



## The influence of fibre optic link availability on network densification and broadband quality of experience in Nigeria

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### General Note



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### ABSTRACT

The exponential growth of internet traffic added to the rising demand for high bandwidth consuming services and applications all over the world has triggered an increasing need for higher capacity in core optical communication networks. This has broadened the scenery for fibre broadband utilization and subsequent requirements for deployment of more fibre optic infrastructures across network edges to satisfy the extensive global appetite for broadband access and high-speed data. In an effort to accommodate the needs of future connected world, improve geographic coverage and address-changing consumer demands, network service

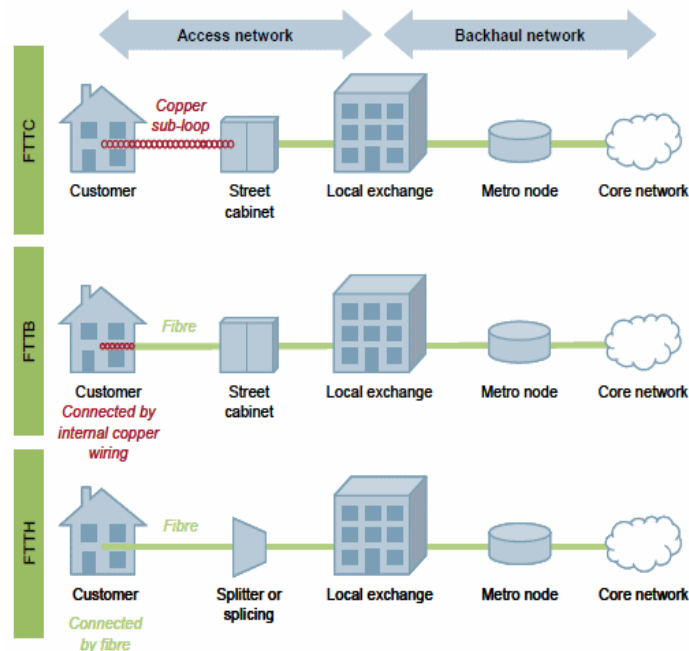
providers are embarking on intense drive to densify and add more capacity to their networks. In this paper, we propose fibre optic links availability across the elements of broadband supply chain as the pathway for network densification and ubiquitous broadband Quality of Experience (QoE) in Nigeria.

**Keywords:** Network densification, Quality of Experience, Availability, Blast Radius, Fibre broadband utilization, backhaul.

## 1. INTRODUCTION

Among broadband access technologies such Digital Subscriber Line (DSL), Cable Modems and more recently Fibre-to-the-X (where X represents the facility of deployment), fibre optic technology provides telecommunication's industry with high capacity, technology robust and low latency solutions for national backbone, metro and access networks. Figure 1 show different FTTx architectures.

Fibre optic deployment is also cost effective to ensure return on investment and carrier profitability compared to the satellite alternative. Consequently, there has been a concerted effort by government and network service providers in their countries of operation to ensure that today's telecommunication transports are predominantly covered by fibre optic infrastructures. On this light, the Nigerian Communications Commission (NCC) had licensed six infrastructure companies (Infracore) for the deployment of broadband fibre across the 774 Local Government Areas of the country. These companies were licensed to deploy services covering all the geo-political zones of the country [1].



**Figure 1** FTTx architectures [2]

In an effort to promote nationwide broadband deployment, uplift broadband endorsement, and ensure availability of broadband services at affordable rates to the citizenry, the Nigerian government inaugurated a presidential committee on national broadband strategy and roadmap in September 2012. The body came out with a five-year strategic roadmap for the Nigerian National Broadband Plan, NNBP, (2013-2018) with a target to increase broadband penetration in Nigeria from then six percent in 2013, to 30% in 2018 [3], which further exemplified how the country would achieve the goals of its National ICT Policy. The ICT policy was earlier formulated to focus on the development of National ICT backbone and Broadband infrastructures that will foster digital literacy and Internet usage; affordable Universal Access to ICT; and national physical infrastructure in the country [4].

To this end, the NCC in 2013 launched an Open Access Next Generation Broadband Network, (NGBN) as one of the critical strategies required to deliver the targets of National Broadband Plan. The Open Access NGBN introduced the Infrastructure

Company (Infracore) model to address existing gaps in the deployment of metropolitan fibre across the country. The objectives of the Open Access NGBN were geared to stimulate:

1. Nationwide Fibre Penetration: Extend backbone fibre infrastructure into metropolitan areas and achieve the National Broadband Plan's target of covered 50% of the population.
2. Coordinated Fibre Deployment: Make available the new network infrastructure, services to all on a fair and non-discriminatory basis, and build a foundation to facilitate fair and effective competition.
3. Improved data Speed: Utilise the advantages of optic cable as a transmission medium to achieve a minimum broadband speed of 1.5Mbps.
4. Investment in Broadband Infrastructure: Offer financial incentives to stimulate increased rollout of broadband infrastructure by private sector, similar to strategies deployed in other jurisdictions.

At the end of five-year period of NNBP, the Commission in [5], informed of empirical data to show a connection of 60,087,199 subscribers to Broadband Networks out of 108,457,051 internet subscribers in the nation's telecom landscape, thus taking the country's broadband penetration depth to 31.48% as at December, 2018. It calculated broadband penetration as a percentage of the number of data or internet subscribers on broadband networks (3G & 4G) against the country's estimated population figure of 190,886,311 (using United Nation's projection as of December 2017). The Commission listed further broadband successes to include auction of six slots of 2x5MHz in the 2.6 GHz Band, re-planning of the 800 MHz band for LTE, licensing of two slots of 10 MHz each in the 700 MHz band, and opening up of the E-band spectrum and 70/80 GHz band for both last mile and backhaul services.

Conversely, the Commission also enumerated major challenges of NNBP to include inadequate metro fibre infrastructure in several towns and cities to effectively distribute the huge bandwidth from international submarine cables at the landing points in Lagos to other locations in the country. Other impediments mentioned include; exorbitant charges for Right of Way (RoW) by state and local authorities in the country, multiple taxation and delays in obtaining site acquisition permits. It pointed out that Nigeria needs more than 120,000 kilometres of metropolitan fibre networks interconnected across the country to achieve its goal of widespread broadband penetration as against 38,000 kilometres presently covered [6].

It follows from the foregoing that despite Nigeria having:

- six active submarine cable systems landed in the country, with substantive international connectivity and numerous network service providers,
- six Infrastructure Companies (Infracores) licensed for the deployment of metropolitan fibre across the country,
- a policy framework in place for actualization of the lofty goals of ICT 2012 policy, and
- the Nigerian National Broadband Plan,

It is alarming that only 31.7% of targeted 50% metropolitan fibre infrastructure was achieved in the country at the end of five-year period of the national broadband plan. It is against this background that the influence of fibre optic link availability on network densification and broadband QoE in Nigeria is thus examined. Moreover, related work on fibre optic infrastructures in the country has not quantified the impact of fibre link disruptions or outages on broadband access and QoE.

## 2. AVAILABILITY MODEL

We consider a fibre link provisioning as a simple series system using a reliability block diagram, RBD, in Figure 2. In this model, the availability of the system is formulated relative to the availability of the various components that make up the system. By using a bottom-up approach, the availability at the component-level is determined using operational measures like mean time before failure, MTBF and mean time to repair, MTTR.



**Figure 2** Fibre Link Provisioning

The rational connection relating the individual components is considered in estimating the system-level availability, and is represented graphically using RBD. We consider a fibre link provisioning system denoted by FLP that consists of a set of subsystems

$$F = \{F_i, i = 1, 2, 3\}, \quad (1)$$

In which the success of the system is an amalgam of every subsystem  $F_i$ . Given the serial configuration as shown in Figure 2, [7] express the availability of  $A_{FLP}$  such that

$$A_{FLP} = \prod_{i=1}^3 A_i, \quad (2)$$

where  $A_i$  is the availability of subsystem  $i$ .

Noting that each subsystem  $F_i$  consists of a universal set of components  $F_i = \{F_{i,j}, i = 1, 2, 3, j = 1, \dots, n_i\}$ , where  $F_{i,j}$  signifies the  $j^{th}$  component of the  $i^{th}$  subsystem, and  $n_i$  connotes the total number of components in the subsystem  $i$ . By assuming that the success of each subsystem is contingent on the success of every individual component  $F_{i,j}$ , then availability of subsystem  $F_i$  denoted by  $A_i$  is hence,

$$A_i = \prod_{j=1}^{n_i} A_{i,j}. \quad (3)$$

Availability is the probability of a system or component being able to provide the service by which it is expected as defined under the service level agreement at a specific instant of time [8]. It is expressed as [9]:

$$\text{Availability} = \frac{\text{Uptime}}{\text{Uptime} + \text{Downtime}} \quad (4)$$

Where, Uptime refer to efficacy to perform the task and Downtime refer to inability to perform the task. The values of Uptime and Downtime used in calculating availability is evaluated through actual field measurements from outage trouble tickets on the network or by service probes embedded in network monitoring system. Practical network performance monitoring calculates availability based on service downtime in addition to the total time by which the link was expected to be operational or in service. Therefore, equation (4) becomes,

$$\text{Availability} = \frac{\text{Total Time In Service} - \text{Downtime}}{\text{Total Time In Service}} \quad (5)$$

Total Time in Service is the sum of uptime over a reporting period that the links in consideration are expected to be operational, while Downtime is the duration by which the link is unavailable. It is apportioned by the percentage of capacity or performances indices impacted during the outage. Information and Technology Infrastructure Library, ITIL, gives a modification of Equation (5) for evaluating Availability,  $A$ , such that [9]:

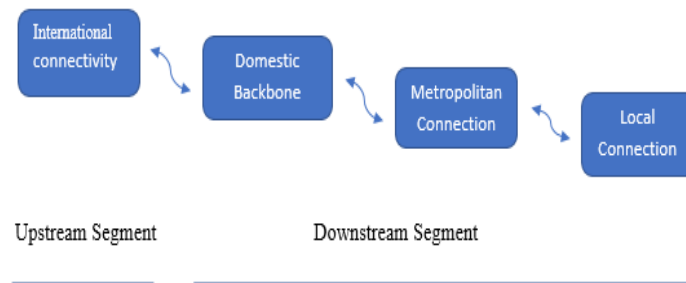
$$A (\%) = \frac{\text{Total Time In Service} - \text{Downtime}}{\text{Total Time In Service}} \times 100\% \quad (6)$$

### 3. METHODOLOGY

This study used Blast Radius methodology or impact analysis method to investigate the consequences of fibre link disruptions or outages by Availability Evaluation of optic fibre infrastructures across the elements of broadband supply chain. The leading benchmark for optimal availability in a network system is to monitor and investigate outages and analyse the relationship or interactions of different elements on the network with a view to point out integrated failures and resolve them within defined service level agreements (SLA). The size of the failure domain is known as Blast Radius. Therefore, at the instance a specific network service or component is disrupted, the dependencies that includes, customers, users and other ancillary services affected by it, falls into

Blast Radius. This concept is utilized in ICT or network systems to describe a domino effect or chain reaction of events occasioned by an incident, impairment or perturbation on the network.

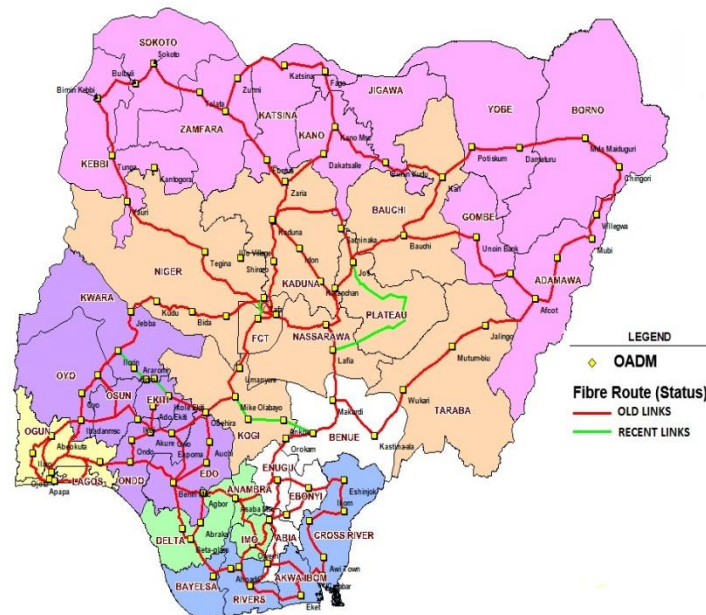
In this study, we grouped the elements of broadband supply chain into the upstream and downstream segments where International connectivity is the upstream and the terrestrial elements of national backbone, metropolitan and local connection make up the downstream segment as illustrated in Figure 3.



**Figure 3** Upstream and downstream segment of Broadband Supply Chain.

To this end, we choose a multi-service provider with footprints at both the upstream and downstream segments for end-to-end analytics. For the upstream segment of broadband supply chain, the West African Cable System (WACS) – high capacity submarine cable system - is used as a case study to analyse the impact of traffic affecting outages leading to Availability Evaluation. Service or traffic affecting impacts was acquired through Principal Component Analysis (PCA) of both the wet and dry plant in the submarine network by logging on to the network management service (NMS) probes at submarine terminal station. By this method, overall system outages in the dry and wet segments that impinge on traffic within WACS submarine network was characterized, analysed and evaluated to produce the overall System's Availability within the period under investigation.

For the downstream segment, the terrestrial fibre network of same multi-service operator is used to analyse the impact of traffic affecting outages, thus leading to availability profiling. Figure 4 is the terrestrial backbone fibre network of the service provider in Nigeria.

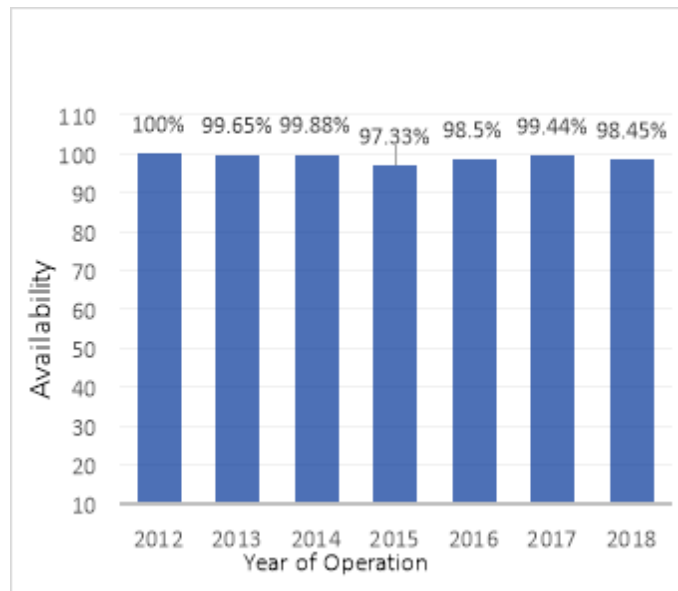


**Figure 4** Terrestrial fibre network of a Service Provider in Nigeria.

From network monitoring system, the NMS is accessed to open the optical node in browsing historical alarms on the terrestrial topology. The alarms relative to link outages appear as optical supervisory channel loss of signal (OSC\_LOS). This was sorted on daily basis for the entire network and analysed to determine percentage availability profile of the fibre links on the downstream, within the period under research.

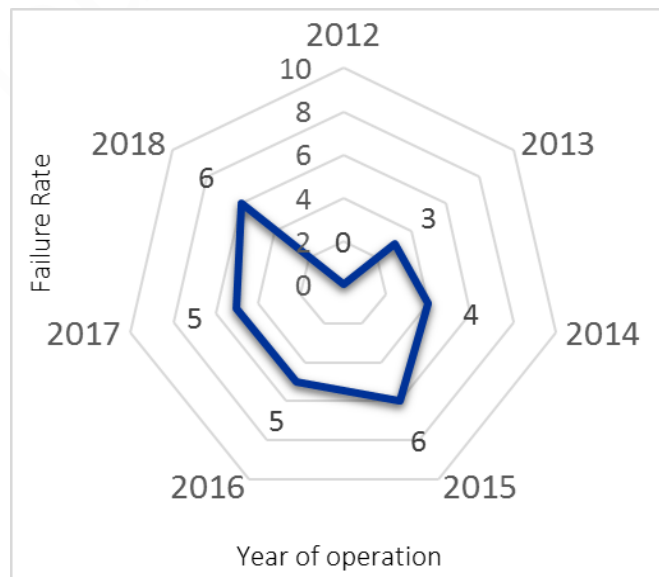
#### 4. RESULTS AND DISCUSSION

The availability of the upstream segment was calculated with the data acquired in the course of study to obtain 99.04%. Figure 5 show a bar chart representation of percentage availability against years of operation for the submarine system used as a case study.



**Figure 5** Upstream availability profile

Using a statistical/quantitative analysis of the system's availability profile, we deduce from the bar chart in Figure 5 that the availability of the system is 99.04%. Though this is about 0.959% less than specified availability benchmark for submarine systems, it is within service level agreement, if force majeure and human induced failures are taken out from the analysis. The mean time between failures (MTBF) for the system was calculated using the radar plot in Figure 6 to obtain 2114.5 hours.



**Figure 6** Determining reliability profile

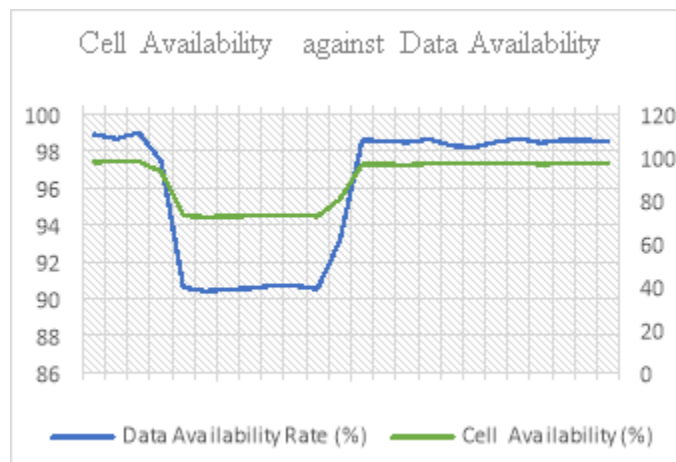
This represents a fidelity index of 88.10 days before any experience of disruption within the period under research and highlights the reliability measure of submarine segment of transmission path to support IP traffic for widespread broadband access.

On the downstream segment, the end user connects readily through a mobile device unto the network of choice. Subsequently, the cell data: before, during and after a fibre outage relative to the base station affected by the outage provides a substantive result on the effect of fibre link disruption on network densification and customer broadband access and experience of the network. Therefore, by considering specific incidents of terrestrial fibre failures using life network data, the impact on Cell Availability occasioned by fibre outages at different locations in the country was sampled. Results show that network data performance indices tabulated below falls and rise with cell availability (fibre link outage and restoration). Table 1 is the impact caused by a fibre cut at 39km from NSITF, Kano – a high population dense city in Nigeria.

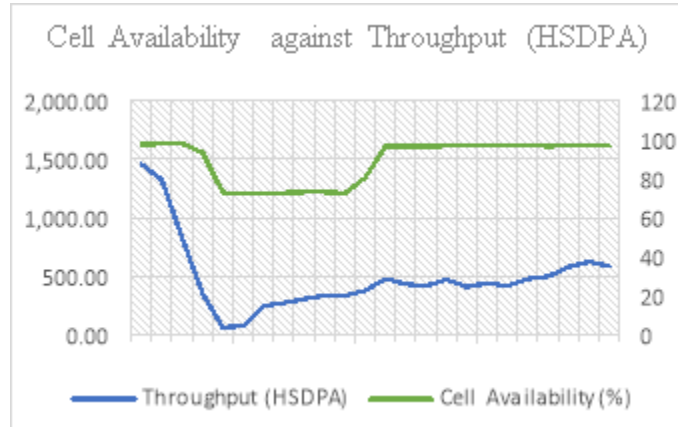
**Table 1** Impact on Cell and Data Rate Availability, Kano

Time	3G RNC	3G Availability Rate (Cell)(%)	Data Availability Rate(%)	3G Data Traffic	Throughput (HSDPA) (Mbps)	Throughput (HSUPA) (Mbps)
2017-09-18 00:00:00	KNHRNC4	97.69	98.90	330,968	1,456.92	123.95
2017-09-18 01:00:00	KNHRNC4	97.87	98.96	292,748	1,322.38	95.38
2017-09-18 02:00:00	KNHRNC4	98.01	99.00	177,441	825.20	60.45
2017-09-18 03:00:00	KNHRNC4	93.38	97.46	80,191	351.56	29.52
2017-09-18 04:00:00	KNHRNC4	72.81	90.60	16,530	59.09	11.01
2017-09-18 05:00:00	KNHRNC4	72.22	90.41	16,053	75.03	15.74
2017-09-18 06:00:00	KNHRNC4	72.48	90.50	50,489	244.01	37.16
2017-09-18 07:00:00	KNHRNC4	72.68	90.56	58,267	270.17	43.68
2017-09-18 08:00:00	KNHRNC4	73.13	90.71	66,442	303.99	52.31
2017-09-18 09:00:00	KNHRNC4	73.09	90.70	75,067	333.00	58.99
2017-09-18 10:00:00	KNHRNC4	72.57	90.52	79,310	332.68	59.37
2017-09-18 11:00:00	KNHRNC4	80.44	93.15	89,293	374.10	74.23
2017-09-18 12:00:00	KNHRNC4	96.77	98.58	124,529	477.30	86.84
2017-09-18 13:00:00	KNHRNC4	96.66	98.55	108,664	430.74	80.54
2017-09-18 14:00:00	KNHRNC4	96.42	98.47	106,599	415.61	76.73
2017-09-18 15:00:00	KNHRNC4	96.94	98.64	113,169	468.96	80.86
2017-09-18 16:00:00	KNHRNC4	97.17	98.29	100,254	407.90	75.99
2017-09-18 17:00:00	KNHRNC4	96.84	98.20	105,849	438.77	78.13
2017-09-18 18:00:00	KNHRNC4	97.16	98.49	103,752	414.98	74.01
2017-09-18 19:00:00	KNHRNC4	97.34	98.67	115,018	475.29	84.80
2017-09-18 20:00:00	KNHRNC4	96.68	98.45	126,299	497.78	83.93
2017-09-18 21:00:00	KNHRNC4	97.13	98.60	147,071	577.01	95.38
2017-09-18 22:00:00	KNHRNC4	97.07	98.58	154,463	623.06	97.29
2017-09-18 23:00:00	KNHRNC4	96.84	98.52	140,293	586.03	85.97

The exposition in Table 1 is illustrated in Figure 7, 8, 9 and 10 showing that Data Availability, Data Traffic, High Speed Downlink Packet Access (HSDPA) and High Speed Uplink Packet Access (HSUPA) all drop with a drop in Cell Availability occasioned by a fibre link outage and picks up when the link is restored.



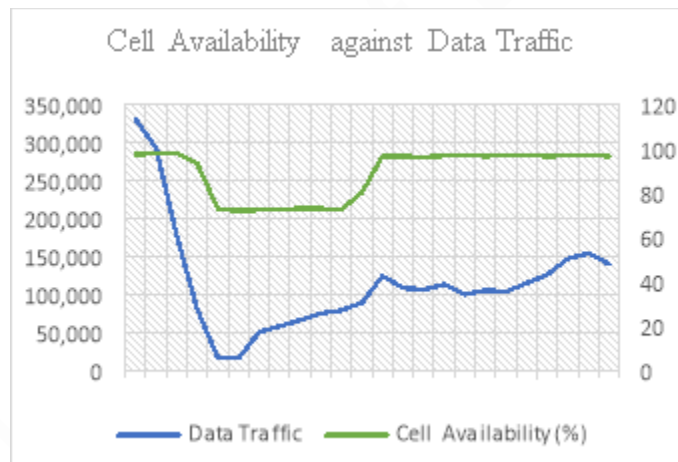
**Figure 7** Dependence of Data Availability on Fibre Link Availability.



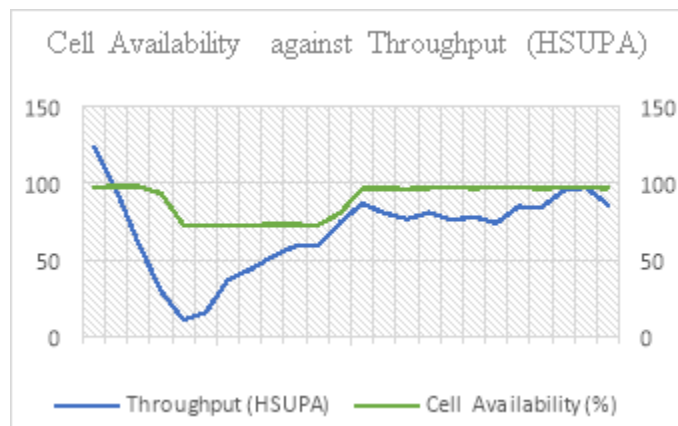
**Figure 8** Dependence of HSDPA on Fibre Link Availability.

A drop in HSDPA transcends to less capacity, high transmission time interval, increase in latency and round trip time, for end user applications. Conversely, an increase in HSDPA leads to an increase in cell capacity, which is the baseline aim in radio densification. The increase in round trip time and latency increases the cost per bit and diminishes support for high performance data applications, thus introducing buffering in applications like VoIP, video streaming and delays in delivering of e-mail messages.

With incessant fibre link outages on the terrestrial backhaul in Nigeria and its impact on network availability as illustrated in this study, it is clear that the downstream segment of broadband supply chain in the country is largely unstable for network densification, widespread broadband access and end user QoE.



**Figure 9** Dependence of Data Traffic on Fibre Link Availability.



**Figure 10** Dependence of HSUPA on Fibre Link Availability.



## 5. CONCLUSION

Deep fibre is a vital element in achieving national infrastructure imperative of the Nigerian national broadband plan to provide consumers with ubiquitous high-speed broadband connections, thus transforming the country into a knowledge-based economy. It is expedient as such, to extend optic fibre as close as possible to network end-points or edges in order to meet this expectation. This portends universality of optic fibre infrastructures across the access network for optimal end-user Quality of Experience.

However, what is not available cannot be universal. Therefore, fibre optic links availability across the elements of broadband supply chain must be ensured as the pathway for network densification and ubiquitous broadband Quality of Experience (QoE) in Nigeria.

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**Conflicts of Interest:** The authors declare no conflict of interest.

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