Annex 2: Network Technology Report

Suitability of shared Optical Distribution Networks to deliver leased line services

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Summary

- Openreach and Altnets have been rolling out new telecoms networks at pace across the UK with gigabit capable services now covering 62% of the UK and rising.
- The networks being built are based on single mode fibre which can be used to support all types of high-capacity services.
- These new networks contain numerous connection points and nodes allowing services to join the cables at various points. Therefore, presence of fibre in an area gives a network a great amount of flexibility to serve end-users of all types, including those that may require high bandwidth services.
- I do not agree that the definitions of "leased lines" and "leased line equivalent" services are as distinct as suggested in the TAR – in particular capacity and security.
- [✂].
- Openreach and the vast majority of Altnets use Nokia and ADTRAN headends both of which support FTTP and carrier grade Ethernet from a common platform.
- These platforms deliver superior performance whilst requiring less power and space compared to traditional Ethernet services using dedicated fibre and equipment.
- Despite being a shared platform, the use of capacity management and service quality management enable operators to offer "dedicated bandwidth" over shared networks invisible to the end customer.
- There are a wide range of technology options for providing Ethernet services over existing fibre, many of which were detailed in Ofcom's Evolution of Fixed Access report published in 2023.
- Altnets are already leveraging 10Gbps and 50Gbps Passive Optical Network (PON) technology to provide dedicated enterprise services over existing FTTP infrastructure. They have also demonstrated their desire and success in winning ethernet business using their networks.
- In conclusion, I believe that once an operator has fibre in an area they can provide FTTP, Ethernet or wavelength services using that fibre and even if the current operator chooses not to, a subsequent owner or entity could easily do so.

Introduction

Openreach and Altnets have made investments to deliver wide availability of gigabit-capable full-fibre networks. These networks are all built using single mode fibre. Single mode fibre is an ultra-high capacity medium which is used for virtually all high-capacity services, ranging from residential FTTP starting at tens of megabits, to inter datacentre connectivity supporting terabits of capacity.

There is no distinction or difference in the fibre used to provide FTTP, Ethernet or Optical services in terms of optical performance and they can be used interchangeably. This is a key feature of the Openreach "single fibre network" approach where we build capacity once for all services leveraging common nodes and fibre cables.

[✂]

This is true of individual fibres and the cables that contain tens, hundreds or thousands of individual fibres in a single ribbon cable.

The only difference from an optical perspective between typical residential fibre services which use a PON[1] and a business connection is the use of a power splitter to share the spine[2] fibre and headend equipment.

Splitters are passive devices are typically sited as near to the end customers as possible to reduce the total kilometres of fibre required, with 32 or 64 or even 128 (for some alt-nets) customers sharing a single fibre until a few hundred meters away from the final end point.

From the splitter back to the point of presence, there would be numerous joints and aggregation nodes where spare elements could be connected to. This is analogous to the branch-like nature of a tree – the fibre spines are the trunk and the branches split and diverge multiple times on their route to the customer and each junction could be used to interconnect.

In this report I explain the technological architecture of the networks that have been, and continue to be built, including the different ways that they can be used to serve different customer types.

- **Evolution of Ethernet** – I explain the differences between traditional Ethernet architecture and the architecture of Openreach's and Altnets new networks;
- **Options to leverage existing fibre** – I explain a range of options that can be used to provide leased lines over existing fibre;
- **Ofcom's definitions of leased lines** – I comment on Ofcom's definitions of leased lines and leased line equivalent services, which unduly distinguish between service types.

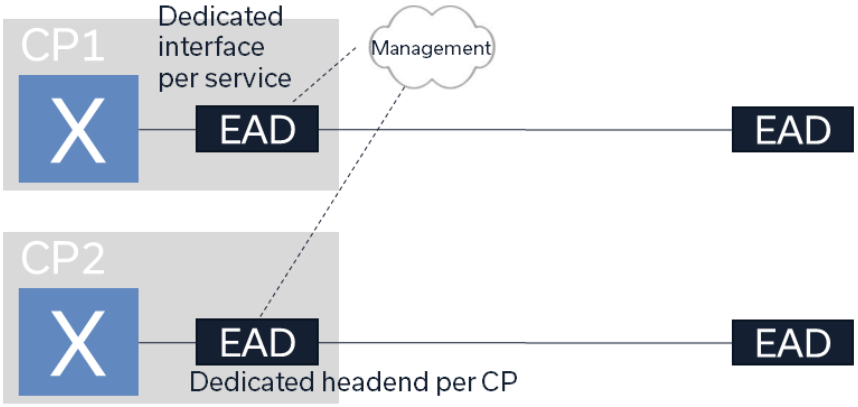
Evolution of Ethernet

[1] A PON is a shared fibre optic network i.e. there is only active electronics at either end of the fibre and no intermediate location.

[2] A spine fibre is the large fibre cable carrying a high number of shared fibres from the aggregation node to the serving headend location.

Openreach's current Ethernet services (EAD)

Until recently, the architecture of Ethernet service delivery from Openreach had not changed in the past 20 years, stemming back to Wholesale Extension Service (WES) / Backhaul Extension Service (BES) services and Digital Wideband Serving Section (DWSS) even earlier. The technology evolved with Ethernet Access Direct (EAD) and increased in speed, but retains the key features of dedicated fibre, dedicated NTEs and installation in CP racks. This is illustrated in the figure below. EAD services remain Openreach's primary and highest volume leased line services.



Openreach's new Ethernet services (EAD2)

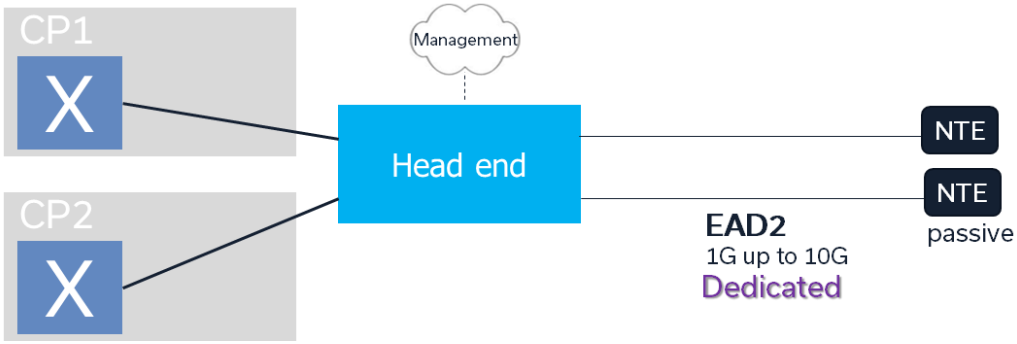
With the development of much higher capacity datacentre equipment, the method of delivery underpinning traditional dedicated Ethernet has been superseded by shared aggregation equipment able to deliver much higher speeds at lower cost, lower energy and lower physical footprint.

This architecture is being adopted by Openreach as part of EAD2 which is a new service currently in development by Openreach in conjunction with our CP customers. [✂][3] and therefore will be present for the majority of the TAR market review period.

EAD2 is an evolution from EAD since it introduces shared switching capacity and interconnect links whilst protecting service quality and access to dedicated bandwidth via ITU / IEEE standardised QoS mechanisms.

This is realised by a "leaf spine leaf" architecture with CP facing Network Node Interface (NNI) devices or leaf, top of rack switches and network facing Ethernet leafs with customer access ports. The structure of EAD2 is illustrated in the diagrams below.

[3] [✂]



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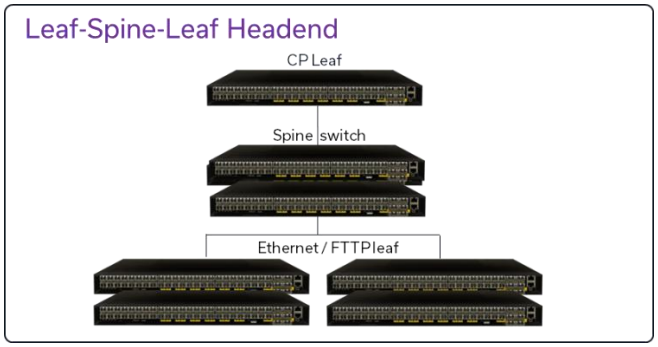
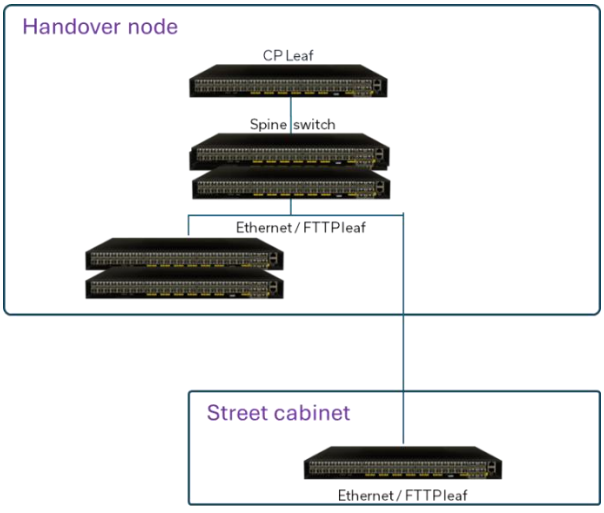


This concept can be further extended to create distributed clusters with the remote Ethernet leaf being in another exchange building or a street cabinet.



This same distributed architecture is used by Openreach for FTTP services – the only difference being the Ethernet leafs are PON Optical Line Terminations (OLTs) either Gigabit Passive Optical Network (GPON) or Combo (GPON and XGS) devices.

[✂]):

This architecture easily enables any FTTP enablement location – be it a handover exchange, a local exchange or a cabinet to be uplifted to support dedicated Ethernet circuits from that location.

This architecture is supplied by ADTRAN[4] and Nokia[5] who also provide equipment to the majority of UK Altnets. Calix[6] also supports similar services.

In conclusion, with modern high-capacity Ethernet architectures there is no meaningful difference between the delivery of dedicated Ethernet services and full fibre FTTP services from an architectural perspective and I believe the major Altnets all use equipment that supports both services.

Service quality

While networks leveraging new datacentre distributed architectures like those described above used shared resources, they are still able to provide "dedicated" bandwidth. On all of these platforms an operator can assure the customer receives their "dedicated" bandwidth though two mechanisms – capacity management and service quality management or both. As part of the latter scheme there are options for strict priority (must come first in all cases) and weighted round robin type mechanisms (taking turns based on weighted priority).

[✂].

Finally, we monitor the load of the various network links to invest in additional capacity ahead of demand if and when required.

In reality, customers rarely use all of their access capacity at the same time and operators benefit from massive statistical multiplexing gain meaning customers experience "dedicated bandwidth" in shared bandwidth networks. This will almost certainly be true of the next step of the end-to-end journey for the customer traffic where statistical multiplexing has been used by CPs for decades at their Provider Edge (PE routers).

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[4] SDX 8000 Series

[5] Lightspan FX for flexible fiber access | Nokia

[6] Active Ethernet | What is Active Ethernet? | Calix Tech

To put this into real world terms, for EAD2 each leaf has 48x 10G ports which can provide 1G, 2G, 3G or 10G with 400G uplink capacity meaning the vast majority of demand will be uncontended at all times. Should all customers take 10Gbps and there was high demand in the uplinks, the devices can be upgraded to 4x 400G uplinks.

The modular nature of this architecture means that in future, should extra capacity ever be needed, the hardware could be incrementally swapped to new boxes supporting 800Gbps connections[7] and there is every expectation that terabit capable links will be available in future.

In short – there is no meaningful technical difference between dedicated and shared infrastructure, apart from how you manage the capacity.

[7] IEEE SA - Ethernet's Next Bar is Now – 800 Gb/s!

Altnets' network architecture

In the UK, the vast majority of Altnets use the same Nokia and ADTRAN equipment as Openreach which supports both FTTP and P2P Ethernet from their OLTs. In many cases this extends to the use of active cabinets as part of the FTTH architecture to minimise fibre / accommodation costs by moving the OLT hardware from the exchange to the street.

I have seen the following examples and evidence of Altnets designing their networks in this way:

- **Hyperoptic** - Hyperoptic shared an image of their FTTP cabinet infrastructure which housed a Nokia FX-8.[8]

- **Go Fibre**[9], **Upp**[10], **Wildanet**[11] and Freedom Fibre[12] all use a cabinet solution from Xantaro which leverages either the Nokia FX-8, FX-16 or MF-2 OLT platforms, all of which support XGS-PON, 25G PON and P2P Ethernet cards today.
- **Gigaclear**[13] - Gigaclear also leverage active cabinets for their FTTP rollouts using ICEE cabinets and ADTRAN equipment that supports Ethernet services.
- **Wildanet**[14] - Wildanet is a particularly interesting example and they secured Project Gigabit funding to deliver services to Cornwall bringing potentially lower cost Ethernet services to these areas via the installation of a linecard costing a few thousand pounds into their publicly funded OLTs.

The Altnets' use of active cabinets gives them an ability to serve a range of different services from the cabinet. Effectively they are able to use a different linecard installed in an existing FTTP asset to leverage the fibre that they have deployed to a cabinet to provide such services.

[8] Hyperoptic Plan Full Fibre for 90% of Islington's Homes and Businesses - ISPreview UK
[9] Go Fibre and Upp Adopt New UK Full Fibre Street Cabinets - ISPreview UK
[10] Go Fibre and Upp Adopt New UK Full Fibre Street Cabinets - ISPreview UK. Note that Upp has recently been acquired by Nexfibre.
[11] Xantaro to accelerate Wildanet deployment with Street Cabinet and Exchange Solutions for Cornwall Full Fibre Network
[12] Xantaro to provide 'Cabinet-as-a-Service' for Freedom Fibre's Shropshire rollout
[13] Gigaclear FTTH UK Roll-Out - ICEE
[14] Project Gigabit network build contracts - Cornwall - GOV.UK

If an OLT slot were free, this could be as simple as installing a new linecard at point of sale, opening up new market opportunities with zero upfront capex.

[✂]

In conclusion, the FTTP equipment and architectures being deployed by Altnets are fully capable of offering carrier grade Ethernet services from their existing platforms.

Options to leverage existing fibre

Even if an Altnet does not deploy active cabinets as part of their architecture, there are a number of other ways to deliver Ethernet leveraging their FTTH investment in single mode fibre.

- Use of spare fibre in spine / aggregation nodes
- PON overlay
- P2P overlay
- WDM PON

I will now discuss these in turn.

Spare fibres

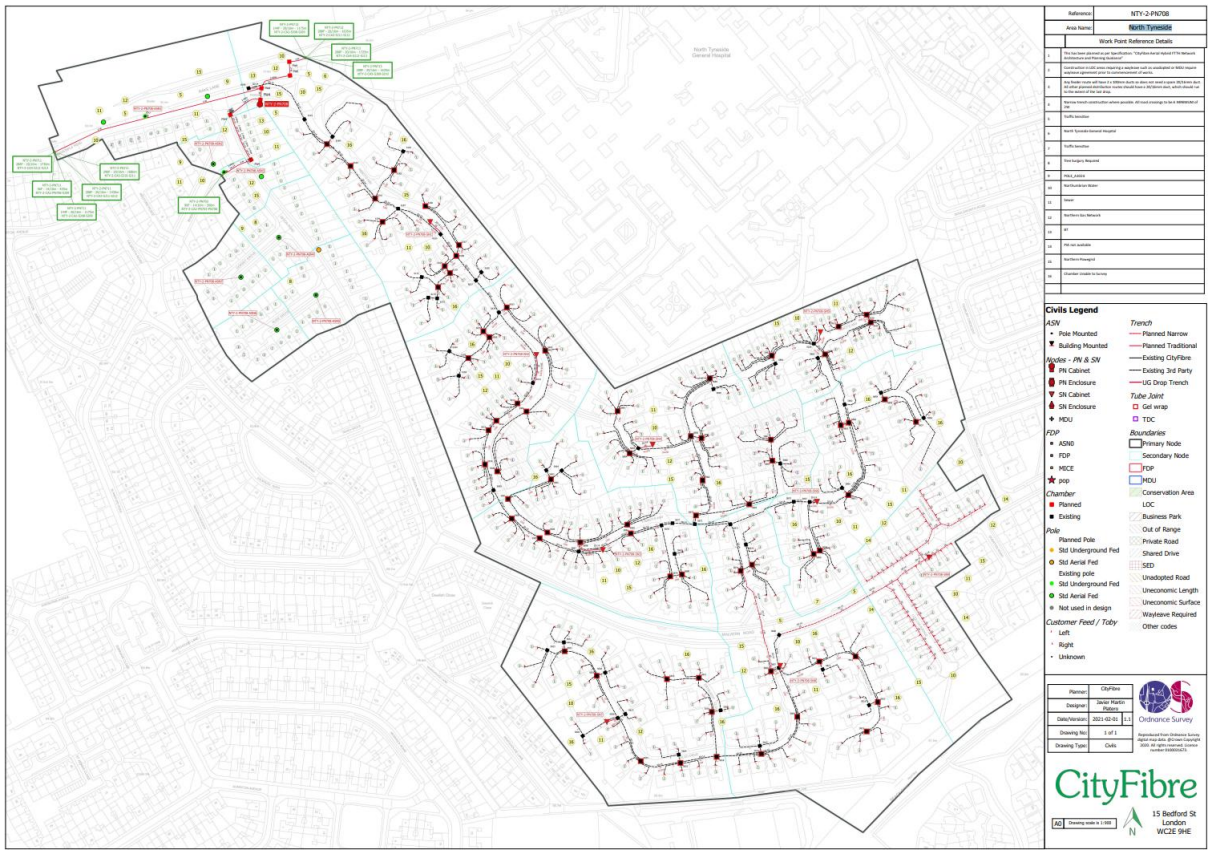
The simplest way to provide a business service would be to leverage spare fibre.

When an operator deploys a fibre network they will have dimensioned the network based on the expected demand and then used fibre cables with at least that number and rounding up to the next cable size which leads to spare fibres in the cables.

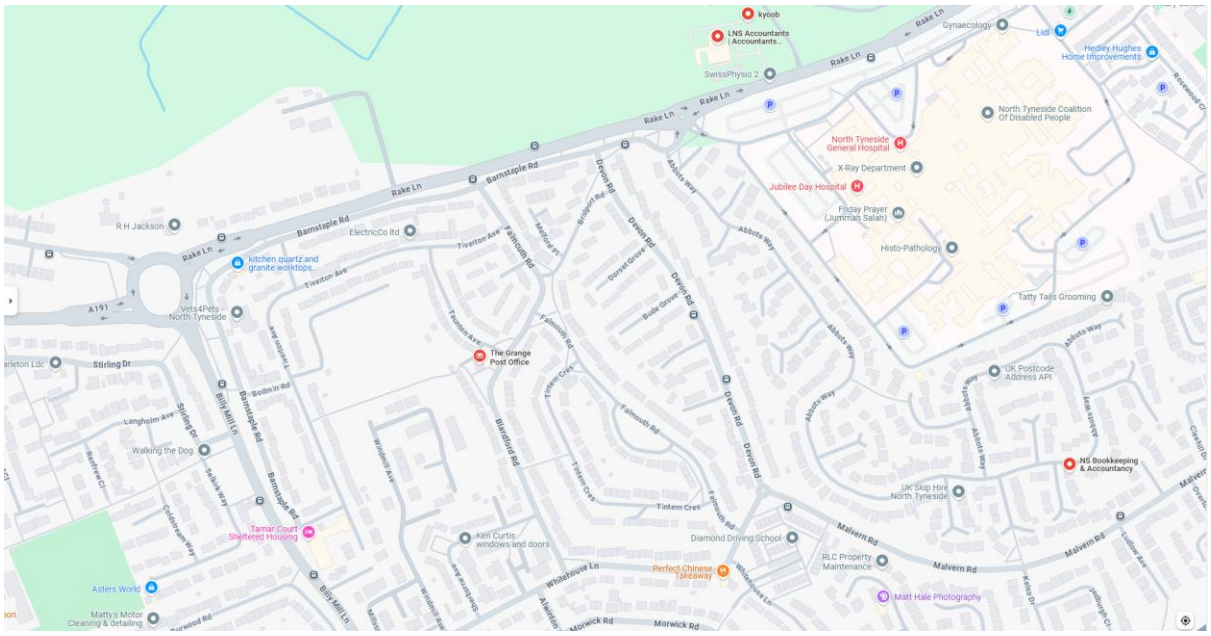
For example cables often increase in elements so 12, 24, 48, 96 and 288 fibre per cable with ribbon cables often having thousands of fibres. Even if not available to the target premise, these spare fibres would be far closer to an end-user than the Altnet's POP, reducing the cost to provide service.

An example of a CityFibre Optical Distribution Network (ODN) from North Tyneside is shown below.[15]

[15] https://docs.planning.org.uk/20210216/222/QOM39YBH0GZ00/yzjwh3xpoxjgq9dc.pdf

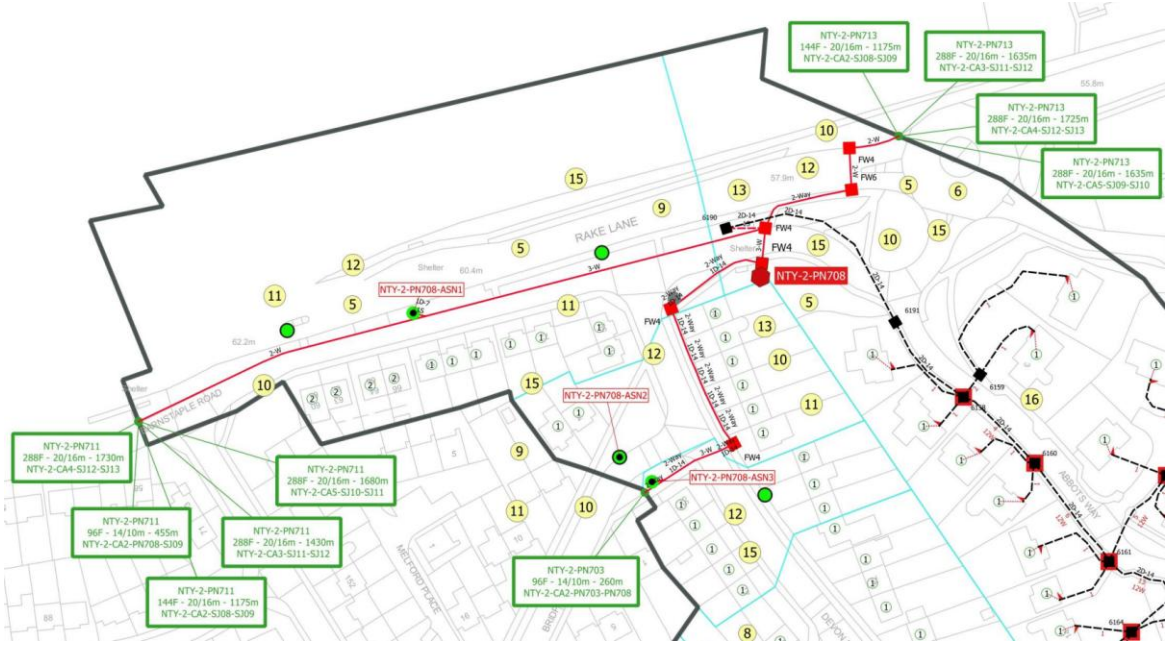


Looking at this same area on Google Maps[16] showed a high number of potential Ethernet customers ranging from North Tyneside General Hospital, schools, accountants, post offices and SMEs:



[16] Barnstaple Rd - Google Maps

Zooming in on the top left of the CityFibre diagram, the incoming spine cables for their ring spine network are shown in the green boxes e.g. 288F is a 288 fibre cable. The total capacity of these spines is 2400 fibres. These spines would then be spliced into the feeder cables show in red and black with the ASN (Aerial subscriber node) having splitters. Squares show footway boxes



Given the level of spine fibre, there is almost certainly going to be one or two spare fibres to provide a dedicated P2P Ethernet service should it be required. Hypothetically, looking at the number of businesses and the proximity of public buildings such as the hospital and school, extra fibre could have been pre-provisioned as CityFibre actively target public sector customers[17] and have already been successful in this market[18]

The presence of nodes along the spine fibres also facilitates broad flexibility. For example, it allows an Altnet to connect into its network to serve different types of sites (perhaps business parks) even if the fibres are ultimately running to residential areas. This could either be at Primary Node locations (PN)[19] or intermediate splicing locations as fibre can only be pulled or blown for hundreds of meters at a time

I also note that the presence of these different aggregation points may allow an Altnet to easily connect to different areas using Openreach PIA. For example, in the CityFibre diagram above, the number 12 signifies "BT" asset and the dotted line representing 3rd party duct and black squares representing existing chambers which is presumably Openreach but couldn't be verified without visiting due to insufficient resolution on Google Street View.

CityFibre is not the only example of networks able to support residential and enterprise services. Ogi have also talk about their ability to provide connectivity for business, datacentres

[17] Public Sector | CityFibre
[18] Suffolk Council awards £75 million contract for new WAN | hSo
[19] https://www.kentonline.co.uk/_media/img/MX4R27QDD4LPF3RK7EMT.jpg, DS_CFNB-BBPN-1X4-P072-G_V1.pdf

and mobile infrastructure[20]. ITS and Boldyn Networks have also announced plans to reach ~70% of London's commercial premises[21].

Optical coexistence

The vast majority of optical services use "colours of light" which can share the same fibre without any interference. By using optical filters, you can reuse the fibre for different services as long as they don't overlap. This could be done in a number of ways.

PON overlays

The easiest way is to use the inherent coexistence of PON technology, designed in from the birth of the technology to allow seamless upgrades for customers.

As part of the ITU standardisation process, each PON technology uses different wavelengths to allow coexistence between generations. Today a single fibre can have GPON, XGS-PON and 50G-PON on the same ODN (aka "Triple coexistence") without conflict and this was demonstrated by Openreach in January 2025 on a residential PON delivering download speeds of 41.9Gbps and upload speeds of 20.6Gbps.[22]

When operating in overlay, all customers receive all wavelengths, but the ONT only processes the wavelength for that technology. Light from the other wavelengths is discarded in the narrowband filter in the ONT.

This means that a business can be connected to "business PON" service at a higher capacity allowing dedicated bandwidth for those businesses and separate authentication and encryption keys compared to the residential PON customers.

This has recently been demonstrated by ITS[23] and Netomnia[24] where they have both deployed Generally Available (GA) 50Gbps PON technology from ADTRAN in an overlay configuration to provide the 50G down / 25G up service to a dedicated customer.

These deployments leverage the SDX 6405 OLT which supports 50G PON and combo operation on four PON ports and 2x100Gbps uplinks and the SDX642 50G ONT that also supports 100G Ethernet connections for the end user. This means the solution can easily support an uncontended 10Gbps or 20Gbps symmetric service today and 40G/20G asymmetric service.

It is fully expected that higher capacity and volume products will be available from both vendors in the next five years.

Looking at the press releases and subsequent articles, it's clear that these services are intended to provide service to enterprises:

ITS: "10Gb+ Business Services: Business customers requiring 10Gbps symmetrical and above can now be served more cost-effectively, with less fibre strain and faster deployment."

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[20] Multimillion-pound package to support next stages of growth - Ogi, Fibre Broadband Wholesale | Unlocking Capacity | Ogi

[21] Boldyn Networks and ITS Tech to Build New Full Fibre Networks in London - ISPreview UK

[22] Openreach run 'hyper-fast' 50Gbps broadband line in UK first.

[23] ITS Technology Claims First Live UK Biz Customer Trial of 50Gbps PON - ISPreview UK

[24] Netomnia Goes Live with First 50Gbps UK Full Fibre Broadband Network - ISPreview UK.

Netomnia: “At Netomnia, we’re building a fibre network for whatever comes next — and with the UK’s first commercial 50G PON deployment, we’re proving it. This isn’t just about speed; it’s about power. From AI-driven smart homes to lag-free metaverse experiences and tomorrow’s enterprise demands, we’re making sure the most powerful internet lives on our network.”

ADTRAN:

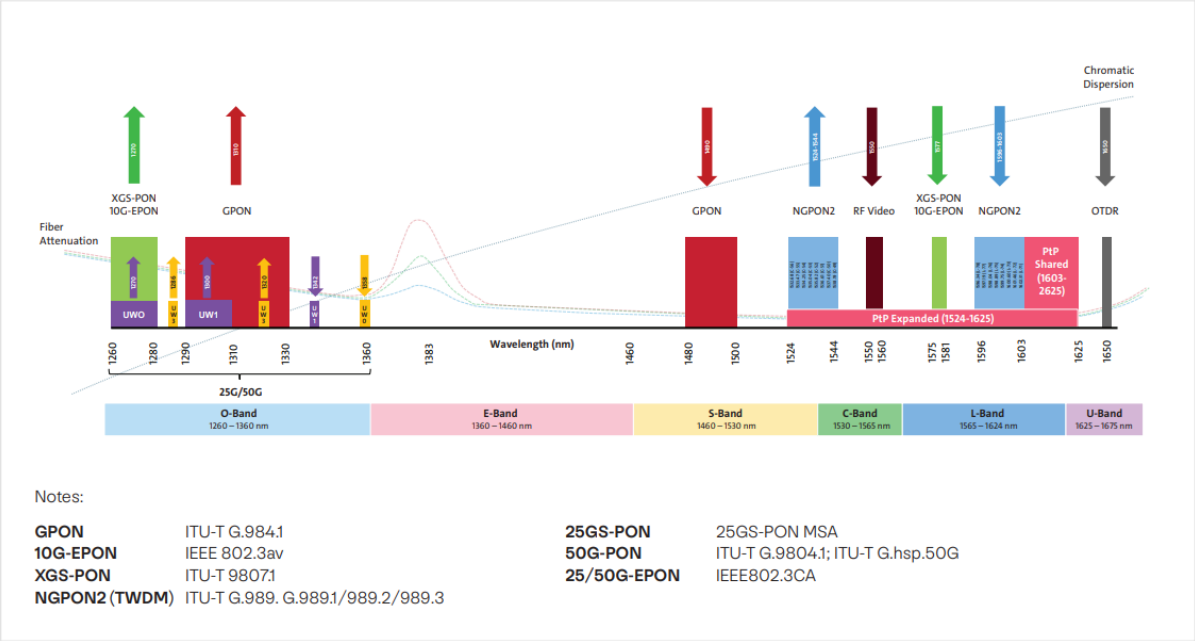
“The deployment demonstrates how our SDX 6400 Series empowers operators to scale capacity, accelerate service delivery and support next-generation applications, all while leveraging their existing infrastructure. As demand surges for bandwidth-intensive services like generative AI, 5G backhaul and enterprise connectivity, this project shows how we’re helping partners like Netomnia stay ahead of the curve.”

With Netomnia passing 2M homes and counting[25] and leveraging PIA[26], this technology will give them ever increasing reach to provide symmetrical business services on either a proactive basis by upgrading their existing footprint or a reactive basis by installing the 50G OLT when they receive a customer order.

P2P overlay

When NG-PON2 was standardised and subsequently used by Verizon it offered 4x10Gbps PON wavelengths and a number of point to point wavelengths for business services over the PON. This allowed the use of dedicated “point to point” services over the common ODN.[27]

This P2P shared region can be seen on the right hand side of this Corning coexistence diagram[28]:



To leverage these point to point links, the enterprise customer or mobile site would install a coloured optic into their equipment at either end of the fibre and then operate as a normal p2p

[25] Netomnia end of year results
[26] Netomnia use of PIA
[27] Verizon VP: NG-PON2 will make future fiber upgrades easier | Fierce Network
[28] CRR-1836-AEN.pdf page 3

link, albeit with a higher optical loss due to the power splitter. In the central office, a WDM component is used to extract the p2p wavelength before the OLT, an example of which is in the Corning documentation.

WDM systems

Should a CP want to leverage existing fibre for access or backhaul connections, this can be done passively using CWDM or DWDM systems and filters to route the different colours of light to the right customer.

Coloured optics are more expensive than grey optics, but are cheaper than installing new fibre.[29]

This could be used either for backhauling a new active cabinet sharing an existing fibre or providing multiple access services over common spine fibre with a WDM splitter to separate them out for the final connection.

[✂].

WDM PON

Slightly more exotic and currently not in deployment is WDM PON, where the passive splitter is replaced with a wavelength splitter (AWG) to give a dedicated wavelength to reach business premise. In this configuration only the spine fibre is shared with each customer receiving a dedicated wavelength and the final customer connection only having their connection.

An alternative approach was pioneered by Infinera[30] using their ZR optics to create virtual P2P links over PON using coherent optics and advance encoding techniques. This gives dedicated spectrum whilst reusing the power splitter[31].

Conclusion

In conclusion there are a number of engineering solutions to leverage and reuse existing fibres to boost capacity and offer dedicated bandwidth to enterprise customers using FTTH infrastructure. Many if not all were covered in the Ofcom report on the Evolution of Fixed Access published in 2023.[32]

In the case of PON overlay and WDM these are already in use in the UK today.

[29] DWDM SFP (mini-GBIC) Transceiver Modules - FS.com United Kingdom

[30] Turbocharge Your Single-fiber Access/PON Network - www.infinera.com

[31] Virgin Media trials cutting edge multi-gigabit network technology - Virgin Media O2

[32] Evolution of Fixed Access

Ofcom's definitions of "leased lines" and "leased line equivalent"

In Ofcom's TAR consultation it defines "leased lines" and "leased line equivalent" services. In making this distinction Ofcom has highlighted some criteria that distinguish between these services. One aspect it focuses on is security which I discuss below.

Further, Ofcom has given a set of criteria to describe what it considers is a "leased line equivalent" services. I do not consider all of these criteria to be useful, since assessing services against these criteria does not lead to such a binary distinction as implied by Ofcom's definitions. I will discuss its consideration of capacity below.

[✂]

Capacity

In relation to leased line equivalent services Ofcom also states *"We also recognise that as of today, these services will not be a substitute to point-to-point leased lines at all bandwidths. The uncontended capacity which can be offered on any symmetric PON (such as XGS-PON) will be limited by the type of PON technology installed and will be below the headline bandwidth of that PON technology."* And *"As such, these services might not be directly substitutable for leased line customers that require 10 Gbit/s or higher bandwidth services (such as MNOs)."* [33]

Current PONs

The majority of leased line customers currently use 100Mbps services. It is obviously easier to guarantee 100Mb to customers than higher bandwidths. Indeed, this means that it is possible to provide services with 'dedicated' capacity suitable for businesses today on GPON. [✂]:

[✂]

	Latest Weekly Values (Mbit/s)					
	Downstream			Upstream		
Measure	Peak	Evening	Midday	Peak	Evening	Midday
Median	12.4	3.0	1.4	1.5	0.2	0.1
80th Percentile	24.2	4.2	2.1	3.1	0.3	0.2
90th Percentile	35.7	5.0	2.7	4.6	0.4	0.3
95th Percentile	50.0	5.9	3.3	6.6	0.5	0.4
99th Percentile	102.2	8.5	5.4	14.5	1.1	1.0
Maximum	1,012.7	315.5	247.2	225.0	74.6	51.6

[✂].

[✂].

[✂].

[✂]

[33] Ofcom, TAR consultation document, Volume 2, 5.29.

[✂].

Ofcom says that leased line equivalent services are those that are delivered over symmetrical PONs, such as XGSPON. It finds that services delivered over GPON are not part of this category.

We believe [✂] that GPON can offer business grade services and while GPON is not symmetric it can be used to provide a symmetric service up to and including 1Gbps with uncontended bandwidth in the majority of cases and assured bandwidth via traffic management under exceptional load.

Ofcom cites CityFibre's services as an example of a leased line equivalent service.[34] Based on what is publicly available, CityFibre only has one product which delivers Ethernet over FTTP listed on their website 'Ethernet 1000 Flex'. This matches Ofcom's description of providing 1Gb symmetrical speeds and an element of uncontented capacity at 200Mb, however as per their product sheet it appears to be delivered over GPON technology not XGSPON. The product sheet states that it is handed over on 'Calix GigaPoint 801G V2 ONT' which is a G-PON based NTE.[35] Further, CityFibre recently unveiled a 5.5Gbps product made possible by a 10Gb XGS-PON.[36]

CityFibre also use XGS-PON to deliver leased line equivalent services, which demonstrates that PON technology is already being used to replicate leased line services.[37]

Future PONs

PON technology continues to move at great pace. [✂].

25Gbps symmetric PON, which offering >20Gbps symmetric throughput is already generally available from Nokia and built into the combo linecards they offer for their FX and MF platforms being deployed by Openreach and Altnets.

The use of 25Gbps PON would allow the uncontended delivery of two 10Gbps Ethernet services to business, whilst still providing up to 8Gbps services to residential customers via XGS-PON. This is the preferred delivery method as 25Gbps ONT will be far more expensive than the XGS ones in the medium term.

50Gbps PON is also being introduced into the market with technology trials and first customer connections already completed and Netomnia and Ogi announcing deployment plans. 50G-PON is widely expected to the next mass market PON technology and is already undergoing interoperability testing by the Broadband Forum[38].

[✂].

Looking slightly further out the development of the next PON technology has already begun with the ITU studying Very High Speed PON or VHSP[39]. [✂].

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[34] Con Doc, Vol2, 5.21.
[35] CityFibre, 'Ethernet 1000 Flex'.
[36] CityFibre unveils new 5.5Gbps wholesale product, its... | CityFibre
[37] CityFibre Says Enterprise-grade Ethernet Services Reach 260,000 UK Businesses - ISPreview UK
[38] 2025.05.07 - 50G-PON gets testing debut at Broadband Forum interoperability 'Plugfest' - Broadband Forum
[39] PowerPoint Presentation – OFC50 ITU-T SG15 update

However a lack of a standard hasn't prevented operators and vendors from trialling 100Gbps systems with Nokia and Elisa demonstrating 100G PON over live network[40]. This is built on the earlier Vodafone 100G results[41].

These high speed PON technology allow a shared ODN to give dedicated symmetric bandwidth of 10Gbps today, rising to 40Gbps in the next few years and potentially 100Gbps leased line equivalent over the next 5 years allowing PON to be competitive with P2P for access connections for the foreseeable future.

Conclusion

Today's fibre networks are technically just as capable of providing leased lines services as they are broadband services. The distinction between these services is not binary and once fibre has been built, network providers have a range of options for providing services to different sorts of end customers to meet their needs, including high bandwidth services for business customers.

This ranges from low cost solutions of reusing the existing PON and assuring the bandwidth via a service quality mechanism all the way through to dedicated fibres and/or wavelengths services.

Just because an Altnet doesn't provide leased lines today, it doesn't mean that they or the entity that takes them over, couldn't do so tomorrow. Indeed, ITS and Netomnia have announced in recent weeks the intent and the technology to do just that.

Ultimately once a fibre spine is deployed to a given area, any service can be offered – even up to Terabit data centre connections.

[40] Nokia and Elisa become first in Europe to trial 100G PON over live fiber broadband network | Nokia.com
[41] Nokia and Vodafone showcase record-breaking 100 gigabit fiber broadband