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Resilient Submarine Fibre Optic Cable Landing Architectures for Broadband Expansion in Emerging Digital Economies

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***Abstract* - Broadband access has become a key driver of economic growth and social development worldwide, yet Nigeria continues to lag behind in achieving widespread, highspeed connectivity [16]. Over the years, several high capacity submarine fibre optic cables have landed on the country's shores, bringing in vast amounts of international bandwidth [3][4]. However, this progress has not fully translated into improved broadband access for much of the population.**

This study explores the underlying reasons for this gap, focusing on challenges such as limited distribution of landing infrastructure, high deployment costs, regulatory constraints, and weak inland connectivity. A major concern is the concentration of submarine cable landing points in a small number of locations, which limits network resilience and contributes to uneven access across regions [5][6].

In response, the research proposes a more distributed approach, where multiple coastal states serve as additional entry points for submarine cables. This strategy aims to improve redundancy, expand access, and make broadband delivery more efficient and affordable. By addressing both infrastructure and policy related issues, the study offers practical insights for strengthening Nigeria's broadband ecosystem and ensuring that existing investments deliver broader national benefits [7].

Keywords – Fibre Optics, Submarine Cables, Broadband

I. INTRODUCTION

Broadband has evolved from a simple measure of internet speed into a critical foundation for modern economies, shaping how people work, learn, do business, access healthcare, and participate in digital society [12]. While early definitions of broadband focused on minimum data rates often as low as 256 kbps, contemporary perspectives emphasize user experience, reliability, and the ability to support data intensive applications. In Nigeria, broadband is formally defined under the National Broadband Plan (2020–2025) as internet access delivered at minimum speeds of 25 Mbps in urban areas and 10 Mbps in rural areas, reflecting a shift toward more meaningful connectivity standards [12][13].

Despite rapid global advances in digital infrastructure, access to fast, affordable, and reliable broadband remains uneven in many developing economies, including Nigeria. The increasing digitization of services ranging from financial technology and e-commerce to e-government and remote work has amplified the urgency of expanding high quality internet access to a broader segment of the population. In this context, broadband is no longer a luxury but a necessity for inclusive economic growth and social development [16][21].

Nigeria has made notable progress in strengthening its international connectivity through the landing of multiple high capacity submarine fibre optic cables along its coastline. These systems collectively provide terabits of potential bandwidth, positioning the country as a key connectivity hub in West Africa [5]. However, this substantial capacity remains underutilized. While wholesale access to submarine cable bandwidth has improved, the benefits have not fully reached many end users.

II. AIM AND OBJECTIVES OF THE STUDY

This study aims to critically examine the key constraints hindering broadband development in Nigeria, with particular emphasis on the deployment and utilization of fibre optic infrastructure. While significant investments have been made in submarine cable systems and national backbone networks, gaps persist between available capacity and actual end user access [20]. This research seeks to identify these structural, economic, and regulatory bottlenecks ranging from limited inland fibre distribution and high right-of-way costs to infrastructure concentration and network inefficiencies.

Building on this analysis, the study proposes an effective and scalable optical fibre network design framework tailored to Nigeria's geographic and socio economic context. The objective is to develop practical solutions that enhance network resilience, improve last mile connectivity, optimize the use of existing submarine cable capacity, and support more equitable broadband access across both urban and underserved regions.

III. SIGNIFICANCE OF THE STUDY

Expanding access to affordable, high speed broadband is widely recognized as a cornerstone of economic growth, social inclusion, and digital transformation. In Nigeria, however, broadband penetration is just a little over 50% compared to the 70% target set in the National Broadband Plan, limiting the country's ability to fully participate in the digital economy [1]. This study contributes to ongoing efforts to address these gaps

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by offering insights into how infrastructure planning and policy interventions can be better aligned to deliver meaningful connectivity.

Beyond its technical contributions, the study is situated within a broader understanding of development in the digital age. Literacy, once defined primarily as the ability to read and write, now encompasses digital skills, access to information, and the capacity to engage with technology in meaningful ways [22]. Reliable broadband connectivity underpins all of these capabilities, influencing education, healthcare delivery, financial inclusion, and access to government services.

Empirical evidence continues to highlight the economic value of broadband expansion. Studies by international development institutions, including the World Bank, have consistently shown that increased broadband penetration is associated with measurable gains in economic productivity, particularly in developing countries. As digital services become more central to everyday life and national competitiveness, improving broadband access is not only a technological priority but also a strategic imperative [16].

By identifying practical pathways to improve fibre optic network deployment and utilization, this research aims to support more inclusive and sustainable broadband development in Nigeria, with implications for other emerging economies facing similar infrastructure and policy challenges.

IV. METHODOLOGY

This study takes a practical and well-rounded approach by combining data analysis with insights from the telecommunications industry. It relies on recent and credible data from sources such as the International Telecommunication Union (ITU), the Nigerian Communications Commission (NCC), the World Bank, and other industry reports. These sources provide useful information on broadband access, submarine cable development, fibre optic deployment, international bandwidth, pricing, and service quality.

To better reflect what is happening on the ground, the study also draws on publicly available information from telecom operators and infrastructure providers. These insights help explain not just the numbers, but the real challenges companies face when expanding broadband networks across Nigeria.

The analysis focuses on identifying trends and gaps in Nigeria's broadband development. It looks at how broadband penetration, data usage, and network coverage have changed over time, and compares Nigeria's progress with that of other countries. Special attention is given to how fibre optic infrastructure is distributed, including submarine cable landing points and inland network connections.

Based on these findings, the study proposes a practical and conscious network design approach aimed at improving connectivity across the country. The goal is to make better use of existing infrastructure, expand access to underserved areas, and build a more reliable and efficient broadband network.

Overall, the methodology is designed to balance data with real world context, ensuring that the study's conclusions are both grounded in evidence and relevant to Nigeria's current broadband challenges.

As of 2025, Nigeria is connected to seven international submarine fibre optic cables that link the country directly to the global internet. These cables carry huge amounts of data running into terabits per second and have helped position the country as an important connectivity hub in West Africa. Some of these submarine cables have been in place for years, while others are more recent additions. Most of these cables come ashore along the coastline and act as the main entry points for international internet traffic into the country.

The table below gives an overview of the major submarine fibre optic cable systems currently landed in Nigeria with their respective bandwidth capacities in supporting the country's international connectivity.

S/N	Cable Name	Year in Operation	Cable Length (Km)	Capacity (Tbps)	Operators in Nigeria
1	SAT-3	Apr-02	14,350	0.8	NATCOM
2	MainOne	Jul-10	7,000	10	MainOne
3	Glo-1	Oct-10	9,800	2.5	Globacom
4	WACS	May-12	14,530	14.5	MTN
5	ACE	Dec-12	17,000	5.12	Dolphin Telecoms
6	Equiano	Apr-22	17,800	144	Google
7	2 Africa	Feb-24	45,000	180	Bayobab
			-	-	MainOne
	Total		**125,480**	**356.92**	

Table 1 Submarine Cable Operators in Nigeria [2][5][6].

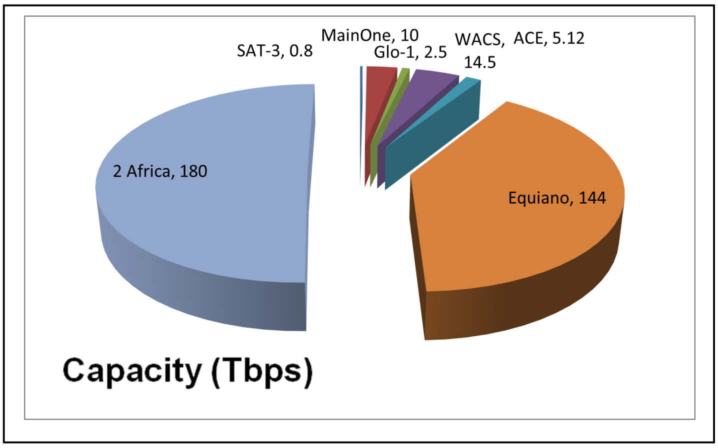

Fig 1 Submarine Cable Operators in Nigeria [2][5][6].

V. COST OF LANDING SUBMARINE CABLES IN NIGERIA

Submarine fibre optic cables are built to last. Most are designed to operate for around 20 to 25 years, although they can often be upgraded along the way to carry more data and stay relevant as technology evolves [17]. Building them, however, is no small task they require huge financial

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commitments, with each cable typically costing hundreds of millions of dollars depending on how far it runs and how much capacity it is designed to handle [8].

In Nigeria, the total amount invested in submarine cables over the years runs into several billions of US dollars. This reflects strong interest from both local and international players who see the country as a key gateway for internet connectivity in West Africa [7][18]. Newer cables have continued to add even more capacity, driven by the rapid rise in internet use, cloud services, streaming, and digital businesses across the region.

Even with all this investment, the benefits are not yet fully felt by many users. The issue is less about how much international bandwidth is available and more about how well it is distributed across the country. Gaps in inland fibre networks and other infrastructure challenges make it difficult to deliver this capacity where it is needed most [20].

The table below highlights the estimated investments made in the major submarine cable systems landing in Nigeria, showing the scale of effort required to build this critical infrastructure.

S/N	Cable Name	Cost (000,000$)	Operators in Nigeria
1	SAT-3	600	NATCOM
2	MainOne	240	MainOne
3	Glo-1	800	Globacom
4	WACS	650	MTN
5	ACE	700	Dolphin Telecoms
6	Equiano	1,000	Google
7	2 Africa	1,000	Bayobab
			MainOne
	Total	**4,990**	

Table 2 Submarine Cable Landing Cost [2][5][7].

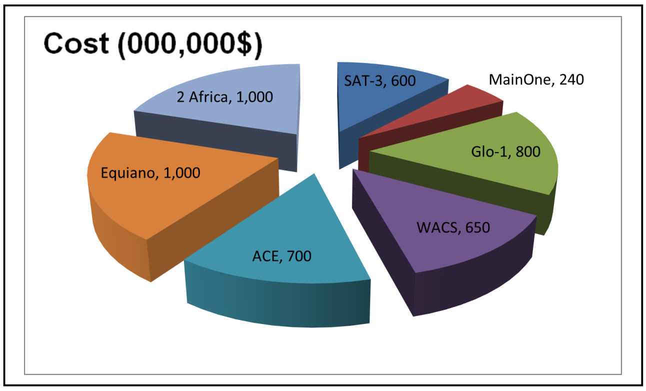

Fig 2 Submarine Cable Landing Cost [2][5][7].

VI. TERRESTRIAL FIBRE DEPLOYMENT

Nigeria has made real progress in expanding its terrestrial fibre optic network over the past decade [1]. By 2023, telecom operators and infrastructure providers had rolled out more than 78,676 kilometres of fibre, according to the Nigerian Communications Commission (NCC). Since then, that number has continued to rise as both government efforts and private investments push connectivity into more parts of the country, including areas that were previously underserved [6][11][14].

This growth is part of a wider push to build a stronger digital foundation for the country. Programmes under the National Broadband Plan, along with increasing demand for fast and reliable internet driven by activities like edutech, streaming, remote work, fintech, and everyday mobile data use have all played a significant role [12][13]. Private companies in particular have been investing heavily in expanding fibre networks across cities and between major regions.

However, there is still a long way to go. Large parts of the country, especially rural and hard-to reach areas, remain poorly connected. For many people, internet access is still slow, expensive, or simply unavailable. So, while the progress so far is encouraging, scaling up fibre deployment and making sure it reaches end users remains a key challenge for Nigeria's broadband future [2][19].

S/N	Operator	Terrestrial Cables (Km)	Submarine Cables (Km)
1	MTN	14,612	17,984
2	AIRTEL	16,112	23
3	GLO	13,000	9,800
4	9MOBILE	4,650	0
5	PHASE 3 TELECOM	6,000	0
6	MAIN ONE / EQUIANO	1,200	15,000
7	IPNX	2,000	0
8	21st Century	8,000	43
9	Others (States / Private)	13,800	0
	Total	**79,374**	**29,350**

Table 3 Terrestrial Fibre Optic Deployment in Nigeria [1][6].

VII. PROPOSED LANDING POINTS FOR SUBMARINE CABLES

Several potential landing points have been identified along Nigeria's coastline to help spread out and strengthen the country's submarine cable network. These include

- Bonny (Rivers State)
- Eket (Akwa Ibom State)
- Escravos (Delta State)
- Calabar (Cross River State)
- Ilaje (Ondo State)
- Gbaran (Bayelsa State)

These areas are not just well positioned geographically they are also close to major industrial and energy hubs like NLNG,

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ExxonMobil, Chevron, and Shell, where there is already strong demand for reliable, high-capacity connectivity.

Nigeria's coastline runs across seven states: Lagos, Ondo, Delta, Bayelsa, Rivers, Akwa Ibom, and Cross River and all of them have the potential to host submarine cable landing points [15]. But in reality, most of the existing infrastructure is concentrated in just a few locations. Lagos, in particular, handles the bulk of international internet traffic, with Akwa Ibom also playing an important role.

Even though newer submarine cables have significantly increased Nigeria's total international bandwidth now well above 300 Tbps not all of this capacity is being fully used. A big part of the problem is that there are too few landing points, and they are not spread out enough. This makes it harder to move bandwidth efficiently across the country and also leaves the network less resilient.

Expanding cable landings to more coastal states could make a real difference. It would help reduce pressure on existing hubs, improve reliability, and bring faster connectivity closer to more regions. In simple terms, by spreading things out more, Nigeria can make better use of what it already has and builds a stronger, more balanced broadband network for the future.

S/N	Landing Points	State	Influence
1	Bonny	Rivers	NLNG
2	Eket	Akwa Ibom	ExxonMobil
3	Escravos	Delta	Chevron
4	Calabar	Cross Rivers	Intels
5	Ilaje	Ondo	Chevron
6	Gbaran	Bayelsa	Shell

Table 4 Proposed Landing Points.

VIII. DESIGN METHODOLOGY

This study proposes a phased and practical network design that takes into account Nigeria's coastal geography and the current limitations of its broadband infrastructure. Rather than treating the network as a single centralized system, the approach gradually builds multiple interconnected hubs across different parts of the coastline.

In the first phase, the focus is on four key landing points: Eket, Ilaje, Bonny, and the already established hub in Lagos. These locations were selected because of their strategic coastal positions and their ability to serve nearby states efficiently based on distance and existing patterns of demand. Surrounding states that fall within reasonable transmission range are included in this phase, allowing the network to begin expanding outward in a structured way. Over time, each of these landing points is expected to develop into a regional hub, gradually extending fibre connectivity deeper inland and improving access for more communities.

The second phase builds on this initial structure by adding Escravos, Calabar, and Gbaran, while still maintaining Lagos as a central interconnection point. As with the first phase, nearby states are linked based on practical distance and feasibility, creating additional clusters of connectivity that mirror real-world demand and geography. These new sites are also expected to evolve into strong regional hubs, further strengthening coverage and reducing pressure on existing infrastructure.

Taken together, this staged approach moves Nigeria away from a highly concentrated network model toward a more balanced and resilient system. By spreading landing points more evenly along the coast and aligning them with nearby demand centres, the design makes better use of existing capacity, reduces congestion, and provides a more realistic pathway for expanding reliable broadband access across the country.

IX. DESIGN APPROACH 1

Landing Stations	Lagos	Eket	Ilaje	Bonny
Proposed Sites	Abeokuta	Calabar	Ado-Ekiti	Warri
	Ibadan	Abakaliki	Lokoja	Owerri
	Ilorin	Makurdi	Benin	Aba
			Osogbo	Yenegoa
				Abuja
				Enugu

Table 5 Landing Stations and Proposed Sites Design 1.

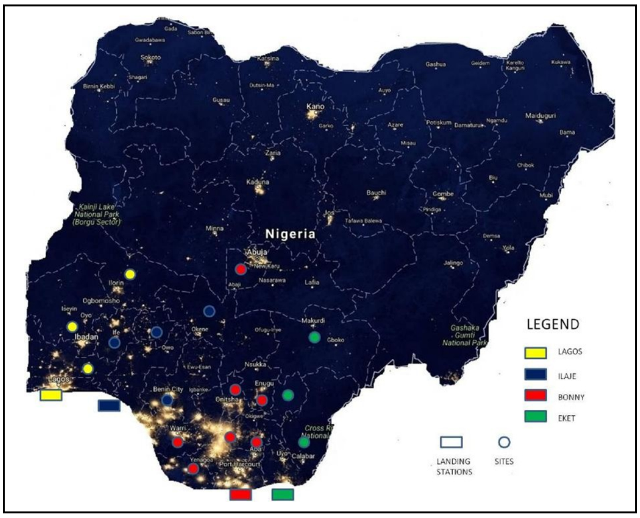

Fig 3 Landing Stations and Proposed Sites Design 1.

X. DESIGN APPROACH 2

In the second stage of the proposed design, attention shifts to the remaining coastal landing locations Escravos, Calabar, and Gbaran alongside the already established hub in Lagos. These sites matter because they help extend connectivity further along Nigeria's coastline and open up more practical routes for improving how broadband capacity is distributed across the country.

To make the design workable in real terms, nearby states and cities are grouped around each landing point based on how

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close they are and how easily they can be connected through fibre links. This creates natural clusters, where each landing site acts as a starting point for spreading connectivity inland. Over time, these points are expected to grow beyond simple landing stations and develop into full regional hubs, supporting both long distance backbone traffic and everyday local internet access.

When this phase is combined with the earlier parts of the design, the overall picture becomes clearer: a shift away from heavy dependence on a single major hub especially Lagos towards a more balanced system with multiple entry points along the coast. This kind of structure helps spread traffic more evenly, reduces pressure on existing infrastructure, and makes the network more reliable when disruptions occur.

More importantly, by matching infrastructure planning with real geography and actual demand patterns, the approach offers a more realistic way to expand broadband access. It also creates a flexible foundation that can grow over time, especially as internet usage increases and new submarine cables continue to land along Nigeria's coastline.

Landing Stations	**Lagos**	**Escravos**	**Calabar**	**Gbaran**
Proposed Sites	Abeokuta	Benin	Uyo	Port Harcourt
	Ibadan	Awka	Makurdi	Owerri
	Ilorin	Akure	Abakaliki	Aba
	Osogbo	Enugu		
	Ado Ekiti	Abuja		

Table 6 Landing Stations and Proposed Sites Design 2.

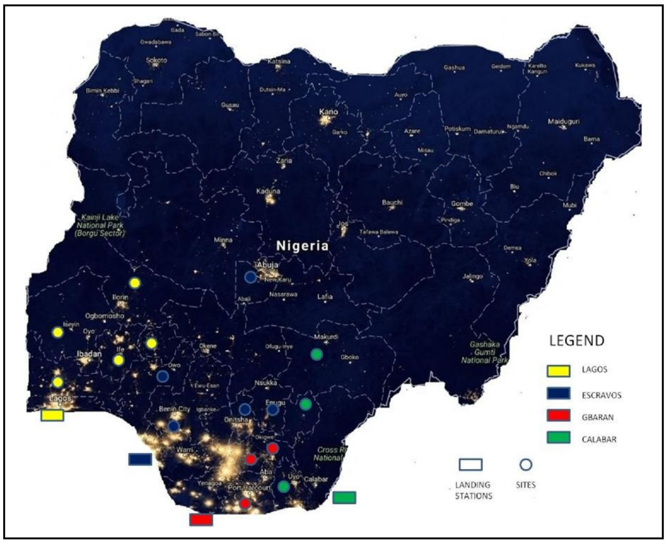

Fig 4 Landing Stations and Proposed Sites Design 2.

The proposed design may not provide fibre optic network coverage for the country all at once in the short run but slowly the whole country will be covered, the proposed sites placed at strategic positions will serve as a hub for the growth of other regions of the country.

XI. KEY FINDINGS AND DISCUSSION

Even though Nigeria now has a large amount of international bandwidth running into hundreds of terabits per second the country still struggles with a basic problem: most of this capacity enters through just one main location. This creates a bottleneck that affects how broadband is delivered across the country, and it remains a central issue in this study.

XII. RESULTS

The findings show that, in practice, most submarine cable systems serving Nigeria have traditionally landed and interconnected in Lagos. Over time, this has made Lagos the natural centre of the country's internet infrastructure. While this has helped build scale, it has also meant that fibre deployment and network expansion have been heavily concentrated around one city, leaving many other regions less connected and less integrated into the national broadband system.

There have been some positive changes in recent years. Newer cable systems have introduced additional landing points outside Lagos, especially in Akwa Ibom, which has started to slowly spread international connectivity to other parts of the coast. However, Lagos still carries the bulk of international traffic and remains the main exchange point for most networks. This continued concentration puts pressure on existing infrastructure and limits how evenly broadband capacity can be distributed across the country.

To help address this, the study looks at other coastal locations that could realistically support submarine cable landings. These are not chosen randomly, they are places that are geographically suitable and capable of handling large-scale infrastructure if properly developed. The goal is to move away from a single-entry system and gradually build a network where multiple coastal points share the responsibility of bringing connectivity into the country.

The study also highlights an important practical point, landing stations alone are not enough. For these new sites to work effectively, they need strong local demand to support early growth. That is why the analysis also considers nearby industrial areas, oil and gas facilities, multinational companies, and emerging commercial centres. These "anchor users" can help generate immediate demand and make new landing points economically viable from the start.

By linking new infrastructure to real economic activity, the proposed approach becomes more than just a technical redesign. It creates a pathway for sustainable growth, one where infrastructure expansion and real world demand support each other. In the long run, this can help Nigeria move towards a more balanced, resilient, and scalable broadband ecosystem that serves the entire country more evenly.

XIII. CONCLUSION

Broadband has quietly become one of those things people now depend on every day, just like electricity or running water. It affects how we work, how students learn, how businesses operate, and even how people access basic services like banking and healthcare. As more of life moves online, having reliable internet is no longer optional it has become a core part of national development.

This study points to a simple but important idea: where submarine fibre optic cables land matters a lot. In Nigeria's case, expanding the number of landing points along the coastline could make a real difference in how broadband spreads across the country. Right now, because most of these landing points are concentrated in only a few locations, it creates a kind of bottleneck. Even though there is a lot of international bandwidth available, getting that capacity out to smaller towns and rural areas is still difficult.

If landing stations are spread out more evenly along the coast, it becomes easier to push fibre networks deeper into the country. This would help reduce pressure on existing hubs, make the network more stable, and lower the cost and difficulty of building new connections in underserved areas. In simple terms, it helps bring the internet closer to the people who currently have the least access to it.

The benefits go beyond just better connectivity. When internet access improves, local economies tend to follow. Small businesses can reach wider markets, new digital services can grow, and sectors like fintech, edutech, and remote work become more realistic options in places that were previously left behind. This direction also fits with Nigeria's National Broadband Plan, which focuses on making internet access more widespread, affordable, and reliable.

At its core, this is not just about cables and infrastructure. It is about creating a system where more people can participate meaningfully in the digital economy, no matter where they live.

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