REGULATORY AND MARKET ENVIRONMENT

Maximising Availability OF INTERNATIONAL CONNECTIVITY IN DEVELOPING COUNTRIES: STRATEGIES TO ENSURE GLOBAL DIGITAL INCLUSION

Telecommunication Development Sector

Maximising availability of international connectivity in developing countries: Strategies to ensure global digital inclusion

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1 Introduction and background

The United Nations General Assembly in its resolution entitled *The Future We Want* provided that "…the goal of sustainable development is to ensure the promotion of an economically, socially and environmentally sustainable future for the planet and for present and future generations. Sustainable development emphasizes a holistic, equitable and far-sighted approach in decision-making at all levels. It rests on integration and a balanced consideration of social, economic and environmental goals and objectives in both public and private decision-making. It emphasizes intra-generational and intergenerational equity".[1]

The achievement of the 17 Sustainable Development Goals (SDGs)[2] adopted in 2015 will rely heavily on the digital ecosystem since there is an ever-expanding variety of services and applications depending on the realization of a truly connected and networked society, in which ICTs can fulfil their potential. Although telecommunication networks and ICTs have already become a vital part of the daily lives of anyone with a reliable Internet connection, many people have yet to take full advantage of the ICT revolution. This especially applies to those living in developing countries and particularly people in the lower-income countries and those in post-conflict or post-natural disaster situations. About 3.2 billion people are now online, representing 43.4 per cent of the global population. While more than 7 billion people now have access to voice services, over 70 per cent of those living in the least developed countries (LDCs) still cannot afford a basic Internet connection, and less than half the people in the world regularly use the Internet[3].

The causes of the lack of connectivity are many. Limited local network infrastructure is often a constraint. In 2015, there were still an estimated 350 million people out of reach of a mobile network. Although 89 per cent of the world's urban population is now covered by a 3G network, only 29 per cent of the 3.4 billion people living in rural areas have 3G coverage. There may also be more basic issues, such as low-income levels or lack of electricity. However ensuring the availability of low-cost reliable international links can often be a particularly difficult problem to solve. International connections are often relatively costly. Some countries are land-locked, unable to reach the global backbones without the additional cost of traversing their neighbours. Small island nations isolated by large stretches of ocean may have difficulties recovering the cost of the necessary infrastructure. In some countries, governments have not stepped in to build demand for ICT services, or the policy and regulatory environment may constrain investment in local and international infrastructure, especially when there is an absence of neutral platforms where stakeholders can meet and exchange information.

Furthermore, many countries may lack experience in the wide range of technical and economic fields required, such as in laying of cables in deep waters and setting up satellite earth stations, to the business and ownership strategies of the large consortia of operators and investors that finance international projects. These and many other aspects of international network deployment and operation must work seamlessly together to ensure that there is sufficient demand for and supply of international connectivity.

Strategies for ensuring that all citizens, wherever they may be, have access to the best possible international infrastructure is therefore an important public policy priority that will also assist in reaching the WSIS targets and SDGs.

This report aims to build awareness of the challenges and strategies for improving international connectivity, and to consider some potential options for promoting increased local, regional and global collaboration to further this objective. In this respect, the report aims to inform the international development community as well as national policy makers, industry and civil society groups.

1 The Future we want: final document of the Rio+20 Conference (E/20, 13/69, para. 6).

2 Transforming our world: the 2030 Agenda for Sustainable Development. United Nations Resolution A/RES/70/1: www.un.org/ga/search/view_doc.asp?symbol=A/RES/70/1&Lang=E

3 www.itu.int/en/mediacentre/pages/default.aspx

Supported by data from case studies that were carried out to provide on the ground experience in international connectivity, the report discusses the technical, economic and policy or regulatory constraints that can prevent the maximal use of international communications infrastructure. It also considers the opportunities, strategies and policies that can assist countries (particularly developing countries) to address these constraints, as well as identifying the institutions that could contribute to efforts to improve the international connectivity environment.

In addition, the report puts forward a detailed set of international connectivity strategy building blocks, providing a framework to address all the elements required for optimal international connectivity ecosystems (see Section 8).

2 The dynamics of international capacity provision in developing countries

2.1 The Global context

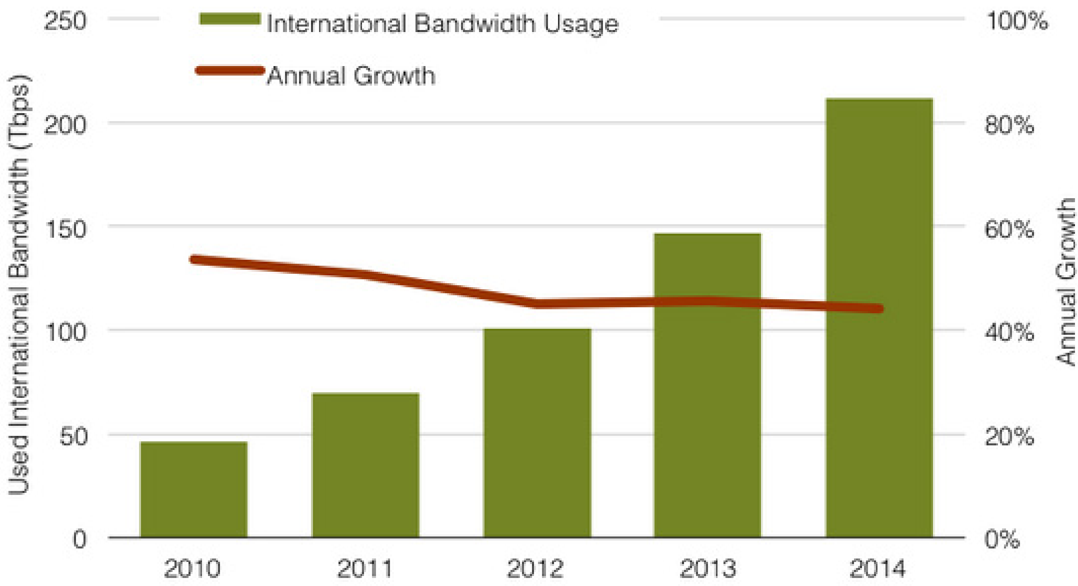
With the explosive growth in the use of broadband, the bandwidth demands of users have increased tremendously, resulting in soaring international capacity requirements. In 2014, it was estimated that international capacity use was growing at about 44 per cent annually (Figure 1)[4]. Reflecting greater pent-up demand, the fastest growth rates occurred in emerging markets, where Africa, Asia, and the Middle East have had annual growth of about 50 per cent between 2010 and 2014.

There were about 400 international carrier networks in 2014[5] providing 221 Tbit/s of international capacity, and this is projected to increase to 900 Tbit/s by 2020. Similarly, Cisco estimated that in 2013, submarine cables carried 51 Exabytes of data per month, which was projected to increase to 132 Exabytes by 2017[6]. According to McKinsey[7], the amount of cross-border bandwidth in use has grown 45 times since 2005 and is projected to increase by an additional nine times by 2020, as flows of information, searches, communication, video, transactions, and intra-company traffic continues to surge. With the expected growth in the Internet of Things (IoT), along with more widespread migration of broadcast and video content distribution channels to broadband, further bandwidth demand increases are expected.

These trends serve to highlight the importance of putting in place national strategies to ensure that there is sufficient and affordable local and international capacity not only for the current levels of use, but also for the higher levels of use expected in the future, when many more people and billions of additional devices will have affordable high-speed broadband links.

4 www.telegeography.com/page_attachments/products/website/research-services/global-bandwidth-research-service/0005/9474/gb15-exec-sum.pdf
5 These networks are being mapped by ITU: www.itu.int/itu-d/tnd-map-public
6 www.slideshare.net/jokosuryana90/international-bw-and-data-market
7 www.mckinsey.com/business-functions/mckinsey-digital/our-insights/digital-globalization-the-new-era-of-global-flows

Figure 1: Worldwide international bandwidth use and growth 2010-2014



Source: Telegeography

2.2 International capacity costs

Prices for international capacity vary widely by region due to differences in available supply, levels of competition and cost of the underlying infrastructure. On large volume submarine cable routes, wholesale capacity is usually priced in 10 Gbit/s wavelengths and prices can vary considerably depending on the route. For example, on some of the most competitive inter-regional or intercontinental routes such as Hong Kong, China to Tokyo, Japan, a 10 Gbit/s wavelength costs an average of about USD 15 000 a month in 2013, while 10 Gbit/s from New York, United States to London, United Kingdom cost USD 7 000 a month. Prices on the same route also vary significantly – for example a 10 Gbit/s circuit between Los Angeles and Tokyo varies in cost between USD 16 000 a month and USD 33 000 a month, depending on the particular submarine cable operator. As would be expected, the cost of international capacity are often up to ten times higher on less competitive, longer distance and lower volume routes, especially those linking smaller economies. Even on the higher volume regional routes, for example Sydney, Australia to Tokyo, Japan or Hong Kong, China to Singapore, 10 Gbit/s cost about USD 35 000 a month, while Sydney – London is about USD 80 000, London to Mumbai, India USD 175 000 and London to Cape Town, South Africa about USD 200 000. Although there have not been any new cables on the Latin America to the United States route recently, cable upgrades have driven prices down substantially, so that Miami, United States – Sao Paulo, Brazil now costs about USD 100 000 a month for 10 Gbit/s[8].

Of particular significance, especially for smaller operators, is that prices are also affected by the size of the circuit being purchased and the length of the contract. On many 'thinner' routes, where there are only one or two cable links operating, prices can be much higher, especially when smaller amounts of capacity are purchased. For example, the cost of a STM-1 (155 Mbit/s) circuit on a short term contract (e.g., on a month by month basis), can be as much as USD 35 000 per month on the west Africa route – equivalent to over USD 2 million per month for 10 Gbit/s.

[8] www.telegeography.com/research-services/global-bandwidth-research-service/index.html

While 10 Gbit/s wavelengths comprise the majority of worldwide international capacity sales, there are significant financial incentives for customers with high bandwidth requirements to purchase 100 Gbit/s wavelengths. For example, median 100 Gbit/s prices on key international routes are on average seven to eight times the price of comparable 10 Gbit/s service[9]. These discounts for higher capacity have led groups of smaller commercial operators as well as members of National Research and Education Networks (NRENs) to band together to aggregate their needs, thereby achieving lower operating costs for their user-base.

With prices for international capacity varying by a factor of 10 or more for equivalent distances, it is evident that the volume and level of competition are the key determinants of the cost of international capacity. Of note is that globally, increased competition is driving capacity prices sharply downwards, by about 15–40 per cent a year, depending on the route. Between Q2 2014 and Q2 2015, prices on key international routes fell an average of 16 per cent, while monthly charges for an STM-1 circuit (Johannesburg to London) fell by more than 40 per cent/year since 2009[10].

With these large price declines on international routes it would appear that network operators would be reducing their international capacity expenditures. However, international bandwidth consumption is growing by much more than the rate of price reduction. It is evident, therefore, that expenditures on international capacity will continue to increase for some time to come. Considering the cost of international capacity has a major impact on end-user broadband prices, the importance of adopting strategies to reduce international capacity prices is evident.

2.3 Global transit

When traffic reaches one of the global hubs, such as Miami, New York and Los Angeles in the United States, or Amsterdam, London, Frankfurt and Paris in Europe, it is currently possible to purchase global transit in these locations for less than USD 0.50 a month/Mbit/s (USD 5 000 for a 10 Gbit/s circuit). Most independent retail broadband providers around the world purchase capacity to one of these locations and by using the regional IXPs present there, obtain the best mix of transit and peering arrangements to minimise their global traffic costs.

The very low costs for transit capacity at the global hubs highlights the need for developing countries to establish their own regional traffic consolidation points. This will create sufficient traffic for the large international carriers to have the incentive to build out their own infrastructure to reach them, rather than the developing countries having to foot the cost for all of their international traffic. These dynamics have been the focus of the ITU-T Study Group 3, which found that the high costs of the international circuit for Internet connectivity in the least-developed countries is a serious barrier to Internet access in these countries.

This resulted in Recommendation D.50 of the of ITU Telecommunication Standardization Bureau (ITU-T), which outlines actions that the international community could undertake, in particular “to include efforts to facilitate the creation of traffic aggregation within localities, countries or within regions in developing countries in order to avoid sending this traffic over satellite or cable links used for intercontinental traffic”. This would aim to maximize the retention of local and national traffic within these regions, and thus reduce their dependence on international communication links. In 2013, ITU also published ITU-T D.50 Supplement 2, which provided guidelines for reducing the costs of international Internet connectivity.[11]

9 Data from TeleGeography. See https://telecomnewsroom.com/tag/wholesale-bandwidth-pricing-database
10 www.itu.int/en/ITU-D/Regulatory-Market/Documents/Events/2015/Sao_Tome/Session6_Seixas_BBcosting-pricing.pdf
11 www.itu.int/rec/T-REC-D.50-201305-I!Sup2/en

3 International connectivity provision

3.1 Ways and means of enabling international connectivity

Today, fibre optic submarine cables, regional terrestrial fibre backbones, and satellites provide the vast majority of international links, although there are still a few terrestrial microwave connections that provide the links between countries.

3.1.1 Optic fibre cable

For nations with coastal borders, submarine fibre optic cables provide the most common option for international connectivity, while terrestrial fibre cables have largely replaced microwave and satellite links on the trunk routes for landlocked countries. Terrestrial international cables may also include routes serving domestic locations, where, for example, there may be wireless base stations every 30 km along the route to the border. Due to the large number of potential locations served along a terrestrial route, a cable laid today will often contain up to 288 optic fibres (cores). Submarine cables are more constrained with the number of fibres due to the long distances involved (often there are only four or six pairs).

In most respects, the market dynamics and policy considerations for international optic cables are little different to domestic links. International cables may run for longer distances and cross borders, but they are not designed or implemented any differently, except perhaps in their ownership models, where they are more likely to have multiple owners in different countries sharing the cost. The availability of cross border utility infrastructure such as roads, rail lines, electricity grids and fuel pipelines, combined with appropriate infrastructure sharing regulations can also have an influence on the strategy adopted for international cable deployment.

In the shared ownership model, each of the investing network operators owns a subset of the total capacity or number of fibres if it is a terrestrial route (submarine cables usually only have about four fibre pairs). Other large networks that require long-term capacity on the route would purchase capacity, fibres or wavelengths on the cable from the consortium, usually on an indefeasible right of use (IRU) basis (long-term lease of capacity), while smaller networks would usually purchase capacity on a per Mbit/s basis, monthly or annually, from one of the operators with a share in the cable. If a spare duct is available on a terrestrial cable (which is usually the case when a dig-once policy is in place in the country), a large operator might also be able to rent access to the duct, and would blow their own cable along the duct on that route.

Fortunately, once a fibre cable is laid, the capacity available is virtually limitless. The electronics at break-out points and repeater stations may need to be upgraded to provide for higher capacities, but the optic cable itself normally has a life of some decades, and is unlikely to need replacing or augmenting to cope with future needs, unless subject to multiple breakages which can create signal attenuation at the splice points. Optic fibre data transmission technology has kept pace with exploding demand, and the latest 100 Gbit/s per wavelength technologies are now commercially available, providing at least 8 Tbit/s per individual fibre core (i.e., a 288 core cable would be capable of transmitting 2 300 Tbit/s).

These technology advances provide ever-increasing amounts of capacity on existing cables, as evidenced in January 2015 when Alcatel-Lucent and the ACE submarine cable consortium completed a field trial using 300 Gbit/s and 400 Gbit/s technology. When the ACE cable entered service in December 2012, it had an initial design capacity of 5.12 Tbit/s using 40 Gbit/s technology, while the trial achieved a transmission of 12.6 Tbit/s of data per fibre pair, demonstrating a more than a fivefold increase in the system's initial design capability to 25.2 Tbit/s [12].

[12] www.alcatel-lucent.com/press/2015/alcatel-lucent-and-ace-achieve-breakthrough-upgrade-africa-coast-europe-system-using-300g400g

Even higher speeds are now being implemented on the next generation of submarine cables, such as the new FASTER submarine running between the United States and Japan, which is due to go into operation this year. With six fibre-pairs in the cable, each carrying 100 wavelengths at 100 gigabits per second, it will have a peak capacity of 60 Tbit/s [13]. Alcatel-Lucent Submarine Networks (ASN) recently demonstrated a record data capacity of 144 Tbit/s on the C-Lion1 submarine cable system (18 Tbit/s per fibre pair) [14], and also in 2015, researchers from Bell Labs successfully sent 31 Tbit/s along a single fibre over a distance of 7 200 km[15].

3.1.2 Satellite connectivity provision

Prior to the Internet revolution, satellite technologies were a common type of international trunk route for many countries. The huge increase in demand for international capacity from broadband users has seen the prevalence of satellite links decrease in use for these high capacity routes (a multi-terabyte optical fibre can carry the traffic of all the world's satellites). However, the increasing importance of access to reliable communications infrastructure has seen the demand for satellite services continue to grow. Satellite remains a vital telecommunication option in remote and rural areas, where these systems have long been used as an efficient means of providing telecom services. In addition, satellites remain an efficient solution to broadcasting, domestic deployment of broadband access and mobile backhaul in remote areas.

Satellite links are inherently faster and easier to set up than burying cable in the sea or on land. For the cost of laying a single kilometre of terrestrial fibre, a satellite link can be deployed to link an isolated community virtually anywhere in the world, no matter how far they are from terrestrial connectivity. There are higher operating expenses with satellite, but lower Capex compared to fibre, so the cost of initial finance has a much lower impact and can make satellite a more viable option in many situations. In addition, the market for satellite capacity is highly competitive, with many different operators serving most locations, which, in contrast to the limited number of submarine or terrestrial fibre backbones that may be present, makes it possible to choose from a wider variety of suppliers.

The 2016 State of the Satellite Industry Report[16] shows that satellite industry revenue was USD 208.3 billion in 2015, with a growth of 3 per cent worldwide in 2015. According to the report, the number of satellites has increased 39 per cent over the last five years, and there were 59 countries with operators of at least one satellite (some as part of regional consortia). The report also found consumer services were a key driver for the overall satellite industry.

3.2 Market developments and strategies

3.2.1 Evolution of international Internet connectivity in the Pacific

Competitive markets, where a diversity of cables operate, clearly have a marked impact on the cost of capacity, as shown in the development of sub-Saharan Africa submarine cable routes. Initially, the only multi-country submarine cable servicing the continent was initially just SAT-3/WASC, except for the Mediterranean countries. The cable began operations in 2001 and the consortium owning and operating it was started by South Africa legacy operator Telkom SA, with investment parts by other incumbent operators along the route as well as with a few international operators. The cable runs from Cape Town to Portugal, stopping in some west Africa countries. Being the only international cable available (except in Senegal, which also had some limited capacity on Atlantis-2 to Brazil), the incumbent operators in the countries of each landing station had exclusive access to the capacity and were able to charge whatever the market would bear. Costs of capacity on SAT-3/WASC were

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13 www.pcworld.com/article/2947932/heres-what-to-takes-to-lay-googles-9000km-undersea-cable.html

14 www.alcatel-lucent.com/press/2016/alcatel-lucent-submarine-networks-and-cinia-demonstrate-record-capacity-144-tbits-c-lion1-submarine

15 www.alcatel-lucent.com/press/2013/002876

16 www.sia.org/wp-content/uploads/2016/06/SSIR16-Pdf-Copy-for-Website-Compressed.pdf

notoriously high, by some estimates, 50 times higher than capacity prices in the United States at the time[17], and often priced as high as satellite bandwidth.

The pace of liberalization was such that it was almost 10 years before the next cables came online and prices began to tumble. In 2009, the privately owned SEACOM cable was the first on the east coast, linking South Africa with Europe and India, and landing in a number of east Africa countries along the way. In contrast to the predominant consortium model for financing international cable links, SEACOM was the first private independently owned submarine cable in Africa (no telcos were investors). At launch, the company stated that it would reduce capacity costs by up to 95 per cent to wholesale customers and likewise it provided deep discounts on capacity for academic and research networks in the countries where it landed.

Of note is that SEACOM also began a trend of partnering with terrestrial and other submarine cable operators to provide redundancy and establish points of presence (POPs) in other coastal and inland locations, including destinations as far from the coast as Rwanda. This allowed the company to sell regional services to customers with multi-country footprints, augmented by wholesale Ethernet and global IP transit services on its network and not just traditional SDH links.

In the Pacific islands, with very small populations scattered over a huge area and isolated by the ocean, the international connectivity challenges are very different. Satellite has a much larger role to play and inter-island collaboration is key to ensuring the economies of scale can support submarine fibre to the larger islands. In addition, taking advantage of the opportunities to gain access to larger inter-continental cable builds has had a major impact for some the island nations.

By mid-2015, 14 of the 27 Pacific island clusters were connected to a submarine cable system, a major improvement over a decade ago when less than nine of them were connected. For the most part, the islands have to rely upon costly satellite connections for both international traffic and traffic within their clusters as the Islands are usually too far from each other to be connected by terrestrial microwave.

- Across the northern Pacific, there is a growing number of high-capacity trans-Pacific cables, with Guam and Hawaii being the only Islands directly connected, although Papua New Guinea is connected to Guam and Australia by the PPC-1 cable and a number of Islands in the Federated States of Micronesia and the Marshall Islands are connected to Guam.
- Across the southern Pacific, there is one trans-Pacific cable, the Southern Cross. Only Fiji and Hawaii are directly connected. An increasing number of smaller Islands are starting to gain indirect connection though and this incremental increase in submarine cable connectivity is a significant improvement, offering lower wholesale prices for Internet transit traffic, lower latency and with less danger of signal attenuation than by satellites, which are subject to rain-fade.

In addition, and subject to sufficient funding, at least two new Australasia to the west coast of the United States cables are being planned. The APX-East[18] and Hawaiki[19] cables will follow routes similar to the Southern Cross, over 12 000 km as the crow flies. APX-East is, like the Southern Cross, designed as a two-cable system at an estimated cost of around USD 450 million, but with a designed capacity of 40 Tbit/s and next-generation 100 Gbit/s wavelengths.[20] The 14 000 km Hawaiki submarine cable system is aims to be built by 2017 with a designed capacity of 8 Tbit/s,[21] offering 64 x 100 Gbit/s wavelengths.[22]

Like the Southern Cross, these cables are planned to land in Hawaii and could potentially offer spurs to the Islands of Samoa, American Samoa, Vanuatu and the Solomon Islands via Fiji, and then to Tonga,

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17 The Case for "Open Access" Communications Infrastructure in Africa: The SAT-3/WASC cable. Association for Progressive Communications. www.apc.org/en/system/files/APC_SAT3Ghana_20080516.pdf

18 www.subpartners.net/cables/apx-east-progress.html

19 www.hawaikicable.co.nz/

20 www.subpartners.net/cables/apx-east.html

21 www.computerworld.co.nz/article/435701/new_international_cable_new_zealand_proposed/

22 www.hawaikicable.co.nz/index.php/network

Niue, New Caledonia, Wallis and Fortuna, French Polynesia, Norfolk Island, Kiribati. The likelihood of all these spurs being constructed is slim due to cost and because indirect routes now become available. Even though, the American Samoa-Hawaii (ASH) cable could now be decommissioned. It is a re-utilized optical fibre cable built in the 1990s known formally as the PacRimEast (PRE) cable connecting Hawaii with Auckland.

Offering a potential connection to the Southern Cross and the proposed trans-Pacific cables are the growing number of shorter cables connecting neighbouring Islands as outlined in Table 1. For example, the Fiji to Tonga cable is over 800 km, the ICN-1 cable from Fiji to Vanuatu just over 1 200 km, and the proposed ICN-2 extension to the Solomon Islands a further 3 500 km, and to Papua New Guinea another 1 500 km.

Table 1: Cable systems and connected Pacific islands, 2015

Islands	Cables[1]
Guam (United States Territory) is a cable hub in the north west Pacific connected by six major trans-Pacific cable systems and connected to **Papua New Guinea**, the **Northern Mariana Islands**, **Marshall Islands** and the **Federated States of Micronesia**.	
Guam – **Federated States of Micronesia** – **Marshall Islands**	HANTRU-1 low-capacity cable system to the **Marshall Islands** and **Federated States of Micronesia**[2] – cables to **Palau** – **Yap** – **Kosrae** approved by WB and ADB
Guam – **Northern Mariana Islands**	MTC – **Rota**, **Sapian**, **Tinian**
Australia – **Guam** – Japan	Australia-Japan Cable via **Guam**
Australia – **Papua New Guinea (PNG)** – **Guam**	APNG-2; PPC-1 (PIPE Pacific Cable 1) + **PNG** Spur
Hawaii (50th State of the United States) is a cable hub in south east Pacific connected by four trans-Pacific cables and three cables connecting to Australia, **American Samoa-Samoa**, and **Tahiti**	
Australia – **Fiji** – **Hawaii** – United States west coast	Southern Cross
Australia – **New Caledonia**	Gondwana-1
Australia – **Solomon Islands**	
PNG – **Solomon Islands** – **Vanuatu** – **Fiji** – **Tonga** – **(planned) New Caledonia**[3]	Interchange Network cable (ICN-2) connecting **PNG to Solomon Islands** to **Vanuatu** awaiting construction; ICN-1 **Vanuatu** – **Fiji** built; **Fiji** – **Tonga** approved; a spur planned to **Noumea (New Caledonia)**
Fiji – **Samoa** – **American Samoa** – **Hawaii** – United States west coast	**Fiji** (approved) – **Samoa** – ASH cable (**American Samoa** – **Hawaii**)
Hawaii – **French Polynesia**	Honotua cable **Hawaii** – **Huahine**, **Moorea**, **Tahiti**, **Bora Bora**
Planned cables	
Australasia – North America	APX-East[4] and Hawaiki[5] cables – potential to link up **Samoa, American Samoa, Vanuatu, Solomon Islands, Fiji, Tonga, Nuie, New Caledonia, Wallis and Fortuna, French Polynesia, Norfolk Island, Kiribati**

[1] ITU www.itu.int/itu-d/tnd-map-public/; Greg's Map www.cablemap.info/; Futures Perfect http://futures-perfect.com/Cable%20Systems%20-%20by%20Country.pdf; http://submarinecablemap.com/#/

[2] http://en.wikipedia.org/wiki/HANTRU-1

[3] *Islands Business* (16th Jan 2014) www.islandsbusiness.com/news/fiji/4284/fiji-vanuatu-cable-to-go-online/

[4] www.subpartners.net/cables/apx-east-progress.html

[5] www.hawaikicable.co.nz/

Note: Names of Islands set in **bold**.

Source: TRPC research

3.2.2 Developments in the skies

In terms of satellite broadband, today there are five major operators: Eutelsat Tooway, HughesNet, ViaSat Exede, Inmarsat Global Xpress, and O3b. Other providers are affiliated with the established satellite operators. With high data rates and more reliable service, consumer satisfaction and confidence has improved, as illustrated by recent FCC broadband reports for best peak period download speeds using satellite. As a result, the satellite broadband market has seen 50 per cent revenue growth over five years, with subscriber numbers growing 11 per cent per year on average.[23]

Satellite for rural connectivity

New developments in satellite technologies and business models mean that satellite communications still has a major role to play in supporting national and international connectivity, in particular for rural and remote areas. Broadband demand is increasingly being met by the new high throughput satellites (HTS) and ground station equipment that have been developed to respond to the need for greater capacity. Through frequency reuse, spot beams and on-board processing, substantial reductions in costs have been achieved.

Eutelsat and Facebook for example are preparing to provide satellite connectivity solutions using in sub-Saharan Africa, based on Hughes' new Jupiter System, which can achieve 100 Mbit/s of throughput per terminal. The companies plan to use high-gain Ka-band spot beam capacity on the Spacecom Amos 6 satellite, which is due to enter service in early 2017.[24]

In 2014, Kacific has announced a five year contract with Tokelau.[25] Although a potential service drawback of Ka-band HTS in some regions is signal attenuation during heavy rainstorms, adaptive coded modulation (ACM) may be adapted to reduce the problem. It lowers signal power during a rainstorm to avoid fade and accelerates once the rain clouds have passed by. However, this is the reason why some satellite operators in the Asia and Pacific region are holding off a decision to invest in them.[26]

Medium earth orbit (MEO) satellite connectivity is gaining particular attention, offering even lower bandwidth costs compared to many GEO satellites while latency is reduced. The O3B (the 'Other 3 Billion' of unconnected people) satellite system consists of eight MEO satellites with hand-off between them.[27] The final four satellites were launched in 2014 and they already provide connectivity in the south Pacific to the Cook Islands, Federated States of Micronesia, Micronesia, Palau, Papua New Guinea, Timor Leste, and Samoa, and many other remote locations.

Next generation technology and innovation

A series of new technologies and innovative solutions based on miniaturization of electronic components are promising to provide new solutions to enhance connectivity. One example is the increasing role of various high altitude platforms (HAPs) such as drones as a miniaturized aerospace vehicle. Facebook, for example, has announced plans to launch drones with a wingspan greater than a Boeing 737 but weighing no more than a car that will soar at 60 000 feet (over 18 000 metres) using solar energy and laser beams to bring Internet connections to remote areas. Google 'Project Loon' HAP opts for Internet balloons 20 km above the Earth surface in the stratosphere guided by algorithmic software to calculate wind-speed and direction. By contrast, the Brazil Government *Conectar* project is experimenting with tethered balloons, fixed at an altitude of about 250 m, which could provide 'very high site' wireless connectivity at a distance of up to 50 km from the balloon[28].

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[23] www.sia.org/wp-content/uploads/2016/06/SSIR16-Pdf-Copy-for-Website-Compressed.pdf

[24] www.satellitetoday.com/telecom/2016/05/10/facebook-eutelsat-tap-hughes-for-jupiter-system-to-provide-internet-in-africa/

[25] http://kacific.com/tokelau-selects-kacific-to-deliver-high-speed-broadband/

[26] High Throughput Satellites: A Growing Opportunity in Asia. www.satellitetoday.com/publications/2014/05/14/high-throughput-satellites-a-growing-opportunity-in-asia/

[27] www.o3bnetworks.com/

[28] www.inpe.br/noticias/noticia.php?Cod_Noticia=3440 / www.theguardian.com/global-development/2014/jan/09/balloons-internet-brazilian-rainforest-amazon

Exploiting the economies of scale in the mass production of small satellites is also gaining increased attention, such as with the OneWeb project, which is partnering with Richard Branson's Virgin Galactic to launch a massive 648 spacecraft into 20 orbital planes at 1 200 km altitude to provide Internet globally at affordable prices. Through miniaturization, OneWeb ambitiously aims to bring the cost of each satellite down from upwards of USD 300 million to around USD 500 000.[29] Already developed is a new generation of miniaturised 'CubeSats' that can be fitted together on a modular basis and launched into low-earth orbit for less than USD 80 000.[30]

Helping bring down satellite launch costs is innovation in the space launch industry, with companies such as SpaceX developing reusable vertical take-off and landing rockets. SpaceX is also proposing to launch up to 4 000 satellites by 2030, which would provide universally accessible low-cost broadband and direct peer-to-peer connections.

It is too early to tell which emerging technologies will ultimately be the most suitable, but what does seem likely is that as some of these technologies move from fiction to fact and so will the idea of connecting everyone. By reducing both capital and operating costs, the demand for broadband access and services continues to grow and so the potential for financial sustainability of these projects should increase.

3.2.3 Leveraging the integration of terrestrial, submarine and satellite technologies

New network architectures, converged/unified licensing regimes and innovative business models for covering remote and rural areas can be used today to more effectively integrate the use of satellite, terrestrial and submarine telecommunication infrastructure, and as a result, new opportunities are emerging which can build on these developments.

The most evident trend in many countries has been the increasing involvement of mobile operators in building their own national fibre backbones, or forming partnerships with other operators to build shared fibre infrastructure. These operators often have presence in neighbouring countries and have found they can join their backbones to create cross-border links. As outlined below in the case of Kenya (see Figure 2), some countries with multiple borders have been able to take advantage of nearby submarine cable landings to become regional hubs which serve as a source of international capacity for their inland or landlocked neighbours. Many of these national backbones and cross-border links can be observed in the ITU interactive transmission maps[31].

A particularly good example of this trend is land locked Rwanda. The country has extended the government owned fibre backbone to all of its borders and it is now able to access submarine capacity from both Kenya (via Uganda) and Tanzania. The Tanzania route is the preferred one because it does not have to pay for the costs of going through a second country (Uganda) to obtain international capacity. In addition, the cross-border linkages, along with low cost of transit capacity in Tanzania, have been facilitated by the presence of the government owned national backbone in Tanzania and the good relations between the two countries. Once infrastructure is in place on the side of the Democratic Republic of Congo (DRC) of the Rwanda border, Rwanda is also expected to become the source of upstream capacity for the eastern DRC, which is currently cut off from the cable infrastructure present in the west of the country.

Across the sub-continent, this upstream/downstream role has also taken place in Cameroon (serving Chad), Ghana (serving Burkina Faso), Kenya (serving Ethiopia, Uganda and shortly South Sudan), Mali (serving Burkina Faso), Nigeria (serving Niger), Tanzania (serving Burundi, Malawi, Rwanda and Zambia), Senegal (serving Guinea Bissau, and Mali) and South Africa (serving Botswana, Lesotho, Swaziland, Zambia and Zimbabwe). In all of these situations, international traffic has essentially 'piggy-backed' on a national network deployment.

[29] www.bbc.com/news/science-environment-33268180
[30] www.ft.com/intl/cms/s/0/2ad23aca-e55a-11e4-bb4b-00144feab7de.html#slide0
[31] www.itu.int/itu-d/tnd-map-public/

Other recent examples of combined efforts to enhance connectivity include:

- Intelsat partnership with local satellite services operator Skynet de Colombia to bring high-speed broadband and Internet connectivity to 600 remote sites, across 250 municipalities in Colombia, making digital inclusion available to people who previously had no access and enabling the same types of advantages and services afforded to those who live in the more developed areas of Colombia.[32]
- Facebook strategy to deliver broadband to rural areas is shaping up to be multi-platform to include high-altitude aircraft and open-source telecom equipment, in addition to satellites. Within this context, Facebook had leased capacity on three in-orbit SES satellites to provide Wi-Fi connectivity in sub-Saharan Africa. SES said it would provide an undisclosed amount of transponder capacity to Facebook from three satellites – Astra 2G, Astra 2B, and Astra 4A. Astra 2G and 4A both have mixed Ku- and Ka-band capacity; Astra 2B is all-Ku-band. As mentioned above, Facebook has also partnered with Eutelsat to jointly lease the Ka-band payload on the Israel-based Spacecom Amos-6 satellite.[33]
- Intelsat satellite capacity supply agreement with Africa mobile communications company Vodacom to extend service to over 700 rural sites in the Democratic Republic of Congo, and has done so profitably with a cost-effective, quickly deployable solution that has given them a first-to-market advantage.[34]
- High throughput satellite Kacific is due for service by 2017 and aims to join an ITU initiative "to donate a total of 50 Mbit/s of dedicated bandwidth for a full year to the 11 Pacific island countries, complemented by 40 terminals. The total value of the donation is estimated to be about USD 380 000."[35]
- Intelsat has reached agreement with Detecon Al Saudia (DETASAD) to deliver Internet connectivity for corporate networks operating in and outside of Saudi Arabia, supporting financial transaction networks in the region (including thousands of ATMs), as well as maritime operators, oil and gas companies, government agencies and ISPs to help power the country's economy and deliver services to urban and remote areas.[36]
- Under the *Rural Satellite Connectivity Project for Pacific Island Countries*[37] – ITU is partnering with the International Telecommunications Satellite Organization (ITSO) and next generation satellite operators to fund services to Fiji, Kiribati, Marshall Islands, Micronesia, Nauru, PNG, Samoa, Solomon Islands, Tonga, Tuvalu, and Vanuatu. The estimated cost is between USD 500 000 – USD 1 million.[38] The initiative envisages up to 100 'e-centres' on the islands where costs can be shared among users, including government services, community centres, and the like. Two of the partners are the operators of the new 17-31 GHz Ka-band high throughput satellites (HTS) service providers using medium earth orbiting (MEO) satellites in elliptical orbits.

3.2.4 Emergence of regional hubs: where countries and cables interconnect

Regional hubs have emerged around the world wherever a large number of cables provide a competitive environment for international capacity. In east Africa for example, Kenya became a regional hub after

32 www.intelsat.com/intelsat-news/intelsat-and-skynet-de-colombia-bring-high-speed-broadband-connectivity-to-remote-areas-of-colombia/

33 http://spacenews.com/ses-announces-facebook-order-for-african-satellite-capacity-unclear-link-with-facebook-eutelsat-deal/#sthash.x8ZvfeRn.dpuf

34 www.intelsat.com/wp-content/uploads/2016/03/Delivering-rural-cellular-services-in-DRC-Vodacom-7251-CS.pdf

35 http://kacific.com/pacific-wave-conference-connectivity-key-to-economic-growth-and-resilience/

36 www.intelsat.com/intelsat-news/intelsat-and-detasad-enhance-broadband-connectivity-for-corporate-networks-in-saudi-arabia/

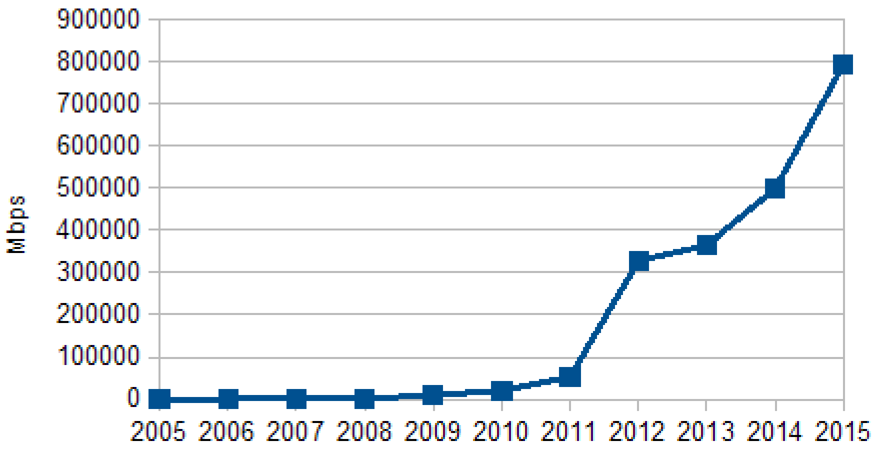
37 PITA/ITU (2013) 'Rural Satellite Connectivity Project for the pacific Island Countries'. www.itu.int/ITU-D/asp/CMS/Events/2013/PacificForum/ITU-APT-S1_Gisa_Purcell-Maui_Sandford.pdf

38 www.itu.int/net4/ITU-D/CDS/projects/display.asp?ProjectNo=7RAS14050

four different cables landed in Mombasa within the space of only five years[39]. This is seen as the result of Kenya's strategic location, combined with government investments in infrastructure and policy development, along with the general opening of the telecommunication markets in east Africa. With a competitive market for capacity, the cable landings in Kenya also serve as primary routes for landlocked countries inland – Uganda and Rwanda, as well as additional/backup routes for Burundi, Ethiopia, Somalia and Tanzania. South Sudan is also expected to obtain access via Kenya for some of its international capacity needs in the future.

With low costs of international capacity and a relatively competitive domestic market, Kenya network operators responded to the low cost of international capacity by investing heavily in local and backbone infrastructure. This, along with other local government initiatives caused Kenya's use of international capacity to take off exponentially, from 2010 onward, as shown in Figure 2.

Figure 2: International capacity in use in Kenya (Mbit/s)



Source: Communications Authority of Kenya www.ca.go.ke/index.php/statistics

3.2.5 Filling in the gaps and increasing capacity

As international capacity markets mature, new routes are often added to fill in gaps that were initially not covered. For example, despite the large number of cables now in service along both coasts of Africa, two major new submarine cable projects are planned that will provide alternate intercontinental routes, additional landing stations for countries with only one or two, and overall increases available capacity. Angola Cables and Telebras are currently planning to build the South Atlantic Cable System (SACS) between Angola and Brazil. Angola Cables is a consortium, comprised of incumbent Angola Telecom, ISPs MSTelcom and Movicel, and mobile operators Unitel and Startel. SACS was initially scheduled to enter service in the fourth quarter of 2014, but is now not expected to begin operations until 2017. The Cameroon government also announced plans last year for a cable linking to Brazil, but details are lacking.

More recently, Liquid Telecom, a southern Africa terrestrial cable operator, announced that it would build a submarine cable to link southern and east Africa with the Middle-East. The cable is expected to directly connect all coastal countries along the east coast of Africa and to provide new routes to the Middle-East and Europe. The project will include landing stations in several ports that are currently not served by existing sub-sea cables.

[39] SEACOM, TEAMS, EASSy, and France Telecom LION2. Also, soon LiquidSea. www.liquidtelecom.com/news-events/news/343-liquid-telecom-to-build-new-undersea-cable

3.2.6 Synchronising domestic network demand with international capacity deployment

The deployment of international capacity needs to take place in co-ordination with the development of domestic infrastructure, otherwise the economic viability of the investment in international infrastructure can be jeopardised. For example, in 2010 a privately financed[40] cable, MainOne, began service on the west coast of Africa, connecting Nigeria and Ghana to Portugal. MainOne rates for capacity were about 20 per cent of SAT-3 rates on the same route, but despite this, the company initially faced difficulties selling its available capacity due to the lack of local broadband infrastructure to service local demand in the countries where the cable landed.

This necessitated MainOne to build a Tier-3 data centre in Nigeria and to prioritise investment in extensions to its cable system in order to gain access to more customers. First, MainOne extended its infrastructure to Togo with an interconnection through Ghana, while servicing Benin from Nigeria. Then in 2015, MainOne built out its network from Lagos to Kribi, Cameroon. MainOne built the new system in partnership with Cameroon Telecommunications (Camtel) and Huawei Marine Networks, with additional investment provided by the Cameroon Government. Fortunately, the stubs had been planned into the original design of the cable and this allowed the company to substantially extend the reach of the MainOne system, both domestically and internationally, thereby much improving its overall revenue potential.

Similarly in October 2010, the Nigeria second national operator Globacom, launched its Glo-1 submarine cable, which linked Nigeria and Ghana to the United Kingdom. The cable was designed with a number of as-yet unused spurs along the way. In March 2016, Globacom announced that the cable would make use of some of its unused spurs and will shortly land in Cote d'Ivoire, Senegal and Gambia[41].

3.2.7 Using cable design strategies for optimal route sharing

Innovative cable designs can also be used to the optimal distribution of capacity to landing stations along the route. For example, in 2012, a consortium of network operators in countries on the west coast of Africa deployed the West African Cable System (WACS) linking South Africa to the United Kingdom, with 11 landing points along the way, providing a number of countries with their first direct connections to the global cable backbones (Namibia, DRC, the Republic of Congo, and Togo[42]). One of the four fibre pairs on WACS is a direct route from South Africa to Europe, a so-called express lane, which carries a large proportion of the overall traffic on the cable. The second and third fibre pairs are designed as semi-express lanes, one with two hops, from South Africa to west Africa, and west Africa to Europe and the other with three stops. The fourth pair is an omnibus fibre that stops off at all landing stations en route.

Also of note is that the landing stations support 'wavelength pass-through' which means that a wavelength coming into a landing station continues onwards through the rest of the cable system, allowing upgrades to be carried out without the necessity to perform an upgrade at each landing point.

One of the lessons learned in the ACE open access landing stations was to plan for the needs of the smaller network operators that wish to purchase capacity of less than an STM-1 (155 Mbit/s). This was not anticipated in some cases, and, as a result, the necessary multiplexing equipment to be able to divide capacity into smaller amounts was not budgeted for. The submarine landing stations took some additional time to obtain this equipment, leading to delays in being to sell capacity to small networks. This reduced the cash flow needed for repayment of the investment capital and delayed the provision of services by small operators.

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40 The major investors were the Africa Finance Corporation, the Pan-African Infrastructure Development Fund (PAIDF) and two Nigerian banks.

41 http://allafrica.com/stories/201603101216.html

42 www.oafrica.com/broadband/west-africa-cable-system-wacs-technically-goes-live

3.2.8 Maximising reliability by limiting the impact of cable breaks

The importance of taking measures to minimise the potential for accidental breakages and vandalism, and the need for ensuring sufficient resiliency through access to multiple physically different paths is highlighted by the experience of Kenya in 2012. In February that year, the TEAMS cable was accidentally cut by a Mombasa Ports Authority dredging ship. The repairs took about four weeks, because the repair ships were already occupied with multiple cable cuts between North Sudan and Egypt that had taken place at about the same time[43]. More than half of the networks in Kenya and Uganda were affected by the interruption and the impact of the break was exacerbated because TEAMS was also carrying re-routed EASSy traffic after three cables had experienced breaks in the Red Sea – Europe India Gateway (EIG), SEA-ME-WE 3, and EASSy[44].

The SAT-3 cable link to Nigeria was cut in June 2013 during a land reclamation project. As a result the local operator NITEL is said to have lost around USD 6 million in revenues during the period in which the infrastructure was inactive[45]. Similarly, the Benin SAT-3 landing station suffered a catastrophic fire that put it out of action for months.

Since the ACE cable began operations in 2012, there have been four service interruptions of about one week each (cable cuts or shunt faults[46]), two of which directly affected some of the west Africa countries due to the lack of an alternative international route. As a consequence, local operators were left scrambling to maintain limited services, which involved contracting for costly short-term capacity (USD 35 000/week for an STM-1) to other undersea cables via Dakar or Abidjan (fortunately the ACE cable had continued to function along these sections).

To accommodate the potential for service interruptions, most of the major international cables in Africa have made provisions for use of alternative routes in the event of a cut, and as a result, their customers can usually purchase 'protected' capacity at a significant premium. Alternatively, customers create their own resilience strategy by spreading their capacity purchases across different links if available.

Minimising the risk of cable breakages also needs to be part of the reliability strategy adopted by cable operators. This is especially important considering that multiple cables may be accidentally cut at the same time and repairs can take weeks. Using armoured cable, ensuring the route survey is accurate, deeper trenching and choosing the least risky but potentially longer route may increase the initial capital costs of the project, but in the longer term this is likely to pay off in lower maintenance costs and more revenues. Similarly, marking of the in-shore route and awareness raising with the shipping and fishing communities has helped to reduce the number of accidental cuts (about 70 per cent of all cable faults are caused by fishing and anchoring in depths of less than 200 m[47]).

Minimising the risk of cable cuts on point-to-point cables dedicated to serving small populations (such as connecting an island) is particularly important. This is because the main difference in establishing a dedicated small island link compared with participation in a larger cable project or consortium is that the risk of cost escalation cannot be spread across more participants. This suggests that projects require careful analysis to ensure the risk of unforeseen cost increases are reduced as much as possible, and in particular that the risk of cable breakages is minimised. Aside from the loss in revenues caused by service interruption, the costs to repair a cable fault can have a major impact on balance sheet, especially on thin route cables with more limited revenue streams. A single cable break can

43 www.cio.co.ke/view-all-main-stories/4948-cable-cuts-whos-up-whos-down-.html
44 http://online.wsj.com/article/SB10001424052970203833004577249434081658686.html
45 www.telegeography.com/products/commsupdate/articles/2015/02/27/cable-compendium-a-guide-to-the-weeks-submarine-and-terrestrial-developments/
46 A submarine cable shunt fault occurs when the cable insulation is compromised, allowing water to contact the copper conductor.
47 www.kis-orca.eu/subsea-cables/maintenance-repair-operations#.V2nL3mIrJZ0

costs hundreds of thousands of dollars to fix (a cable ship is needed to travel[48] to the area, find the break and pull the cable to the surface for repair).

3.3 Ownership and financing models for international infrastructure

3.3.1 Submarine cables

The shared ownership model is the basis of one of the most common strategies for deploying fibre – a consortium of operators club together to share the costs of the project for their mutual benefit. Each operator obtains a proportion of the overall capacity of the cable in proportion to its share of the total investment required. This is a sunk cost (aside from the annual maintenance fees of about 3-5 per cent of the capital cost), for which the operator can choose to recoup over a longer or shorter period, depending on their business/pricing model, for example by providing discounts for higher capacity purchases or longer contract lengths.

In the first two major submarine cables in Africa, the two different ownership models that initially emerged were the consortium model (SAT3/WASC), where a club of operators financed the cable in proportion to their use of the capacity provided, and the independent private investment group financing a cable 'startup' (SEACOM), where the primary aim was to take advantage of a market opportunity. Since then a variety of other business/financing models have also emerged, some with public-private partner (PPP) ownership and in some cases, state monopolies in landing station ownership.

EASSy – A hybrid consortium model

In contrast to the pure consortium or investor driven models that were used in the first two international cable projects in Africa (SAT-3/WASC and SEACOM), the next cable, EASSy,[49] was noteworthy for being a 'hybrid consortium', with an open access element to the cable ownership. This was achieved through the establishment of the West Indian Ocean Cable Company (WIOCC) as one of the shareholders in the EASSy cable (along with 15 other large on-continent and off-shore telecom operators). As a peer with the other consortium members, WIOCC is able to supply capacity at the same price to its own shareholders – 14 of the smaller network operators in Africa, with financial support from five international development finance institutions: International Finance Corporation (IFC), African Development Bank (AfDB), French Development Bank (AFD), German Development Bank (KfW) and European Investment Bank (EIB).

Similarly to the SEACOM and MainOne business strategies mentioned above, WIOCC also broadened its offering beyond purely the provision of capacity on the submarine cable, and has made investments in other submarine cables, providing its customers with route diversity and a virtual 'ring' around the continent. In addition, it has also established a number of inland POPs to provide capacity for networks located in land locked countries.

ACE – Open access landing stations on a consortium cable

Open access elements to international cables were also included in the subsequent and most recently deployed submarine cable, the Africa Coast to Europe (ACE) consortium financed system, which went into service along the west coast of Africa in December 2012. The USD 700 million project was initiated by Orange/France Telecom, primarily to support its subsidiaries along the west coast of Africa. However, some additional operators and a number of governments along the route also participated – Benin, Gambia, Guinea, Liberia, São Tomé and Príncipe, and Sierra Leone. These were supported by the World Bank West African Regional Communications Infrastructure Program

48 Alcatel now maintains a cable distribution and repair depot in Cap Verde, and a SAT-3 cable maintenance ship is stationed in Cape Town.

49 On the east coast, the Eastern African Submarine Cable System (EASSy), came online in July 2010, linking South Africa with Sudan and nine other east coast countries along the way with then the highest capacity system serving sub-Saharan Africa – more than 10 Tbit/s.

(WARCIP), which loaned each country the USD 20 to 25 million investment required for participation in the ACE consortium.

In each country, special purpose vehicles were established to manage the capacity and operate the landing station, in which the government and local operators took shares. The proportion of shareholding corresponded to the percentage of the landing station total bandwidth capacity allocated to the shareholder. A significant portion of the shareholding/capacity was held by government for future operators, as well as retaining some for their own potential use in public sector connectivity projects, such as connecting health and educational institutions.

It is also of interest to note that WARCIP financing not only covered the funds necessary to become a consortium member in the ACE cable but also included funds to support the development of an enabling policy environment for broadband infrastructure in the country.

As a result, of the ACE open access cable landings, capacity costs in the countries that did not previously have access to international fibre have dropped substantially. For example, in Liberia before the arrival of the cable, network operators were paying about USD 2 000/Mbit/s a month for international satellite connectivity. After the ACE landing, the mobile operator Cellcom 10 per cent share gave access to an initial 600 Mbit/s of capacity at a one-time cost of USD 2 million (not taking into account the Cellcom cost of finance). To provide a rough idea of what this means in effective costs, if Cellcom fully amortized the USD 2 million investment over only five years, its cost for international capacity would be just USD 60/Mbit/s per month – a reduction of over 30 times.

Table 2: List of investors in international submarine fibre infrastructure in Africa

Access Kenya Group	MaIN OnE
African Development Bank	Mauritius Telecom
Angola Telecom	MTN (SA)
Angola Cables	Neotel (SA)
BCS Group	OCPT (Office Congolais des Postes et
Benin ACE GIE	Telecommunications)
Bharti Airtel Limited (India)	ONATEL Burundi
Botswana Telecommunications Corporation	Orange Cameroon
British Telecommunications	Orange Guinée
France Telecom	Orange Kenya Ltd.
Broadband Infraco	Orange Mali
Cable & Wireless	Orange Niger
Cable Consortium of Liberia	Portugal Telecoms
Canalink	PT Comunicações
Comores Telecom	**Republic of Cameroon**
Congo Telecoms (formerly Sotelco)	**Republic of Equatorial Guinea**
Convergence Partners	**Republic of Gabon**
Côte d'Ivoire Telecom	Safaricom Ltd.
Dalkom Somalia	Saudi Telecom Company

DFI Consortium (World Bank/IFC, EIB, AfDB, AFD,	**Shanduka Group**
and KfW)	Sierra Leone Cable Company
Djibouti Telecom	Sonatel
Dolphin Telecom	Sotelgui
Etisalaat (United Arab Emirates)	SPIN Gabon
Expresso Telecom Group	Sudan Telecom Company
France Telecom	STP Cable (Sao Tome)
Gambia Submarine Cable Company	Tanzania Telecommunications Company (TTCL)
Gilat Satcom Nigeria	Tata Communications (Neotel)
Government of Kenya	Telecom Malagasy
Guineenne de la Large Bande	Telecom Namibia
Herakles Telecom LLC (Blackstone)	Telecommunicacões de Mocambique (TDM)
Industrial Promotion Services (Aga Khan Fund for	Telkom Kenya
Economic Development)	Telkom/Vodacom (SA)
International Mauritania Telecom	TelOne Zimbabwe
Jamii Telecom Ltd	The Government of Seychelles
Lesotho Telecommunications Authority	Togo Telecom
Libyan Post, Telecom and Information Technology	U-COM Burundi
Company (LPTIC)	Uganda Telecom Ltd.
Liquid Telecom Kenya Ltd	**VenFin Limited**
	Vodacom
	Wananchi Group
	Zambia Telecommunications Company
	Zantel Tanzania
	Zanzibar Telecom

Note: Names in **bold** reflect non-telecom investors.

Source: ITU

Lessons can be learnt from the experience of ACE. One issue with participation in many submarine fibre cable projects is that the administrative costs of the cable and landing station were higher than expected. For example, contributions to the ACE cable maintenance programme costs each landing station party about USD 720 000 per year, and staffing and power supply also needs to be covered. A revenue stream to cover these costs needs to be built into the initial business model or the budgeting and cash flow calculations. In the case of the Liberia ACE landing station, the shareholders dealt with this by each ceding 25 per cent of their capacity to the landing station itself, which could then sell this to smaller networks in order to cover the administration costs.

Another dynamic highlighted by the ACE cable experience relates to the fact that each consortium participant normally incurs remote activation fees to bring up the circuit on the ACE cable. In addition, as is the case everywhere, the purchaser of capacity on the cable must also pay transit fees at the destination to carry traffic on to the global backbones. Orange/France Telecom recently began using its market position to make the France cable landing more competitive with the Portugal landing by reducing the activation fee for circuits to France from USD 10 000 per STM-1 to a virtually negligible amount (USD 250/STM-1). This is expected to attract more business by helping to compensate for the higher transit fees that are present in France compared to Portugal (due to the higher level of competition from multiple cables landing there).

3.3.2 Satellite

The most significant aspect of HTS satellites is the business model they can offer based upon their greater efficiency at various stages along the communications chain.[50] Traditionally, in high-density regions, the 'Mbit/s model' is used where a single operator provides the whole range of satellite services, including Earth stations and terminals, and sells Mbit/s to an intermediary, such as an Internet service provider (ISP) and a content distribution network (CDN) or directly to end-users. In smaller markets, the 'MHz model' is more likely where the satellite operator leases out transponder capacity to different service providers that sell capacity to wholesale service providers on the ground that operate the Earth stations and terminals such as VSATs (very small aperture dishes) and satellite phones, and that separately package terrestrial Mbit/s retail services.

The lowest Mbit/s prices in the 'Mbit/s model' maybe around USD 1 800 per Mbit/s per month if 50 Mbit/s capacity is purchased and USD 800 if 100 Mbit/s is purchased. The corresponding figures for the 'MHz model' are likely to be USD 1 000 and USD 600. But for small projects providing rural connectivity where the economies of scale are lacking, the cost of a small C-band satellite capacity may well be around USD 3 000 per month. Although by lengthening the period of the contract to a minimum of ten years and negotiating a sharing of multi-transponders amongst islands it is possible to bring down costs per MHz by up to 80 per cent.[51] For individual islands even HTS prices can seem high, but if HTS transponder capacity can be shared with other islands using spot-beam technology that can target the footprint to multiple markets and costs can be reduced.

3.3.3 Regional backbones

Another approach to the provision of international capacity has been taken by some larger scale initiatives to create regional networks, which interconnect multiple countries terrestrially. These projects have consisted of knitting together national backbones, or completely new greenfield cable digs, or making creative use of existing passive cross-border infrastructure.

In the first category are the long-standing efforts of the regional economic communities to improve regional integration by linking together the backbones of the national operators, primarily the legacy fixed line incumbent operators. In southern Africa, this project is known as SRII (SADC), in west Africa; Intelcom II (ECOWAS) and EABS in east Africa (EAC). These projects have had limited success due to their reliance on often cash-strapped state owned or partially state owned operators with little incentive to invest in regional infrastructure. They have also been overtaken by multi-country mobile network operators that have linked their national backbones where they share common borders.

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50 This includes their use of spot beams to optimize coverage, by combining C, Ku and Ka-band transponders to maximize business opportunities, and by operating next generation gateways that can handle the higher throughput with greater levels of efficiencies while using less rack space, thereby reducing unit costs. See 'High Throughput Satellites and the Asia-Pacific Region' Dave Rehbehn, Senior Director, Marketing, International Division, Hughes Network Systems High.

51 Figures from www.itu.int/ITU-D/asp/CMS/Events/2013/PacificForum/ITU-APT-S1_Gisa_Purcell-Maui_Sandford.pdf

In total, four private network operators present on the continent have built significant multi-country optic fibre networks to provide regional connectivity services. These are:

- Etisalat/Maroc Telecom with the cross border networks it has built from its acquisitions or investment in operators in 13 countries in Africa[52].
- Orange/France Telecom, which has similarly built a regional platform through its operations in sixteen countries in Africa[53].
- Phase3, a Nigeria based private wholesale telecom infrastructure provider that uses high-tension power line infrastructure to provide an aerial fibre optic network in Nigeria linked to other west Africa countries. This has commenced with Benin, Togo and Niger, with on-going plans to extend the network to Ghana, Côte d'Ivoire, and as far as Senegal[54].
- Liquid Telecom, owned by Zimbabwe-based fixed and mobile operator Econet, has constructed a large regional fibre network spanning southern and east Africa through a combination of new buried cable and acquisition of other network operators. In March 2016, Liquid Telecom also announced plans for a submarine cable that will take another route to Europe via the Red Sea, and interconnect east Africa countries en-route[55].

Liquid Telecom's move into the submarine cable arena has parallels with the expansion of submarine cable operators into the terrestrial market, as described above for MainOne, SEACOM, and EASSy. Aside from Liquid Telecom's regional fibre backbone across east and southern Africa, it also has satellite and wireless operations in its group. In this respect regional operators are becoming increasingly air/land/sea agnostic in their international network offerings.

4 Countries with special challenges in meeting international connectivity needs

Connectivity issues vary tremendously from one country to another and it can be difficult to generalize about their causes and solutions. Nevertheless, it is also possible to identify countries that are likely to face the most difficulties in achieving affordable universal access.

Among the developing countries, these can be divided or selected, according to the following features or groupings:

- Small Island Developing Nations (SIDS) – as discussed earlier, these are nations isolated by oceans and combined with their small size, have low economies of scale relative the cost of providing international capacity
- Landlocked[56] low-income countries, dependent on their neighbours for obtaining international capacity, often at a much higher cost than their coastal counterparts
- Least developed, small coastal nations without submarine connections – dependent on terrestrial connection(s) with neighbour(s)
- Countries with, or emerging from, civil strife which has damaged infrastructure and have high real or perceived risk for investors.

52 www.etisalat.com
53 www.orange.com/en/About/Global-footprint/Orange
54 www.phase3telecom.com
55 www.liquidtelecom.com
56 Being landlocked refers to the geographical location of a country without direct access to the sea (Glassner, 1970). According to this definition, there are 44 landlocked countries in the world. Of these, the United Nations lists 32 as landlocked developing countries that are low and middle-income countries based on the World Bank country classification (LLDCs) with a population of nearly 440 million.

This section draws on case studies and examples from developing regions to identify and discuss the various policy and regulatory issues that have an impact on the development of international telecommunication infrastructure.

4.1 The case of the Pacific islands

Ensuring good international connectivity is a particularly difficult challenge for small island nations and other low-income countries with small populations or geographic isolation. This section draws on case studies in the Pacific islands to consider the special constraints they face, however the lessons may still apply to many other countries where connectivity issues may not be quite so severe.

Among the island nations of the Pacific, there are a variety of reasons for lack of access to international infrastructure:

- **Distance and remoteness**: the distance between island states is often thousands of kilometres, and between islands and islets within a Pacific island state frequently hundreds of kilometres, too far for the use of domestic microwave.
- **Size**: There are 21 Pacific island states. The largest is Papua New Guinea (PNG) with a population of over 7.5 million, followed by Fiji with a population of 890 000. Thereafter only nine states have populations above 100 000. The smallest is Niue with 1 000, Norfolk Island with 2 000 and Tuvalu with 10 000. The economies of scale for network investment are lacking, especially when these populations are scattered across many islands.
- **Scale and scope**: Due to small population size and often low incomes, the demand for value-added services has been limited. This is slowly changing due to the advent of the digital age and some markets will sustain new entrants and the demand for international connectivity.
- **High cost of submarine cables and satellites**: Investment for a single (no-redundancy) cross-Pacific submarine cable is not less than USD 200 million and the revenues to cover the investment come mainly from the demand for broadband capacity and services in North America and Australasia.
- **Lack of inter-island sharing**: Sharing satellite capacity is possible where satellites are capable of dynamic spectrum assignment (DSA), meaning they can split their transponder paths with beams to cover islands in different geographical locations. However, the Pacific islands have had difficulties in collaborating to bring about such cost-sharing arrangements.
- **Facilities and services competition**: In many islands, there has been a lack of competition due to the dominance of an incumbent and a failure of regulation to open markets, partly in the belief that markets are too small to support multiple operators or service providers. In recent years, this picture has changed dramatically, notably with the assignment of radio spectrum to competing mobile operators. However, regulations that open international capacity to competition through equal access to the cable landing station are lacking.
- **Information and knowledge**: A major hurdle facing the islands has been a lack of local expertise in rapidly changing telecom technologies, spectrum management best practices, in market data collection and analysis, and in incentive regulation. This has not been helped by loss of technology skilled human resources. Again, the picture is slowly changing, faster in some island states than others.

Fourteen of the 20 Pacific island states either have connectivity to one of the trans-Pacific Ocean submarine fibre cables or firm plans for a connection. This is a transformation from a decade ago when only nine were connected to cables. The submarine connections to the islands mainly owe their existence to the high-volume cable routes from Asia to Europe and Africa going westwards, and to East Asia and North America going eastwards. Very little of the traffic on the six cables actually originates or terminates in the Pacific islands. This is also true of the islands to the south.

Despite the fact that the Pacific island states are not in a strong position to take direct advantage of these economies of scale because the volumes of traffic they originate and terminate are too low, they can nevertheless benefit from the economies of scale elsewhere. As broadband and ICTs come to drive the surrounding economies of North America, East Asia, South-East Asia, Australia, and New Zealand, so these technologies and services are having an impact on the Pacific islands. For example, Internet and cloud computing are encouraging the spread of outsourcing and Fiji in particular has been developing as a centre of outsourcing for Australian companies for over a decade.[57] Another example is Tonga, where the use of Internet went up five-fold within six months of the opening of the cable to Fiji in 2013.[58]

However, Internet transit prices remain high, and this arises from low economies of scale. The wholesale price (USD 475/Mbit/s in November 2014) for access to the Tonga to Fiji undersea cable seems to be an issue of current capacity use, struggling to cover fixed costs of the cable. The wholesale price would be lower if more capacity is used. In effect, operators and the consumers are paying for the unused portion of the cable because the most significant cost of undersea cables is their fixed cost. The Vanuatu-Fiji cable, for example, costs about USD 350 per Mbit/s at 1.1 Gbit/s utilization, yet it has similar fixed costs to Tonga Cable Limited (TCL), such as a cable maintenance ship and landing station access in Fiji[59].

Hopefully, the growth of broadband-enabled sectors of the economy (from tourism and business process outsourcing to e-commerce, social media and online services, such as e-health and e-education) will ultimately be reflected in international bandwidth utilization. The current challenge is to put in place the local infrastructure that can help drive these developments.

4.2 The case of Rwanda: a landlocked country

Rwanda is a low-income, landlocked and predominantly agricultural country of around 12 million people, where even pre-paid wireless broadband is relatively expensive for most inhabitants. In terms of continental distances to submarine cable connectivity, it is akin to being a Pacific island.

Nevertheless, Rwanda has been proactive in securing access to closer submarine landing stations and is connected to two submarine cables on the east coast. The first, EASSY, is accessed through Uganda to the landing station in Kenya, a 10 Tbit/s, two fibre-pair configuration that was upgraded in 2010 to 40 Gbit/s wavelengths and in 2014 to 100 Gbit/s wave-lengths. [60] The second is the 5 000 Km East African Marine System (TEAMS).[61] TEAMS came online in 2009 and is planning to add a fifth underwater fibre to its capacity, which "will have larger capacity than the current four other cables altogether."[62] Partners in the cable include the Wananchi Group, owner of the Zuku pay TV and fibre brand with presence in Kenya, Tanzania, Malawi, Zambia, and Uganda[63], and Liquid Telecom, operator of the largest international terrestrial fibre open access cable network in southern and eastern Africa, including Rwanda.[64] MTN membership of the EASSY consortium allowed the operator to increase its broadband capacity to 355 Mbit/s from 200 Mbit/s, of which 155 Mbit/s was over optical fibre and 45 Mbit/s from backup by satellite.[65]

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57 Charles Davis, et al (2004) 'Realising the Development Potential of North-South Business Processing Outsourcing: The Case of Fiji'. www.ryerson.ca/~c5davis/publications/Davis-McMaster-Nowak-potential%20of%20BPO%20in%20Fiji.pdf

58 Noelle Francesca de Guzman (2015) 'What you need to know about the Internet in the Pacific' Internet Society. www.internetsociety.org/blog/asia-pacific-bureau/2015/06/what-you-need-know-about-internet-pacific

59 PRIF, 2015, 'Economic and Social Impact of ICT in the Pacific' p.54.

60 www.eassy.org/news.html

61 www.teams.co.ke/about-us/

62 www.teams.co.ke/kenya-lands-a-fifth-underwater-fibre-optic-cable/

63 http://wananchi.com/

64 http://liquidtelecom.com/about-us/network-map

65 Telegeography (2010) 'MTN Rwanda taking it EASSy in the New Year' 29 December. www.telegeography.com/products/commsupdate/articles/2010/12/29/mtn-rwanda-taking-it-eassy-in-the-new-year/

For any landlocked country to connect to cable landing stations via overland cables, the costs involved include rights-of-way, securing all the licences, permits and permissions that are required from different ministries and local authorities in each of the neighbouring countries, and then the costs of trenching and ducting or the construction of towers. If highways or railway tracks or power lines are available, this can cut the costs and the time it takes to build the cable connections to the coast, although where these conduits by-pass towns that need to be connected then additional costs will be incurred building spurs. Given these obstacles, by comparison laying a cable across the Pacific Ocean is relatively straightforward, but the important difference is that overland cables can more easily pick up traffic along the way, making the business case for the investment stronger.

Rwanda, along with Burundi, Kenya, Tanzania and Uganda, is a member of the East African Community (EAC) that, with backing from the African Development Bank (AfDB), has been supporting a number of initiatives that promote an integrated regional approach to a broadband infrastructure. Under its *Connect Africa* framework, the African Development Bank (AfDB) helped finance EASSY and is supporting the East Africa Broadband ICT Infrastructure Network (EAC-BIN). The latter is an effort to integrate the broadband networks of EAC Member States to promote cross-border broadband traffic and trade, link the landlocked countries to coastal landing stations and encourage the harmonization of broadband regulations across the region. A significant progress in this area was achieved through the joint EU-ITU *Harmonization of ICT Policies in Sub-Saharan Africa* (HIPSSA) programme for African, Caribbean, and Pacific Group of States (ACP).[66]

Building and operating cables across country borders is challenging. First, authorizations and licences are required for each jurisdiction. Second, cabling by ducting is generally more secure, but expensive. Cabling by towers and poles is less expensive, especially where facilities sharing may be involved, but more vulnerable to extreme weather and other causes of damage. In either case, selecting routes and permissions is time consuming and will incur expenses. Third, local carriers may raise obstacles if the cable operators are seen as commercial rivals. Fourth, regulations governing cross-border transit charges, interconnection charges, or accounting rates need to be established in an efficient manner. Similarly, local open access provisions are necessary to ensure that the additional capacity is available at competitive prices. And fifth, relations between neighbouring countries needs to be on a good working basis, unimpeded by conflicts.

The 'One Area Net' project is another important regional initiative taken by Rwanda as part of the EAC that will improve wireless broadband demand and usage by reducing roaming charges across the region, and it is already having an effect. Kenya mobile operator Safaricom has "already implemented the initiative with all operators in Rwanda, resulting in a reduction of retail roaming and international calling rates by 60 percent."[67] Rwanda cross-border traffic rose by more than 150 per cent (incoming) and 350 per cent (outgoing) after just one month following implementation in October 2014.[68]

Regional fibre networks

Two services that provide a direct link between international, regional and domestic markets are mobile roaming, as just discussed, and the other is broadband Internet connectivity and traffic. An important player in both Rwanda and the regional markets is Liquid Telecom, a subsidiary of Econet. In 2011, Liquid Telecom acquired ownership of the optical fibre network of Rwandatel, the Rwanda incumbent fixed-line operator, and in 2013 of Altech East Africa (AEA), a subsidiary of Altech of South Africa, and with it a combined ownership of a 15 000km optical fibre network straddling South Africa, Botswana and Lesotho in the south to Kenya, Uganda, Rwanda, the Democratic Republic of the Congo

66 EU-ITU (2013) 'Access to Submarine Cables: ECOWAS. www.itu.int/en/ITU-D/Projects/ITU-EC-ACP/HIPSSA/Pages/default.aspx

67 PC World (2015) 'One Network initiative creates cheaper calls in East Africa' 16 January. www.pcworld.com/article/2871992/one-network-initiative-creates-cheaper-calls-in-east-africa.html

68 ITU (2015) 'Regional roaming with East Africa – One Network Area. www.itu.int/en/ITU-D/Regulatory-Market/Documents/Events/2015/Sao_Tome/Session5-1%20_Lukas0regional%20roaming.pdf

(DRC), Zambia, and Zimbabwe in east and central Africa.[69] Liquid Telecom offers IP transit, VSAT, and high-speed data services through Altech Stream in Rwanda.

National networks

Within Rwanda, the national backbone optical fibre network was undertaken by a public-private partnership joint venture with Korea Telecom to support Internet and backhaul for mobile operators on an equal access wholesale basis. In 2014, the nationwide optical fibre network, which adds 3 000 km to network of Rwandatel,[70] started operations in support of a 4G LTE wireless broadband network.[71] The total cost of the network was estimated at USD 260 million of which Korea Telecom invested USD 140 million. A Public-private partnership joint venture company Olleh Rwanda Networks (ORN) operates the wholesale network, licensed for 25 years, and the three mobile operators (Airtel, MTN and Tigo) lease accounts from Olleh at wholesale rates and resell them to end-users.[72]

Another wholesale model is the sharing of towers. In 2013, MTN sold on a leaseback basis all its towers to IHS, a communications infrastructure company in Africa.[73] Towards the end of 2014, Bharti Airtel concluded a similar arrangement.[74] The Rwanda Utilities Regulatory Authority (RURA) has been particularly supportive of facilities sharing to reduce costs and encourage investment in network coverage and capacity, introducing comprehensive guidelines in 2011.[75] RURA is a standout case of incentive regulation, enforcement and transparency that is a key component of the success of Rwanda in driving access and the demand for connectivity. RURA and the Rwanda Development Board (RDB),[76] the agency responsible for the ICT Masterplan, have joint roles in the creation of, and access to, broadband networks in Rwanda. It may be compared to the role of the Singapore regulator, the Infocomm Development Agency (IDA).[77] Both sets of regulatory agencies play a proactive role in fostering the ICT sector linked to the development of technologies, such as fast Internet and HDTV that require broadband.

City metropolitan area network (MAN)

Part of the agreement with Korea Telecom was to construct the Kigali Metropolitan Network broadband network to interconnect all government agencies in the capital city, Kigali, and some homes and businesses using a high-capacity optical fibre backbone, including a RWF 4.5 billion (USD 6.2 million) WiBro project.[78] It complements the national broadband backbone (NBB) project to which the World Bank Regional Communications Infrastructure Program (RCIP) contributed USD 24 million.[79]

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69 "AEA operates a network of fibre-optic, satellite, WiMAX, Wi-Fi and microwave radio infrastructure across key markets in East and Central Africa, including Kenya, Rwanda and the DRC. The firm's subsidiaries also have interests in some submarine cable systems in the region such as TEAMs and SEACOM." BMI Research (2013) 'Liquid Telecoms Gains Scale With Altech East Africa Acquisition' 30 January. www.bmiresearch.com/news-and-views/liquid-telecoms-gains-scale-with-altech-east-africa-acquisition

70 Reuters 'Rwanda signs 4G internet deal with South Korea's KT Corp' 10 June 2013. www.reuters.com/article/2013/06/10/net-us-rwanda-internet-idUSBRE9590SH20130610

71 Republic of Rwanda 'Rwanda 4G LTE project scoops Global Telecom Business Innovation Award '15th May 2015. www.gov.rw/news_detail/?tx_ttnews[tt_news]=1193&cHash=20a177278a02e615b7520cdf478759dc

72 MYICT (2014) *Rwanda ICT Sector Profile 2013.* www.myict.gov.rw/fileadmin/Documents/ICT_Sector_Profile_2013/ICT_Sector_Profile_for_Web_copy.pdf

73 IHS 'MTN announces sale of mobile network towers to IHS in Rwanda and Zambia' 20 December 2013. www.ihstowers.com/media/press-releases/2013/12/20/mtn-announces-sale-of-mobile-network-towers-to-ihs-in-rwanda-and-zambia/

74 The New Times 'IHS, Airtel finalise tower takeover deal' 20 February 2015. www.newtimes.co.rw/section/article/2015-02-20/186161/

75 RURA (2011) Guidelines for siting and sharing of Telecommunication Base Station Infrastructure. www.rura.rw/fileadmin/docs/Board_Decisions/GUIDELINES_SITING_SHARINGB_BTS.pdf

76 www.rdb.rw/departments/information-communication-technology.html

77 President Kagame himself has referred to Rwanda as the "Singapore of Africa". CAI (2010) 'Going Online: Bringing the Internet to Rwanda'. www.consultancyafrica.com/index.php?option=com_content&view=article&id=384&Itemid=224

78 The New Times (2011) 'Kigali WiBro trail process impressive' 2 March. www.newtimes.co.rw/section/article/2010-03-02/17235/

79 World Bank (2015) 'Regional Communications Infrastructure Program (Phase 2) – Rwanda Project'. www.worldbank.org/projects/P106369/regional-communications-infrastructure-program-phase-2-rwanda-project?lang=en

According to the Rwanda implementing agency, the Rwanda Development Board (RDB),[80] the project has increased "the availability of broadband to over 700 Rwandan institutions including schools, health centers and local government administrative centers",[81] and assisted in interconnecting to the two east-coast submarine cable systems, EASSY and TEAMS.

A study in 2011 by the World Bank found a strong correlation in landlocked countries between policy liberalization and economic growth, and that opening the telecoms sector "would on average result in an increase of cellular subscriptions by 7 percentage points and an increase in mainlines by 4 percentage points."[82] Such developments provide the incentive for investment and for demand for international connectivity. Rwanda has adopted forward-looking ICT policies, well thought-out regulations to encourage investment in broadband networks and services, an openness to foreign investors and the adoption of a wholesale model of equal access built on a PPP-basis.

4.3 The case of a country emerging from civil strife

Countries emerging from civil strife or manmade disasters might be faced with a range of peculiar challenges, too. If not handled timely and effectively at the political level, those can result in bottlenecks to the development of and access to ICT services and applications. This is the case where, for instance, a foreign state detains control over the nation's international gateway or when all international traffic has to be routed through that foreign state. In some cases, national operators are not allowed to operate while foreign operators are, withholding radio spectrum for wireless broadband network investment. Restrictions on the assignment of radio frequencies for security reasons are sometimes extended to spectrum for the provision of mobile broadband services. In other cases, countries might not be adequately connected to otherwise available international connectivity links, fibre or satellite, because of the lack of political will or clearance. To illustrate a related issue, in Box 1 there is a non-exhaustive list of systematic obstacles to importing ICTs.

80 The original implementing agency was to be the Rwanda Information Technology Agency (RITA) that was also proposed by the government to invest in EASSY, but that initiative was finally given to MTN in the private sector. RITA was folded into the RDA. See MYICT ICT Sector Strategic Plan, 2013-2018, p.19. www.academia.edu/6160755/ICT_Sector_Strategic_Plan

81 Rwanda Development Board (RDB) Infrastructure. www.rdb.rw/departments/information-communication-technology/infrastructure.html

82 Ingo Borchert, et al. (2011) Landlocked or policy Locked? How Services Trade Protection Deepens Economic Isolation The World Bank. www.imf.org/external/np/seminars/eng/2011/trade/pdf/session3-Borchert-paper.pdf

Box 1: Systematic obstacles to importing ICTs

- Official list of restricted items listed under the dual-use (e.g., mobile phones) that need to be approved by authorities prior to import.
- Complex procedures regarding the import of such ICT devices and spare parts, and delay in equipment inspection and in security checks, thus disrupting the supply chain and ultimately penalizing customers of ICT services.
- High cost and delays related to clearance of the devices and appliances covered by manufacturer warranty that are requested by maintenance centres.
- Additional conformity and interoperability requirements imposed without legal ground.
- Strike action at ports and airports that increases shipment costs.
- Absence of a permanent and trusted import regulation information channels and lack of information on newly-introduced rules, procedures and regulations.
- Lack of business opportunities for local operators that are de facto excluded from the national ICT market.

Source: Author's research.

In all such cases, the impact upon the economy can be devastating. Income losses to the private sector as well as to the national government can reach hundreds of millions. Lack of broadband wireless connectivity implies lack of development of an ecosystem around it, lack of the applications that could increase the local productivity of users, lack of products and services to market at home and abroad, lack of devices for the spread of e-commerce and e-services, and lack of demand for streamed digital content. The consequences of denying international connectivity and 3G spectrum and therefore access to mobile broadband is not limited to consumer interests and convenience; rather, it has material consequences for the entire economy and society.

In this setup, the problems are political, not technical, financial or economic. Indeed, greater and cheaper international bandwidth would boost the economies, encourage inward investment and generate more international traffic. This suggests that interested stakeholders have an interest to find solutions that achieve a more open market and at the same time do not compromise on security issues. In other words, unlike cases in Africa and the Pacific islands, the focus of stakeholders is not likely to be primarily on the financial issues but on ways to surmount security concerns and barriers to entry.

5 Economics of international Internet connectivity

5.1 Factors having an impact on international Internet connectivity

In considering the demand-side factors that directly influence a country's international capacity requirements, aside from the obvious aspects of population size, economic development, language isolation and level of domestic network coverage, there are also a variety of other important factors:

- **The uptake of broadband and telephony among the local population**: in countries where access to broadband is unaffordable for many, or there are other basic constraints, such as limited electricity, the needs for international capacity will be correspondingly lower.
- **The role of the country in providing international capacity to neighbouring states**: some countries carry international traffic for their neighbours, most often because the downstream

countries are landlocked, or in need of backup routes for traffic, or because operators there wish to take advantage of the lower international capacity prices that may be present in the upstream country (often a 'hub' country with access to many different international cables – see below).

- **The availability of local applications and content**: if these are at low levels of development, then the local population is likely to access a higher proportion of international content, for example if there is a lack of local e-payments platforms. By the same token, if the country is the source of applications and content that are in demand elsewhere in the world, then international bandwidth needs will also be correspondingly higher.
- **The level of interconnection between local networks**: when there is a low level of development of hosting and interconnection infrastructure (data centres, leased lines, Internet exchange points (IXPs), then domestic networks must exchange traffic between each other abroad, resulting in even higher needs for international capacity, than would otherwise be the case. Similarly, little content will be hosted locally. Along with physical network interconnection, operators have also adopted widespread use of content caching facilities[83]. These and other shared local resources, such as DNS servers, reduce international bandwidth needs while improving network performance for users. However, this only takes place when the domestic distribution infrastructure is in place, which is not yet the case in all countries. As a result, some countries have unnecessarily high needs for international capacity.
- **The degree of language isolation of the country**: in smaller countries that have less common national languages, the population is more unlikely to visit international sites; the most well-known example of this is the Republic of Korea. Other cultural, demographic and climatic factors may also affect relative levels of broadband utilisation between countries, however little research has taken place to identify their significance.
- **The level of international content blocking**: some countries have put in place measures to limit access to foreign web sites, which results in relatively lower needs for international capacity, and by the same token, less local capacity is also required.

5.2 Barriers to connectivity

International connectivity projects can be subject to delays

The inherently multi-country nature of international connectivity projects can lead to unexpectedly long lead times before the project is finalised. The development of the EASSy cable project was a protracted process that took four years, subject to extended negotiations between the country governments and state owned operators along the east coast. The delays, combined with doubts over the initial business model that was proposed, lead the Government of Kenya to fast track an independent submarine cable project in partnership with United Arab Emirates incumbent operator, Etisalat, called The East African Marine System (TEAMS). The cable directly linked Kenya with the Etisalat hub in Fujairah, and 20 per cent of the cost was financed by the Kenya Government, with the remainder from Etisalat and Kenya network operators.

High cost of cross connects

An issue encountered by many cable operators where landing points are in markets with little competition or regulatory oversite, such as in the cases of both EASSy and TEAMS, was the high cost of the cross-connect fees charged to allow the passage of traffic through to the other cables present at the landing point. TEAMS and EASSy are relatively short cables and do not land at one of the globally competitive hubs in Europe or Asia. Therefore to provide access to the global backbones, as well as to maximise resiliency, short fibre cables (the cross-connectors) need to be present between the landing stations of the different cables present – in this case, in Djibouti (EASSy) and Fujairah,

[83] As a result, many of the most popular international web sites and streaming video services such as Youtube, Facebook, and Netflix actually use much lower amounts of international traffic than would be expected.

United Arab Emirates (TEAMS). In many cases the cable lands at a station that hosts multiple cables, so installation of cross-connects is often relatively trivial.

For EASSy, the cross connects are levied by the incumbent monopoly operator, Djibouti Telecom, which charges more for 1 metre of cross connect cable to the SEA-ME-WE-3 (for example), than it costs for capacity from Djibouti to London. Similarly, for TEAMs, to get to Europe, high cross connect charges are present in Fujairah where the landing station is owned by Etisalat.

Challenges to open access/equal access models

Open access business models for infrastructure help ensure that smaller operators are not disadvantaged when competing against larger operators, which helps to drive down capacity prices, however these models are not as easy to implement as the traditional consortium or private investment models. The West African Cable System (WACS) cable project for example, was originally planned as an open access project, initiated by the South Africa Government in early 2008 to ensure reliability and sufficient low cost international capacity to cater for the FIFA 2010 football world cup. Negotiations between potential participants in the cable project took longer than expected. One of the sticking points in the negotiations was that the larger operators (such as MTN, Telkom and Vodacom), who were going to invest the bulk of the funds for the cable, did not wish to assume the majority of the financial risk without being able to obtain a capacity price advantage over the smaller investors.

In the end, the interests of the larger players won out and the cable became a traditional consortium of the larger players, and the other smaller telecom operators in the region were excluded from making minor investments in the cable. Because of this, and due to there being only one consortium investor in the cable per country, prices for WACS capacity are controlled by a single landing party/investor (except in SA). As a result, operators in the other countries where the cable lands are able to charge prices that make it less competitive for other carriers to use capacity on the system, even those investing in the cable from other countries.

Landing station fees and local ownership requirements

Fees to the government for establishing a submarine landing station and local ownership can also drive up the cost of international capacity. To make investment in the provision of submarine cable infrastructure more attractive, some countries have adopted limits to submarine landing fees.

A related issue is that incumbent fixed line operators are in some countries still seen as having rights to all international infrastructure. For example, in the case of WACS, the landing station in Cameroon was initially owned by mobile operator MTN, but the government decided that the incumbent fixed line operator, Camtel, still had the only rights to service international traffic, and after long negotiations, the landing station was eventually transferred to the Cameroon Government in 2012.

6 Possible operational strategies for improving connectivity

6.1 Ensuring reliability

In international backbone infrastructure and cross-border links, at least two physically independent connections are usually required for reliability. Ideally, more than three will also help to ensure competitive pricing based on market forces, thereby reducing the burden of regulated pricing. Similarly, access to a minimum of two independent submarine cable landings and/ or satellite redundancy is required for reliability, while competitive pricing is usually achieved with more than two landing stations.

6.2 Joint planning and shared deployment costs

In terrestrial networks, the civil works necessary to bury the cable is by far the largest cost item for new optic fibre deployment (up to 90 per cent). The bulk of this investment is preserved if dig-once policies are in place and coordinated duct planning is carried out[84]. Thus, the financing required in order to upgrade links to meet additional demand will be much smaller than the initial Capex. Once the ducting and fibre is in place, marginal investments are required to upgrade capacity when it is needed, and costs can easily be covered by the revenue generated by the link.

Inclusion of ducts on all new roads/rail lines, pipelines and power grids infrastructure cuts costs for cable deployment by an order of magnitude, helping to ensure affordable pricing and encouraging investment in low traffic cross-border links and rural areas that would otherwise be uneconomic to serve. The additional marginal cost for the inclusion of ducts or fibre in these utility infrastructure projects usually adds less than 5 per cent to the overall budget, and the benefits more than justify the added expense.

In particular, optic fibre and electric power distribution are often deployed together to achieve considerable cost savings. Optic fibre is normally included in high-tension power lines to provide high speed communications to control the substations, and excess fibre cores can be used for telecommunication purposes. Additional fibre cores solely for telecom purposes can also be included when planning the energy distribution network.

In many cases, high-tension power lines are used to distribute power across borders, resulting in many opportunities to use these grids to establish low cost international fibre links. As a result, many communication network operators around the world have formed partnerships with electricity supply networks to provide capacity. In addition, a number of power distribution agencies have formed subsidiaries to sell telecommunication capacity on their networks.

Perhaps less well-known is that this approach can also be used when supplying electricity through sub-sea cables. For distances up to 500 km, submarine power distribution is now a well-established industry[85]. Optic fibres are already included in cables manufactured by companies such as Nexans[86] that, for example, supplied a system to provide power between two Indian Ocean islands (Pemba and Zanzibar) and this link is now being to provide telecom capacity.

84 Conduit/ducts of sufficient size and buried sufficiently deeply (or protected overhead) to minimize the chances for accidental breakage or vandalism.

85 http://en.wikipedia.org/wiki/Submarine_power_cable for a list of submarine cable projects.

86 Nexans marine power and fibre optic cable supplier: www.nexans.co.uk

Figure 3: 3-Core AC submarine power cable

Source: Nexans

6.4 Planning for future links – submarine cable branching units and stubs

Submarine cables are generally not amenable to adding branches or spurs after the cable has been deployed. Each landing station location needs to be already known when the cable is being planned. In some cases, the cable operator may have a high degree of confidence that a new landing station will be required at a date after the cable has been deployed. In these cases, the cable can be deployed with a stub at the appropriate location, which makes it possible to extend the cable to the new landing at some point in the future. For example, both the MainOne and Glo-1 submarine cables running along the west coast of Africa have left stubs for future landing stations. The ACE cable, also running along the same route, recently made use of a stub it had left for Benin, which had not been able to finalise its participation the project by the time the cable was initially laid.

6.3 Linking coastal countries: Festoon systems

Coastal festoon systems use low cost repeaterless fibre cables, which require no submarine power or electronics. The systems have been used as a means of connecting points up to about 500 km apart, and are often strung together to link a series of coastal cities.

Depending on the location, festoon systems also present an option for meeting some international backbone requirements, however backup links are also required to ensure reliability when disruptions occur.

6.5 Making use of the next generation of high-capacity satellite systems

The main features of the newly emerging satellite systems is that they are relatively fast to develop and cheap to build and launch, compared to their earlier counterparts. In addition, they make use of low and medium earth orbits (LEO/MEO). Being located much nearer to the Earth surface compared to geo-stationary satellites, this greatly reduces the latency or lag; the time that takes for signals to travel from the Earth to the satellite and back again (about 130 ms for packet round trip time compared to about 650 ms for a geostationary satellite). The effect is to greatly improve performance when compared to geostationary satellites, allowing the satellite operators to provide a quality of service that is much closer to fibre.

LEO/MEO orbits have been used before, for relatively low capacity data and some voice, however the new satellites offer considerably more capacity, and thus cost savings over traditional satellites. For example the O3b system of 12 satellites, which have already been deployed, is able to provide capacity at about USD 400/Mbit/s. By using two earth station terminals, capacity available on a single link is up to 800 Mbit/s downlink and 650 Mbit/s uplink.

As a result, a growing number (31 in mid-2016) of mainly island countries have adopted the O3b service, including the Cook Islands, East Timor, Papua New Guinea, South Sudan, Madagascar, and the DRC. The Solomon Islands, Palau are among other island nations that are in the process of implementing them. In American Samoa, O3b is a backup for the existing fibre-optic network.

The O3b current total constellation capacity is 192 Gbit/s. Given that this is less than two wavelengths of a single fibre, it is apparent that current satellites will not be used for the major routes between countries, or even for backing them up, but will instead find their chief use in domestic thin-routes and perhaps to link some very small island nations.

However, new projects in planning propose to use constellations of hundreds if not thousands of satellites to provide cheaper and higher capacity links than currently available. One such project is OneWeb, which is aiming to launch 648 small satellites into 20 orbital planes at 1 200 km altitude to provide Internet globally at affordable prices. OneWeb aims to bring the cost of each satellite down from about USD 300 million to USD 500 000.[87] Started by Virgin Galactic and Qualcomm, OneWeb has announced that it has secured USD 500 million in initial investment from additional partners Airbus, Bharti Enterprises, Hughes Network Systems, Intelsat, Coca-Cola and Totalplay.

Similarly, Oneida, LeoSat, and a variety of other initiatives are in the process of investing billions in high capacity satellites.[88] A new generation of miniaturised 'CubeSats' have already been developed that can be fitted together on a modular basis and launched into low-earth orbit for less than USD 80 000.[89] In addition, satellite operators Iridium and Globalstar have begun plans to launch a series of LEO satellites to provide broadband and voice services. Helping bring down the launch costs is the idea of Elon Musk, a founder of PayPal and the Tesla electric vehicle, whose SpaceX project is developing reusable launch vehicles.[90]

If these projects come to fruition, it is possible to envisage that a different topology for the direction of some international traffic may exist at some time in the future – where data packets never touch the ground at all, moving directly between the satellites linking two individuals in different nations.

Last but not least, a variety of innovative new high altitude platforms are being tested as options for better local connectivity. These include drones, high altitude and tethered balloons, as described in section 3.2.1.

87 www.bbc.com/news/science-environment-33268180
88 http://wftp3.itu.int/pub/epub_shared/BDT/2016/2016-Trends/flipviewerxpress.html
89 www.ft.com/intl/cms/s/0/2ad23aca-e55a-11e4-bb4b-00144feab7de.html#slide0
90 www.spacex.com/news/2013/03/31/reusability-key-making-human-life-multi-planetary

7 Policy and regulatory consideration with regard to international Internet connectivity

7.1 Easing access to rights of way

As indicated in the discussion above efficient permitting and affordable access to rights of way (ROW), for green field digs, as well as on utility infrastructure such as roads, energy grids, rail lines, fuel pipelines and sanitation systems, are important to help minimise the financing needs for cable infrastructure and to reduce delays in deployment.

Where roads, power grids, pipelines and rail link cross international borders, smooth access to rights of way can substantially simplify the process for laying cable along these routes.

7.2 Addressing land crossing requirements

Local land crossing laws may need to be taken into consideration in deploying multi-country cables. One of the unexpected issues encountered by SEACOM when laying its cable up the east Africa coast to France, was that it was unable to traverse the Suez Canal, and was instead required by Egypt to make a 'land crossing' to Alexandria and continue from there. The land crossing needed to take place through leasing capacity from Telecom Egypt, which added to the overall cost of services to SEACOM customers. The other submarine cables following the route from the Indian Ocean to the Mediterranean have also been required to make land crossings, although the FLAG cable actually travels along the Suez Canal route (not actually under water, but along the canal wall).

7.3 Regional mechanisms to ensure equal access by all network operators

At a regional policy level, the Economic Community of West African States (ECOWAS) has developed regional guidelines[91] in 2011 for policy makers in Member States to promote better access to submarine cables, especially for the land locked countries and operators that are not members of cable consortia. The guidelines were developed with assistance from the ITU HIPSSA project to help harmonise ICT policies in ACP countries, and building on existing regulatory frameworks on interconnection. It is still necessary to transpose the guidelines into regulations within national frameworks, at which point they will aim to ensure that:

1. service providers have access to the international bandwidth capacity under the same terms as cable consortium members;
2. access is not be unduly prevented or delayed by the consortium member having control over cable landing station;
3. landing stations have transparent and non-discriminatory access charges.

7.4 Political projects

Some regional projects have had a broader political dimension to support continent-wide socio-economic integration. In support of this vision, in 2012 African Heads of State endorsed the Programme for Infrastructure Development for Africa (PIDA), which is an integrated programme of projects across the continent for energy, transport, ICTs, and water infrastructure[92].

One of the ICT components of PIDA was designed to respond to earlier requests by Heads of State to close infrastructure gaps and ensure that every country on the continent has access to at least

[91] www.itu.int/en/ITU-D/Projects/ITU-EC-ACP/HIPSSA/Documents/FINAL%20DOCUMENTS/FINAL%20DOCS%20ENGLISH/submarine_cables_ecowas_regulation.pdf
[92] www.au-pida.org

two international fibre optic cables. Partially in response to this, a joint declaration was signed by the governments of Algeria, Niger, and Nigeria for the roll-out of a 4 500-kilometre terrestrial cable running from Algeria to Niger and to Nigeria, taking advantage of the planned Trans-Sahara Highway and fuel pipeline on that route. The project was initially scheduled for completion in 2013 and although Algeria and Nigeria had built backbone infrastructure to their borders, Niger and Chad lacked the funds for the construction of the 200-kilometre link from Assamaka (Algeria) to Arlit (Niger). Then in early 2016, the African Development Bank announced that it would fund the missing link[93].

7.5 The island-hopping approach

The 'island-hopping' approach involves linking islands together with submarine cable using international aid and supporting loans to these island economies, for example, the World Bank and the Asian Development Bank (ADB). Similar to the financing of the ACE open access landing stations described earlier, the strategy involves individual Pacific island states in contractual relationships with the DFIs, including their adoption of good regulatory practices, such as equal access, transparency and the promotion of competitive markets, and at the same time involves collaboration between the Island states as traffic transits between them.

In the past, it often proved difficult to achieve collaboration despite the efforts of regional organizations to promote the common good, due in part to the uncertain economic and financial returns involved. But as modern economies come to depend ever more on ICTs, this in turn drives up the volumes of international traffic, so the economic returns become more transparent and attainable, especially in areas such as tourism, health and education, monitoring and managing the marine environment to reduce over-fishing, and coping with early warnings and disaster relief. These activities are in turn expected to ease some of the financial burden of investment in submarine cable capacity.

7.6 Regional connectivity initiatives

The regional connectivity initiatives of the World Bank in west and east Africa have been discussed earlier, and similar such initiatives exist in most other developing regions of the world. For decades, the goal of providing international telecommunication connectivity across such vast distances by satellite or by submarine cable has been an agenda item of multilateral and aid agencies, and of regional organizations such as:

- the Pacific Forum, the Pacific Islands Telecommunications Association (PITA);
- the Pacific Islands Computer Emergency Response Team;
- the Pacific Islands Internet Chapter of the Internet Society (PICISOC);
- the World Bank-funded Council of the Regional Organizations in the Pacific (CROP);[94] and since 2010-11
- the Pacific ICT Regulatory Resource Centre (PIRRC).[95]

To meet challenges of bringing international connectivity to the Pacific islands a necessary step has been the collection and analysis of data to identify the gaps, the needs and the potential benefits. But that too has proved a challenge and to meet it, in 2008 the World Bank and other donors supported the establishment of the Pacific Region Infrastructure Facility (PRIF).

93 http://allafrica.com/stories/201603280956.html. Also see PICI 2015 annual report: www.nepad.org/resource/presidential-infrastructure-champion-initiative-pici-report

94 CROP comes under the auspices of the Secretariat of the Pacific Islands (SPC), which includes all 22 Pacific islands, see http://gsd.spc.int/crop and also www.spc.int/en/about-spc/history.html

95 Founding members: Cook Islands, FSM, Fiji, Kiribati, Nauru, Niue, Palau, PNG, RMI, Samoa, Solomon Islands, Tonga, Tuvalu, Vanuatu. www.pirrc.org/home/index.php?option=com_edocman&task=document.viewdoc&id=50&lang=en

In addition, a growing cause for optimism is the increasing involvement of regional organizations and their collaboration with multilateral agencies and other stakeholders, such as investors in networks, including the donor agencies and investment banks, other regional bodies and regulatory associations, and island governments. For example, ITU has partnered with other entities such as, for example, the International Telecommunications Satellite Organization (ITSO) in its initiative and part-funding of the *Rural Satellite Connectivity Project for Pacific Island Countries* project.

Another initiative, started in 2009 with the European Commission, is the project on *Capacity Building and ICT Policy, Regulatory and Legislative Frameworks for the Pacific Island Countries* (ICB4PAC)[96], which focuses on ways to achieve broadband universal access and service and looks in detail at 15 Pacific small island state economies. The project is also part of the ITU-EU *Harmonization of Policies for the ICT market in the ACP*[97] programme, working in close collaboration with the Pacific Islands Forum Secretariat (PIFS), Secretariat of the Pacific Community (SPC), Pacific Islands Telecommunication Authority (PITA), and the Pacific ICT Regional Regulatory Centre (PIRRC) and supported by the University of the South Pacific (USP).

7.7 Domestic infrastructure and demand building

The synergistic relationship between international and domestic infrastructure has been referred to a number of times in this report – good local broadband infrastructure builds demand for international capacity, and vice versa.

Thus, one of the key issues for countries with special challenges in international connectivity is to stimulate sufficient demand so that connectivity solutions can be more sustainably deployed. A wide variety of factors affects the uptake of bandwidth. These in turn also affect supply, by making it more or less attractive for new providers to enter the market, or for existing suppliers to take advantage of improved economies of scale. The key demand-side factors include:

- Cost and coverage of access, which is directly influenced by the level of competition in the sector and by the business strategies of the wholesale and retail providers, such as low-cost data plans and usage independent tariffs, and distance independent cross-border tariffs implemented by the regional mobile operators.
- Availability of payment services, multimedia services, local language content.
- Indirect constraints such as literacy and income levels, availability of electric power, import duties and service taxes.
- Extent of smartphone, tablet, IP TV and personal computer usage.
- Government as a consumer – government is potentially a very large consumer of broadband and can therefore have a big impact on the level of demand.
- Other anchor consumer, such as universities, medical centres, financial institutions and others.

7.8 Capacity building and innovation

Another related challenge facing these countries is human capacity in policy-making, such as experience in drawing up well-formulated legislation, effective enforcement and a transparent, accountable and corruption-free environment. Ongoing capacity building programmes are needed here. An additional strategy here is to quickly respond to new technology developments, which could have an impact on access provision by setting up innovation units within governments to test the feasibility of emerging technologies. Such units could identify regulatory roadblocks and also

[96] ITU (2013) Universal Access and Service: Knowledge-based Report ICB4PAC www.itu.int/en/ITU-D/Projects/ITU-EC-ACP/ICB4PAC/Documents/FINAL%20DOCUMENTS/uas.pdf

[97] African, Caribbean, and Pacific Group of States (ACP).

work closely with other stakeholders to gauge the prospects and implications of these emerging technologies.

Making use of the latest technologies and innovative business models will also be a special priority for these countries in order to build sufficient demand. This could range from using the new HTS satellites and dynamic spectrum access technologies such as TV White Space (such as the example of the Philippines), to providing free WiFi in public spaces.

In this respect innovative uses of radio spectrum and new means of managing spectrum are emerging as important tools to meet connectivity needs at low cost. As a result, expertise in the area of radio spectrum and adoption of strategies to maximise the potential of innovative use of spectrum may be needed.

Unlicensed WiFi technologies hold particular promise for stimulating demand because the technology is very mature; anyone with a smart phone can use it and it is highly cost effective. An interesting example of an initiative using WiFi is Liquid Telecom in Kenya, which will this year invest USD 1 million in hundreds of free WiFi hotspots[98]. The company has launched an app mapping the more than 350 free Wi-Fi hotspots it has installed so far across the country, all of which have some form of free, public access, running from a minimum of 15 minutes of free use to unlimited free use. The project uses a local partnership model, so for example, the hotspots in the town of Nakuru are between the State House Digital Team, Nakuru County government and Liquid Telecom.

A platform for ideas in innovation, covering technologies, finance and regulations is a constructive way to engage stakeholders. This can be supplemented with data collection and analysis of global, regional and local trends to identify emerging opportunities, and to help develop business planning models and identify special needs. An advantage of this approach is that these units can work together with enterprises that develop these technologies to be involved in shaping or 'co-creating' the technology so that it more fully suits the local needs of the country. Such 'innovation centres', are already operational within governments in countries such as Denmark, Singapore, South Africa, and United States.

7.9 Special arrangements for landlocked countries

As indicated above, a particular problem for the landlocked countries is the inherent extra costs of traversing the networks of neighbouring countries in order to reach the submarine landing stations. This makes it much more difficult for these countries to achieve the same level of wholesale pricing for bandwidth that can be achieved by the coastal countries.

Considering the importance of this issue, and that there is often government participation in many of the national fibre backbones, one option is to reach agreement at the regional policy level to determine a specified price for cross-border wholesale capacity. For example, this approach has already been used to set common electricity tariffs across west Africa for use of the West African Power Pool (WAPP).

7.10 Ensuring strong regulation to address market dominance

Ultimately, considering there are likely to be only a few dominant operators in these markets, a vital component in any strategy for connectivity challenged countries will be the role of regulation in ensuring services are affordable. In particular, regulation will need to focus on the conditions of access to cable landing stations, and/or the wholesale pricing models the incumbent is permitted to use.

Aside from the standard tariff cap, other innovative ways of regulation in this area need to be considered. For example, in the Pacific, the PRIF has suggested that the high wholesale prices charged in Tonga could be paralleled by larger allocations of unutilized bandwidths at those prices. This would

[98] www.telecompaper.com/news/liquid-telecom-launches-app-mapping-350-free-wi-fi-hotspots--1135596

maintain the revenue to the incumbent and at the same time give service providers an opportunity to reduce retail prices and to stimulate the domestic market.[99]

8 Principles and guidelines for ensuring better international access

To aid in the process of formulating the most appropriate local strategies to improve international and domestic connectivity, based on the lessons outlined above, a set of guidelines with high level principles to promote communication infrastructure development has been developed, as described in detail below.

The set of guidelines aims to provide a systematic way of ensuring that all the relevant factors affecting the connectivity environment are identified and addressed. The assumption is that if all the building blocks that are described below are present at their optimal levels, then the country in question will have a sufficiently enabling environment and an unobstructed potential to achieve maximal levels of domestic and international connectivity.

The building blocks as outlined below have been divided into three categories:

1. Availability of basic infrastructure and openness of markets.
2. Strength of policy making and regulatory institutions.
3. Enabling strategies and incentive schemes.

8.1 The connectivity strategy building blocks

#	Building Block	Description	Principle
1	**Availability of Basic Infrastructure and Openness/Competitiveness of Markets**		
1.1	**Security and Affordability of International Capacity**	Provisions for multiple international links and wholesale international capacity available at competitive prices: 1) Plans for more than 1 international link, with each submarine landing /earth station/ border crossing at separate physical locations 2) Cost based submarine station landing, earth station and border crossing fees, with streamlined permitting processes 3) Open access, competitive or capped wholesale capacity pricing 4) Tariff caps on cross-connect fees between different cable NOCs/Landing /Earth stations in the same country 5) Sustainable business model for administration of the international facility 6) Capacity building of marine community to minimise accidental cable cuts 7) Co-ordination of international infrastructure deployment with domestic needs for international capacity	Duplication of international circuits on different physical paths is vital to maintaining reliable connectivity to the rest of the world and also to aid in competitively priced wholesale services to local operators. Countries with only one or two international links may have unreliable international connectivity and can find prices charged for capacity are not competitively priced and may require price caps. International infrastructure needs to be able to meet domestic demand without congestion.

[99] PRIF (2015) 'Economic and Social Impact of ICT in the Pacific' p.54.

#	Building Block	Description	Principle
1.2	**National Backbone Capacity**	Pervasive national backbone networks complemented by terrestrial wireless and satellite links where necessary: 1) Open access, competitive or capped wholesale capacity pricing 2) Coverage of all significant population centres 3) Metropolitan area networks (MANs) in major urban areas 4) Extension to national borders where needed (including for international and cross border traffic)	As bandwidth requirements grow, optic fibre will ultimately be required to interconnect virtually all wireless base stations, necessitating national backbones extending to remote and border areas.
1.3	**Inter-connection**	Local traffic stays local with minimal congestion and efficient interconnection: 1) Mandatory, transparent cost-based interconnection agreements 2) Availability of DID numbers/VoIP gateways to the PSTN 3) Presence of Local Internet Exchange Points (IXPs) in major urban areas	Reduces potential for market dominance, improves opportunities for using low cost VoIP services and cost of entry for small operators, allows for increased customer choice and improved competition, and downward pressure on costs and improved service quality along with improved network performance and resiliency for the end-user.
1.4	**Hosting and Cloud Services**	Affordable and reliable local content distribution and hosting services that also help ensure local data stays local: 1) Multiple (competitive and reliable) local carrier neutral data centre(s) 2) public VPN services 3) Secure and competitive local web hosting and cloud services 4) Presence of international Content Distribution Networks (CDNs) 5) Simple, fast and low-cost multilingual Domain Name registration with authentication and encryption 6) Legislation protecting against intermediary liability	Keeps data local and therefore reduces costs to operators and improves network performance for end-users as well as improving local navigation, security, branding, control and management of local content and domain name services. Improves ability for international and local web services to gain traction and better data sovereignty. Helps to attract foreign Content Distribution Networks (CDNs), thereby reducing the amount of international capacity required.
1.5	**Radio Spectrum**	Cost based, transparent, efficient radio spectrum licensing: 1) Cost based spectrum assignment fees 2) Access to existing unlicensed spectrum bands 3) Provision for shared use of the TV wavebands for TV White Space (TVWS) broadband 4) Availability of the digital dividend spectrum for mobile broadband 5) Dynamic spectrum management regulatory frameworks.	Improves availability of a vital resource for delivery of broadband services. Allows for the use of the latest, most efficient technologies, limits ability of incumbents to maintain franchises through technology. Low- spectrum fees reduces the cost of service to the end user. Use of TVWS will have a major impact on the potential for wireless broadband systems to reach areas that were previously cut off by distance and obstacles such as hills, vegetation and buildings, while minimising the potential for interference.

#	Building Block	Description	Principle
1.6	**Licensing**	An open market for telecommunication services with provisions for encouraging universal access: 1) Service and technology neutral licence structure 2) Streamlined licensing process 3) No legal barriers to market entry except minority local ownership requirement in certain cases 4) Tiered licensing frameworks which limit licensing burdens on small local community level operators (e.g. small entrepreneurs, municipalities or cooperatives) 5) Wholesale capacity licences available to both private and government operators for providing bandwidth to retail/end-user providers, dark fibre, ducts and tower space 6) Requirement for operators, which provide both wholesale and retail services to separate their operations and accounts. 7) Streamlined provisions for facilities-based/passive infrastructure providers – dark fibre, duct and tower operators which minimise (or eliminate) telecom licensing requirements. 8) Licensing obligations which promote inclusion and universal access and service obligations, including: i Contributions to the Universal Service Fund ii connecting public institutions iii Connecting marginalised social groups, including those with disabilities iv Submitting usage data regularly v Network neutrality adherence	Allows competition that is not restricted by limiting market access to types of technology or services, and encourages local communities to self- provide services, and ensures the availability of competitive wholesale fibre services. Historic markets with large installed customer base of fixed copper and co-ax (cable TV) may require separate treatment. Similarly, more densely populated urban areas may require separate treatment to rural areas.
1.7	**Market Structure**	Measures in place to address negative influence on the market by dominant operators: 1) Tariff caps on wholesale capacity and passive infrastructure such as masts 2) Asymmetric interconnection rates 3) Open access for other operators to essential facilities 4) Local loop unbundling 5) Number portability 6) No prohibitions on VoIP. Note: Needs competition authorities and regulators with sufficient capacity to implement measures to address Significant Market Power (SMP), when involving large companies often with even larger international parent companies or interests aligned with government (see next section).	Operators with a large proportion of the market may need special regulation to ensure their market dominance does not disadvantage smaller market entrants. Measures to address dominance create increased customer choice and therefore improved competition and downward pressure on costs while improving service quality. This section is also related to the conditions set in the national licensing regime.

#	Building Block	Description	Principle
1.8	**Consumer Protection and Own-ership Alignment**	Limitations imposed on cross-ownership and state own-ership of dominant retail ICT service providers, and in content/access services bundling: Restrictions on relative size of shareholding specified in law.	Cross ownership and govern-ment ownership in dominant retail broadband service pro-viders and/or broadcasting networks can cause a conflict of interest with other private operators, as well as within gov-ernment, which on the one hand wishes to maximise profitability of its shareholding while on the other, the public requires the most affordable services. Oper-ation of internal government networks by parastatal entities usually fall outside this provision.
2		**Strength of Policy Making and Regulatory Institutions**	
2.1	**Institutional Governance**	Maintenance of independence: 1) Executive structures from vested interests, governmental entities, broadcasters and telecom providers 2) Provided with authority, jurisdiction, accountability to enforce regulations, including effective regulation of anti-competitive behaviour. 3) Incentives within agencies to work across other gov-ernment agencies to promote government, health and others to serve as early broadband adapters	Regulators aim to be strong advocacy for consumer/public interests – decision making needs to be objective and not influenced by politics or vested interests. Improves indepen-dence and effectiveness but may also need supportive competi-tion / anti-trust authority.
2.2	**Operational Support**	Ensuring stability of income for the regulator: Sufficient and predictable funding streams to sup-port the capacity needed to develop, implement and enforce regulations.	Helps ensure independence and that regulator has human and financial capacity to enforce reg-ulations that affect large private or public vested interests
2.3	**Decision Making**	Confidence and transparency of decision-making: 1) Track record of regulatory certainty with clear, transpar-ent regulations 2) Evidence-based policymaking and regulatory procedures that include public participation	Helps ensure the most appropri-ate policies and regulations are adopted and minimises investor sense of risk and improves ability of private sector to make long term investments.
2.4	**Data Gathering**	Up-to-date market information: Regular (quarterly) data collection and publication of key market indicators disag-gregated according to vulnerable groups (including gender) and including pricing, speed, total bandwidth and adoption rates. Note: needs licence obligations to include require-ment to submit market data.	Provides the basis for informed decision-making and evi-dence-based policy development.
2.5	**Information Sharing and Capacity Building**	Institutional development: Participation in international net-works and associations for sharing best practice and learnings. Broadband and ICT training across government departments	Helps to ensure regulatory framework stays up to date and is harmonised within the region.
3		**Enabling Strategies and Incentive Schemes**	

#	Building Block	Description	Principle
	National Broadband Strategy	Up to date plan ensuring all citizens have access to sufficient broadband at affordable rates along with sufficient high quality international capacity: A coherent and integrated approach to implementing the other building blocks, with: 1) targets and timelines 2) top level executive support 3) guided by a multi-stakeholder cross-sectoral advisory committee. Targets would include: i Everyone with affordable multi-megabit broadband connections and their own e-mail address ii Every business with an online presence iii Direct fibre access to regional and international hubs.	Improves co-ordination, economies of scale, accountability and cross-sectoral synergies while reducing duplication. A well co-ordinated cross-sectoral broadband deployment strategy aimed at reaching all people in the nation requires clear goals, clear support from head of state, tight inter sectoral co-ordination, and effective feedback mechanisms from government, private sector and civil society.
3.1	**National Infrastructure Atlas**	Geographic decision support for infrastructure deployment and maintenance: Use of a national utility infrastructure database/GIS containing routes and features of telecom/transport/energy grids/water/waste pipelines) augmented by complementary data such as location of population centres and public service outlets (schools, clinics, municipal authorities).	Improves planning process, reduces cost of network deployment and increases reliability of networks by helping to minimise accidental fibre cuts. Has spin-off benefits for public planning in other sectors such as national health and education systems.
3.2	**Rapid Deployment Framework**	Fast, cost-effective and efficient permitting process for infrastructure deployment: 1) A one-stop shop for access to rights of way/wayleaves, ducts, poles, masts, government land/buildings 2) Rapid cross-border permitting 3) Tariff caps for lease fees and submarine landing station fees. 4) Transparent dispute resolution procedure 5) Streamlined environmental impact assessment procedures.	Helps to minimise network deployment time and overheads, and reduces the cost of infrastructure operations.
3.3	**Infrastructure sharing**	Minimise infrastructure deployment and operational costs, and time to deploy: 1) Mandatory dig once public works requirements – first to dig/lay must share conduit 2) Co-ordinated infrastructure deployment – all new roads/pipelines/rail lines must have ducts and fibre included, OPGW on electricity grids 3) All new public buildings and housing estates and other anchor institutions, e.g., universities, health facilities, banks, power include provision for ducts in order to obtain planning permission.	Minimises disruption and creates major savings in costs of telecom network deployment and improves the competitive environment. Research shows that network deployment costs can be dramatically reduced if operators collaborate with each other for example, in deploying shared fibre optic backbones or masts for wireless broadband. Even greater impacts have been noted when other utility infrastructure such as roads, rail lines and power cables are shared with telecom operators, especially when 'dig once' policies require the inclusion of ducts for optic fibre and provisions for masts in any new public works project.

#	Building Block	Description	Principle
3.4	**Infrastructure finance**	Source of capital for underserved areas: Supportive PPP environment – Provision of guarantees for long-term soft finance and other incentives for rural infrastructure investment, such as an efficient Universal Service Fund which subsidizes infrastructure in non-market attractive areas and is available to all players on a non-discriminatory basis.	Improves opportunities for private sector to invest in network deployment in areas with marginal profit potential. Improves potential for private sector to leverage government support
3.5	**Taxation Regime**	Minimising costs for deploying infrastructure, purchasing access equipment and using communication services: Low taxation levels and import tariffs on broadband goods and services.	Reduces network deployment and maintenance costs as well as minimising customer equipment acquisition and service costs
3.6	**Government Services**	Exploiting the potential of digital services in government while building demand: 1) Investment in e-government applications development 2) Connectivity for government service outlets – municipalities, libraries, schools, clinics, community centres 3) Support for academic and research networks. 4) Support for those with disabilities.	Improves potential for universal access and thus improves overall demand for broadband services and therefore attractiveness of further e-government and private applications and services investment
3.7	**Inclusion Strategies**	Encourage access among low-income households and minority social groups: 1) Subsidised access for low income groups 2) Digital and functional literacy training 3) Building a cadre of information intermediaries 4) Investment in public access facilities 5) Support for community network self-provisioning Requires building awareness among policy makers of the need to support public access facilities.	Helps to ensure equal access among all population groups and builds demand for local services. For those that cannot afford their own equipment and connectivity, public access facilities (such as in public libraries) should offer an alternative to personal access. However, public investment in libraries, tele-centres, and multi-purpose community centres and other venues that can support public access to the Internet has so far been relatively limited.
3.8	**Content-Use and Convergence Policies**	Policy incentives that ensure confidence and security of data: 1) Legal framework for cyber security and protection of privacy 2) Restrictions on content blocking, except due to human rights violations 3) Clear and transparent IPR legal framework 4) Open Data Strategy for government and private information 5) Planning process for ensuring smooth convergence of broadcast (radio and TV) and broadband channels for mass-media use.	Ensures abuses of the Internet and associated risks for the public are minimised. Underlies adherence to democratic freedom of speech values. Creates incentives for business investment and allows re-use and value addition from existing information.

#	Building Block	Description	Principle
3.9	**Innovation and Learning**	Facilitate local capacity building in connectivity provisioning, content and applications development: 1) Support use and teaching of ICT at all academic levels 2) Investment in campus fibre networks, and National Research and Education Networks (NRENs) 3) Encourage presence of iHubs, incubators, science parks and other shared research, learning and workspace environments 4) Mechanisms to ensure coordination in regulation of emerging technologies and integration of strategic technology foresight into policy making	Affects level of demand from the public and ability to grow broadband-based businesses from skilled population. Supports ability to exploit the latest technologies, and generally benefit from improved innovation, skills development, networking, knowledge sharing and business development.
3.10	**E-Payments**	Efficient and Widespread means of making electronic payments: Support for presence of open carrier neutral mobile and broadband payments and banking platforms.	Basis for broad-based adoption of e-commerce
3.11	**Energy Supply**	Reliable and affordable electric power: Efficient low cost, reliable electricity distribution	Affects cost of network operation and ability of end-users to make use of the network.
3.12	**Business Environment**	Enabling environment for commerce: 1) Business registration – minimal overheads and rapid transaction times 2) High transparency of procedures, absence of corruption 3) Availability of startup and investment finance 4) Low interest rates 5) Low tax rates and tax incentives 6) Favourable trade policies	Affects ability to start and operate businesses thereby affecting availability of services to potential customers.

In addition, some concrete recommendations have been formulated based on the experience of sub-Saharan Africa[100], and the Americas and the Caribbean[101] to enable dynamic competition in the ICT market as well as for the reduction of the cost of Internet connection at the international level. The two studies also contain proposals and measures to encourage use of the Internet, and to promote development of local content especially in developing countries.

8.2 Monitoring and evaluation of the impact of connectivity strategies

To gauge the success of strategies and identify emerging issues, changes in a set of expected outcomes can be measured over time. The measures need to be pragmatic, rather than exhaustively accurate, i.e. they need to be easily obtained, objective, comparable and up-to-date. Comparison between countries can be useful in identifying effective policies, but the key aim with the use of indicators is to be able to measure progress in a country over time. Therefore, the data points should ideally be updated on a quarterly basis and authorities may need regulations to ensure that network operators provide the necessary data in a timely fashion.

[100] See ITU, Study on international Internet connectivity in sub-Saharan Africa, 2013. www.itu.int/dms_pub/itu-d/opb/pref/D-PREF-EF.IIC.AFR-2013-PDF-E.pdf

[101] See ITU, International Internet connectivity in Latin America and the Caribbean, 2013. www.itu.int/dms_pub/itu-d/opb/pref/D-PREF-EF.IIC.CAR-2013-PDF-E.pdf

Additional 'nice-to-have' indicators are described below, but the following set of three measures would be sufficient to provide not only an indication of the level of connectivity in terms of numbers of people connected, but also the overall level of Internet utilization:

- Number of broadband subscriptions per capita (%). 'Broadband' being defined as a connection of at least 512 Kbit/s today but growing to the higher rates available in developed countries. Data should be disaggregated according to gender, age, geographic area and minority groups. Full data disaggregation may only be feasible on an annual basis.
- Domestic data traffic per capita – bits per second (bit/s per capita). Defined as the total of all domestic network fixed and mobile data circuits provisioned, divided by the total population.
- International Data traffic per capita – bits per second (bit/s per capita). Defined as the total of all international network fibre, satellite and terrestrial microwave circuits provisioned, divided by the total population.

A number of additional indicators can be useful in helping to determine the source of problems in achieving the expected levels of connectivity. These are:

- Network coverage: Proportion of geographic territory and population for which broadband connectivity is available.
- Affordability: Cost of 10 Gb per month of broadband data traffic relative to average income levels (% of GNI/capita). 10 Gb is a common tariff package and on a monthly basis would be a desired minimal level of utilisation, corresponding to a 10-20 hours per month of video.
- Broadband Speed: Average download and upload speed per subscriber (bps)
- Reliability and Maturity: Autonomous System Numbers (ASNs) per capita. AS numbers are used by IP networks that are reliable, they are needed if the network has more than one connection to the rest of the Internet. As a result, they provide a reliable indication of the extent of network development in the country. AS number visibility is also easily measurable and available in real-time, and up-to-date statistics are simple to produce.
- Regional connectivity: Number of ASNs visible in-country that are from neighbouring and regionally associated countries.
- Global connectivity: Number of ASNs visible in-country that are from out-of-region/all other countries.

8.3 Global and regional collaboration to improve international capacity for developing countries

The wide variety and large number of factors in the connectivity equation outlined above underscores the need for an integrated approach to maximising connectivity levels. A bottleneck in any component of the broadband ecosystem acts to limit overall use. For example, limited local interconnection infrastructure is also likely to have a negative impact on local content development and on the presence of foreign carriers and content distribution networks.

There is also a close relationship between the qualities of international versus domestic infrastructure – countries with more international connectivity have lower domestic broadband prices and countries with better domestic infrastructure have lower international bandwidth prices. It is for these reasons that building local demand should be an essential part of the international connectivity strategy, and it is necessary to take into account the interrelation of many independent components when developing strategies for improved connectivity, as envisaged in further ITU work on international Internet connectivity strategy building blocks.

Accelerating the deployment of needed international connectivity will benefit from discussions among key stakeholders to reach a global commitment to collaborate on identification of challenges, take advantage of opportunities and to develop and execute solutions to specific problems. The solutions could include international, regional or other groupings that address common challenges of a more specific nature, such as a submarine cable group, a satellite group, a cross-border cable group etc.

Annex 1: References and further resources

ITU Broadband Capacity Indicators

www.itu.int/en/ITU-D/Technology/Documents/InteractiveTransmissionMaps/Misc/BroadbandTransmissionCapacityIndicators.pdf

ECOWAS Regulation on Access to Submarine Cables – ITU 2013

www.itu.int/en/ITU-D/Projects/ITU-EC-ACP/HIPSSA/Documents/FINAL%20DOCUMENTS/FINAL%20DOCS%20ENGLISH/submarine_cables_ecowas_regulation.pdf

Green Cables Funding Study, ITU-WMO-UNESCO IOC Joint Task Force, 2016,

www.itu.int/en/ITU-T/climatechange/task-force-sc/Documents/JTF%20Report%20Green%20Cable%20Funding%20Study.pdf

Haut débit en eau profonde: www.lemonde.fr/pixels/visuel/2016/03/10/haut-debit-en-eau-profonde_4880125_4408996.html

International cables, gateways, backhaul and international exchange points, OECD 2014

http://oecdinsights.org/wp-content/uploads/2014/02/International-cables-gateways-IXPs.pdf

International Internet Connectivity in Sub Saharan Africa – March 2013

www.itu.int/en/ITU-D/Regulatory.../IIC_Africa_Final-en.pdf

International Internet Connectivity in Latin America and the Caribbean – March 2013

www.itu.int/dms_pub/itu-d/opb/pref/D-PREF-EF.IIC.CAR-2013-PDF-E.pdf

International Bandwidth and Data Markets – Asia Pacific and Middle East 2013

www.slideshare.net/jokosuryana90/international-bw-and-data-market

International Satellite Directory 2016

www.satnews.com/products.php?product=isd

ITU Interactive Transmission Map

www.itu.int/itu-d/tnd-map-public/

ITU-T Manual – Fibre, Cables and Systems, 2009

www.itu.int/dms_pub/itu-t/opb/hdb/T-HDB-OUT.10-2009-1-PDF-E.pdf

Mapping Support for Africa Infrastructure Investment (OECD 2012)

www.oecd.org/daf/inv/investment-policy/MappingReportWeb.pdf

Master Plan for wireless broadband in Asia and the Pacific 2012

www.itu.int/net4/ITU-D/CDS/projects/display.asp?ProjectNo=9RAS10036

Open Access To Submarine Cables. Presentations from the 2012 Kigali Knowledge Sharing Event.

www.itu.int/en/ITU-D/Projects/ITU-EC-ACP/HIPSSA/Pages/HIPSSA_Preparatory_work/Open-access-to-submarine-cables.aspx

The regulation of undersea cables and landing stations.

www.cablesm.fr/2007_esselaar-et-al-2007-undersea-cables.pdf

SADC Regional ICT Infrastructure Development Master Plan (2012)

www.sadc.int/documents-publications/show/Regional_Infrastructure_Development_Master_Plan_ICT_Sector_Plan.pdf

Submarine Cable News

www.subcablenews.com

Submarine Telecoms Forum

http://subtelforum.com

Where are the funding sources for submarine cables projects? Andrew Lipman 2013.

www.suboptic.org/wp-content/uploads/2014/10/WE2A-2_Oral_5.pdf

WSIS Targets Review: Connectivity

www.itu.int/en/ITU-D/Statistics/Documents/publications/wsisreview2014/WSIS2014_review_target3.pdf

Annex 2: Glossary and abbreviations

Backbone	The trunk routes of a network, also used as the path for transporting traffic between different networks. Backbones can be the physical telecommunication cable infrastructure, or the circuits established over them by a particular network operator.
Bandwidth	The size or capacity of a communications channel indicating its ability to transfer data, usually measured in the speed of data transfer, in bits per second (Bps) for packet networks such as the Internet, or SDH STMs, or also often stated in the frequency range assigned to the channel, measured in Hertz (Hz).
Bit	Binary Digit – a 0 or a 1 – the way information is encoded digitally
BPL	Broadband over electric Power Lines – use of power cables to transmit data
Business Process Outsourcing (BPO)	Use of a third party, often offshore, to carry out a set of business activities for a company, such as a help desk, or accounts processing
Bits per Second (BPS)	The number of bits passing a point every second. The transmission rate for digital information, i.e a measure of how fast data can be sent or received. Often expressed as Mbit/s, for Megabits per second, or Gbit/s, for Gigabits per second for high speed links.
Broadband	A high speed (multi-megabit) data connection sufficient to support streaming multimedia connections. Target speeds for broadband are continually evolving.
Byte	8 bits of data, sometimes called a "word" or and "octet" – used as a measure of storage capacity or traffic – e.g a 1 Gigabyte mobile data package.
Cable Landing Station (CLS)	The facility where a submarine cable 'lands' on shore with equipment for distribution of the capacity and in most cases also for powering the cable.
Cloud Service	A service provided via the Internet that gives access to applications and data storage facilities that are hosted on the service provider's network and servers, typical examples are Amazon WS, DropBox, Gmail, MSN.
Co-location	The renting of space for housing computer server equipment, usually in specially designed buildings (called data centres, telehouses or carrier hotels).
Connection Redundancy	Two or more communication links via physically separated network providers. Redundancy ensures reliability – continued operations in the event of one connection going down.
Construction and Maintenance Agreement (C&MA)	A type of detailed shareholder's agreement made between consortium members/owners of a fibre project.
Content	The data that travels over a network – traffic – any form of digitised information ranging from text to multi-media audio and video, and may include software/applications as well as financial and gaming transactions

Dark Fibre	Optic fibre which is not yet in use, and therefore unlit.
Demand Forecast	Projects future demand for capacity on system, typically for at least ten years, assuming market growth and competition factors.
Dense Wave Division Multiplexing (DWDM)	A technology that enables data from different sources to be transmitted simultaneously on a single optical fibre, each signal (data source) being carried on a discrete optical wavelength. Up to 80 (and theoretically more) wavelengths can be transmitted on a single optical fibre.
Detailed Feasibility Study (DFS)	A demonstration that a system can be economically viable based on projected cash flow given the demand forecast and cost estimate along with projected pricing for capacity in the system
Domain Name	A name, registered with, and held on a database by a 'domain name registry', consisting of a name, sometimes a second level domain and a top level domain. E.g. total.com.ng, mycompany.co.uk
Desktop Study (DTS)	A preliminary layout of the cable system based on assumptions about landing points and known route details – includes armouring and burial assumptions
Downstream	A network's paid traffic – in contrast to upstream traffic, for which a network must usually pay transit fees, and peered traffic, which is usually settlement free, downstream traffic is paid for by network users.
Digital Subscriber Line (DSL)	A technique for delivering broadband services over copper cables
Exabyte	A billion gigabytes
Fibre optic cable	A technology using glass fibre for the transmission of data. The signal is imposed on the fibre via pulses (modulation) of light from a laser or a light-emitting diode (LED). With advances in modulation technology, international fibre cables are now usually deployed with terrabit capacities.
Fibre to the Home (FTTH)	The provision optic fibre broadband communications links to domestic premises – a more generic term to include other buildings or to the kerb would be FTTx
Gigabits per second (Gbit/s)	A data transfer rate of Giga (a billion or a thousand million) bits per second. (Also Gb/s)
Hosting	A loose term for the service of managing data servers or web sites for third parties. Similar to co-location but may be on shared equipment
Instruction to Proceed (ITP)	A document authorising a system supplier to begin work on a system before a formal contract is negotiated, in the interest of timeliness. Requires system developers to commit a fraction of the system cost immediately.
International gateway	A facility to provide international connectivity and termination points. In practice it is a licensing term used by many government regulators which only allow licensed operators to carry international voice traffic or lease international data circuits (IPLCs see below).

International Private Leased Circuit (IPLC)	A physical circuit of dedicated capacity provided at two points – one inside the country and one outside the country. In many cases the circuit is charged in two sections, each from the location to the border, or in the case of submarine cable, one local origination and one foreign origination.
Internet	A global mesh of networks sharing a common communications protocol called TCP/IP. The Internet's international backbones are high-speed fibre trunk lines usually owned by telecommunication companies.
Internet Exchange Point (IXP)	A physical infrastructure allowing many ISPs to exchange Internet traffic. Traffic is exchanged by peering agreements made between the ISPs connected to the Internet Exchange. By peering at an Internet Exchange the connected ISPs reduce their reliance on a small number of networks (usually their upstream provider(s)), and this improves the delivery and receipt of traffic.
Internet Service Provider (ISP)	An organisation that connects end-users and businesses to the public, global Internet. ISPs often provide other services such as storing and forwarding email, and hosting web sites for their customers. They may or may not own the underlying physical infrastructure used to provide the service. ISPs which purchase bandwidth from other companies that have direct links to the Internet in turn sell that bandwidth to customers in smaller chunks.
Internet Protocol (IP)	See below.
IP Packet	A discreet datagram of Internet traffic constructed according to the Internet Protocol, between 40 and 1599 bytes long, having source, destination (i.e. routing information) and other management information as well as the actual user's data (the 'payload').
Indefeasible Rights of Use (IRU)	A means of purchasing long term rights (usually 10-15 years) to the capacity or physical resource (optic fibre or wavelength) on a communications circuit. IRUs are treated as assets for accounting purposes that adds to their tax advantage compared to leasing.
Leased Line	A telecommunications circuit leased between two or more locations from a telecom provider.
Link Aggregation	Various methods of combining (aggregating) multiple network connections in parallel to increase throughput beyond that which a single connection cn sustain, and to provide redundancy in case one of the links fails.
Local Area Network	(LAN) A network of computers spread over a relatively small physical area, often in one building and often belonging to one organization. See also MAN, WAN.
Long Term Evolution (LTE)	A standard for 4G wireless networks.
Memorandum of Understanding (MOU)	Defines relationships among developers.
Metropolitan Area Network (MAN)	Metropolitan Area Network – usually an optic fibre network covering a city.
Mbit/s	A data transfer rate of Mega (million) bits per second. (Also Mb/s).

National Regulatory Authority (NRA)	See Regulator.
Network	Two or more interconnected computers or data communications devices See also IP Network MAN, WAN.
Open Access	When referring to optic fibre infrastructure, Open Access service delivery models ensure that all operators, regardless of the size of investment or capacity purchase, have equal terms of use for access to fibre optic cables on a capacity (Mbit/s), wavelength, or dark fibre basis.
Optical Fibre Cable (OFC)	The cable that carries data by modulating light pulses, usually in glass fibres, although plastic fibres can be used over short distances.
Optical Ground Wire (OPGW)	A cable that runs along high tension electric power lines used to provide control information for the power network. OPGW often has additional cables for use by communication network operators.
Packet	A discreet "chunk" of data traffic. See IP Packet.
Peer	A network with which one has a peering relationship, where traffic is usually exchanged between peers at no cost to either party.
Petabit	One thousand terrabits.
Point of Presence (POP)	A location where a network has physical infrastructure to provide services to end users or to interconnect with other networks.
Public-Private Partnership (PPP)	A mutually beneficial relationship between government and private sector entities, such as shared investment in a submarine fibre cable and landing station. Not to be confused with Purchasing Power Parity, a mechanism to compare the relative values of currencies.
Public Switched Telephone Network (PSTN)	The traditional voice telephone system, including both fixed and mobile networks. Most networks today are in a process of migrating from a switched architecture to an IP packet based architecture.
PTO	Public Telecom Operator, usually refers to the incumbent often legacy state-owned operator, although technically, the distinction between fixed line, mobile operators and ISPs is increasingly blurred (see PSTN above).
QOS	Quality of Service – a measure of the quality of the service provided by a network. There are many different QOS measures, depending on the nature of the traffic – common examples include ping time, packet loss, round-trip time etc. Also see Service Level Agreement (SLA). QOS rules can also be applied to different types of traffic passing through a router – for example voice traffic might be given a higher priority to email.

Regulator	A government entity that has responsibility for executing national policy by establishing a set of regulations that govern the telecom sector. The regulator is normally semi-autonomous, with an income derived from licence fees, although the state usually appoints the executive body. The regulator helps ensure that there is a level playing field in the market and it has a major responsibility to curb the impact of market dominance of the incumbent operators, especially in developing countries. In some economic regions with a high level of integration, such as the EU and ECOWAS (west Africa) a substantial amount of policy and regulatory development takes place at the regional level, which the Member States are obliged to adopt.
Request for Proposal (RFP)	A formal request for suppliers to propose their detailed solutions for provision of a system, defining the system technical and commercial details as closely as possible.
Rough Order-of-Magnitude (ROM) Estimate	An approximation of system cost based on knowledge of route and product prices, using standard estimating practices.
Route	The path of a cable, radio transmission or through one or more networks that is taken by IP packets. Due to the dynamic nature of routing on the Internet, packets from the same data stream may travel to their destination by different routes and reassembled by the router at the final destination.
Significant Market Power (SMP)	A definition used by regulators to help ensure a level playing field in the presence of an operator which is dominant in the market and therefore able to charge uncompetitive prices (often the incumbent previously state-owned monopoly and mobile operators). An SMP determination will allow the regulator to set tariffs charged and place other conditions on the operator.
Submarine Line Terminal Equipment (SLTE)	The electronics necessary to carry traffic over the fibre optic cable.
Supply Contract	The formal detailed definition of the suppliers' obligations to manufacture, install, and test the system, and the developers' obligation to pay.
Special Purpose Vehicle (SPV)	A company set up for a particular purpose, often with not for profit goals where shareholders are a mix of public and private entities, such as an open access submarine cable landing station.
Synchronous Digital Heirarchy (SDH)	The traditional carrier network transmission protocol (see below), now being superseded by Ethernet and IP services.
Synchronous Transport Module (STM)	The SDH ITU-T fibre optic network transmission standard – an STM-1 has a capacity of about 155 Mbit/s, an STM-4 has a capacity of 622 Mbit/s.
Terabit (Tb)	One thousand gigabits. The latest fibre optic cables are able to carry tens of terabits per second over thousands of kilometres.

Transit	Transit is an arrangement in which a network sells access to other networks. Transit charges are set by negotiation, and are often not disclosed publicly. Transit arrangements typically provide access to an array of networks, not limited to one country. In many cases one Internet transit arrangement with a large network is used to provide a small network with access to the Rest of the World (ROW).
Upstream	The network traffic generated or consumed by the network's users that is passed out of or into the network from or to other networks. Typically a proportion of the upstream capacity required is peered away to some other networks at no cost, while the rest of the capacity required is purchased from a transit provider.
Wavelength	A carrier of data on a fibre optic cable. See DWDM.
Weighted Average Cost of Capital (WACC)	A measure of the financing cost of the capital used in making an investment, such as in a submarine cable
Wide Area Network	(WAN) A network of computers spread over a large physical area, from regional to global. WANs may be operated and used by single organizations, or used by many. Perhaps the ultimate WAN is the Internet. See also MAN.

Annex 3: Technical background to optic fibre communications

A3.1 Introduction

With the invention of the laser in 1966, it was discovered that modulated laser beams traveling through optical fibres might be the best choice for telecommunications as they are capable of transmitting light over long distances. By 1970, the dramatic reduction in high transmission losses in fibre from 1000 dB/Km to 20 dB/Km and technical feasibility of operation of Gallium Arsenide semiconductor lasers at room temperature, gave a big boost to further research in the area of optical communications through fibres.

Further innovations led to reduced path losses (to the tune of 0.04 dB/Km), availability of compact and efficient optical sources and detectors, verity of optical multiplexers/demultiplexers and other related devices and low cost systems. This has resulted in extensive deployment of optical fibre networks all over the world.

A fibre optic network is composed of optical fibre cable, a transmission system, active and passive components and some accessories. ITU has defined standards for different types of fibre optic cables, subsystems, and protocols, etc. The following subsections provide a brief overview of fibre optic system components and respective ITU recommendations.

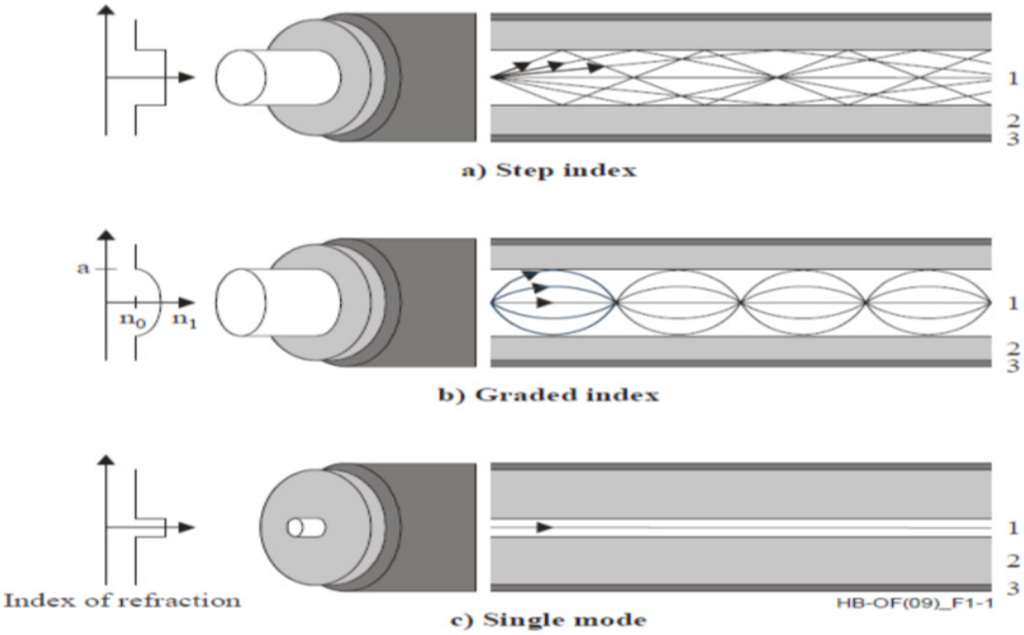
A3.2 Optical fibre

Optical fibres are dielectric waveguides. Two types of fibres are used for telecom applications. These are single-mode and multimode optical fibres.

Multimode fibre cores may be either step index or graded index. Step index multimode fibre derives its name from the sharp step like difference in the refractive index of the core and cladding. In the graded index multimode fibre the light rays are also guided down the fibre in multiple pathways. But unlike step index fibre, a graded index core contains many layers of glass radiating outwards from the axis, each with a lower index of refraction. The effect of this grading is that, to match those rays taking the shorter pathway directly down the axis, the light rays speed up in the outer layers. The result is that a graded index fibre equalizes the propagation times of the various modes, so that data can be sent over a much longer distance and at higher rates.

Figure A1 shows light in these modes (a, b and c) following these paths, where the core, cladding and coating, are numbered 1, 2 and 3 respectively. The cladding glass has a refractive index slightly lower than the refractive index of the core glass.

Figure A1: The three types of fibres



Source: ITU

The fibre in Figure A1 (a) is called step index because the refractive index changes abruptly from cladding to core. Graded index fibres are commercially available with core diameters of 50, 62.5 and 100 microns. The single mode fibre allows only a single light ray or mode to be transmitted down the core. This virtually eliminates any distortion due to the light pulses overlapping. The core of the single mode fibre is extremely small, approximately five to ten microns. The single mode has a higher capacity and capability than either of the two multimode types. For example, undersea telecommunication cables can convey 60 000 voice channels on a pair of single mode fibres. By reducing the core diameter and the refractive index difference between the core and the cladding only one mode (the fundamental one) will propagate and the fibre is then "single-mode" (Figure A1 (c)).

The optical fibres are specified in the following ITU-T Recommendations ITU-T G.650.1, ITU-T G.650.2, ITU-T G.650.3, ITU-T G.652, ITU-T G.653, ITU-T G.654, ITU-T G.655, ITU-T G.656, ITU-T G.657 and ITU-T G.651.1.

Optical fibre cable

The basic purpose of optical fibre cable is to keep the transmission and mechanical strength properties of the optical fibres stable in the course of the cable manufacturing, installation, and operation.

The dimensional and transmission characteristics of the optical fibre cables used for telecommunication must follow ITU-T Recommendations ITU-T G.651.1, ITU-T G.652, ITU-T G.653, ITU-T G.654, ITU-T G.655, ITU-T G.656 and ITU-T G.657.

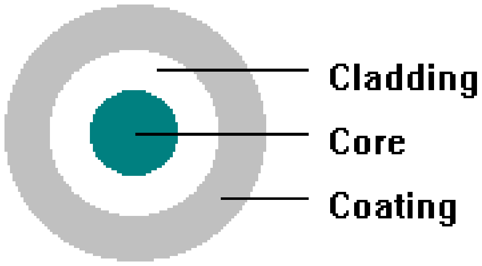
General structure of optical fibre cables

The three basic elements of a fibre optic cable are the core, the cladding and the coating.

- Core: This is the light transmission area of the fibre, either glass or plastic. More light will be transmitted into the fibre when the core is larger.
- Cladding: The function of the cladding is to provide a lower refractive index at the core interface in order to cause reflection within the core so that light waves are transmitted through the fibre.

- Coating: Coatings are usually multi-layers of plastics applied to preserve fibre strength, absorb shock and provide extra fibre protection. These buffer coatings are available from 250 microns to 900 microns.

Figure A2: The basic elements of a fibre optic cable



Source: ITU

Fibre size

The size of the optical fibre is commonly referred to by the outer diameter of its core, cladding and coating. Example: 50/125/250 indicates a fibre with a core of 50 microns, cladding of 125 microns, and a coating of 250 microns. (A sheet of paper is approximately 25 microns thick). The coating is always removed when joining or connecting fibres.

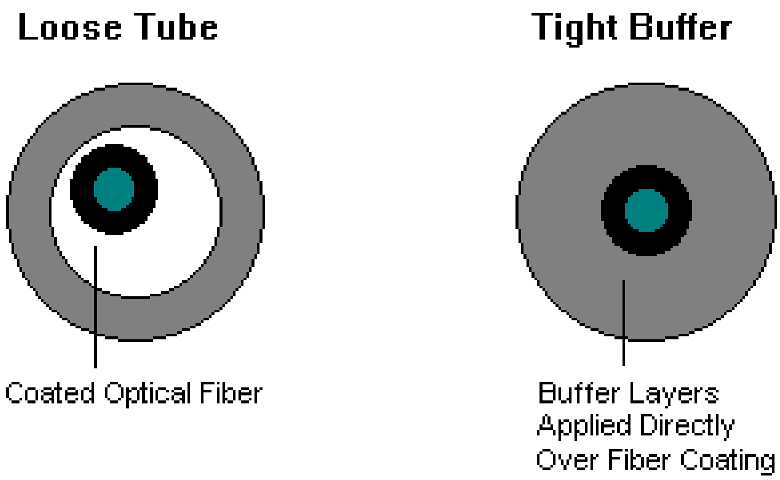
Design considerations

Considerations of tensile strength, ruggedness, durability, flexibility, size, resistance to the environment, flammability, temperature range and appearance are important in constructing optical fibre cable.

First level of fibre protection

The optical fibre is a very small waveguide. In an environment free from stress or external forces, this waveguide will transmit the light launched into it with minimal loss, or attenuation. To isolate the fibre from these external forces, two first level protections of fibre have been developed: loose tube and tight buffer.

Figure A3: The first level protections of fibre



Source: ITU

In the loose buffer construction, the fibre is contained in a plastic tube that has an inner diameter considerably larger than the fibre itself. The interior of the plastic tube is usually filled with a gel material. The loose tube isolates the fibre from the exterior mechanical forces acting on a cable. For multi-fibre cables, a number of these tubes, each containing single or multiple fibres, are combined with reinforcing to keep the fibres free of stress, and to minimize elongation and contraction. By varying the amount of fibres inside the tube during the cabling process, the degree of shrinkage due to temperature variation can be controlled, and therefore the degree of attenuation over a temperature range is minimized.

Tight buffer is the other fibre protection technique. It uses a direct extrusion of plastic over the basic fibre coating. Tight buffer constructions are able to withstand much greater crush and impact forces without fibre breakage. The tight buffer design however, results in lower isolation for the fibre from the stresses of temperature variation. While relatively more flexible than loose buffer, if the tight buffer is deployed with sharp bends or twists, optical losses are likely to exceed nominal specifications due to micro-bending. A refined form of tight buffer construction is breakout cable. In breakout cable, a tightly buffered fibre is surrounded by aramid yarn and a jacket, typically PVC. These single-fibre subunit elements are then covered by a common sheath to form the breakout cable. "This cable within a cable" offers the advantage of direct, simplified connector attachment and installation.

Each construction has inherent advantages. The loose buffer tube offers lower cable attenuation from microbending in any given fibre, plus a high level of isolation from external forces. Under continuous mechanical stress, the loose tube permits more stable transmission characteristics. The tight buffer construction permits smaller, lighter weight designs for similar fibre configuration, and generally yields a more flexible, crush resistant cable. The type of installation of the fibre optic cable in the telecommunication network decides the basic characteristics of the structure and dimensions and the materials of an optical fibre cable.

Various ITU-T recommendations define different fibre optic cables for different applications. Some of the commonly used fibre cables with ITU-T recommendations are:

ITU Recommendations	Fibre optic cable for
ITU-T Rec. L.10	ducts, tunnels and bridges
ITU-T Rec. L.43	directly buried in the ground
ITU-T L.26	Arial applications
ITU-T G.978	Submarine cable installation
ITU-T G.972	Use in different type of protected environments

Recommendation ITU-T G.972 describes different types of protected cables with mechanical characteristics and the ability of the cable to be installed, recovered and repaired.

A3.3 Transmission systems

In an optical communication system, a source of monocratic light source is modulated as per electrical voice, data, and video signals. This modulated light is made to travel through optical fibre cable over long distances. Different data streams can be launched in the same fibre on other monochromatic light beams. Since the signal loses its power due to attenuation in the fibre, repeaters / signal boosters are provided to maintain the desired signal level. On the way, many signal tributaries are added and dropped in response to traffic requirements. At the receiving end, the modulated light signals are detected using a light detector and converted to electrical signals. An optical transmission system includes the following main components / subsystems:

- optical transmitters;
- sources and modulators;

- optical receivers;
- optical amplifiers and their different applications;
- adaptive chromatic dispersion compensators;
- PMD compensators;
- OADMs / ROADMs;
- photonic cross-connects;
- optical wavelength MUX/DMUX;
- regenerators and transponders;
- optical attenuators and optical branching devices.

Optical transmitters

The optical transmitters are used to convert an electrical input signal into an optical signal and then transmission of optical signal through optical fibre as a communication channel. The major components of optical transmitters are the optical sources and the modulators.

Optical sources

Optical transmitters use semiconductor optical sources such as light-emitting diodes (LEDs) and semiconductor lasers because of advantages such as monochromatic source of light, compact size, high efficiency, good reliability, small emissive area, possibility of direct modulation.

- Light emitting diode (LED): LED emits light when a voltage is applied between its two terminals. If this voltage varies according to the intelligence (signal), then the output light gets modulated. This modulated light is transmitted through fibre to the desired location.
- Semiconductor Laser: Semiconductor lasers are costly in comparison with LEDs but provide much better performance characteristics in comparison with LEDs. Though the laser can be directly modulated by a large signal, the sharp pulse does get distorted and hence external modulators are used.

Optical receivers

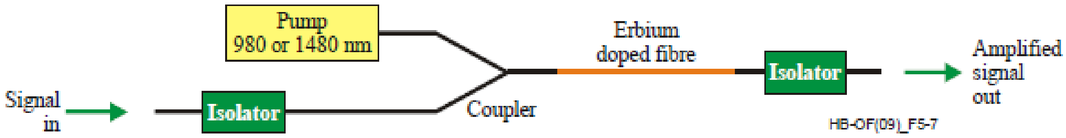
An optical receiver converts the optical signal back into electrical form and recovers the data transmitted through the optical system. It uses a *photo detector* to convert light into electricity through the photoelectric effect. Generally, PIN photodiodes and avalanche photodiodes of compact size with high efficiency and good reliability are used.

Optical amplifiers (OA)

The transmission distance in an optical system is generally limited by optic fibre losses. Such losses are compensated by using regenerators / optical amplifiers. In regenerators, the optical signal are first converted into an electric current and then regenerated using a transmitter. The regenerators become complex and inefficient for wavelength division multiplexed (WDM) systems. Alternatively, optical amplifiers are used to compensate such optical losses. In optical amplifiers, the optical signals are boosted directly in the optical domain without conversion to electronic format.

Recommendations ITU-T G.661, ITU-T G.662 and ITU-T G.663 describes optical amplifiers in detail. Optical amplifiers are based on laser principles and simultaneously amplify all wavelengths. For long distance communication, generally erbium-doped fibre amplifier (EDFA), semiconductor optical amplifiers (SOA), and Raman amplifiers are used.

Figure A4: Basic EVDO Amplifier

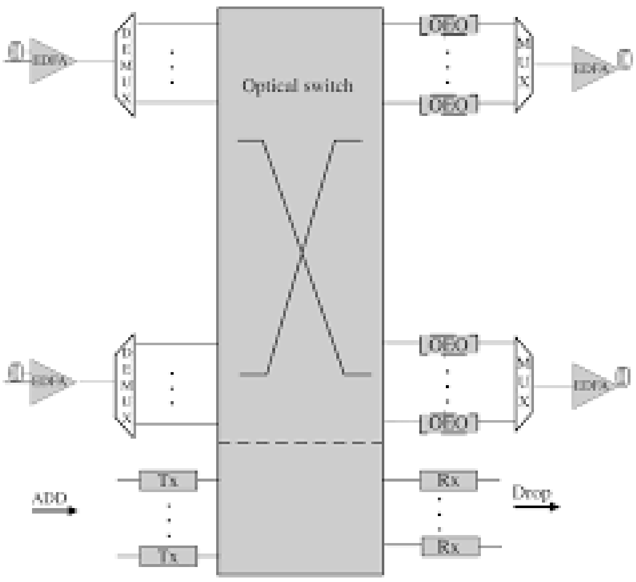


Source: ITU

Optical cross connects or photonic cross connects (OXC or PXC)

Optical cross connects, described in ITU recommendations ITU-T G 680, are used in wide area WDM (wavelength division multiplexing) networks for switching traffic in an optical domain. Optical cross connects facilitates optical switching of optical signals from any input port to any output port of the cross connect. This is analogous to electronic switching function in an electronic telephone exchange.

Figure A5: Optical cross connect

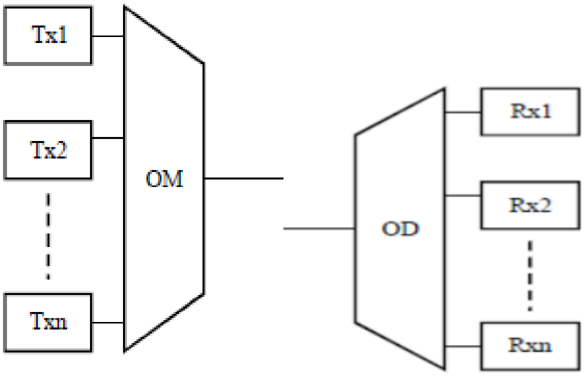


Source: ITU

Optical wavelength MUX/DMUX

The main function of an optical de-multiplexer is to receive from a fibre a beam of multiple optical frequencies and separate it into its frequency components, which at the output are coupled in as many individual fibres as there are frequencies. An optical multiplexer functions in the opposite manner. It receives many optical wavelengths from many fibres and converges them into one beam that is coupled into a single fibre.

Figure A6: Optical multiplexer and de-multiplexer

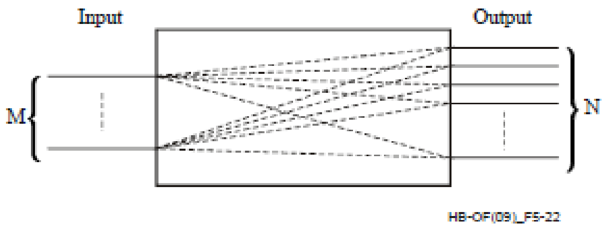


Source: ITU

Optical branching devices including passive optical network splitters

An optical branching component (optical dividers, optical combiners etc.) described in ITU Recommendations ITU-T L.37 and ITU-T G.671 is a passive component with three or more ports, that shares optical power among its ports in a predetermined fashion, without any amplification, switching, or other active modulation. Optical branching is a method of splitting optical signals between input and output ports. Optical branching components are used for splitting an incoming optical signal into two or more fibre lines or when several signals coming from different fibre lines have to be mixed in to a single fibre line.

Figure A7: Splitters: input - output



Source: ITU

Optical branching

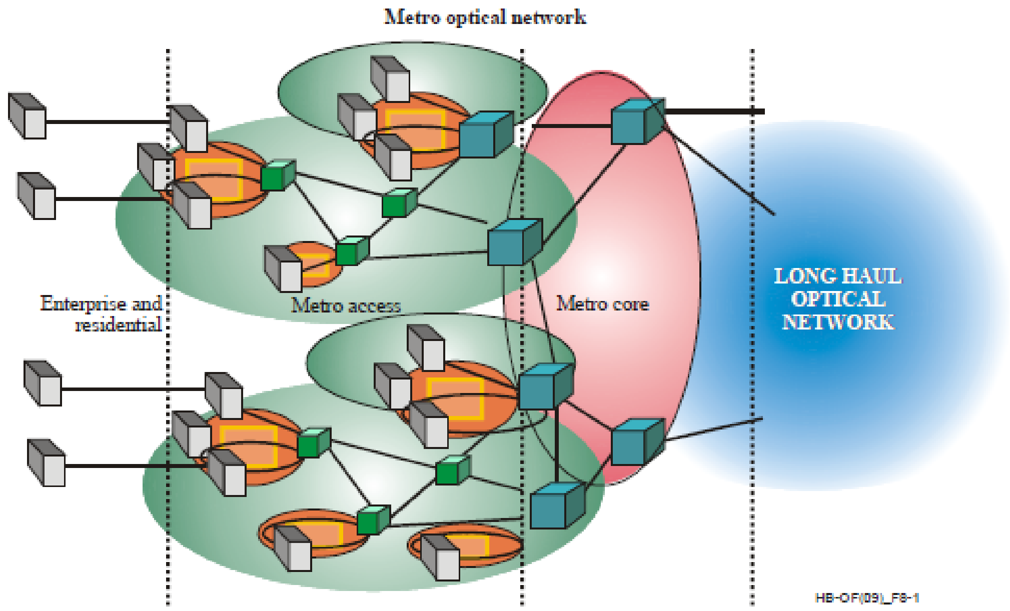
In passive optical networks (PON) with a point-to-multipoint distribution architecture, optical splitters are used to connect an OLT to several ONUs located at subscriber premises. ITU recommendation ITU-T G.671, defines the parameters of optical branching components such as insertion loss, reflectance, optical wavelength range, polarization-dependent loss, directivity and uniformity etc. for passive optical networks.

A3.4 Fibre optical communication systems and networks

The optical transport network (OTN) is a combination of:

- access networks;
- metropolitan access networks;
- metropolitan core networks (or regional networks); and
- long-haul networks (or backbone networks).

Figure A8: Metro optical network



Source: ITU

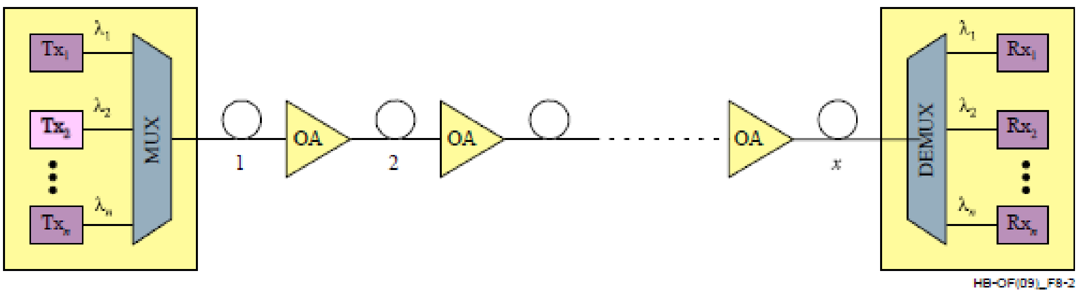
An optical transport network (OTN) is composed of a set of optical network elements (ONEs) connected by optical fibre links, which provide functionality of transport, multiplexing, routing, management, supervision and survivability of optical channels carrying client signals, according to the requirements given in Recommendation ITU-T G.872.

ITU Recommendations on key optical network topologies

Point-to-multipoint topology is generally used for access networks, while ring topology is generally used for metro networks. Backbone nodes are usually interconnected by point-to-point WDM lines in a mesh topology.

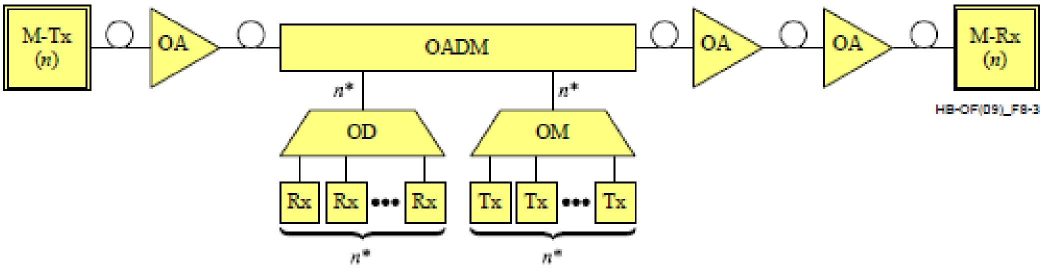
Recommendations ITU-T G.692, ITU-T G.693 and ITU-T G.959.1 relates to point-to-point transmission systems, generally used for access networks. Recommendations ITU-T G.695, ITU-T G.698.1 and ITU-T G.698.2 includes optical add/drop function (bus structure). Recommendation ITU-T G.983.x and the ITU-T G.984 x-series covers a point-to-multipoint topology for optical access networks. Recommendation ITU-T G.959.1 and ITU-T G698.1 specifies DWDM system for metro networks

Figure A9: WDM optical point to point link



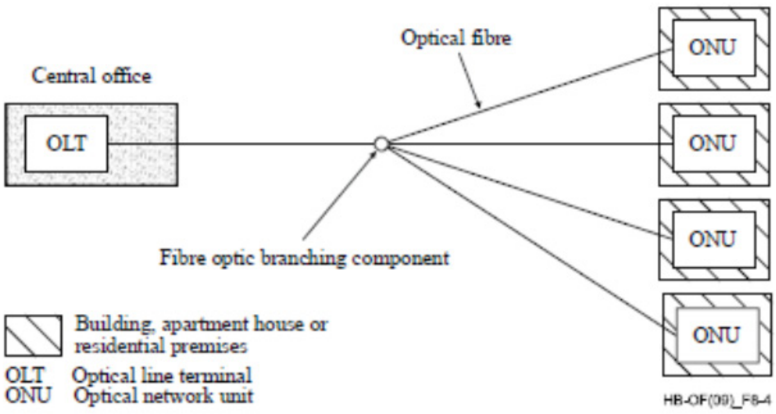
Source: ITU

Figure A10: Optical bus with optical amplifier and add/drop multiplexer



Source: ITU

Figure A11: Point to multipoint structure

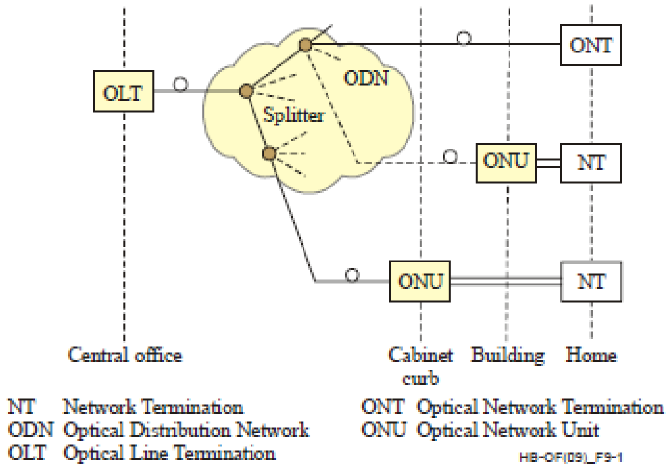


Source: ITU

Passive optical network (PON)

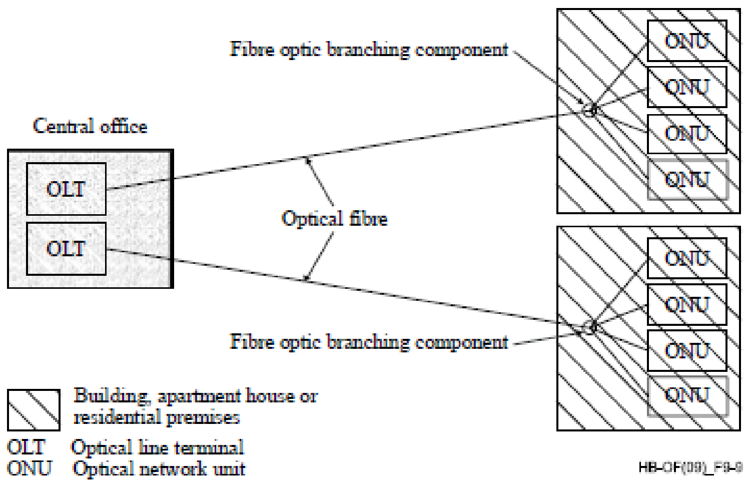
Passive optical networks are optical access networks used to extend optical signals from central office to subscriber premises. PONs are generally characterized by the absence of active components, with the exception of the sites where the OLT (optical line termination) and the ONU/ONT (optical network unit / optical network termination) are placed. However, a PON can also include a RE (reach extender), which contains active components, when a long distance between the OLT and the ONU is required. PONs are generally based on tree network topologies that use passive optical splitters.

Figure A12: Passive optical network



Source: ITU

Figure A13: PON configuration for buildings



Source: ITU

References: ITU recommendations as mentioned in the text: ITU-T Manual 2009 "Optical Fibre Cables and Systems"

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