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Fibre Development Index: Driving Towards an F5G Gigabit Society

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1 Executive Summary

Fibre deployment is essential for overall economic growth and societal development, driving more significant innovation and business efficiency.

The COVID-19 pandemic has served to highlight our growing dependency on broadband, and countries that already have highly developed broadband networks will be able to rebound faster from the current crisis and be better prepared for future ones. However, without immediate additional investment, emerging markets are in danger of being left further behind – resulting in more profound social inequalities.

Fibre is pervasive in most telecom networks, both fixed and mobile, and is being deployed to serve society's needs for enhanced broadband services in residential, business, and enterprise segments. It offers a superior level of connectivity and is very efficient on energy consumption. It is therefore highly relevant for governments, regulators, operators, manufacturers, and users to have a globally accepted index that can provide a holistic view of fibre development around the world. This study will help to identify critical factors underlying fibre deployment in different markets, and hence facilitate the evaluation of technologies and services contributing to the building of efficient evolution paths towards a fully connected and green society, aligned with the EU Green Deal and Gigabit Society (Toolbox) and with F5G vision for "fibre to everywhere."

This White Paper will address the main driving forces for fibre investment, proposing a way forward for a fibre development index (FDI), including the definition of country clusters that present similar stages of development, requirements, and evolution paths. Finally, it proposes some future directions, recommendations, and related actions.

With this White Paper, the authors intend to set the guidelines for an FDI and the fundamentals for related standardization work in this scope.

1.1 Key takeaways

- The move to a gigabit society is now more important than ever
- Fibre has a range of benefits over other broadband technologies
- The F5G vision is for FTTE
- An FDI is now required to monitor FTTE progress
- The FDI enables individual countries to create a migration path to advanced fibre access and a gigabit society, following best-practice principles
- Strong national broadband policies are essential for FTTE development
- Emerging markets should look to move directly to fibre

2 The importance of measuring fibre development

2.1 The need for fibre-to-the-everywhere-and-everything (FTTE)

2.1.1 COVID-19 has accelerated the urgency for more significant infrastructure investment

The COVID-19 crisis has brought fundamental changes to people's daily lives, and how companies, government, and social organizations carry out their operations. Even before the pandemic, the world was entering a new era in communications, underpinned by the next generation of fixed and mobile communication networks. The COVID-19 pandemic has only served to highlight the importance of this evolution, accelerating the urgency around infrastructure investment to ensure the world doesn't enter a new, starker phase of social inequality brought on by a widening digital divide.

During the pandemic, a large proportion of the world's population was confined to their homes for significant periods. Remote working became the norm and, according to World Economic Forum, over 1.2 billion children in 186 countries were affected by closures of education facilities. All other aspects of daily life such as shopping, socializing with friends and loved ones, receiving healthcare and entertainment also increasingly moved online.

The impact of the pandemic will stretch far beyond the initial health and social crisis, with industry trends and people's behaviour undergoing a step-change rather than a temporary spike. The world will increasingly rely on technology to manage such a dramatic change. Unfortunately, this means that developed countries, which are already more technologically advanced, could pull even further ahead of their emerging market counterparts – driving further and more profound social inequalities on a global scale.

2.1.2 Measuring the real digital divide

At the end of 2020, 42% of the world's population remained unconnected via any personal internet connection (i.e., personal mobile data subscription and/or fixed home broadband connection). The good news is that this figure is expected to drop to 30% over the next five years. However, a key driver of this reduction will be mobile data-only connections, with 33% of the world's population accessing the internet in this manner by 2025 (see Figure 1). By 2025, only 37% of the world's population will have the luxury of fixed-home broadband and mobile data.

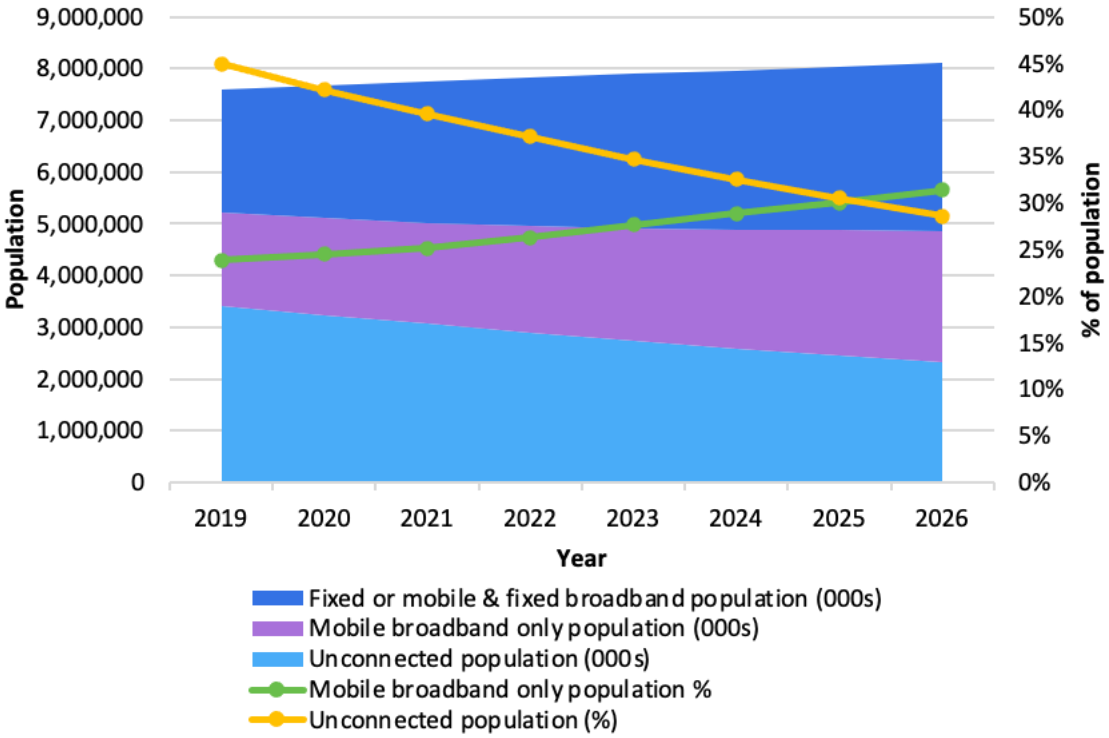

Figure 1: By 2025, 30% of the population will still be unconnected; 33% will be only via a mobile handset

However, this still doesn't tell the whole story as, even once connected, the type of service customers receive is far from equal, especially when one compares different geographies. For example, in Latin America, just under 50% of households will have a broadband subscription by 2025. However, only 5% will be on a connection delivering 500Mbps or more, and only 1% on 1Gbps. While in the US, the equivalent factors compare to 90%, 30%, and 13%, or even 75%, 39%, and 17% in Oceania, Eastern & South-Eastern Asia. At the other end of the spectrum, in Africa, only 2% of households will be on broadband speeds of over 30Mbps, with just 10% of households having a fixed-broadband connection at all (see Figure 2)

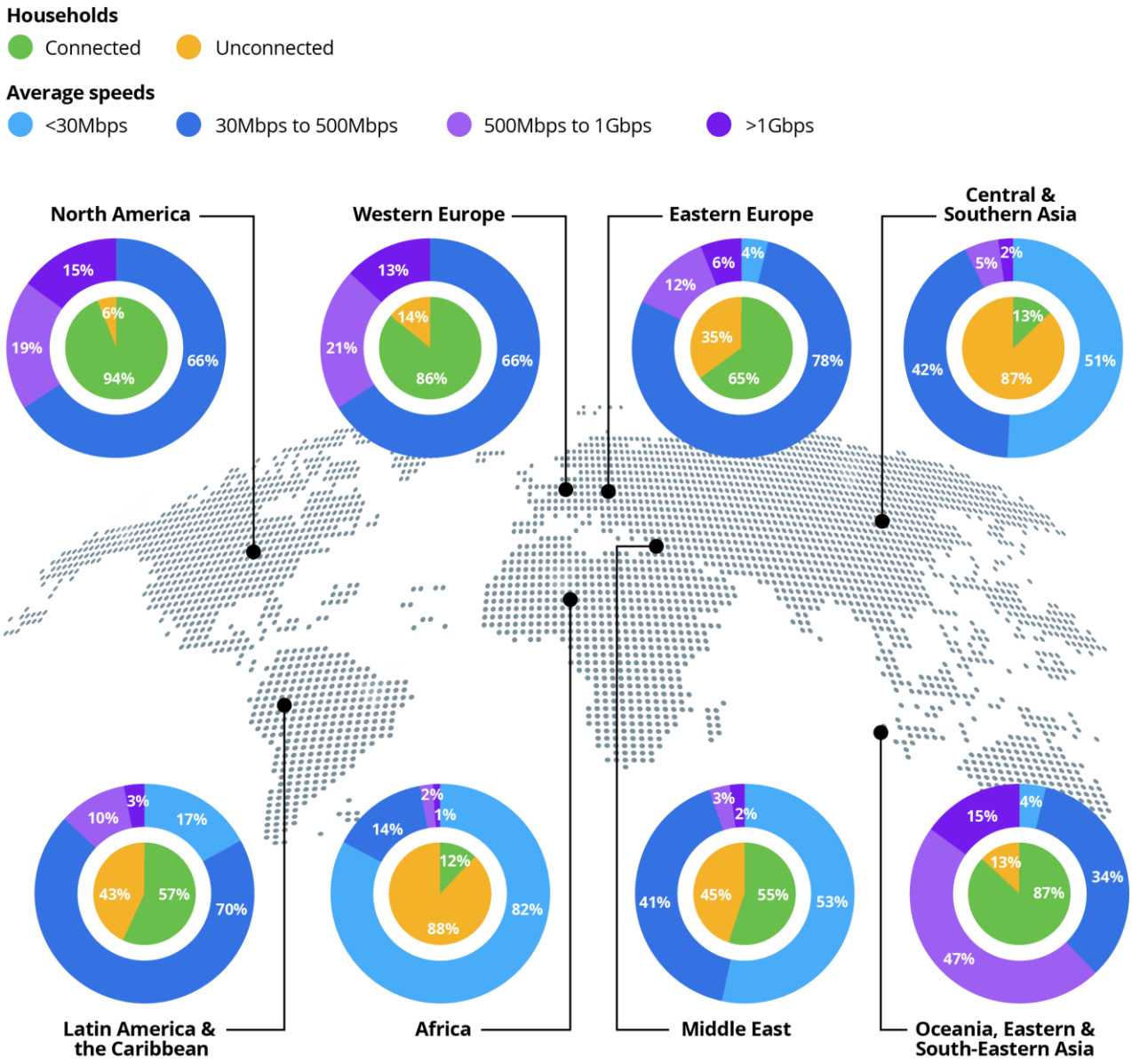

Figure 2: Percentage of connected households by speed, by region, 2025

In summary, the percentage of ultrafast speed households in developed regions such as North America and Oceania, and Eastern & South-Eastern Asia are growing significantly faster than the overall number of connected households in emerging areas such as Africa. The digital divide will be less about the connected versus the unconnected but more about the well served and the underserved – a growing gap rather than shrinking at a regional level.

2.1.3 Why FTTE is so crucial for future socio-economic growth

It is now generally accepted that broadband investment positively impacts economic growth and overall market competitiveness, as it is an enabler of more significant innovation and business efficiency. Global studies have tried to quantify this impact, three of which are summarized below:

- ITU's analysis of more than 200 studies on broadband impact notes that a 10% increase in broadband penetration yields an increase in GDP ranging between 0.25% and 1.5% (ITU, 2016, *Working Together to Connect the World by 2020: Reinforcing Connectivity Initiatives for Universal and Affordable Access* [1]).
- OECD estimates that a 10% increase in broadband penetration can raise labour productivity by 1.5% (OECD, 2011, "National Broadband Plans," OECD Digital, Economy Papers, No. 181, OECD Publishing, p. 10 [2].
- An EIB study asserts that a doubling of broadband speeds can result in 0.3% GDP growth (Bohlin et al., 2014, EIB Institute, "The economic impact of broadband speed: Comparing between higher and lower-income countries") [3].

Therefore, more significant investment in broadband infrastructure helps drive a country's GDP by optimising its national broadband capabilities. Fibre-based networks are recognised as providing sustainable and cost-efficient communication networks with high bandwidth, stability, reliability, and reduced latency – especially when compared to other fixed-network broadband technologies (see Figure 3).

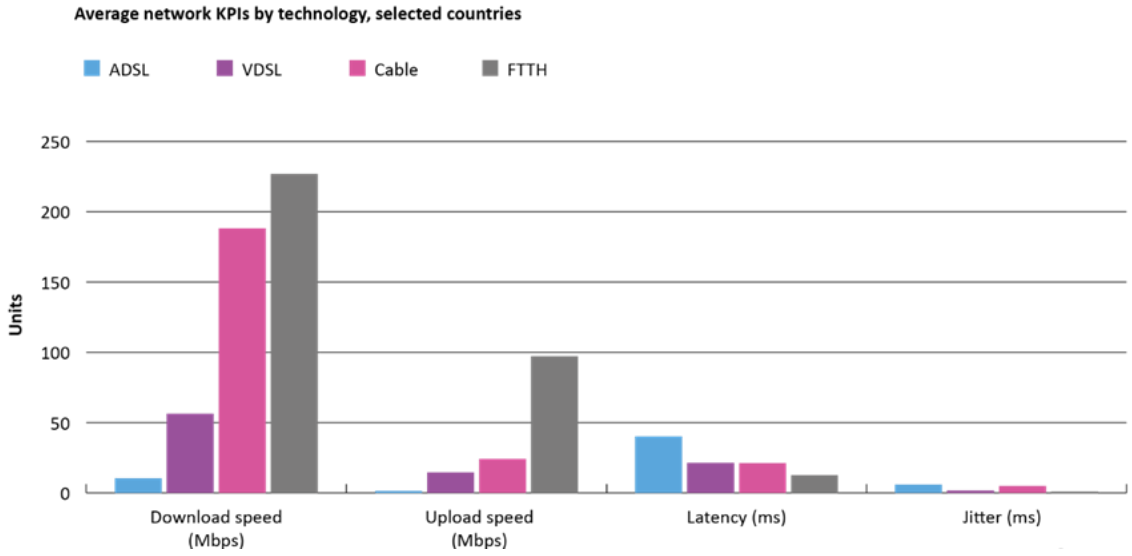

Figure 3 FTTH networks provide a truly high-end experience

This overall enhanced customer experience has provided fibre-to-the-home (FTTH) operators with a competitive advantage over other forms of broadband competitor in the way of superior net promoter scores (NPS) and reduced customer churn. For example, in 2019, the Spanish operator Masmovil topped the network quality rankings with its FTTP network, enabling it to boast an NPS ahead of its competitors at that time. A second example is Bell Canada, which has highlighted that its churn rates are lower when customers are on a full-fibre (FTTH) network. On average, the company found that churn rates for fibre access subscribers are 30–35 basis points lower than those on fibre-to-the-node (FTTN) or digital subscriber line (DSL) networks.

This focus on fibre has led to several benchmarks centred on FTTH coverage or penetration. However, such measures are incomplete by their nature as, at least for the foreseeable future, it will be impossible to connect every home and business premise to a fibre network. Additionally, for many applications, a mobile wireless connection is vitally important. Therefore, it is critical that governments and other organizations stop focusing purely on FTTH/P and take a broader, fibre-to-the-everything (FTTE) view of the world (Figure 4).

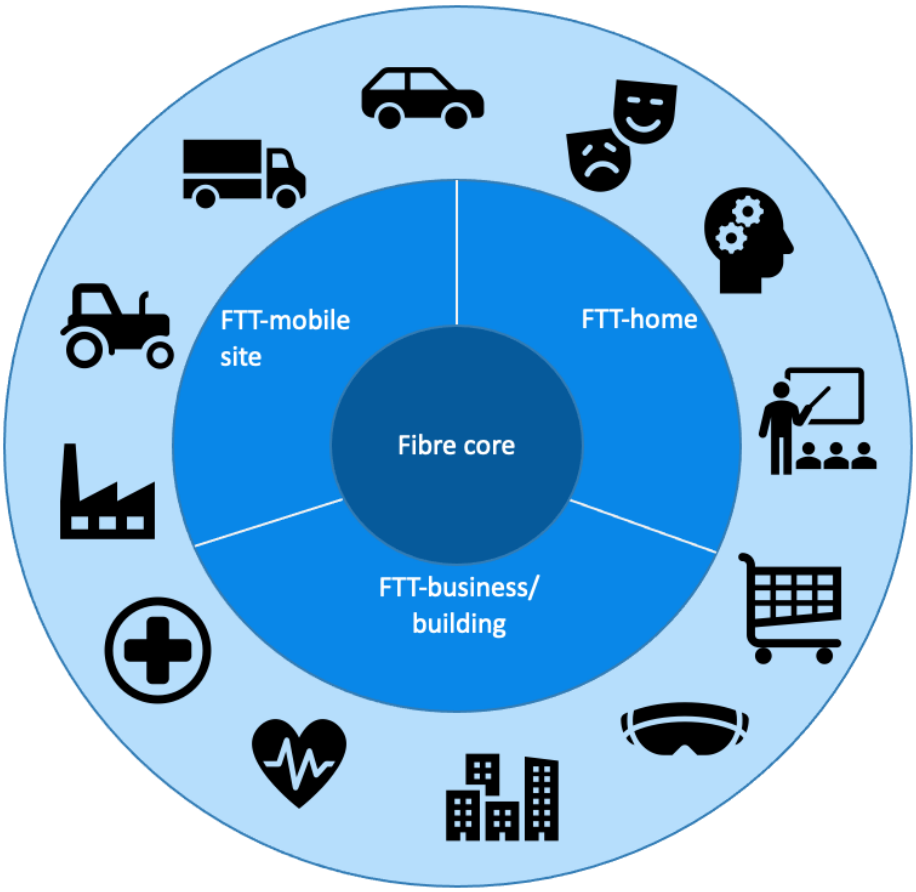

Figure 4: FTTE communication will improve all aspects of daily life

2.1.4 The move towards a more sustainable and cost-effective fibre network

In addition to delivering a superior quality-of-service (QoS) experience and helping to accelerate socio-economic growth, full-fibre networks have several environmental benefits. In many developed countries, the traditional access part of the communication networks is still primarily made up of copper

infrastructure. xDSL technology utilized this investment, but many of these copper access networks have been around for many generations and need near-constant maintenance. Full-fibre networks are newer, made of highly resilient material, and are more passive. These features mean far less maintenance, and as they don't require as much active equipment in the field to power them, the energy consumption is lower, and there is less need for field maintenance.

In addition, as optical fibre cabling offers significantly higher bandwidth capacity at a fraction of the size and weight of copper wiring, it uses far less cabling and fewer racks and switches than copper-based networks. These characteristics save additional energy as less power and cooling are required and installed in a smaller physical space. Finally, the smaller size of the optical cables makes it possible to deploy using a technique known as "micro-trenching," which is cheaper, quicker, and less environmentally destructive than traditional telecom network trenches.

In 2019, Telefónica (Spain) stated that its FTTH network was 85% more energy efficient than its old copper infrastructure. Over three years, the operator said its FTTH initiative had saved 208GWh, representing a reduction of 56,500 tons in CO2 emissions.

3 The F5G vision

ETSI's Industry Specification Group (ISG) Fifth Generation Fixed Network (F5G) aims to create the foundations for a structured approach to the evolution of the fixed network, establishing generational planning and promoting the expansion of a fifth-generation (F5G) network to as many sectors as possible. Although a significant aim of ISG's F5G is to facilitate the FTTE evolution to allow a complete end-to-end vision, it also considers other complementary last-mile technologies such as Wi-Fi 6/6E and 5G.

The characteristics of an F5G network can be characterised by ultra-high bandwidth fixed broadband, full-fibre connection, and optimal service quality experience (see Figure 5).

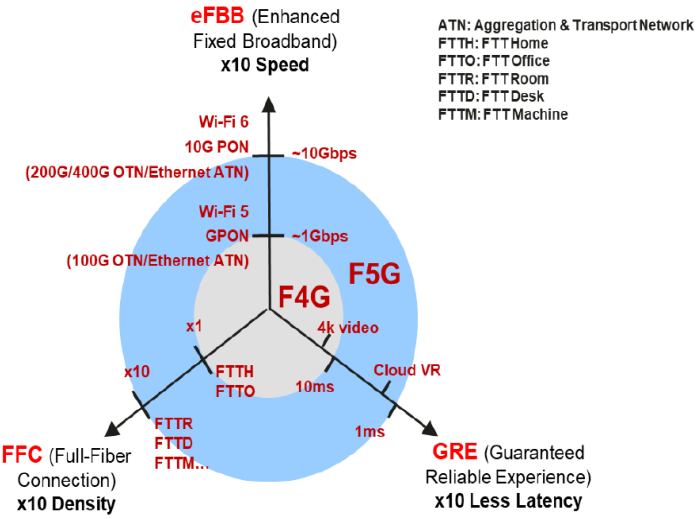

Figure 5: Features of F5G

Enhanced Fixed Broadband (eFBB) is a feature group of F5G supporting the demand for high bandwidth within the fixed network, enabling speeds of greater than 1Gbps symmetric access bandwidth per user.

Full-Fibre Connection (FFC) provides many connections for extending the number of scenarios and fibre-connected devices. F5G extends fibre connections from FTTH to a much broader application space – including business and vertical users – to provide ubiquitous connections. Hence the number of connections is increased more than tenfold over the FTTH equivalent, enabling full-fibre connectivity.

Guaranteed Reliable Experience (GRE) is the third feature of F5G increasing customer experience. High quality of experience needs to be guaranteed for the new applications enabled by F5G. Optical fibre technologies are the only means to support and ensure high-quality data transportation, minimum packet loss and latency levels in the order of microseconds.

4 The fibre development index (FDI)

4.1 The drive to create a new index

A fibre development index (FDI) is crucial to measure countries' evolution towards a fifth-generation FTTE network and identify areas to develop further. It will help to contrast where countries stand with F5G's main features: Enhanced Fixed Broadband, Full-Fibre Connection and Guaranteed Reliable Experience. Only by doing this kind of comparison can countries understand where they still have gaps in their development strategy and learn from best-of-breed countries.

4.2 Splitting countries into clusters to create realistic recommendations

The aim of an FDI is to create a standard way of measuring a country's fibre development and identify areas for further focus to maximise overall socio-economic growth. However, a meaningful way to rank and compare countries is critical to draw valuable and actionable recommendations.

To this end, it is recommended that countries are split into specific groups, or clusters, of comparable countries. Other index models often do such categorisation based on some economic factors, such as GDP. However, it makes sense for this index to split the countries according to their current broadband characteristics, especially broadband speed and network latency as, as shown in Figure 3, these are two distinct advantages of fibre over other types of broadband technology and are two of the core features of F5G. The more countries move towards advanced fibre deployment, the lower the latency and higher the speed will become.

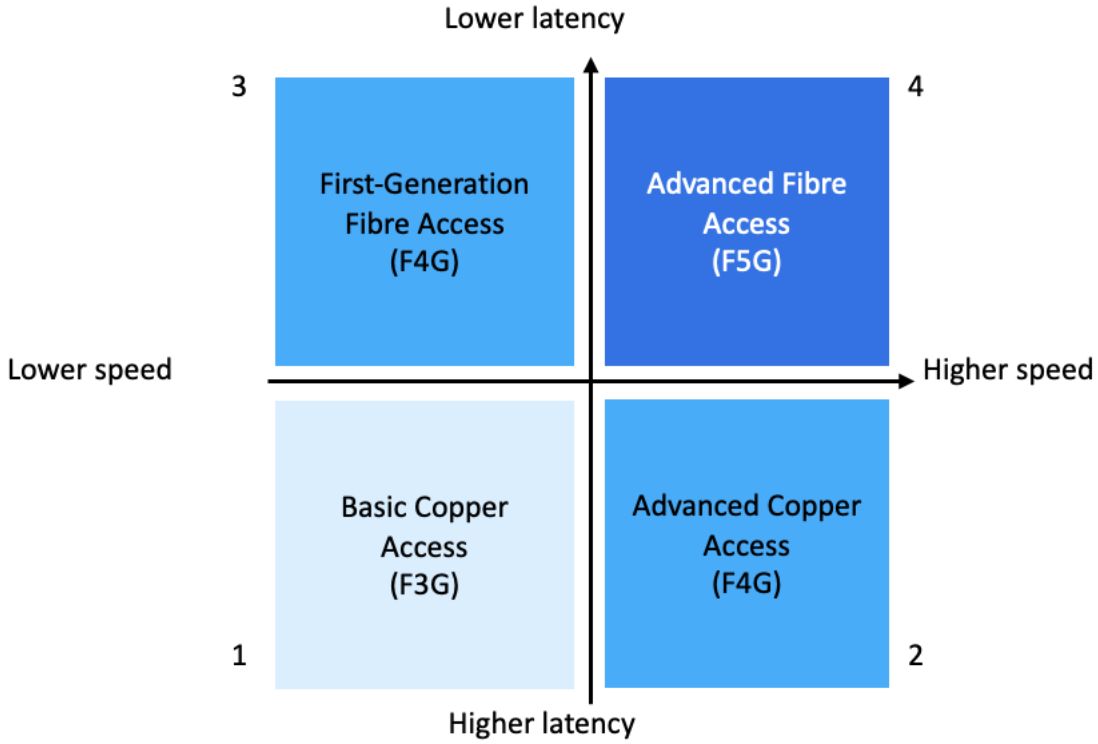

Figure 6: Suggested fibre development country clusters

This White Paper outlines four country clusters that can be used to better rank and compare individual countries: basic copper access, advanced copper access, first-generation fibre access and advanced fibre access. These clusters are briefly defined as:

- **Basic copper access:** Includes the more basic xDSL (up to VDSL) family of technologies and cable technologies up to DOCSIS 3.0 – equivalent to what ETSI ISG F5G calls F3G broadband generation
- **Advanced copper access:** Includes the most advanced xDSL technologies (G.Fast) and cable technologies above DOCSIS 3.1 – equivalent to ETSI ISG F5G's F4G generation
- **First-generation fibre access:** Includes basic fibre access technologies that include EPON and GPON technologies – also equivalent to F4G generation
- **Advanced fibre access:** Includes advanced fibre access technologies such as XG(S)PON and other future technologies, enabling a gigabit society – equivalent to what ETSI ISG F5G calls F5G.

4.3 Creating a comprehensive fibre development index

As previously discussed in this White Paper, to measure a country's progress towards an F5G society, an index must consider all levels of fibre development rather than just FTTH coverage and penetration. Parametrizing and measuring all the factors defining F5G would be extremely challenging. However, a comprehensive index would at least cover the metrics outlined in Table 1.

Table 1: Recommended FDI metrics and definitions

Group	Metric	Definition	Importance
Coverage	FTTP coverage	The total number of residential and business premises covered by the optical fibre network.	Represents the current potential of the fibre access network. A limited coverage will mean that only a small selection of households and businesses can gain access to the full benefits of a fibre network.
	Fibre density	The total installed fibre length ratio to households, with a weighting factor to account for population density.	Fibre throughout the network supports the necessary quality of experience and reliability broadband services need. Therefore, a higher amount of fibre per household installed drives greater reliability and performance for broadband networks.
Penetration	FTTH penetration	The number of FTTH subscriptions divided by the total number of households.	FTTH household penetration represents the current take-up of FTTH services. The greater the percentage, the higher the number of households that can take advantage of fibre network characteristics.
	FTTBusiness penetration	The number of FTTBusiness subscriptions divided by the total number of business premises.	FTTBusiness penetration represents the current take-up of FTTBusiness services. The greater the take-up, the more businesses will be taking advantage of FTTBusiness services, enabling a more efficient and more dynamic enterprise.
	FTTSite Mobile cell site fibre penetration	The percentage of total mobile cell sites that are fibre-connected.	Mobile cell sites need high-speed and high-quality backhaul capabilities if they are to optimise the mobile-access performance. A high FTTSite penetration will therefore mean a more optimised mobile data network.

Group	Metric	Definition	Importance
Experience	Download speed	The average end-user download speed.	Advanced fibre networks can deliver very-high-speed broadband services. Although not the only important network metric, speed is essential for delivering bandwidth-hungry applications such as 8K video in a quality fashion.
	Upload speed	The average end-user upload speed.	Unlike most other access network technologies, fibre networks can also offer symmetrical services. Although historically deemed more suitable for business, symmetrical services are becoming increasingly important in the residential market.

4.4 Index ranking methodology

The index aims to combine the individual metrics outlined in Table 1 of this report into a single benchmark measure following a five-step process.

4.4.1 Step 1: Data collection and analysis

For each metric various datasets will be utilised to gather as accurate information for each country as possible. Sources will include:

- National regulators
- National broadband operators
- Third-party specialist companies.

Where official data does not yet exist for a particular metric, estimations of the value based on other relevant market information must be made.

4.4.2 Step 2: Data normalisation

The data for each metric is then standardized to offer the same unit of measurement and scale before generating a single overall measure. It is a vital step as each dataset can be expressed in various ways, such as perhaps a percentage or some other metric such as Mbps, or perhaps km per household. Normalizing the metrics transforms these different measures onto a standard scale such as 0–100.

Datasets expressed in a percentage can directly convert into a score out of 100. For other metrics, calculations are required based on a reference measure, i.e., the ideal goal, or using the top country as the reference if the objective is open-ended. It is important to note that in such cases, the goals or calculation method can change as markets develop over time.

4.4.3 Step 4: Weighting and index calculation

In each case, the metric and metric group (see Table 1) is weighted to apply a higher level of importance of particular metrics to the final index over others. In the case of the FDI, the weighting is suggested as per Table 2. However, this is expected to change over time as countries continue to develop and other metrics rise in importance.

Table 2: Suggested metric weightings, FDI, 2021

Group	Group weighting	Metric	Metric weighting within group
Coverage	40%	FTTP coverage	50%
		Fibre density	50%
Penetration	30%	FTTH penetration	33%
		FTTBusiness penetration	33%
		Mobile cell site fibre penetration	33%
Experience	30%	Download speed	50%
		Upload speed	50%

The final index measure is calculated as follows: the group score is created by summing the metrics in that group, multiplying these totals by their weightings, and then summing the group scores multiplied by their weightings.

4.4.4 Step 5: Sensitivity analysis

Finally, sensitivity analysis is carried out to investigate the robustness of the overall index result. To this end, different methods are used to calculate the individual metric scores and the global measure to estimate the general impact on the index results. Such an approach is essential as data sources can vary from country to country and can often change as their processes are reviewed, or local definitions change.

5 How to leverage the FDI to improve fibre development

5.1 Strong national broadband policies are key to becoming advanced fibre countries

FTTE deployment is simplified in countries with smaller geographical footprints and/or highly urbanised populations. It is easy therefore to dismiss such countries as having an unfair advantage and hence offer little in the way of best practice for other countries to follow. However, although country demographics are a solid contributing factor, they are far from the only defining factor of leading FDI countries. Top FDI countries are likely to also have strong national broadband policies with ambitious goals around broadband connectivity, FTTH, and ultra-high speeds, often with government subsidies and grants available, providing strong incentives for operators to invest in fibre networks – something all countries, regardless of size and demographic characteristics, can learn from.

Additionally, it must also be recognised that even for leading FDI countries further improvements will be required. Although leading FDI countries will have very high FTTH coverage and penetration, many are still likely to score lower in other areas, for example, perhaps still in upload speed or FTTS penetration. Therefore, further investment will still be required, even in such markets, to continue developing and moving further towards gigabit-ready countries.

5.2 Advanced copper countries need stronger national policies to foster greater connectivity

Advanced copper countries are relatively developed broadband countries but are still more reliant on copper access technologies. Such countries are also more likely to suffer from less clear or less ambitious national plans, resulting in far weaker incentives for operator investment in fibre access. This scenario is often linked to those less favourable geographical and demographic conditions discussed earlier, meaning that government initiatives can be expensive and so come up against significant political resistance. However, such arguments are counterproductive as government reluctance to invest will only serve to restrict a country's ability to compete on the global stage in the long run.

Therefore, there has recently been a fresh impetus for advanced copper countries to push fibre deeper into the access network. However, there can be significant differences between the leading and laggard countries within this group, and even in countries with higher levels of coverage, customer penetration can often remain low.

Because of the move to more advanced access technologies such as G.Fast and DOCSIS 3.1, average download speeds in this sector can already be relatively high in some countries. However, these technologies are not yet ubiquitous across all copper networks. Even then, such countries still tend to have relatively low upload speeds and won't enjoy the same degree of consistency and low levels of jitter and latency as witnessed in more fibre-rich countries. Further investment, therefore, in full-fibre networks will lead to better overall broadband QoE scores across all countries.

5.3 Emerging markets/basic copper should look to move directly to advanced fibre

More emerging and rudimentary copper countries have often adopted national broadband plans or strategies. Still, these tend to boost general broadband availability and often lack meaningful objectives and specific policies. Countries capitalising on fibre development tend to be focused on a particular area, usually around FTTBusiness, FTTSite, and fibre backbone. Investment spikes represent that behaviour. This more focused strategy is to be expected in such emerging markets, but it is important that they build on these investments and expand into the other areas of fibre development, preferably moving directly towards Cluster 4: the advanced fibre sector.

6 Migration paths to a gigabit society

Within the Cluster matrix (see Figure 7), all evolution paths eventually point to Cluster 4, Advanced Fibre Access. However, the evolutionary path can change depending on whether the country comes from a GPON environment (Cluster 3), a more heavily copper-based xDSL environment (Cluster 2), or an emerging market with rudimentary copper access (Cluster 1).

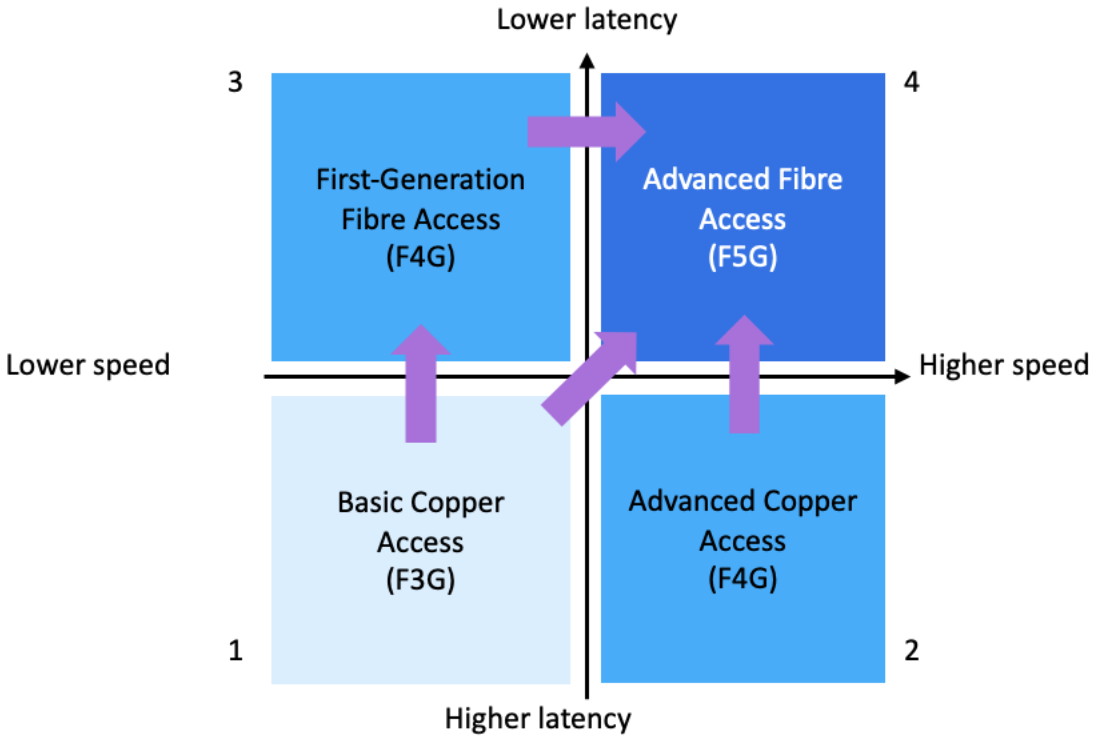

Figure 7: Migration paths to advanced fibre access and a gigabit society

At a very high level, the evolution path of each cluster should be as follows:

- **Cluster 1:** Where broadband networks are still in their infancy, countries should adopt a strategy to move to a fibre-first network and focus initially on major cities to connect mobile base stations. The focus should be first on fibre backhaul in emerging broadband markets to enable other suitable technologies such as 5G fixed wireless access (FWA).
- **Cluster 2:** Where broadband penetration is high, but FTTH penetration is still low, countries should implement investment strategies to enable a faster migration to fibre access. Marketing strategies must then focus on the advantages of fibre-to-the-premises (FTTP) services to encourage quick customer take-up.
- **Cluster 3:** Where FTTH penetration is already high, continued investment is required to upgrade to F5G – namely by replacing active parts in both the optical line terminal (OLT) and optical network unit (ONU) side – for the backhaul network, enterprise services and demanding FTTH users, to move to a gigabit network and beyond.

However, regardless of a current position, each country must also follow some common best-practice principles to foster improved connectivity. These include:

- Developing a national broadband plan with concrete and ambitious goals around coverage and ultra-high speeds, matched by legislation designed to encourage investment
- Remove all barriers to access to key infrastructures such as ducts and building access
- Consider financial incentives such as taxation, subsidies, or public investment
- Support network-sharing agreements between operators to eliminate network overbuild, accelerate rollout and help manage investment costs
- Deploying new optical fibre can be expensive but this investment can be shared by exploring new use cases across consumer, enterprise, and wholesale markets. By maximising fibre investment, countries can move towards next-generation, smart city networks.

7 Overall conclusions and next steps

The FDI provides a comprehensive way for countries to measure their fibre development across access, backhaul and core networks, creating an evolution path towards FTTE and a gigabit society.

Even leading countries in the FDI will still require further development to reach this goal, and the FDI can be utilised to identify areas of priority investment and national strategy for countries within each cluster. Regardless of their current position, however, for all countries creating a robust national broadband policy with ambitious broadband connectivity and FTTH and ultra-high-speed goals, backed by government subsidies and grants, where necessary, it is essential to foster this evolution. It is now critical that governments worldwide take the steps required to enable the communication companies in their countries to make investments in high-speed, fibre-based communication networks.

The EU is one example where this has been recognised, with directives being revised and revamped. In 2014, the EU established the "Broadband Cost Reduction Directive," which aims to "facilitate and incentivise the rollout of high-speed electronic communication networks." The regulation promotes measures for facilitating the joint use of existing physical infrastructure and more efficient deployment of new physical infrastructure at a lower cost. The member EU states implemented the directive into their national rules. However, in 2018, the European Commission (EC) reviewed the directive's implementation and found problems related to its efficiency and consistency.

In 2020, the EC launched a further review and created the European Electronic Communications Code to improve the regulatory conditions to incentivise private investment and deploy and take up high-speed broadband networks. The European Electronic Communications Code also addressed the timely and investment-friendly access to the 5G spectrum. The EU instructed the member states to transpose and apply the code's provision by 21 December 2020.

In September 2020, the EC adopted a recommendation calling for all member states to develop and agree on a common Union Toolbox of best practices to foster connectivity. In terms of reducing network deployment costs, the best practices are as follows:

- Streamlining permit-granting procedures for civil works
- Improving transparency and reinforcing the capabilities of the single information point
- Expanding the right of access to existing physical infrastructures controlled by public sector bodies
- Improving the effectiveness and efficacy of the dispute resolution mechanism
- Reducing the environmental footprint of networks
- Performing and taking account of the results of environmental impact assessments.

Therefore, the following is proposed:

- The adoption of the FDI as a way forward to measure the evolution of fibre deployment in different countries/entities around the world
- To yearly evaluate refinements to the FDI metrics and cluster definition for increasingly better characterisation of each region
- To continue the development of the F5G ecosystem providing the guidance for a fibre-to-everywhere environment with reliable service experience
- Further explore the key factors on fibre adoption and the recommendations and possible evolution paths in the direction of a F5G gigabit society.

Annex A: References

[1] (ITU (2016), "Working Together to Connect the World by 2020: Reinforcing Connectivity Initiatives for Universal and Affordable Access").

[2] (OECD (2011), "National Broadband Plans", OECD Digital, Economy Papers, No. 181, OECD Publishing, p. 10).

[3] Bohlin et al. (2014), EIB Institute, “The economic impact of broadband speed: Comparing between higher and lower-income countries”.

[4] Global Fibre Development Index Analysis: 2020, Omdia

[5] Directive on measures to reduce the cost of deploying high-speed electronic communications networks (2014/61/EU)

Annex B: Glossary

ADSL	Asymmetric Digital Subscriber Line
DOCSIS	Data Over Cable Service Interface Specifications
DSL	Digital Subscriber Line
EC	European Commission
eFBB	Enhanced Fixed Broadband
EIB	European Investment Bank
FDI	Fibre Development Index
FFC	Full-Fibre Connection
FTTB	Fibre to the Business
FTTE	Fibre to Everything
FTTH	Fibre to the Home
FTTN	Fibre to the Node
FTTP	Fibre to the Premise
FTTS	Fibre to the Site
FWA	Fixed Wireless Access
GRE	Guaranteed Reliable Experience
ITU	International Telecommunication Union
ISG	Industry Specification Group
NPS	Net Promoter Score
OECD	Organisation for Economic Co-operation and Development
OLT	Optical Line Terminal
ONU	Optical Network unit
VDSL	Very high bit rate digital subscriber line

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