CONSULTING

BSG
Broadband
Stakeholder
Group

analysys
mason

Report for the Broadband Stakeholder Group

Research on Very Hard to Reach Premises: technical and commercial analysis

Matt Yardley, Andrew Daly, Helena Fyles

12 August 2021

Contents

Background

High-quality digital infrastructure has been essential to support the UK during the pandemic. We expect it to play a significant role in underpinning our economic recovery and future growth.

The Government's stated ambition is to make gigabit-capable broadband widely available across the UK. The goals are to ensure that at least 85% of UK premises have access to gigabit-capable broadband by 2025 and for 80% of that coverage to be delivered commercially. For the 20% expected to be beyond commercial deployments, £5 billion funding is being allocated to support the delivery of gigabit-broadband through Project Gigabit.

However, the Government recognises that this Project Gigabit programme will still leave some premises unserved. It is estimated that there will be around 100,000 such premises. The Government is exploring options for improving broadband connectivity. A call for evidence was launched by the Department for Digital, Culture Media and Sport (***DCMS***) on 19 March 2021.

To advise the Government on how to improve connectivity for very hard to reach areas, the Broadband Stakeholder Group (***BSG***) commissioned Analysys Mason to undertake a research project to identify the commercial and technical practicalities of providing coverage to these, so called, "Very Hard to Reach Premises".

The Analysys Mason Report (***Report***) details a wide range of broadband technologies, including fixed and wireless, terrestrial and non-terrestrial that could be deployed in the UK between 2021 and 2027. The Report also provides an assessment of the ability to deliver either 30Mbit/s or 300Mbit/s download speeds.

The Report is divided into two parts. The first is a technical analysis with detailed performance information (e.g. speed, coverage, latency), maturity and barriers to deployment for each of the technologies. The second is a commercial analysis of the cost of deploying the network infrastructures. This commercial analysis considers viability for two specific business case scenarios: over 10-year and 20-year investment periods.

Source: Broadband Stakeholder Group

Background [continued]

The Government has not specified what it considers to be a suitable service specification for these Very Hard to Reach Premises. When the BSG instructed Analysys Mason, we asked them to look at technologies capable of delivering either 30Mbit/s or 300Mbit/s download speeds. The rationale for choosing the download speeds is to provide sensible reference points to compare with the Government aspiration of delivering gigabit-capable broadband and the minimum speed requirements under the Universal Service Obligation. For example, if the cost of building or upgrading the network connection is more than £3,400, the customer will have to pay the excess costs. We believe 30Mbit/s would ensure people who have a very poor connection or no connection at all, would at least benefit from a service that is likely to deliver a sufficient level of connectivity to support their online activities in the short to medium term. 300Mbit/s is likely to support the majority of high demand for connectivity in the longer term.

At present, only fibre and cable networks can provide a fixed broadband service with a typical download speed of 300Mbit/s. Unfortunately, they have a high initial cost of deployment which is exacerbated by increasing line lengths. Low Earth Orbit (***LEO***) satellites and Fixed Wireless Access (***FWA***) deployments have the potential to provide such speeds to Very Hard to Reach Premises at lower cost. However, the contended access nature of these solutions means that the number of customers that can be supported simultaneously is likely to be limited.

Whilst all the technologies mentioned in the Report can potentially deliver 30Mbit/s, there is a need to consider the cost of deploying each solution to ensure that a cost-effective subsidy programme is achieved in very hard to reach areas. The overall quality of service could also vary significantly. There is a trade-off to consider between the cost, the different quality of service metrics and the longevity of the solution. Any proposed solution should take into account increases in data consumption per household (in particular with TV migrating to IP) and the potential impact on the contention ratio.

The Government is responsible for developing the policy which will govern the specifications for the service that premises in the most remote and isolated parts of the UK should have access. We believe that this Report significantly adds to the evidence base available. We hope that the Report, together with our recommendations below, will help inform the Government’s approach in relation to subsidising delivery of services to the hardest to reach parts of the UK. We encourage the Government to consider our recommendations as it makes its policy decisions.

Source: Broadband Stakeholder Group

Recommendations

Based upon the information contained in the Report and our knowledge of the market, the BSG makes the following recommendations:

- The Report reinforces the fact that, although there are technologies that could deliver in these areas, none is expected to be commercially viable to do so. Consequently, deployment would require some form of public financial intervention for these technologies to be deployed in very hard to reach areas. **The BSG encourages the Government to seize the opportunity to consider innovative approaches to fully support this ambitious programme.** For example, (i) procurements would need to define large enough blocs to allow network providers to scale effectively; (ii) public funding should be allocated for both capital and operational expenditures, including ongoing funding of satellite monthly rental.

- While most of the Very Hard to Reach Premises have similar characteristics (i.e. geographic isolation), there is great diversity between each of them. Some premises are located at a substantial distance from any neighbouring premises and/or any existing network, whilst others are located on islands. **A mix of technologies will therefore be required. We believe the approach to be followed by the Government must be technology agnostic.**

- **The Government will also want to consider how services are delivered in areas where nearby premises are already benefiting from enhanced connectivity.** We believe it may be possible to utilise nearby infrastructures to help reach Very Hard to Reach Premises.

Source: Broadband Stakeholder Group

Recommendations [continued]

- **Where there is an overlap between remaining mobile Total Not-Spots and Very Hard to Reach Premises, the BSG suggests addressing mobile and broadband coverage issues at the same time.**

- **The BSG urges the Government to continue tackling existing barriers that impede the roll-out of new terrestrial infrastructures.** Ambitious reforms to lower the cost and speed up the process of building and upgrading digital infrastructures including backhaul capacity are critical to allow stakeholders to increase the footprint of their commercial deployment. Examples include wayleaves, permits and land rents. These interventions would potentially reduce the number of premises within the very hard to reach category. An effective subsidy programme will be achieved for very hard to reach areas when the relevant policies that are developed address these existing barriers as well as the fundamental national needs of accessibility, reliability and resilience.

- The stated Government policy and subsidies so far have focused almost exclusively on gigabit speed. We believe that businesses and consumers value the other aspects of digital connectivity at least as much as they value speed. **In particular, the BSG recommends that (i) availability, (ii) accessibility, (iii) reliability and (iv) resilience of digital services are addressed, as well as speed.**

The Broadband Stakeholder Group

Source: Broadband Stakeholder Group

Contents

This research project provides input to DCMS on the technical and commercial practicalities of connecting Very Hard to Reach Premises

Introduction

- The main purpose of this research project is to provide input to the Department for Digital, Culture, Media & Sport (DCMS) consultation on connecting Very Hard to Reach Premises (VHtRPs) in a way that has cross-industry support
  - the research summarises the technical and commercial practicalities of various candidate broadband technologies
  - the project is loosely related to Sections 6 and 7 of the DCMS Call for Evidence (CfE)
  - the project will also inform the BSG sponsors' own submissions to DCMS and their approach to potential solutions for VHtRPs

Scope and key considerations

- The project will focus on VHtRPs, estimated by DCMS to be 100 000 premises
  - DCMS's estimate of 100 000 is based on the extent to which gigabit-capable networks will be deployed (in turn based on the impact of Project Gigabit and deployments made under the broadband universal service obligation (USO)
- The scope of the project includes:
  - technologies that can be deployed between 2021 and 2027
  - the ability of technologies to deliver either 30Mbit/s or 300Mbit/s download speeds

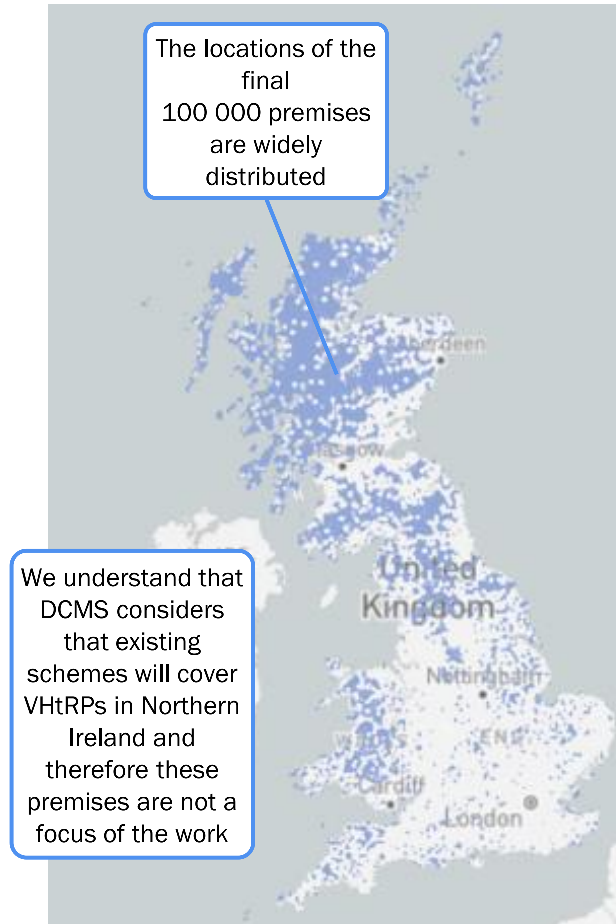
Sources of information

- The sources for the research include publicly available information (i.e. desk research), multiple workshops and bilateral discussions with BSG sponsors and other industry stakeholders, and Analysys Mason's in-house industry knowledge

We have assumed that the final 100 000 premises are those which are furthest from their local telephone exchange

- The DCMS CfE provides an estimate that there are 100 000 VHtRPs in the UK:
  - *"A very small proportion of premises - potentially less than 100,000 - are therefore likely to be significantly above the broadband USO's reasonable cost threshold and considered "Very Hard to Reach" with gigabit-capable broadband technologies like fibre to the premises technology."*
- We characterise the 100 000 VHtRPs as the 'final' 100 000
- DCMS's reasoning appears to be based on the effect of two key initiatives:
  - the application of Project Gigabit in the final 20% of premises
  - the fact that many of the premises being upgraded under the USO will be served with gigabit-capable full fibre
- To estimate where the final 100 000 premises are actually located, we have assumed that they are the furthest 100 000 premises from their local telephone exchange
  - we recognise that this is a fixed-telecoms measure, but believe it is a good proxy for the hardest-to-reach premises
- As DCMS's estimate of 100 000 is based on the extent to which gigabit-capable networks will be deployed, our consideration of 30Mbit/s vs. 300Mbit/s will not have a material effect on the number VHtRPs, but will affect which technologies could be suitable for serving them and the timelines involved

Estimated locations of the final 100 000 premises



Source: DCMS, Analysys Mason

We have considered a wide range of fixed and wireless, terrestrial and non-terrestrial broadband technologies

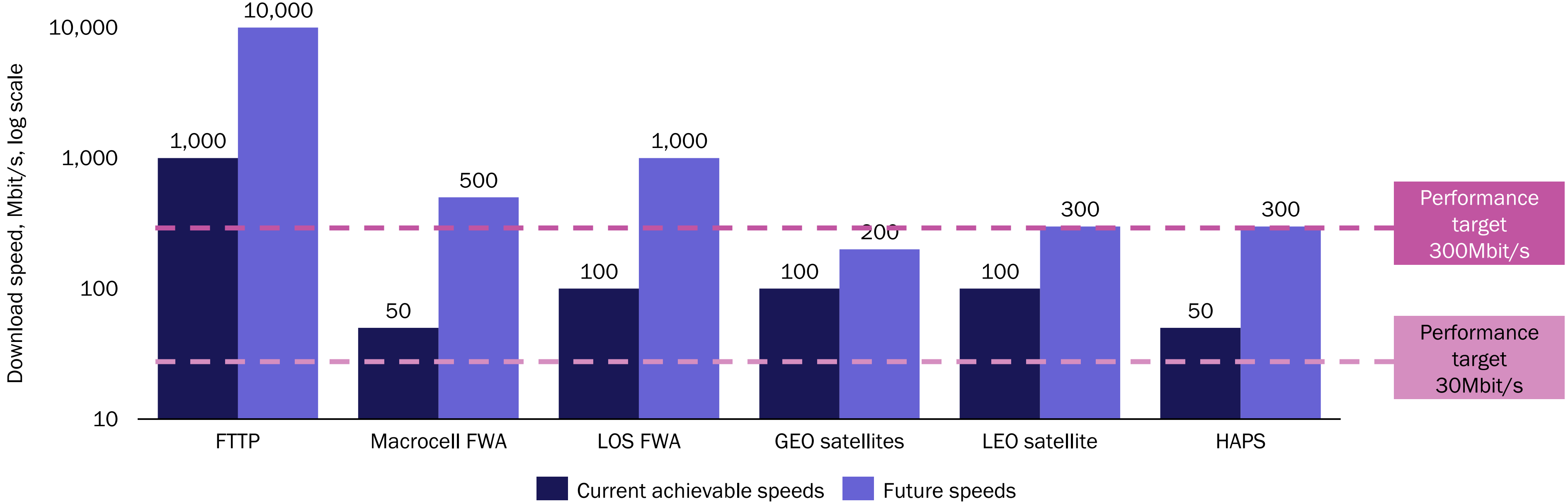
Summary of candidate technologies which could serve the final 100 000 premises

Technology	Description
Fibre to the premises (FTTP)	The laying of a fibre-optic connection from user premises to the nearest fibre-enabled backhaul location
Macrocell fixed-wireless access (FWA)	Antennas on a tower/mast connect to a base station which performs signal processing Different generations of mobile technologies (2G/4G/5G)
Line-of-sight (LOS) FWA	Short-range high-frequency wireless uses unlicensed or lightly licensed spectrum (e.g. 5.8GHz, 60GHz) for last-mile connectivity. Technology standards include WiGig and other vendor-proprietary solutions Typically deployed in combination with fibre to provide backhaul from local access point
Geostationary orbit (GEO) satellites	GEO satellites hold a fixed position in the sky and are large (c.5 tonnes) with a long lifespan (c.15 years) Connectivity is provided to a static very small aperture terminal (VSAT) which is mounted on the user premises and connected to a modem via coaxial cable
Low Earth orbit (LEO) satellites	LEO satellites move position relative to the Earth's surface and are smaller than GEO satellites (c.50–800kg) with a shorter lifespan (c.5 years). Modern LEO satellites are expected to have short lifespans, though previously launched constellations have lasted much longer There are two main technology options for the consumer antenna: (1) a mechanical system (parabolic dishes/radomes/motors, etc.), which physically moves to track the passing satellites; (2) electronically scanned array (ESA) antennas which can track multiple satellites simultaneously without physically moving
High-altitude platform systems (HAPS)	HAPS involves an airborne vehicle providing connectivity from high in the Earth's atmosphere. This can be achieved from an unmanned aerial vehicle (UAV), a balloon or an airship Altitude of platform can vary from a few hundred metres to several kilometres HAPS and its payload need to stay in approximately the same location relative to the ground to provide consistent coverage

Source: Analysys Mason

There is a range of performance characteristics across the candidate technologies, with many capable of meeting the 30Mbit/s or 300Mbit/s requirement

Typical achievable download speeds now and in the future for different fixed broadband technologies



Summary of typical achievable upload speed and latency performance

	FTTP	Macrocell FWA	LOS FWA	GEO satellites	LEO satellites	HAPS
Upload speeds	30–1000Mbit/s	5–50Mbit/s	20–200Mbit/s	5–10Mbit/s	20–30Mbit/s	10–50Mbit/s (estimated)
Latency	<1ms	20–30ms for 4G, <10ms for 5G	<20ms	500–600ms	20–100ms	10–30ms

All of the technologies in this report would be capable of carrying broadcast TV services. However, consideration of issues beyond the scope of this research would be required, e.g. network reliability, compatibility with interactive services, and various regulatory and commercial issues

Source: Analysys Mason, discussions with stakeholders

The relative maturity of the different technologies might affect how quickly each can be scaled up, while a range of other deployment barriers must be considered

Summary of maturity and barriers to deployment for different technologies

<table>
<tr><th>Technology</th><th>Maturity</th><th colspan="2">Barriers to deployment</th></tr>
<tr><td>FTTP</td><td>High</td><td>▪ High up-front costs mean that a lack of existing infrastructure to re-use can create a barrier
▪ Availability of deployment resources is a potential issue</td><td rowspan="4">All terrestrial technologies are potentially affected by:
▪ Access to local grid power at the location of network equipment (nodes, sites, access points)
▪ Permissions from local landowners and other groups to authorise deployments</td></tr>
<tr><td>Macrocell FWA</td><td>High</td><td>▪ For new rural sites, there may be (significantly) higher costs due to difficulty of installation of site and backhaul in challenging terrain</td></tr>
<tr><td rowspan="2">LOS FWA</td><td>High (30Mbit/s)</td><td rowspan="2">▪ Significant LOS requirements: any buildings or foliage will disrupt signal propagation
▪ Some locations which would be suitable for an access point may not always be made easily available (e.g. water towers)</td></tr>
<tr><td>Medium (300Mbit/s)</td></tr>
<tr><td>GEO satellites</td><td>High</td><td colspan="2">▪ LOS is required – steep hills or buildings may block signal
▪ Some latitude limitations (unlikely to be an issue for the UK)</td></tr>
<tr><td>LEO satellites</td><td>Medium</td><td colspan="2">▪ Large numbers of ground stations are required
▪ LOS requirements: trees could significantly affect signal propagation during partial coverage phase</td></tr>
<tr><td>HAPS</td><td>Low</td><td colspan="2">▪ Aviation regulation is a potential barrier (how to classify the HAPS vehicle; avoiding existing traffic during ascent and descent)
▪ Some spectrum approvals for access and backhaul communications are still required
▪ Solar-powered UAV-type HAPS can be constrained to certain latitudes</td></tr>
</table>

In the following slides, we present a summary of the commercial analysis of the technologies which include FTTP, macrocell, unlicensed wireless, GEO satellite and LEO satellite. While we understand that UAV-based HAPS is expected to reach commercial deployment within the period 2021–27, no detailed information is available on the cost and capacity performance of this technology, so it is not included in the commercial analysis

[1] We note that GBP40 is c.50% of the current retail offers for LEO satellites (e.g. Starlink), but have assumed the same revenue as other technologies to compare on a like-for-like basis | Source: Analysys Mason, public data

For the commercial analysis, we have compared the technologies on a like-for-like basis, with similar revenue assumptions and a carefully defined cost base

Summary of revenue and cost approach for each technology

Technology	Take-up in covered area	Revenue	Scope of network costs
FTTP	80%	GBP40 per subscriber per month retail revenue for fixed voice and broadband 50% of retail revenue allocated to recover cost of modelled network [Macrocell wireless includes a further 30% revenue uplift to reflect improved/new mobile revenue and revenue from new rural use cases]	Deployment and operation of full-fibre access network, including fibre and associated electronics, including customer premises equipment (CPE). A blend of new duct and rented existing infrastructure (ducts and poles) is included
Macrocell FWA			Deployment and operation of macrocell sites, including power and backhaul where required. A combination of existing sites (requiring upgrade) and new sites is assumed. Each premises has an external CPE
LOS FWA			Deployment and operation of a hybrid fibre-wireless network, whereby the final connection to the home is provided from a LOS access point (AP). Where fibre is used, costs for those segments are equivalent to the relevant portion of FTTP costs. Each premises has an external CPE
GEO satellites	Analysed on a per-subscriber basis	GBP40 per subscriber per month retail revenue[1] 80% of retail revenue is allocated to recover cost of modelled network	Deployment of a satellite CPE to each premises (e.g. a VSAT terminal), plus estimate of wholesale bandwidth costs of satellite connectivity
LEO satellites			Deployment of a satellite CPE to each premises (e.g. a phased array antenna), plus estimate of wholesale bandwidth costs of satellite connectivity
HAPS	HAPS not included in commercial analysis as no information on costs or throughput performance is currently available		

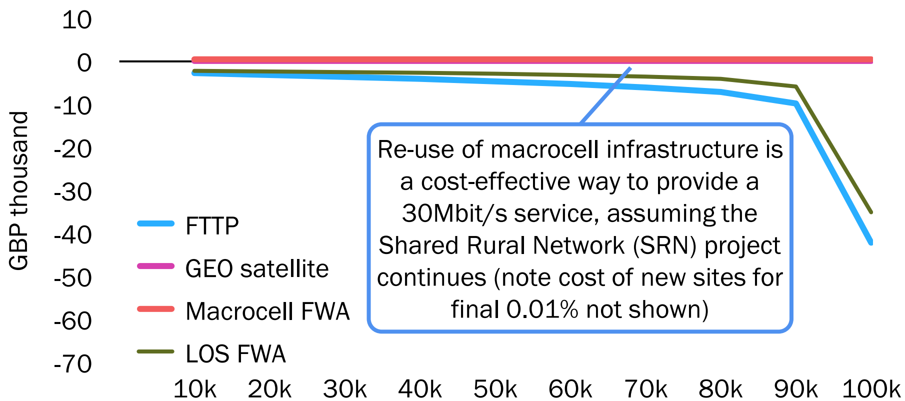
On the following slide, we present a summary comparison of the results of the commercial analysis:

- The results show the final cash position of the business case for each technology, at different points in the final 100 000 (as coverage is pushed further into the final 100 000, the costs for some technologies increase)
- A negative final cash position suggests that some form of subsidy may be required (which may be up-front subsidy and/or ongoing subsidy)
- Results are shown for both the 30Mbit/s and 300Mbit/s scenarios, but also for 10- and 20-year business cases

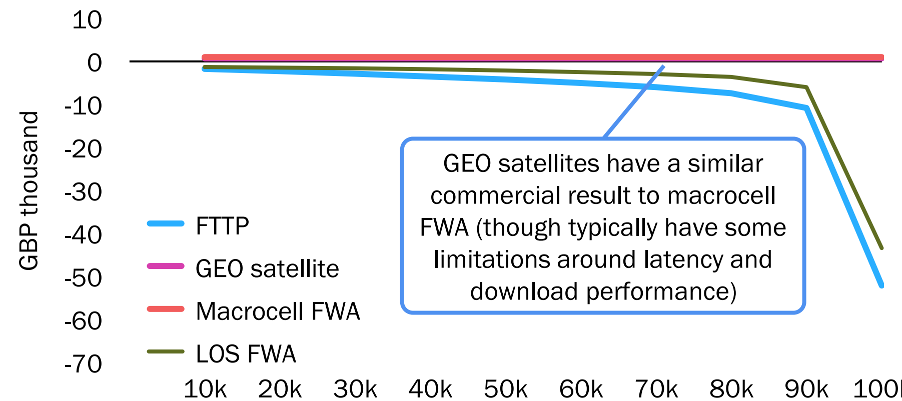
[1] We note that GBP40 is c.50% of the current retail offers for LEO satellites (e.g. Starlink), but have assumed the same revenue as other technologies to compare on a like-for-like basis | Source: Analysys Mason, public data

Overall, macrocell FWA looks the lowest cost option for 30Mbit/s, while at 300Mbit/s LOS FWA looks best up to a point, after which LEO satellite takes over

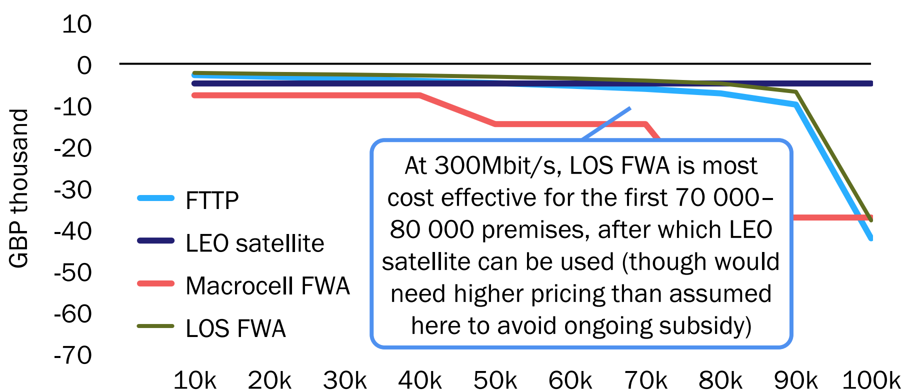
Final cash position per premises connected at 10 years, variation across the final 100 000 premises, 30Mbit/s case



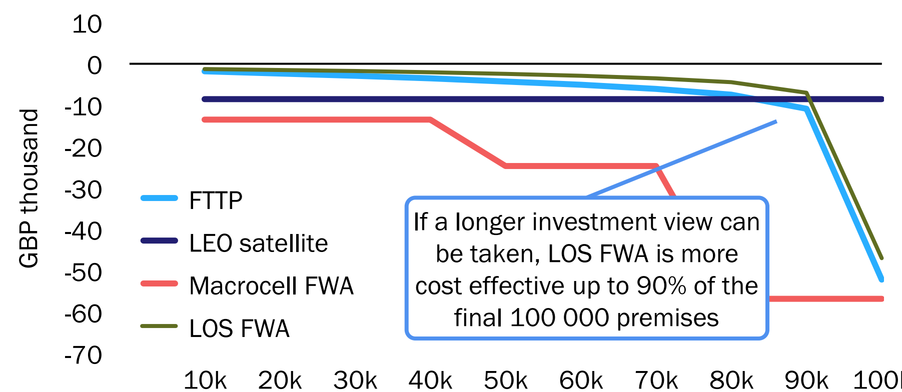
Final cash position per premises connected at 20 years, variation across the final 100 000 premises, 30Mbit/s case



Final cash position per premises connected at 10 years, variation across the final 100 000 premises, 300Mbit/s case



Final cash position per premises connected at 20 years, variation across the final 100 000 premises, 300Mbit/s case



Source: Analysys Mason

Due to the very remote nature of the final 100 000 premises, the pros and cons of each technology must be considered carefully when choosing the right solution

General conclusions

Tech	Comments
FTTP	▪ FTTP is the most futureproof of the technologies (easily capable of 1Gbit/s and beyond), but also the most expensive ▪ Due to the very long line lengths in the final 100 000, up-front costs are significant, but opex is also potentially higher than the available revenue ▪ Deployment in the final 100 000 may require both a large up-front subsidy and ongoing subsidy to make any project viable. ▪ Potential solutions could include reducing some of the barriers to deployment (increasing infrastructure re-use, lowering deployment costs through new techniques) and/or combining the final 100 000 premises with other more profitable locations
Macrocell FWA	▪ The applicability of macrocell FWA depends strongly on the level of speed to be delivered ▪ At 30Mbit/s, re-use of existing macrocells can provide a cost-effective and viable solution. However, this result assumes that the SRN project will continue (and that these sites are effectively paid for and can be used for FWA too), and does not consider the very most rural 0.1% of the UK, which the SRN would not reach and would require new ultra-rural sites ▪ At 300Mbit/s, the extra equipment and new sites make macrocell FWA unsuitable for reaching VHtRPs: the lower cell radius (required to provide higher speeds) and low premises density make this option the least viable in almost all areas including final 100 000 premises ▪ We note that macrocell FWA is likely to be able to play more of a role in other rural areas (e.g. less rural areas than final 100 000 areas)
LOS FWA	▪ Using a similar architecture to FTTP, but replacing part of the final connection with wireless, LOS FWA provides a more cost-effective alternative to FTTP when offering 300Mbits. According to our commercial analysis, LOS FWA is the most cost-effective solution for providing 300Mbit/s to 70–90% of the final 100 000 premises (depending on the investment timeframe) ▪ We note that should the requirement be pushed up to 1Gbit/s (which is not part of the scope of this study), the costs of FTTP and LOS FWA may become more similar
GEO satellites	▪ GEO satellites are established, commercially viable solutions for providing ultra-rural connectivity, and can be used today to provide a connection when no other is available ▪ However, the end-user experience has limitations, including limits on maximum speed, high latency and usage/download speed restrictions
LEO satellites	▪ LEO satellites appear to be the most cost-effective solution for providing 300Mbit/s to the final 10 000–30 000 of the final 100 000 premises ▪ However, the technology and commercial offers are still being developed (including the wholesale bandwidth costs, contention ratios, and whether users will face usage limitations over the medium term), and may require ongoing subsidy if users are not expected to pay twice as much as for other broadband technologies
HAPS	▪ HAPS is expected to reach commercial deployment during 2021–27, but no commercial data was available at the time of writing ▪ The technology remains an interesting option for covering ultra-rural areas, and its development should be carefully monitored

Source: Analysys Mason

The results of the study can be complemented by further technical, commercial and policy considerations

Potential areas of further technical and commercial considerations

- For FTTP, insights from ultra-rural pilots and surveys could be used to refine the line length distances, clustering of premises and proportion of existing infrastructure that can be re-used
- For macrocell FWA, detailed radio planning of the sites required to cover the final 100 000 premises could help to refine the number of sites required, for example by further exploring the trade-off between maximising cell areas and maximising data throughput (i.e. to provide fixed broadband levels of data throughput)
- For LOS FWA, similar radio planning analysis could help to refine both the number of access points needed, and the length of backhaul fibre needed
- For LEO satellites and HAPS, close attention should be paid to how these technologies develop

Recommended areas of policy analysis

- The procurement of potential solutions for the final 100 000 premises should be technology neutral
  - the analysis has shown that a mix of technologies may be required, and the final 10 000–30 000 could require a different broadband specification, given the very high costs
  - there may also need to be a review of State-aid restrictions (e.g. in the case of macrocell FWA, State-aid has typically only been applicable to networks providing broadband, but not mobile)
- The contracting model for providing subsidy for the final 100 000 premises must be carefully constructed:
  - network providers will require commitment from the subsidy provider to secure deployment resources across their supply chains
  - the contracting (and procurement/evaluation) must consider the right timeframe (which may need to be an extended period e.g. 20 years)
  - depending on the area of deployment and technology chosen, both up-front and ongoing subsidy may be needed
  - it may be possible to combine VHtRPs with other more commercially viable premises

Contents

analysys mason

We have provided an analysis of the broadband technologies structured across various technical characteristics and implementation factors

Components of the structure assessment of candidate technologies

	Assessment component	Description
Technical characteristics	Technology overview and technical characteristics	• Introduction to the basic architecture and function of the technology • Explanation of technical constraints and characteristics, e.g. spectrum availability, distance from nearest network node
	Coverage characteristics	• Factors affecting coverage of the technology (e.g. limits on line length, propagation distance, latitude coverage)
	Capacity characteristics	• Factors affecting the available capacity of the technology (e.g. wavelength capacity, spectrum bandwidth, contention ratios, upgrade pathways)
	Download speed performance	• Ability to deliver the required 30Mbit/s and 300Mbit/s speeds over 2021–2027
	Other performance characteristics	• Latency and upload speed performance • Availability (coverage and reliability) performance
Implementation issues	Business model	• Commercial models and delivery mechanisms e.g. multi-operator core network (MOCN) • Scope to combine VHtRPs with commercially viable premises • Scope for home-owner subsidy
	Commercial deployment drivers	• Deployment cost drivers (capex and opex) • Revenue potential (which may vary by technology) • End-user cost structure (e.g. up-front vs. ongoing costs)
	Barriers to deployment	• Summary of relevant barriers to deployment, including physical (line length, population density, terrain, foliage) and administrative (wayleaves, spectrum, other permissions)
	Maturity	• Assessment of current maturity, including ability to deliver required services over the 2021–2027 timeframe
	Case studies	• Relevant case studies of technology being deployed in rural areas

FTTP offers very high performance today, although it must be laid close to all premises (and with final connections made upon service take-up by user)

Analysis of technical characteristics for FTTP

Characteristic	Description
Technology overview and technical characteristics	▪ Fibre to the premises (FTTP) involves laying a fibre-optic connection between the end-user premises (whether residential or business) and the nearest fibre-enabled backhaul point (e.g. local telephone exchange or other fibre-enabled node) ▪ There are two main architectures for FTTP networks: – in a passive optical network (PON) architecture, optical splitters enable a single optical fibre from an exchange node to serve multiple subscribers (typically 32 or 64). This reduces the total amount of fibre-optic cable required in the network (since fewer fibres need to go to the backhaul node) – in a point-to-point (PTP) architecture, every premises has its own dedicated fibre-optic cable which goes all the way to the backhaul node. This provides more capacity for each household (since capacity is not being shared with other premises), but requires a greater overall amount of fibre to be installed ▪ Architecture choice: we assume that if FTTP is used to connect VHtRPs, a PON architecture will be used
Coverage characteristics	▪ ‘Coverage’ of an area is often achieved by laying fibre to a location near to each premises (e.g. running down a street), with the final connection to each premises made once take-up of the service is confirmed ▪ Consideration must be given to the amount of connection cost which is passed onto the consumer ▪ The nearest fibre-enabled node may be a previously completed FTTP deployment (e.g. in commercial or Project Gigabit-funded areas) or the local telephone exchange (though the most remote exchanges may not be fibre enabled).
Capacity characteristics	▪ Very high capacity (effectively only limited by the capability of terminating electronics once fibre installed)
Download speed performance	▪ End-user speeds: 100Mbit/s to 10Gbit/s are currently possible, with further upgrades on vendors’ roadmaps ▪ Performance assessment = high: both 30Mbit/s and 300Mbit/s service level are possible with current technologies
Other performance characteristics	▪ Upload speeds range between 10% and 20% of download speed to symmetric (same as upload speed) ▪ Latency typically <1ms

Source: Analysys Mason

FTTP’s very high up-front costs are offset by low opex, though there are barriers including infrastructure re-use and permissions

Analysis of implementation issues for FTTP

Characteristic	Description
Business model	▪ Both wholesale and vertically integrated business models are possible ▪ Given the likely need for public funding, a wholesale model is likely to be mandatory ▪ A typical investment timeframe for fibre is assumed to be 20 years
Commercial deployment drivers	▪ Very high up-front deployment cost, which is largely determined by the length of fibre required per premises (and therefore highly sensitive to population density: low density = higher cost) ▪ Other factors affecting the cost of deployment include: – underground or overhead deployment, and level of infrastructure re-use – cost and speed of deployment labour (i.e. cost per day, metres deployed per day) – planning and permission costs ▪ Once installed, ongoing (operating) costs are low
Barriers to deployment	▪ High up-front costs mean that re-use of existing infrastructure can create a barrier (e.g. if there is no infrastructure to be re-used) – use of utility infrastructure (e.g. utility ducts, overhead power lines) can help, though there are additional challenges around permissions, health and safety requirements, and additional costs not found in telecoms networks – infrastructure re-use may be generally lower than urban areas, e.g. too rocky to dig, too windy for poles ▪ Getting permissions from land owners (e.g. wayleaves) can create barriers, and in certain areas (such as national parks and forests, co-ordinating with local groups can create an additional barrier) ▪ Availability of deployment resources is a potential issue (i.e. in the context of widespread FTTP roll-out across the UK by multiple fibre providers) ▪ (Un)certainty over level of take-up can be a key barrier, requiring the use of demand stimulation and/or pre-commitment schemes
Maturity	▪ Maturity assessment = high; technology is mature and currently being widely deployed
Case studies	▪ The UK government lists six case studies of community-led FTTP roll-out projects in rural communities, funded via a mixture of public and private sources. The cost per premises passed included GBP1200 for a community of 100 premises three miles from an urban centre, and GBP2000 for a network of 14 premises five miles from a small town

Source: Analysys Mason, https://www.gov.uk/government/publications/community-led-broadband-schemes/case-studies

The characteristics of macrocell-based wireless networks are closely linked to the spectrum they use, both in terms of coverage and capacity

Analysis of technical characteristics for macrocell-based wireless

Characteristic	Description
Technology overview and technical characteristics	▪ In a traditional radio access network (RAN) architecture, there is a base station (BTS) on the tower/mast which performs signal processing, and connects to antennas at the top of the tower ▪ Different generations of mobile technologies (2G/3G/4G/5G) have introduced new logical and physical architectures, functionality and higher user speeds ▪ Licensed spectrum is typically used, and bands for public mobile networks have traditionally been in the 300–3000MHz (UHF) range, with 5G introducing higher-frequency bands (e.g. 3.5GHz, and 26–28GHz known as mmWave) ▪ Architecture choice: we assume that sites will use modern 2G/4G/5G equipment, with dynamic spectrum sharing for the 4G/5G bands
Coverage characteristics	▪ Wide-area coverage can be achieved using a combination of large towers (e.g. over 30m in height), high transmission power (typically between 4000W and 6000W per site) and low-frequency spectrum; in rural areas, cell radius can reach up to 10–15km, although 8–10km is more typical (depending on the terrain) ▪ For higher speeds (bandwidth), high-frequency spectrum is used, though this has a lower coverage radius
Capacity characteristics	▪ The total data throughput per site is determined by the number of sectors (usually three), amount of spectrum used and spectral efficiency, as well as antenna configuration ▪ Users are able to use part of the capacity on a site, shared with other users in that cell; as demand increases, additional sites may be required to provide enough capacity (though this is not expected to be necessary in ultra-rural areas)
Download speed performance	▪ End-user speeds vary between 1Mbit/s and 1000Mbit/s in a wide-area coverage rural site, depending on the amount and frequency of spectrum, location of the end user, and generation of technology (2G/3G/4G/5G) ▪ Performance assessment = medium: 30Mbit/s is expected to be possible with low-frequency, high-coverage cells; 300Mbit/s is currently possible, but requires advanced antenna (e.g. Massive MIMO) and higher frequency spectrum (e.g. 3.4–3.8GHz), the latter of which reduces cell size
Other performance characteristics	▪ Latency: 20–30ms for 4G, <10ms for 5G ▪ Upload speeds potentially quite variable, depending on spectrum use/allocation and cell position

Source: Analysys Mason

There is some uncertainty regarding the deployment of macrocells in ultra-rural areas, in terms of whether new sites are needed

Analysis of implementation issues for macrocell-based wireless

Characteristic	Description
Business model	▪ There are a large number of wholesale and sharing models (e.g. sharing of passive assets only, sharing of passive and active assets (MORAN), sharing of passive and active assets and spectrum (MOCN). MORAN sharing is established in the UK, and a move to a new business and spectrum usage model (e.g. MOCN) may not be justified for the relatively small number of premises under consideration. ▪ Operators are currently cautious about the use of OpenRAN (as equipment cost savings are potentially offset by higher integration costs), though the technology could certainly play a role in the future
Commercial deployment drivers	▪ The number of sites required (and therefore cost) is driven by the coverage and capacity characteristics of the network – For a given coverage area, higher capacity sites will require smaller cell sizes and therefore more sites ▪ Site capex for a large rural greenfield site (including foundations, power, fencing, active equipment plus installation) is much higher than a rooftop urban site with grid power ▪ The network equipment usually has a substantial power requirement; if the site is 'off-grid', alternative sources (typically diesel generators) must be used to enable sites to run 24x7, even when photovoltaic cells are deployed on site; power requirements increase with the data rate of the site
Barriers to deployment	▪ For rural sites, there may be (significantly) higher costs due to difficulty of installation of site and backhaul in challenging terrain; if off-grid, there are high costs for power (either requiring a generator or extension of grid power – UK MNOs generally require grid power) ▪ National parks, as protected areas, can be a barrier to deploying in rural areas. However, MNOs came to an agreement in 2018 with national parks to seek practical solutions to deploying in these areas
Maturity	▪ Maturity assessment = high; technology is mature and currently being widely deployed
Case studies	▪ The Shared Rural Network (SRN) is a GBP1 billion deal signed by all four UK mobile network operators (MNOs) (EE, O2, Three UK and Vodafone) with support from DCMS to boost 4G coverage in rural areas of the UK, with a view to achieving 95% mobile coverage of the UK's land mass – where some but not all MNOs have coverage, existing masts would be shared by all four MNOs at a cost to the MNOs – new masts would be built at the expense of the UK government in areas with no coverage

Source: Analysys Mason

Line-of-sight FWA solutions can provide gigabit speeds and are typically deployed in combination with fibre backhaul

Analysis of technical characteristics for short-range high-frequency wireless

Characteristic	Description
Technology overview and technical characteristics	▪ Short-range, high-frequency wireless uses unlicensed or lightly licensed spectrum for last-mile connectivity ▪ Technology standards include WiGig and other vendor-proprietary solutions (e.g. LTE-U from Ubiqiti) ▪ Typically deployed in combination with fibre, to provide backhaul from local access point ▪ Various frequencies are possible: – 5.8GHz is widely used by existing rural wireless operators – 60GHz equipment (e.g. Facebook's Terragraph) is expected to be commercially available in 2021 – other frequencies include 26GHz (mmWave) and 3.8–4.2GHz ▪ Access point equipment can be mounted on street furniture or the side of houses ▪ Line-of-sight (LOS) between access point and customer premises equipment is critical, and affects the addressable market from a particular access point location (e.g. issues caused by trees, buildings, landscape and other obstructions)
Coverage characteristics	▪ Lower frequencies (5.8GHz, 3.8–4.2GHz) can reach up to 10–20km depending on height and power of access point, and type of CPE, although ranges of 2–3km are more typical ▪ 60GHz has a typical range of up to 500m, but if prioritising gigabit-level services, 200–250m is a more realistic goal
Capacity characteristics	▪ 5.8GHz is capable of 100Mbit/s, though lower-speed services tend to be provisioned ▪ 60GHz is gigabit capable, subject to range (see above) ▪ There are constraints on concurrent users depending on the cost and capability of the access point (though in ultra-rural locations, constraints are mainly due to LOS and range, rather than capacity)
Download speed performance	▪ Performance assessment = high; 1Gbit/s at a range of 200–250m
Other performance characteristics	▪ Upload speeds are c.20% of download speeds (dictated by time-division allocation of bandwidth) ▪ Latency is <20ms ▪ Interference from radar has created service reliability issues with the 5.8GHz band ▪ Rain fade and other weather conditions (e.g. snow) can create service issues, depending on the band

Source: Analysys Mason, discussions with stakeholders

To date, LOS FWA has been deployed on a small scale, and LOS requirements create deployment uncertainty

Analysis of implementation issues for short-range high-frequency wireless

Characteristic	Description
Business model	▪ Typically deployed by small 'altnet' broadband providers in ultra-rural areas
Commercial deployment drivers	▪ The wireless components of networks can be deployed in a point-to-point, point-to-multipoint and mesh configuration – the mesh configuration can be useful for backhaul, if several premises can be meshed together ▪ Site installation/deployment can be completed very rapidly (e.g. less than a day) ▪ Short-range low-power wireless likely to be chosen when time to deployment is key, or where there is a ban on aerial fibre deployment ▪ LOS issues typically limit addressable market to 50% of homes within range ▪ There may be scope to refine the licensing approach for higher frequencies, to increase number of licences and reduce cost per licence
Barriers to deployment	▪ Significant LOS requirements: any buildings or foliage will disrupt signal propagation ▪ Some locations which would be suitable for an access point may not always be made easily available (e.g. water towers) ▪ Similar wayleave and permission issues to other technologies ▪ Access to local grid power can also be an issue
Maturity	▪ Maturity assessment – 30Mbit/s = high; established deployments of rural FWA around the UK (though typically on a small scale) – 300Mbit/s = medium; higher-frequency equipment (e.g. 60GHz) expected to be available by end 2021
Case studies	▪ Nokia unveiled a hybrid wireless PON solution in 2017, intended to eliminate the need to extend fibre all the way to a building, with speeds of up to 1Gbit/s and a range of up to 300m – however, Nokia is no longer pursuing this technology ▪ Terragraph (owned by Facebook) is a project intended to improve last-mile access using a 60GHz unlicensed wireless network from devices mounted on street furniture – Terragraph has achieved speeds of up to 1Gbit/s with link distances of up to 150m – commercial deployment has so far been limited to one development of c.106 homes in California

Source: Analysys Mason, CommsUpdate, Terragraph

Geostationary satellites provide connectivity to premises in virtually any location, though capacity is heavily shared and latency is high

Analysis of technical characteristics for GEO satellites

Characteristic	Description
Technology overview and technical characteristics	▪ For broadband, connectivity is provided directly to a very small aperture terminal (VSAT) which is mounted on the user's property and connected via coaxial cable to an internal modem ▪ Because the position of the geostationary orbit (GEO) satellite is fixed in the sky, the dish is static (i.e. does not need to track the satellite's location) ▪ Satellites are large (c.5 tonnes) with a long lifetime (c.15 years) ▪ High-throughput satellites (HTSs) and very high-throughput satellites (VHTSs) typically operate in the Ku (12–18GHz) and Ka (26–40GHz) bands; more spectrum is available in these bands than at the lower frequencies used by conventional GEO satellites (e.g. the C-band)
Coverage characteristics	▪ A single GEO satellite can 'see' over 40% of the Earth's surface. From the user's viewpoint, the satellite gets closer towards the horizon as the user moves away from the equator (and dips below the horizon at 81 degrees latitude, meaning that coverage of the poles is not possible) ▪ While conventional GEO satellites use a single broad beam to cover a wide area, HTSs re-use frequencies (similar to a conventional 2G mobile network) across separate spotbeams, each of which covers a different geographical area
Capacity characteristics	▪ Large capacity on each HTS (of order 100Gbit/s or even a few Tbit/s), though this is shared by many thousands of users ▪ Historically, usage allowances have been quite restrictive, and satellite internet service providers (ISPs) have often imposed traffic throttling policies (though the latest generation of HTSs may mean this practice is used less)
Download speed performance	▪ Performance assessment = low; end-user speeds c.20–100Mbit/s ▪ These speeds may improve to speeds of c.200Mbit/s with the development of very high throughput satellite (VHTS) technology (launches expected in the early 2020s)
Other performance characteristics	▪ Due to the satellite's altitude, there is high latency: total round-trip latency may be as high as 500–600ms, which is problematic for certain applications ▪ Upload speeds are typically low (c.5–10Mbit/s) ▪ Rain fade and other weather conditions (e.g. snow) can create service issues ▪ Retail offers typically include usage caps and/or reduced speeds during peak times, due to each satellite potentially serving a large number of users

Source: Analysys Mason, satellitetoday.com

GEO satellites can reliably reach almost any location, and have been the ‘default’ ultra-rural broadband solution for many years

Analysis of implementation issues for GEO satellites

Characteristic	Description
Business model	▪ Satellite operators are often wholesale only: they charge a certain rate (USD per Mbit/s per month) for capacity, which is often resold to end users via local ISPs and distributors
Commercial deployment drivers	▪ CPE costs per premises are high (requires a VSAT satellite dish, plus modem/router) ▪ High satellite build and launch costs are recovered via bandwidth charges made at the wholesale level (hundreds of USD per Mbit/s month is typical, with prices forecast to continue decreasing) – shared use by large numbers of concurrent users is typically managed with data caps and/or bandwidth throttling ▪ In a direct-to-home (DTH) model (i.e. individual connection for each household), population density has no effect: the cost of serving end users does not vary by location. ▪ High launch cost and capex for satellite (USD100–500 million per satellite, launch risk is covered by insurance, which contributes to the high cost)
Barriers to deployment	▪ LOS is required – steep hills or buildings may block signal ▪ Some latitude limitations (unlikely to be an issue for the UK)
Maturity	▪ Maturity assessment = high; technology is mature and currently being widely deployed
Case studies	▪ In January 2020, Eutelsat launched its Konnect broadband satellite, the first of a new generation of all-electric propulsion satellites, to complement its existing KA-SAT satellite and enable commercial broadband speeds of up to 75Mbit/s, an upgrade on previous speeds of 30–50Mbit/s

Source: Analysys Mason, Eutelsat

Low Earth orbit satellites provide lower latency and increased throughput compared to GEO systems

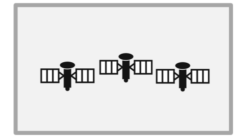
Analysis of technical characteristics for LEO satellites

Characteristic	Description
Technology overview and technical characteristics	▪ In contrast to GEO satellites, low Earth orbit (LEO) satellites sit at lower orbits and move position in relation to the surface of the Earth ▪ LEO satellites are small (e.g. 50–800kg or even smaller) with a short lifetime (c.5 years)[1] ▪ Compared to GEO, throughput is higher and latency is lower ▪ Satellites can be connected with laser intersatellite links (ISLs), which provide high throughput. ▪ CPE must track the moving LEO satellites (meaning a rooftop/outdoor position is required). There are two main technology options: (1) a mechanical system (parabolic dishes/radomes/motors, etc.) which physically moves to track the passing satellites; (2) electronically scanned array (ESA) antennas which can track multiple satellites simultaneously without physically moving
Coverage characteristics	▪ Full coverage of the Earth's surface (or a region of the Earth's surface) is possible provided there is a LEO constellation of sufficient size ▪ OneWeb expects to provide coverage everywhere above 50 degrees north by the end of 2021 and to have global coverage by mid-2022. Starlink expects to have "near-global coverage", but currently only covers northern latitudes
Capacity characteristics	▪ Greater spectrum reuse possible compared with GEO satellite, meaning the total system capacity is much greater (though much of this capacity is underused, e.g. over oceans) ▪ Mainly uses the Ku, Ka and potentially V bands (which are all subject to rain fade) ▪ Total OneWeb global capacity is 1.12Tbit/s, which it is planning to increase with a second generation of satellites and partnerships with space agencies
Download speed performance	▪ Performance assessment = medium; potential to download deliver 20–300Mbit/s or more broadband speeds to end users (with fixed CPE) worldwide – OneWeb has been able to achieve download speeds of up to 195Mbit/s – Starlink is hoping to offer download speeds of up to 300Mbit/s by the end of 2021
Other performance characteristics	▪ Latency is lower than for GEO, but quite variable at c.20–100ms ▪ Rain fade and other weather conditions (e.g. snow) can create service issues ▪ OneWeb has been able to achieve 30Mbit/s upload with latency of just under 50ms in speed tests ▪ Starlink's upload speed is currently 20Mbit/s

[1] Modern LEO satellites are expected to have short lifetimes, though previously launched constellations have lasted much longer

Source: Analysys Mason, press search

LEO satellites will be well suited to rural broadband services, once capacity, coverage and business models are fully developed



Analysis of implementation issues for LEO satellites

Characteristic	Description
Business model	▪ OneWeb plans to partner with local telcos to deliver a residential service to end-user premises ▪ Starlink is employing a direct-to-consumer model
Commercial deployment drivers	▪ As with GEO satellites, in a DTH model the cost of serving end users does not vary by location. ▪ Satellites are smaller than GEO, and therefore much reduced build/launch costs ▪ Because the satellites move relative to the Earth's surface, at any given time there are many satellites covering areas with no market (e.g. oceans) ▪ Cost of tracking antenna and ESA antenna currently relatively high (e.g. a few thousand USD); SpaceX has indicated that it intends to charge beta customers of its LEO broadband service USD499 for the ground terminal, tripod and router hardware (and USD99 per month for the service rental). OneWeb has indicated that CPE will cost c.USD800 ▪ Wholesale bandwidth costs and contention ratios are still being firmed up, and therefore whether users will face usage limitations over the medium term is still uncertain ▪ Licensing charging structure in the UK was designed for GEO satellites (which are few in number and large in capacity). This per-satellite charge becomes expensive for large numbers of LEO satellites
Barriers to deployment	▪ Large numbers of ground stations are required ▪ LOS requirements create potential to be significantly affected by trees during partial coverage phase
Maturity	▪ Maturity assessment = medium; beta services available, but capacity, coverage and business models are still being firmed up
Case studies	▪ Starlink (owned by SpaceX) is one of the main 'new' LEO players (following the failed initiatives of various players in the 1990s). – each Starlink satellite weighs approximately 260kg, has four array antennas that enable large amounts of throughput, a singular solar array, krypton-powered ion thrusters, and autonomous collision avoidance – Starlink has launched several hundred satellites and plans for a total constellation of over 4000 by 2024. Public beta tests began in October 2020 in the USA. Reports state that speeds of 50–150Mbit/s are expected in the tests, at a latency of 20–40ms, and services will be retailed at a cost of USD99.99/month.

Source: Analysys Mason, press search

High-altitude platform systems (HAPS) include providing connectivity from an unmanned aerial vehicle

Analysis of technical characteristics for HAPS

Characteristic	Description
Technology overview and technical characteristics	▪ HAPS technology involves an airborne vehicle providing connectivity from high in the Earth's atmosphere – this can be achieved from a solar-powered unmanned aerial vehicle (UAV), balloon or airship ▪ Altitude of the platform can vary from a few hundred metres to several kilometres ▪ A HAPS and its payload need to stay in approximately the same location relative to the ground to provide consistent coverage ▪ For example, the Airbus UAV HAPS takes nine hours to reach the stratosphere – once up there, the UAV can travel 1000 nautical miles a day – only three launch/recovery sites are needed across the world ▪ Several other HAPS platforms are also currently in development, including those from SPL, Avealto, Tao Tech and Sceye
Coverage characteristics	▪ Coverage radius of each HAPS is c.40–200km ▪ Actual deployment radius depends on network provisioning, contention ratios, etc.
Capacity characteristics	▪ Users share capacity on a HAPS ▪ Communication payloads are still being developed: probably hundreds of Mbit/s total throughput
Download speed performance	▪ The Airbus UAV (Zephyr) can currently offer 50Mbit/s speeds over a 30km radius; eventually as antenna and payload technology matures, this is expected to increase to 300Mbit/s
Other performance characteristics	▪ Latency is 10–30ms

Source: Analysys Mason

HAPS is still maturing as a commercial broadband solution, and is expected to become mainstream at some point in the next decade

Analysis of implementation issues for HAPS

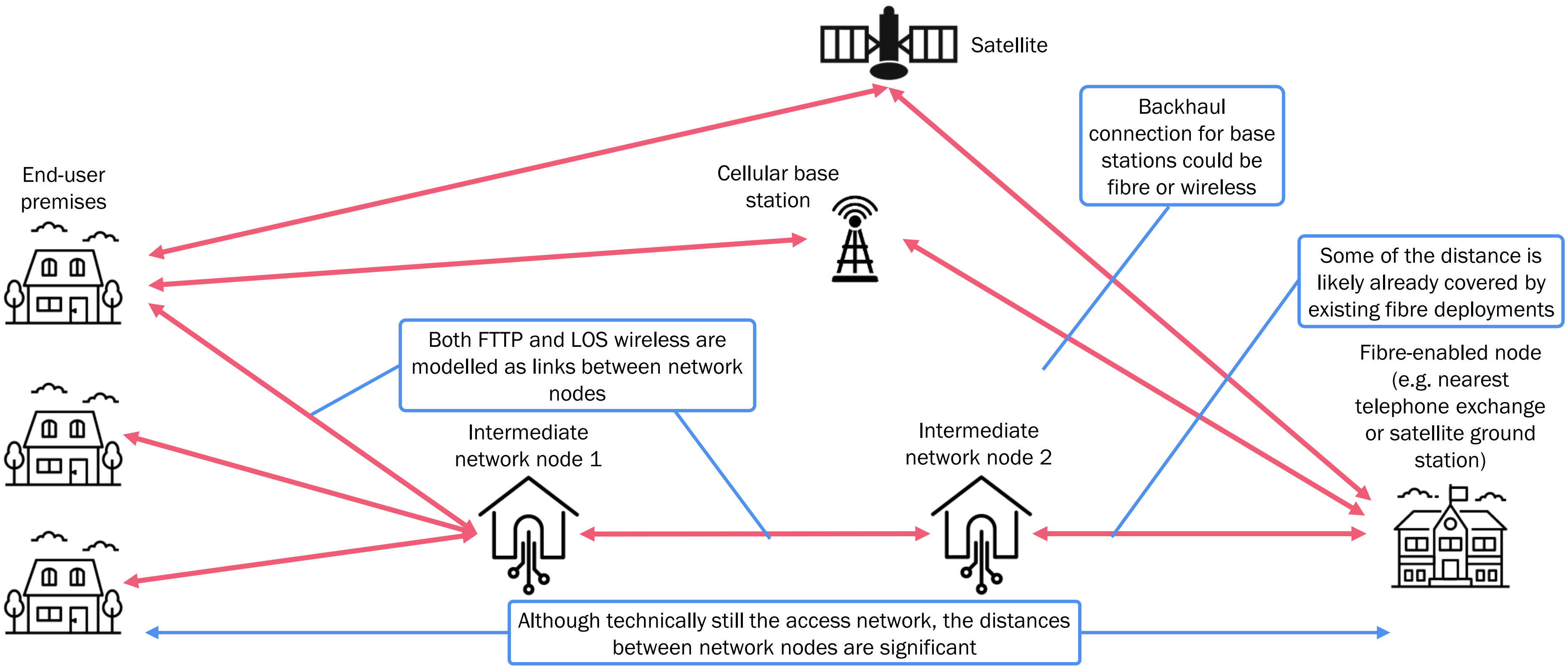
Characteristic	Description
Business model	▪ Three main target customers: military, institutional (e.g. emergency services/response) and rural connectivity ▪ Likely to go to market in collaboration with established terrestrial telecoms operators to provide DTH connections
Commercial deployment drivers	▪ HAPS technology is intended to target rural areas with currently unserved, sparse populations, as this is compatible with potential throughput ▪ Each HAPS costs less than a mobile site, but only has a limited lifespan (e.g. several months) – For example, the current max flight time of Airbus UAV is 26 days, though current battery technology could support 100 days, and long-term goal is to have one year between take-off and landing
Barriers to deployment	▪ Aviation regulation is a potential barrier: – how to classify the HAPS vehicle (aviation vs. space) – getting the HAPS up and down while avoiding commercial air traffic ▪ Some spectrum approvals for access and backhaul communications are still required ▪ Solar powered UAV-type HAPS can be constrained to certain latitudes. For example, the current operating range of the Airbus UAV is between +/- 40 deg of the equator (i.e. below the UK, constrained by the intensity of the sun to power the solar arrays)
Maturity	▪ Maturity assessment = low; target timeframe to become a mainstream solution within the next decade
Case studies	▪ Zephyr, developed by Airbus, is a solar-powered electric UAV able to be airborne for over 25 days at c.70 000ft. Coverage estimated to be 250 times that of a cell tower, with low latency ▪ Google's Loon project (a balloon-based HAPS) was closed in early 2021 due to commercial viability concerns ▪ Several other HAPS platforms are also currently in development, including those from SPL, Avealto, Tao Tech and Sceye

Source: Analysys Mason

Contents

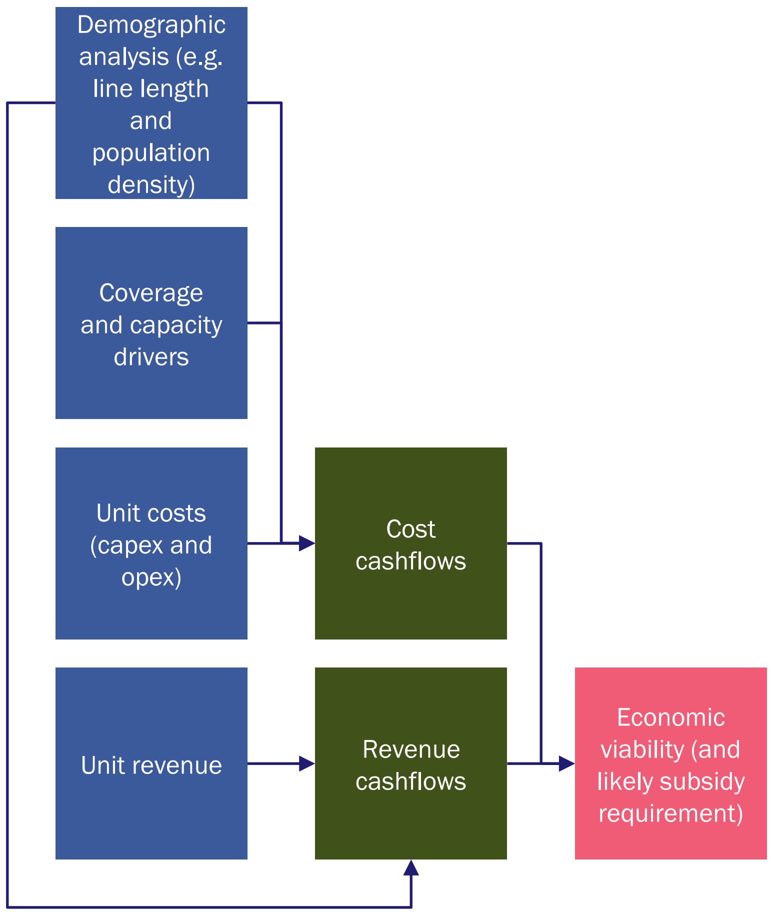
We have undertaken economic modelling of the candidate technologies, which connect to a fibre-enabled backhaul point

Overview of network scope included in the modelling



Our modelling breaks down the costs of each technology and compares this to the available revenue to assess economic viability

Overview of model components



Summary of key concepts in the modelling

Model component	Examples
Passing or coverage costs	• Installing fibre to the last network node before the premises • Deploying wireless base stations or access point nodes • [note: the high fixed cost of satellite launch is typically recovered through bandwidth costs – see below]
Per-subscriber costs	• Final-drop or final connection costs for fibre and point-to-point technologies • CPE costs, including modem/router and antenna (internal or external)
Bandwidth costs	• Charges related to bandwidth provisioned and data consumed
Revenue potential	• Revenue per subscriber for fixed voice and broadband services • Potential additional sources of revenue

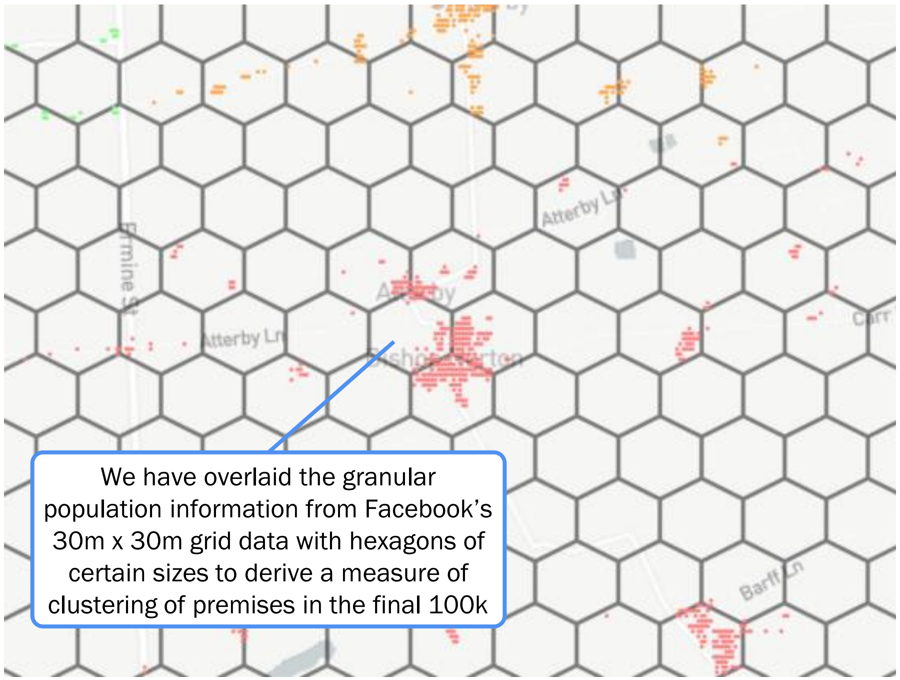
We use a range of network modelling techniques to estimate the cost of each technology:

- FTTP cost is based on a bottom-up estimate of line length
- Macrocell FWA is based on estimates of the number of new and existing sites
- LOS FWA is based on a combination of access point coverage and requirement for fibre backhaul
- Satellite is based on per-subscriber costs of premises equipment and wholesale bandwidth costs

Source: Analysys Mason

An important input to our network modelling is a new analysis of population clustering in ultra-rural areas

Illustration of 30m Facebook grid overlaid with 250m hexagons



- Fewer than 0.7 people per 30m by 30m grid square
- 0.7–0.8 people per 30m by 30m grid square
- More than 0.8 people per 30m by 30m grid square

We have created a distribution of the average number of premises in a certain radius for different increments of the final 100 000 premises. This is used to inform clustering assumptions for certain technologies (FTTP and LOS FWA)

Line length and population density at different granularity levels

Premises increment	Average distance from exchange	Average number of premises in a 250m radius	Average number of premises in a 500m radius	Average number of premises in a 1000m radius
0–10 000	4.82km	10.7	19.0	34.5
10 000–20 000	4.90km	12.8	21.7	36.5
20 000–30 000	4.99km	12.5	21.9	36.8
30 000–40 000	5.11km	10.4	19.9	32.7
40 000–50 000	5.26km	8.5	18.4	33.1
50 000–60 000	5.47km	6.4	13.6	28.4
60 000–70 000	5.76km	6.7	14.2	33.8
70 000–80 000	6.19km	5.9	13.5	27.7
80 000–90 000	7.06km	6.0	12.0	24.1
90 000–100 000	9.68km	2.2	5.0	7.0

Facebook's 30m square population data is available here: https://data.humdata.org/dataset/united-kingdom-high-resolution-population-density-maps-demographic-estimates

Our FTTP assumptions are based on recent market data, with a detailed breakdown of capex for various asset types

General assumptions for FTTP

	Assumption
Take-up	▪ 80% take-up rate, which is uniform across time and the final 100 000 premises
Revenue	▪ Retail revenue from voice and broadband services of GBP40 per month ▪ Assumed 50% of retail revenue is attributable to recovering the costs of the access network
Infrastructure types	▪ Overhead (pole) and underground (duct) deployment varies by segment of the access network ▪ Access network, excluding final drop: – 5% road – 25% footpath – 35% grass verge – 35% aerial ▪ Final drop – 25% footpath – 15% grass verge – 60% aerial
Infrastructure re-use	▪ Re-used infrastructure includes ducts and poles ▪ Up to the first access network node (e.g. cabinet), 100% re-use is assumed to proxy the beneficial effect of previous fibre deployments ▪ 70% infrastructure re-use is assumed in the remainder of the access network
Asset lifetime	▪ Active equipment, incl. CPE – 8 years ▪ Passive equipment – 25 years

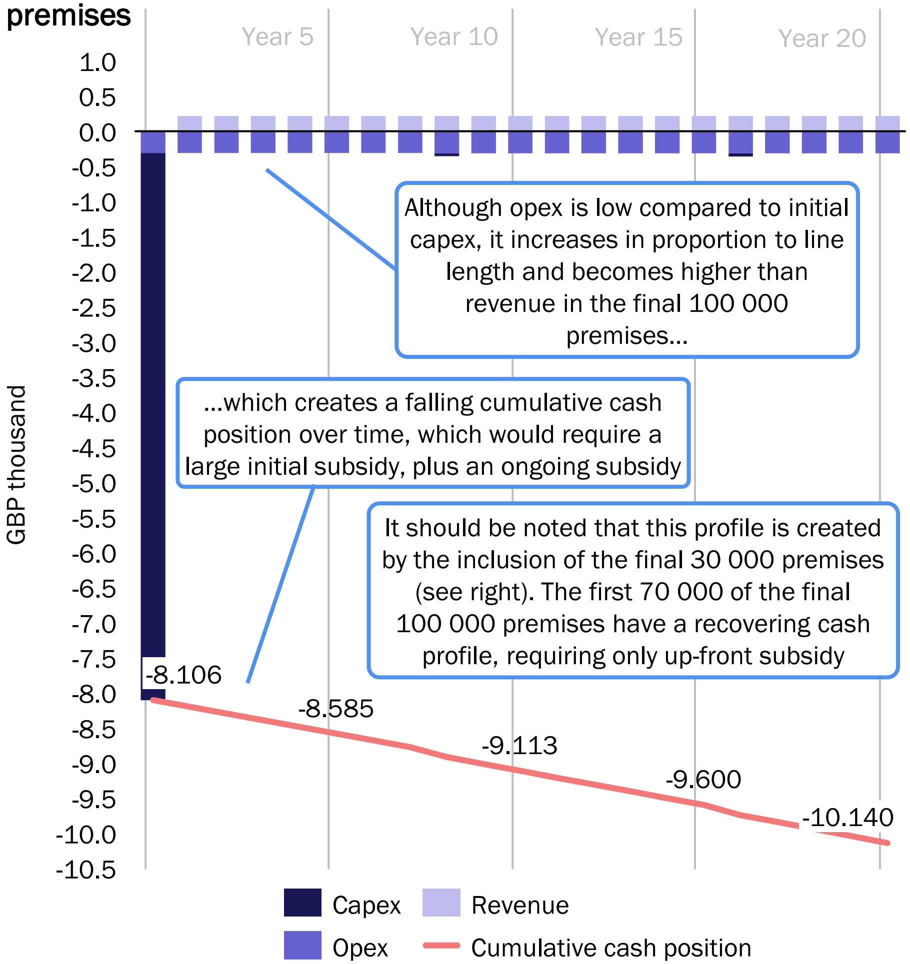
Detailed capex and opex assumptions

Assumption	Values used
Capex	
Optical Distribution Frame	▪ GBP1000 per ODF
PON Optical Line Terminal	▪ GBP57 600 per OLT
New duct deployment	▪ Road – GBP175 per metre ▪ Footpath – GBP98 per metre ▪ Grass verge – GBP48 per metre
Fibre cable	▪ 48 fibres – GBP3 per metre ▪ 8 fibres – GBP1.20 per metre ▪ 2 fibres – GBP1 per metre
Cable install	▪ Ducts – GBP11 per metre ▪ Aerial – GBP11 per metre
Splitters	▪ First splitter – GBP24 ▪ Second splitter – GBP24
Connection	▪ Fixed cost of GBP100 to connect to each premises
PON CPE	▪ GBP35 per household
Opex	
Opex	▪ Annual opex assumed to be 4% of initial capex ▪ Assumed to cover maintenance, power and rental of existing infrastructure (where it can be reused)

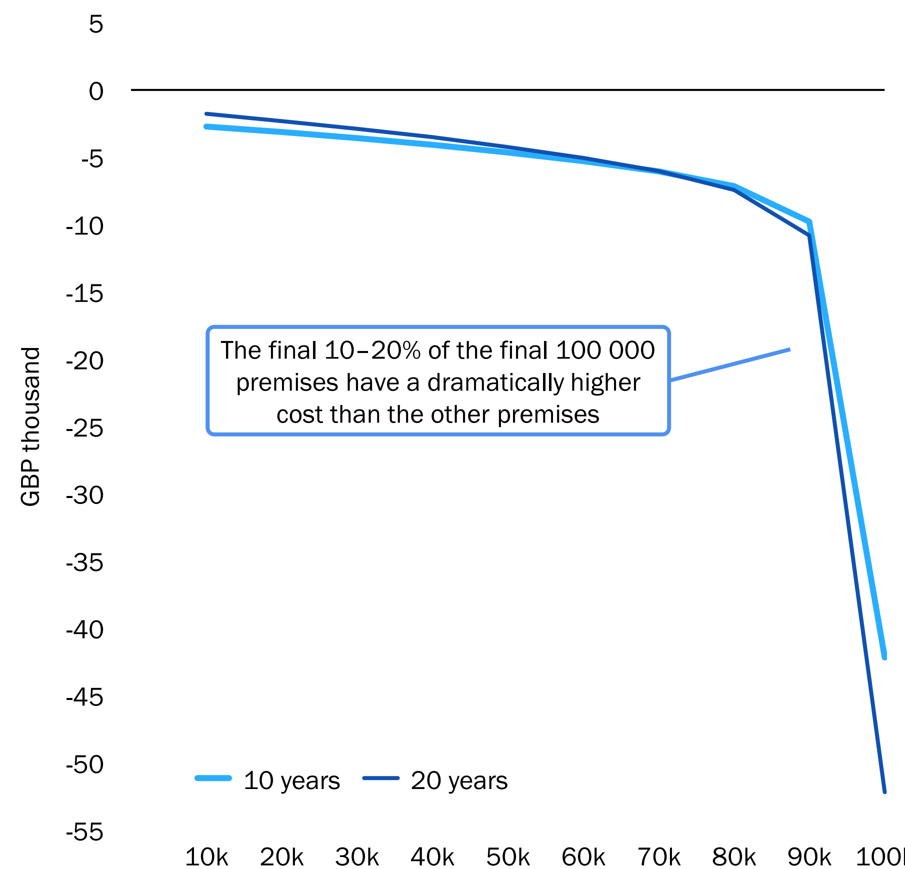
Source: Analysys Mason, public data

The high initial cost of fibre deployment is exacerbated by increasing line lengths, though required subsidy can be reduced with a long-term view

Cashflow per premises connected, average over final 100 000 premises



Final cash position per premises connected, variation across the final 100 000 premises

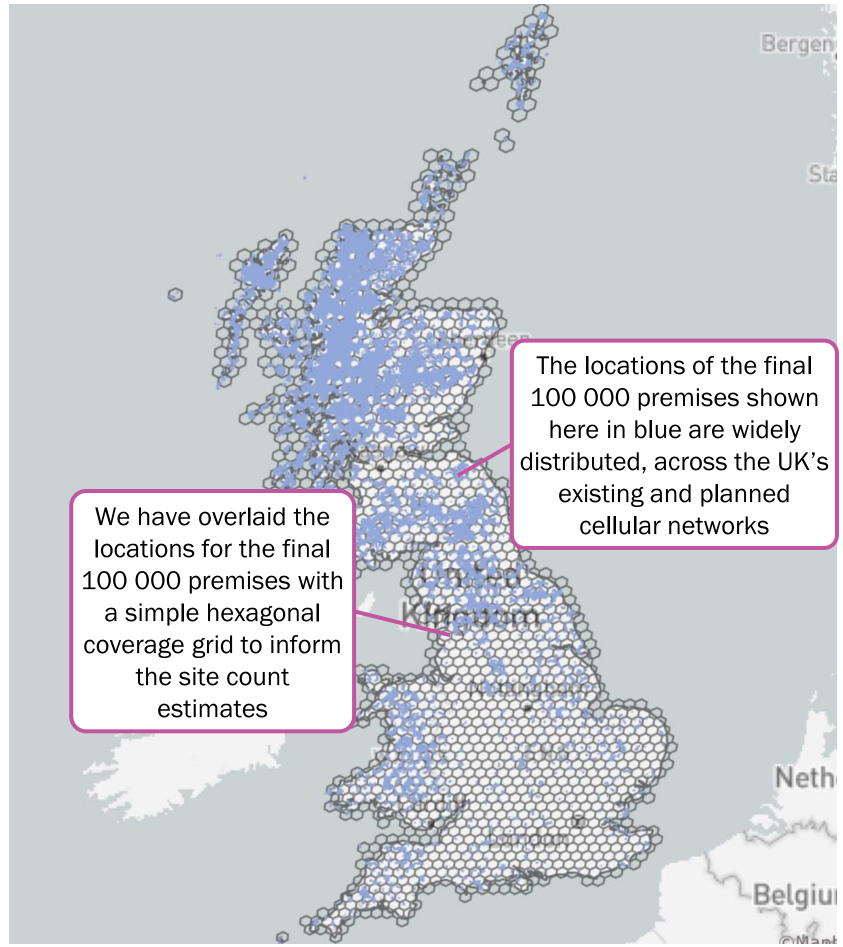


Source: Analysys Mason

The modelling of macrocell FWA requires an estimation of the number of sites, and how the final 100 000 premises are spread across those sites

- For macrocell FWA, we have modelled two network scenarios to deliver the two levels of end-user performance:
  - to deliver 30Mbit/s, we assume low-band spectrum can be used (i.e. 700/800/900MHz), which gives a cell coverage radius of 8km (assuming each end user has an externally mounted antenna)
  - to deliver 300Mbit/s, we assume high-band spectrum will need to be used (i.e. 3.4–3.8GHz and/or 3.8–4.2GHz), which gives a cell coverage radius of 5km (again assuming the end user has an externally mounted antenna)
  - we have assumed that the signal boost provided by an external antenna is used to support fixed broadband levels of data throughput, rather than maximising the range of each cell
- We have considered the number of required sites, and the distribution of the final 100 000 premises, in three zones:
  - area of pre-existing commercially deployed network coverage from MNOs (where existing sites can be upgraded, though some infill sites may be required)
  - area of SRN deployment in 'Total Not-Spots' to 95% of land area (we assume these sites will use already secured funding and can be treated as 'existing')[1]
  - final 5% of UK land area, beyond the SRN (this area will require new sites to be built)
- However, the final 100 000 premises are quite widely distributed (see right) requiring us to make assumptions on the split of sites and premises (see next slide)

Simple mapping of cell areas across the UK



[1] We note that the Emergency Services Network (ESN) could also provide a source of existing sites, though no data is available on the number of sites that could be re-used

Source: Analysys Mason

To model the number of sites required for cellular FWA, we have used a combination of geographical modelling, industry knowledge and estimates

Summary of methodology used to estimate site counts and location of final 100 000 premises

	Final 5% of UK land area, beyond the SRN	Area of SRN deployment in 'Total Not-Spots' to 95% of land area	Area of pre-existing commercially deployed network coverage from MNOs
Proportion of UK area	95.0% to 100.0%	65.0% to 95.0%	Up to 65.0%
Proportion of UK population	99.99% to 100.0% (i.e. final 0.01%)	99.0% to 99.99%	Up to 99.0%
30Mbit/s case, low-frequency spectrum, 8km cell radius			
Number of existing sites (requiring upgrade)	-	**500 sites**, based on Analysys Mason estimate of number of sites for SRN Total Not-Spots	**450 sites**, based on simple coverage mapping analysis, and wide distribution of final 100 000 premises
Number of new sites	**275 sites**, estimated from industry datapoint on total sites required for a 100% coverage SRN scenario	-	-
Allocation of final 100 000 premises	**3333 premises**, as final 5% of land area is final 0.01% of population (3.3% of the final 100 000 premises)	**50 862 premises**, allocated according to the split of required existing sites	**45 805 premises**, allocated according to the split of required existing sites
300Mbit/s case, high-frequency spectrum, 5km cell radius			
Number of existing sites (requiring upgrade)	-	**500 sites**, same as the 30Mbit/s case	**450 sites**, same as 30Mbit/s case
Number of new sites	**704 sites**, based on relative coverage of 5km and 8km sites, and sites required in the 30Mbit/s case	**780 sites**, based on relative coverage of 5km and 8km sites, sites required in the 30Mbit/s case and number of existing sites	**702 sites**, based on coverage of high-frequency site, area of the UK that includes 'final 100 000' premises, and number of existing sites
Allocation of final 100 000 premises	**3333 premises**, as final 5% of land area is final 0.01% of population (3.3% of the final 100 000 premises)	**50 862 premises**, allocated according to the split of required existing sites	**45 805 premises**, allocated according to the split of required existing sites

Source: Analysys Mason, public data, discussions with industry stakeholders

For revenue, we have included an uplift for mobile and new use cases, while our costs are based on detailed bottom-up assumptions

We have assumed multi-operator radio access network (MORAN) sharing on all macrocell FWA sites. We have modelled this by assuming:

- 50% of covered premises are addressable
- 100% of active equipment costs are allocated in the modelling
- 50% of passive infrastructure costs are allocated in the modelling

General assumptions for cellular FWA

	Assumption
Take-up	▪ 80% take-up rate, which is uniform across time and throughout the final 100 000 premises ▪ Assume 50% of this subscriber base included in the modelling, to represent MORAN sharing
Revenue	▪ Retail revenue from voice and broadband services of GBP40 per month (assumed 50% of retail revenue is attributable to recovering the costs of the access network) ▪ A further 30% revenue uplift is included to represent additional revenue from new and enhanced mobile subscriptions, and from new use cases (e.g. smart rural, smart automotive)
Sites required	▪ See previous slide
Split of premises by site type	▪ See previous slide
Asset lifetime	▪ Active equipment – 12 years ▪ CPE – 8 years ▪ Passive equipment – 25 years

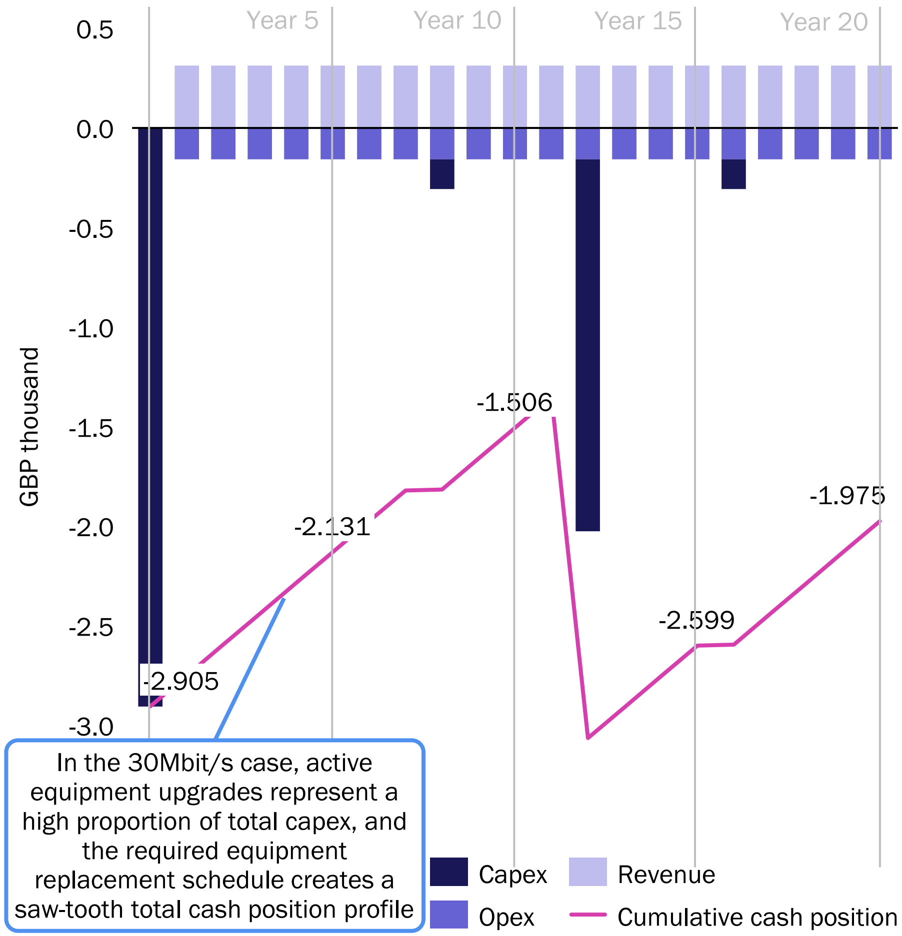
Detailed capex and opex assumptions

Assumption	Values used
Capex, 30Mbit/s case	
Active equipment	GBP61 000 – latest 2G/4G/5G (with DSS) equipment, on 700/800/900MHz, plus microwave (MW) backhaul upgrade
New infill sites	GBP86 000 (50% allocated) – standard infill tower
New ultra-rural site	GBP258 000 (50% allocated) – new ultra-rural site, plus electricity supply
CPE	GBP150 per premises (incl. installation)
Capex, 300Mbit/s case	
Active equipment	GBP70 000 – as per 30Mbit/s case, plus equipment for 3.4–3.8GHz or 3.8–4.2GHz (without MW backhaul; fibre backhaul included in passive costs)
Existing sites	GBP48 000 (50% allocated) – site strengthening to hold new high-band antenna, plus new fibre backhaul
New infill sites	GBP134 000 (50% allocated) – new infill site, plus strengthening, plus fibre backhaul
New ultra-rural site	GBP322 000 (50% allocated) – new ultra-rural site, plus strengthening, plus electricity supply, plus fibre backhaul
CPE	GBP150 per premises (incl. installation)
Opex	
Energy, 30Mbit/s	▪ GBP2700 per annum
Energy, 300Mbit/s	▪ GBP4900 per annum
Maint., 30Mbit/s	▪ GBP900 per annum
Maint., 300Mbit/s	▪ GBP2200 per annum
Ground rent	▪ GBP6800 per annum

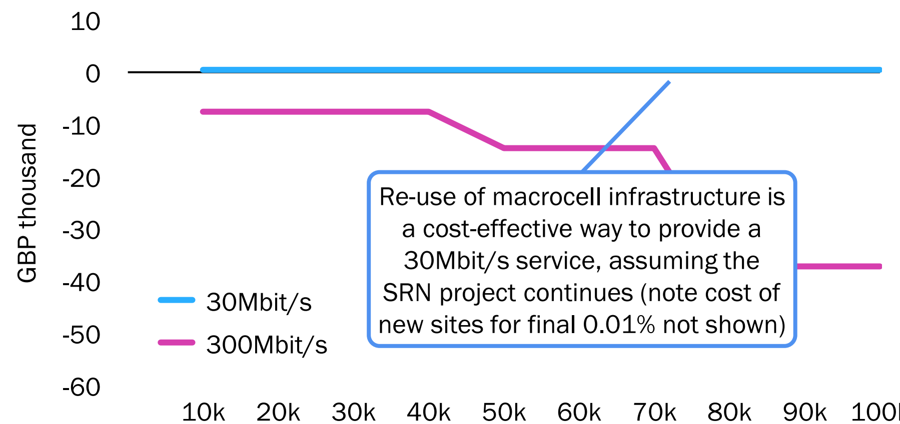
All active equipment capex figures are assumed to include hardware, software, installation and commissioning
Source: Analysys Mason

The 300Mbit/s case viability is strongly affected by whether existing or new sites are used, whilst for 30Mbit/s that trade-off is more marginal

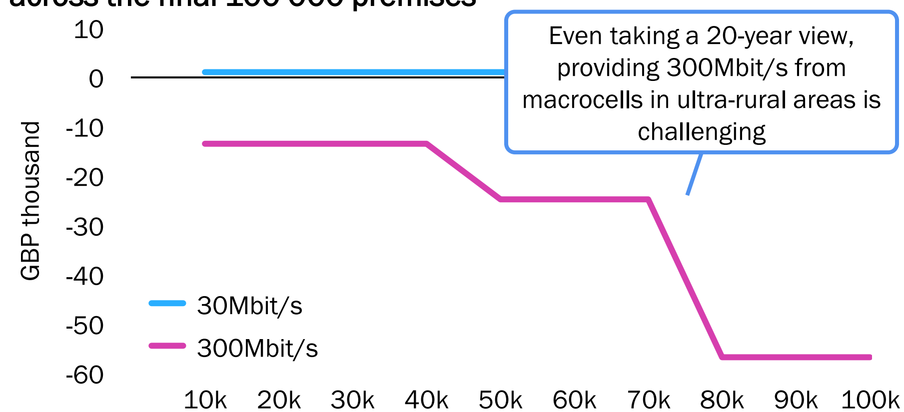
Cashflow per premises connected (average over final 100 000 premises, 30Mbit/s)



Final cash position per premises connected at 10 years, variation across the final 100 000 premises



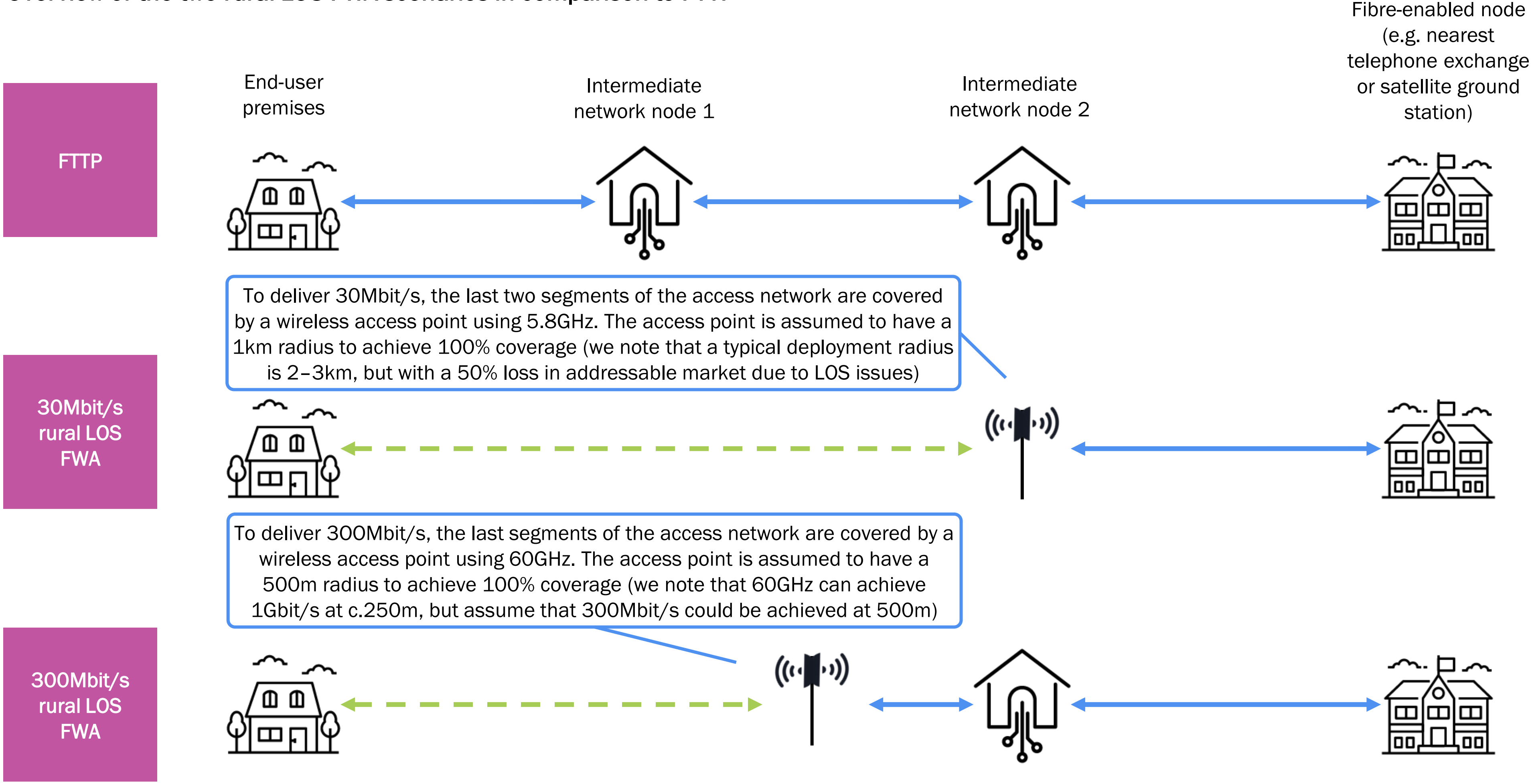
Final cash position per premises connected at 20 years, variation across the final 100 000 premises



Source: Analysys mason

For rural LOS FWA, we have modelled different network scenarios for 30Mbit/s and 300Mbit/s, which replace different portions of the FTTP network

Overview of the two rural LOS FWA scenarios in comparison to FTTP



We understand that some ultra-rural wireless operators are exploring the use of the 3.8GHz band. However, we consider that this band would have economics which are more similar to macrocell wireless technology option discussed previously.

The assumptions for LOS FWA are similar to FTTP (where applicable), plus the inclusion of the relevant access points and CPE

General assumptions for FTTP

	Assumption
Take-up	▪ 80% take-up rate, which is uniform across time and throughout the final 100 000 premises
Revenue	▪ Retail revenue from voice and broadband services of GBP40 per month ▪ Assumed 50% of retail revenue is attributable to recovering the costs of the access network
Fibre infrastructure types	▪ As per assumptions for FTTP (for the segments of the network that are used for LOS FWA)
Fibre infrastructure re-use	▪ As per FTTP (for the segments of the network that are used for LOS FWA)
Asset lifetime	▪ Active equipment, incl. CPE – 8 years ▪ Passive equipment – 25 years

Equipment costs for the 300Mbit/s case (based on 60GHz) are estimates, as commercially available equipment is still being developed (expected later in 2021)

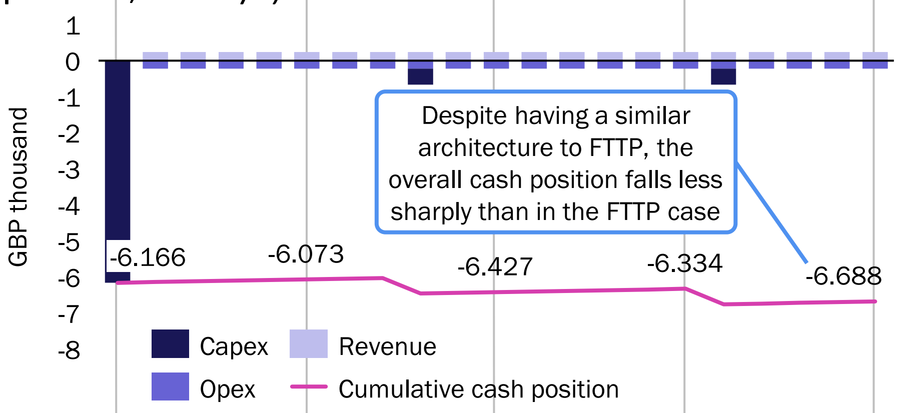
Detailed capex and opex assumptions

Assumption	Values used
Capex	
Fibre related	▪ As per assumptions for FTTP (for the segments of the network that are used for LOS FWA)
Access point, 30Mbit/s	▪ GBP1000 for 5.8GHz access point
Supporting inf., 30Mbit/s	▪ GBP9000 for medium-height pole, including power
CPE, 30Mbit/s	▪ GBP350 per premises, incl. installation
Access point, 300Mbit/s	▪ GBP500 for 60GHz access point
Supporting inf., 300Mbit/s	▪ GBP4500 for low height pole, including power
CPE, 300Mbit/s	▪ GBP200 per premises, incl. installation
Opex	
Fibre related	▪ Annual opex assumed to be 5% of initial capex ▪ Assumed to cover maintenance, power and rental of existing infrastructure (where it can be reused)
Access point	▪ Annual opex assumed to be 10% of initial capex
Passive infrastructure	▪ Annual opex assumed to be 1% of initial capex

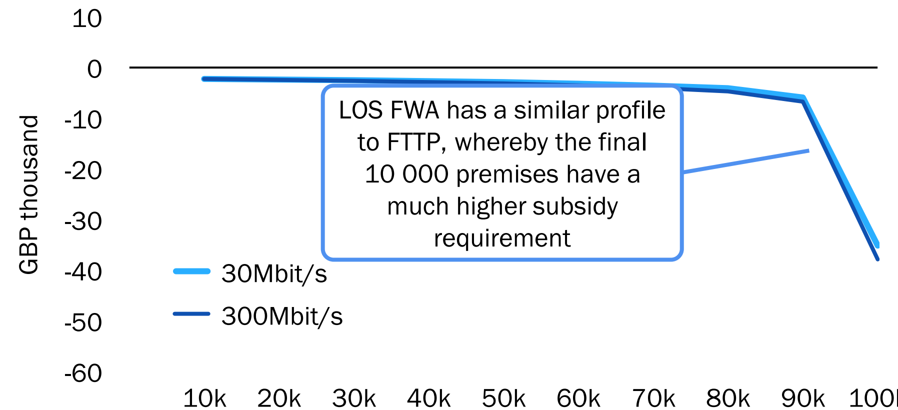
Source: Analysys Mason

Our modelling suggests that LOS FWA offers a cost saving over full fibre, as portions of the network are replaced with wireless

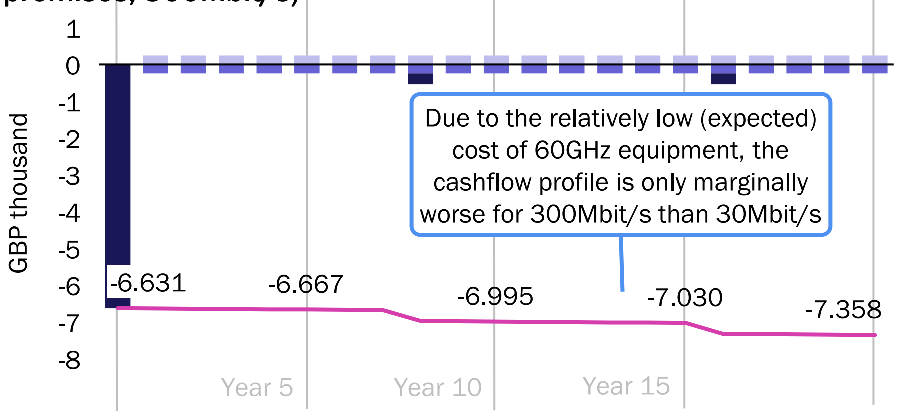
Cashflow per premises connected (average over final 100 000 premises, 30Mbit/s)



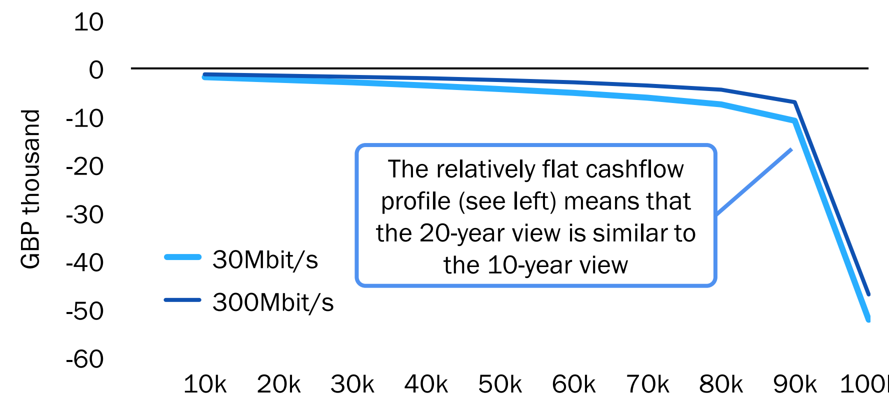
Final cash position per premises connected at 10 years, variation across the final 100 000 premises



Cashflow per premises connected (average over final 100 000 premises, 300Mbit/s)

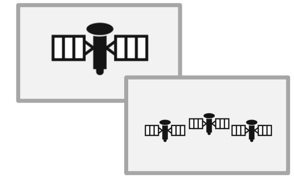


Final cash position per premises connected at 20 years, variation across the final 100 000 premises



Source: Analysys Mason

We have modelled the satellite technologies with simple assumptions, and assumed GEO can provide 30Mbit/s, whilst LEO can provide 300Mbit/s



Assumptions for GEO satellites (for 30Mbit/s)

	Assumption
Take-up	▪ 80% take-up rate, which is uniform across time and throughout the final 100 000 premises
Revenue	▪ Retail revenue from voice and broadband services of GBP40 per month ▪ Assumed 80% of retail revenue is attributable to recovering the costs of the access network (note this is higher than assumptions for terrestrial networks, as the satellite and ground station network effectively provide the access, backhaul and some of the core network)
Capex	▪ Capex is for CPE only: for VSAT antenna ▪ GBP500 per premises connected, incl. installation | 8-year replacement lifetime
Opex	▪ Opex covers wholesale bandwidth costs, which are assumed to cover satellite build and launch, plus ground station(s) ▪ GBP23 per premises per month, calibrated to create a reasonable return on simple cashflow business case (we assume that current GEO satellite services are profitable)

Assumptions for LEO satellites (for 300Mbit/s)

	Assumption
Take-up	▪ 80% take-up rate, which is uniform across time and throughout the final 100 000 premises
Revenue	▪ Retail revenue from voice and broadband services of GBP40 per month – we note that this is c.50% of current LEO retail pricing, but kept at GBP40 for fair comparison with other technologies (see note below) ▪ Assumed 80% of retail revenue is attributable to recovering the costs of the access network (as per GEO above)
Capex	▪ Capex is for CPE only: for phased array antenna ▪ GBP1000 per premises connected, incl. installation | 8-year replacement lifetime
Opex	▪ Opex covers wholesale bandwidth costs, which are assumed to cover satellite build and launch, plus ground station(s) ▪ GBP81 per premises per month, calibrated to create a reasonable return on simple alternative cashflow business case using the actual contributions from LEO retail customers (i.e. double the assumed ARPU, plus GBP500 contribution to CPE – see note below)

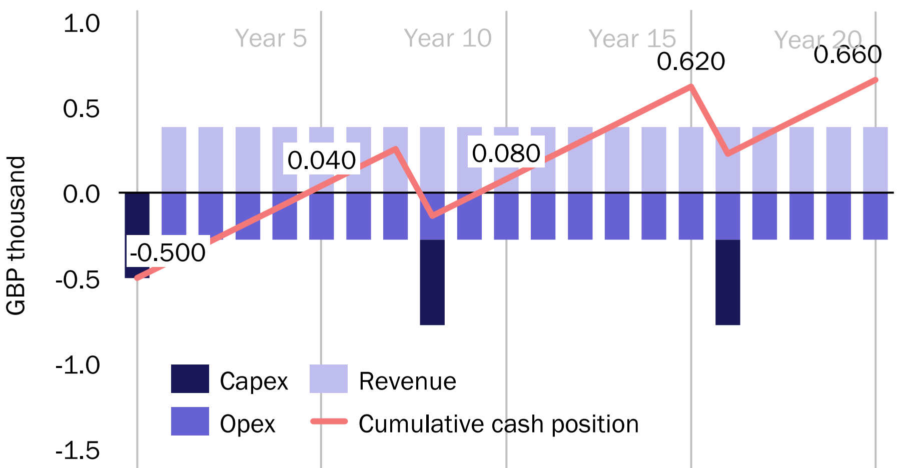
We have assumed that LEO satellites can create a commercially viable case based on the retail pricing currently available in the market: c.GBP80 per month subscription and c.GBP500 customer contribution to CPE.[1] We use these inputs to back-calculate an estimate of the network costs. However, to compare LEO on a like-for-like basis, we have kept the network costs the same, but then reduced the revenue assumptions to GBP40 per subscription and no contribution to CPE

[1] Assumptions on current LEO retail pricing based on Starlink

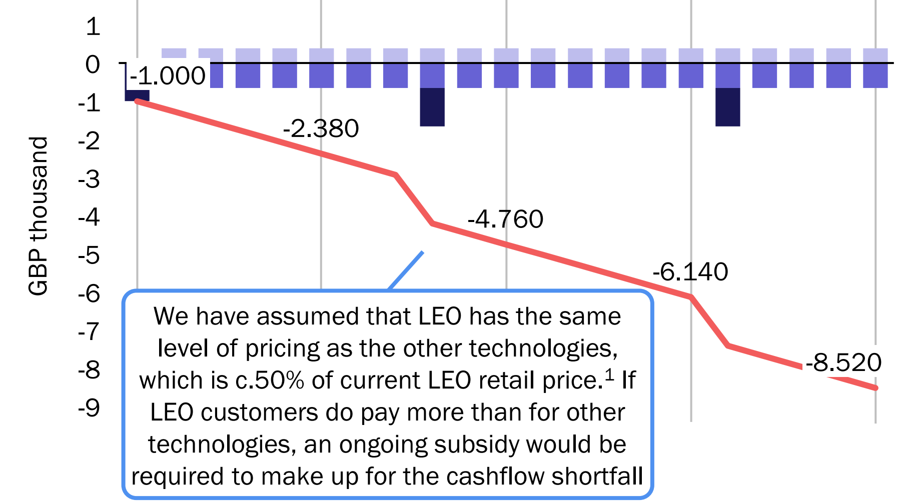
Source: Analysys Mason, public information

GEO satellite can provide 30Mbit/s on a commercial basis, while LEO can provide 300Mbit/s but needs higher pricing than the other technologies

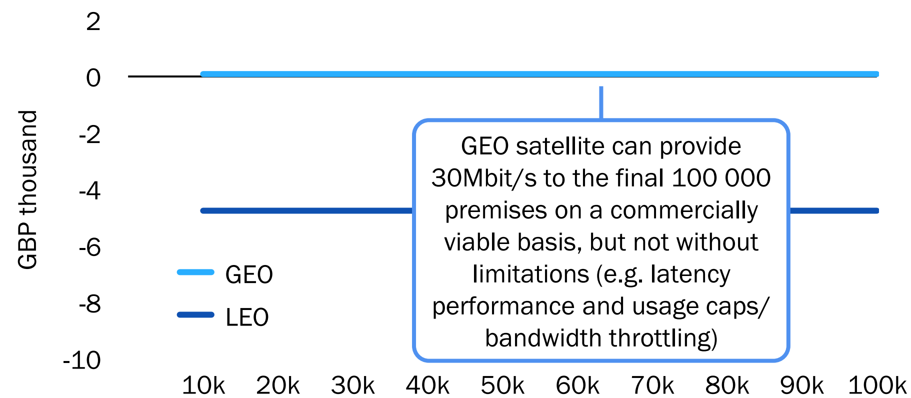
Cashflow per premises connected over time (GEO satellite)



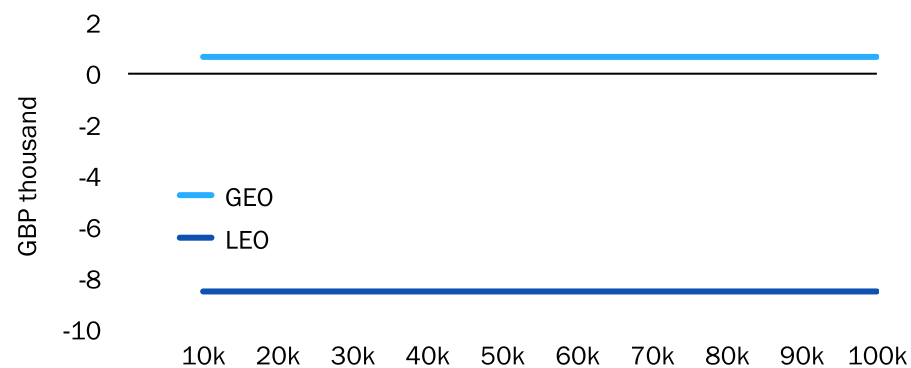
Cashflow per premises connected over time (LEO satellite)



Final cash position per premises connected at 10 years, variation across the final 100 000 premises



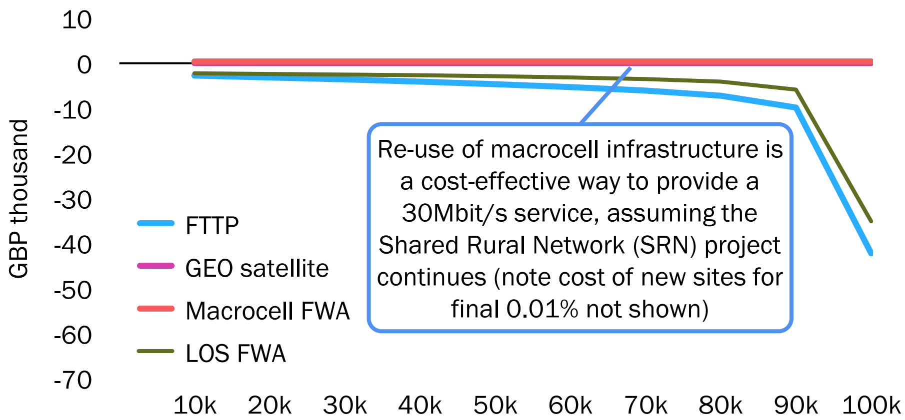
Final cash position per premises connected at 20 years, variation across the final 100 000 premises



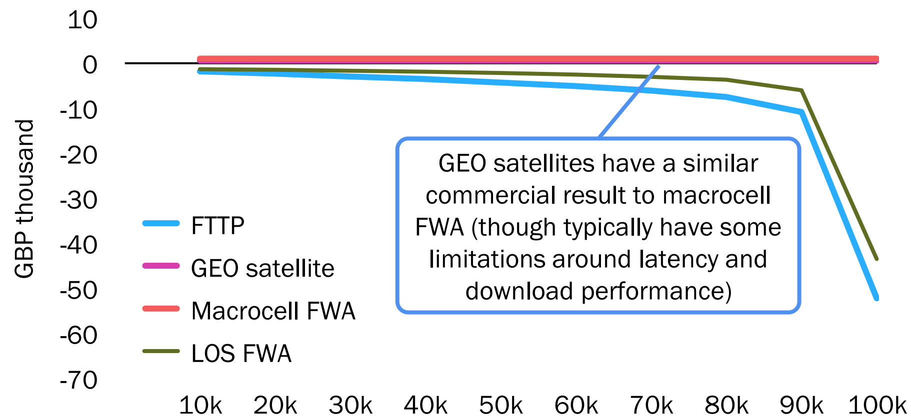
[1] Assumptions on current LEO retail pricing based on Starlink | Source: Analysys Mason

Overall, macrocell FWA looks the lowest cost option for 30Mbit/s, while at 300Mbit/s LOS FWA looks best up to a point, after which LEO satellite takes over

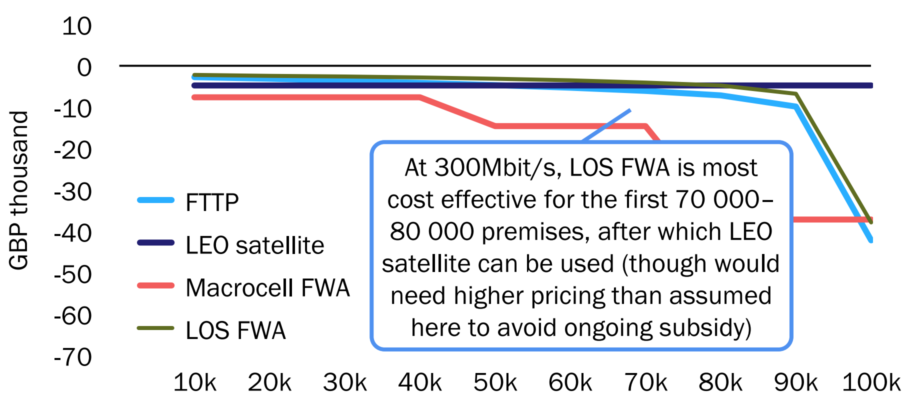
Final cash position per premises connected at 10 years, variation across the final 100 000 premises, 30Mbit/s case



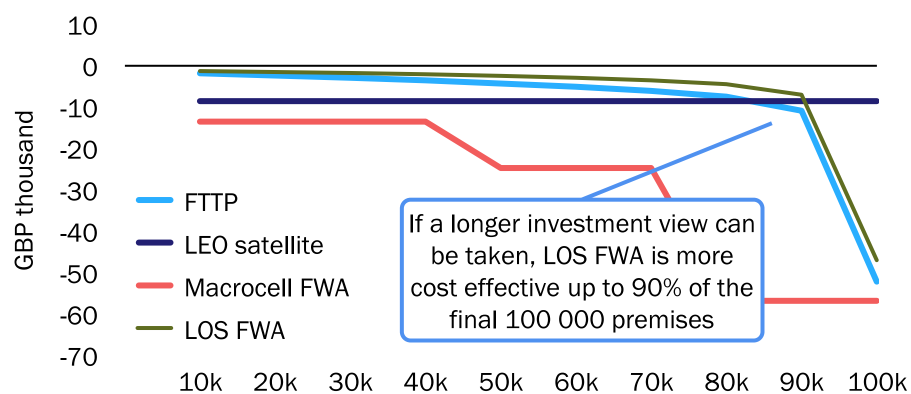
Final cash position per premises connected at 20 years, variation across the final 100 000 premises, 30Mbit/s case



Final cash position per premises connected at 10 years, variation across the final 100 000 premises, 300Mbit/s case



Final cash position per premises connected at 20 years, variation across the final 100 000 premises, 300Mbit/s case



Source: Analysys Mason

Copyright notice

Contact details

Matt Yardley

Partner

matt.yardley@analysysmason.com

Andrew Daly

Principal

andrew.daly@analysysmason.com

Bonn
Tel: +49 176 1154 2109
bonn@analysysmason.com

Cambridge
Tel: +44 (0)1223 460600
cambridge@analysysmason.com

Dubai
Tel: +971 (0)4 446 7473
dubai@analysysmason.com

Dublin
Tel: +353 (0)1 602 4755
dublin@analysysmason.com

Hong Kong
+852 9313 7552
hongkong@analysysmason.com

Kolkata
Tel: +91 33 4084 5700
kolkata@analysysmason.com

London
Tel: +44 (0)20 7395 9000
london@analysysmason.com

Lund
Tel: +46 73 614 15 97
lund@analysysmason.com

Madrid
Tel: +34 91 399 5016
madrid@analysysmason.com

Manchester
Tel: +44 (0)161 877 7808
manchester@analysysmason.com

Milan
Tel: +39 02 76 31 88 34
milan@analysysmason.com

New Delhi
Tel: +91 124 4501860
newdelhi@analysysmason.com

New York
Tel: +1 212 944 5100
newyork@analysysmason.com

Oslo
Tel: +47 920 49 000
oslo@analysysmason.com

Paris
Tel: +33 (0)1 72 71 96 96
paris@analysysmason.com

Singapore
Tel: +65 6493 6038
singapore@analysysmason.com

Stockholm
Tel: +46 8 587 120 00
stockholm@analysysmason.com

@AnalysysMason   linkedin.com/company/analysys-mason   youtube.com/AnalysysMason   analysysmason.com/RSS