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EVALUATING CAPACITY UTILIZATION IN SUBMARINE OPTIC FIBRE COMMUNICATION SYSTEMS

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ABSTRACT

The advent of submarine optical fibre cable established the most effective medium of communication in terms of data carriage capacity, immunity to interference, low drop calls amongst many others. In the light of these outstanding breakthrough, developing economies are yet to maximize the utilization of the wealth of data deposit at their landing stations. The utilization of submarine optic fibre capacity and broadband access in a developing economy was investigated using the West African Cable System (WACS) and its Lekki Cable Landing Station in Nigeria as a case study. The broadband ecosystem model is employed to determine capacity utilization from Lekki Cable Landing Station. At the International connectivity level, a nodal, port utilization analysis and backhaul provider profile was used to provide measurement criteria for submarine system capacity utilization. Capacity utilization of submarine optic fibre communications route is calculated in Minimum Assignable Units (MAU) of activated capacity in STM-1 (Synchronous Transport Module level-1) by distance of navigation. The International connectivity segment of broadband supply chain was calculated and found to be optimally available at 99.13% for broadband access and end user experience. The terrestrial backhaul suffers from poor availability occasioned by the fluctuating state of the terrestrial fibre infrastructure in Nigeria, thereby impeding broadband penetration in the country.

Keywords: ***Optical Fibre, Submarine, Broadband, Utilization, Landing Station, Minimum Assignable Units (MAU).***

1.0 INTRODUCTION

The exponential growth of internet traffic juxtaposed with the rising demand for high bandwidth consuming services and applications like; high definition video, cloud storage, video streaming services, interactive gaming and the deployment of Web Real-Time Communication (WebRTC) technology to deliver richer forms of Unified Communication Services to more connected users across nations of the world has triggered an increasing need for higher capacity in core optical communication networks. This, in turn, has led to a broadening landscape for fibre broadband utilization and subsequent boom in the deployment of submarine fibre optic communication cables around the world, in an effort to satisfy the burgeoning global appetite for broadband access and high speed data.

Unlike developed economies of Europe and North America where enterprise data markets are nearing saturation, Africa was left behind in the earlier rush for submarine fibre optic connectivity around the world and was farther back of other continents relative to information technology and the essential bandwidth availability. For instance, prior to 2009, only 16 African countries were connected to a submarine cable system (Miller, 2017). The West African sub-region on its part was served by a single old generation submarine fibre optic communications cable called South Atlantic 3 (SAT-3) (Forden, 2015). During this period, Satellite services with its myriad of problems and high cost were the only other source of international telecommunications connectivity in sub-Saharan Africa which buttressed why the region accounted for only 0.2 percent of global telecommunications bandwidth during the 2004-2009 eras (Miller, 2017). However, within the same period also, there was tremendous growth in mobile communications across the African continent as a whole, which spurred further demand for telecommunication services against the backdrop of providing increased communications access as a potential catalyst in opening up sustainable economic and social development.

2.0 MATERIALS AND METHODS

In any field of human endeavour, if we cannot measure what we do, then it becomes difficult to improve upon it, optimise or upgrade it and hence, evolve a better or more economic ways of discharging business objectives.

In this work, the West African Cable System (WACS) was chosen as a case study to determine the utilization of allocated capacity at Lekki Cable Landing Station, Nigeria. To achieve this, an analytical method was adopted through the node, the port and backhaul service provider platform, in the investigation. The Services so obtained from WACS submarine cable by a Network Service Provider was followed up on the Internet Protocol Transit to appraise its availability or percentage downtime.

By collating field data on terrestrial fibre failures from the same network for a period of five years, an analysis was made of the terrestrial fibre infrastructure in the distribution and delivery of access links in the network. The availability of these links, together with 3G cells connected to it was evaluated and compared with the fidelity of international connectivity segment, towards ubiquitous broadband access and end user experience.

Node Element Method

To optimize its network and business models in the new age of digital and communications economy, network and communication service providers incorporate special features and key performance indices which serve as benchmarks to monitor and manage their networks. The International Telecommunications Union, ITU, defined five levels of management for Telecommunications Management Network, TMN, as illustrated in Figure 1.

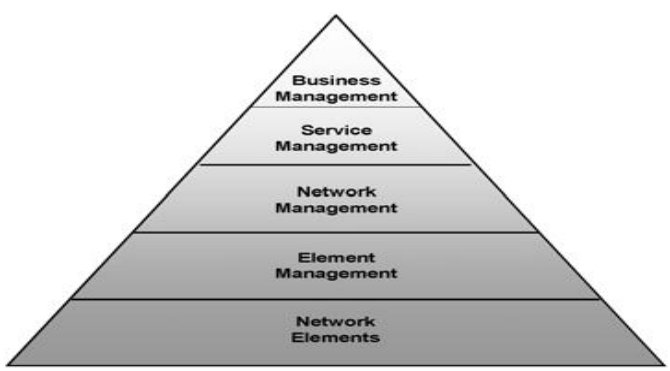

Figure 1: TMN Management Structure (Alcatel-Lucent, 2010).

In most submarine networks, configuration management is performed at the Element and Network Management Level (the node). The EML and NML provide the Network provider with Software tools to configure and manage the Network Elements distinctively. While the

EML is mainly connected to the management of physical resources, the NML on the other hand is devoted to the management of logical resources including traffic routing, path provisioning and circuit rate dimension (Alcatel-Lucent, 2010).

In undertaking this research to measure capacity utilization of allocated WACS capacity for a Network Provider from Lekki Landing Station in Nigeria, the equipment manager for SDH WDM and packet Network Elements (1353 OMS-SDH/WDM/PKT) at Lekki Station was investigated through the Submarine Network Manger, 1353 OMS–EML, to pull out and collate all circuits terminating and traversing the station since the system started commercial traffic in May 2012 till July 2017. Figure 2 is the WACS network topology Map showing DXCLKI, the logical representation of SDH Interconnection Equipment (SIE) at Lekki Station.

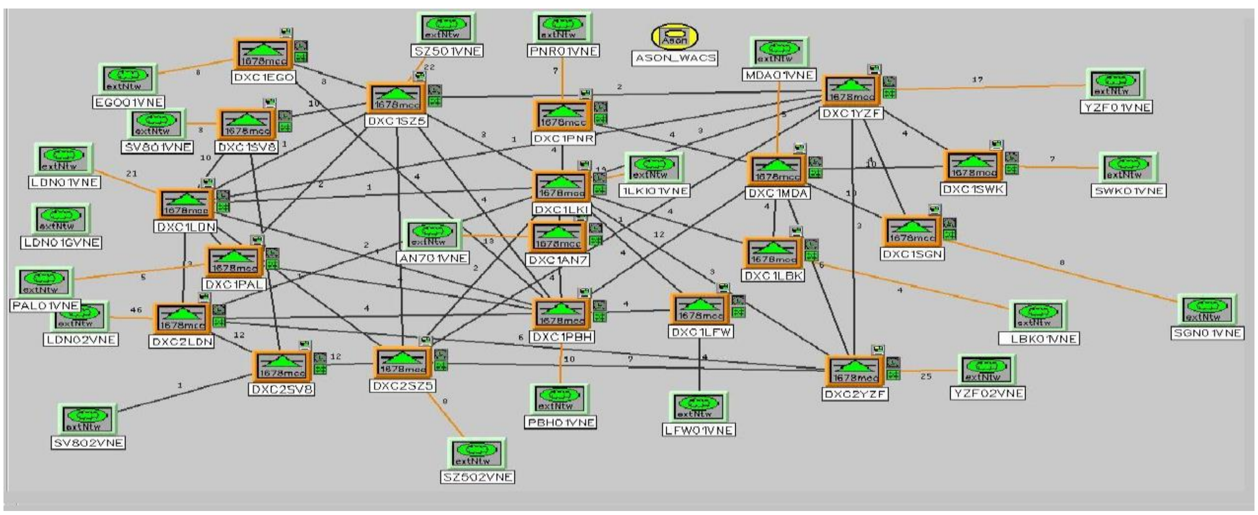

Figure 2: WACS Network Topology Map (Alcatel , 2010).

By interrogating the node element of DXCLKI and port details in the Element Manager, both the SDH and Direct Wavelength Access, DWA, paths were pulled out to analyse the circuit details and calculate capacity utilization for Lekki assigned wavelengths within the years since the system became life and open to commercial traffic. Figure 3 illustrates the node view of the Element Manager at Terminal station level.

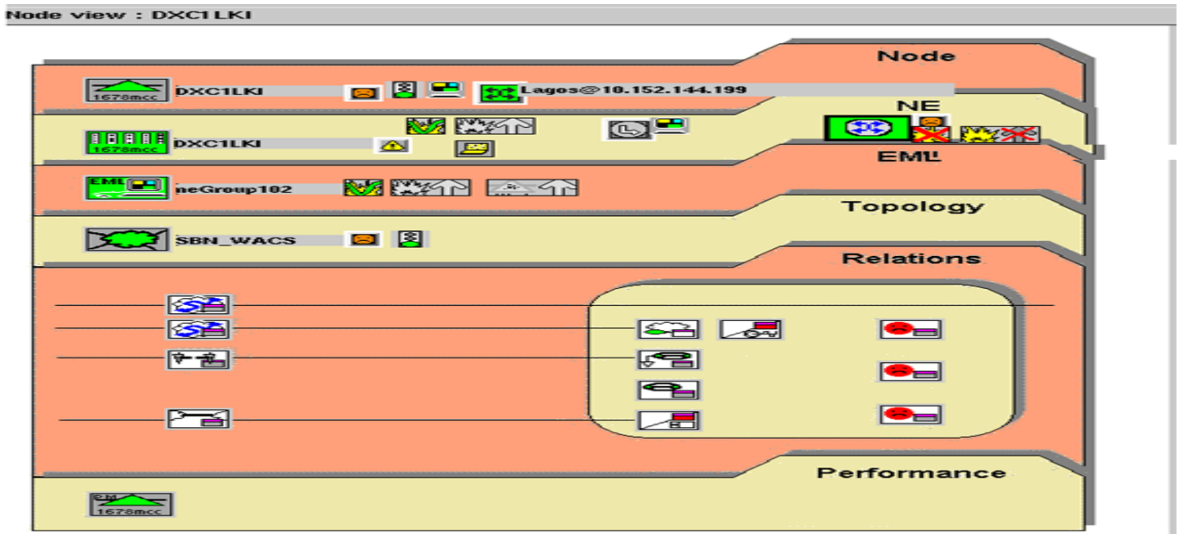

Figure 3: Node view at terminal station

An activation work order details the circuit path through which the circuit is created in a submarine system as shown in Table 1.

Table 1: Activation Work Order

MAIN WORKORDER

ACTIVATION WORK ORDER	
WorkOrder No.	3160MCAR230617
GENERAL INFORMATION	
To be Activated	
Circuit Internal Id	LKI/SZ5/STM-64/001/M
Circuit Designation	LAG/TATA-SZ5/TATA/WACST 64S001
Extended Circuit Internal Id	LKI/SZ5/STM-64/001/M/NP-NR
Admin A	Tata Communications (Bermuda) Limited
Admin B	Tata Communications (Bermuda) Limited
Terminal A	Seixal
Terminal B	Lekki Lagos
Circuit Rate	STM-64
Traffic Type Node A	Terminating
Backhaul Provider in Node A	Tata Communications (Portugal)
Direct Access Party in Node A	
Submarine cable system in Node A	
Traffic Type Node B	Terminating
Backhaul Provider in Node B	MTN
Direct Access Party in Node B	
Submarine cable system in Node B	
Bandwidth Type	DWA
Interface Type in Node A	STM-64
Interface Utilization in Node A	Dedicated
Interface Type in Node B	STM-64
Interface Utilization in Node B	Dedicated
Interface Protection Scheme in Node A	NO
Interface Protection Scheme in Node B	NO
Protection requirement	NON-PROTECTION
Restoration requirement	NON-RESTORABLE
CONFIGURATION INFORMATION	
Optical Routing Details	
LKI-SZ5 STM-64 001/# 1-64	S2a/LKI-SZ5 SEMIEXPRESS FP1-194.95/90-HMN L28 /Slot# 1-64 S2b/LKI-SZ5 SEMIEXPRESS FP1-194.95/90-HMN L28 /Slot# 1-64 S2d/LKI-SZ5 SEMIEXPRESS FP1-194.95/90-HMN L28 /Slot# 1-64 S3b/LKI-SZ5 SEMIEXPRESS FP1-194.95/90-HMN L28 /Slot# 1-64 S3d/LKI-SZ5 SEMIEXPRESS FP1-194.95/90-HMN L28 /Slot# 1-64 S3f/LKI-SZ5 SEMIEXPRESS FP1-194.95/90-HMN L28 /Slot# 1-64 S3h/LKI-SZ5 SEMIEXPRESS FP1-194.95/90-HMN L28 /Slot# 1-64
Circuit Configuration Details	
LKI/SZ5/STM-64/001/M	

Station Name	SIE/SLTE Information
Seixal	HWOTU1SZ5Dsl3/port8_AU4# 1-64
Lekki Lagos	HWOTU1LKIDsl13/port8_AU4# 1-64

Capacity utilization for the submarine route is then calculated in Minimum Assignable Unit (MAU) of activated capacity (equivalent to STM1 kilometre) by using the distance matrix table.

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Each submarine cable system also has their propriety distance matrix along its cable routes. For WACS submarine cable system, its distance matrix in Minimum Assignable Unit (MAU) of activated capacity

(equivalent to STM1 kilometre) is given in Table 3.2.1.

Table 3.2.1: Distance matrix in MAUs (WACS Network, 2017)

Each submarine cable system also has its propriety distance matrix along its cable routes. For WACS submarine cable system, its distance matrix in Minimum Assignable Unit (MAU) of activated capacity (equivalent to STM1 kilometre) is given in Table 2.

Table 2: Distance matrix in MAUs (WACS Network, 2017)

	Namibia	Angola	DRC	Congo	Cameroon	Nigeria	Togo	Ghana	Ivory Coast	Cape Verde	Canary Island	Portugal	UK	London
South Africa	1,736	3,710	3,938	4,235	6,146	5,589	5,982	6,263	6,685	10,095	11,505	9,168	10,539	10,843
Namibia		2,273	3,055	3,240	4,852	5,908	6,035	6,172	5,802	9,212	10,622	11,555	13,269	13,649
Angola			1,037	1,222	2,834	3,890	4,017	4,154	3,784	7,194	8,604	9,537	11,251	11,631
DRC				297	2,208	3,264	3,391	3,528	2,747	6,157	7,567	8,500	10,214	10,594
Congo					2,096	3,152	3,279	3,416	3,044	6,454	7,864	8,797	10,511	10,891
Cameroon						1,662	1,789	1,926	2,585	5,839	7,249	8,353	10,067	10,447
Nigeria							393	674	1,333	4,587	5,997	6,691	8,405	8,785
Togo								408	1,067	4,321	5,731	7,084	8,798	9,178
Ghana									771	4,025	5,435	6,680	8,394	8,774
Ivory Coast										3,410	4,820	5,909	7,623	8,003
Cape Verde											1,798	3,465	5,179	5,559
Canary Island												1,857	3,571	3,951
Portugal													1,714	2,094
UK														380
London														

With the circuit rate from activation profile and the distance matrix shown above, capacity utilization of all the activated circuits between the periods under research was evaluated by multiplying the circuit rate with the distance of navigation.

Port Utilization Method

The ports in the SDH Interconnection equipment for SDH circuits and those on the Submarine Line Terminal equipment for Direct Wavelength Access of 10GbE LAN circuit rates and above were physically counted to evaluate the number of connected and free ports on the Node Element and confirmed from the NMS to authenticate their level of usage for Lekki and Accra Stations.

Figures 4 & 5 illustrate connected and free ports, respectively.

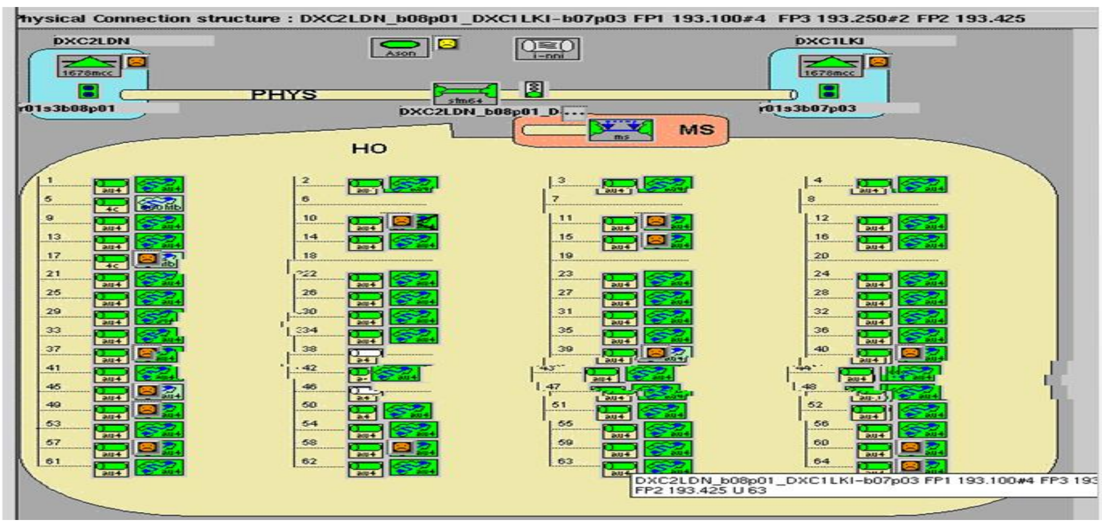

Figure 4: Connected ports in STM-64 physical structure

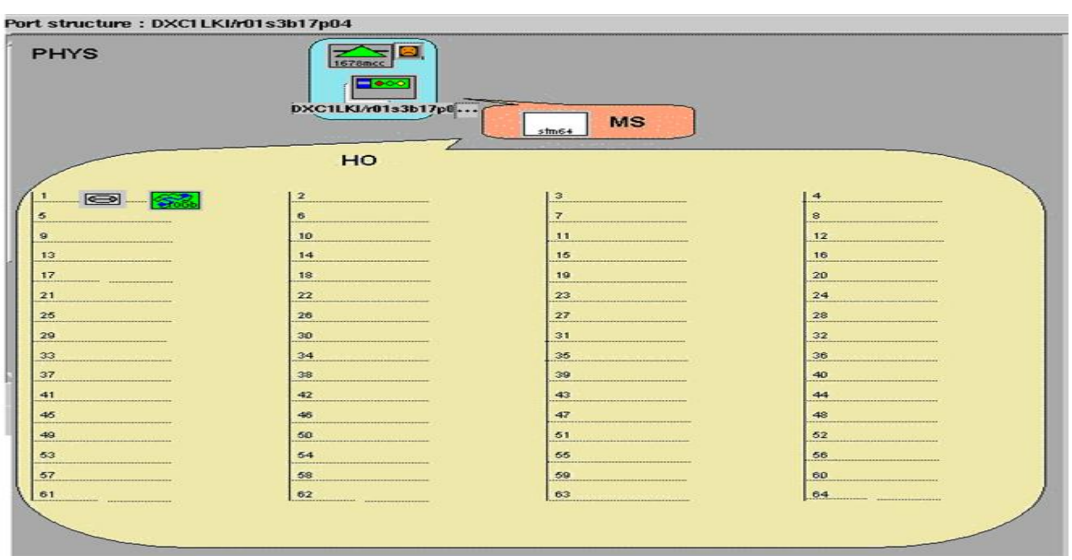

Figure 5: Free ports in STM-64 physical structure

The equipped ports so observed from May 2012 till June 2017 were analysed to obtain traffic port utilization.

Terrestrial Fibre Connectivity

In the broadband supply chain, the terrestrial fibre forms the link between international connectivity and the last mile connection to the end users. Hence, for an end-to-end broadband solution, the terrestrial backhaul infrastructure must be robust and reliable (Kelly, 2012). This research therefore investigated the fibre network connectivity of the service provider in Nigeria, under study, between 2014 to August 2017 focusing at its fibre failures and impact on the network to establish its robustness and reliability relative to broadband access and user experience in the country.

3.0 RESULTS AND DISCUSSION

Evaluating Submarine Fibre Optic Capacity Utilization

Capacity utilization for the submarine route is calculated in Minimum Assignable Unit (MAU) of activated capacity (equivalent to STM-1 kilometre) by distance of navigation. The STM-1 (Synchronous Transport Module level-1) is the SDH ITU-T fibre optic network transmission standard and has a bit rate of 155.52 Mbit/s (ITU-T, 1988).

For WACS submarine cable system, the distance between landing points form a matrix by which capacity utilization of activated capacity, in STM-1 kilometre, is determined. To find the capacity utilization of a 10GbE LAN activated circuit from Lekki in Nigeria to the Global Switch in London, for instance, the distance matrix table (Table 2) is accessed to note the intersection point between Nigeria and London and that distance multiplied with the circuit rate in STM-1 capacity. In this case we have that distance to be 8785km. Since the circuit rate is 10GbE (10G = STM-64), it follows that capacity utilization would be 562240.0 MAU*Km as evaluated in Table 3.

Table 3: Evaluation of Capacity Utilization

CIRCUIT DETAILS

<table>
<tr><th colspan="2">General Information</th></tr>
<tr><td>Internal ID</td><td>LDN/LKI/10GbE LAN/007/M</td></tr>
<tr><td>Extanded Internal ID</td><td>LDN/LKI/10GbE LAN/007/M/NP-NR</td></tr>
<tr><td>Circuit Designation</td><td>LND/NGR/MTNG 10GBE/005/M</td></tr>
<tr><td>Admin-A</td><td>MTN</td></tr>
<tr><td>Node-A</td><td>Lekki Lagos</td></tr>
<tr><td>Admin-B</td><td>MTN</td></tr>
<tr><td>Node-B</td><td>Global Switch</td></tr>
<tr><td>Circuit Rate</td><td>10GbE LAN PHY</td></tr>
<tr><td>Bandwidth Type</td><td>DWA</td></tr>
<tr><td>Restoration Requirement</td><td>NON-RESTORABLE</td></tr>
<tr><td>Protection Requirement</td><td>NON-PROTECTION</td></tr>
<tr><td>Capacity Utilization (MAU*km.)</td><td><table>
<tr><th></th><th colspan="2">Allocated</th></tr>
<tr><th></th><th>Main</th><th>Protected</th></tr>
<tr><td>Admin A</td><td>281120.0</td><td>0.0</td></tr>
<tr><td>Admin B</td><td>281120.0</td><td>0.0</td></tr>
<tr><td>Total</td><td>562240.0</td><td>0.0</td></tr>
</table></td></tr>
<tr><td>Circuit Type</td><td>WAC</td></tr>
<tr><td>Circuit Status</td><td>Active</td></tr>
<tr><td>Activation Date</td><td>29-JUL-2016</td></tr>
<tr><td>Deactivation Date</td><td></td></tr>
</table>

The significance of this calculation is most appreciated in commercial circles where it is used to calculate the cost of circuit provisioning from one destination to the other. Therefore, for the customer that picks up a circuit at any location, the corresponding commercials are calculated in MAU*Km to give capacity utilization of the service.

At the terminal points (cable landing stations) where the trunk branches into nodes, a nodal analysis of circuit trajectory in and out of the node is used to calculate capacity utilization.

Another method of evaluating capacity utilization is by taking statistics of port usage at the terminal points to do a port utilization analysis by comparing the active and free ports with respects to equipped units for each circuit rate. The results so obtained for Lekki and Accra Cable Landing Stations are as tabulated in Tables 4 and 5 respectively.

Table 4: Traffic port utilization for Lekki CLS, Lagos

Port Utilization Analysis											
	Total Equipped Units	**Total Client Ports**	**Port Usage**						**Free Client Ports**	**% Client Port Utilization**	**%Total Port Utilization**
Port Type			**Reserved Ports (Wavelengths, Interlinks etc.)**	**Wavelength (Line) Protection Port**	**Port Reserved for Internal Restoration**	**Port reserved for External Restoration**	**Client Port carrying Traffic**	**Client Protection Port**			
STM-64	**112**	**52**	**58**	**-**	**-**	**2**	**10**	**2**	**40**	**23.08%**	**64.29 %**
STM-16	**64**	**64**		**-**	**-**	**-**	**7**	**1**	**56**	**12.50%**	**12.50 %**
7*VC4	**1**	**1**		**-**	**-**	**-**	**-**	**-**	**1**	**0.00%**	**0.00 %**

Traffic Port Utilization Analysis				
Port Type	**Traffic Carrying Units**	**Total AU4 Equivalent**	**Utilized AU4 Equivalent**	**% Utilization**
STM-64	**10**	**640**	**447**	**69.84 %**
STM-16	**7**	**112**	**24**	**21.43 %**
7*VC4	**0**	**0**	**0**	**0.00 %**
Total	**17**	**752**	**471**	**62.63 %**

In addition, the number of interface details connected to each backhaul provider at Cable Landing Stations was analysed relative to its Synchronous Digital Hierarchy Auxiliary Unit 4 (AU4) equivalent (155.52 Mbit/s) to arrive at percentage utilization for different backhaul providers as illustrated in Table 5 as averaged for MTN, Emerging Markets, Airtel Networks and Vodacom Business Africa, respectively.

Table 5. Summary of Averaged utilization of the communication units as provided.

Interface Type	Port Type	Units	Port Details	Equipped AU4 Equivalent	Utilized AU4 Equivalent	% utilisation
MTN	**7**		**Average % utilization**			**57.81 %**
Emerging markets	**2**					**87.50 %**
Airtel Networks	2					**40.63 %**
Vodacom Business	4					**46.88 %**

These tables show the methods by which capacity utilization can be evaluated in a submarine system; node element method, port utilization method and backhaul provider usage.

5.0 CONCLUSION

Capacity utilization of submarine optic fibre communications route is calculated in Minimum Assignable Units (MAU) of activated capacity in STM-1 **(**Synchronous Transport Module level-1**)** by distance of navigation, port utilization analysis and backhaul provider circuit pick up, through direct wavelength access. The utilization of submarine optic fibre capacity and broadband access for end user QoE is dependent on the availability of the network resources by which the customer is connected. Hence, improving network infrastructures and connectivity will accelerate ubiquitous broadband penetration in Nigeria.

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