ovum

HFC: Delivering Gigabit Broadband

Cable broadband in the Gigabit era

July 22nd 2016

Contents

Summary

Ovum was engaged by **nbn™** (**nbn**) to provide an overview of HFC evolution, the market environment and technology enhancements.

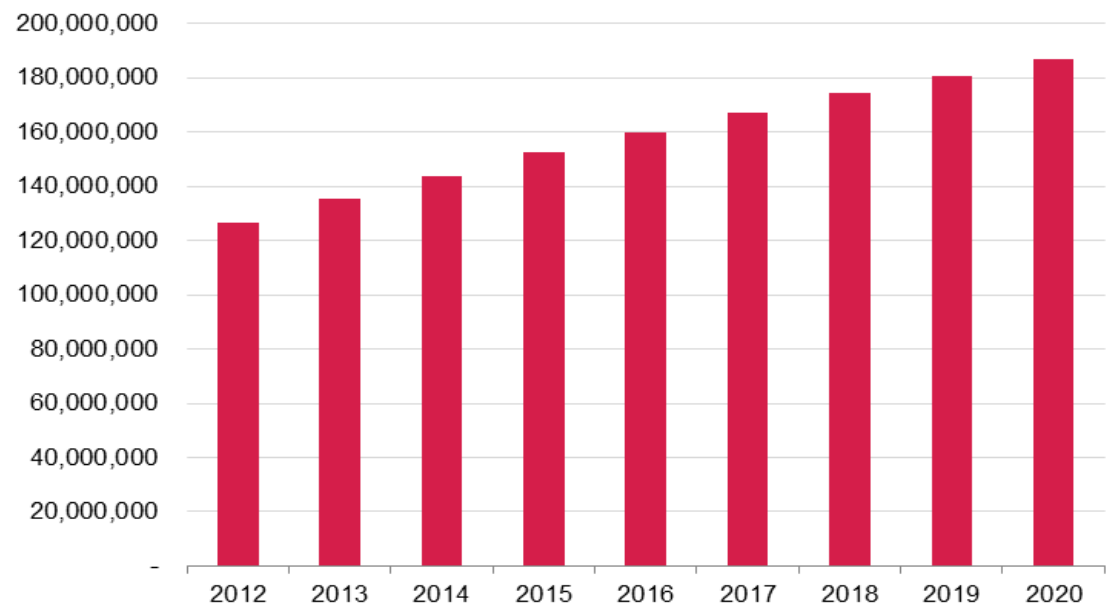
On 30 June 2016 **nbn** launched its first commercial Hybrid Fibre Coaxial (HFC) service to its Retail Service Providers. The 18,800 premises made ready for service in Redcliffe, Queensland, represent the first step to delivering nbn HFC access to a footprint of more than 3 million premises nationally.

HFC is a key component of **nbn**'s multi technology mix strategy, aiming to enable every home, business and community across Australia to receive high-speed broadband, while leveraging existing infrastructure and managing rollout costs in order to complete the project faster and more cost effectively.

HFC, or cable broadband, will play a key role in meeting the future broadband needs of subscribers around the world. Cable broadband subscribers continue to grow, with forecast growth of 4% per year for the remainder of the decade – this is in line with the growth in the global broadband market.

Worldwide cable broadband subscribers will increase from 152 million to 187 million over 2015 – 2020 - a 23% increase. This growth continues even as telecommunication carriers invest considerable sums in FTTB/P deployments. This shows that HFC will still have a substantial role to play in high-speed broadband markets.

Worldwide Cable Broadband Subscribers



Source: Ovum: Fixed Broadband Subscription Forecasts 2015-2020

Many international cable broadband operators already offer speeds of 100Mbps and above, and these operators are actively pursuing upgrade paths to enable gigabit speeds. Recent comments from Rogers, the leading cable operator in Canada, highlight not only the imminent move to gigabit speeds, but also the modest costs involved.

> *"Through our advanced, hybrid fibre-coaxial network, we expect to be able to offer consumers across our entire DOCSIS 3.0/3.1 footprint Internet download speeds up to 1 Gbps by the end of 2016. We will be able to upgrade our entire footprint of over four million homes with Gigabit Internet at an incremental in-year capital cost of less than C$50 per home."* (2015 Annual Report)

The strength of HFC is not only the current performance, but the opportunity to continue to leverage existing infrastructure to provide faster speeds without the high costs of a full FTTP build. Avoiding the need for new builds gives HFC operators, like **nbn**, the advantage of bringing high speed services to market quickly, while keeping capital investment low.

This is particularly true for dense urban environments. HFC networks have typically been deployed in urban and heavily populated suburban areas where operators looking to over-building with a FTTP network face complicated civil works that are extremely expensive and time-consuming.

A lot more speed ahead

The future evolution of cable broadband standards will allow operators to further enhance their gigabit services. The cable industry is addressing the need for improved upstream speeds and the requirement for symmetric services with the development of Full Duplex DOCSIS. Initial DOCSIS 3.1 performance targets are for plant capacity of 10Gbps, allowing speeds of 1Gbps to be offered to end-users. This will rival existing FTTP XG-PON services which provide upstream and downstream capacities of 10Gbps and 2.5Gbps.

Many cable operators globally have commenced, announced or are evaluating the upgrade of their network to the latest standard, DOCSIS 3.1. The drivers of these upgrades include

- Increasing end-user demand for capacity driven by use of video services and multiple devices in the home
- Competitive responses to rollouts of FTTx services, with the need to offer gigabit services
- Efficiency improvements, with a focus on reducing power and space requirements

For operators, the roadmap for further enhancements permits confidence that they will be able to continue to compete with investments in fibre (FTTP, FTTB and FTTN).

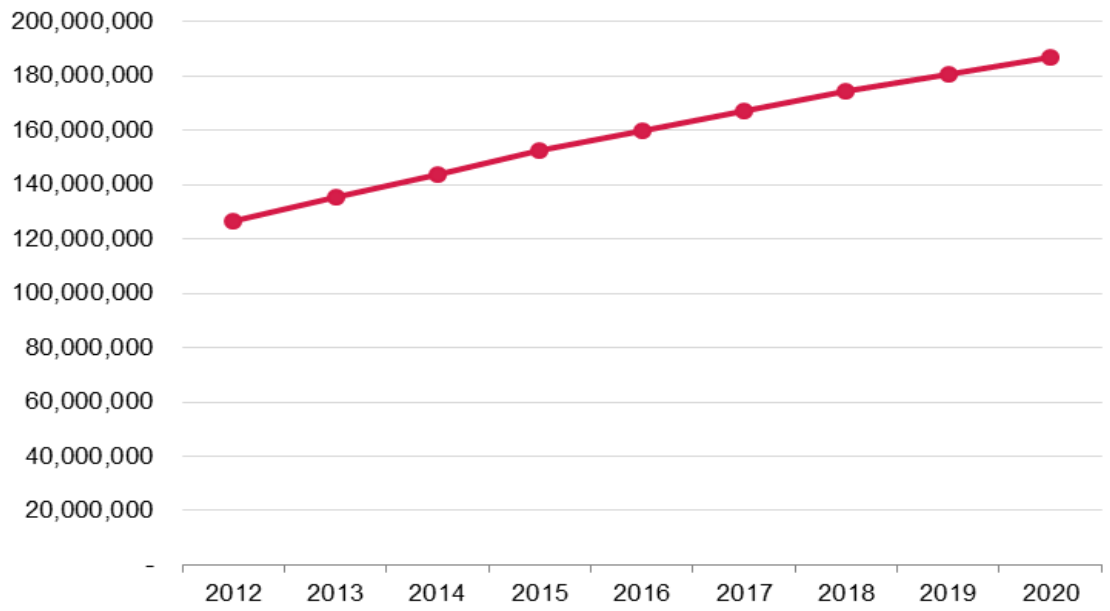
This report reviews the history of cable services, illustrating the decades of innovation, overviewing current broadband specifications and capabilities, and outlining future enhancements. Case studies review the status of leading HFC operators in Europe and North America.

These case studies illustrate how market leading services on HFC are being used to provide superior product performance and deliver revenue growth in an environment where traditional pay-tv services are facing OTT and cord-trimming headwinds.

The State of the Market

In 2015 HFC held a 19% share of the global fixed broadband market, as calculated by Ovum's *World Broadband Information Service*. In the four years to 2020 the number of cable broadband subscribers is expected to grow from 152 million to 187 million, at an average of 4% per year, with global share expected to remain stable through to the end of the decade.

Chart 1: Worldwide Cable Broadband Subscribers



Source: Ovum: Fixed Broadband Subscription Forecasts 2015-2020

Globally the trend to FTTH/B services will see a migration from DSL to fibre platforms, with other technologies, including fixed wireless solutions, modestly gaining share.

Existing and future market share varies greatly by region and country depending on the current market share, network coverage, and scope for market growth.

HFC tends to be common in more developed countries where there is less scope to drive growth through network extension. As illustrated in Table 1, few markets have universal HFC coverage reflecting the economics of the original deployments for the delivery of pay-tv services.

Table 1: Country HFC Rollouts and Broadband Share

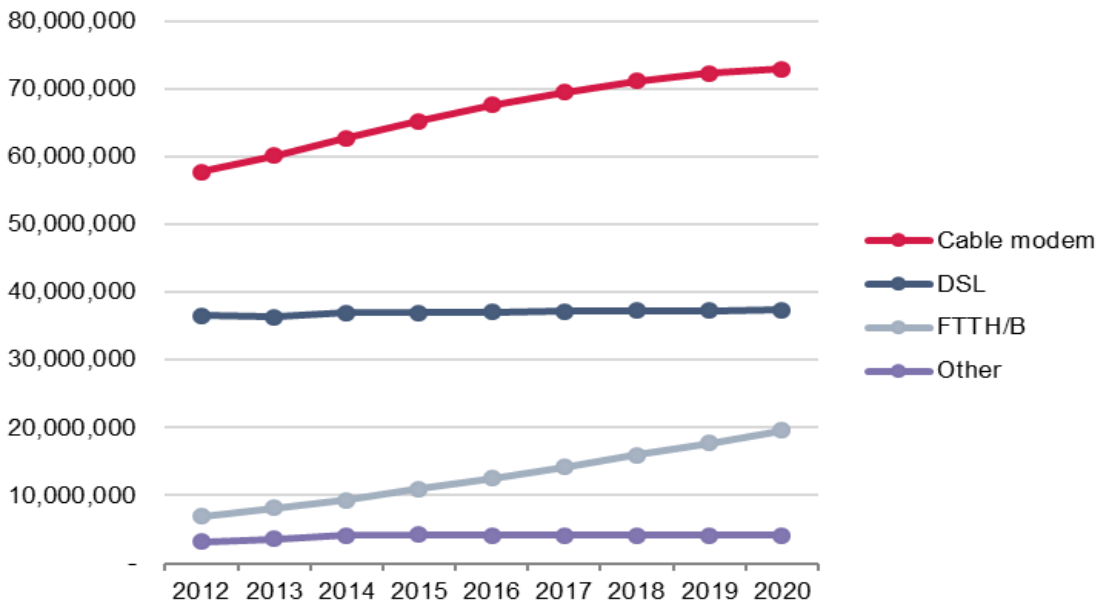
Country	Coverage	Broadband penetration	HFC Share
USA	89%	75%	59%
United Kingdom	44%	85%	19%
Canada	82%	82%	49%
Ireland	42%	79%	29%
Norway	50%	85%	30%
Denmark	63%	93%	29%
Sweden	39%	71%	20%
Germany	62%	76%	21%
Australia	29%	73%	15%
Singapore	100%	118%	26%
Belgium	96%	89%	50%
Spain	48%	87%	18%

Source: Ovum

North America

Cable broadband is the dominant platform in North America reflecting the broad coverage of network and the high penetration of pay-tv services. Cable broadband has secured a 56% share of the North American market and is expected to only cede a small loss (2%) of share by 2020. During this period cable is expected to secure 47% of market growth, only slightly behind FTTH/B with 52%.

Chart 2: North America – Fixed Broadband Subscription by Technology

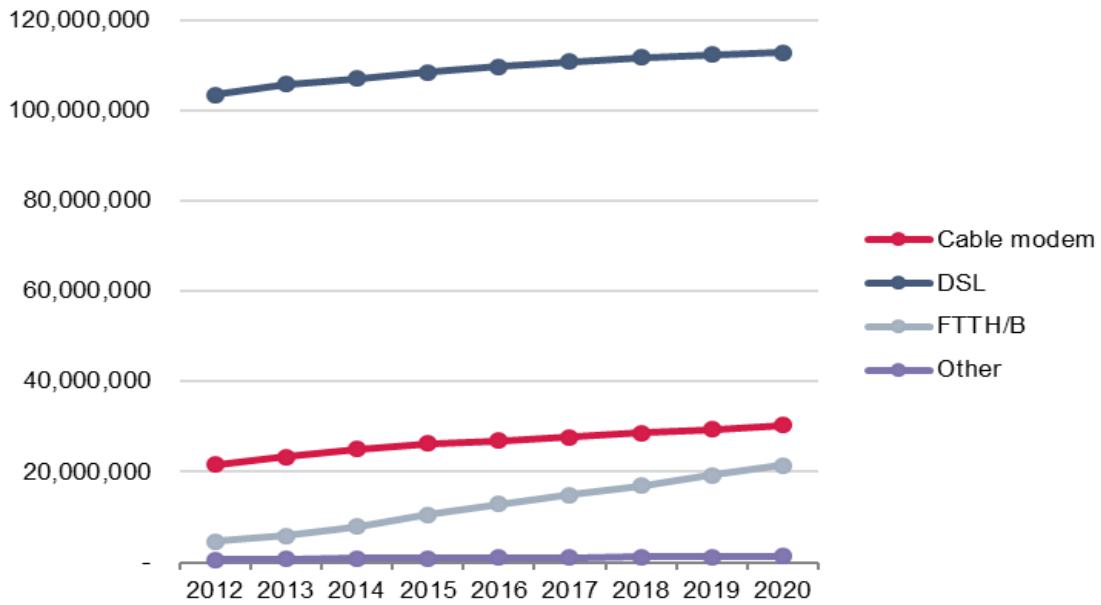


Source: Ovum: Fixed Broadband Subscription Forecasts 2015-2020

Western Europe

The more fragmented market in Western Europe did not see as extensive deployment of HFC and the broadband market has become dominated by DSL services. Cable broadband has an 18% share and this is forecast to remain stable out to 2020, compared to DSL's current 74% share. Growth in the market is expected to be largely FTTH/B as the telecommunications operators upgrade copper services to fibre.

Chart 3: Western Europe – Fixed Broadband Subscription by Technology

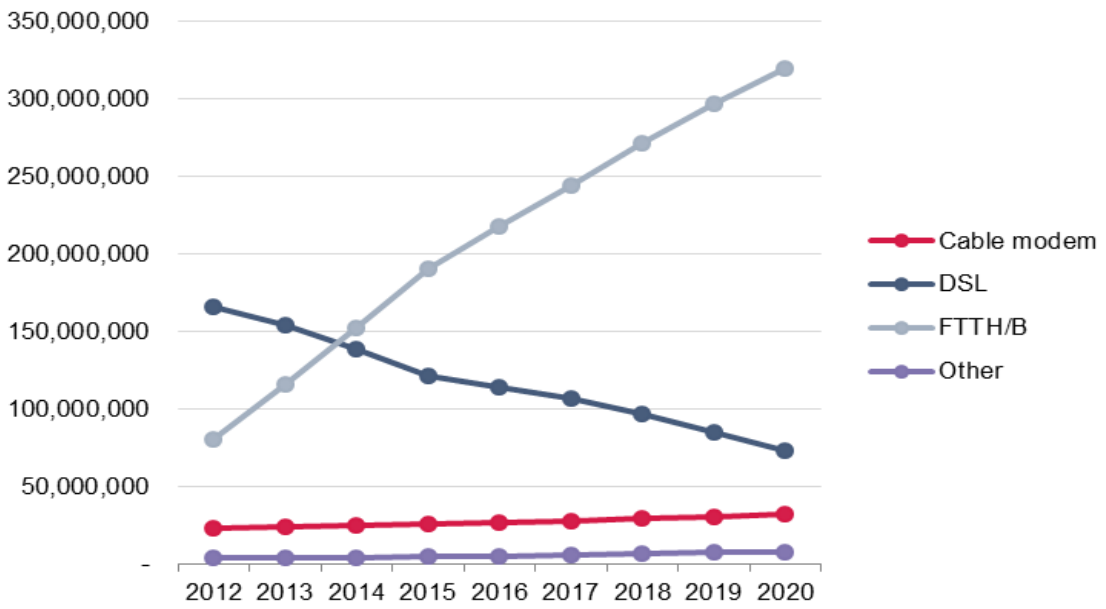


Source: Ovum: Fixed Broadband Subscription Forecasts 2015-2020

Asia Pacific

In the large developing markets of Asia, cable broadband is playing a secondary roll to the large rollouts of FTTB services. Still, the base in Asia is expected to grow over 20% during the next four years, retaining its share of the market.

Chart 3: Asia & Oceania– Fixed Broadband Subscription by Technology

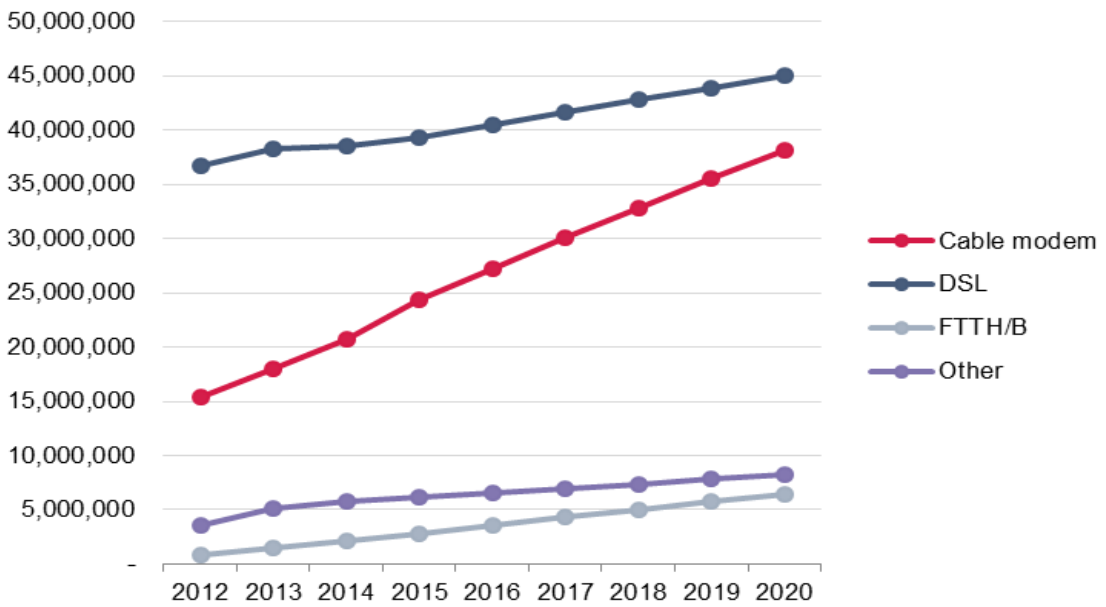


Source: Ovum: Fixed Broadband Subscription Forecasts 2015-2020

Latin America

Cable broadband is expected to see strong growth in South America, with Cable set to become the leading broadband solution in Brazil by the end of the decade. Relatively low broadband pricing and a challenging economic outlook has constrained the substantial investment needed to migrate from DSL to FTTP, leaving cable operators with their more incremental network upgrade and extension options well placed to win market share.

Chart 3: Latin America & the Caribbean – Fixed Broadband Subscription by Technology

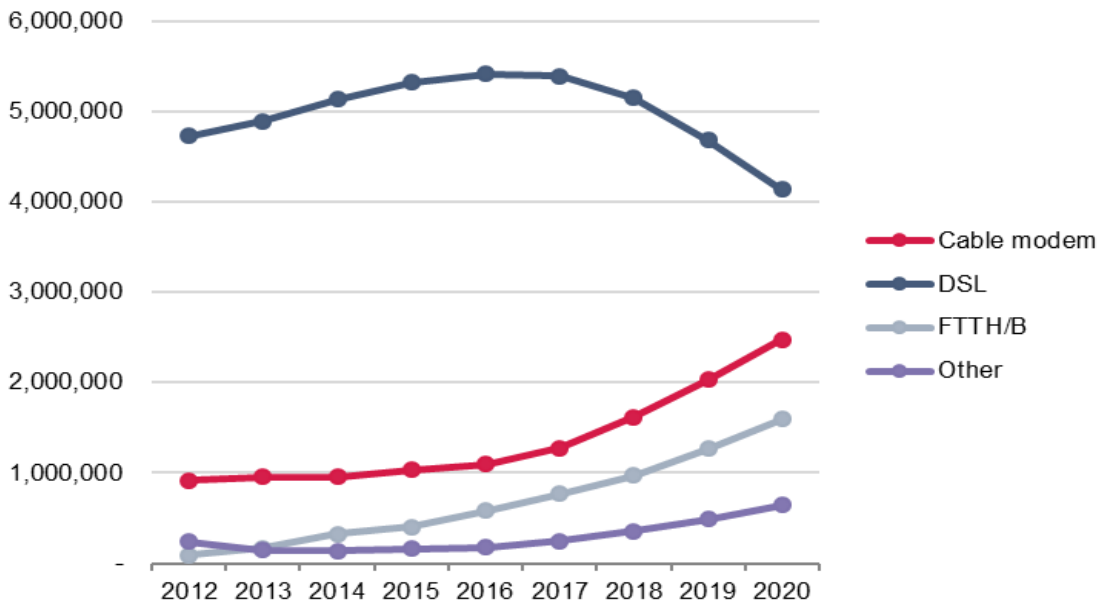


Source: Ovum: Fixed Broadband Subscription Forecasts 2015-2020

Australia

Cable has a low share of the broadband market in Australia reflecting the limited HFC rollout and lack of economic incentive for the network operators to promote cable ahead of DSL services. While HFC only had 15% market share in 2015, the unification of broadband services in the HFC footprint onto cable as migration to the **nbn** ensues is expected to see share rise to 28%. Unlike other markets, Australia will see a pronounced copper to cable migration rather than just a copper to fibre migration due to nbn's rollout strategy.

Chart 4: Australia – Fixed Broadband Subscription by Technology



Source: Ovum: Fixed Broadband Subscription Forecasts 2015-2020

Performance measures and comparisons

Cable services currently compare well to other fixed solutions across key performance metrics; downstream speed, upstream speed, actual perform vs advertised speeds, latency and packet loss.

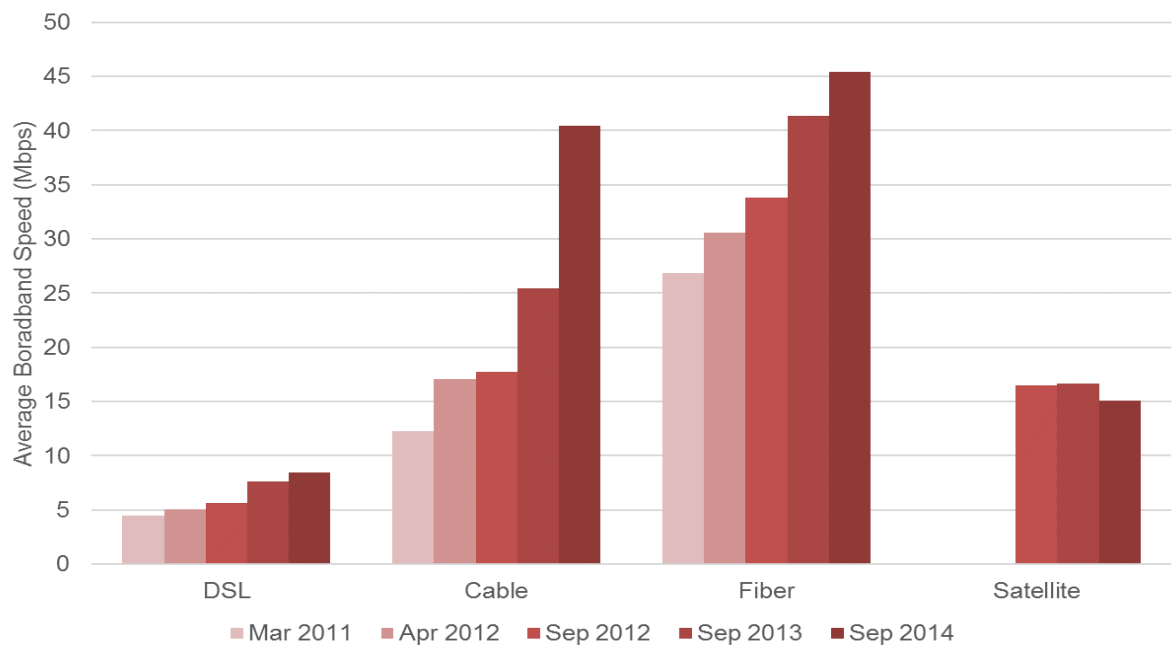
Latency and packet loss performance comparisons in the United States and United Kingdom are illustrated in Charts 11 to 14 in the Appendix.

Downstream speeds

Recent history has seen US and UK Cable operators deliver end-users substantial downstream speed increases. Cable speeds reported in the most recent monitoring reports from the local regulators marginally lag fibre services, and are now substantially ahead of DSL services.

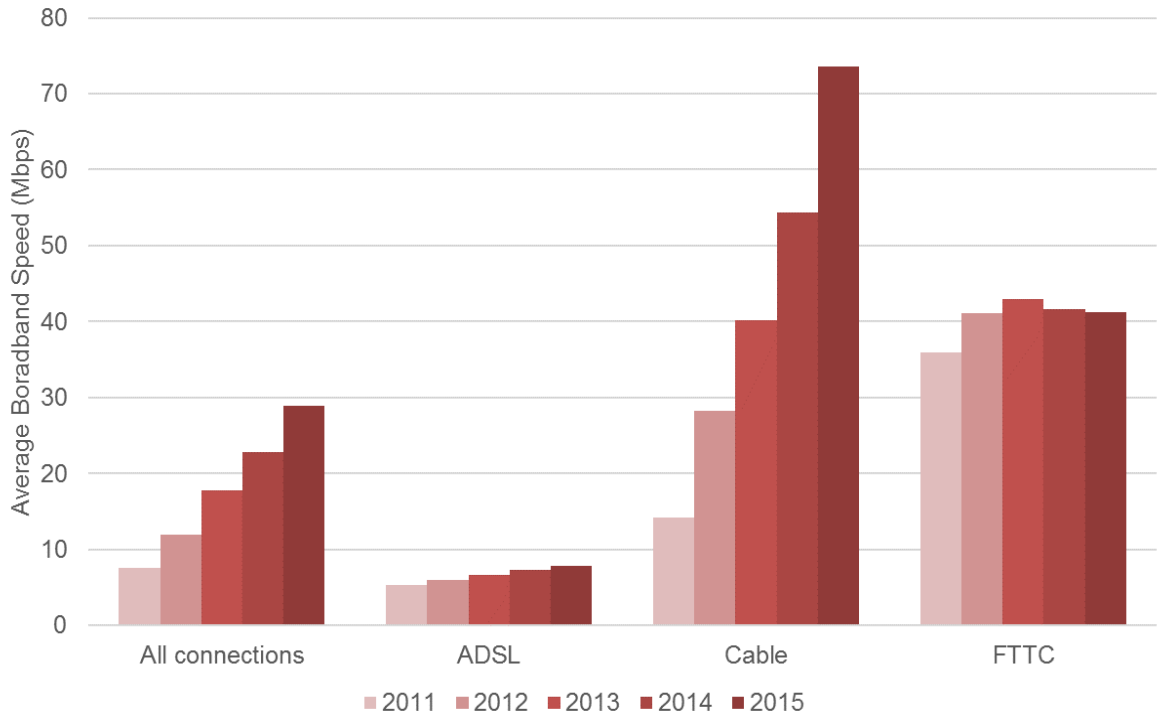
(Speeds reported reflect end-user service experience and are impacted by both providers' service provisioning and customer purchase decisions.)

Chart 5: USA – Average Download Speeds by Technology (2011-2014)



Source: Measuring Broadband America 2015

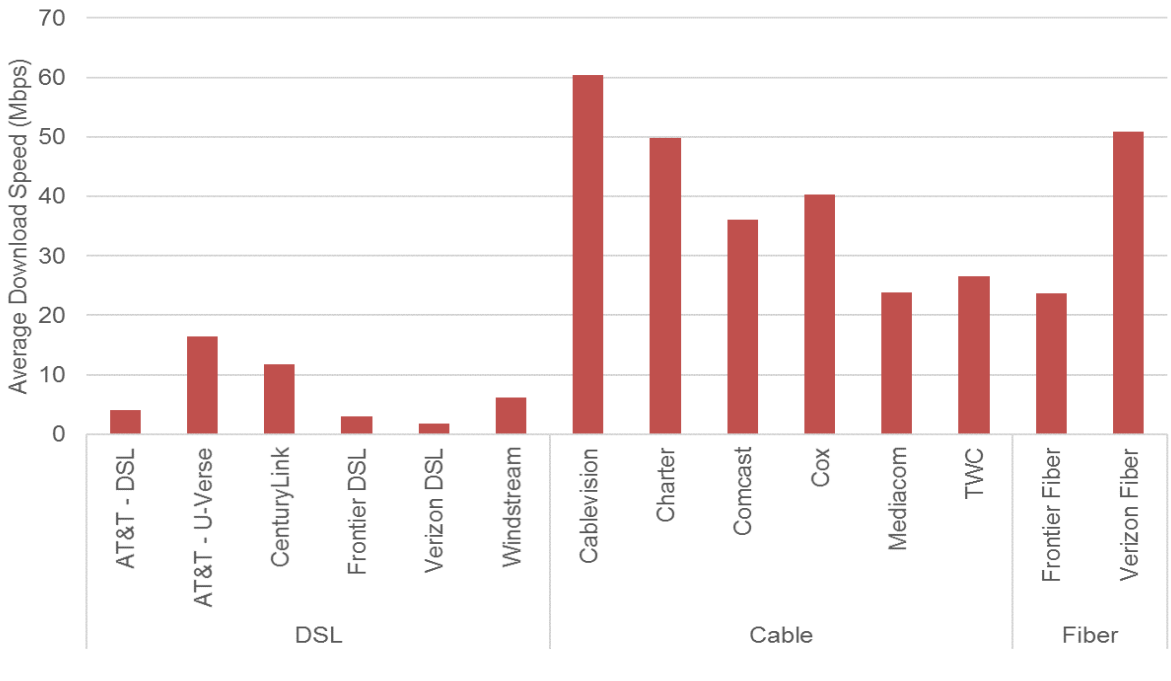
Chart 6: UK - Average download speeds for fixed broadband connections, all connections including 'up to' 2Mbit/s and less, by technology (2011-2015)



Source: OFCOM - UK home broadband performance, November 2015: The performance of fixed-line broadband delivered to UK residential consumers

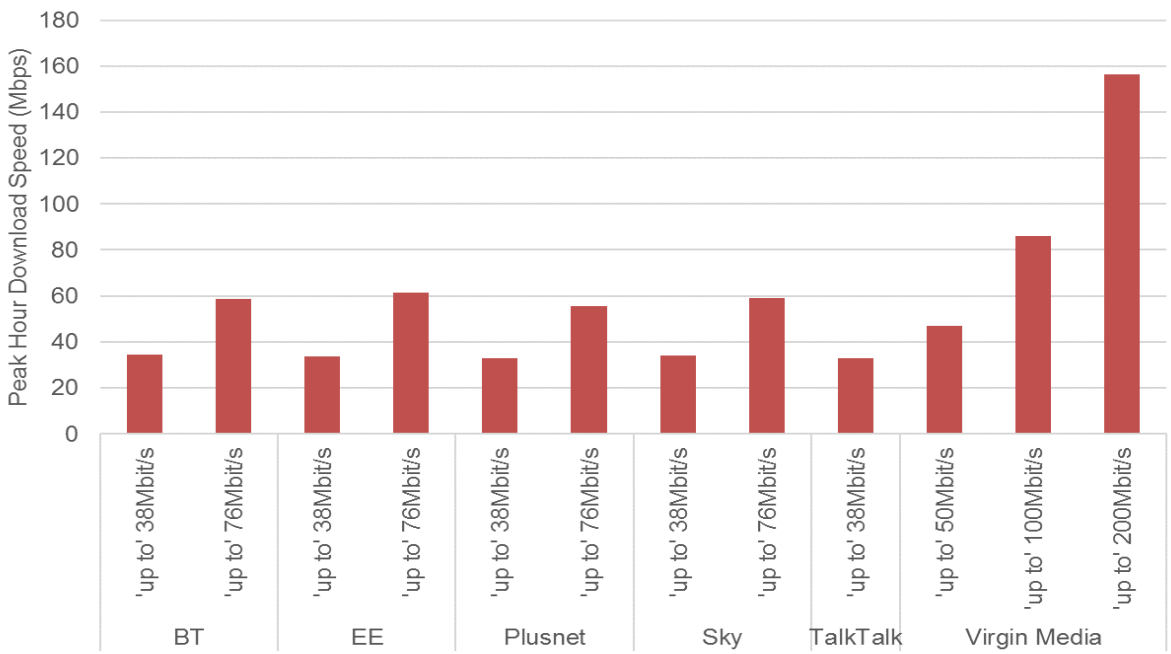
HFC operators also individually rate well in the most recent regulator testing.

Chart 7: USA – Average Sustained Download Speeds (2014)



Source: Measuring Broadband America 2015

Chart 8: UK – Average Peak Hour Download Speeds (Nov-2015)

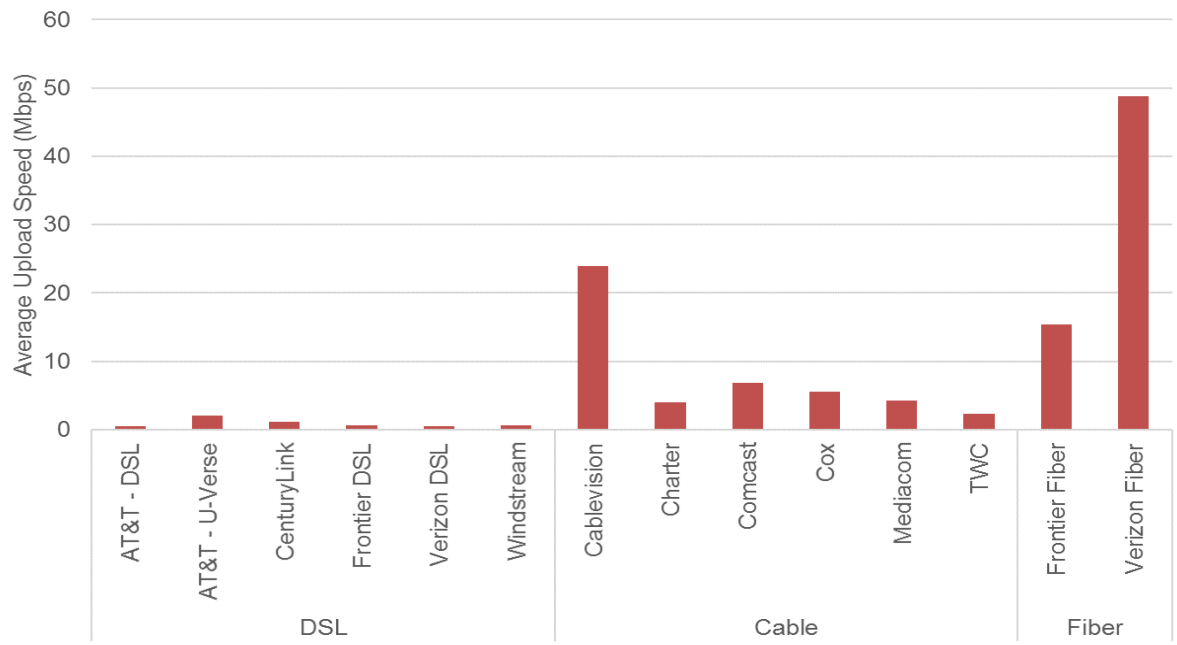


Source: OFCOM - UK home broadband performance, November 2015: The performance of fixed-line broadband delivered to UK residential consumers

Upload Speeds

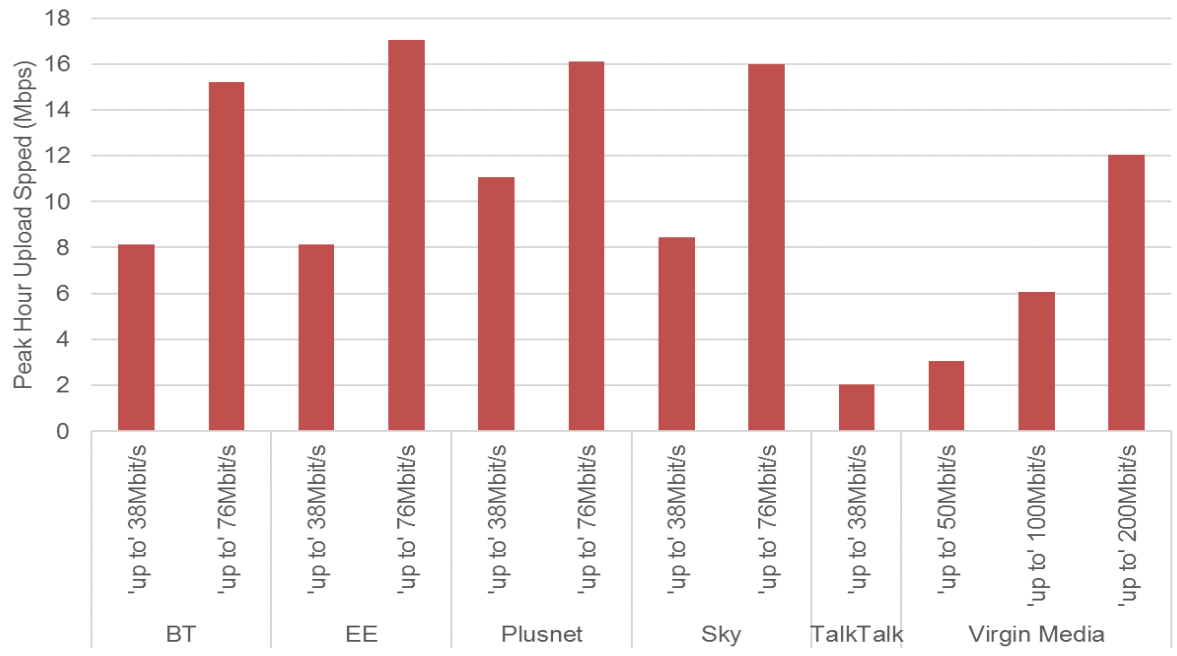
Upload speeds are more limited reflecting the limited capacity allocated to upstream bandwidth in most deployments. These results reflect performance ahead of DOCSIS 3.1 upgrades.

Chart 9: USA – Average Upload Speeds (2014)



Source: Measuring Broadband America 2015

Chart 10: UK – Average Peak Hour Upload Speeds (Nov-2015)



Source: OFCOM - UK home broadband performance, November 2015: The performance of fixed-line broadband delivered to UK residential consumers

Operator Case Studies

The following case studies illustrate major HFC operators successfully competing and growing revenues in the face of increasing fibre competition and the declines in traditional pay-TV revenues. Each operator is showing strong broadband subscriber growth, market leading network performance and growing revenue per customer.

United States - Comcast

"The beauty of DOCSIS 3.1 is that it is backwards compatible, so no digging up streets or backyards. This technology, when combined with the extensive upgrades we have already completed on our advanced Hybrid Fiber-Coaxial network, will provide more gigabit choices for our customers."

Tony Werner, Comcast CTO

Comcast Cable is the largest broadband provider in the United States, offering cable broadband, video and phone services under the XFINITY brand. Comcast Cable is one of two primary operated by Comcast Corporate, the other being NBCUniversal (cable networks, broadcast television, filmed entertainment and theme parks).

Network details and upgrade programs

Comcast's cable network passes 55.7m premises, of which 27.7m (50%) take at least one product – Internet, video or phone.

Comcast has been on the forefront of the adoption of DOCSIS 3.1, being the first operator to deploy a DOCSIS 3.1 enabled modem in a live network. Comcast has indicated that it will implement DOCSIS 3.1 throughout service areas during 2016 thereby making gigabit speeds available to all cable customers. Direct fibre services are also available, with business customers able to purchase plans with speeds up to 2Gbps.

Competitive positioning

Comcast faces competition from the incumbent phone companies, currently deploying FTTP and FTTN, as well as a mix of new infrastructure competitors including municipal and Google Fiber networks. With multiple competitors launching high speed services, Comcast has launched innovative products including cloud DVR capability, shared Wi-Fi access (XFINITY WIFI gives subscribers access to over 10m hotspots) and home automation and security solutions under the "XFINITY Home" brand.

During 2015 Comcast grew its high-speed internet customer base by 1.4m or 6.2%, gaining share in the US market that grew at 4.8%.

Network performance

The FCC's Measuring Broadband America ranked Comcast 5th of 14 for download speeds (36Mbps) and 4th fastest for upstream. This placed Comcast in a cohort of cable operators that offered superior speeds to DSL services and were challenging fibre products.

Ookla rates XFINITY from Comcast as the fastest broadband service in the United States, with downloads (for the top 10% of samples) averaging 104.6Mbps. Upload speeds are solid at 12Mbps, but lag other providers including Verizon's optical fibre service FiOS (87Mbps).

In May 2016 Comcast ranked 6th of 15 on the Netflix ISP Speed Index trailing FiOS and other cable operators; Bright House, Cox, Cablevision and Charter.

UK - Virgin Media

"Our £3bn investment to bring ultrafast connectivity to more parts of the UK is not just about better broadband, it's about future-proofing the country's network infrastructure with the best and most modern technology"

Tom Mockridge, Virgin Media CEO

Virgin Media offers broadband, phone, TV and mobile services to customers in the UK and Ireland. A subsidiary of Pan-European cable operator, Liberty Global, Virgin Media is the primary HFC operator in the UK.

Network details and upgrade programs

Virgin's Network covers 13m homes in the UK and 836,000 in Ireland.

Virgin is notable as one of the few developed market operators undertaking a material expansion of its network coverage. *Project Lightning* was announced in February 2015 with a target of extending coverage to an additional 4m premises, thereby increasing network reach from approximately 45% to 60%. The £3bn initiative is focused on in-fill, targeting premises which are within 50m of existing network and will use FTTP in a quarter of the premises with the remainder new HFC.

Competitive positioning

Virgin Media has progressively increased the speeds provided to customers over the last five years to build a competitive advantage over BT and its FTTC investment program. Copper services are widely available with speeds of up to 76Mbps, while Virgin's premium VIVID broadband product offers 200Mbps downloads.

Virgin is well placed to offer gigabit speeds with the rollout of DOCSIS 3.1, as BT looks to accelerate its copper services by deploying G.fast and expanding its FTTP deployment. In May BT announced the intension to invest £6bn to bring superfast broadband to 10-12m premises, including 2m premises with FTTP, by 2020.

Ovum has forecast that Virgin Media will see a minor (<1%) loss of market share during the period to 2020.

Network performance

Ofcom's home broadband performance research (most recently undertaken by SamKnows in November 2015) reported Virgin Media as providing the fastest speeds of the largest UK service providers. (See Charts 6, 8 and 10). Virgin also publishes more recent SamKnows data

Table 2: Virgin Media Network Performance

Tier	Average download Speed Peak	Average download Speed	Average upload Speed	Average upload Speed
	(8pm-10pm)	Over 24hr	Peak (8pm - 10pm)	Over 24hr
Up to 50Mb	48.53Mb	52.14Mb	3.08Mb	3.09Mb
Up to 100Mb	89.59Mb	100.17Mb	6.26Mb	6.29Mb
Up to 152Mb	156.82Mb	187.51Mb	12.65Mb	12.78Mb

Source: SamKnows

Ookla rates Virgin Media as the fastest broadband service in the United Kingdom, with downloads (for the top 10% of samples) averaging 125.8Mbps. Upload speeds are solid at 12Mbps, matching other leading providers.

In May 2016 Virgin Media was ranked 1st of 6 on the Netflix ISP Speed Index.

Sweden - Com Hem

"Investment in our network capacity is central to our strategy of improving customer experience, and our ambition to be the undisputed leader in the broadband market. Demand from our customers' for ever faster broadband tiers continues to grow at an exceptional rate, underlying the opportunity for our broadband services."

Anders Nilsson, CEO (2015 Annual Report, April 2016)

Founded in 1983, Com Hem was divested from Swedish incumbent Telia in 2003. It provides broadband, video and phone services to consumers and businesses via its own HFC network and via wholesale access to open LAN platforms.

Network details and upgrade programs

Com Hem's HFC network passes 1.7m, or more than 40% of Swedish homes. The network is almost solely focused on multi dwelling units (MDUs), with fibre to the building and coaxial cable used for internal distribution. In the consumer market Com Hem has secured a take-up rate of 46% within its network footprint, inclusive of video, broadband and phone services.

Com Hem has been implementing Converged Cable Access Platform ("CCAP") technology with the aim of doubling capacity for a small capital investment. CCAP is also a precursor for DOCSIS 3.1 and the ability to deliver up to 10 Gbps over the coax cable infrastructure. This follows the previous upgrades started in 2012 which enabled the capability to deliver 1 Gbps speeds across most of the network.

Competitive positioning

Com Hem is the second largest in Sweden despite have a relatively limited footprint. Offering plans with HFC speeds of up to 500Mbps (and 50Mbps upstream) has secured it the position of fastest service provider, as well as bundling video and phone services.

The MDU focus has seen Com Hem enter access contracts with 20,000 landlords and 13 wholesale communications operators, giving access to nearly 2m homes. Given the successful MDU focused

platform and growing business offering, Com Hem is now moving into the broader single dwelling unit (SDU) market with the June 2016 purchase of Boxer TV-Access AB.

Network performance

Bredbandskollen, a local internet speed test site, rated Com Hem's cable platform the fastest in Sweden during 2015, reporting an average speed of 87Mbps.

Com Hem also holds the leading position in both the Swedish Netflix ISP Speed Index and Google video quality reports.

Canada - Rogers

On our cable network, we introduced Rogers IGNITE, giving customers unlimited Internet usage options and speeds of up to 250 Mbps across our entire footprint. Roughly 40% of our customers were on Rogers IGNITE at the end of 2015 and the majority had signed up for speeds of 100 Mbps or faster. We have also started to future-proof our customers' growing demand for streaming by introducing a gigabit Internet service. These new speeds are now available to 130,000 homes and we expect to offer them to our entire cable footprint; that's 4.2 million homes by the end of 2016.

Rogers Communications Annual Report 2015 (February 2016)

Headquartered in Toronto, Rogers Communications offers wireless, cable and media services to consumers and businesses in Canada. The cable network is the largest in Canada, with services offered in Ontario and Atlantic Canada.

Network details and upgrade programs

At the end of 2015 Rogers' cable network passed 4.15m homes or about 30% of Canadian households. Of the homes passed

- 49% subscribed to an internet services,
- 45% of homes passed purchased a pay-tv service, and
- 26% a phone service.

In total over five million products were supplied over the HFC network at the end of 2015.

During 2016 Rogers will undertake network upgrades with the objective of being able to support gigabit services throughout its footprint. This upgrade, which will see an average of 100,000 homes upgraded per week, leverages the existing cable plant and will cost less than C$50 per home. The upgrade will see DOCSIS 3.0/3.1 implemented across the network.

Competitive positioning

Rogers network upgrades are intended to remain competitive with the copper and fibre services offered by the incumbent telecommunications carrier Bell Canada and Bell Aliant. Bell's investment program targeted delivery of fibre services to homes in the Ontario and Atlantic Canada regions in the second half of 2015.

Rogers network speeds supplement the traditionally strong media services portfolio which is a key component of the bundle offering.

Network performance

- 2015 analysis by SamKnows indicated that the Rogers Cable network consistently deliver speeds in excess of advertised rates, with peak-hour download speeds averaging 108% of the advertised rates.
- Ookla rates Rogers as the fastest service provider in Canada, with download and upload speed tests (for the top 10% of test samples) averaging 135.8Mbps and 17.8Mbps respectively. These results are almost double that of the next fastest service provider.
- In May 2016 Rogers ranked 6th of 19 on the Netflix ISP Speed Index trailing optical fibre services from MTS, SaskTel and Shaw, and cable services from Videotron, Shaw and Eastlink.

Technology Overview

Cable broadband evolution

CableLabs is the industry backed innovation and R&D lab tasked with developing the technologies and specifications for HFC networks and products. Its role extends from developing and setting technical standards to supporting the testing and certification of vendor solutions. CableLabs' endeavors look to balance the objectives of

- Improving product capability
- Improving efficiency and cost effectiveness

Guiding these efforts are the principles of consistency of standards (including the adoption of open standards) and interoperability across the industry.

Table 3: DOCSIS standard evolution

Standards	Introduction	Node capacity		Enhancements
		Downstream	Upstream	
DOCSIS 1.0	1996	38Mbps	9Mbps	
DOCSIS 1.1	1999	38Mbps	9Mbps	Added enhanced security and Quality of Service
DOCSIS 2.0	2001	38Mbps	27Mbps	Improved upstream capacity via improved modulation (64-QAM, 256QAM)
DOCSIS 3.0	2006	1Gbps	200Mbps	Channel bonding, IPv6 support
DOCSIS 3.1	2013	10Gbps	2Gbps	Added OFDM, improved error checking, active queue management

The above illustrative speeds are system speeds, with capacity shared across end-users. Capacity is dependent on both physical topographies deployed and the communication protocols implemented. While a network may upgrade its CMTS to the latest version (3.1), a mix of new and older modems will limit the aggregate capacity of the system while it continues to support the older modems.

End-user speeds for customers with DOCSIS 3.0 modems are constrained by the number of channels that are bonded. With the move to OFDM in DOCSIS 3.1 network operators have greater flexibility to allocate capacity to individual end-users.

Upgrade Roadmap and Business Benefits

Many cable operators globally have commenced, announced or are evaluating the upgrade of their network to the latest standard, DOCSIS 3.1. The drivers of these upgrades include

- Increasing end-user demand for capacity driven by use of video services and multiple devices in the home
- Competitive responses to rollouts of FTTx services, with the need to offer gigabit services
- Efficiency improvements, with a focus on reducing power and space requirements

While DOCSIS 3.1 is central to the upgrade path, operators have a menu of options available which can be used to meet their customers and operational efficiency requirements. Broadly these options include implementing solutions that

- Change physical network topography

- Manage spectrum resources
- Increase spectrum efficiency

Network topography

The most capital intensive option, network operators are progressively moving fibre deeper into the network (closer to the end-user) and reducing the number of end-users allocated to network components with limited shared capacity (such as node-splitting). The end-point of this upgrade process is fibre to the last amplifier leaving short runs of coaxial shared between few end-users. This *n+0* topography can be leveraged to offer selective direct fibre connectivity where customer demand arises.

Vendors have also introduced solutions implementing CableLabs *Converged Cable Access Platform (CCAP)* standard. CCAP headend components provide the functionality of a CMTS (broadband connectivity) and an Edge QAM (video distribution) in a single architecture. The primary benefit is a reduction in headend hardware requirements with corresponding reduced power and space requirements. Vendors have suggested 40% capital and operations spending savings over five years from CCAP deployments.

Managing spectrum resources

Central to the development of the DOCSIS standards has been the increased use of spectrum resources within the cable plant. HFC networks allocate spectrum to the delivery of traditional pay-tv services (SD video, HD video, radio) as well as upstream and downstream internet traffic. Upgrade options include

- Reallocation of existing pay-tv spectrum to support broadband through implementation of more efficient video compression codex (MPEG-2 to MPEG-4) or migration of broadcast distribution to an all-IP platform
- Extend spectrum allocations. For example, the upper bound specified for the downstream spectrum allocation has been extended by DOCSIS 3.1 from between 300-1002 MHz to 1218- 1794 MHz, allowing an increase in available spectrum of up to 50%

Improved transmission efficiency

As well as increasing the broadening the road (increasing available spectrum resources), operators have option for increasing the speed of the traffic.

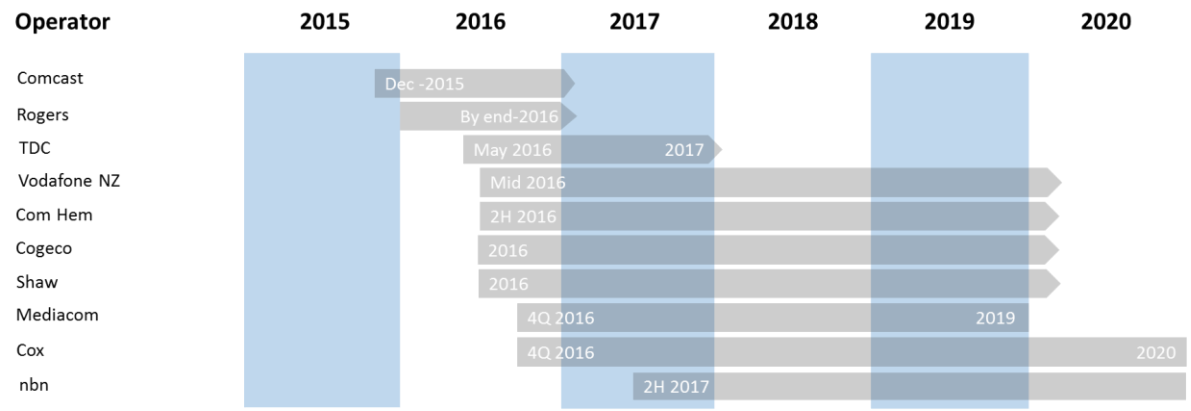
- OFDM – core to DOCSIS 3.1 is the implementation of *Orthogonal Frequency-Division Multiplexing*. OFDM uses bit coding across parallel data streams rather than channel allocation between the CMTS and the cable modem. The removal of channel allocations increases efficiency by effectively allowing all end users to access the whole road rather than being restricted to a limited number of lanes. The implementation of OFDM in cable systems has parallels to the modulation protocols introduced with the launch of 4G mobile networks
- Use of more advanced modulation schemes - A further feature enabled with OFDM is the use of multiple modulation schemes, allowing a combination of higher rate (but potentially more error prone) signaling. DOCSIS 3.0 supported 256 QAM (8 bits/symbol) while DOCSIS 3.1 supports up to 4096 QAM (12 bits/symbol), allowing downstream efficiency improvements of 35% (assuming a mix of modulation schemes are used)

- Active queue management solutions (also standardized for DOCSIS) coordinate and prioritize traffic to ensure smooth delivery of traffic for more time sensitive applications
- Forward error checking (FEC) based on Low Density Parity Check (LDPC), improving the performance of the data error checking to reduce requests for data retransmission

Current operator plans for DOCSIS 3.1 migration

Although not required in every instance, the deployment of DOCSIS 3.1 equipment is being used to support the launch of Gigabit broadband services. With the release of the first certified cable modems at the beginning of the year, 2016 is set to feature the first wave of upgrades.

Figure 1: DOCSIS 3.1 deployments



Source: Cable operator and vendor announcements

The timetable of the migration to DOCSIS 3.1 is generally open ended with the replacement of cable modems undertaken on an as required basis. Few operators specify the timing for the complete migration and deployment completion may be an indication of availability of gigabit services extending across the complete footprint.

Not all operators have committed to a DOCSIS 3.1 upgrade. This can reflect

- Existing network capability – the implementation of DOCSIS 3.0 and past investment in infrastructure is allowing some operators to offer gigabit services to some customers without investing in 3.1. Cable One expects to offer gigabit services across its 3.0 network in 2016
- Alternative technology selection – i-Cable is leveraging its existing fibre network connecting Hong Kong buildings to offer gigabit services via FTTP as an upgrade from DOCSIS 3.0. This "*Leapfrogging technology from HFC to GPON*" is a strategic reaction to an environment where competing fibre is abundant
- Deferral – in markets where competition is not driving demand for gigabit services operators can defer upgrades and benefit from lower future cable modem prices

Network upgrade announcements from leading HFC cable operators have included

Comcast (USA)

- Feb 2016 - Announced initial rollout to Nashville and Atlanta, with Chicago, Detroit and Miami to follow. Widespread rollout to follow in the next couple of years
- Dec 2015 - Installed the first commercial DOCSIS 3.1 modem for a customer in Philadelphia.
- Aug 2016 – Indicated rollout to across footprint in 2016

Cox Communications (USA)

- May 2016 - First DOCSIS 3.1 commercial trial later this year (Q4), with deployment to ramp up between 2017 and 2020.

Mediacom (USA)

- Mar 2016 - US$1 billion initiative it claims will bring gigabit broadband to "nearly all" of the company's customers. "Project Gigabit" to use DOCSIS 3.1 technology to bring gigabit speeds to the 3 million homes and businesses in 22 states in Mediacom's footprint

Shaw (Canada)

- *"We are committed to enhancing our broadband performance in 2016 through the technology provided by the DOCSIS 3.1 protocol – known as Gigasphere. We know that we are now just scratching the surface of what our network is capable of and we have a plan that will continue to deliver the speed and capacity that our customers want today and into the future. Our promise is simple: our customers will always be ready and always be connected so they never miss a thing."* 2015 Annual Report

Cogeco Cable & Atlantic Broadband (USA, Canada)

- Oct 2015 – Announced DOCIS 3.1 to be rolled out throughout Connecticut with other markets to follow through 2016

Rogers (Canada)

- *"Through our advanced, hybrid fibre-coaxial network, we expect to be able to offer consumers across our entire DOCSIS 3.0/3.1 footprint Internet download speeds up to 1 Gbps by the end of 2016. We will be able to upgrade our entire footprint of over four million homes with Gigabit Internet at an incremental in-year capital cost of less than C$50 per home."* (2015 Annual Report)

TDC (Denmark)

- Aug 2015 – Announced DOCSIS 3.1 upgrade of *YouSee* cable network, passing 1.3m homes, starting in May 2016, with work to be completed by the end of 2017

Liberty Global (multiple European markets)

- *"The focus continues to be on high end internet products to safeguard our high-end customer base and allow us to become more aggressive at the low- and medium end of the internet market. By fully utilizing the technical capabilities of Euro DOCSIS 3.0 technology, we can compete with local FTTx initiatives and create a competitive advantage compared to DSL infrastructures and LTE initiatives on a national level. With the expected commercial*

deployment of Euro DOCSIS 3.1 in late 2016, we plan to further increase our high-speed internet offers." – Annual Report 2015

DNA (Finland)

- *"We want to offer our clients an excellent customer experience as well as reliable, fast network connections for the increasing use of online services. In fixed broadband networks, DOCSIS 3.1 technology offers the best solution for meeting this objective. In cooperation with Teleste, we have already noted that the technology really does do what it promises. We are highly satisfied that this upgrade will enable us to bring our cable network customers within the reach of fixed broadband connections that are incomparable in speed and which respond to the requirements of both the current and future information society."* on the announcement of DOCSIS 3.1 rollout – June 2016

Com Hem (Sweden)

- *"Our upgrades use the new Converged Cable Access Platform ("CCAP") technology giving us the ability to double the capacity to these customers with a significantly lower investment. With CCAP we have also taken the first step towards DOCSIS 3.1 which is the next DOCSIS (Data Over Cable Service Interface Specification) standard giving us the ability to deliver up to 10 Gbps over coax cable infrastructure."* – 2015 Annual Report
- Com Hem has indicated the deployment of DOCSIS 3.1 will take place in in the second half of 2016

Vodafone (New Zealand)

- Nov 2015 – Wellington, Christchurch and Kapiti network upgrade to DOCSIS 3.1 announced with first customers to get access from mid-2016. Upgrade cost NZ$22m

Altice (multiple European markets)

- *"With a combination of Cisco's Evolved CCAP, DOCSIS 3.1 and migration to NFV/SDN, Altice will continue providing the best customer experience, based on the highest bandwidth and cutting edge technology"* on announcing the vendor for its network upgrade, beginning with Numericable-SFR – Apr 2015
- Jun 2016 - In its recent Gigabit broadband service field trial in France, Altice hit a record speed of more than 3 Gbps per subscriber, as well as proving capabilities for more than 7 Gbps of aggregate bandwidth in the same cable segment

Vendor announcements

In addition to the cable operators noted above, leading vendors Cisco, Arris and Casa Systems have announced DOCSIS 3.1 enabled hardware contracts with the following.

- KBRO (Taiwan)
- LG U+ (South Korea)
- Midcontinent (USA)
- Quickline AG (Germany)
- SK Broadband (South Korea)

- Time Warner Cable (USA)
- VOO (Belgium)
- Wave Broadband (USA)

In addition to Altice and Comcast above, Cisco has announced that it has secured over 100 customers worldwide for its flagship CCAP product, with over 30 currently undertaking deployments.

Beyond 3.1

The upgrade path for HFC does not stop with DOCSIS 3.1, with CableLabs and vendors continuing to develop the roadmap to improve product capability and network efficiency.

Full Duplex DOCSIS

CableLabs is currently undertaking a feasibility study into adding a full duplex capability to the DOCSIS standard. This capability will use noise cancelling solutions to allow upstream and downstream signaling across the same spectrum, rather than requiring the spectrum to be split. This would make available substantially more spectrum for upstream traffic and enable service providers to offer symmetrical services.

The DOCSIS 3.0 and 3.1 standards currently constrain the spectrum allocated to upstream traffic with upper bounds of 85MHz and 204MHz respectively. This compares to spectrum allocations for downstream traffic of 1GHz or more in current deployments, and result in the asymmetric services available today.

CableLabs is expected to commence the standardization process for full duplex mid-2016.

Future Innovation Roadmap

Arris provided its view of the potential roadmap for cable innovation in March 2016.

Table 4: Arris HFC technology Evolution Roadmap

2016	DOCSIS 3.1 750 MHz to 1.2 GHz + Adds 4096QAM OFDM for 10 Gbps Service
2017	Distributed Access Architectures Reduce HE Power & Rackspace for Node-splits
2018	Full Duplex DOCSIS Supports Symmetrical BW for HSD & 1+ Gbps Upstream
2019	Higher Density I-CCAPs & CCAP Cores & RPHY Shelf For Fiber Deep Node-splits
2020	Virtualized CCAP Cores and a targeted transition to PON/RFoG. Support Cloud based Services & higher Feature Velocity
2021	Extended Spectrum DOCSIS Permits higher Spectra & 50-200 Gbps Service

More broadly the industry is contemplating (and working on) the expansion of software defined networking (SDN), network function virtualization (NFV), Ethernet passive optical network over cable (EPOC), remote PHY, in addition to solutions to manage the broadcast distribution of 4k and 8k content.

Conclusion and nbn Positioning

Hybrid fibre-coax networks have evolved over the past seven decades and today remain highly competitive platforms offering market leading performance. This evolution is set to continue with increases in capacity supporting gigabit speeds both downstream and upstream on the horizon. For operators, the roadmap for further enhancements permits confidence that they will be able to continue to compete as investments in fibre (FTTP, FTTB and FTTN) challenge.

HFC is currently the leading broadband platform in the United States and is expected to retain a steady share of the global broadband market for the remainder of the decade. Ovum expects Cable broadband's global market share to be stable at 19%, with a minor loss of share (from 56% to 54%) in the United States.

Network performance by HFC now rivals fibre platforms, with HFC operators enabling substantial increases in download speeds over the last five years. In the US average cable download speeds, as measured on behalf of the FCC, have improved from 12Mbps to 40Mbps. A similar improvement has been reported in the UK with cable speeds averaging over 70Mbps in November 2015.

These performance improvements are set to continue with global operators commencing the rollout of DOCSIS 3.1 across their networks this year. This step will enable the launch of gigabit speeds in many markets. The continued evolution of cable broadband is set to continue with the evaluation of full duplex techniques underway, a solution that will enable dramatic improvements in upstream capacity and speeds, ultimately allowing gigabit speeds both downstream and upstream.

30 June 2016 saw the launch of the first commercial HFC services by **nbn**. By leveraging the existing DOCSIS 3.0 HFC infrastructure, **nbn** will…..

- facilitate the acceleration of its rollout,
- minimise capital works,
- minimise truck rolls, appointments and need for entry into premises,

...and so deliver world leading broadband services while managing cost of deployment.

With the development roadmap for HFC, nbn and Australia's broadband uses can have great confidence that as broadband requirements continue to grow, the HFC network will be more than capable of meeting expectations.

Appendix

The Evolution of HFC

Since its genesis in the form of community access television (CATV), cable networks have been a platform of technology and product innovation, driving change across the media and telecommunications sectors. Widely deployed, HFC networks continue to be upgraded around the world to support the latest technologies to support rising customer requirements.

Genesis

In 1948 the first community access television (CATV) solutions were introduced in the US to address blackspots in television coverage. Starting with simple cabling connecting homes to an antenna on a local high point, these subscription services were the first fixed line platforms to deliver media services. The first of these systems using coaxial cable was deployed in 1950. The addition of simple signal amplification allowed the extension of the cabling to homes further from the headend, the point at which the video signal first enters or is injected into the network.

The customer benefit was soon extended beyond opening up access to local channels, to include greatly increased channel choice by picking up the broadcasts of transmitters hundreds of miles away, with retransmitted service via microwave links commencing in 1953.

By 1960 the number of entrepreneurial CATV systems had growth to 640, providing services to 650,000 customers. This growth continued with the cable connected households reaching one million in 1963. The growing market attracted corporate investment and the formation of the first Multiple System Operators (MSOs). In 1965 the rapidly growing industry attracted its first regulation by the FCC, introducing must-carry and non-duplication requirements on all providers aggregating signals of multiple and distant broadcasters.

Patents for the first set-top box, still a key device in cable network infrastructure, were submitted at the end of 1965.

Going national

1972 saw the addition of signal distribution via satellite transmission giving rise to the launch of specialty channels (weather, news, sports), movie channels including Home Box Office (HBO) and the rise of the superstations. Superstations used c-Band satellite transponders to give availability of their programming across the country. With the growing availability of programing and increased commercial backing, the number of US cable households had grown to 16 million by the end of the 1979.

The early 1970's also saw the introduction of the first two-way systems, allowing subscriber responses to be received, and was soon followed by the first use of Fibre optics for backhaul (trunk) distribution in 1976.

Cable News Network (CNN) satellite distribution was launched in 1980, followed closely by MTV, as premium and pay-per-view options grew in popularity.

HFC arrives

The first commercial deployment of an amplitude modulation on fibre solution in Hawaii was the precursor for HFC to become the industry standard. TCI, Time Warner and Viacom begin building

systems with fiber-to-the-node designs in 1992. Pay-tv services then exploded with consumer packages rising to as many as 500 channels following the implementation of digital video compression.

Cable operators also commenced evaluation of using the return band (5-30 MHz) for telephony, data and impulse pay-per-view. This supported the arrival of the first “intelligent” set-top boxes and the launch of third-party interactive services.1994 saw the testing of the first cable modem solutions, as cable operators extended their push in to telecommunications with long-distance calling and mobile (PCS) products. Local calling solutions soon followed.

The cable modem became the first mass market broadband solution, offering always on connections and transmission speeds far above that available on dial-up modems.

…and in Australia

1994 also saw the commencement of the HFC rollouts in selected Australian cities by Telstra and Cable & Wireless Optus.

DOCSIS standardisation

CableLabs launched efforts in 1997 to lead the standardisation of cable broadband systems and provide a roadmap for the development of enhanced services. (See Table 5 below.) Initial efforts focused on Data Over Cable Service Interface Specifications (DOCSIS) and Multimedia Cable Network System (MCNS) standards. These standards have become central to ensuring interoperability between vendor equipment and reducing cable modem costs. The first certified DOCSIS (1.0) platform was trialed in 1998 in Ontario, Canada. Pre-DOCSIS modems illustrate the initial demand for broadband, with more than 100,000 sold across 29 US states in 1997, and more than 400,000 by the end of 1998.

In addition to the DOCSIS standard, a European version (EuroDOCSIS) was introduced to work with the broadcasting channel widths used in Europe, 8MHz rather than the North American standard of 6MHz.

The first cable modem services in Australia were launched by Optus under the Optus@Home brand, in 1999. Despite the limited reach of the HFC networks, cable broadband was the leading broadband platform until 2004.

New millennium and DOCSIS evolution

By the year 2000 cable was truly a scale industry with 28 million set-top boxes sold, with growth continuing in 2001 when 36 million were sold globally.

CableLabs has continued to evolve the DOCSIS standard, with the latest version, 3.1, delivering a further ten-fold increase in bandwidth.

Table 5: DOCSIS standard evolution

Standards	Introduction	Node capacity		Enhancements
		Downstream	Upstream	
DOCSIS 1.0	1996	38Mbps	9Mbps	
DOCSIS 1.1	1999	38Mbps	9Mbps	Added enhanced security and Quality of Service
DOCSIS 2.0	2001	38Mbps	27Mbps	Improved upstream capacity via improved modulation (64-QAM, 256QAM)
DOCSIS 3.0	2006	1Gbps	200Mbps	Channel bonding, IPv6 support
DOCSIS 3.1	2013	10Gbps	2Gbps	Added OFDM, improved error checking, active queue management

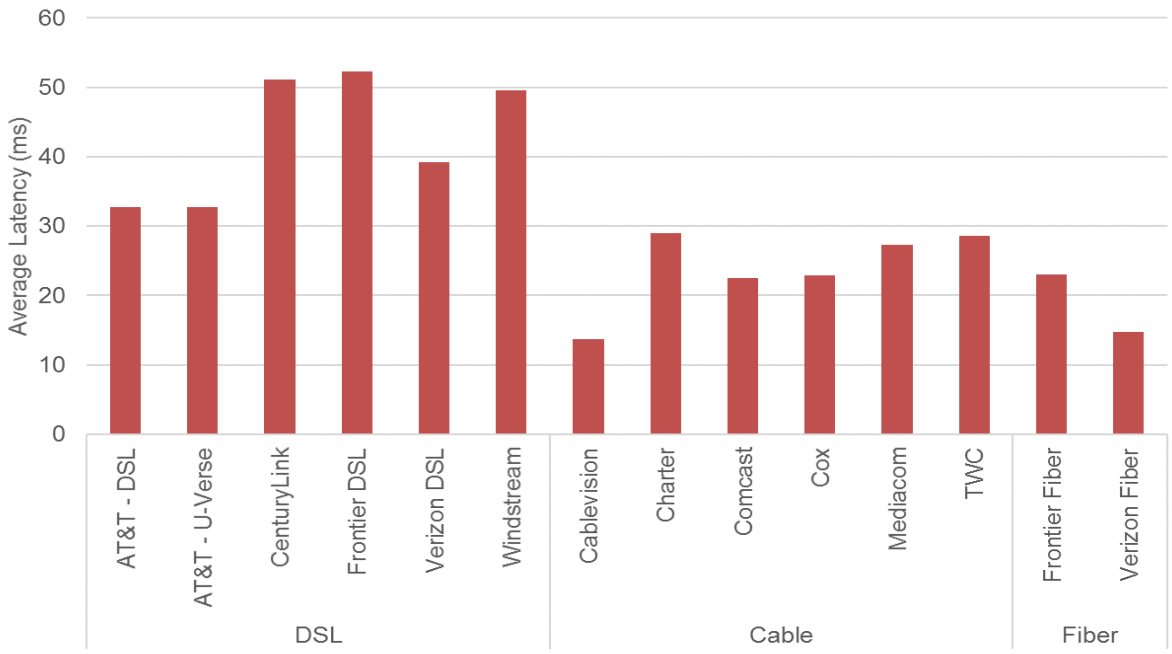
To date the CableLabs certification process for 3.1 has seen six modems qualified, with the first wave approved in January 2016. Comcast was first to install a DOCSIS 3.1 modem in a commercial environment, with a residential customer in Philadelphia receiving the upgrade.

The progressive upgrade of broadband capabilities was the technical focus of cable operators in the new millennium, rolling out successive standards as they became available. Operators have also needed to evolve their product offerings to compete in the era of over-the-top (OTT) content offers during this period. Bundles of broadband, calling and video services leveraging the core HFC network have been augmented with Wi-Fi, TV everywhere (OTT), home security and mobile services. Extension of networks has been limited, although targeted initiatives have seen some residential expansion and targeting of the corporate market with both cable and direct fibre offers.

Network Performance - Latency and Packet Loss

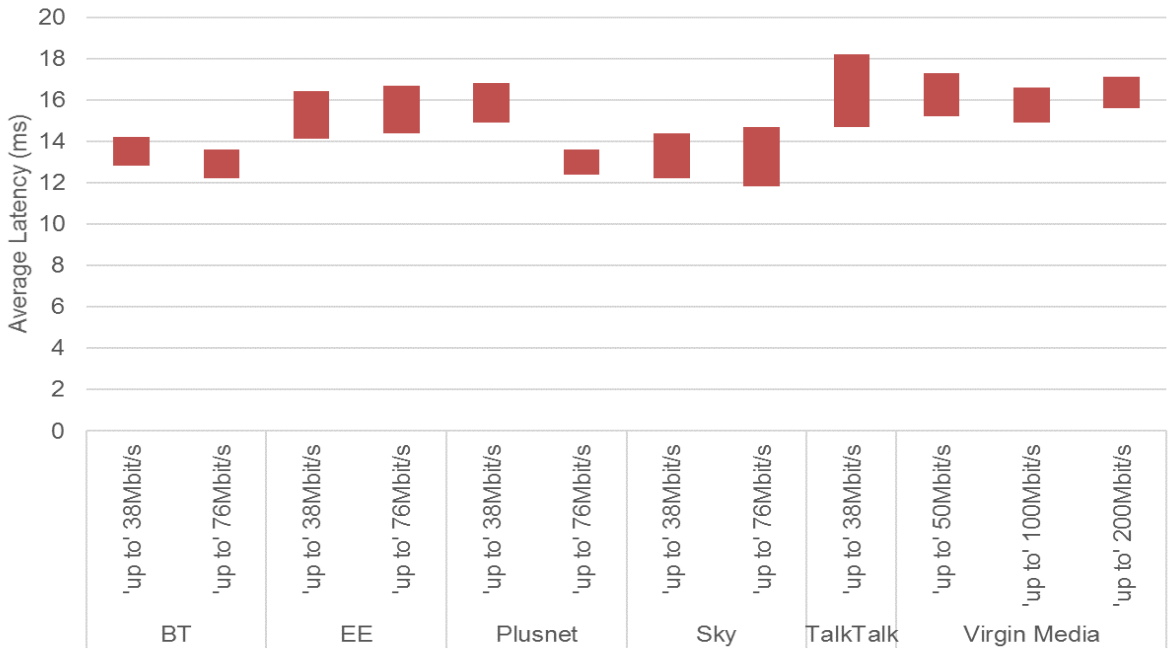
Latency

Chart 11: USA – Latency by ISP (2014)



Source: Measuring Broadband America 2015

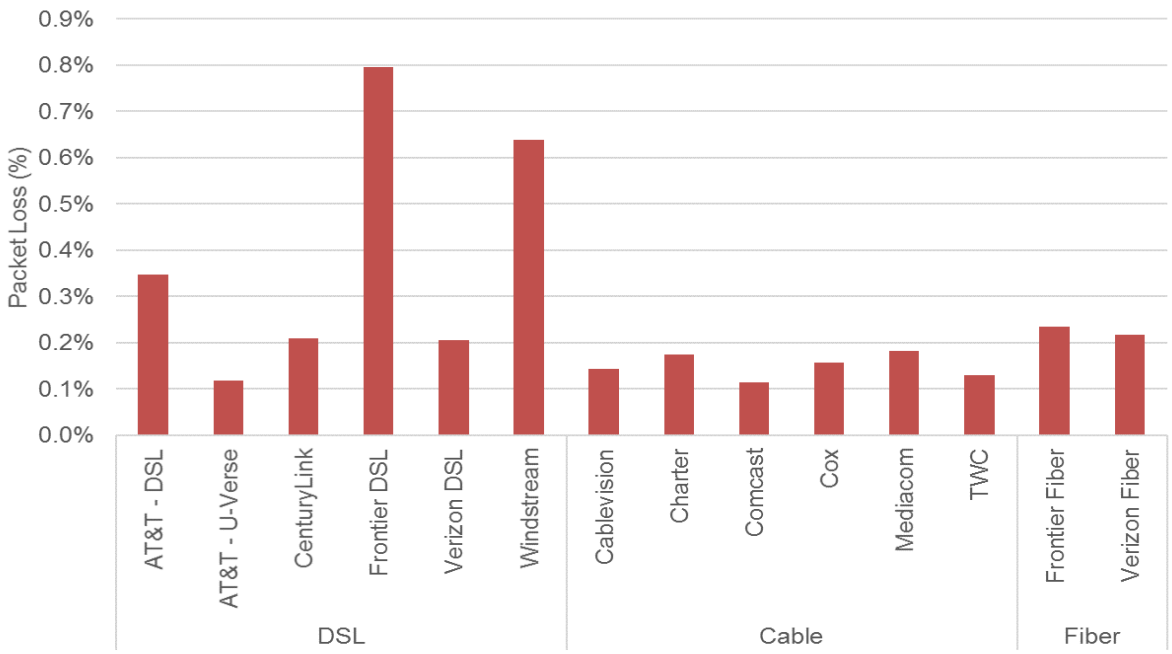
Chart 12: UK – Peak Hour Latency by ISP (Nov-2015)



Source: OFCOM - UK home broadband performance, November 2015: The performance of fixed-line broadband delivered to UK residential consumers

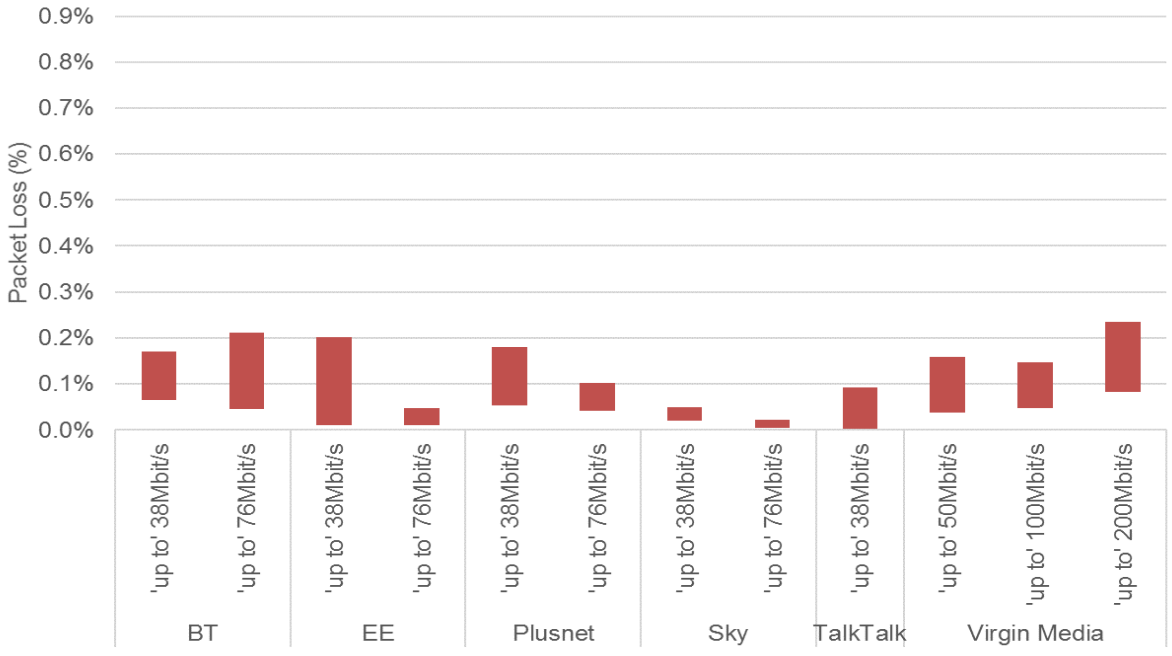
Packet loss

Chart 13: USA – Packet Loss (2014)



Source: FCC – Measuring Broadband America 2015

Chart 14: UK – Packet Loss (Nov-2015)



Source: OFCOM - UK home broadband performance, November 2015: The performance of fixed-line broadband delivered to UK residential consumers

Methodology

For this report, Ovum drew on interviews, presentation announcements by vendors and operators, and desk research. We also used data from Ovum's *Fixed Broadband Subscriptions Forecast: 2015–2020* and World Broadband Information Service.

Further reading

2016 Trends to Watch: Telecoms Market, TE0009-001486 (21 December 2015)

Cable Broadband Market Outlook, TE0009-001451 (28 August 2015)

US Cable: Comcast's strategy for growth beyond M&A, TE0009-001438 (June 2015)

Global Fixed Industry Survey: 2015, TE0009-001431 (May 2015)

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