

Telecommunications and Energy Infrastructure Sharing: Technical and Socio-Economic Impact Analysis in a Multi-Operator Environment in Burundi

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Abstract

The sharing of telecommunications infrastructure and power supply equipment is currently an applicable and very common model for grouping signal transmission and reception equipment and their power supply on the same site to ensure coverage of fixed, mobile, Internet and radio and television broadcasting networks. This study consists of producing an inventory of telecommunications and energy infrastructure sharing, focusing on the one hand on analyzing the impacts of active and passive sharing of telecommunications infrastructure from a technical point of view, particularly in terms of legal framework, deployment, coverage and exposure to electromagnetic radiation, and on the other hand on identifying the effects of infrastructure sharing from a socio-economic point of view in a multi-operator mobile telephony environment, by indicating the economic value of the revenue generated as a result of infrastructure sharing. Finally, the results will contribute to identify strategies for ensuring maximum deployment and coverage of the country, and for developing the information and communication technologies (ICT) sector in order to contribute to the digital transformation by digitising services using mobile telephony and the Internet in Burundi.

Keywords

Infrastructure Sharing, Mobile Telephony, Energy, Multi-Operators

1. Introduction

The development and evolution of fixed, mobile, Internet and radio and television broadcasting technologies is leading operators to intensify their networks and multiply the number of base stations adapted to each type of technology.

The constraints linked to the installation and deployment of these base stations are multidisciplinary in nature, as they depend on the technical and operational parameters of each station.

Efforts from the various players are brought together to find solutions to the challenges and thus resolve the problems of network coverage and deployment.

Around the world, infrastructure and energy sharing is seen as a solution implemented by Telecommunications Operators (TO) and National Telecommunications Regulators (NTR) to minimize investment and operating costs in the telephony, internet and radio and television broadcasting markets.

According to the study produced by (K. Amadasun *et al.*, 2020) [1], the idea of infrastructure sharing started in Europe in 2000s by the telecommunication industry association (TIA) which prepared and shared a report on 3 G Network. The paper argues that infrastructure sharing, and co-location of sites will therefore help in the reduction of operational and capital expenditure, call tariff, proliferation of masts and environmental pollution.

The International Telecommunication Union (ITU) also indicates that some European countries for instance the United Kingdom and Spain have encouraged the sharing of active and passive infrastructures. It also indicates that Vodacom company claims that 30% of investment and operating costs have been reduced through the implementation of infrastructure sharing models.

GSMA indicates that for the Indian market, it has been estimated that mast and site sharing together may allow operators to save close to 30% on capex and opex. In addition, Canada adopted a new licensing regime since 2017, this new regulation allowed the sharing of antenna masts on infrastructure sites in order to reduce deployment costs and visual pollution of the environment.

In Asia, Malaysia Telecoms Regulator, “the Malaysian Communications and Multimedia Commission (MCMC)” has included infrastructure sharing in its regulations as one of the criteria for issuing licenses for the use of frequencies by 3G mobile services, requiring all operators to comply with this legal obligation and enabling the implementation of the telecoms infrastructure sharing policy.

In research conducted in Japan by (Yamajo, T., 2022) [2], Infrastructure sharing offers many advantages to mobile operators, including reduced costs and rapid deployment of networks and services, which can lead to multiple benefits in the mobile industry and society.

However, operators need to pay particular attention to infrastructure sharing contracts, which can be detrimental to competition in this sector. Therefore, to

ensure healthy competition in the market, it is imperative that stakeholders in infrastructure sharing, including governments, national regulatory authorities and operators, place particular emphasis on analyzing contracts while applying regulations and guidelines.

According to (Sanguanpuak *et al.*, 2018) [3], the study analyzed the problems in mobile network operator and customers in terms of cost and quality of service (QOS). The study analyzes and proposes solutions that infrastructure sharing points out that mobile network operators are obliged to increase their capital expenditure (CAPEX) and operational expenditure (OPEX) when covering isolated areas. Hence, there is the need to share infrastructure in order to maximize existing resources and minimize operational expenditure as far as possible.

According to (Isiaka *et al.*, 2021) [4], in their article the basis of wireless broadband data transmission is twofold, fixed and mobile broadband, and infrastructure sharing adds value to deployment and connectivity.

In Sub-Saharan Africa, the evolution of the telecommunications sector led to a growth in services of 6.3% [5] between 2005 and 2014. The World Trade Organization (WTO, 2019) report states that digitalization has transformed services in many developing countries.

Several African countries, Togo, Gabon and Senegal, have developed infrastructure sharing models and the national telecoms regulatory authorities are working with operators to implement these best practices in relation to infrastructure and energy sharing. Furthermore, during 2019, the sharing of telecommunications infrastructures was stimulated in several African countries by the liberalization of the telecommunications sector, which significantly increased the performance of the mobile sector in the long term. According to the study carried out by (Daniel, 2022) [6], the penetration rate of telecommunications services ranged from 39.9% to 145.3% in the UMEOA countries, notably Niger, Togo, Benin, Burkina Faso, Senegal, Mali and Côte d'Ivoire.

In East Africa, the sharing of telecommunications infrastructures is attracting particular attention within the countries of this community. Within the organization, the countries of the sub-region have set up a working group on infrastructure development, sharing, connectivity and digital inclusion, which deals with all issues relating the infrastructure sharing through the Electronic Communications Organization (EACO) [7], which lead the management and sharing of critical infrastructures but also developed guidelines and strategies to:

- Set up a national communications infrastructure database containing the list, location and ownership of critical infrastructure;
- Develop backup and redundancy systems for all critical communications infrastructures;
- Implement remote monitoring and physical security controls;
- Implement disaster recovery plans, including early warning systems;
- Implement cyber security measures, including CERTS, among others;
- Implement alternative power supply systems using environmentally friendly sources;

- Decentralization of networks to improve resilience and minimize single points of failure;
- Formulation of national legal and regulatory frameworks for critical infrastructure;
- Establish collaboration and partnerships between government and the private sector in a joint effort to protect critical communications infrastructure;
- Capacity building to obtain a skilled workforce in the management of critical communication infrastructures;
- Set up public awareness programmes to protect critical communication infrastructures;
- Establish national and sectoral policies on infrastructure and information sharing agreements, crisis and incident management.

In Burundi, infrastructure-sharing initiatives are voluntary and are carried out between telecommunications, radio, and television broadcasting operators. The latter send their agreements to the Burundi Telecommunications Regulation and Control Agency [8], which, through its legal department, approves licenses and agreements before they are implemented, and also in the event of disputes arising from failure to comply with agreements to share telecommunications infrastructure in order to maintain the population's connectivity to the network.

The regulator must adopt precautionary technical and operational provisions to address public concerns, without undermining the scientific basis of these guidelines by incorporating safety and performance factors.

The aim of this study is to determine the benefits of sharing telecoms infrastructure by looking at the current situation in Burundi and illustrating the actions taken in Burundi and within the East African community.

The technical and socio-economic aspects of sharing telecommunications and energy equipment was identified through the study.

In the sharing of telecommunications infrastructure, it is important that the guidelines specify reasonable terms and conditions for implementing infrastructure sharing, taking into account the need to protect the value of existing investments in infrastructure and services.

However, the terms and conditions applicable, particularly with regard to prices, should not constitute an artificial obstacle to this sharing.

The objectives of pooling mobile telephony, data transmission and broadcasting infrastructures will be:

- To promote new investment in the sector,
- To establish and make maximum use of fiber optic infrastructure,
- To deploy wireline links, and
- To lease and share passive and active infrastructures in Burundi and within the East African Community by routing operators' national and international traffic, but also by ensuring maximum coverage of the population while reducing white areas in sound and television broadcasting.

The benefit of this study is to identify the technical, economic and environmental benefits, while addressing the challenges of infrastructure installation and the

socio-economic consequences for operators and residents living approximately base stations.

Finally, it is important to put in place and enforce regulations on network management and to encourage operators in the field to share telecommunications infrastructures in order to reap the many benefits resulting from this good practice.

2. Literature Review

An overview and history of telecommunications infrastructure sharing indicate that mobile communications technologies have undergone a rapid change and development since the 1980s when MOTOROLA Company created the 1st Generation Network using analogue frequencies. Progressively, the technologies innovation changed from 1G to actually 5G.

According to a report by the World Trade Organization (WTO, 2019) [9], digitization has facilitated access to goods and services for many people and access to markets for many businesses.

That was possible due the deployment of telecommunications infrastructures where the process of sharing facilitates the business between operators. Furthermore, the digitization of services has transformed the service sector in most developing countries, and this requires the deployment and pooling of telecommunications infrastructures [10].

This pooling requires new deployment strategies to optimize the network and make telecommunications operators' investments profitable. One of the models adopted to achieve this is the sharing of telecommunications infrastructures.

The various technological changes have prompted operators, equipment manufacturers and the international bodies responsible for regulating and managing the radio frequency spectrum to adopt new strategies and policies to ensure standardization in order to enable the deployment and technical and economic optimization of telecommunications infrastructures.

The International Telecommunication Union (ITU) [11], developed strategies with the Global Systems for Mobile Associations (GSMA) to guide National Telecommunications Regulatory Authorities, associated members, including the academy and civil society representing consumers of telecommunications services to promote the telecommunication Infrastructure sharing around the world.

In Burundi, telecommunication infrastructure sharing is still an issue. Before the liberalization of the telecommunications sector in 1997, ONATEL, the only incumbent operator, was responsible for operating wireline telephony. Decree no. 1/011 of 4/9/1997, laying down organic provisions on telecommunications in Burundi [12] opened up the mobile telephony market and enabled the national territory to be cover by mobile and Internet services. Since that year, mobile telecommunications operators, have provided national coverage for mobile telephony and data transmission. Internet service providers have also joined the sector. BBS provides national coverage of the country with a fiber optic network, giving the population access to telecommunications services and connectivity.

However, in the broadcasting sector, the number of radio broadcasters has

multiplied over the last ten years including public and private Media's broadcasters.

All these companies have equipped themselves with infrastructures enabling them to carry out their activities. These telecommunications infrastructures include telecommunications spaces (premises), access routes (ducts, cable trays), cables and related components, etc. They involve the energy, roads, bridges and pavements, land administration and construction sectors.

Finally, very recently, base station (BS) standby has emerged as a more efficient approach to reducing energy consumption in cellular mobile networks. To save the energy used by mobile equipment base stations, manufacturers and network operators have turned to the manufacture and operation of low-power equipment known as "standby mode", which is beneficial during off-peak hours when network traffic is relatively low. The base station equipment (BTS) currently in use consumes up to 80% of the energy in cellular networks, and putting it into standby mode can significantly reduce energy consumption [13].

3. Materials and Methods

This study was carried out based on quantitative data collection method by submitting a questionnaire produced by Kobo Collect software Tool. This questionnaire collection was addressed to mobiles telephone operators, Internet Access Providers and Radio and Televisions Operators. The main purpose was to identify those had deployed the base stations (BTS: Base stations Transceivers), or leased land and masts, and who could co-locate other operators with or without sufficient infrastructure to provide full coverage of the country. The comparative and analysis method will focus on operators with their own base station and having already started the process of sharing telecommunication and energy infrastructure.

We targeted also the operators of broadcasting sound and television signals with stations to rent or which could rent masts to transmit or retransmit signals using retransmitting equipment has to extend coverage.

By processing the quantitative data supplied by the operators, we were able to identify the sites, masts, land, security and energy sources that was shared, as well as the costs associated with infrastructure sharing.

Analysis and interpretation of the results will make it possible to show the technical and socio-economic impact of sharing telecommunications and energy infrastructure in Burundi, which could stimulate decision-making by the authorities to encourage investment and the granting of licenses in order to cover the country's remote and isolated areas.

3.1. Study Sampling

A random sample was carried out on three operational mobile operators, ten Internet access providers and for broadcasting stations. We have chosen four broadcasting operators, including Burundi national radio television broadcasters, which has towers on the high peaks approved since 1984 by the International

Telecommunications Union (ITU).

The sample is chosen by field of study where in mobile telephony the sector was liberalized since 1998, with actually three mobile operators in the market, eleven Internet Services provider licenses, a new comer, STARLINK, which obtained Internet Service Provider license since 30 May 2024.

The main objective is to determine the number of base stations, to indicate the monetary income resulting from the sharing of telecommunication infrastructure.

The incumbent public operator ONATEL, which operates fixed and mobile telephony, has its own infrastructure including offices, masts and antennas in all the main towns of the country's eighteen provinces, and is working to extend 3G and 4G coverage in order to increase the number of customers it has.

The other two operators, ECONET LEO and VIETTEL, have a large share of the mobile telephony and Internet market, given their number of subscribers and their investment in CAPEX throughout the country, despite the need to fill in a few grey areas to maximize network coverage.

3.2. Regulatory Framework for Infrastructure Sharing in Burundi

According to Articles 117 and 118 of Act no. 1/22 of 22 August 2022 on the electronic and postal communications code, which stipulate that:

With the aim of fostering the development of healthy and fair competition and guaranteeing optimum quality in the provision of electronic communications services, any operator shall, as far as possible, allow other licensed operators in Burundi to share its infrastructure, in particular poles, towers, ducts, electronic equipment, land and high points.

The Agence de Régulation et de Contrôle des Télécommunications (ARCT), in agreement with the operators, adopts the infrastructure sharing guidelines, in particular inviting operators to apply non-discriminatory tariffs when sharing infrastructure.

The ARCT draws up a list of strategic points at which operators must agree to resize infrastructure so that it can be shared under objective, transparent and non-discriminatory conditions.

Failing the resizing of existing infrastructures, the ARCT will encourage the conclusion of co-investment agreements between operators. Pursuant to article 118, infrastructure-sharing agreements are in the nature of private law agreements.

They are submitted to the ARCT for approval before being signed. The same applies to any amendments made to them.

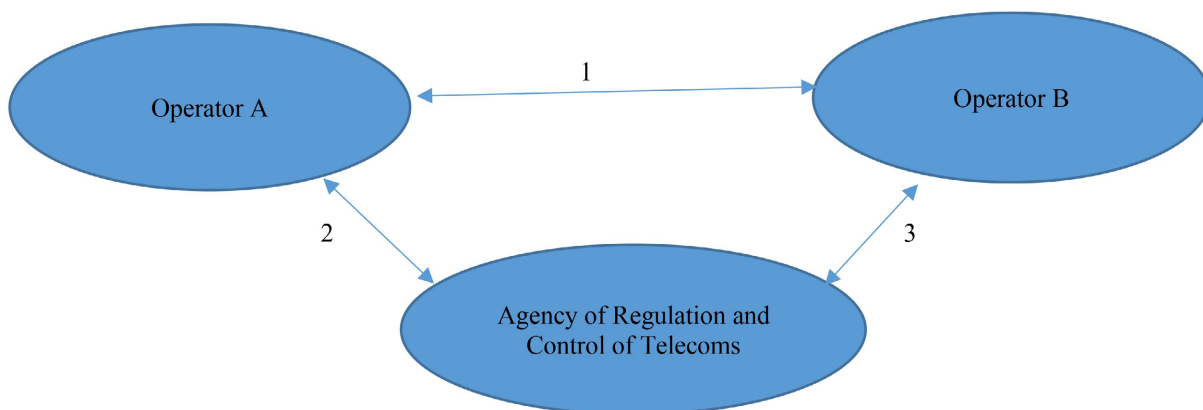
The agreements specify the rules for apportioning the costs of sharing the land resource or the works, as well as the conditions of access to the information required for their implementation.

Prior to the promulgation of the aforementioned law, Burundi did not have a legal framework for infrastructure sharing, and infrastructure sharing was implemented by mutual agreement between operators. The provisions of this law will enable operators to implement this policy, which is conducive to the development of telecommunications networks and accessibility to ICT services in the country.

3.3. Method of Active and Passive Sharing of Telecommunications Infrastructures

Telecommunications infrastructure sharing focuses on active and passive sharing. Passive sharing concerns the sharing of buildings, masts, land, electrical power equipment, security guards, roads and other access routes. Active sharing focuses on software, frequency and number resources, etc. Our study did not identify this type of sharing because the country's regulatory framework does not authorize the sharing of radio frequency and number resources, and consequently this type of sharing is not applied in Burundi.

The infrastructure sharing process involves the following stages: (**Diagram 1**)



- 1: Request to share infrastructure: operator A initiates a request to share infrastructure by sending a request to operator B. Operator B agrees or disagrees with A's request.
- 2: Operator A sends the draft agreement or disagreement to the Regulator for approval or mediation.
- 3: Operator B may also follow the same process with other operators, as sharing Infrastructure is a voluntary operation.

Diagram 1. Structure of the infrastructure sharing process between operators and the telecommunications regulator.

In the event of disagreements or disputes arising from failure to comply with the clauses of the contracts or agreements on the sharing of telecommunications infrastructures, the two parties reach an amicable agreement. If a solution is not found, the matter is referred to the regulator for arbitration, and if the request is still pending, the matter is referred to the country's courts.

3.4. Sharing Energy Sources

Electricity is an essential source of power for telecommunications, radio and television broadcasting equipment. Burundi is a mountainous country where, according to INSBU statistics, more than 80% of the population live in rural and isolated areas. In their concession and license contracts, operators have an obligation to cover the whole country, but the shortage of electricity supplied by REGIDESO, that operators have to use other sources of energy, in particular generators, solar panels and wind power. Our study also focused on identifying shared energy equipment. Operators passively share sites, pylons, electrical energy (REGIDESO, generators, solar panels) and security.

3.5. Electromagnetic Radiation and Concerns of Base Station Residents

According to the article by Lincheng Dai and Hongtao Zhang, measurements of signal propagation parameters from equipment, in particular power, antenna height and the geographical coordinates of stations, are crucial [14]. Electromagnetic radiation from base stations, transmitting and receiving stations, retransmitters and relay stations must comply with the radiation standards laid down by the International Commission on Non-Ionizing Radiation Protection (ICNIRP). This organization has established guidelines specifying quantitative levels of electromagnetic fields for personal exposure [15].

Compliance with these levels is intended to protect people from any proven harmful effects of exposure to radiofrequency electromagnetic fields. We are going to indicate some exposure restriction values known as ‘basic restrictions’ in the frequency range from 100 KHz to 300 Ghz, which includes the frequencies used by broadcasting, mobile telephony and Internet services. Below 6 Ghz, propagating electromagnetic fields also penetrate the tissues of the human body and it is necessary to determine the “specific energy absorption rate” (SAR), which indicates the power absorbed per unit of mass ($W \cdot kg^{-1}$).

For antennas grouped together on a site, the radiation of electromagnetic fields propagates and staff and residents are exposed. The following values produced by ICNIRP provide information on electromagnetic exposure levels: the average whole-body SAR for the frequency band from 100 kHz to 300 GHz is $4 W \cdot kg^{-1}$, while the local SAR for the frequency range from 100 kHz to 6 GHz for exposure of the head and torso of the human body is $20 W \cdot kg^{-1}$.

People living near base stations are concerned about protecting their health from exposure to electromagnetic fields and noise from the operation of generators. The solutions applied by telecoms operators and regulators include technical measures to ensure compliance with the technical and operational parameters of the equipment installed at the stations, as well as awareness-raising sessions for residents on electromagnetic radiation standards and the use of soundproof generators to limit noise.

4. Analysis of the Results of the Pooling of Telecommunications Infrastructures

The study-analyzed data collected from Mobile Network Operators (MNO), Internet Service Providers (ISP) and the Radiobroadcasters (RB) and present the results obtained. The overview of sites available for sharing, the socioeconomic impact in terms of financial revenue accessibility, strategies for improving the quality of service and concern of populations living near the base stations related to the infrastructure sharing as at follow.

4.1. Mobile Telephone Operators

Three mobiles telecommunications operators in the country got licenses with

validity of twenty years deployed base stations (BTS) in urban and rural areas. The case study shows that VIETTEL mobile Company has 591 sites, including 10 roof-tops that cannot be shared.

Based on a geolocation study and data collected from the sites provided by the MNO, 581 sites could be shared, as the pylons they have are between 30 and 50 meters high. The base stations cover an area of between 300 to 400 square meters, or 15 m to 20 m on each side, which is enough space to house other equipment including radio aerials and signal transmission microwave links.

The ECONET LEO mobile operator, provided 186 sites all of the country, with taking into account their location and the height of their towers. The main issue provided by MNO was that REGIDESO electrical company had not enough and adequate power supply to cover all areas where electrical power is needed. It observed that more 85% of sites are connecting to generators, which consume a lot of fuel. This shows that the lack of energy in rural areas is a limiting factor in the deployment and coverage of telecommunications networks.

Table 1 shows the variation in the number of mobile telephony stations to be shared as a function of tower height.

Table 1. Shareable sites of the two operators providing extensive mobile telephony coverage in Burundi.

Number of VIETTEL/Lumitel Stations	Number of ECONET Stations	Height of pylons in (m)
10	6	Stations placed on the roof (Roof-Top)
92	45	20 - 40
183	323	41 - 60
306	8	More than 60
591	382	Total number of Sites

Table 1 and **Figure 1** show the number of sites that can be shared by operators and the height of the masts installed on these sites.

Progressive pooling will provide good coverage, reduce investment costs and give residents living in rural and isolated areas access to ICT services. The operators ECONET LEO and ONATEL lease certain sites from other operators.

Table 2 below shows the number of sites leased by these operators between 2020 and 2023, as well as the economic impact in terms of mounts paid following leasing operations.

The table below was produced using data collected from the mobile operators over a period of four years.

It illustrates the sites shared and the income generated by sharing telecommunications and energy infrastructures. Leasing reduces expenditure, maximizes profitability and minimizes the cost of access to telecommunications services (**Figure 2**).

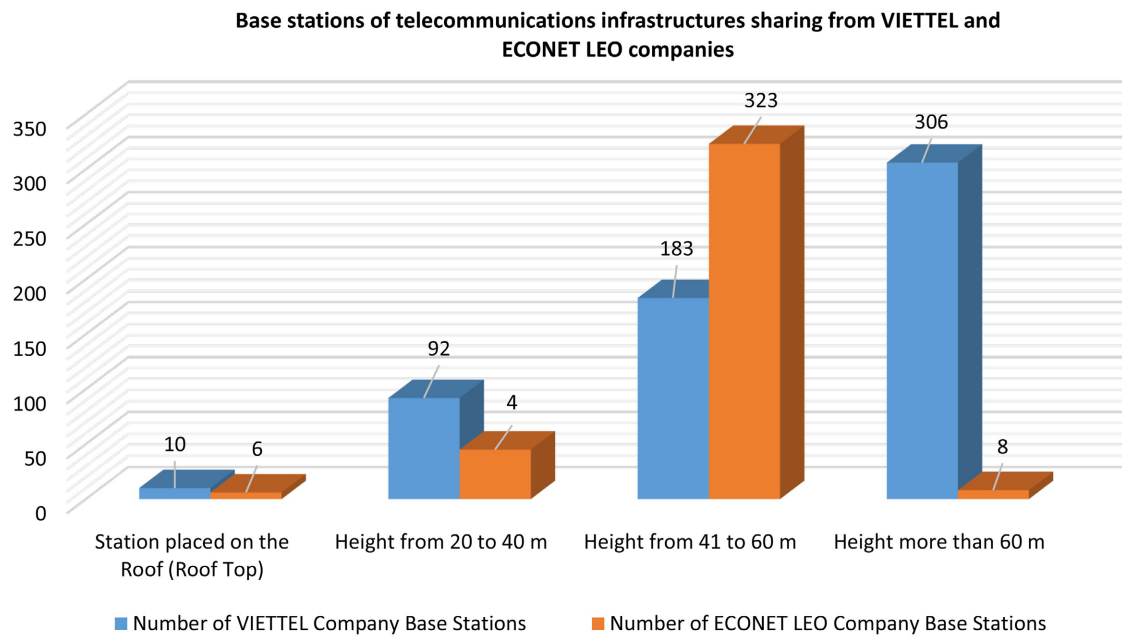


Figure 1. Evolution of mobile telephony stations to be shared according to tower height.

Table 2. Economic impact of revenue from leasing shared stations from 2020 to 2023.

Operators	2020		2021		2022		2023	
	Number of sites rented	Annual amount in Fbu	Number of sites rented	Annual amount in Fbu	Number of sites rented	Amount	Number of sites rented	Mutant
VIETTEL	0	-	0	.	0	-	0	-
ECONET	26	8,196,876	24	8,856,000	25	8,856,000	25	12,118,908
ONATEL	21	11,980,920	21	11,980,920	21	11,980,920	21	11,980,920
Total	47	20,177,796	46	20,836,920	46	20,836,920	46	24,099,828

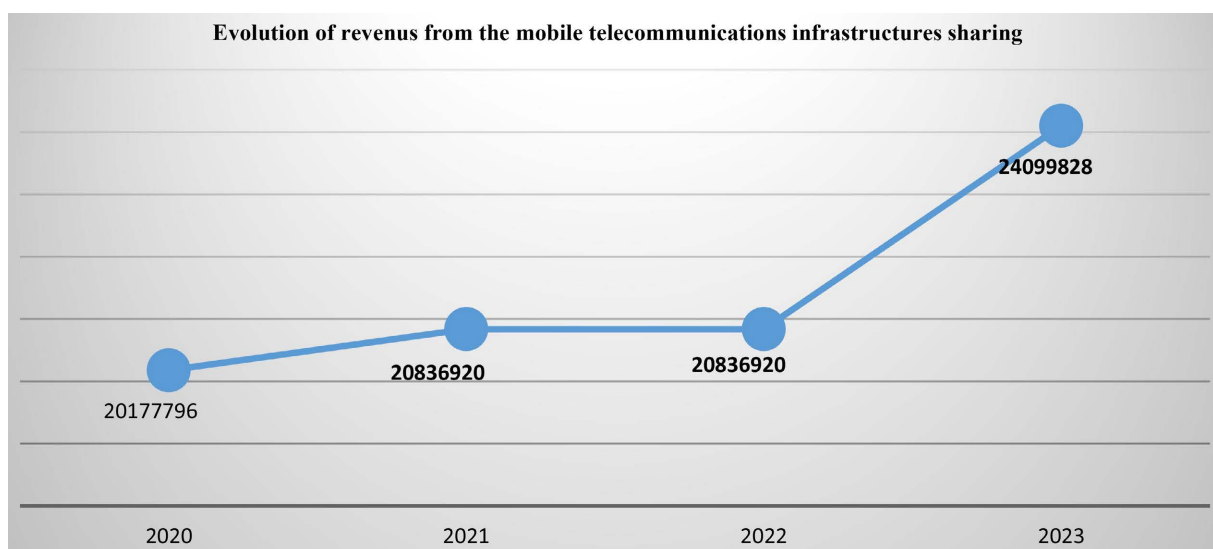


Figure 2. Overall trend in revenue from sharing mobile station infrastructure.

4.2. Sound and Television Broadcasting Operators

In Burundi, the International Telecommunications Union has adopted high peaks intended to house radio and television broadcasting sites. Thus 6 sites have been identified and are managed by the “Radiotélévision Nationale du Burundi (RTNB)” [16], the leading state medium for news broadcasting, which has a main station and rebroadcasting stations in six points of the country. These are BUJUMBURA, MANGA, BIRIME, INANZERWE, KABERENGE and MUTUMBA.

Broadcasting operators with need to extend their radio or television signal coverage installed their retransmitting stations to extend the signal in North, East, Centre and South of the country.

During our research, a data collection questionnaire was sent to four broadcasting stations and two television stations on infrastructure sharing: Radiotélévision Nationale du Burundi (RTNB), Radiotélévision ISANGANIRO, Radio Scolaire NDERAGAKURA and Radio Voix d’Espoir Ijwi RIREMESHHA.

The choice of these radio and television stations was motivated by the level of geographical coverage of the territory and the population, but also by the income generated or paid following the rental of masts when infrastructure is shared. All these stations have sent their data for analysis, the result is given in **Table 3**.

Table 3. Sharing of broadcasting stations and economic impact.

Radio and TV Stations	Station Status	Number of sites occupied/rented	Revenue generated/collected in (Fbu)	Amount paid in rental (Fbu)
RTNB	Public Radio	6 (owners)	21,143,657	-
School Radio NDERAGAKURA	School Public Radio	6 (rented)	-	9,993,636
Radiotelevision Isanganiro	Private radio	5 (rented)	-	5,769,221
Radio Voice of Hope Ijwi RIREMESHHA	Religious Radio	1 (rented)	-	5,380,800
Total	-	12	-	21,143,657

Table 3 shows the stations leased, the lessees and the annual revenue generated in 2023.

Analysis of the revenues of some broadcasting stations from 2020-2023 paid to RTNB.

Table 4 shows the evolution of revenues generated by the sharing of telecommunications infrastructures from 2020 to 2023.

Table 4. Evolution of revenues generated by the sharing of sound and television broadcasting infrastructure, received by RTNB.

Radio Station	2020	2021	2022	2023
School Radio NDERAGAKURA	5,782,800	5,717,436	5,717,436	9,993,636

Continued

Radiotelevision ISANGANIRO	3,479,424	4,914,603	4,914,603	5,769,221
Radio Voice of Hope Ijwi RIREMESHHA	5,380,800	5,380,800	5,380,800	5,380,800
Total Amount	14,643,024	16,012,839	16,012,839	21,143,657

The resources generated by the sharing of broadcasting stations will increase from 2020 to 2023 (Figure 3).

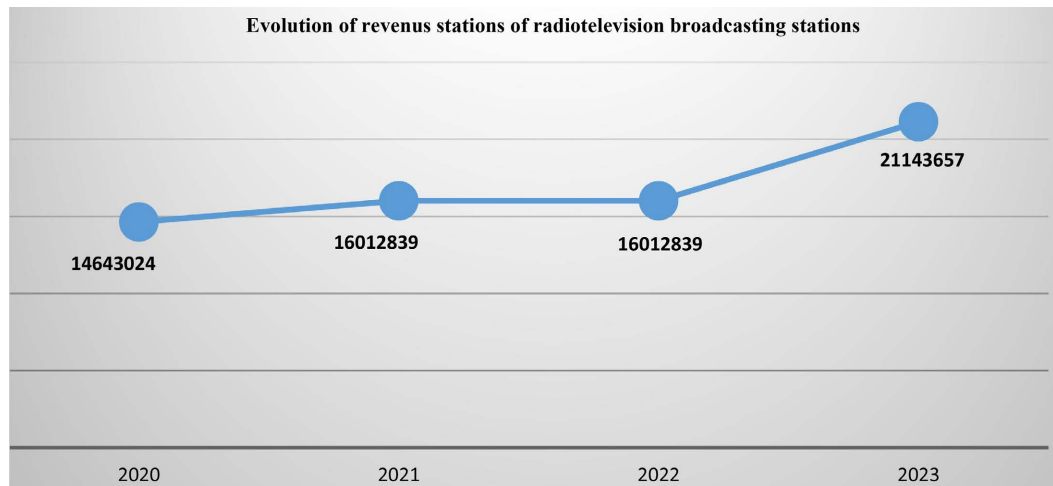


Figure 3. Growth in revenues from the sharing of radio and television broadcasting stations.

4.3. Internet Operators (BBS)

BBS (Burundi Backbone System) is a major Internet capacity provider which has deployed a national fibre optic backbone in all 18 provinces of the country with a capacity of more than 16 GBps. The company is able to share and lease fibre optic lines and manholes built throughout the country, subject to compliance with sharing conditions, which may be set out in an agreement, contract or memorandum of understanding between the two parties negotiating the sharing of infrastructure. Sharing fibre optic networks improves connectivity by creating economically viable broadband backbones.

Table 5 shows the standards for the installation of fibre optic infrastructures, which must be applied during any fibre optic infrastructure installation activity.

Table 5. Optical fibre installation standards, source BBS.

Wording	Minimum depth in place (m)	Maximum depth in place (m)
Trench depth	0.8	1.2
Crossing distance with the REGIDESO power line	0.3	0.6
Road crossing depth	1	1.2
Method of crossing a river	Construction of two manholes and fixing of galvanized metal pipe through which the fiber optic cables pass and placed along the bridge.	

4.4. Comments on the Results Obtained

Telecommunications infrastructures play an important role in socio-economic affairs and development. They provide connectivity for mobile networks and the Internet via mobile smartphones and computers. In order to guarantee the smooth operation and good quality of service of the networks, while preserving the environment within, an infrastructure sharing and interconnection model is essential to minimise investment costs and guarantee fair competition.

The results in **Table 1** show that the operators VIETTEL and ECONET LEO have stations that can be used to share infrastructure, given the technical characteristics of the sites, in particular the height of the masts and the surface area occupied by the sites. However, the constraints of supplying the sites with electricity are a very difficult challenge to overcome, as more than 85% of the sites are supplied by generators, making infrastructure sharing in rural areas inoperable.

Table 2 shows that for the period 2020 to 2023 forty-seven (47) sites were shared and leased by the operators ECONET LEO and ONATEL. The revenue paid following the infrastructure sharing operations for the two operators was 24,099,828 Fbu, with an increase of 3,922,032 Fbu, a growth rate of 19.43%.

Table 3 shows that Burundi's national broadcaster manages the ITU-approved high peaks and rents them out. This study shows that some public, private and religious radio and television stations rent RTNB masts, buildings and land to rebroadcast their signals throughout the country. The table shows that for the year 2023, out of the twelve (12) leases analyzed, RTNB received an annual income of twenty-one million one hundred and forty-three thousand six hundred and fifty-seven Burundian francs (21,143,657 Fbu) to cover the costs of running the radio station. This shows that the revenue curve is rising from 2020 to 2023.

Table 4 shows that the revenue generated by the sharing of sound and television broadcasting infrastructure, collected by RTNB for the period from 2020 to 2023, rose from 14,643,024 Fbu to 21,143,657 Fbu, an increase of 44.39%.

Table 5 shows the standards for laying fibre-optic infrastructure for Internet provision when laying cables across roads, rivers and at power line crossings.

During the study, it was noted that many ISPs have their own base stations. However, the ISP USAN reported that it had pooled its stations by renting them from other operators. In analysing the results obtained, we make a number of observations:

The sharing of telecommunications infrastructure is a voluntary operation in Burundi, as there is no regulatory obligation for operators to use this model, which is nonetheless more practical for network coverage and deployment.

Burundi's Agency of Regulation and Control of Telecommunications (ARCT), like other African regulators such as Senegal's, should impose the sharing of telecommunications infrastructure in order to guarantee competition and accessibility to ICT services. As Mauritania and Benin are doing, the ARCT should be encouraged to publish data relating to infrastructure sharing and to encourage operators to provide data on the sites and infrastructure available for sharing.

An analysis shows that there is a proliferation of pylons and poles throughout the country belonging to certain companies, which shows that the telecommunications infrastructure sharing operation has not yet developed in the country, even though the operators should priorities this policy.

Infrastructure sharing is currently at primary level because it essentially concerns passive sharing. However, with the new law recently promulgated, guidelines for sharing telecommunications infrastructures will be implemented to promote strategies of deployment and network coverage in the country. These texts to be drawn up must specify the minimum information that infrastructure-sharing agreements and contracts must contain in order to allow flexibility in sharing, reduce disputes as far as possible, encourage investment and bring added value in terms of cost, while promoting interconnection, connectivity and the digital inclusion of users. Infrastructure sharing reduces barriers to entry for new operators and promotes competition.

5. Conclusions

In Burundi, operators are gradually adopting the sharing of telecommunications and energy infrastructure based on voluntary contracts, despite the lack of regulations governing infrastructure sharing many years ago in the country.

However, articles 117 and 118 of the recently promulgated law no. 1/22 of 22 August 2022 set out the basic arrangements for sharing telecommunications infrastructure. This is a new benefit in this sector, which will provide a framework for the policy of sharing infrastructure and property in the telecommunications sector in order to boost network coverage, quality of service and healthy competition, and to promote accessibility to ICT services by the population, including those living in rural and isolated areas.

According to France's "Agence de Régulation des Communications Electroniques et des Poste" (ARCEP, 2022) [17], active and passive infrastructure sharing is a form of pooling that allows several mobile operators to install their equipment on the same support, which is passive infrastructure elements: high points, masts, flat roofs, feeders, in particular the coaxial cables that link antennas to base stations, premises, or the technical environment of network equipment, including electricity, air conditioning and civil engineering.

The aim of this study was to show the current situation regarding the sharing of telecommunications and energy infrastructures in Burundi, and to indicate the added value that has made it possible to identify the advantages offered to service operators on a technical, economic and social level in Burundi.

According to the study produced by the Association Progressive des Communications (APC), the sharing of telecommunications infrastructures makes it possible to:

- Improve Internet connectivity for fibre-optic networks by multiplying the number of fibre-optic backbone connection points in less economically viable rural areas, while reducing deployment costs.
- Reduce the cost of extending and operating the telecommunications networks

of operators in this sector to make ICT services more accessible.

- Increase the income of infrastructure operators who provide telephony, Internet and broadcasting services by renting out masts, land, energy sources, buildings and security.
- Encourage competition and allow the entry into the market of new operators whose means of setting up infrastructures would require significant investment capital.
- Enable the population to access ICT services at lower cost, but also to enjoy the benefits of new technologies and smart grids, making life easier both economically and socially.

During the study, a visit to the operators' sites showed that telecommunications infrastructure sharing and energy involves land, buildings, rights of way, security and guarding, power supply generators, access roads to sites such as MANGA, BIRIME, INANZERWE, MUTUMBA, KABERENGE and other localities and mobile telephone and Internet sites.

The Agency of Regulation and Control of Telecommunications, in collaboration with others stakeholders, are in the process of putting in place strategies; guidelines and a regulatory framework for infrastructure sharing to promote investment, foster competition and competitiveness in the mobile telephony and Internet sector in order to ensure accessibility, connectivity and digital inclusion in isolated areas, and consequently universal service for all.

To achieve this, the government of Burundi has just set up a Universal Service Fund to finance the deployment of broadband infrastructure in economically less profitable areas, where operators are reluctant to install telecommunications equipments, because these are low-income areas.

In conclusion, the remedies for ensuring national coverage of the territory are to support the policy of sharing telecommunications infrastructures to reduce the cost of installing equipment, reduce visual pollution from pylons, minimise social concerns linked to the probable dangers of electromagnetic wave radiation and reduce noise from power supply generators, and deploy renewable and alternative energy sources in isolated areas.

To remedy the psychological constraints of the population (living in the vicinity of base stations), linked to electromagnetic radiation, the Telecommunications Regulation and Control Agency periodically carries out awareness-raising campaigns, but also carries out measurements to monitor the technical and operational parameters of equipment to ensure compliance with standards, quality of service and to combat harmful interference that could be caused by malfunctioning stations.

Operators must also install soundproof generators to reduce as far as possible the propagation of noise in households close to base stations, as well as promoting the use of renewable energy sources in rural and isolated areas.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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