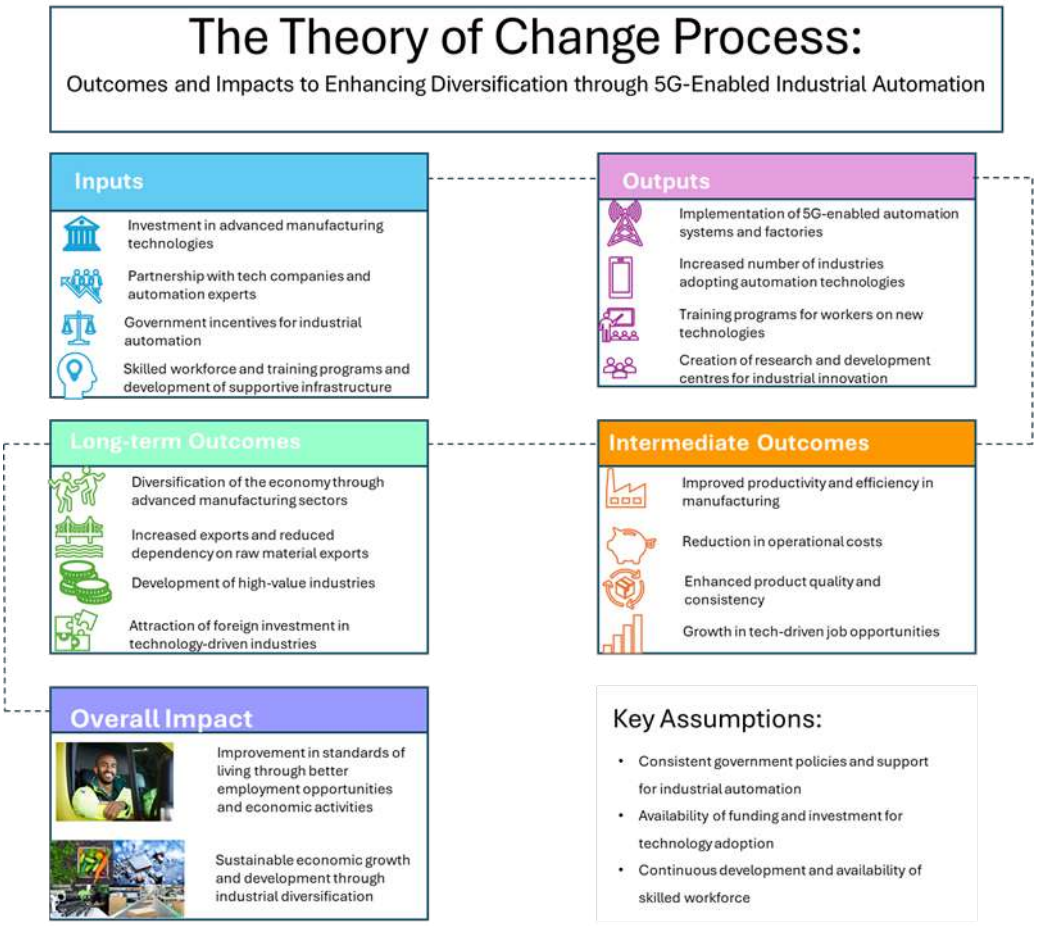


Source: ITU

9.2.1 Theory of change

The theory of change for economic diversification through industrial automation asserts that if Uganda can successfully implement IoT and automation technologies in key industries, it will lead to increased productivity, higher quality products and economic diversification. The transition from 4G to 5G is essential in this context, as 5G low latency and high capacity will enable more advanced applications, such as real-time data analytics and machine-to-machine communication. This change will contribute to the DUV goal of transforming Uganda into a middle-income country by enhancing the industrial sector contribution to GDP.

Figure 15. The theory of change process: Outcomes and impacts to enhancing diversification through 5G-enabled industrial automation



Source: ITU

9.3 Five-year roadmap for improving healthcare and education outcomes

The five-year roadmap for improving healthcare and education outcomes aims to deploy 5G technology to enhance access to quality services, particularly in underserved areas. This includes expanding telemedicine, supporting remote learning platforms and investing in the necessary infrastructure to support these initiatives. However, the roadmap also emphasizes the need to maximize the use of existing 4G networks to build a user base and infrastructure that can later transition to 5G. By doing so, Uganda can make significant strides toward achieving the Digital Uganda Vision goal of improving the quality of life for all citizens.

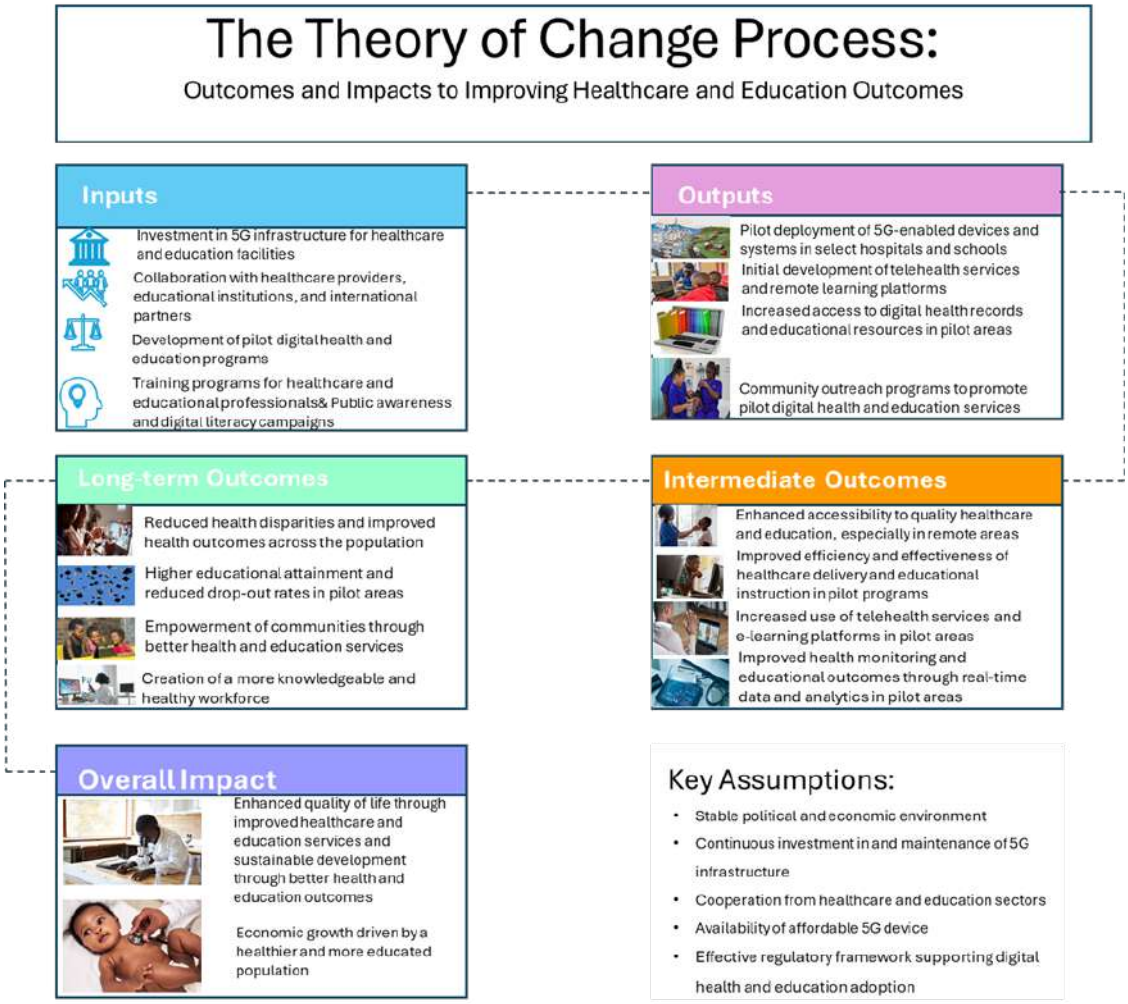
Figure 16. Five-year plan for improving health care and education

Source: ITU

9.3.1 Theory of change

The theory of change for improving healthcare and education outcomes posits that if Uganda can effectively utilize 4G networks to enhance service delivery, particularly in remote areas, then the country will be better positioned to transition to 5G, which will further improve these services. The introduction of 5G will enable more sophisticated healthcare and education applications, such as real-time diagnostics and interactive virtual classrooms, leading to better health outcomes and educational attainment. This theory supports the DUV commitment to reducing inequality and promoting inclusive growth.

Figure 17. The theory of change process: Outcomes and impacts to improving healthcare and education outcomes



Source: ITU

9.4 Five-year roadmap for fostering smart urban development

The five-year roadmap for fostering smart urban development outlines a strategic plan to leverage 5G technology in managing Uganda's rapidly growing urban areas. Key initiatives include implementing smart traffic management systems, enhancing public safety and promoting environmentally sustainable urban practices. This roadmap begins with the utilization of existing 4G networks to lay the groundwork for these smart city technologies, ensuring a seamless transition to 5G. This approach aligns with the DUV vision of creating modern, liveable cities that drive economic growth.

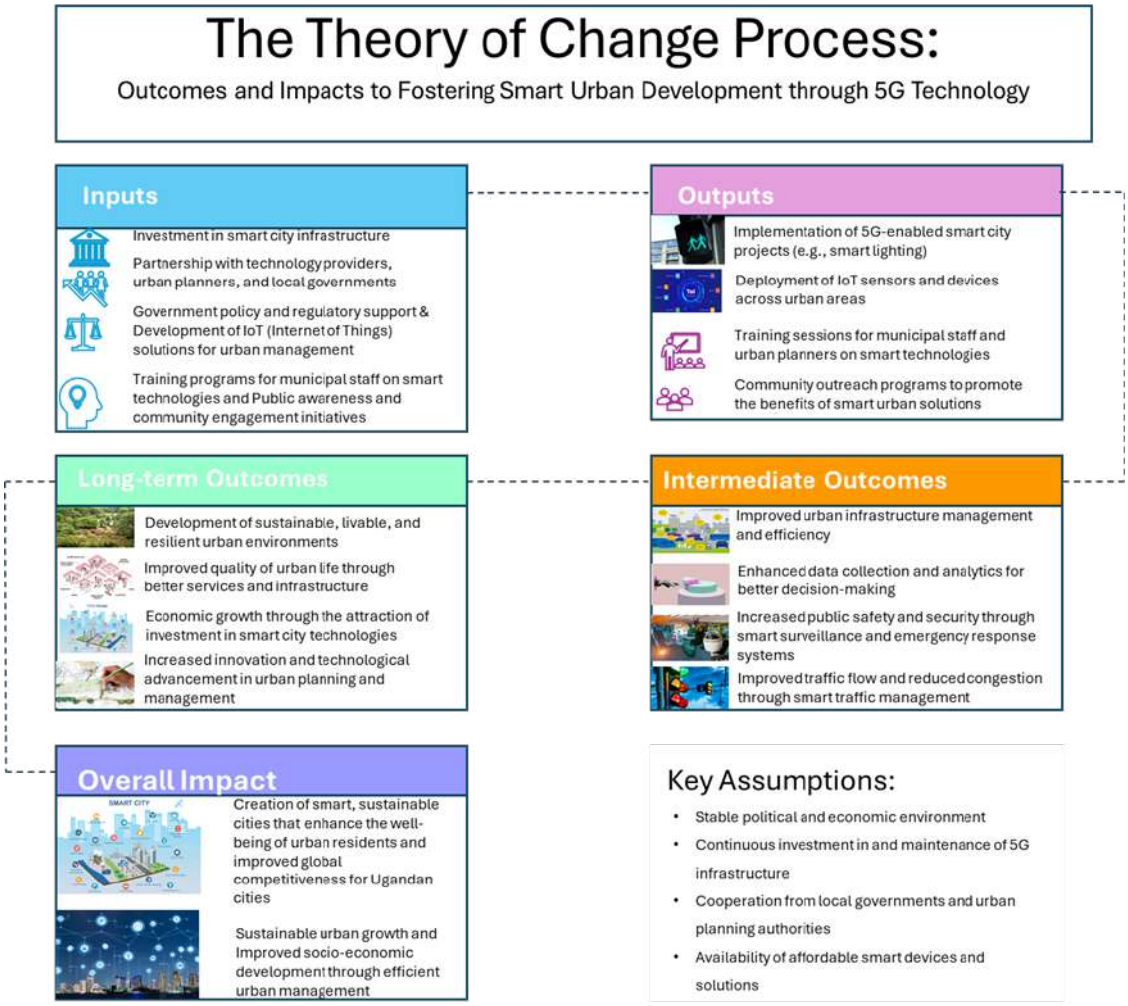
Figure 18. Five-year plan for fostering smart urban development

Source: ITU

9.4.1 Theory of change

The theory of change for fostering smart urban development suggests that if Uganda can implement smart technologies using 4G networks, it will establish a foundation for more advanced 5G applications in urban management. The adoption of 5G will enable real-time data collection and analysis, leading to more efficient and responsive urban services. This change is expected to improve the quality of life in urban areas, reduce congestion and support sustainable development, contributing to the DUV objectives of fostering modern, inclusive urban environments.

Figure 19. The theory of change process: Outcomes and impacts to fostering smart urban development through 5G technology



Source: ITU

9.5 Five-year roadmap for enhancing cybersecurity

The five-year roadmap for enhancing cybersecurity focuses on building a secure digital environment that can support the safe deployment and operation of 5G networks. This roadmap includes the adoption of international security standards such as NESAS, capacity building for cybersecurity professionals, and regular security audits. Initially, the roadmap emphasizes securing existing 4G networks to build a resilient cybersecurity framework that can be expanded with the introduction of 5G. This strategy is crucial for maintaining public trust and protecting the digital infrastructure essential for the DUV.

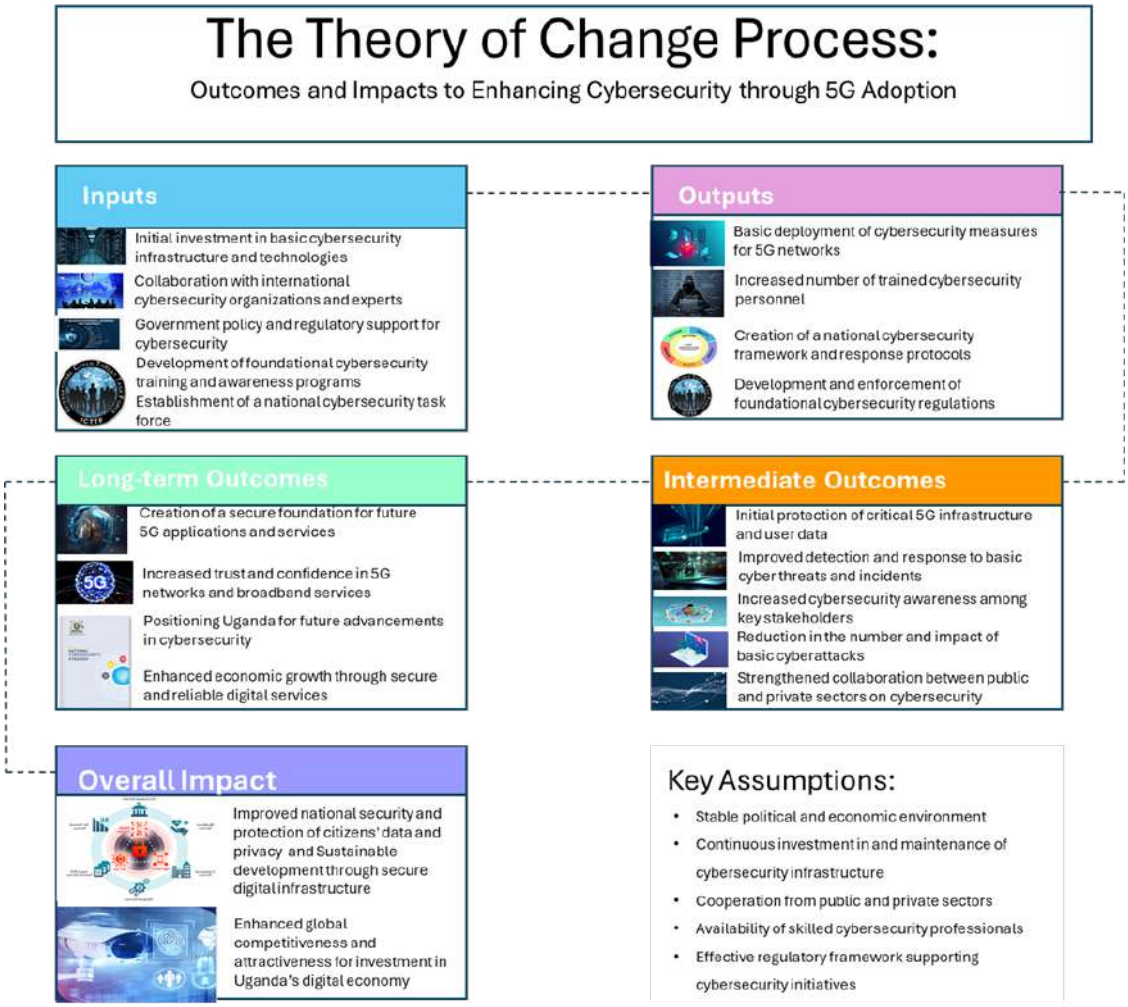
Figure 20. Five-year roadmap for enhancing cybersecurity

Source: ITU

9.5.1 Theory of change

The theory of change for enhancing cybersecurity asserts that if Uganda can establish a robust cybersecurity framework for its 4G networks, it will be well prepared to secure 5G networks as they are deployed. By adopting global standards and building local cybersecurity capacity, Uganda can protect its digital infrastructure from emerging threats, ensuring that the benefits of 5G are realized safely and securely. This change supports the DUV goals of fostering a secure, reliable digital ecosystem that underpins economic growth and social development.

Figure 21. The theory of change process: Outcomes and impacts to enhancing cybersecurity through 5G adoption



Source: ITU

9.6 Chapter summary

This chapter has provided detailed five-year roadmaps and theories of change for Uganda's 5G adoption strategy, focusing on the key areas of increasing broadband demand, economic diversification, healthcare and education outcomes, smart urban development and cybersecurity. Each roadmap outlines a phased approach to deploying 5G technology, beginning with the optimization of existing 3G and 4G networks to build a foundation for the full benefits of 5G.

The theories of change articulate how these strategic initiatives are expected to bring about significant improvements in various sectors, contributing to the overarching goals of the DUV. By ensuring that every step is carefully planned and executed, these roadmaps and theories of change provide a clear path forward for Uganda, ensuring that 5G adoption is not only technologically successful, but also socially and economically transformative.

10 Study recommendations

Introduction

As Uganda stands at the threshold of a 5G revolution, it is imperative to adopt a comprehensive and collaborative approach to ensure the successful deployment and widespread adoption of 5G technology. This chapter provides recommendations to address current challenges and leverage 5G to drive socio-economic growth. These recommendations aim to foster a robust 5G ecosystem that benefits all sectors of the economy.

10.1 Establish a national 5G steering committee

Policy recommendation: Form a national 5G steering committee comprising representatives from both the public and private sectors. This committee should meet quarterly to review the status, progress and future directions of 5G implementation in Uganda.

Rationale: A steering committee will ensure coordinated efforts, sharing of best practices and continuous evaluation of progress. Examples from countries such as South Africa and Thailand highlight the effectiveness of this approach.

Responsibilities:

- Oversee the deployment and use of 5G across different sectors.
- Coordinate efforts between various government agencies, private sector players and international partners.
- Review and update 5G deployment strategies based on emerging trends and technologies.

10.2 Review and reduce import taxes on 5G-compliant devices

Policy recommendation: Re-evaluate and reduce import tax rates on 5G smart devices. Additionally, taxes on Internet data bundles and other related services should be revised to make them more affordable. More 5G-compliant smart phones at reduced taxes will still result in the same net tax contribution to the annual government revenue from this item.

Rationale: High import and value-added taxes make 5G devices prohibitively expensive for many consumers, hindering widespread adoption. Reducing these taxes will lower the cost barrier, making 5G devices more affordable and accessible.

Implementation steps:

- Conduct a comprehensive review of the current tax structure.
- Engage with stakeholders to understand the impact of taxes on 5G device affordability.
- Propose and implement tax reductions to the relevant government bodies.

10.3 Enhance digital workforce training

Policy recommendation: Expand digital workforce training programs to all levels of society and incorporate targeted and segmented physical and online accessible courses for learners of various levels and specializations.

Rationale: A skilled workforce is essential for successfully implementing and maintaining 5G infrastructure. Such a workforce is also necessary to design and roll out new 5G services in the market. Current training opportunities are limited and must be scaled up to meet the growing demand for digital skills.

Implementation steps:

- Develop and offer online courses covering various aspects of 5G technology.
- Partner with international institutions to provide world-class training resources.
- Establish certification programmes to validate the skills acquired by learners.

10.4 Support the set-up and management of innovation hubs

Policy recommendation: The Government should actively support establishing, funding and managing innovation hubs focused on 5G applications.

Rationale: Innovation hubs can serve as research, development and training centres in 5G technologies. They will foster innovation and entrepreneurship, driving the development of new 5G applications and services.

Implementation steps:

- Provide financial and logistical support for the creation of innovation hubs.
- Facilitate partnerships between universities, tech companies and innovation hubs.
- Encourage PPPs to sustain and grow these hubs.

10.5 Foster public–private partnerships

Policy recommendation: Encourage and facilitate PPPs to drive investment in 5G infrastructure and applications.

Rationale: PPPs can leverage the strengths of both sectors, ensuring adequate funding, innovation and efficient implementation of 5G projects. They are crucial for sharing risks and rewards and driving large-scale 5G adoption.

Implementation steps:

- Identify potential areas for PPPs in 5G projects.
- Create a supportive regulatory framework to facilitate these partnerships.
- Promote successful case studies to attract private sector interest.

10.6 Implement public awareness campaigns

Policy recommendation: Launch comprehensive public awareness campaigns to educate citizens on the benefits and uses of 5G technology.

Rationale: Public awareness is critical to driving adoption and addressing misconceptions about 5G. Informing the public about the advantages of 5G in areas such as health care, education and industry will encourage greater acceptance and use.

Implementation steps:

- Develop informative and engaging content highlighting the benefits of 5G.
- Utilize various media channels – including social media, television and radio – to reach a broad audience.
- Partner with community leaders and influencers to amplify the message.

10.7 Strengthen cybersecurity measures

Policy recommendation: Enhance cybersecurity measures to protect the integrity of 5G infrastructure and user data.

Rationale: As 5G networks expand, so does the potential for cyberthreats. Robust cybersecurity frameworks are essential to protect against data breaches, ensure service continuity and maintain public trust.

Implementation steps:

- Implement comprehensive security protocols and standards.
- Ensure that all 5G equipment meets the Network Equipment Security Assurance Scheme (NESAS), developed by GSMA and 3GPP, as a baseline for assessing the security of 5G network equipment.
- Deploy advanced real-time monitoring tools to detect and respond to cyberthreats.
- Conduct regular training and awareness programmes on cybersecurity best practices.

10.8 Address complementary infrastructure and services

Policy recommendation: Develop a holistic approach to infrastructure development, including electricity and road networks, to support the roll-out of broadband and 5G services.

Rationale: The absence of complementary infrastructure increases operational costs and hampers network roll-out. An integrated infrastructure development plan is essential for sustainable broadband expansion.

Implementation steps:

- Coordinate infrastructure development projects to ensure alignment between broadband and other essential services.
- Provide incentives for the development of complementary infrastructure in underserved areas.

10.9 Optimize Universal Service Fund

Policy recommendation: Optimize using the Universal Service Fund (USF) to support broadband connectivity in underserved areas.

Rationale: The USF can play a crucial role in financing broadband infrastructure in areas that are not commercially viable, ensuring that all regions benefit from digital connectivity.

Implementation steps:

- Review and revise the USF allocation criteria to prioritize underserved areas.
- Monitor and evaluate the impact of USF-funded projects to ensure effectiveness.

10.10 Focus on population coverage over geographic coverage

Policy recommendation: Measure broadband coverage based on population rather than geographic boundaries. This change of focus needs to be discussed with the regulator, UCC, to get its approval. Geographical coverage requirements are vital components of the operator licence obligations.

Rationale: Focusing on population coverage ensures that most citizens can access broadband services, even if some geographic regions, such as national parks and reserves, are excluded.

Implementation steps:

- Adjust coverage targets to reflect population density and demand.
- Prioritize high-density areas for initial broadband roll-out.

10.11 Localize quality of service standards

Policy recommendation: Develop localized quality of service standards that reflect the needs of different areas, including rural, urban and high-end customer segments.

Rationale: Uniform quality standards may not be practical or necessary for all areas. Localized standards will ensure appropriate and cost-effective service levels.

Implementation steps:

- Conduct consultations with stakeholders to determine appropriate quality standards for different regions.
- Implement and monitor localized standards to ensure service quality.

10.12 Promote the right mix of alternative technologies

Policy recommendation: Continue promoting a mix of alternative technologies to complement 5G and broadband services.

Rationale: Different technologies – such as fibre, satellite and wireless – can address varying connectivity needs and geographical challenges.

Implementation steps:

- Identify and support the deployment of appropriate technologies for different regions.
- Provide incentives for adopting alternative technologies where 5G is not feasible.

10.13 Pilot projects for key sectors

Policy recommendation: Implement pilot projects in sectors such as health, education, agriculture and dairy to demonstrate the practical benefits of broadband and 5G.

Rationale: Pilot projects play a crucial role in the 5G roll-out, providing a tangible proof of concept and encouraging broader adoption by showcasing the benefits of the technology.

Implementation steps:

- Identify and implement pilot projects in collaboration with relevant sector stakeholders.
- Monitor and evaluate pilot projects to gather data and refine strategies.

10.14 Create public awareness and engagement

Policy recommendation: Enhance public awareness and engagement through targeted campaigns using local languages and media.

Rationale: Effective communication in local languages and through familiar media channels will ensure broader reach and understanding.

Implementation steps:

- Develop simple, clear guidelines and promotional materials in local languages.
- Use various media channels to disseminate information and engage with the public.

10.15 Solidify use of existing 4G and 5G infrastructure

Policy recommendation: Implement strategies that maximize the use of existing 4G and 5G infrastructure. This will not only ensure a return on investment, but also prepare the market for broader 5G adoption.

Rationale: Despite investments in 4G and initial 5G sites, utilization rates remain low, resulting in limited returns. Increasing demand for existing infrastructure will strengthen the foundation for 5G expansion.

Implementation steps:

- Launch targeted marketing campaigns to promote the benefits and applications of 4G and available 5G services.
- Develop affordable data packages and bundles to attract more users.
- Provide incentives for businesses and institutions to adopt broadband services.
- Conduct outreach programmes to educate potential users on how to leverage broadband for productivity and growth.
- Implement pilot programmes in key sectors such as education, health care and agriculture to demonstrate the practical benefits and drive demand.

By implementing these strengthened recommendations, Uganda can effectively address the challenges highlighted by stakeholders, stimulate demand for broadband services, and pave the way for successful 5G adoption. This comprehensive approach will not only drive

socio-economic growth, but also enhance public services and improve the quality of life for all Ugandans, instilling a sense of optimism and hope for the future of telecommunications in the country.

11 Monitoring and evaluation framework

Introduction

Monitoring and evaluation (M&E) is a critical component of Uganda's strategic plan for the 5G roll-out. It ensures that the implementation of the 5G strategy is on track, goals are being met, and the intended impacts are realized. This chapter outlines the M&E framework, including key performance indicators (KPIs), data collection and analysis methodologies, and roles and responsibilities.

11.1 Objectives of the monitoring and evaluation framework

1. Track progress: Continuously monitor the implementation of the 5G strategy to ensure it aligns with the planned roadmap.
2. Assess effectiveness: Evaluate the impact of 5G deployment on targeted sectors and communities.
3. Ensure accountability: Provide transparent reporting on the use of resources and the achievement of objectives.
4. Facilitate learning: Use insights from the M&E process to inform future strategies and improve ongoing projects.

11.2 Key performance indicators

The following KPIs will be used to measure the success of the 5G strategy across various focus areas.

Table 16. 5G strategy key performance indicators

Focus area	Objective	Key performance indicators
Increasing demand for broadband services	Drive broadband adoption and utilization across various sectors to build a foundation for 5G.	- Percentage increase in broadband subscription rates. - Number of pilot projects implemented in critical sectors (education, health care and agriculture). - Percentage increase in broadband usage for e-learning, telemedicine and e-commerce. - Number of public awareness campaigns conducted. - Increase in digital literacy rates among the population. - Number of affordable broadband devices distributed through subsidy programmes. - Number of partnerships established for broadband promotion.
Economic diversification through industrial automation	Utilize 5G to improve industrial efficiency.	- Percentage reduction in production downtime. - Increase in manufacturing output.
Healthcare and education	Improve accessibility and quality of services using 5G-enabled solutions.	- Number of telemedicine sessions conducted. - Student performance metrics in e-learning environments.
Smart urban development	Implement smart technologies for efficient city management.	- Reduction in traffic congestion. - Improvement in emergency response times.

11.3 Monitoring and evaluation process

1. Data collection:
    - Surveys and interviews: Conduct regular surveys and interviews with stakeholders, including government officials, private sector partners and end users.
    - System analytics: Utilize data from 5G networks and related systems to track usage patterns, service quality and performance metrics.
    - Reports and documentation: Collect and review progress reports from implementing agencies and partners.
2. Data analysis:
    - Quantitative analysis: Use statistical tools to analyse numerical data and identify trends, patterns and correlations.
    - Qualitative analysis: Interpret feedback from surveys and interviews to understand the experiences and perspectives of stakeholders.
    - Comparative analysis: Compare performance against baseline data and predefined targets to assess progress.

3. Reporting:
    - Regular updates: Provide quarterly and annual reports detailing the progress of the 5G strategy, including achievements, challenges and lessons learned.
    - Public transparency: Publish key findings and updates on a public platform to ensure transparency and foster stakeholder trust.
4. Review and adaptation:
    - Continuous improvement: Use M&E findings to make informed decisions and adjust strategies to enhance effectiveness.
    - Stakeholder feedback: Incorporate stakeholder feedback into the ongoing refinement of the 5G strategy.

11.4 Roles and responsibilities

- Ministry of ICT and National Guidance: Lead agency responsible for overall coordination and oversight of the 5G strategy implementation.
- National Information Technology Authority Uganda (NITA–U): Monitor and report on the technical aspects of 5G deployment and usage.
- Uganda Communications Commission (UCC): Ensure compliance with regulatory requirements and monitor network performance.
- Telecommunication operators: Provide data on network usage, service quality and customer feedback.
- Independent evaluators: Conduct external evaluations to objectively assess the 5G strategy impact, ensuring the involvement of all stakeholders in its success.

11.5 Detailed monitoring and evaluation framework

The consultant proposes the following M&E approach to be used to assess progress of 5G adoption KPIs (the baseline performance to be determined at the beginning of each year). Annual targets for each KPI are also proposed.

Table 17. Detailed monitoring and evaluation framework

Result (Key result area (KRA))	Indicator	Indicator definition	Means of verification	Data analysis and reporting	Baseline	Target	Responsibility centre
KRA 1: Increasing demand for broadband services	Percentage increase in broadband subscription rates	Increase in broadband subscription rates	NITA-U annual statistical abstract	Annual	TBD	20% subscriptions	Ministry of ICT and National Guidance / NITA–U
	Percentage increase in broadband usage for e-learning, telemedicine and e-commerce	New services supported by broadband services	UCC reports	Annual	TBD	5 pilot projects	UCC

Table 17. Detailed monitoring and evaluation framework (continued)

Result (Key result area (KRA))	Indicator	Indicator definition	Means of verification	Data analysis and reporting	Baseline	Target	Responsibility centre
KRA 2: Economic diversification through industrial automation	Percentage reduction in production downtime	Decrease in time lost due to production halts	Annual reports/statistical abstracts, Ministry of Trade and Cooperatives	Annual	TBD	10%	Ministry of Trade and Cooperatives
	Increase in manufacturing output	Rise in overall production output	Annual reports/statistical abstracts, Ministry of Trade and Cooperatives	Annual	TBD	10%	Ministry of Trade and Cooperatives
KRA 3: Health care and education	Student performance metrics in e-learning environments	Improvement in student grades and engagement in e-learning platforms	Annual performance reports, Ministry of Education and Sports	Annual	TBD	5%	Ministry of Education and Sports
	Number of telemedicine sessions conducted	Telemedicine consultations performed	Reports, Ministry of Health	Annual	TBD	30 sessions	Ministry of Health
KRA 4: Smart urban development	Reduction in traffic congestion	Decrease in traffic congestion levels	Police annual reports/Ministry of Works and Transport annual reports	Annual	TBD	10%	Ministry of Works and Transport
	Improvement in emergency response times	Faster response times for emergencies	Reports, Ministry of Health	Annual	TBD	10%	Ministry of Health
KRA 5: Cybersecurity enhancement	Percentage reduction in cybersecurity incidents	Fewer reported cybersecurity breaches	NITA-U annual statistical abstract	Annual	TBD	5%	NITA–U
	Compliance rate with international cybersecurity standards	Adherence to recognized cybersecurity frameworks and protocols	NITA-U annual statistical abstract	Annual	TBD	95%	NITA–U

12 Conclusion

The 5G adoption strategy for Uganda represents a pivotal step towards achieving the aspirations of the Digital Uganda Vision, which aims to transform Uganda into a modern, prosperous and digitally empowered society. This strategy is not just about the introduction of a new generation of mobile networks; it is about leveraging 5G technology to drive innovation, economic growth and social inclusion, aligned with the pillars of the DUV – Digital Infrastructure and Connectivity, Digital Services, Cybersecurity and Data Protection, Digital Skills, and Innovation and Entrepreneurship.

The strategic focus areas – Increasing Demand for Broadband Services, Boosting Economic Diversification through Industrial Automation, Improving Healthcare and Education Outcomes, Fostering Smart Urban Development, and Enhancing Cybersecurity – are crucial for the nation's transformation. These initiatives are designed to revolutionize multiple sectors by enhancing efficiency, accessibility and the quality of services, accelerating Uganda's progress towards its goal of becoming a middle-income country.

Central to this strategy is the emphasis on increasing the demand for broadband services. Stakeholder feedback has underscored the significant challenges faced by investors in 5G technology, particularly due to low utilization rates and limited returns on investment. To justify the substantial investments required for 5G infrastructure, it is imperative to stimulate demand and ensure that the existing 4G networks are fully utilized, laying a robust foundation for the gradual and sustainable deployment of 5G technology.

Investors in 5G technology encounter high operational costs and substantial financial risks, especially in low-demand environments. Without a robust user base, the economic viability of these investments remains uncertain. Therefore, prioritizing demand stimulation – through targeted public awareness campaigns, comprehensive digital literacy programmes and the provision of affordable broadband solutions – is essential. This approach will not only enhance returns for stakeholders, but also establish a strong foundation for future technological advancements.

The five-year roadmap detailed in this strategy advocates a phased approach to deployment, ensuring that each stage is meticulously managed to minimize risks and maximize benefits. The guiding principles – Inclusivity, Sustainability, Scalability, Security, Partnerships, Regulatory Compliance, Innovation and Transparency – will underpin the execution of this strategy, ensuring that the roll-out is equitable and beneficial for all Ugandans.

To ensure the successful implementation of this 5G strategy, the following are imperative:

- Government and regulatory bodies: Must foster an environment conducive to innovation and investment by streamlining regulations and providing support for the rapid and effective deployment of 5G technologies.
- Industry leaders and stakeholders: Should collaborate, share expertise and invest in the requisite infrastructure and training to ensure the benefits of 5G are realized across all sectors.
- The Ugandan people: Need to be actively engaged and informed about the transformative potential of 5G technology. Effective community involvement and comprehensive public awareness campaigns will be critical in gaining widespread acceptance and optimizing the use of new technologies.

The successful implementation of this strategy will require coordinated efforts, ongoing vigilance and adaptive management. By adopting this forward-thinking approach, Uganda can significantly elevate its technological capabilities, enhance its global competitiveness and improve the quality of life for its citizens.

This strategic plan serves as both a blueprint for technological advancement and a steadfast commitment to sustainable national growth and development. With a unified vision and dedicated execution, Uganda can harness the power of 5G to create a brighter, more connected future for all its citizens.

13 References

(1) H. Cervell, *5G for business: the rise of wireless* (2020).

(2) Uganda Communications Commission, *Market Performance Report 4Q FY 2022/23 (April-June 2023)* (2023).

(3) Ministry of ICT and National Guidance, *Digital Transformation Roadmap 2023/2024-2027/2028* (2023).

(4) Ministry of ICT and National Guidance, *National Broadband Baseline Survey and Infrastructure Blueprint* (2022).

(5) National Information Technology Authority Uganda, *National Information Technology Survey Final Report* (2022).

(6) R. Chataut and R. Akl, "Massive MIMO Systems for 5G and beyond Networks–Overview, Recent Trends, Challenges and Future Research Direction", *Sensors 2020*, Vol. 20, No. 10, p. 2753 (May 2020). Available at doi: 10.3390/S20102753.

(7) Ericsson, *Leveraging the potential of 5G millimeter wave* (2021).

(8) GSMA, *Improving wireless connectivity through small cell deployment* (2017). Available at www.gsma.com/publicpolicy/wp-content/uploads/2016/12/GSMA_Small_Cell_Deployment_Booklet.pdf.

(9) I. Taboada and H. Shee, "Understanding 5G technology for future supply chain management", *International Journal of Logistics Research and Applications*, Vol. 24, No. 4, pp. 392–406 (2021). Available at doi: 10.1080/13675567.2020.1762850.

(10) Y. Liu, D. Lan, Z. Pang, M. Karlsson and S. Gong, "Performance Evaluation of Containerization in Edge-Cloud Computing Stacks for Industrial Applications: A Client Perspective", *IEEE Open Journal of the Industrial Electronics Society*, Vol. 2, pp. 153–168 (2021). Available at doi: 10.1109/OJIES.2021.3055901.

(11) Y. Hao, "Investigation and Technological Comparison of 4G and 5G Networks" *Journal of Computer and Communications*, Vol. 09, No. 01, pp. 36–43 (2021). Available at doi: 10.4236/JCC.2021.91004.

(12) P. Yadav, A. Upadhyay, V.B.S. Prasath, Z. Ali and B.B. Khare, "Evolution of Wireless Communications with 3G, 4G, 5G, and Next Generation Technologies in India", *Lecture Notes in Electrical Engineering*, Vol. 709, pp. 355–359 (2021). Available at doi: 10.1007/978-981-15-8752-8_35.

(13) IHS Markit, *The 5G Economy* (2019). Available at www.qualcomm.com/content/dam/qcomm-martech/dm-assets/documents/the_ihs_5g_economy_-_2019.pdf.

(14) Capgemini, *Industrial Revolution Accelerating the 5G State of 5G and edge in industrial operations* (2021).

(15) GSMA, *5G in China: Outlook and regional comparisons* (2017). Available at https://www.gsma.com/about-us/regions/greater-china/gsma_resources/5g-in-china-outlook-and-regional-comparisons/.

(16) WBG, *Entering the 5G era: Lessons from Korea* (2021). Available at https://news.joins.com/article/23958383.

(17) RootMetrics, *A look at 5G in South Korea: consumers enjoying incredible 5G availability and speeds* (2022).

(18) ONDE, *Action Plan for Promoting the Adoption of 5G Technology in Thailand Phase 1*, Bangkok (2021).

(19) A. Nandi, B.T. Ce and N. Mpstme, *5G Technology in India* (2023). Available at https://www.ijert.org/research/5g-technology-in-india-IJERTV12IS020121.pdf (20) P. Ntshalintshali, The State of 5G in South Africa From Readiness to Recommendations (2021).

(21) FMC&DE, "National Policy on Fifth Generation (5G) Networks for Nigeria's Digital Economy," 2021. Accessed: Aug. 18, 2024. (Online). Available: https://fmcide.gov.ng/wp-content/uploads/2023/11/National-policy-on-5G.cdr .pdf

(22) GSMA, "Roadmaps for 5G Spectrum: Sub-Saharan Africa," 2021. (Online). Available: https://www.gsma.com/connectivity-for-good/spectrum/wp-content/uploads/2023/07/Sub-Saharan-Africa-Roadmaps-for-5G-Spectrum.pdf

(23) Uganda Ministry of Agriculture, Animal Industry and Fisheries, *Implementation Status of the NRM Manifesto 2021-2026 Commitments within Agriculture* (2023).

(24) Uganda Ministry of Health, *Annual Health Sector Performance Report* (Fiscal Year 2022/2023) (2023).

(25) C. Gillispie, *Networked Benefits: Realizing the Potential of 5G in South Korea* (2019).

(26) H.J. Son, "Real-world use cases of private 5G in hospital and healthcare industries", NETMANIAS, (28 November 2023). Available at www.netmanias.com/en/post/oneshot/15946/private-5g/real-world-use-cases-of-private-5g-in-hospital-and-healthcare-industries.

(27) PwC, "5G In Healthcare" (2020). Available at www.pwc.com/gx/en/industries/tmt/5g/5g-in-healthcare.html.

(28) Verizon, "5G and the Impact on Healthcare" (28 February 2020). Available at www.verizon.com/about/news/5g-impact-on-healthcare.

(29) M.M. Rahman, F. Khatun, S.I. Sami and A. Uzzaman, "The evolving roles and impacts of 5G enabled technologies in healthcare: The world epidemic COVID-19 issues", *Array*, Vol. 14, p. 100178 (July 2022). Available at doi: 10.1016/J.ARRAY.2022.100178.

(30) M. Chen, S. Xu, L. Husain and G. Galea, "Digital health interventions for COVID-19 in China: a retrospective analysis", *Intelligent Medicine*, Vol. 1, No. 1, p. 29 (May 2021). Available at doi: 10.1016/J.IMED.2021.03.001.

(31) Ministry of Education and Sports, *Annual Performance Report (Fiscal Year 2019/20)* (2020).

(32) R. Nanyanzi, *Programmatic approaches to the gender-related impacts of COVID-19 on education: Lessons from 2020 Case study: Ministry of Education and Sports Uganda* (2021).

(33) Korea Education and Research Information Service, *Responding to COVID-19 in South Korea: Discovering Online Education as a Key for Future Education* (18 August 2024). Available at https://blogs.iadb.org/educacion/en/covid19southkorea/.

(34) D. Pandit and S. Agrawal, "Exploring Challenges of Online Education in COVID Times", *FIIB Business Review*, Vol. 11, No. 3, pp. 263–270 (September 2022). Available at doi: 10.1177/2319714520986254.

(35) P. Bonini, "When Tomorrow Comes: Technology and the Future of Sustainability Learning in Higher Education", *Environment*, Vol. 62, No. 4, pp. 39–48 (July 2020). Available at doi: 10.1080/00139157.2020.1764300.

(36) R.K. Nag, "Is India ready to accept an EdTech-intensive system in post pandemic times? A strategic analysis of India's 'readiness' in terms of basic infrastructural support", *Decision*, Vol. 49, No. 2, p. 253 (June 2022). Available at doi: 10.1007/S40622-022-00313-0.

(37) Samsung, "Samsung and KDDI Showcase 5G-Powered Education in Japanese Elementary School", Samsung Global Newsroom (10 January 2019). Available at https://news.samsung.com/global/samsung-and-kddi-showcase-5g-powered-education-in-japanese-elementary-school.

(38) M. Sakamoto, "FOCUS: Japan faces long, difficult road to promote inclusive education", Kyodo News (22 November 2022). Available at https://english.kyodonews.net/news/2022/11/504def3ea81f-focus-japan-faces-long-difficult-road-to-promote-inclusive-education.html.

(39) S. Cho and J. Park, "Inclusive education in Japan and its role in international cooperation: analysis of a project for children with disabilities in Mongolia", *Asia Pacific Education Review*, Vol. 25, No. 1, pp. 229–242 (March 2024). Available at doi: 10.1007/S12564-023-09923-4/TABLES/1.

(40) UN-HABITAT, *A better quality of life for all in an urbanizing world* (2023).

Uganda State of Urbanization Report (2022) Uganda-State-of-Urbanisation-Final-Draft-September-2022-new-1.pdf.

(41) KCCA, *Kampala Capital City Road Safety Strategy* (2021).

(42) GSMA, "NESAS Conformance Results – Industry Services", SGMA NESAS Conformance Results. Available at www.gsma.com/solutions-and-impact/industry-services/nesas-conformance-results/.

Office of the Director
International Telecommunication Union (ITU)
Telecommunication Development Bureau (BDT)
Place des Nations
CH-1211 Geneva 20
Switzerland

Email: bdtdirector@itu.int
Tel.: +41 22 730 5035/5435

Office of the Deputy Director
Operations Coordination Department (DDR)
Place des Nations
CH-1211 Geneva 20
Switzerland

Email: bdtdeputydir@itu.int
Tel.: +41 22 730 5131

Digital Networks and Environment Department (DNE)
Email: bdt-dne@itu.int
Tel.: +41 22 730 5421

Digital Knowledge Society Department (DKS)
Email: bdt-dks@itu.int
Tel.: +41 22 730 5900

Projects, Partnerships and Digital Skills Department (PPS)
Email: bdt-pps@itu.int
Tel.: +41 22 730 5447

Africa

Ethiopia

International Telecommunication Union (ITU) Regional Office
Gambia Road
Leghar Ethio Telecom Bldg. 3rd floor
P.O. Box 60 005
Addis Ababa
Ethiopia

Email: itu-ro-africa@itu.int
Tel.: +251 11 551 4977
Tel.: +251 11 551 4855
Tel.: +251 11 551 8328
Fax: +251 11 551 7299

Cameroon

Union internationale des télécommunications (UIT)
Bureau de zone
Immeuble CAMPOST, 3e étage
Boulevard du 20 mai
Boîte postale 11017
Yaoundé
Cameroon

Email: itu-yaounde@itu.int
Tel.: + 237 22 22 9292
Tel.: + 237 22 22 9291
Fax: + 237 22 22 9297

Senegal

Union internationale des télécommunications (UIT)
Bureau de zone
8, Route du Méridien Président
Immeuble Rokhaya, 3e étage
Boîte postale 29471
Dakar - Yoff
Senegal

Email: itu-dakar@itu.int
Tel.: +221 33 859 7010
Tel.: +221 33 859 7021
Fax: +221 33 868 6386

Zimbabwe

International Telecommunication Union (ITU) Area Office
USAF POTRAZ Building
877 Endeavour Crescent
Mount Pleasant Business Park
Harare
Zimbabwe

Email: itu-harare@itu.int
Tel.: +263 242 369015
Tel.: +263 242 369016

Americas

Brazil

União Internacional de Telecomunicações (UIT)
Escritório Regional
SAUS Quadra 6 Ed. Luis Eduardo Magalhães,
Bloco "E", 10º andar, Ala Sul (Anatel)
CEP 70070-940 Brasilia - DF
Brazil

Email: itubrasilia@itu.int
Tel.: +55 61 2312 2730-1
Tel.: +55 61 2312 2733-5
Fax: +55 61 2312 2738

Barbados

International Telecommunication Union (ITU) Area Office
United Nations House
Marine Gardens
Hastings, Christ Church
P.O. Box 1047
Bridgetown
Barbados

Email: itubridgetown@itu.int
Tel.: +1 246 431 0343
Fax: +1 246 437 7403

Chile

Unión Internacional de Telecomunicaciones (UIT)
Oficina de Representación de Área
Merced 753, Piso 4
Santiago de Chile
Chile

Email: itusantiago@itu.int
Tel.: +56 2 632 6134/6147
Fax: +56 2 632 6154

Honduras

Unión Internacional de Telecomunicaciones (UIT)
Oficina de Representación de Área
Colonia Altos de Miramontes
Calle principal, Edificio No. 1583
Frente a Santos y Cía
Apartado Postal 976
Tegucigalpa
Honduras

Email: itutegucigalpa@itu.int
Tel.: +504 2235 5470
Fax: +504 2235 5471

Arab States

Egypt

International Telecommunication Union (ITU) Regional Office
Smart Village, Building B 147,
3rd floor
Km 28 Cairo
Alexandria Desert Road
Giza Governorate
Cairo
Egypt

Email: itu-ro-arabstates@itu.int
Tel.: +202 3537 1777
Fax: +202 3537 1888

Asia-Pacific

Thailand

International Telecommunication Union (ITU) Regional Office
4th floor NBTC Region 1 Building
101 Chaengwattana Road
Laksi,
Bangkok 10210,
Thailand

Email: itu-ro-asiapacific@itu.int
Tel.: +66 2 574 9326 – 8
+66 2 575 0055

Indonesia

International Telecommunication Union (ITU) Area Office
Gedung Sapta Pesona
13th floor
Jl. Merdeka Barat No. 17
Jakarta 10110
Indonesia

Email: bdt-ao-jakarta@itu.int
Tel.: +62 21 380 2322

India

International Telecommunication Union (ITU) Area Office and Innovation Centre
C-DOT Campus
Mandi Road
Chhatarpur, Mehrauli
New Delhi 110030
India

Email:
Area Office: itu-ao-southasia@itu.int
Innovation Centre: itu-ic-southasia@itu.int
Website: ITU Innovation Centre in New Delhi, India

CIS

Russian Federation

International Telecommunication Union (ITU) Regional Office
4, Building 1
Sergiy Radonezhsky Str.
Moscow 105120
Russian Federation
Email: itu-ro-cis@itu.int
Tel.: +7 495 926 6070

Europe

Switzerland

International Telecommunication Union (ITU) Office for Europe
Place des Nations
CH-1211 Geneva 20
Switzerland

Email: eurregion@itu.int
Tel.: +41 22 730 5467

International Telecommunication Union
Telecommunication Development Bureau
Place des Nations
CH-1211 Geneva 20
Switzerland

ISBN 978-92-61-40001-9

Published in Switzerland
Geneva, 2025

Photo credits: Adobe Stock