UDC 004.71

INFORMATIONAL LINEAR CAPACITY OF FIBER-OPTIC BACKBONES OF THE COUNTRIES OF THE WEST COAST OF AFRICA

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Received February 18, 2022

Abstract. This article describes an assessment of the ways in which the international digital data backbone is serviced, which is determining the development of the economy. The focus of the article is on the west coast of Africa and direct interregional data delivery channels. The concept of informational linear capacity was introduced and substantiated.

Keywords: optical fiber, digital cable, international Internet backbone, Tbit/sec, linear information capacity.

Introduction

The organization of information flows and access to them for the modern economy is as relevant as access to waterways and energy resources in the 19th and 20th centuries, respectively. In modern conditions, fiber-optic backbones are used as large elements of the infrastructure for organizing and supporting information flows. Laying fiber-optic lines on land is costly, but a fairly straightforward task. The advantage of such a solution is the ability to organize data logistics and start a return on investment in stages until the completion of the entire project, since the communication and intermediate routing strongholds through which the fiber-optic backbone passes provide access to the user audience that is geographically located around it.

The essential complexity of this solution lies in the need to lay the bandwidth of the backbone, taking into account the potential rapid growth of information growth in the load on the network both at each of the endpoints of the backbone and at its intermediate nodes.

Relevance of laying fiber-optic lines along the sea and ocean bottom

It can be argued that laying fiber-optic backbones over land solves local regional problems and cannot always provide targeted traffic to regions that are geographically distant from routing centers. An additional limitation on the choice of such a solution may be unfavorable geological conditions, environmental restrictions, natural disasters and the risk of military conflicts, which can damage the infrastructure of the backbone networks and complicate its operation or maintenance.

Subsea fiber-optic trunklines have similar risks: extraterritorial deployment, fixed cable structure configuration (from laying to decommissioning), potential damage from vessel traffic (commercial fishing, use of anchors), potential intentional damage (Figure 1) [1] and even harm from the local fauna (for example, aggressive behavior of sharks).

Based on these risks, all types of fiber-optic trunk cables must be protected, and the degree of protection depends on the topography of the ocean or seabed and the depth of their placement. The decision to place fiber-optic lines at the bottom in the coastal zone in some cases turns out to be the only alternative and the most economical way.

For example, in 1989, a Scotland-Northern Ireland 1 cable connection between Donaghadee and Portpatrick, UK, across the North Strait Between the Atlantic Ocean and the Irish Sea, was commissioned. The length of the highway is about 35 km. The data transfer rate at the time of commissioning was 3,36 Gbps (0,00336 Tbps). It was supposed to complete the operation of this highway by 2014, but its use continues in 2021.

Figure 1. Precedent for damage to submarine cables at the Lofoten-Vesteralen Marine Observatory of the coast of Northern Norway

In the same 1989, three more fiber-optic trunk lines were created between Belgium and Great Britain, between Denmark and Sweden and two Danish islands in the Baltic Sea. The main task of the sea lanes of that period was the organization of traffic transit between separated networks.

The disadvantage of organizing work of this type of highways is the technical complexity of maintenance and the need to introduce redundancy in the number of optical fibers to ensure reliability, maintain the bandwidth and the possibility of its expansion with increasing load in the future. The confirmed possibility of extending the service life of highways in relation to copper solutions, as well as the potential to increase the speed characteristics of the fiber used by upgrading the terminal interfaces, has led to a rapid increase in investments in these technologies.

Another convenience that was quickly mastered on the market was the guaranteed quality of communication over long distances. Since the number of bends between the point of immersion of the mainline and its withdrawal to the shore was strictly regulated, therefore, the "intermediate analysis of traffic" characteristic of fiber-optic mains on land did not interfere with the solution of the target problem.

Already in 1998, the Atlantic Crossing-1 (AC-1) transatlantic project was completed. He connected communication nodes Sylt (Germany), Beverwijk (Netherlands), Whitesands Bay (Great Britain), Brookhaven, NY (USA) into a ring structure. The length of the highway is about 13,168 km. The data transfer rate at the time of commissioning is 40 Gbps (0,04 Tbps). For 2014, the data transfer rate was increased to 2,35 Tbps (2.35 Tbps). Its operation is expected to be completed by 2023. At the moment, about 20 fiber-optic lines cross the Atlantic Ocean, most of which were put into operation after 2008. Their resource for modernization, that is, increasing information capacity, is very large.

From this point on, it makes sense to introduce a classification of submarine fiber-optic highways based on the principle of geographic coverage and nationality of communication nodes that are connected to the backbone directly, or as a "tap-off point from the backbone".

1. National fiber-optic backbone – connects communication nodes on the territory of one state.

2. Regional fiber-optic backbone – connects communication nodes on the territory of neighboring states of the same region.

3. Interregional fiber-optic backbone – connects communication nodes on the territory of different states located far from each other.

4. Intercontinental fiber-optic backbone – connects communication centers on the territory of states located on different continents.

Atlantic Crossing-1 (AC-1) is an example of an intercontinental fiber backbone, Scotland-Northern Ireland 1 is an example of a national fiber backbone.

Backbone of the west coast of Africa

The most developed communication center is the port of Lagos (Nigeria) in the Gulf of Guinea (Table 1). Of the six operating fiber-optic highways with access to Lagos (Nigeria), five can be classified as intercontinental. In 2022 and 2023, two more intercontinental fiber-optic highways are expected to be commissioned with access to Lagos (Nigeria). Traffic processing is done on the coast. At the moment, technical sites of six data centers are involved in this work. Most often, cities in the geographical environment of Lisbon (Portugal) are the extreme European points of contact for this direction.

Table 1. **List of underwater fiber-optic communication lines with access to Lagos [2]**

Name	Trunk type	Length, km	Commissioning year	Baud rate, Tbps
South Atlantic 3/West Africa Subm. Cable (SAT-3/WASC)	intercontinental	14400	2002	0,8
Glo-1	intercontinental	9800	2010	2,5
MainOne	intercontinental	7000	2010	10
Africa Coast to Europe (ACE)	intercontinental	17000	2012	12,8
West Africa Cable System (WACS)	intercontinental	14500	2012	14,5
Nigeria Cameroon Subm. Cable System (NCSCS)	regional	1100	2015	12,8
Equiano	intercontinental	12000	2022	200
2Africa	intercontinental	45000	2023	180

The cost of designing and installing communication systems of this scale is many times higher than the economic capabilities of the countries of the region and their construction is carried out at the expense of foreign investments. In particular, the owners of the investment packages of the 2Africa highway are China Mobile, Facebook, MTN Group, Orange, Saudi Telecom, Telecom Egypt, Vodafone, WIOCC.

Countries neighboring Nigeria have more modest opportunities for technical connection to fiber-optic backbones.

In the Republic of the Congo, for operational use, there are only two inputs of submarine fiber-optic lines:

– West Africa Cable System (WACS) intercontinental fiber backbone (Pointe-Noire, Congo, Rep.) launched in 2012. The total length of the highway is 14,530 km. Terminal nodes Portugal-South Africa. The data transfer rate at the time of commissioning was 14,5 Tbit/s (14,5 Tbps).

– Intercontinental fiber optic backbone 2Africa (hub at Pointe-Noire, Congo, Rep.) with an official commissioning date of 2023. The total length of the highway is 45,000 km. End nodes UK-India, UK-Djibouti-Spain (Figure 2). The estimated speed of information transfer at the time of commissioning is 180 Tbps (180 Tbps).

It is extremely difficult to forecast the analysis of the information traffic of this highway by country. In information flows, tense areas are likely to be highlighted. Probably in the future this highway will be divided into independent projects.

Figure 2. 2Africa cable map (Source: 2Africa Consortium)

The local terrestrial optical operator in the Republic of Congo Congo Telecom has been operating since 1999 and has at its disposal a section of local fiber-optic backbones of 1,529 km. Processing of information traffic between terrestrial and submarine fiber-optic lines is carried out by means of the Congo Telecom Carrier Facility PNR1 data center.

In Guinea, a solution was applied to distribute network traffic between north and south. Two information highways have created independent technical sites and infrastructure in coastal cities that are quite remote from each other.

In the north, in the Kamsar region, and in the south, in the Conakry region, the connection is provided by the Africa Coast to Europe (ACE) intercontinental fiber backbone (Pointe-Noire, Congo, Rep.), Which was commissioned in 2012. The total length of the highway is 17,184 km. Terminals France-South Africa. The data transfer rate at the time of commissioning was 12,8 Tbit/s (12,8 Tbps).

Two independent inputs allow simultaneously and without delays in the implementation of local provider projects to develop the country's economy much faster.

Informational linear capacity of the fiber-optic backbone and the possibility of its expansion

Within the framework of the study, the term informational linear capacity of a fiber-optic backbone is used. This is a numerical characteristic equal to the ratio of the data transmission rate in terms of the total number of light guides involved in the physical backbone to the maximum distance of the information signal delivery.

The error in assessing intercontinental fiber-optic backbones, which is incorporated during integration into the topology of optical fibers for organizing national and regional communication sections, will have to be neglected. In conditions when standard cable types with unified requirements for suppliers are used within the framework of one project, the total number of optical fibers (used and unused, that is, in reserve) along the entire length of the trunk is considered the same.

For example, according to the official technical specifications, the 2Africa backbone uses 16 fiber pairs for the entire operating distance (45,000 km), while the WACS backbone uses only 4 fiber pairs (14,530 km).

The information capacity of the assessment of these highways is:

$$\text{2Africa} = 80\ \text{Tbps}/45{,}000\ \text{km} = 4\ \text{Gbps / km},$$
$$\text{WACS} = 14{,}5\ \text{Tbps}/14{,}530\ \text{km} = 1\ \text{Gbps / km}.$$

The practice of long-term operation under modernization conditions has shown the following values of changes in the information capacity of the Atlantic Crossing-1 (AC-1) optical highway:

$$1999 = 0{,}04\ \text{Tbps}/14{,}301\ \text{km} = 0{,}0003\ \text{Gbps / km},$$
$$2002 = 0{,}12\ \text{Tbps}/14{,}301\ \text{km} = 0{,}008\ \text{Gbps / km},$$
$$2007 = 0{,}635\ \text{Tbps}/14{,}301\ \text{km} = 0{,}044\ \text{Gbps / km},$$
$$2008 = 0{,}815\ \text{Tbps}/14{,}301\ \text{km} = 0{,}057\ \text{Gbps / km},$$
$$2009 = 1{,}165\ \text{Tbps}/14{,}301\ \text{km} = 0{,}081\ \text{Gbps / km},$$
$$2010 = 1{,}455\ \text{Tbps}/14{,}301\ \text{km} = 0{,}1\ \text{Gbps / km},$$
$$2012 = 1{,}76\ \text{Tbps}/14{,}301\ \text{km} = 0{,}12\ \text{Gbps / km},$$
$$2013 = 2{,}1\ \text{Tbps}/14{,}301\ \text{km} = 0{,}14\ \text{Gbps / km},$$
$$2014 = 2{,}35\ \text{Tbps}/14{,}301\ \text{km} = 0{,}16\ \text{Gbps / km}.$$

Later speed indicators for AC-1 are not given in open sources.

The backbone is built according to the specifications of the Synchronous Digital Hierarchy (SDH) standard and includes 8 DWDM (Dense Wavelength Division Multiplexing) channels in two fiber-optic pairs [3].

The distance between the carrier frequencies in DWDM systems can be from 25 to 200 GHz; in modern networks, a grid of channels with a step of 50 GHz is used. Depending on the type of cable used, the spectral ranges C (1530…1565 nm), S (1460...1530 nm) and L (1565…1625 nm) can be used for transmission. An example of the channel filling density is shown in Figure 3.

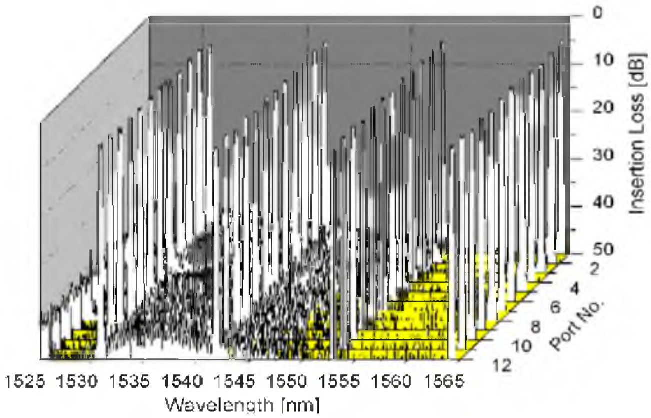

Figure 3. Channel allocation with a step of 50 GHz for a 12-port WSS fabric

To assess the growth of information linear capacity on the west coast of Africa, let us consider the most promising of the region's intercontinental fiber-optic backbones. 2Africa will use PROADM Wavelength Selective Switching (WSS) technology for the first time in Africa, allowing for more flexible bandwidth management.

The WSS consists of one common optical port on one side and X split multi-wavelength ports on the other side, where each DWDM wavelength input from the common port can be switched (routed) to any of the X multi-wavelength ports regardless of how all the remaining X wavelength channels are routed.

The first industrial WSS systems were based on movable mirrors using microelectromechanical systems (MEMS), now technology development using liquid crystal elements based on silicon (LCoS) is relevant. The existing samples propose the implementation of 1 WSS×4 DWDM channel multiplexing, the transition to 1 WSS×20 DWDM solutions is predicted. The technical implementation of this forecast will give a fivefold increase in the informational linear capacity of optical lines.

Unfortunately, a method for producing submillisecond SLM LCoS crystals is currently not commercially available.

Conclusion

Intercontinental fiber-optic backbones made it possible to organize information flows from end-use networks or the generation of targeted traffic in African countries to large routing nodes and data processing centers in Europe and America. This provides the conditions for the future leveling of commercial activity, the development of the education system, modern production and living standards in these countries.

Planning the growth of the information capacity of the involved fiber-optic backbones should take into account the technical limitations of the cable systems and communication devices used that provide signal retransmission.

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