The future of connectivity

"Prediction is very difficult, especially if it's about the future" Niels Bohr

The past

If prediction is difficult, let's start with the past. It's an amazing story.

1794: Optical telegraph between Paris and Lille. The network eventually reached 5,000 km. First message "Si vous réussissez, vous serez bientôt couvert de gloire." Speed 0.1-0.3 bps.

1844: Long-distance telegraph between Washington, D.C., and Baltimore. First message "What hath God wrought?". The first successful transatlantic telegraph was laid in 1866 over which Queen Victoria messaged the US President. The cost per word was over $100 in today's money with a speed of 1-2 bps.

1876: Bell demonstrated the telephone saying "Mr. Watson, come here, I want to see you." The first telephone exchange was operating by 1878. By 1900 there were around 2 million subscribers globally, by 1950 around 50 million and by 2000 around 1 billion.

1897: Marconi demonstrated wireless communication over the Bristol Channel. The speed using morse code was 10 bps.

1979: First commercial cellular network launched in Tokyo. There were around 700 million mobile users by 2000, and around 5.6 billion by 2024. The first SMS message was sent in 1992, 3G was introduced in 2001, 4G in 2009 and 5G in 2019.

1983: Dial-up internet access with speeds of 300 bps. ADSL was introduced in 1991 allowing speeds of 1.5-6 Mbps.

1996: Fibre broadband introduced in Japan. By 2024 there were around 850 million subscribers worldwide.

1998: First satellite call made over Iridium network by Vice President Al Gore.

1999: Home Wi-Fi introduced.

2020: Starlink launch low-earth orbit satellite broadband with around 800 satellites. By May 2024 there were around 6000 operational satellites and 3 million users. The first direct to mobile message was sent in 2024, with operators partnering to launch services. Starlink coverage includes the Americas, Europe, and Australasia and is 'coming soon' to other regions excluding China, Russia, North Korea and Iran. Others, including OneWeb and Amazon (Project Kuiper), are building constellations.

The future

Lessons from history

First, some lessons from history:

- Rapid long distance communication of information is valued highly, as willingness to pay for the first transatlantic telegraph and mobile in developing countries has demonstrated.
- Mobile trumped fixed in terms of the pace and extent of deployment and adoption. Deployment was competitive.
- Satellite is delivering ubiquitous high-speed low-latency broadband, and will complement cellular to deliver SMS, voice, internet of things (IoT) and (limited capacity) data services by 2025. [1]

Ubiquity (outdoor) will soon be delivered

One of the greatest connectivity challenges, delivering a ubiquitous service, will soon be met by low-earth orbit satellite constellations.

Satellite constellations have limited capacity, they are not a high-density broadband substitute. But they deliver ubiquity, and ubiquity is potentially immensely valuable in an age of automation and autonomous machines in roles such as agriculture, inspection/sensing and land, sea and air transport.

Indoor coverage remains a challenge

Cellular and satellite both struggle to deliver coverage indoors, and whilst Wi-Fi is great it is not available – or where available, accessible – everywhere. This challenge needs more attention both in terms of future spectrum assignment or shared use, and innovative technical and business models for frictionless shared use.

The returns to bandwidth increments are sharply declining

A rule of thumb has been that the value of increasing broadband speed follows the logarithm of bandwidth i.e. each order of magnitude increase in bandwidth doubled the value.

However, this rule of thumb was based on studies in the low Mbps range[2], and may not hold for successive order of magnitude increases. Is the step from 100 Mbps to 1 Gbps worth as much for households as from 1 Mbps to 10 Mbps or 10 to 100 Mbps?

It seems highly unlikely, based on revealed preferences in relation to adoption and on requirements for applications and content. This might change, but what might plausibly change demand for speed increments?

One possibility is higher definition content; but there are limits to the resolution of our eyesight, adoption of simultaneous streaming within households has limits, more consumption is now on smaller screens, compression continues to improve, and AI-based upscaling (say from an HD stream to an 8K picture) is now commercially available. It seems plausible that bandwidth demands for video will plateau or even decline.

Another possibility is new applications, immersive video presence, virtual and augmented reality (VR and AR), the metaverse and AI. This involves greater uncertainty, but whilst one can imagine scenarios in which peak bandwidth demand increases, it is also plausible that new applications could reduce demand.

[1] Starlink, January 2024, SpaceX sends first text messages via its newly launched direct to cell satellites. https://api.starlink.com/public-files/DIRECT_TO_CELL_FIRST_TEXT_UPDATE.pdf

[2] Rohman and Bohlin, 2013, Does broadband speed really matter as a driver of economic growth? Investigating OECD countries, *International Journal of Management and Network Economics*, Vol. 2(4). Working paper: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2034284

On the one hand immersive video presence may be demanding. For example, Google Project Starline requires 30 to 100 Mbps.[3]

On the other hand, photorealistic avatars allow virtual meetings that are "*much more bandwidth efficient than transmitting a full video especially a 3D immersive video…*".[4]

The bandwidth difference between using immersive video versus photorealistic avatars for online interaction might be around two orders of magnitude, with existing video intermediate between the two.

Another area of uncertainty is the impact of AI. On the one hand it may increase and deepen online behavior and motivate increased use of real-time inputs including video.

On the other hand, scaled down AI models can run on-device and IoT sensor input (including video) could be processed locally with 'insights' transmitted at much lower bandwidth. (Eyes do something similar). The net impact of AI on bandwidth demand is uncertain.

One way to put plausible bounds on future bandwidth demand is to model applications probabilistically to build up a picture of the likely range of growth, or decline, in demand.

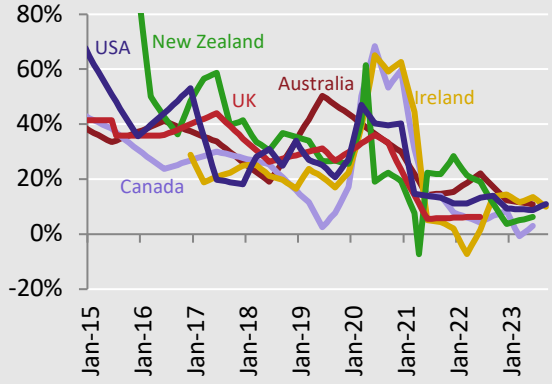
A Communications Chambers study utilizing this approach in 2013 estimated median household demand for the UK in 2023. The modeling predicted that for all but 1% of households, 35 Mbps downstream is likely to be sufficient, and that with a range of more aggressive assumptions the figure rises to 71 Mbps.[5]

In contrast, a 2018 study for Ofcom by WIK forecast that 40 per cent of households would require 1 Gbps by 2025, and that 82 per cent would require 300 Mbps or more (the study appeared to 'stack' applications to derive peak demand without considering the likelihood of simultaneous use[6]). Evidence to date suggests that the WIK study may have overestimated bandwidth demand by roughly an order of magnitude.

Data growth is declining – it is not exponential

Data growth is not exponential, it has been declining for both fixed and mobile access and is forecast by Ericsson to continue to decline for mobile out to 2029[7]:

Year-on-year growth in traffic per fixed broadband line (English speaking markets)[8]



[3] Lawrence and Goldman et al, December 2021, Project Starline: A high-fidelity telepresence system. ACM Trans. Graph., Vol. 40, No. 6, Article 242. *https://storage.googleapis.com/gweb-research2023-media/pubtools/pdf/3696afb4c1cccbe0876a9fedd1586f0f9c84f737.pdf*

[4] Meta, October 2023, Meta's New Photorealistic Avatars Show Metaverse is Real. *https://metanews.com/metas-new-photorealistic-avatars-show-metaverse-is-real/*

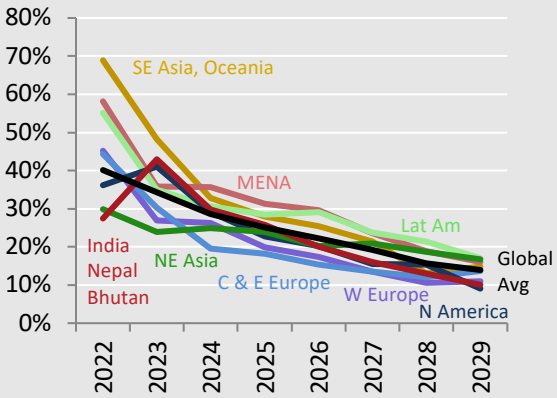
[5] Robert Kenny and Tom Broughton, November 2013, Domestic demand for bandwidth - An approach to forecasting requirements for the period 2013-2023. *http://www.commcham.com/pubs/2013/11/6/forecasting-domestic-uk-broadband-demand-2013-2023.html*

[6] Robert Kenny, March 2018, Examining WIK's bandwidth demand forecast. *http://www.commcham.com/pubs/2018/3/5/examining-wiks-bandwidth-demand-forecast.html*

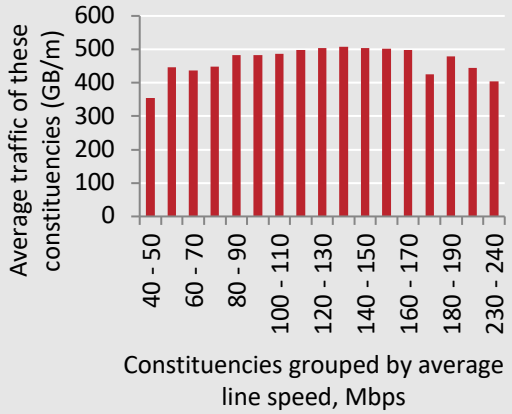
[7] Ericsson Mobility Report, November 2023. *https://www.ericsson.com/4ae12c/assets/local/reports-papers/mobility-report/documents/2023/ericsson-mobility-report-november-2023.pdf*

[8] Robert Kenny, December 2023, *Patterns of fixed traffic growth, 2023*

Forecast annual mobile traffic growth rates[9]



Traffic vs speed, UK parliam'ary constituencies[11]



To gain insight into likely future developments it is useful to consider the drivers of demand.

For fixed, given that the price of data is typically zero at the margin, the drivers of consumption include the number of users in a household, the applications they use and the amount of time they use them (as Netflix CEO Reed Hastings put it "Netflix's biggest competitor is sleep").

To the extent that the speed of broadband access impacts the quality of the user experience this could increase data consumption. However, a study that considered drivers of fixed broadband traffic found that: "*after allowing for demographic factors, higher speed has a very limited relationship to traffic.*"[10]

Whilst it is possible that a new data intensive application which is widely used could see a return to higher growth for fixed access, nothing on the horizon suggests this is likely.

For mobile, given higher incremental capacity costs and tiered pricing, the constraint on data consumption can be thought of as the incremental cost of data. The drivers of mobile data growth can therefore be modelled in terms of willingness to pay for data versus the incremental costs of data.[12]

Mobile incremental costs have fallen rapidly with improvements in technology (including successive G's 2G, 3G, 4G and 5G) coupled with the addition of spectrum. However, 5G approaches the technical (Shannon) limits for efficiency and there is limited scope to add prime spectrum bands. Thus, falls in unit costs may slow, and by extension price reductions are unlikely to reignite data growth.

On the demand, or willingness to pay, side new mobile apps could in principle drive data

[9] Ericsson Mobility Report, November 2023. https://www.ericsson.com/4ae12c/assets/local/reports-papers/mobility-report/documents/2023/ericsson-mobility-report-november-2023.pdf

[10] Robert Kenny, Charles Kenny and Zack Gehan, October 2023, What drives broadband traffic? *Telecommunications Policy,* Volume 47 (9). https://www.sciencedirect.com/science/article/abs/pii/S0308596123001325

[11] Communications Chambers analysis of data from Ofcom, Fixed performance parliamentary constituency data, 15 December 2022. Figures are for May 2022. Note that sample sizes are small below 50 Mbps and above 160 Mbps

[12] Brian Williamson and Sam Wood, January 2017, Mobile value, spectrum and data demand – a bootstrap approach to estimation. *Digital Policy, Regulation and Governance*, Volume 19(1). Working paper: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2799357

growth, however without falling unit costs this would drive up bills, likely choking growth.

Investment expectations

An indicator of market expectations of future demand is investment. Globally telecoms capex fell in 2023 and is expected to fall further in 2024.[13] Whilst these are short-run changes, they are consistent with supply overtaking demand.

Policy – A vision beyond targets

Policy developed over the past decade has been conditioned on an expectation of exponential growth in traffic and bandwidth requirements.

Whilst there was a need to update networks to improve coverage and meet demand for speed and capacity, growth in demand has not proved exponential, rather neither data growth nor valued speed increments have sustained exponential growth.

The EU Digital Decade Targets for 2030 include ubiquitous gigabit capable fixed networks and widespread 5G coverage. Yet the EC White Paper noted that achievement of 2030 fibre targets were "in doubt" [14].

Given the extent of change on the supply and demand sides of the market; the increasingly diversity of supply and the sharp decline in growth of both fixed and mobile data and peak bandwidth demand, it would be timely to re-evaluate both the existing focus in terms of targets and broader policy in relation to connectivity.

It is important to recognise that not only have expectations changed, but that expectations remain uncertain and contingent.

Given that supply and demand are increasingly heterogenous, and that supply may now be outstripping demand for many fixed and mobile access users, an ongoing focus on broadband targets is called into question.

Further, a greater focus on the demand side is warranted; and taxing demand - such as was proposed under the 'fair share' proposal - would be counter-productive.

Industry has argued that its capacity to invest is constrained and recent declines in investment do suggest they are not finding returns on incremental investment attractive. Thus, it is crucial that further investment is efficient and well targeted.

Public policy should arguably now pivot to ensuring that everyone has good enough connectivity rather than pushing for gigabit for all despite a growing expectation that it may not be achieved, or indeed valued. A broader focus, including low earth orbit satellite constellations, would open the potential for rapid gains in terms of universality.

Further, given declining mobile data growth, the challenge of delivering indoor coverage and the potential to enhance satellite broadband, spectrum priorities should be re-evaluated.

Overall, a nimbler approach, less focussed on almost decade long plans and targets, and more focussed on adapting policy as supply side possibilities and valued demand applications are revealed, should be pursued. In the short-term error-correction is called for.

Brian Williamson and Rob Kenny, June 2024

[13] Analysys Mason, May 2024, Network capex has started a long decline, opening up new options for operators. *https://www.analysysmason.com/research/content/articles/network-capex-decline-rdns0/*

[14] EC, February 2024, How to master Europe's digital infrastructure needs?, White Paper. *https://digital-strategy.ec.europa.eu/en/library/white-paper-how-master-europes-digital-infrastructure-needs*