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# Current Shifts & Future Opportunities in the Physical Layer

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# HellermannTyton Connectivity

FTTH Connectivity and Blown Fibre Solutions

A specialist manufacturer of structured cabling systems and broadband fibre optic infrastructure solutions.

INCA
the independent networks cooperative association

Member of Fibre to the Home Council Europe

The Fibreoptic Industry Association
FIA

bsi. ISO 9001 Quality Management FM 34289 ISO 14001 Environmental Management EMS 504454

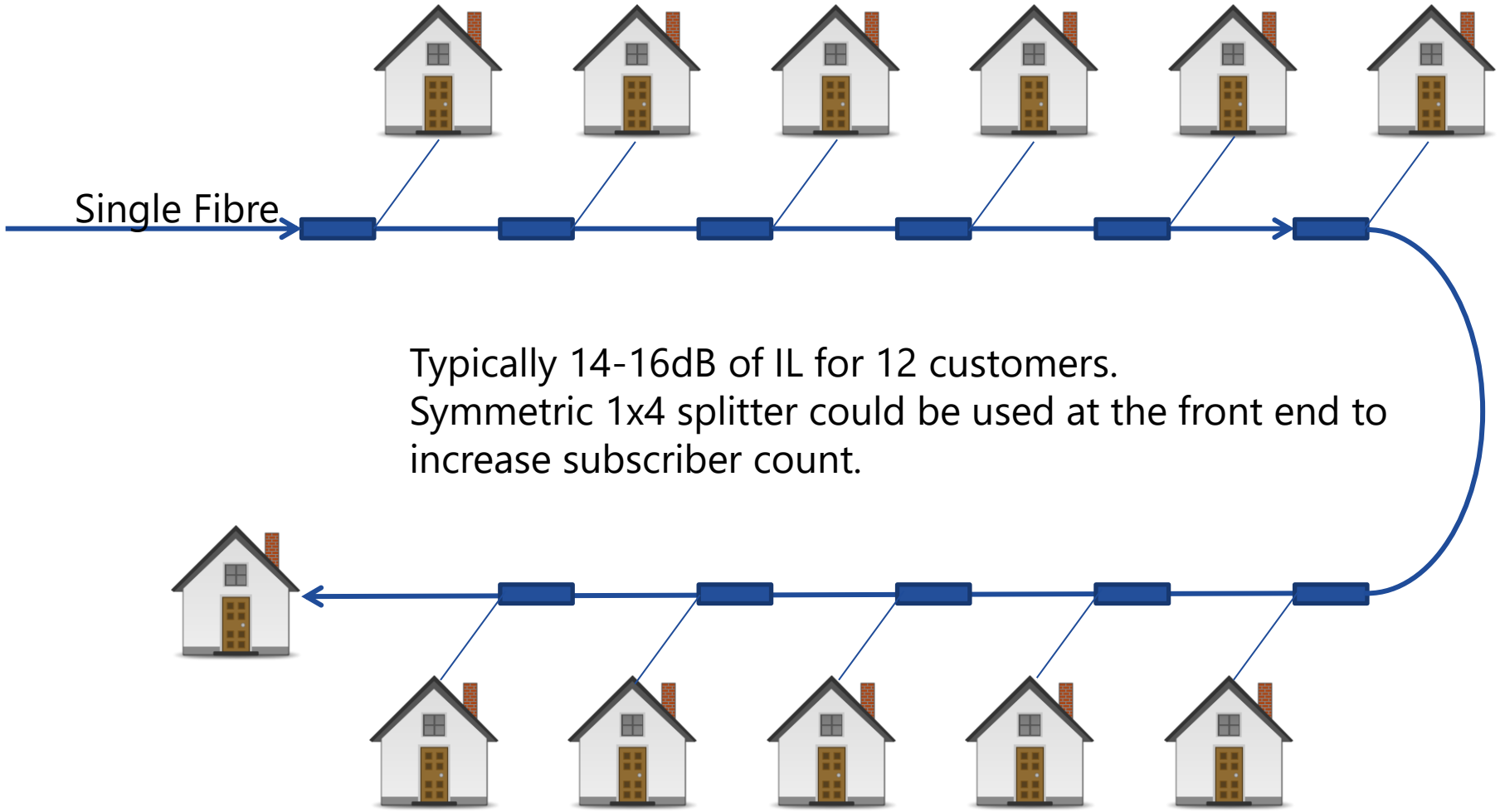
# Builds Slowly Shifting Towards A Rural Focus

## Enabling our rural communities

- Although many urban areas are still  being actively built and in many cases over-built, more and more of the larger CPs are now selecting, designing and planning builds in areas with a lower population density.
- This is leading towards a greater number of overhead (OH) deployments instead of underground (UG) as many rural areas are already serviced this way.
- There are of course exceptions and much of the recently introduced fibre network delivered by the likes of GigaClear is UG.

- To optimise OLT port efficiency and improve OpEx costs, operators are considering a dual or triple split approach to this type of build, placing the lowest split count closest to the subscriber with cross-connect style ODF solutions up-stream to allow for long term management and configuration.
  - This allows the more gradual illumination of active OLT ports.
- As builds become smaller and further apart operators are deploying µPOPs as well as ever-evolving disaggregated OLTs to combat fewer subscribers and longer reaches.

# Distributed Splitters Reduces Fibre Requirements



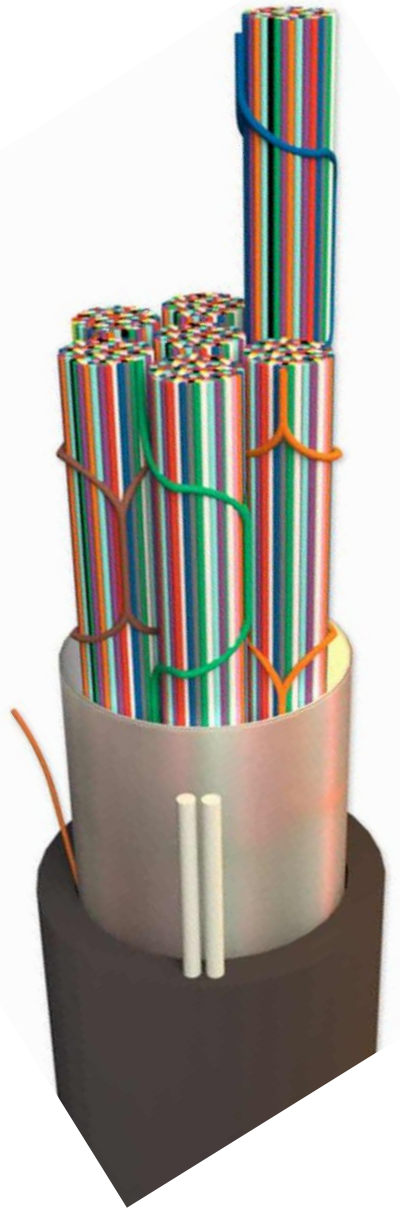
# Fibre Unbundling

## Providing more choice for the customer

- Customer choice in the rural space is just as important as it is in the urban one.
- Rural builds have been somewhat neglected (ear-marked for phase 2) as they are significantly more expensive to reach and service.
- Those providers who have risen to the challenge have an asset that they can sell *wholesale* to others to help ensure choice and healthy competition.

- Wavelength unbundling, usually as a passive DWDM solution, is also an option and one that is likely to see more interest in the future as more and more providers start to overbuild.

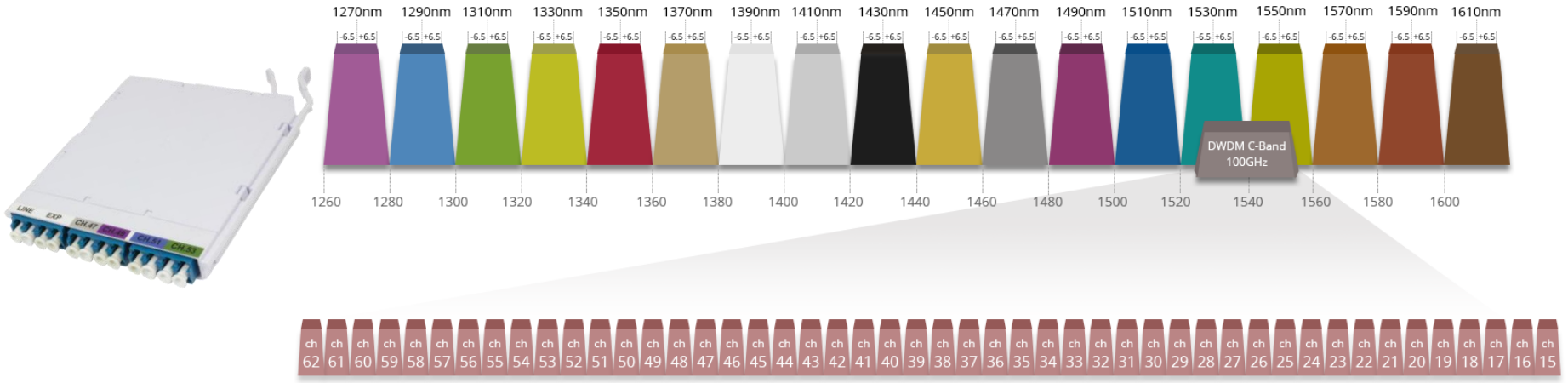
- Fibre unbundling may not be the long-term solution to this challenge but until common infrastructure and service unbundling is a reality in the UK, it's the next best thing for the customer.

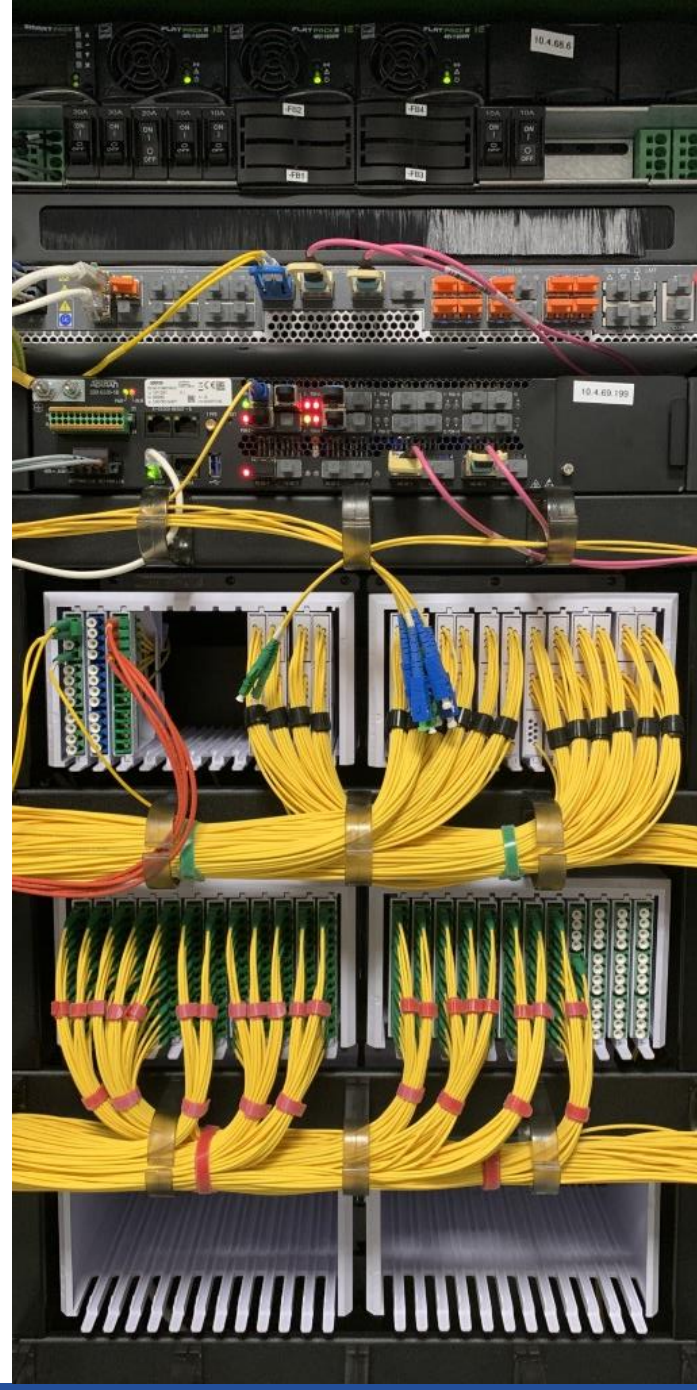


# Dark-Fibre & POP Backhaul

## The case for Wavelength Division Multiplexing

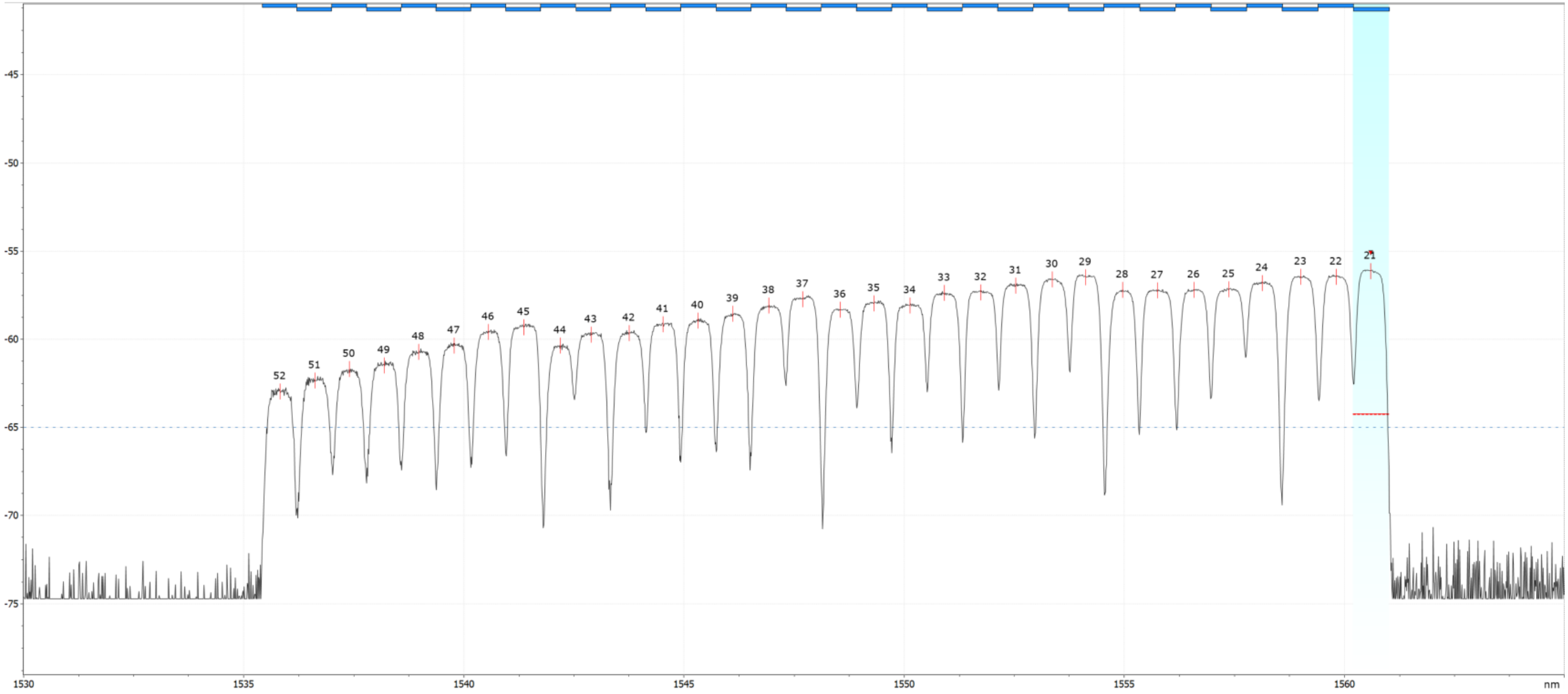
- Wavelength division multiplexing isn't new in the long-haul and carrier space but it is gaining momentum for use over shorter distances where high fibre counts are challenging and costly to deploy.
- P2P DWDM and OADM solutions, especially with tuneable optics, allows highly cost effective inter-connectivity between distributed µPOPs where densely populated fibre routes don't exist or are commercially prohibitive.
- CWDM is being employed where bandwidth sharing using XGS-PON or similar isn't desirable for some SME or similar subscribers. Maximising fibre resource allocation with multi-wavelength utilisation further improves investment in fibre deployments. Offering a hybrid solution is of course the best of both worlds.



# DWDM FBG Filter Spectral Performance

32 Channels (Ch.21 – Ch.52) – Wavelength from left to right



# 100GHz DWDM Channel Spacings

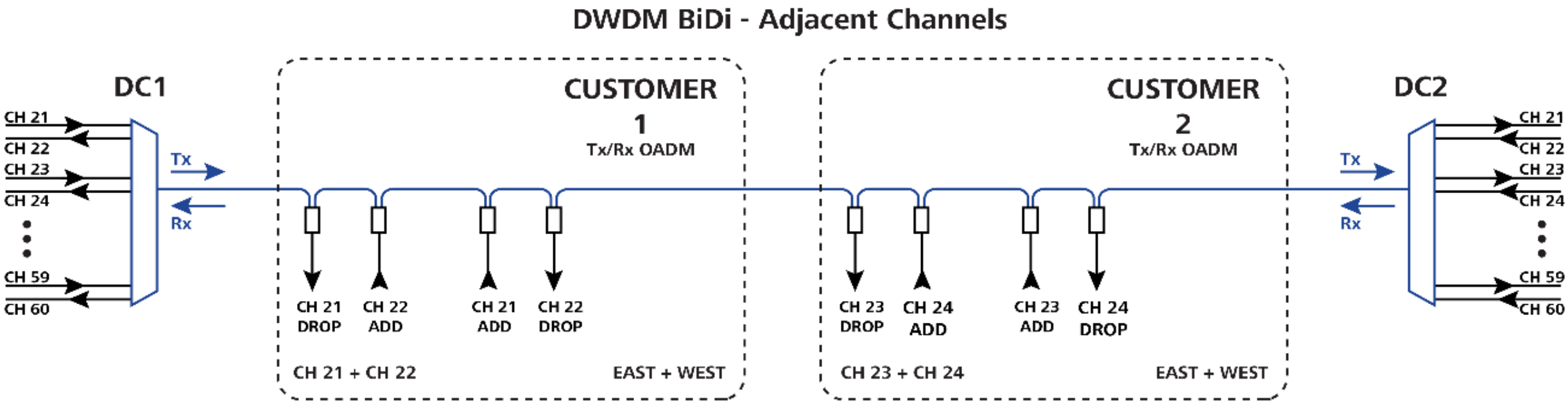
## Typical 32 Channel DWDM Allocations

- ITU-T G.941.1 allows for 100GHz channel spacing.
- 50GHz, 25GHz and 12.5GHz are also covered in the standard.
  - Channel numbers double for the same bandwidth as spacing is halved.
- Numerous vendor specific and generic transceivers available that operate up to 100Gbps on these grid spacings.

| 100 GHz Spacing | | | | | |
|---|---|---|---|---|---|
| Channel | Freq (GHz) | Wavelength (nm) | Channel | Freq (GHz) | Wavelength (nm) |
| 21 | 192100 | 1560.61 | 37 | 193700 | 1547.72 |
| 22 | 192200 | 1559.79 | 38 | 193800 | 1546.92 |
| 23 | 192300 | 1558.98 | 39 | 193900 | 1546.12 |
| 24 | 192400 | 1558.17 | 40 | 194000 | 1545.32 |
| 25 | 192500 | 1557.36 | 41 | 194100 | 1544.53 |
| 26 | 192600 | 1556.55 | 42 | 194200 | 1543.73 |
| 27 | 192700 | 1555.75 | 43 | 194300 | 1542.94 |
| 28 | 192800 | 1554.94 | 44 | 194400 | 1542.14 |
| 29 | 192900 | 1554.13 | 45 | 194500 | 1541.35 |
| 30 | 193000 | 1553.33 | 46 | 194600 | 1540.56 |
| 31 | 193100 | 1552.52 | 47 | 194700 | 1539.77 |
| 32 | 193200 | 1551.72 | 48 | 194800 | 1538.98 |
| 33 | 193300 | 1550.92 | 49 | 194900 | 1538.19 |
| 34 | 193400 | 1550.12 | 50 | 195000 | 1537.40 |
| 35 | 193500 | 1549.32 | 51 | 195100 | 1536.61 |
| 36 | 193600 | 1548.51 | 52 | 195200 | 1535.82 |

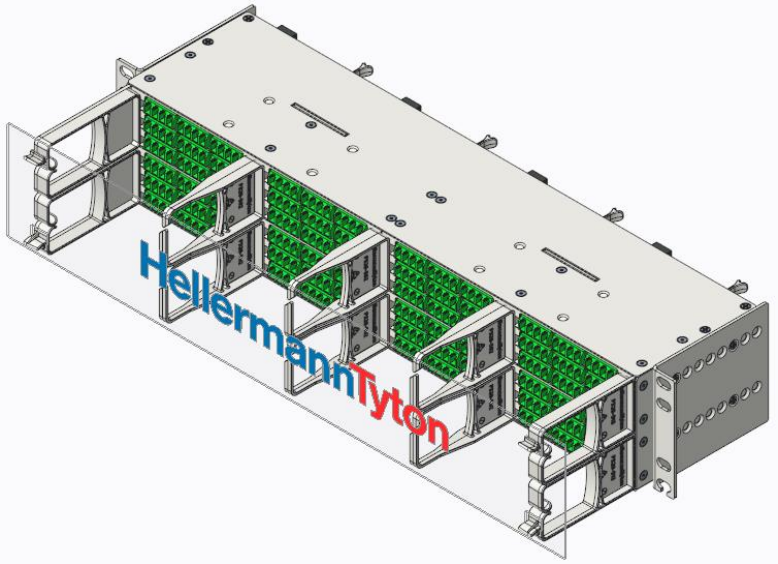
# BiDi DWDM & Dynamic Routing

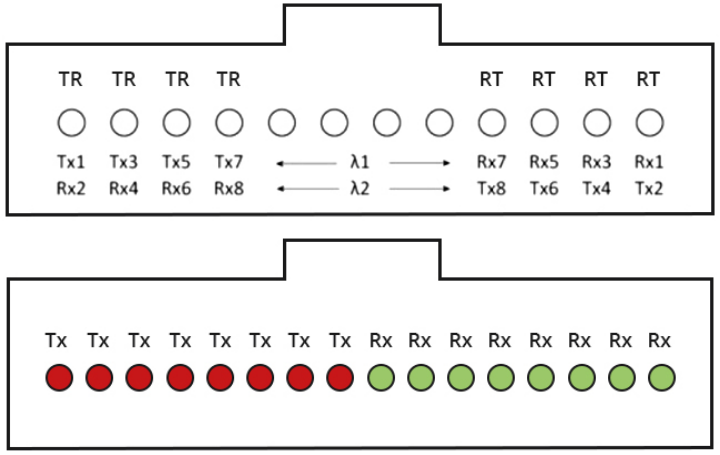
Using OADMs and WDM to improve µPOP availability in a disaggregated FTTH Network



# Optical Densification & Parallel Transmission

- Advances in laser baud rate, encoding, coherent optics and WDM are constantly increasing the overall throughput of optical transceivers.
- Increasing the number of fibre lanes is an alternative way to achieve similar results but requires an uplift in the physical layer that can cause significant disruptions.
- 400GBase-SR4.2 uses PAM4 signalling and existing 8F MPO connectivity, 400GBase-SR8 requires new 16F MPO connectivity.
- 800GBase-SR utilises PAM4 over multiple lanes in the near term but baud rate increases will allow the number of fibre lanes to reduce in time.




| | 400GBASE-SR4.2 | 400GBASE-SR8 |
|---|---|---|
| Alliance | IEEE 802.3cm | IEEE 802.3cm (breakout: 802.3cd) |
| Max reach | 150m over OM5 | 100m over OM4/OM5 |
| Fibers | 8 fibers | 16 fibers (ribbon patch cord) |
| Wavelength | 2 wavelengths (850nm and 910nm) | 1 wavelength (850nm) |
| BiDi technology | Support | / |
| Signal modulation format | PAM4 signaling | PAM4 signaling |
| Laser | VCSEL | VCSEL |
| Form factor | QSFP-DD, OSFP | QSFP-DD, OSFP |

# Ethernet Alliance – Roadmap to 1.6TBase-xxx

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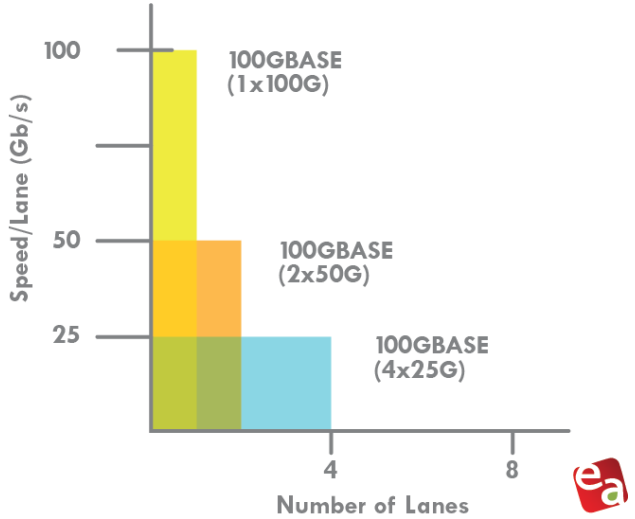
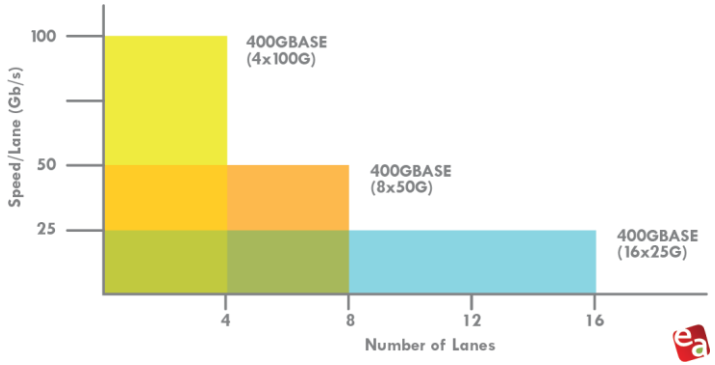
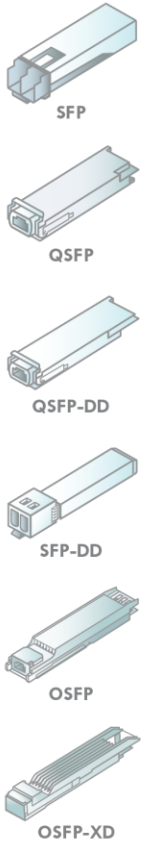



| | Backplane | Twinax Cable | 15-40m(OT) Single Twisted Pair | >100m (OT) Single Twisted Pair | 100m (IT) Twisted Pair (2/4 Pair) | MMF | 500m PSM4 | 2km SMF | 10km SMF | 20km SMF | 40km SMF | 80km SMF | Electrical Interface | Pluggable Module |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10BASE– | T1S | | T1S | T1L | T | | | | | | | | | |
| 100BASE– | | | T1 | T1L | T | | | | | | | | | |
| 1000BASE– | | | T1 | | T | | | | | | | | | SFP |
| 2.5GBASE– | KX | | T1 | | T | | | | | | | | | SFP |
| 5GBASE– | KR | | T1 | | T | | | | | | | | | SFP |
| 10GBASE– | | | T1 | | T | SR | | | -BR10-D/U LR | -BR20-D/U | -BR40-D/U ER | | | SFP |
| 25GBASE– | KR1 KR | CR1 CR/CR-S | T1 | | T (30m) | SR | | | LR EPON -BR10-D/U | EPON -BR20-D/U | ER -BR40-D/U | | 25GAUI | SFP |
| 40GBASE– | KR4 | CR4 | | | T (30m) | SR4/eSR4 | PSM4 | FR | LR4 | | ER4 | | XLAUI XLPPI | QSFP |
| 50GBASE– | KR2 KR | CR2 CR | | | | SR | | FR | EPON LR -BR10-D/U | EPON -BR20-D/U | ER -BR40-D/U | | LAUI-2/50GAUI-2 50GAUI-1 | SFP/QSFP |
| 100GBASE– | KR4 KR2 KR1 | CR10 CR4 CR2 CR1 | | | | SR10 SR4 SR2 VR1 SR1 | PSM4 DR | CWDM4 FR1 | LR4 4WDM-10 LR1 | 4WDM-20 | ER4/ 4WDM-40 | ZR | CAUI-10 CPPI CAUI-4/100GAUI-4 100GAUI-2 100GAUI-1 | SFP/SFP-DD QSFP/QSFP-DD OSFP |
| 200GBASE– | KR4 KR2 | CR4 CR2 CR1 | | | | SR4 VR2 SR2 | DR4 DR1 | FR4 FR1 | LR4 | | ER4 | | 200GAUI-4 200GAUI-2 200GAUI-1 | QSFP/QSFP-DD SFP-DD |
| 400GBASE– | KR4 | CR4 CR2 | | | | SR16 SR8/SR4.2 VR4 SR4 | DR4 DR2 | FR8 FR4 400G-FR4 DR4-2 | LR8 LR4-6 400G-LR4-10 | | ER8 | ZR | 400GAUI-16 400GAUI-8 400GAUI-4 400GAUI-2 | QSFP/QSFP-DD OSFP |
| 800GBASE- | ETC-KR8 KR8 | ETC-CR8 CR8 CR4 | | | | VR8 SR8 | DR8 DR4 | DR8-2 DR4-2 FR4 | TBD | | TBD | | 800GAUI-8 800GAUI-4 | |
| 1.6TBASE- | | CR8 | | | | | DR8 | DR8-2 | | | | | 1.6TAUI-16 1.6TAUI-8 | QSFP/QSFP-DD OSFP/OSFP-XD |

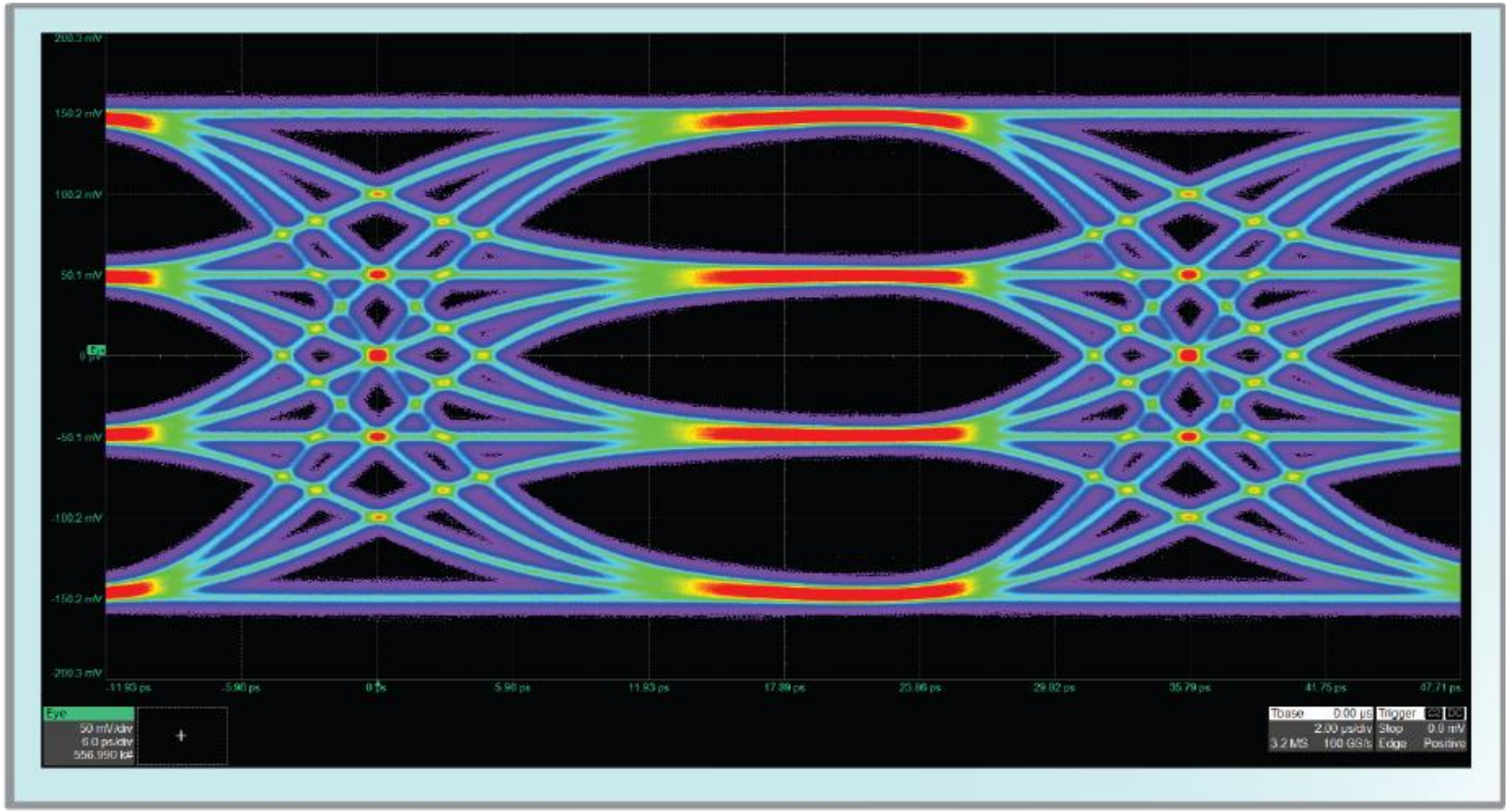



Gray Text = IEEE Standard  Red Text = In Task Force  Green Text = In Study Group

Blue Text = Non-IEEE standard but complies to IEEE electrical interfaces  * Note: As of publication, subject to change

# Optical Encoding Schemes

How do we increase the bits per baud?



# Small & Micro-Cell Front Haul

- G.Metro is an ITU-T recommendation (G.698.4) and auto-tuning WDM optics that all but remove the burden of manual wavelength allocations and management.
- WDM, especially BiDi can realise massive fibre savings and make *small* cell deployments viable, even on the scarcest of fibre resources.
  - CWDM – short distances, low channel count.
  - DWDM – longer distances and higher channel count.
- Small form factor interconnect from existing FTTH providers are probably the most prevalent, convenient and commercially viable for large scale MNOs.
- Tremendous numbers of assets and opportunities in countless towns and cities will have a significant impact on MNOs' build plans and *smart-city* realisation.

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# Thank you – let's stay in contact


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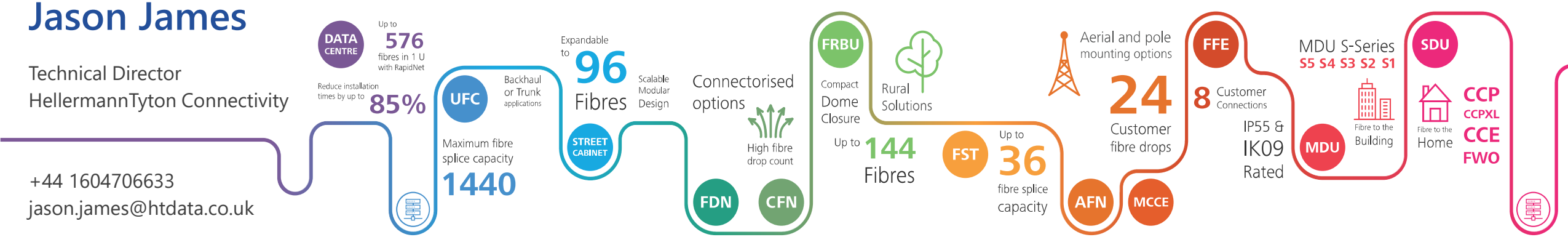

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