CONNECTIVITY FOR THE GIGABIT SOCIETY

COMMUNICATIONS CHAMBERS

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Connectivity for the Gigabit Society:

A framework for meeting fixed connectivity needs in Europe

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Content

1. Executive summary

The Commission has set out a vision for a Gigabit Society

- Ample broadband ahead of requirements is important for Europe's economy and society
- The Commission has set a 2025 target of 1 Gbps for socio-economic drivers and 100 Mbps for households
- More generally, it has called for widespread very high capacity (VHC) networks

The Commission rightly anticipates that much of the necessary investment will be purely commercial

- Next Generation Access (NGA) is now widely (though not universally) deployed, based on supportive regulation, including pricing flexibility
- Assuming supportive regulation continues (including the Electronic Communications Code), VHC networks will also see widespread commercial deployment, not least because of the rapid development of technologies such as DOCSIS, G.fast and fixed wireless
- This rapid development is causing operators such as Google Fibre, Australia's nbn and Swisscom to shift from FTTP to these technologies
- Since these technologies are cheaper, they can be commercially deployed to more customers

DOCSIS 3.1 on cable networks will be a key contributor to Europe's VHC ambition, with deployment on a purely commercial basis likely over much or all of cable's footprint of roughly half of EU households

- DOCSIS 3.1 is already being commercially deployed to provide symmetric 1 Gbps services. In time speeds as high as 10 Gbps are possible making cable's network 'GigaReady'. Hence this technology is likely to meet the needs of virtually all residential and business customers for many years to come.
- Real world latency and packet loss on cable networks are effectively indistinguishable from those achieved on FTTH (and in some cases better)
- With the exception of a very small number of extremely demanding business customers, the capabilities of DOCSIS 3.1 will be more than sufficient for end-users for at least a decade ahead
- DOCSIS 3.1 is quick to deploy, with several operators expecting to complete their roll-out by the end of 2017 (far ahead of the Commission's 2025 target)
- It is also cost-effective, with a cost per home in the tens of euros (within existing coverage areas)

While the availability of high quality access is important, it is not the only (or even the most important) constraint to delivering a good experience to end-users

- Other network elements (such as Wi-Fi or the transit or core networks) may constrain end-to-end speeds to well below the theoretical capability of the access link, and thereby have a bigger impact on the user experience
- 100m EU adults use the internet rarely or not at all

Against this background, national broadband plans and any market interventions need to be designed carefully, to be sure they are focused and cost effective, and avoid unintended consequences

- In particular, any push to overbuild with FTTP risks chilling investment in a range of other competing networks, making broadband worse in the short to medium term (this was the experience in Australia)
- Korea and Japan's substantial government interventions to support FTTP have also been disappointing. Both countries have performed relatively poorly in their use of socially or economically valuable internet applications such as e-government and e-health, despite their superior (and expensive) infrastructure

Thus as member states develop their broadband plans (within the context of the EU's Gigabit Society objective), the evidence suggests they should

- Continue to rely to the extent possible on commercial investment supported by regulatory flexibility
- Keep to a mixed technology approach, maximising scope for innovation, infrastructure competition and cost reduction
- Provide financial support only in those cases where the market is not delivering and material externalities are at risk
- Support improvements in areas such as Wi-Fi capacity and internet and broadband adoption

2. Introduction

The Commission has set out its vision of a 'Gigabit Society'.[1] This states that:

> "The full economic and social benefits of this digital transformation will only be achieved if Europe can ensure widespread deployment and take-up of very high capacity networks".

More specifically, the Commission proposes Gigabit connectivity for all 'socio-economic drivers' by 2025. (This category covers schools, hospitals, larger enterprises, and so on). It also proposes 100 Mbps for all households by that date, 'upgradeable to Gigabit speed'. The Commission has called on member states to reflect these targets in their national broadband plans.

The Commission's announcement is the latest step in an ongoing debate about what broadband infrastructure is required for Europe's future. Some argue that only ubiquitous fibre-to-the-premise will do, and that this should be the policy objective. By contrast, the Commission includes within the category of very high capacity (VHC) technologies: "G.fast very close to the end user/FTTB, DOCSIS 3.1 and FTTH".[2]

Converting the Commission's Gigabit Society ambition into detailed policy within member states' national broadband plans will be a complex task. This paper seeks to contribute to that task, by offering a framework for broadband policy.

We first consider the potential benefits from information and communications technology (ICT). We then discuss what improvements to broadband the market is likely to deliver. Against this, we discuss the evidence for demand *beyond* what the market will offer, and how this fits into the wider set of constraints for internet usage.

We then turn to a discussion of broad principles for an appropriate policy intervention in this area (particularly in light of past interventions globally which have not fully realised their ambitions). Finally we offer a set of practical recommendations in the European context, to support a targeted, cost-effective and impactful policy.

1. EC, Connectivity for a Competitive Digital Single Market - Towards a European Gigabit Society, 14 September 2016
2. EC, Connectivity for a Competitive Digital Single Market - Towards a European Gigabit Society [Commission staff working document], 14 September 2016 (p43)

3. Economic and societal objectives

In 2000 Alan Greenspan, then Chairman of the Federal Reserve Board, remarked:

> "The full value of computing power [for productivity] could be realised only after ways had been devised to link computers into large-scale networks..."[3]

Information and communications technology (ICT) has made a substantial contribution to productivity growth in Europe – both directly and via network effects. In relation to connectivity, for the eight countries for which data was available (Austria, Finland, France, Germany, Italy, Netherlands, Spain, and United Kingdom) a significant direct, and indirect (due to spillovers) impact of connectivity on productivity growth was found.[4]

The European Commission has recognised the central role of connectivity, alongside other measures, as part of the Digital Agenda and Digital Single Market initiatives. The Gigabit Society communication goes further, asserting that:

> "For Europe's growth, jobs, competitiveness and cohesion, very high-capacity networks are becoming a necessity"[5]

As such, the European Commission, in its proposal for a European electronic communications code, makes it incumbent upon national regulatory authorities to promote "the deployment of very high capacity networks".[6]

We agree that connectivity should not constrain the development of the digital single market or the European economy. However, market developments are uncertain and formulating the right policy mix is a challenge.

First, though broadband passed 50% household adoption in Europe in 2008 and speeds have increased, the growth contribution of ICT has not accelerated but diminished.[7] The reason for this productivity paradox is unclear - perhaps it is a pause before the mobile internet reaches critical mass and drives the next wave of growth?

Second, we have moved from a world of homogenous fixed voice provision and use to a heterogeneous world of diverse technologies and demands, from low data rate wireless machine-to-machine connectivity to multi-gigabit connections.

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3. Alan Greenspan, The revolution in information technology, March 2000
4. Corado and Jager, Communication Networks, ICT and Productivity Growth in Europe, December 2014.
5. EC, Connectivity for a Competitive Digital Single Market - Towards a European Gigabit Society, 14 September 2016
6. EC, Proposal for a Directive of the European Parliament and of the Council establishing the European Electronic Communications Code (Recast), 14 September 2016 (Article 59)
7. Evidence for the US points to a significant slowdown post 2007. John G. Fernald (Federal Reserve Bank of San Francisco) Productivity and Potential Output Before, During, and After the Great Recession, 5 June 2014

Communications services are becoming more like a normal market in their diversity, however, this also makes policy decisions and interventions more challenging and risky since priorities may be misjudged in a rapidly changing market and the wrong intervention at the wrong time may crowd out or delay private investment.

Figure 1: Definitions

Bandwidth
A rate of transfer of data, in (eg) Mbps

Traffic
An amount of data transferred over a period, in (eg) MB

Download / Downstream
Traffic or capacity to the end-user

Upload / Upstream
Traffic or capacity from the end-user

Latency
Time taken for a packet of data to travel between two points, typically measured in milliseconds (ms)

Packet loss
A measure of a network's reliability in delivering data, typically measured as a percentage

Third, whilst demand for internet traffic (in GB – or actual **amount** of data transferred) is almost certain to rise, demand for peak speed (in Mbps – or **rate** of throughput of data) may become somewhat decoupled from this. Doing more does not necessarily involve doing more at the same time. For example, additional usage of video outside peak hours adds to traffic, but makes no difference to peak bandwidth requirements.

Fourth, as commercially driven next generation access investment (in a range of technologies) moves ahead of demand, the challenge is shifting to: maintaining incentives for ongoing timely upgrades as demand develops; provision of higher speed broadband in less commercially attractive areas; and stimulating adoption and use.

Improving connectivity, adoption and use should remain a priority. However, great care is needed as to if, where, when and how governments intervene to improve connectivity. The wrong intervention could be wasteful, or even damaging. For example, support for an expensive and slow-to-deploy technology could drive up prices and paralyse investment in other technologies which might have delivered improved performance more quickly.

This paper is focussed on examining available evidence and supporting appropriate policy formulation.

4. Improving infrastructure without intervention

The majority of the improvements in Europe's broadband infrastructure to date have been driven by commercial investment. Several factors point to further commercial rollout of NGA and upgrade to VHC networks. First, a more favourable regulatory framework was put in place by the Commission in 2013 and is being progressively implemented by national regulators. Second, innovation is lowering the cost of delivering NGA (and VHC networks in particular) via a diverse set of access technologies.

In this section we first consider the success to date, and its relation to policy. We then look at how different national circumstances relate to policy. Finally we consider how access technology innovation over time can influence optimal policy.

Figure 2: Fixed NGA availability (%)[8]

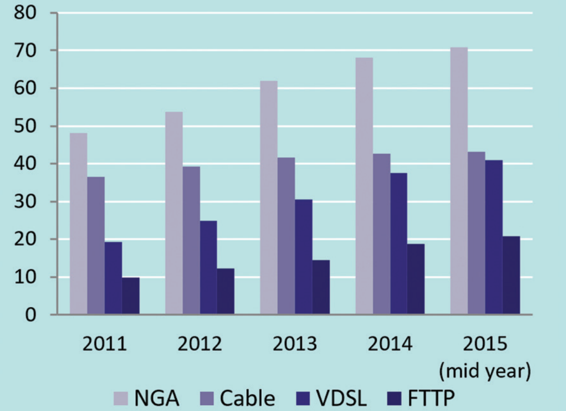
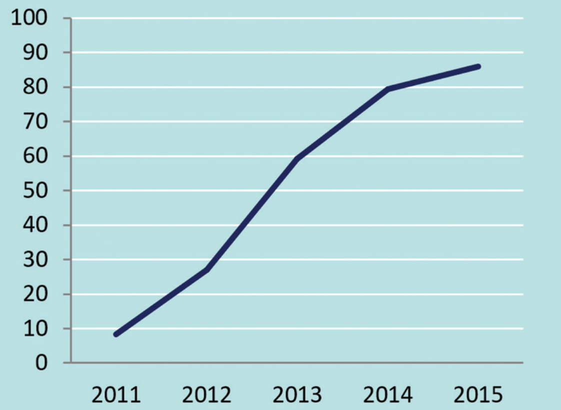


Figure 3: Mobile 4G availability (% households)[9]



Growing availability of next generation access

Availability of next generation access (NGA) has increased steadily in Europe, from 48% in 2011 to over 70% in 2015 (Figure 2). Much of this investment has been commercial with investment in Cable DOCSIS 3.0, FTTP and VDSL.

4G coverage has also increased from 8% to 86% over the same period, almost entirely as a result of commercially driven investment. With the right policy environment, commercial investment does respond quickly. In this instance it was delayed by spectrum liberalisation, but once spectrum for 4G was freed up, investment followed and Europe has been catching up with other regions after a late start.

Not only has overall NGA coverage grown, but infrastructure competition and consumer choice have also expanded. In covered areas, the number of NGA networks available to the average premise has increased from 1.40 at the end of 2013 to 1.48 in mid-2015.

This expansion in availability of NGA has occurred against a backdrop of a challenging overall revenue position for the industry, and investment in areas of progressively greater difficulty (for instance, lower population density) as time goes by.

8. European Commission Digital Economy & Society Index, Broadband indicators, 2016.
9. European Commission, Digital Agenda Scoreboard [accessed 17 April 2016]

Commercial investment in NGA is not restricted to the densest urban areas. Fixed NGA investment has occurred in a range of locations, and 4G is expected to deliver high levels of coverage – at the upper end of the 95-100% range - in many member states in the near term.

Satellite coverage is near universal today and substantially higher satellite capacity is planned before 2020 with the launch of satellites with a capacity of 1 Terabit per second, enabling 100+ Mbps consumer services.[10] (However, satellite does have some disadvantages compared to terrestrial solutions, notably higher latency - which is problematic for certain applications - and lower upload speeds).

Implementation of existing policy is supporting investment

Only comparatively recently was a more supportive approach to NGA investment adopted in Europe. Prior to 2013 national regulators had driven down the price of copper lines – depressing prices in the market as a whole. Flexibility for NGA pricing was also the exception rather than the rule for telecommunications operators. However, the Commission costing and non-discrimination recommendation of September 2013 supported real copper price stability and wholesale NGA pricing freedom, and noted:

> "…pricing flexibility at wholesale level is necessary to allow both the access seeker and the SMP operator's retail business to introduce price differentiation on the retail broadband market in order to better address consumer preferences and foster penetration of very high-speed broadband services" [11]

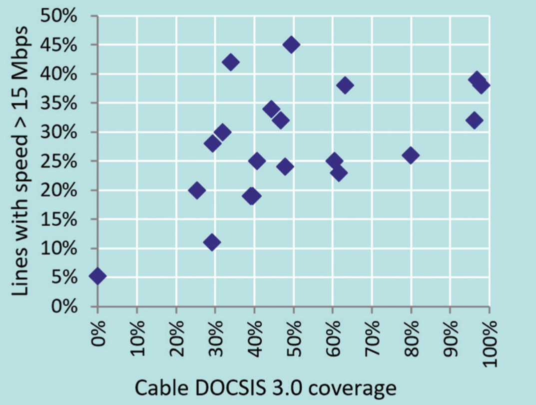
As this approach, which supports pricing flexibility and service-price differentiation, is adopted by NRAs it is spurring commercial investment.

Different national circumstances drive different technology choices

The nature of that investment depends on a range of national circumstances however. We here consider relevant circumstances and then review cases studies of Germany, UK and Malta. (Unusually, Malta anticipates 100% FTTP coverage, but as we will see this is due to some very specific local conditions).

10. ViaSat, ViaSat Unveils First Global Broadband Communications Platform to Deliver Affordable, High-Speed Internet Connectivity and Video Streaming to All, 9 February 2016
11. EC, Commission recommendation on consistent non-discrimination obligations and costing methodologies to promote competition and enhance the broadband investment environment, September 2013. ¶49

Figure 4: Speed >15 Mbps vs. cable coverage, European countries[12]



Impact of cable availability and other local circumstances

A technology neutral approach has allowed for a mix of solutions and encouraged innovation. The contribution of cable DOCSIS 3.0 to raising speeds in Europe, both directly, and indirectly, by spurring investment by others, is evident from Figure 4. Higher levels of DOCSIS 3.0 coverage based on pre-existing cable networks in a country appear to ensure that a higher proportion of *all* internet users in that country have connectivity at speeds greater than 15 Mbps.

The availability of high quality duct and pole access, and/or high population density (particularly in MDUs [13]) may make fibre to the premise deployment cost effective and rapid. This is the case in Malta, and in parts of Spain and Portugal.

The pre-existing configuration of the copper network in a country also has impact, since it may facilitate or impede deployment of VDSL, vectored VDSL, G.fast and so on.

Malta – cable and fibre to the premise

Malta is an example of a country where circumstances are particularly favourable to fibre. It has the highest population density in Europe with 1,320 persons per square kilometre. (The Netherlands come second with 492 persons per square kilometre). Malta also has near universal cable coverage. Malta also has good ducts (including defensive tunnels dug by the Knights of St John – history matters) and brackets on buildings used for power and cable. NGA pricing flexibility was also a key factor in the decision to invest, with an expectation it would be granted following the Commission recommendation. (A final decision endorsing the approach in Malta was made in 2016.). [14]

With these underpinning factors, GO, who had deployed VDSL, from April 2015 has been deploying FTTP. More than 30,000 homes (out of 150,000) have been passed already, with nationwide coverage expected within five years. Much of this is commercial, but there is also funding from the European Investment Bank. In parallel with mass market FTTP deployment GO is also building a dedicated gigabit fibre network for the Bank of Malta.[16]

12. Akamai, State of the Internet (Q4 2015) and European Commission DESI (2014)
13. Multiple Dwelling Units – apartment blocks
14. MCA, Virtual Unbundled Access to Fibre-to-the-Home. Response to Consultation and Decision, February 2016
15. GO, Interim Directors' Statement, May 2016
16. Malta Independent, Bank of Valletta commissions GO to deliver Gigabit fibre network, September 2015

The UK – VDSL, cable expansion and plans for G.fast

The UK is seeing a mix of technologies deployed including VDSL, cable expansion, fibre to the premise and plans for G.fast

The initial trigger for BT's investment was a combination of cable competition and NGA pricing freedom formalised in 2010 by Ofcom.[17] BT has invested primarily in VDSL, reaching 65% coverage by 2014 commercially (beyond the cable footprint at the time). By March 2016 NGA reached 90% of households with 95% coverage anticipated by December 2017.[18] BT's future ultrafast plans include 2m premises to be passed with FTTP (delivering a gigabit), and 10 million with G.fast (delivering up to 500 Mbps) by 2020.[19] Other companies, including Gigaclear[20], are also investing in fibre to the premise.

In 2015 Virgin Media (a subsidiary of Liberty Global) announced Project Lightning, an investment of £3 billion to expand cable coverage from just under 50% to around 65% of households by 2020. The investment involves an extension of the cable network and fibre to the premise (for at least 1m of the 4m premises concerned).[21] Virgin Media has also begun trials of DOCSIS 3.1 technology which can deliver gigabit per second speeds (discussed in more detail below).

The UK case demonstrates how investment in a mix of technologies, with a supportive regulatory environment (see Chapter 6), can deliver rapidly growing coverage of NGA, subsequent upgrades and an expansion of infrastructure competition resulting in a self-perpetuating cycle of competing counter investments.

Germany – VDSL and vectoring

In Germany cable covers 63% of households. NGA coverage was 81% in 2015, including VDSL.[22] Cable competition, favourable regulation and flexibility over technology have delivered good outcomes.[23]

Deutsche Telekom plan to upgrade VDSL utilizing vectoring which offers higher speeds and greater consistency of speed across premises. As vectoring can only in practice be provided on a coordinated basis, this required regulatory agreement, granted by the regulator in September 2016.[24]

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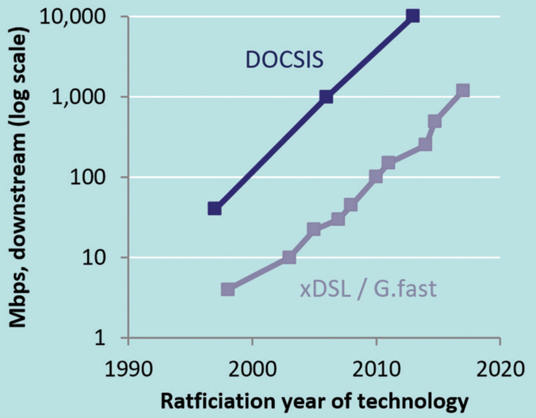
17. See, for instance, Ofcom, Strategic Review of Digital Communications: Discussion document, 16 July 2015
18. DCMS, Broadband Delivery UK, 21 December 2015
19. BT, BT to invest billions more on fibre, 4G and customer service, 5 May 2016
20. Gigaclear, Gigaclear secures £24 million new equity investment, April 2016
21. Virgin Media, Virgin Media announces largest UK fibre broadband rollout, 27 April 2016
22. EC, Broadband coverage in Europe 2015, 30 September 2016
23. See, for example, Plum (for ETNO), Fostering investment and competition in the broadband access markets of Europe, February 2016
24. Bundesnetzagentur, Bundesnetzagentur gibt endgültige Vectoring-Entscheidung bekannt, 1 September 2016.

Innovation over time drives different technology choices

Thus different national circumstances can drive different technology choices. But so too can the passage of time. Rapid broadband access technology innovation is transforming the capabilities of copper, cable and other networks. This extends the scope for commercially-driven NGA and VHC investment and improves the performance of existing technologies.

Figure 5 Copper & cable maximum data rates[25]



We here consider the developments of cable (DOCSIS) and copper (xDSL/G.fast) technologies, both of which have seen rapid speed improvements (Figure 5), before turning to other technologies. We then discuss the policy implications of technology development.

DOCSIS 3.1

The latest cable standard is DOCSIS 3.1, commercially launched by operators this year. It will allow cable to rapidly meet future needs at a moderate cost. DOCSIS 3.1 is much more than an incremental upgrade: it enables a real shift in capability and performance. Numerous operators are now actively deploying the technology, generally offering gigabit speeds to consumers (as do each of these examples):

- Comcast has launched services in Chicago, Atlanta and Nashvhille[26]
- Rogers (in Canada) has deployed DOCSIS 3.1 to 2m homes, as of June 2016[27]
- TDC expects to deploy DOCSIS 3.1 across its entire Danish cable network by the end of 2017[28]
- Vodafone will be upgrading its 7m cable homes-passed in Spain to DOCSIS 3.1 in 2017, offering a 1 Gbps symmetrical service.[29]

The technology already allows for multi-gigabit downstream services. For the future, symmetric
The technology already allows for multi-gigabit downstream services. For the future, symmetric
speeds as high as 10 Gbps have already been demonstrated in the lab, based on 'XG-CABLE' technology.[30] As we discuss later, DOCSIS 3.1's high performance (both on speed and other technical parameters) mean it is 'GigaReady' a well qualified as a VHC network.

25. Bell Labs Alcatel-Lucent, The Future of Copper, May 2014; Analysys Mason (for Ofcom), Future capability of cable networks for superfast broadband, 23 April 2014; CableLabs, Cable Broadband Technology Gigabit Evolution, September 2016
26. FierceCable, Comcast set to launch DOCSIS 3.1-powered 1-gig services in Chicago, 17 August 2016
27. Rogers, Q2 2016 Results, 21 July 16
28. LightReading, TDC Denmark Launches DOCSIS 3.1 With Huawei, 6 August 2016
29. Advanced Television, Spain: Vodafone to launch symmetric 1 Gbps, 6 September 2016; Vodafone, Acquisition of ONO, 17 March 2014
30. CableLabs, Full Duplex DOCSIS 3.1 Technology: Raising the Ante with Symmetric Gigabit Service, February 2016; Nokia, Nokia Bell Labs achieves world's first 10 Gbps symmetrical data speeds over traditional cable access networks, May 2016

The deployment of DOCSIS 3.1 is also quick. As the examples above show, many operators expect to complete by the end of 2017, and deployment is likely across much of Europe's cable footprint not long thereafter. (IHS estimate cable's coverage as 44% of EU28 households in 2015. Arthur D Little put it at 54%).[31] By contrast, it has taken over 15 years for European FTTP coverage to reach 21%.

DOCSIS 3.1 is also inexpensive. The Commission has been advised that:

> "the upgrade to DOCSIS 3.1 will require an extension of the fibre access network from the cabinets to the last amplifiers. This constitutes a major investment, which in high density urban areas is equivalent to providing fibre to the building or fibre to the basement".[32]

This advice is incorrect. In fact, DOCSIS 3.1 is in principle a cheap upgrade. Liberty Global expects it to cost $22 (€20) per home. Canadian cable operator Rogers has suggested:

> "the incremental in-year capital cost to offer a 1-gigabit service is less than $50 [€34] per home passed".[34]

It is these low costs which mean that DOCSIS 3.1 is likely to see widespread deployment without any need for government support.

G.fast

G.fast provides a case study in terms of technology evolution, in part planned but also offering unanticipated possibilities. G.fast was initially developed via a series of EU collaborative projects.[35] The intention was to allow fibre-like capabilities over short copper lines to avoid the cost, complexity and delay of within-premise installation of fibre. However, ongoing development of the G.fast standard by operators and vendors has shown that it will be able to offer multi-hundred Mbps speeds over longer copper lines, enabling quick and efficient upgrades where fibre has already been taken to the cabinet. BT, for instance, expects to deliver 300 Mbps at 300 metres.[36]

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31. IHS (for European Commission), Broadband indicators, 2016; Arthur D Little (for Cable Europe), Cable Operator's Contribution to the European Digital landscape, July 2016
32. WIK, Deloitte & IDATE for the EC, Regulatory, in particular access, regimes for network investment models in Europe, September 2016
33. Fierce Telecom, Liberty Global will trial DOCSIS 3.1 in early 2016, 11 August 2015
34. Rogers, 2015 Annual Report, February 2016
35. FP5 programme MuSE and CELTIC projects 4GBB and HFCC/fast
36. G.fast News, BT Data: G.fast working for 75%, 2016

Over shorter connections far higher speeds are possible, up to 1 Gbps and beyond.[37] Moreover, there is the potential to dynamically allocate this bandwidth between upstream and downstream, enabling users to receive near-gigabit upload speeds if (for example) they are backing up a hard drive to the cloud. This is far beyond the 250 Mbps symmetrical cited by the Commission as G.fast's capability in its recent working document, highlighting how rapid are developments in this area.[39]

Deployment of G.fast is partially a competitive response to improving cable networks. According to Adtran (an equipment manufacturer):

> "[G.fast] is a no-brainer for service providers, as it can immediately combat cable's emerging DOCSIS 3.1 network initiatives".[40]

Strategy Analytics makes a similar point:

> "There is strong pressure from cable competitors with increased broadband speeds, and G.fast should help the Telcos deliver competitive services".[41]

Other technologies

Other technologies are developing too. For example:

- Long-reach VDSL offers the prospect of higher speeds over substantially longer copper lines.
- More bendable fibre and fibre plug and play connectors lower the costs of fibre to the premise and fibre on demand from cabinets.
- Evolution of 4G and 5G is raising speeds and lowering the costs of mobile capacity expansion
- Fixed wireless based on very high frequency spectrum is increasingly being considered as a FTTP substitute (by, for example, Google – see below)[42]

37. Analysys Mason, Gigabit access will influence G.fast technology choices for operators, May 2016
38. The Register, Sckipio touts fibre-like symmetrical G.fast kit, 12 October 2016
39. EC, Connectivity for a Competitive Digital Single Market - Towards a European Gigabit Society [Commission staff working document], 14 September 2016
40. Fierce Telecom, Adtran CEO says G.fast will combat cable's DOCSIS 3.1 threat, and MDUs are the place to start deployment, 9 August 2016
41. Fierce Telecom, CenturyLink's G.fast deployment is a credible response to cable's gigabit strategy, 15 September 2016
42. See, for instance, Facebook's Terragraph project. Facebook, Introducing Facebook's new terrestrial connectivity systems — Terragraph and Project ARIES, April 2016

Impact on technology strategy

The rapid development of cable and copper based technology is leading to a re-assessment of how future demand may be met in parts of Europe, Australia and the US. Operators and governments which previously had focussed on FTTP are now using alternatives:

- Australia's nbn (national broadband network) has radically changed its plans. Originally 93% of coverage was to be with FTTP. In the latest corporate plan, 17% will be FTTP (with cable broadband rising from 0% to 24%)[44]
- Google Fiber is switching plans to wireless from FTTP in multiple markets, after the latter proved expensive and slow to deploy[45]
- Swisscom has reached 30% FTTP coverage, but recently told investors:

> "Don't start [FTTP] if you haven't done it yet. Put all your efforts on to FTTS [Fibre To The Street] or FTTD [Fibre To The Distribution point]"[46]

Conclusion

The rapid and sometimes unanticipated development of G.fast, cable and wireless technologies illustrates the value of a multi-technology approach, and fast incremental upgrades that keep options open in light of ongoing innovation. In particular, such innovations are making possible far greater coverage of VHC networks on a purely commercial basis. A multi-technology approach is also appropriate given significant national differences.

Such an approach is also reflective of a rational commercial investment strategy, whereby fibre is gradually deployed deeper into the network, anticipating future demand. G.fast and cable may not be the right solution in all circumstances (for instance, rural areas), but they look likely to offer a faster upgrade path and a viable commercial return. By contrast, fibre to the premise may require state support in many circumstances.

The appropriate technology mix will continue to evolve driven by changing costs, capabilities and demand. We now turn to the evidence regarding demand.

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43. NBN Co, Strategic Review, 2013
44. NBN Co, Strategic Review, 2013; NBN Co, Corporate Plan 2017, August 2016
45. Jack Nicas, "Google's High-Speed Web Plans Hit Snags", Wall Street Journal, 15 August 2016
46. Heinz Herren, Head of IT and Networks, Swisscom. Quoted in Redburn, Copper into Gold - the Sequel, 5 February 2016

5. Demand and supply for broadband capabilities

Any future public intervention to support VHC networks must necessarily be anchored in a view that the commercial deployment discussed above is insufficient – be that in certain regions, for certain types of customer or (conceivably) for users in general.

In implementing the Gigabit Society vision, the Commission and member states will want any intervention to have greater benefits than costs. In this context, it is vital to understand the incremental benefits that an intervention may bring.

By this we mean benefits in the sense of outcomes (a stronger economy, healthier citizens and so on), not benefits as measured by metrics such as extra infrastructure spend, deployment of a particular technology or improved line speed. These metrics have no inherent value – they are only the means to the ends of improved societal outcomes.

Equally, it is important to focus on the *incremental* impact of a policy. As we have seen, substantial upgrades to Europe's broadband are already underway. A new broadband intervention can only bring benefits if the additional broadband infrastructure it delivers *uniquely* enables societal or economic outcomes. So, for example, state-supported FTTP might enable home working, but if the broadband infrastructure already available to a particular area *also* enables this, then the fact that FTTP enables home working is not relevant to a cost-benefit analysis of FTTP.

In designing an intervention, policy makers also need to take account two important aspects of broadband demand – its variability, and its uncertainty.

Broadband demand is variable in that different users have enormously different requirements. A single retiree who surfs occasionally may need just a few megabits per second. A family who regularly stream 4K TV and download console games may need far more. Equally, the requirements of a hairdresser are very different from those of a TV production business.

Demand is uncertain in that the growth of future bandwidth requirements is unknown. Some assume there will be widespread requirements for gigabit speeds, others anticipate far less. The picture is complicated by growing usage, the possibility of new, currently unknown applications, improvement in compression and so on.

In this section we consider both variability and uncertainty of demand. We start by looking at the most demanding users, and then turn to future mass market demand. Finally, we compare demand to the capability of different technologies

In broad terms, we find that – with the exception of a small number of specialist use cases – bandwidth requirements will readily be met by the evolution of copper and cable technologies being deployed today. In particular, aside from large enterprises, we find no evidence of demand for speeds beyond the gigabit capability of DOCSIS 3.1.

We also note that in the face of variability and uncertainty, it is particularly important to retain technological flexibility in policy for VHC networks. If expensive solutions are necessary only for a small fraction of highly demanding users, better to deploy them on a targeted, rather than mass market basis. Equally, if future demand is uncertain, better to follow a path of incremental upgrades rather than spend very heavily early, and risk stranding significant investment.

Very high speed broadband demand

There is enormous variation in bandwidth demand. As we will see, mass market requirements are moderate, but specialist users may have needs for VHC broadband, in some specific instances beyond 1 gigabit per second.

Businesses and institutions with demand for very high speeds

Firms working with very large media files may need VHC speeds to transfer those files. However, firms with such use cases generally seek bespoke solutions. For example, Framestore, a company offering computer generated image services, has a bespoke network in central London:

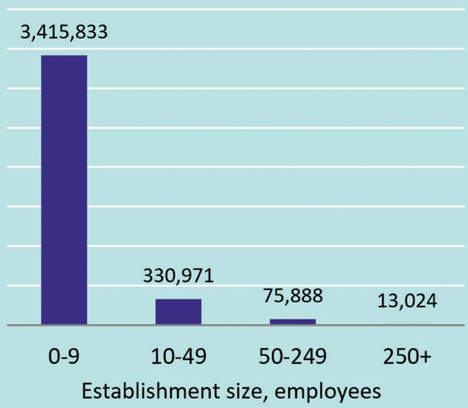
> "Framestore, which spreads its … render farms over various locations in central London, even has its own dark fibre network … for sub-millisecond latency and 10Gbps connection speeds."[47]

Users such as hospitals and large financial institutions may also have very high requirements. Again they frequently purchase bespoke solutions, with financial trading also demanding redundancy and ultra-low latency (in some instances based on line of sight microwave links since light travels faster through air than glass fibres).

Universities may be working with very large datasets, requiring the highest speeds. They also need to meet the personal bandwidth needs of large numbers of students. The University of Southampton, for example, has 5,000 staff and 23,000 students, and recently upgraded its internet connectivity to 10 Gbps.[48]

47. Ars Technica, From Paintbox to PC: How London became the home of Hollywood VFX, April 2016.
48. Paloalto Networks, University of Southampton: Top UK Research University Gets Future-Proof Solution for Bandwidth and Security Needs, September 2015

Figure 6: German business premises by number of employees[49]



More generally, very large sites from any sector may require large bandwidth. However, such sites are relatively rare. For example, in Germany there are just over 13,000 business premises across the country with more than 250 employees, or 0.3% of the 3.8m total (and 0.03% of the total 44m German premises, including homes).[50] Conversely, almost 90% of business premises have 9 or fewer employees.

Mobile macro-site backhaul may also demand very high speed. An extreme example is the "Terragraph" wireless technology under development by Facebook which would act as a "last mile" fibre substitute. It could require over 10 Gbps to each wireless transmitter site to support multiple symmetric 1 Gbps wireless streams.[51] This example illustrates the interplay between wireless and fixed access. On the one hand fixed is a complement to wireless for backhaul to the core network. On the other hand advances in relation to wireless may substitute for fibre for the final connection to premises.

Households with demand for very high speeds

While almost all media can now be streamed in real time using relatively modest bandwidth, those users who wish to download very large files in much faster than realtime may prefer very high speeds. For instance, the XBox game Halo 5 requires a 54GB download.[52] To complete this in 5 minutes would require a 1.44 Gbps connection (and similar connectivity available end-to-end in the network).[53]

Users might wish very high upload speeds to enable rapid one-off transfer of a photo collection to the cloud, say. High upstream speeds might also be required for streaming the output from a VR camera at home, for example. A current model requires 25 Mbps upstream,[54] beyond the capabilities of many broadband offers in the market today - though not necessarily a challenge for DOCSIS 3.1 or G.fast based offers. (Professional VR cameras are more demanding, producing raw video at a 1.5 Gbps bitrate).[55]

Finally, some users may want the highest speeds for 'bragging rights'. In other words, even if it doesn't enable tangibly better performance for applications, for some users the speed itself may have value - analogous to choosing a car for a top speed which will never be used.

49. Statistisches Bundesamt, Unternehmensregister, 31 May 2015
50. There are 40.2m households in Germany. Statistisches Bundesamt, In three quarters of the households there are not more than two people (accessed 10 October 2016)
51. Facebook, Introducing Facebook's new terrestrial connectivity systems — Terragraph and Project ARIES, April 2016.
52. Includes day one patch. Gadgets 360, Pre-Ordered Halo 5 Digitally? You May Have to Download 46.19GB Again, 22 October 2015
53. In practice, many users pre-load the bulk of a game file before its release date, with a much smaller authorisation or final patch required to enable play on that date
54. Orah, Technical Specifications [accessed 28 June 2016]
55. Nokia. Ozo technical specifications [accessed June 2016]

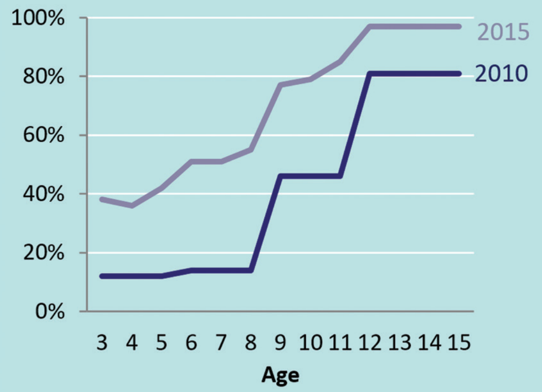
Thus there are various specialised instances where very high speeds may be necessary or desired, particularly in the business market (though these are generally being met by bespoke solutions). We now turn to the requirements of more typical users, starting with households and then turning to small businesses.

Limits to growth of peak bandwidth drivers

At a high level, growth in household bandwidth requirements is primarily driven by three factors:

- *The number of people online in a household* (since this creates the possibility for overlapping usage)[56]
- *The time they spend online* (since this increases the probability of overlapping usage)
- *The 'bandwidth intensity' of their usage* (streaming video is more bandwidth intense than email, for example)

Figure 7: Portion of Swedish children using the internet daily, by age (%)[57]



However, the first two of these growth drivers may be approaching saturation, which we discuss below. We also briefly consider the internet of things.

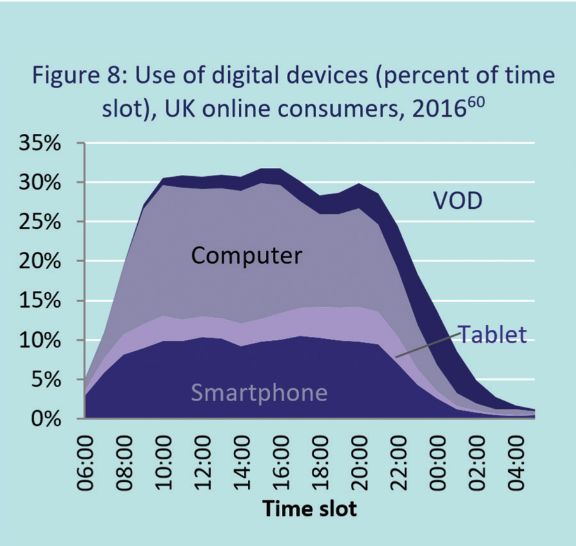
People online per household

The number of people online clearly reaches a limit when all people in online households are internet users. One important driver in the number of people online per online household in recent years has been the number of children online. The combination of more devices and improving skills means that evermore children are internet users.

Figure 7 shows (for example) Swedish figures for the number of children using the internet. In 2010, just 42% of those aged between 3 and 15 used the internet daily – now 69% do.[58] For those aged 12-15, 97% use the internet daily. Thus there are obvious limits to children's contribution to future growth of people online per online home in Sweden.

Moreover, those coming online now are generally older – and older people generally live in smaller households. To continue with the Swedish example, in that country 59% of those aged over 65 live in a two-person household, and 39% in a single person household.[59] As these small households come online, the average number of people online per online household may actually fall.

56. Devices that send traffic independent of a person using them – such as an internet-connected security camera – can drive additional bandwidth requirements
57. Stiftelsen för Internetinfrastruktur, Svenskarna och Internet 2010, 26 October 2010; Internetstiftelsen i Sverige, Svenskarna och internet 2015, 12 November 2015
58. Simple averages
59. Eurostat, Distribution of population aged 65 and over by type of household - EU-SILC survey, 7 October 2016



Time per person

Equally, there are limits to the amount of time individuals who use the internet can spend online at home – there are only so many hours in the day, some of these are spent asleep or out of the home, and so on.

Moreover, usage in peak hours is already heavy. Figure 8 shows utilisation of digital devices by time of day for UK online consumers (in 2016). These consumers spent (on average) 27% of the evening domestic peak hour using a computer or mobile device.[61] A further 3% was spent streaming TV. Not all this usage is necessarily online, but a substantial portion likely is. Moreover, these are average figures – for heavier users, the percentages will be much higher.

Usage of digital devices will never reach 100%, and this suggests that time per user in the evening peak (which drives domestic bandwidth requirements) may be in sight of reaching saturation – certainly it is unlikely to contribute an order-of-magnitude growth in bandwidth requirements.

Bandwidth intensity of usage

If the number of users and their time online are approaching saturation, bandwidth requirements can still be driven upwards by a shift of usage to higher bandwidth applications.

One such transition has been the rise of streaming video, which already represents approximately 45% of European fixed traffic in peak periods.[62] That said, while video is important for traffic, it is less important for bandwidth.[63] In 2015 67% of video streams had a bandwidth of less than 2 Mbps, and 97% of less than 5 Mbps.[64]

There will be upward pressure on video bandwidths as consumers move to higher video resolutions. The transition to HD is already well underway, and in time there will be a move to 4K (and eventually 8K). The additional pixels, greater colour depth and so on of these formats require more bandwidth, all else being equal. The Commission has taken the view that:

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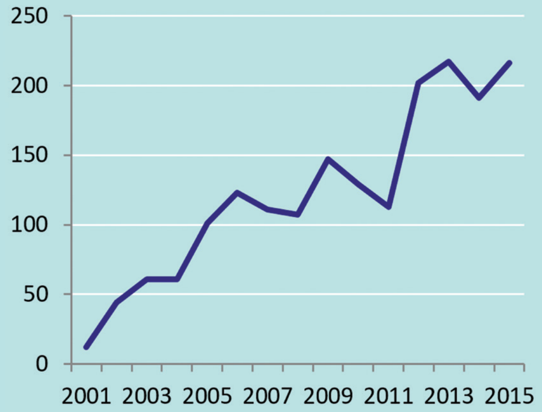
60. Communications Chambers analysis and estimates based on Ofcom, Digital Day 2016, 4 August 2016
61. Note that this figure is the simple sum of usage of the individual devices. Since there may be some overlapping usage, aggregate usage may be slightly lower
62. Sandvine, Global Internet Phenomena, Asia Pacific and Europe, September 2015. 'Real Time Entertainment' is 45.57%. The vast majority of this will be video, though the category includes streaming audio
63. For a more detailed discussion of the difference, see page 26
64. Convivia, 2015 Viewer Experience Report: End of Year Edition, 30 December 2015

> "Next generation TV is likely to be a significant driver of bandwidth demand for households in the coming years."[65]

Figure 9: US video compression patents[66]



However, precisely because of the rise of video, there has been enormous attention to developing techniques for efficiently compressing video. Figure 9 shows the rapid growth in patent filings in this area.

This has resulted in substantial and ongoing improvements. The bandwidth required to deliver a given video quality has halved every seven years.[67] The successor to the currently widely utilised H.264 compression standard – H.265 – roughly halves the required bit rate. Adoption of H.265 is steadily increasing.

It is possible this rate is accelerating. For instance, as of 2013 most sources were suggesting 4K (or UHD) TV required 20 Mbps.[68] Codec developers are now demonstrating systems carrying 4K in 7-8 Mbps,[69] or even as low as 2 Mbps[70] (though it will take time for systems to be widely deployed in the field). Clearly this represents substantial downward pressure on domestic bandwidth requirements – and is in sharp contrast to the 100 Mbps that the Commission has suggested will be required for UHD TV.[71] Even 8K – the generation beyond UHD TV – only requires 50 Mbps, and will likely require much less before it is widely available to consumers.[72]

Video compression also supports telepresence (very high quality video conferencing). The Cisco IX5000, a professional system for six people with three 4K screens - requires just 11 Mbps and 150 ms latency.[73] Again, these requirements are well below those cited by the Commission, which suggested 100 Mbps and 10 ms for a multi-person video call..

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65. EC, Connectivity for a Competitive Digital Single Market - Towards a European Gigabit Society [Commission staff working document], 14 September 2016
66. US Patent & Trademark Office, Patent Application Full Text and Image Database [accessed 19 March 2016]. Search for abstracts containing "Video coding" or "Video compression"
67. ZetaCast, Technical Evolution of the DTT Platform, 2012
68. See for example "HEVC goes beyond HD", TVBEurope, 4 June 2013. A wider range of sources are available in Communications Chambers, Domestic demand for bandwidth -An approach to forecasting requirements for the period 2013-2023, 5 November 2013
69. BBC, V-Nova streaming tech produces 4K compression 'worth watching', 1 April 2015
70. The Online Reporter, Tveon Claims 4K Streams at under 2 Mbps, 19 October 2015
71. EC, Connectivity for a Competitive Digital Single Market - Towards a European Gigabit Society [Commission staff working document], 14 September 2016
72. ISP Review, YouTube Tests 8K Video Streams – Demands 50Mbps UK Broadband Speed, 16 June 2015
73. Cisco, Cisco Collaboration System 10.x Solution Reference Network Designs (SRND), 15 January 2015; Cisco, Cisco TelePresence IX5000 Series Data Sheet, 20 October 2015. Bandwidth requirement based on H.265 compression

Similar compression techniques are also being used for virtual reality. NextVR reports delivering real-time VR in 4-6 Mbps, for example.[74] Speeds as low as 2 Mbps (for 4K VR) are being demonstrated in the lab.[75]

Augmented reality can need even less. Pokémon Go, for instance, worked well on mobile networks (with performance far below the 1 Gbps bandwidth and 1ms latency suggested by the Commission as necessary for AR).[76]

These developments are part of a wider trend of application providers reducing the network requirements of their services, driven in particular by the need to make them viable over mobile networks, including those without widespread 4G. For the markets with the greatest prospects for growth, such as India, this is essential. Facebook, for instance, is investing considerable effort in making its service viable on 2G connections.[77] In many cases the innovations that support delivery on mobile networks also translate into lower loading on fixed networks.

Internet of things

The above discussion relates to the use of bandwidth by humans. The rise of the internet of things (IoT) means that there will be an increasing number of devices also driving bandwidth consumption. However, the impact of this on peak fixed bandwidth requirements is likely to be limited, for two reasons.

First, IoT networks are very often wireless rather than fixed. For networks associated with utilities, every premise requires a connection, whether or not the household in question has its own fixed internet connection. Even for households with broadband, it can be awkward to rely on the associated Wi-Fi – settings may change, the router may be turned off and so on. For this reason, utilities generally procure their own wireless connectivity, rather than riding on the householder's bandwidth. Power companies may use power-line communication.

Wireless may also be preferable for IoT because the 'things' in question are mobile (for example, public transport, cars and location trackers for logistics) or located remotely from places with fixed connectivity (agricultural sensors, highway street lighting).

Second, the bandwidth required for IoT is also often low. This enables the use of wireless networks, but means even if the data is carried over the fixed network, the impact is limited. Smart meters may have a data rate of 9.6 Kbps.[78] A remote health monitoring system

74. [a] list, NextVR Lands $30.5M in Funding, Looks to Pioneer the Promise of VR, 16 November 2015
75. Conduit, Efficient Video Compression for Live VR Streaming [accessed 21 March 2016]
76. EC, Connectivity for a Competitive Digital Single Market - Towards a European Gigabit Society [Commission staff working document], 14 September 2016
77. See for example: Facebook, The technology behind preview photos, 6 August 2015
78. Hugo Café et al, Planning Wireless Mesh Networks for IoT Smart Grid Applications, 2015

(including video, personal alarms and motion sensors) requires less than 300 Kbps.[79]

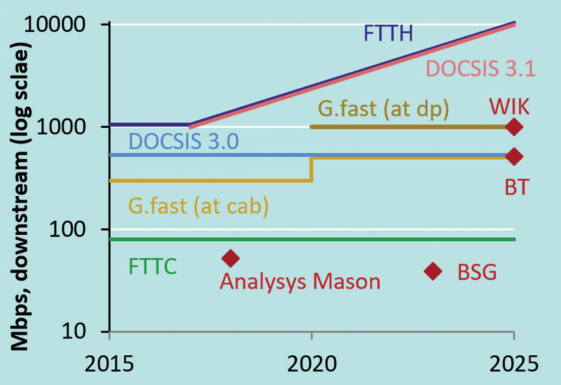
Consumer wearables (which are more likely to sync over a fixed network) generally have small file sizes. For instance, the Fenix 3 (a top-of-the-range GPS watch and heart rate monitor) has just 23MB of available memory.[80]

There are exceptions. A household with multiple security cameras streaming to the web may require material bandwidth, for example. However, even in this case, the speeds required are lower tens of Mbps, not hundreds.

Overall, while Cisco expects IoT traffic to grow, it still expects it to represent just 4.1% of Western European IP traffic in 2020.[81]

IoT is a vast domain, and the above use cases are not exhaustive – however, they do cover the examples discussed in the European Parliament's briefing paper on IoT.[82] The same paper cited a number of potential barriers to IoT (including spectrum availability), but did not mention fixed bandwidth as a constraint.

Figure 10: Forecast domestic bandwidth needs (demanding users) & access link capabilities [84]



Forecasts of Bandwidth Demand

There are increasing array of forecasts of technical[83] domestic bandwidth demand. However, they are all consistent in suggesting that requirements for some years ahead will be well within the range of DOCSIS 3.0 and upgraded copper technologies such as G.fast.

Residential demand

Of the forecasts we have identified[85], those by BT and WIK are the most aggressive at around 350 and 1,000 Mbps downstream respectively for the most demanding users. But even these forecasts suggest that needs in 2025 will be within the capabilities of DOCSIS 3.1 networks being deployed today, and within those of G.fast deployed to the distribution point. Forecasts at the lower end suggest requirements within even the capabilities of FTTC.

79. NM Khio et al (Luleå University of Technology), An Efficient IoT-based Remote Health Monitoring System for Smart Regions, February 2016
80. Garmin, Fenix 3 [accessed 4 July 2016]
81. Cisco, VNI Complete Forecast Highlights Tool [accessed 8 July 2016]
82. EPRS, The Internet of Things - Opportunities and challenges, May 2015
83. In the sense of bandwidth actually used – the bandwidth a household chooses to pay for may be more or less than this
84. Communications Chambers for BSG, Domestic demand for bandwidth, 2013; WIK, Deloitte & IDATE for the EC, Regulatory, in particular access, regimes for network investment models in Europe, September 2016; BT, Can you ever have enough bandwidth?, 2015; Analysys Mason for BT International benchmark of superfast broadband, 2013. G.fast at cabinet bandwidth based on proposed BT deployment. Both FTTH and DOCSIS 3.1 assumed to upgrade to 10 Gbps service (already within the parameters of each technology) by 2025

Moreover, the BT and WIK forecasts include contributions to demand that have limited externalities. For instance, the BT forecast depends on a 425 Mbps requirement for console game downloads (which is anyway unlikely to be a sustained demand). WIK incorporates 300 Mbps per 4K TV stream in 2025 (which seems implausible compared to less than 20 Mbps needed today). Gaming and 4K are undoubtedly part of future usage, but they bring limited wider social or economic benefits that would justify public intervention.

Turning to upstream 2025 requirements, WIK suggests 600 Mbps for demanding home users. (The BT forecast did not include an upstream figure). This figure would be well within DOCSIS 3.1's capabilities – as we have noted 1 Gbps symmetric speeds will be available on DOCSIS 3.1 in Spain in 2017, for example.

Moreover, the 600 Mbps forecast is again based on a number of aggressive assumptions, such as 25 Mbps for HD videoconferencing. This compares to Skype's recommendation of 1.5 Mbps for HD video calling.[86] WIK's expectation of roughly symmetric demand is also at odds with experience in markets such as Japan, where notwithstanding the wide availability of symmetric high speed bandwidth, the down:up traffic ratio is 5.2:1 and rising.[87]

We underline that these are forecasts for the most demanding users. However, in a policy context it is important not to focus unduly on the needs of such users. Each of the forecasts cited predicts lower demand for typical users. For example, BT suggest these users will need just 50 Mbps downstream in 2025.

Small business demand

Nor do forecasts of small businesses needs show universal requirement for VHC networks. Communication Chambers produced such a forecast for the UK's Broadband Stakeholder Group.[88] This considered 2450 different small business premise types, based on 1-49 employees and 50 different industry types. Forecast median demand in 2025 was just 8/2 Mbps down/up, in part because 90% of UK small businesses have 4 employees or fewer. In addition, many industries (ranging from hairdressers to plumbers) have low requirements for fixed broadband.

That said, there was significant variation. The 95th percentile in 2025 required 41/36 Mbps down/up, and a smaller group of the most demanding businesses (such as larger hotels and software businesses) required much more. Nonetheless, 99% of small business employees worked in premises with requirements well within the capabilities of G.fast and DOCSIS 3.1 (and the great majority would have their needs met by VDSL and DOCSIS 3.0).

85. We have set aside one study, namely Dialogic and TUE for NLkabel & Cable Europe, How the speed of the internet will develop between now and 2020, 2014. A technical flaw in the way in which this study converts traffic to bandwidth leads it to produce implausible (implicit) results – for instance, that in 2020 power users will each have a requirement for more than ten 4K simultaneous video streams, plus 138 Mbps of 'overhead', 117 Mbps for simple surfing and so on
86. Skype, How much bandwidth does Skype need? (accessed 8 July 2016)
87. Ministry of Internal Affairs and Communications [Japan], 我が国のインターネットにおけるトラヒックの集計結果 (2016年5月分), July 2016
88. Communications Chambers for BSG, The broadband requirements of small businesses in the UK, 2 September 2015

Certain organisations will of course require bandwidth beyond this. Examples are hospitals (for a combination of medical imaging, video consultations, large staff numbers and patient requirements), universities (for research data sets, large staff numbers and resident student use) and other 'socio economic driver' premises noted by the Commission. However, market based solutions already exist (and are being used) in such cases, with the industry deploying VHC solutions to customers who have such a requirement, without state intervention.

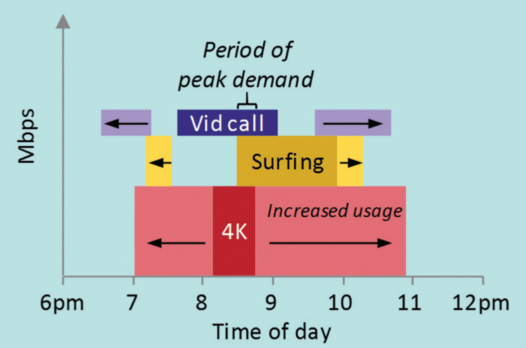
The FCC's view

While not a forecast, the FCC has taken a view on speed requirements. The FCC is required to assess the availability of "advanced telecommunications capability", and – by extension – to determine what constitutes such capability. In 2015 the FCC published the result of extensive consultation and analysis, and found that broadband with speeds of 25 Mbps down, and 3 Mbps up represented "advanced telecommunications capability".[89] (In setting this benchmark, the FCC emphasised the term 'advanced', as a reason for not setting a lower threshold).

This conclusion was based in part on an assessment of speeds likely to be required by typical households now and in the future. The FCC has recently confirmed that it still regards this as the appropriate benchmark.[90]

The FCC also sets a benchmark for schools, at 100 Mbps per 1,000 students and staff in the short term, and at 1 Gbps per 1,000 in the long term. (New Zealand also sets a specific objective for schools - 100 Mbps to 97% of them - targeting intervention where it believes externalities are likely to be largest.)[91]

Figure 11: Illustrative bandwidth demand



Traffic ≠ Bandwidth

Finally regarding future bandwidth, we note that though the terms 'traffic' and 'bandwidth' are sometimes used interchangeably, they are two very different things. In particular, traffic can grow substantially without requiring additional bandwidth.

For example, if a user's use of 4K video grows from 30 minutes to 4 hours per day, then her traffic will increase greatly (Figure 11). However, her peak bandwidth requirement is likely entirely unchanged. If 4K video was already part of her peak period of usage, the fact that 4K video is now also being used at other times of day makes no difference to that peak requirement.[92]

89. FCC, 2015 Broadband progress report and notice of inquiry on immediate action to accelerate deployment, 4 February 2015
90. FCC, 2016 Broadband progress report, 29 January 2016
91. Commerce Commission New Zealand, Rural Broadband Initiative [accessed 23 March 2016]
92. For a modelling analysis of the (non) impact of increased video consumption on bandwidth requirements, see B. Allan and D. Williams [BT], "Anticipating Households' Demand for Peak Bandwidth: a Revision of a Model From the Broadband Stakeholder Group", Innovations in Clouds Internet and Networks (ICIN), 19th International Conference on, Paris, 2016.

This is not to argue that increased usage has *no* impact on peak bandwidth. It may, for instance, increase the probability of overlapping usage, either within and individual's set of applications, or with other individuals in the household. However, traffic and access-link bandwidth are not nearly as tightly linked as is often assumed.

Figure 12: UK traffic growth by line speed[93]

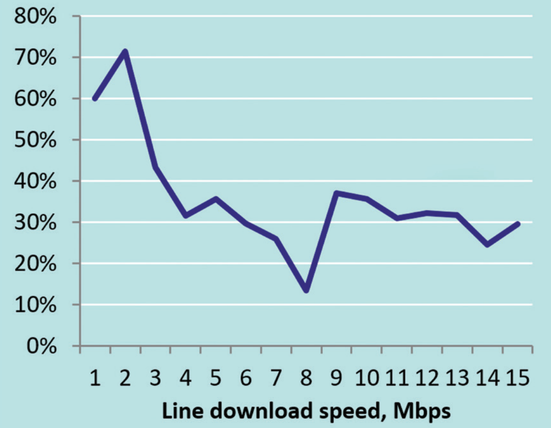
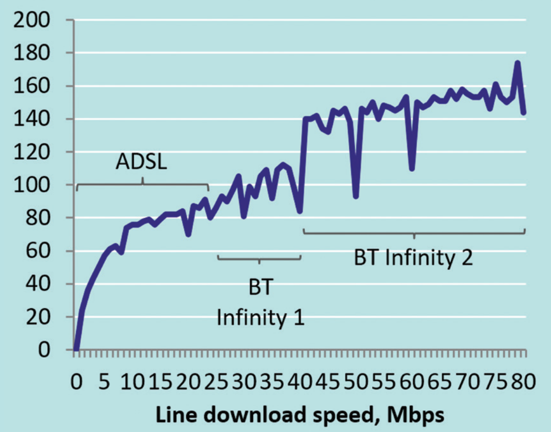


Figure 13: UK Traffic (GB/month) by line speed[95]



This is more than theoretical. Figure 12 shows UK growth in traffic by line speed, based on Ofcom data. For example, for lines with a speed of 10 Mbps, traffic grew by 36% from 2014 to 2015. This demonstrates that substantial growth in traffic is possible without any growth in available bandwidth, even on lines with relatively low speeds.

An extreme case of the traffic possible over consumer broadband was a customer identified by Verizon, using a 300/65 Mbps connection to run a server farm from home. In a single month he generated 77 TB of traffic – roughly 1000 times typical consumer usage today.[94]

Impact of higher speeds on usage

We now turn to empirical evidence for the impact of higher speeds on usage (as measured by traffic).

Patterns of traffic consumption in the UK do not suggest that higher speeds have a transformative effect on usage. Figure 13 shows the relationship between line speed and traffic.

Certainly higher speed lines do have more traffic, but the pattern is stepped. For instance, there is a sharp increase in traffic at around 40 Mbps. The significance of this figure is that the line speed of BT's basic superfast product, Infinity 1, was until very recently 'up to 38 Mbps' (now increased to 'up to 52Mbps'). Customers with line speeds above this have chosen to pay a premium for Infinity 2 (or similar products from competitors). This is likely to be a self-selected group, who would have higher traffic *regardless of line speed*.[96]

Further speed above 40 Mbps (within this self-selected group) has only modest further impact. For instance, users with 80 Mbps have usage of 160 GB, not very different form the 140 GB of those with half this speed.

93. Communications Chambers analysis of data from Ofcom, Connected Nations 2015, 1 December 2015
94. Ars Technica, FiOS customer discovers the limits of "unlimited" data: 77TB a month, 23 May 2013
95. Ofcom, Connected Nations 2015, 1 December 2015
96. An exception is the cable customers who were given free upgrades to higher speeds. This group is not self-selected, and indeed has sharply lower usage – this explains the steep dips in the traffic chart at 50 and 60 Mbps (the relevant standard cable speed offers)

Thus, while the Commission has cited Ofcom evidence of higher use on NGA connections to argue that demand responds to supply,[97] it may simply be that heavier users choose higher speeds, not that higher speeds lead to heavier usage.

At best, the linkage between supplied bandwidth and usage is weak. For example, markets such as Japan and Portugal, with widespread FTTP, have significantly *lower* per-household traffic than countries with little FTTP, such as Australia and the UK.[98]

WIK conducted a preliminary assessment of this issue in 2013, which they found:

> "strongly suggests that whatever 'build it and they will come' effect might exist cannot be very strong. This in turn poses troubling policy questions as regards public policy to promote the deployment of ultrafast broadband".[99]

Product choice & willingness to pay for speed

The evidence that customers place value on higher speeds is mixed.

Consumers

A number of European countries have reasonable penetration of higher speeds, but these figures can not necessarily be taken to mean that there is material willingness-to-pay (WTP) for such speeds. For example, these speeds may be available at a minimal price premium; or the customers may have been given a free upgrade to such speeds without needing even to request it;[100] or operators may structure their offers so that the most basic tier comes with superfast speed.

Figure 14: 100+ Mbps share of BB in covered areas & price premium over 30-100 Mbps, 2015[101]

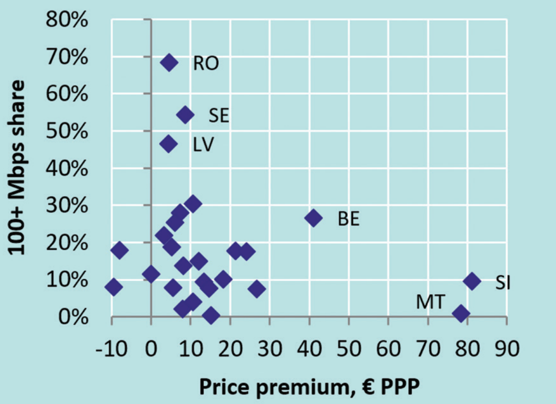


Figure 14 shows the relationship between 100 Mbps+ broadband's share of connections in NGA coverage areas versus the price premium of such lines over 30-100 Mbps lines. With the exception of Belgium, no country has achieved more than a 20% share if their price premium was greater than €10 per month. This suggests that the pool of customers who place a material value on the incremental benefits of 100 Mbps broadband is low.

97. EC, Connectivity for a Competitive Digital Single Market - Towards a European Gigabit Society [Commission staff working document], 14 September 2016 (p24)
98. For further detail on traffic by country, see page 37
99. Scott Marcus & Dieter Elixmann (WIK), Build it! ... But What If They Don't Come?, 13 March 2013
100. For a more detailed discussion of this issue, see BSG, Demand for superfast broadband, November 2012
101. EC, Digital Agenda Key Indicators [accessed 22 March 2016]; Communications Chambers analysis. Belgium's outlier status is likely due to a free upgrade to 100 Mbps (or more) which Telnet, a leading provider, gave to all its customers in March 2015

Even for more modest speeds, demand is not overwhelming. Across the EU, as of 2015 just 31% of households with access to NGA had taken up speeds of 30 Mbps or more.[102]

In Australia, richer data is available on consumer choice of speed tier, and there has not been a history of free upgrades, which allows a 'cleaner' view of consumer preference.

Figure 15: NBN Fixed Line Speed Tier Mix[105]

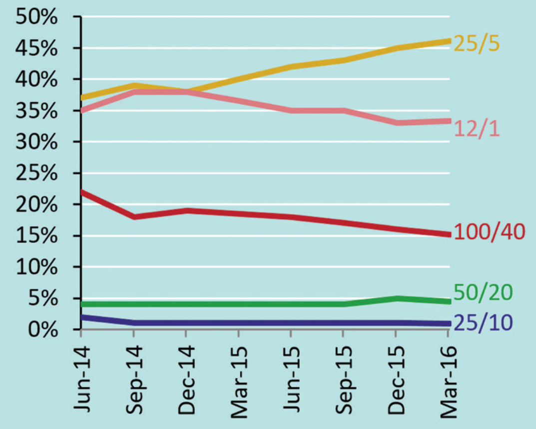
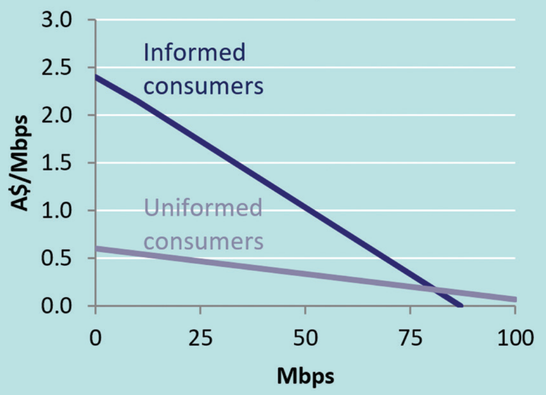


Figure 16: Australian marginal willingness-to-pay for download speed[106]



There nbn users[103] have not shown significant demand for the higher speed tiers. Almost 80% of fixed line customers take a line with a downstream speed of 25 Mbps or less. Only 16% have taken the 100/40 Mbps speed tier – a portion that has been *falling* over time. (The price premium for 100/40 Mbps offer over a 25/5 Mbps offer is approximately €13).[104] Just 65 customers out of 760,000 on FTTP have taken speeds higher than 100 Mbps.

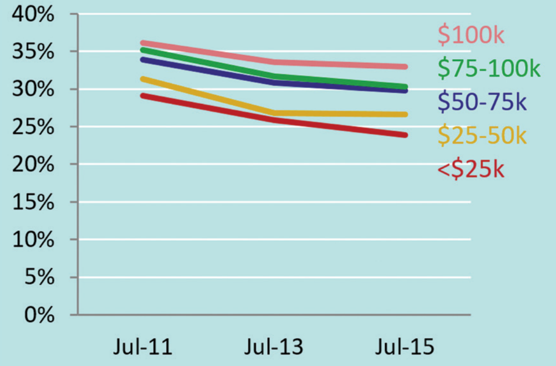
This market outcome was consistent with Australian consumer willingness-to-pay research conducted as part of a major cost-benefit analysis of the nbn.

This research had one unusual and important feature. Rather than simply asking all respondents what price they would be willing to pay, for half the respondents they first took the step of informing them what speeds a range of applications actually required. The results showed that informed consumers had a *higher* willingness-to-pay (WTP) for an incremental Mbps at low speeds, but a lower WTP at high speeds.

This research highlights the challenges in achieving meaningful results from simply asking customers to state their speed requirements, given the highly technical nature of the question. Moreover, asking respondents to state their preferred speed without attaching a cost tells us little about the actual value they attribute to a given speed.

102. Communications Chambers analysis of data from EC, Digital Scoreboard (accessed 11 October 2016)
103. nbn co's customers are ISPs, since it is wholesale only
104. See for instance Optus, nbn speed packs [accessed 24 March 2016]
105. nbn co, Half Year Results 2016 Presentation, 5 February 2016 (and earlier equivalents)
106. Vertigan Panel (for Australian Government), The costs and benefits of high-speed broadband, August 2014

Figure 17: Portion of Americans saying speed is most important BB feature, by income (%)[107]



US data points to declining importance for speed as a feature of broadband (Figure 17) – not what we would expect to see if speed requirements were outstripping supply. Moreover, there are significant income differences – those on lower incomes are the least likely to focus on speed. Conversely they are more likely to say that affordability is most important. However, for all groups bar those with household incomes below $25,000, reliability is more important than either affordability or speed.

The differences in attitudes between income groups highlights one of the risks of expensive upgrades such as FTTH. This may bring value to a group of well-off early adopters with a wealth of electronic devices at home, but conversely may increase broadband costs for poorer households that place little value on extra speed.

There is also evidence from the US that some consumers choose to downgrade their speeds. For example, the FCC found that of consumers with 30-50 Mbps connections, 5% were on a lower speed a year later.[108]

Analysys Mason's overview is that

> "Consumers are reluctant to pay a premium for faster speeds. This, combined with the lack of clear applications for high bandwidth services for many users, diminishes potential consumer interest in superfast broadband."[109]

Business users

There is less empirical data on small business requirements for different speeds. However, in Hong Kong (where low-cost, very high speed fibre broadband has been available for a number of years), 35% of businesses still take broadband with speeds of 10 Mbps or less.[110] In Norway the figure is 36% (and almost 80% take less than 30 Mbps),[111] though superfast is available to over 80% of the country.[112] Spain now has 73% NGA coverage,[113] but 71% of businesses are choosing speeds of under 30 Mbps.[114] (Notably, this is higher than the 65% of residential users who take such speeds).

107. US Department of Commerce, Digital Nation Data Explorer, 21 March 2016
108. FCC, 2014 Measuring Broadband America, June 2014 [figures not included in 2015 report]
109. Analysys Mason, Multi-play pricing benchmark 4Q 2014, 3 April 2015
110. OFCA, Statistics on Customers of Internet Service Providers ("ISPs") in Hong Kong, 2016
111. Norwegian Communications Authority, The Norwegian Electronic Communications Service Market 2015, 19 May 2016
112. Norwegian Communications Authority, Broadband in Norway 2015, 4 January 2016
113. EC, Digital Single Market – Country Information – Spain [accessed 21 March 2015]
114. CNMC, Estadística Trimestral III 2015, 15 February 2016

Figure 18: Speed by technology (Sweden)[115]

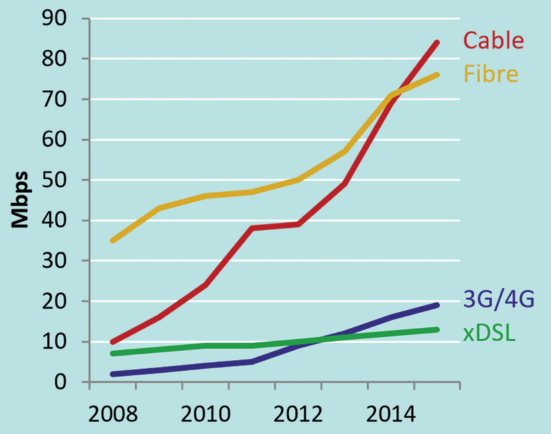
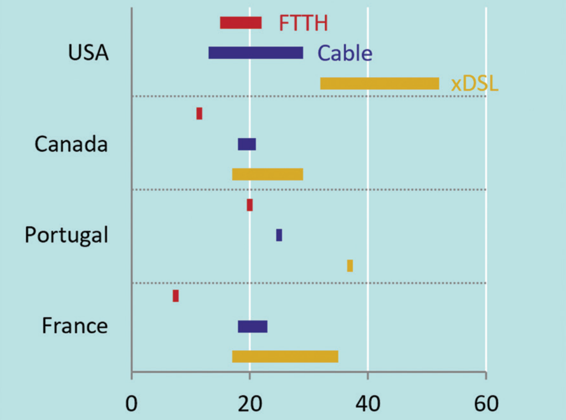


Figure 19: Measured latency (ms) by technology[116]



Speed and technology

Finally regarding speed, we note that achieved speeds are not tightly linked to the theoretical capabilities of different access technologies. This may be because customers choose access speeds below the maximum available, or because the real world 'weak link' is not actually the access link, but rather Wi-Fi, backhaul, peering points and so on.

In Sweden for example, while FTTP has the highest theoretical speed in the access link, it no longer is delivering the fastest speeds to consumers – rather cable customers now achieve higher speeds on average (Figure 18).

Other technical characteristics of broadband

Speeds are not the only relevant technical characteristics of broadband – latency and packet loss can also be important to performance and the end-user's experience.

Latency

Reported latency for different technologies varies across countries, and between operators within a given country (Figure 19). Figures for xDSL are in the range 17-52ms, for cable 13-29ms and for FTTH 7-22ms. Thus FTTH's advantage over cable is approximately 5-10ms.

Note that these real-world 7-22ms latencies for FTTH are very different from the 0.3ms cited for FTTH by the Commission in its recent working paper.[117] This appears to be because the Commission has only considered the latency associated with the passage of light through the fibre, not that caused by the associated electronics. (Indeed, signals actually travel *faster* in coax cable-network cables than they do in optical fibre. The speed of light in glass fibre is 2/3 the speed of light in a vacuum, whereas signals propagate at 9/10 the speed of light in coax).[118]

Even the relatively narrow differences in real-world latency cited above need to be treated with care. It is possible, for instance, that lower latency for FTTH is in part because it is

115. Internetstiftelsen i Sverige, Bredbandskollen Surfhastighet i Sverige 2008-2015, 17 February 2016

116. ARCEP, Qualité du service fixe d'accès à internet - Mesures de la qualité du service effectuées au 1 er semestre 2015, November 2015; Anacom, Evolução dos acessos à Internet em Portugal, November 2015; SamKnows (for CRTC), SamKnows analysis of broadband performance in Canada, October & November 2015, 7 April 2016; FCC, 2015 Measuring Broadband America Fixed Broadband Report, 30 December 2015. For France and the US, range represents different ISPs. For Canada it is different speed tiers

117. EC, Connectivity for a Competitive Digital Single Market - Towards a European Gigabit Society [Commission staff working document], 14 September 2016 (p44)

118. Fiber Optic Association, FAQs (accessed 11 October 2016)

primarily deployed in cities, and thus FTTH users may be closer to test servers. Conversely, ADSL users are more likely to be in rural areas, with more 'hops' from the servers. In other words, the latency difference may not be fundamental to the technology. Certainly G.fast is intended to have a latency (for the access element of the network) of less than 1 ms.[119]

Even if we take FTTH's reported advantage of 5-10ms or less at face value, this needs to be seen in context. To take three examples of highly demanding use cases:

- For remote surgery, trials found no impact on performance once latency was below 300 ms.[120]
- Cisco's professional telepresence systems have a target latency of 150 ms, though will work at much higher levels[121]
- For online gaming, "delays under 50 milliseconds do not impact player performance. Delays over 50 milliseconds but under 100 milliseconds begin to have a slight impact … but are rarely noticed"[122] (This is in contrast to the Commission's view that 10ms latency is required for real time gaming)[123]

Of course, for most applications such as streaming or email, latency tolerances are far higher than for these demanding cases.

Given this, even if FTTH's latency advantage is inherent (rather than a function of where it is deployed), it is in almost all cases likely to have minimal impact. Other sources of delay in the wider network are likely to be far more significant. As the FCC puts it:

> "the differences in average latencies among terrestrial-based broadband services are small, and are unlikely to affect the perceived quality [even of] highly interactive applications."[124]

SamKnows (for Canada's CRTC) has taken a similar view:

> "For the majority of use cases, the approximately 20ms latency difference between the best and worst service [of any technology]… would be indistinguishable."[125]

119. Adtran, Accelerating Gigabit Broadband, January 2014
120. Manuela Perez et al, "Impact of delay on telesurgical performance: study on the robotic simulator dV-Trainer", International Journal of Computer Assisted Radiology and Surgery, 8 October 2015
121. Cisco, Extended Reach: Implementing TelePresence over Cisco Virtual Office, 2010
122. Christopher Canfield, Latency & State Consistency in Networked Real-Time Games, 2013
123. SamKnows (for CRTC), SamKnows analysis of broadband performance in Canada, October & November 2015, 7 April 2016
124. FCC, 2015 Measuring Broadband America Fixed Broadband Report, 30 December 2015
125. SamKnows (for CRTC), SamKnows analysis of broadband performance in Canada, October & November 2015, 7 April 2016

Particularly as regards FTTH versus cable, the latency difference between the two technologies is immaterial, and certainly not a justification for a policy difference between the two.

Packet loss

Nor does FTTH have a particular advantage in packet-loss. FCC figures found that US fibre networks (Verizon and Frontier) actually had *higher* packet loss than cable networks, and similar rates to a number of DSL providers.[126] This suggests that backbone network configuration is more important for packet loss, and the access network is not acting as a meaningful constraint.

Conclusion

Bandwidth requirements will continue to grow, and this has been an impetus for the Commission's ambition for very-high capacity networks. The Commission defines a VHC Network as one:

> "which either consists wholly of optical fibre elements at least up to the distribution point at the serving location or which is capable of delivering under usual peak-time conditions similar network performance in terms of available down- and uplink bandwidth, resilience, error-related parameters, and latency and its variation."[127]

The evidence above suggests that DOCSIS 3.1 (and, in time, G.fast) meet this test. They deliver performance that is technically similar to that of FTTH.

Moreover, the capabilities of DOCSIS 3.1 are more than sufficient for needs of the very great majority of residential and business users, to 2025 and beyond.

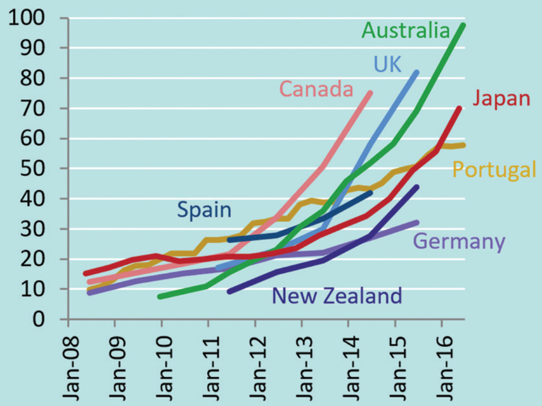
FTTH will be part of Europe's broadband mix, but is not a necessary part of the mix to meet mass market demand in the near, medium or possibly long-term. Indeed, taking account of time to invest and connect, a mixed strategy is more likely to stay ahead of demand. In particular, the gigabit capabilities of DOCSIS 3.1 are already being commercially deployed, and are likely to meet the needs of virtually all residential and business customers for many years to come.

126. FCC, 2015 Measuring Broadband America Fixed Broadband Report, 30 December 2015
127. EC, Connectivity for a Competitive Digital Single Market - Towards a European Gigabit Society, 14 September 2016

6. A ssessment of FTTH policies in Japan, South Korea & Australia

Given the uncertainty over future demand and the increasingly capable access networks that will be deployed purely commercially, an intervention to further support broadband is not without risk, and will need to be carefully designed. In this chapter we briefly discuss three international interventions which appear not to have met their goals to date: Japan, Korea and Australia.

Figure 20: Traffic per fixed BB line, GB/month[128]



Japan

Japan was an early and substantial investor in FTTP. However, this does not appear to have fed through into substantial network usage. Japan's traffic per line has in fact been moderate by comparison to other countries (for which data is available). Countries such as Canada, the UK and Australia all have substantially higher usage than Japan, though they lack widespread FTTP (Figure 20).

Japanese incumbent NTT (Nippon Telegraph and Telephone) has in the past highlighted the contrast between the country's leading network and lagging usage:

> "Japan truly has one of the world's leading broadband environments. However, Japan lags behind other countries in the use of ICT in such areas as education, medicine and government services".[129]

NTT went on to note that the US and UK were well ahead in areas such as school LAN deployment, online income tax filing and electronic medical records.

This lack of tangible outcomes from FTTP is particularly problematic since NTT incurred substantial accumulated losses in deploying the network, not least because it had to price the service at similar levels to DSL in order to attract customers.[130]

128. Source from relevant national regulatory authorities or government statistical services. Figures are average for both business and residential lines, except for the UK which is residential only. Australia traffic is for download only – upload also included for other countries. For visibility of other data points, Hong Kong (with current average usage of 135 GB/month) has been excluded

129. NTT, Annual Report 2010, 24 June 2010

130. BSG, Demand for superfast broadband, November 2012

Kenji Kushida, writing in *Communications and Strategies*, found that:

> "Japan quickly discovered that taking advantage of the broadband environment to produce innovation, productivity growth, and economic dynamism, was far more difficult than facilitating its creation. It discovered regulatory barriers for the use of [ICT] in various areas of the economy. Like Europe, Japan was not home to the ICT lead-user enterprises and industries that drove the ICT revolution, producing innovation and productivity gains. Moreover, the advent of US-centered cloud computing services potentially decreases the minimum bandwidth requirement to access global-scale computing power. The development of wireless technologies far cheaper than Japan's nationwide FTTH also merits serious consideration for European policy discussions." [131]

The Japanese experience suggests that FTTP is not, by itself, *sufficient* to trigger social or economic gains (and indeed, given the benefits the UK has drawn from broadband without material FTTP, may not be necessary either).[132]

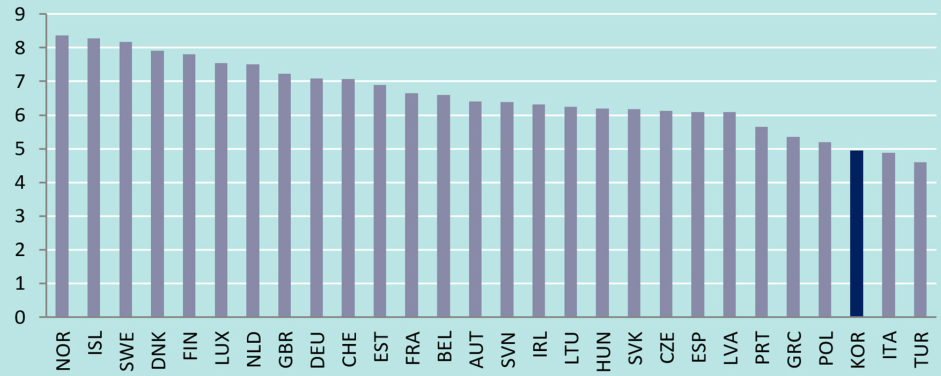
South Korea

Like Japan, Korea has been a heavy and early investor in FTTP, with substantial support from the government. Household penetration stands at around 75%.[133] However, also like Japan, it isn't clear that this has had material benefits for society and the economy. For example, the OECD has noted that:

> "While Korea … benefits from extensive broadband deployment, the share of firms with less than 50 workers that engaged in e-commerce in 2013 was only 15%, one of the lowest in the OECD. For large companies, the share is higher at 25% but still below the OECD average of 40% ... Similarly, the share of Korean small firms using cloud computing was the fourth lowest in the OECD in 2014".[134]

131. Kenji Kushida, "Public Private Interplay for Next Generation Access Networks: Lessons and Warnings from Japan's Broadband Success", Communications and Strategies, 2013.
132. For a discussion of the UK's strong position, see Plum, This Connect'd Isle, September 2015
133. FTTH Council, Der FTTH Markt in Europa: Status, Ausblick und die Position Deutschlands, 2 March 2016
134. OECD, OECD Economic Surveys :Korea, May 2016

Figure 21: Number of activities performed online[135]



Korean consumers also make narrower use of the internet than those in other countries (Figure 21), typically participating in five activities, compared to over seven in Germany and the UK, which each have very little FTTH. (Example activities are email, social networking, online banking, use of e-gov services and so on).

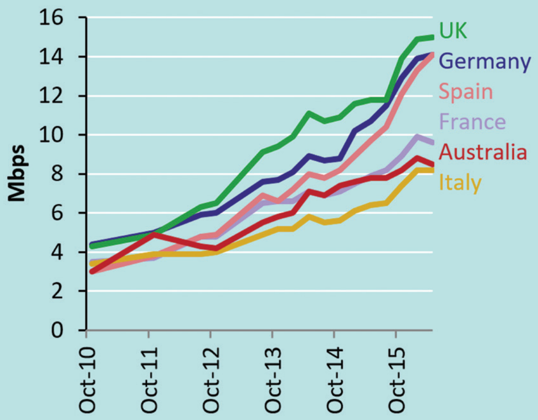
The Commission has stated that:

> "Gigabit connectivity is already a reality in countries such as Japan and South Korea, and is translating into increasing usage of video and high bandwidth applications".[136]

However, in reality South Korea's internet video use is only moderately higher than the UK (31.9 vs 23.4 GB/month per capita in 2015), and Japan's use is far lower, at 12.6 GB/month – this despite an almost complete absence of FTTP and gigabit offers in the UK market.[137]

135. OECD, OECD Science, Technology and Industry Scoreboard 2015 – Korea Highlights, October 2015
136. EC, Connectivity for a Competitive Digital Single Market - Towards a European Gigabit Society [Commission staff working document], 14 September 2016 (p43)
137. Communications Chambers calculations based on data from Cisco, VNI Complete Forecast Highlights Tool (accessed 11 October 2016)

Figure 22: Broadband Speed, Mbps (Akamai)[138]



Australia

Australia has, to date, invested over €11bn of state funds in its nbn superfast network (or €470 per capita).[139] The peak funding requirement is expected to be €33bn.[140]

Until recently, nbn has been primarily focused on deploying FTTP – with an initial coverage target of 93%. However, despite this enormous investment, Australia has not moved up the broadband rankings – quite the reverse.

Figure 22 shows Australia's performance compared to the EU5. It has fallen further behind UK, Germany, Spain and France over the last five years, and (despite the substantial investment) only held steady with Italy. Reasons for this include:

- FTTP has proven far more challenging to deploy than expected, so still has relatively narrow availability
- Even when available, consumers have generally chosen lower speed products
- The pending deployment of FTTP has paralysed investment in other forms of technology such as VDSL and cable DOCSIS 3.0 (which have improved speeds in other markets). These technologies have seen virtually no deployment by commercial players in Australia

For these reasons nbn has changed strategy, and now will place far greater emphasis on copper and HFC-based broadband. The report recommending the change in strategy argued:

> "[The new approach] leaves more options for the future open because it avoids high up-front costs while still allowing the capture of benefits if, and when, they emerge. It is, in that sense, far more 'future proof' in economic terms: should future demand grow more slowly than expected, it avoids the high sunk costs of having deployed FTTP. On the other hand, should future demand grow more rapidly than expected, the rapid deployment of the [new approach] allows more of that growth to be secured early on, with scope to then upgrade to ensure the network can support very high speeds once demand reaches those levels."[141]

138. Akamai, State of the Internet reports (various dates)
139. nbn, Half-year report for the six months ended 31 December 2015, 4 February 2016
140. nbn, Corporate plan 2016, August 2015. Note that this is the estimate for the revised multitechnology approach (moving away from FTTH). The cost of the FTTH-oriented plan would have been significantly higher
141. Vertigan Panel (for Australian Government), The costs and benefits of high-speed broadband, August 2014

Finally regarding Australia, we note that the country's poor performance on speed and strong performance on traffic underlines the weak linkage between these two metrics.

Lessons

FTTP appears not to have delivered on its promise in Japan, South Korea and Australia. It has neither given them leading domestic application usage, nor has it positioned them as global players in the applications market. Indeed, US experience suggests that very high speeds are certainly not required to be a global internet leader – average US speeds would be mid-tier by European standards.[142]

That said, the disappointments of FTTP in Japan, South Korea and Australia (and some other markets) certainly do not prove that ultrafast cannot be a worthwhile intervention. However, it does suggest that great care is required to ensure that:

- The benefits of the intervention outweigh costs
- The benefits are delivered in the most cost-efficient manner possible
- There are not unintended adverse consequences.

Mandates for particular technical requirements and/or use of certain technologies can easily distort the market, particularly since they represent an undue focus on means (the nature of the network) rather than the ends (the applications enabled). This is particularly relevant given the importance of cost-efficiency. As we have seen, technologies such as DOCSIS 3.1 will deliver similar capabilities (and hence benefits) to FTTH, and at a substantially lower cost.

142. Akamai, State of the Internet Q4 2015, 22 March 2016

7. Remaining and emerging connectivity constraints

Previous chapters have illustrated commercial progress in terms of NGA investment, and that VDSL and DOCSIS 3.0 (let alone DOCSIS 3.1, G.fast and FTTH) represent investment ahead of demand. However, this is not a call for complacency. Far from it, remaining and emerging connectivity constraints need to be addressed.

It is important that incentives are maintained across all technologies to ensure timely upgrades to the access network when and where required ahead of demand. However, this chapter addresses other constraints on the value of the internet, including the need to:

- Extend NGA to reach those who do not currently benefit from adequate broadband
- Ensure that constraints in other parts of the network- (in particular in-building) are addressed
- Ensure that adoption and use continues to grow.

Ensuring that all have access to quality broadband

As NGA and VHC investment proceeds the emerging challenge is not primarily making even higher speed access available to some, but ensuring that access capable of supporting key applications is extended to all.

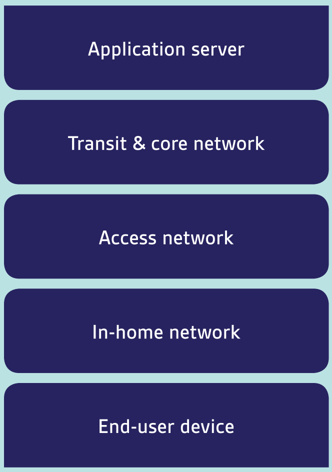
A mixed technology approach is even more important in more economically challenging areas to ensure that those that do not have decent broadband get it as fast as possible and at reasonable cost.

Wireless and hybrid solutions, including long-reach VDSL (under development and trial) and new cable technology offer the prospect of quick gains in terms of NGA coverage. Upgrades to cable can also deliver higher speeds quickly, as the rapid deployment of DOCSIS 3.1 demonstrates. Some cable operators, such as Virgin in the UK, are also investing to expand their coverage. Incentives for all forms of upgrade and extension should be maintained.

Overcoming end-to-end constraints beyond access

The maximum speed available to an application depends on the weakest link in a chain of potential end-to-end connectivity constraints. These include the content/application server, transit and core networks, backhaul/broadband access networks, the in-home Wi-Fi or fixed connection (or mobile access), and the end user device.

Figure 23 : Chain of end-to-end connectivity



As data traffic continues to grow, substantial investment in the core network and in international capacity will be required. With little attention from policy makers, and commercial freedom, these demands are being met through commercial initiatives, for example, the recently announced 160 Tbps fibre cable across the Atlantic.[143]

However, downstream of access to the premise, constraints may also arise. As access speeds increase, and as usage across multiple wireless devices grows, Wi-Fi will increasingly be the constraint on end-to-end connectivity (and not just for fixed access, but also in providing continuity and offload for mobile users whilst indoors). Overcoming this constraint cannot be left to the market alone, but requires a policy framework that ensures that additional spectrum is made available for Wi-Fi use.

Illustrating the importance of such constraints, an Ofcom study found that the performance of in-home Wi-Fi networks played a significant role in approximately 25% of households that experience problems with their broadband in the UK.[144] The study also found that for consumers with line speeds of 10 Mbps or more, almost two-thirds of performance problems were caused by issues other *than* the access network.

As broadband access speeds increase it will become more likely that Wi-Fi, or other elements of end-to-end connectivity, become the weakest link. Wi-Fi often delivers speeds well below a router's headline capability, for reasons such as congestion, distance and barriers including walls.[145] Wi-Fi receivers in devices may also constrain speeds. Even for devices physically connected to a router, the capacity of Ethernet ports can be a limit – many new laptops have ports capable of no more than 100 Mbps.[146] These constraints can be expected to limit access speeds in practice to rates below those attainable with cable DOCSIS 3.1 and G.fast.

A policy option would be to allocate additional 5 GHz spectrum for Wi-Fi, as Ofcom have proposed in the UK.[147] This approach should be prioritised and appraised for Europe as a whole. Improving Wi-Fi would help overcome an increasingly important constraint, not to the home, but to the device/user.

143. Microsoft, Microsoft and Facebook to build subsea cable across Atlantic, 26 May 2016.
144. Ofcom, Connected Nations 2015, 1 December 2015
145. Williamson, Punton and Hansell, Future proofing Wi-Fi – the case for more spectrum, 2013.
146. See, for instance, the mid-range HP 17-x013na
147. Ofcom, Improving spectrum access for consumers in the 5 GHz band, May 2016.

Adoption and usage is becoming a relatively important constraint compared to availability

When broadband coverage was patchy, a supply side focus offered rapid gains. However, now that basic broadband is near universal and NGA coverage is expanding rapidly, the relative importance of demand side constraints is growing.

Over 100 million adults in the EU (primarily the elderly) do not use the internet regularly.[148] Getting more people online - for instance, via digital skills support and training - would improve the overall business case for fixed NGA upgrades. Further, the need to get price sensitive consumers online points to the importance of service-price differentiation in order to maximise utilisation of NGA networks (and recover the fixed costs of NGA efficiently across the greatest possible pool of users).

Conclusion

Constraints may emerge anywhere in the chain of end-to-end connectivity and use. A focussed approach is required, addressing those binding connectivity bottlenecks that require policy attention.

The market, given sufficient freedom, can and will address most emerging constraints in transit, core and access networks ahead of demand. However, constraints in relation to universal broadband, in-home wireless connectivity and adoption may require policy action to ensure they are overcome on a timely basis.

148. EC, Digital Agenda Scoreboard (accessed 14 October)

8. Suggested policy approach

We now turn to guiding principles for designing interventions and national broadband plans within the context of the Gigabit Society, before considering specific policy priorities.

Policy considerations for a European intervention

Recognise the central and ongoing role of commercially driven investment

The bulk of investment in NGA to date has been commercial. Further, the major gains in terms of availability of NGA and increases in actual speed delivered have come about via upgrades of cable and copper networks. These can be carried out quickly and step-wise in alignment with developing user needs, rather than requiring substantial upfront investment. Such upgrades are also better able to migrate customers to higher speed packages compared to new network build (which may require a switch of provider and/or in-home installation).

Whilst fibre will increasingly be brought closer to users, fibre to the premise remains a slow and costly option in significant parts of Europe. Government support may play a greater role in future as less commercially attractive areas are tackled, though the fiscal position of governments in Europe remains challenging.

Commercial investment can be expected to continue to play the major role in terms of NGA extension and upgrades to VHC networks. As the Commission has noted, "the necessary investments [will] primarily … be achieved by the market".[149]

VHC networks based on DOCSIS 3.1 will enable gigabit speeds while allowing a commercial return, for example – not least because it is inexpensive. According to Frontier Economics:

> "[T]he incremental network cost faced by cable operators to obtain higher speeds [using DOCSIS 3.1] may often be substantially lower than that faced by either DSL or FTTH/B networks".[150]

Further, more challenging areas will also see progress on commercial terms with technical progress in relation to network build, long-reach technologies, wireless and satellite all lowering the costs of delivering higher speeds.

The primary focus should therefore be to ensure that commercial investment is supported by a sound policy and regulatory environment and is not delayed by the prospect of overly ambitious public schemes (which may, in any event, be slow to implement or fail to materialise – the experience in Australia).

149. EC, Connectivity for a Competitive Digital Single Market - Towards a European Gigabit Society, 14 September 2016
150. Frontier Economics (for Telenor), Ultrafast network developments, competition and the EU Telecoms Regulatory Framework, June 2016

Moreover, interventions should be allowed to conform to local circumstances and requirements, rather than subjected to a 'one size fits all' approach. As the Commission has said:

> "Regulation will be more effective if it is based on in-depth local knowledge of an increasingly diverse network landscape, with a variety of different local, national and multi-national actors."[151]

A targeted approach will allow deployment to keep pace with demand, rather than crowding out near term upgrades and/or (inefficiently) running far ahead of demand.

Maintain and strengthen investment friendly regulatory environment

The existing European regulatory approach - copper price stability and NGA pricing freedom – should be maintained. However, over time the anchor product concept which has underpinned pricing freedom may need to be adapted, as demand changes.

Further, if competing commercial NGA networks are given "space" to develop, potentially alongside long-term voluntary commercial agreements regarding investment and access, the scope to reduce regulation will grow – resulting in a virtuous circle.

Recognise uncertainty in policy design

Technology, consumer behaviour and market circumstances are evolving rapidly and are uncertain; so inflexible plans involving substantial capex may be inefficient compared to a more incremental and adaptive approach.

We have seen a pivot towards mobile, with the majority of time online now on mobile devices. This is changing demand in terms of applications use and connectivity requirements. We have also seen rapid progress in improving the capability of existing cable and copper networks. At the time the current Digital Agenda targets were set these developments were not fully anticipated.

As a result of these changes, the prospects of societally beneficial applications that can *only* be delivered by FTTH are now more remote. For now, consumer demand for ultrafast also remains narrow, with only limited willingness-to-pay. Consequently, investors, with due respect for risk, may favour incremental approaches to upgrades.

In terms of targets and policy this suggests maintaining a technology neutral approach and remaining focussed on the objective of ensuring that connectivity is unconstraining for the development of the digital single market.

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151. EC, Connectivity for a Competitive Digital Single Market - Towards a European Gigabit Society, 14 September 2016

Focus on outcomes

The reason for an incremental approach in anticipation of demand is pragmatic. Attempting to build too far in advance of demand may crowd out or delay commercial investment, and involves trade-offs in terms of cost, coverage and time-to-market that make it more, rather than less likely, that connectivity will prove constraining on the development of the single market. It is also important to focus resources on the most constraining element in terms of end-to-end connectivity and use, rather than only considering the access link.

Policy implications

In terms of implications, this suggests policy makers should:

Keep an active watching brief

Monitor developing user requirements, capabilities of commercially viable technologies and other related issues. For example, the Commission has suggested that supply of VHC networks will create its own demand. Given that widespread commercial deployment of VHC networks is imminent, we will soon have a 'laboratory' to test this theory. If it is proved out, that may form a more solid basis for intervention elsewhere.

Adopt an end-to-end focus in relation to usage constraints

When looking at infrastructure, if it is proven that intervention is necessary, it should be focused on those elements of the connectivity chain likely to have the highest societal return on investment. For example, providing additional Wi-Fi spectrum at 5 GHz to improve in-premise connectivity may have more impact on overall performance than evermore investment in the access network.

Beyond infrastructure, policy should also consider other barriers to usage, such as lack of digital skills and affordability. (Higher adoption and therefore demand would also improve the business case for improvements to infrastructure)

Consider the benefits of 'now-proofing' as well as 'future-proofing'

It is of course important to anticipate long-term demand. But it is also important to speedily meet current and short-term demand (in part to ensure that richer applications develop, as developers have short time horizons).

For this reason, the speed of deployment of different technologies is critical, since this can bring forward the benefits of VHC networks. In particular the Gigabit Society's goals for 1 Gbps and 100 Mbps connectivity can be met for roughly half of European premises using DOCSIS 3.1 within roughly three years – far ahead of the 2025 target, and without a requirement for state funds.

Conversely, favouring slow-to-deploy technologies (such as FTTP) could cause real and imminent harm (the 'Australia trap'), as well as undermining longer term prospects for new applications and closing off possible options to meet long-term demand using emerging technologies.

Recognise that targets can be met with a mix of technical solutions

This will keep options open. By contrast, if national plans force the use of a particular technology this risks precluding the use of other technologies that (particularly with refinements over time) may be far more cost effective.

FTTH and DOCSIS 3.1 are already VHC networks, and an increasing number of technologies are likely to meet this test over time.

Target government intervention at those situations with demand beyond what the market will provide and significant externalities

For intervention to be justified in the broadband market, it must generate meaningful externalities – value not simply to the relevant consumer, but to society as a whole. For example, reducing the time to download a large console game from ten to five minutes might require gigabit speeds, but this would not in itself justify intervention to support gigabit broadband, since the benefits are fundamentally private. If the consumer in question was not willing to pay the full cost of gigabit broadband for this purpose, why should taxpayers in general subsidise him?

In some circumstances very high speeds will create externalities. The Commission's Gigabit Society vision rightly prioritises schools, hospitals, and other socio-economic drivers. A targeted rather than mass market intervention may be most appropriate in such instances.

Thus, to ensure government investment and other interventions in support of broadband are efficiently and appropriately targeted, each should be justified based not just on the technical capabilities it will bring beyond the market, but also the specific externalities those capabilities will support which market-based broadband would not have been able to deliver.

Help the 'Have nots' before super-serving the 'Haves'

Indeed it seems likely that there will be greater benefits from other interventions with more obvious externalities. For example, public support for improvements to poor broadband in rural areas may bring greater benefits than pushing for ultrafast in areas that already have superfast (and which can expect commercially funded improvements anyway). Equally, helping non-users get online can be transformative for them, and far more impactful than extra speed for those who already use the internet. (The Gigabit Society communication touches on affordable connectivity, but lack of skills is generally a more important barrier to adoption than cost).

Minimise unintended consequences and maximise intended consequences

To minimise unintended consequences, in particular the risk of delaying or crowding out commercial investment, any intervention should be targeted. Given uncertainty over what will be achieved without intervention it should therefore not be too far reaching.

To support a connected digital single market, we do however want to go beyond basic availability which aims to capture externalities and increase the level of social inclusion.

We want to see innovation and investment in connectivity responding to and anticipating demand when and where it arises. That is hard to predict, and that is precisely why strong incentives rather than a long-term plan are likely to be the best approach.

In turn strong incentives depend on a long-term commitment to maintain as much commercial freedom as possible (consistent with protecting consumers' long-term interests) and a commitment not to expropriate sunk investment once it is made by imposing price controls that cap investment upside whilst leaving investors exposed to downside risk (assessed from the perspective of expectations at the time investment was made).

Conclusion

A capable fixed broadband access network is a vital component of European digital infrastructure, and it is right that it is a policy priority to ensure that this access network does not constrain the continent's digital ambitions.

Fortunately, with a supportive regulatory regime the market will continue to invest substantially to improve fixed broadband. For the great majority of customers, these investments will provide them with more than enough bandwidth. In particular, the imminent and widespread commercial deployment of DOCSIS 3.1 will go a long way to meeting the Commission's targets for VHC networks.

This means policy interventions can and should be focused on the specific cases where the market may not provide (such as remote rural areas), allowing limited state funds to have maximum return on investment and avoiding unintended consequences.

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