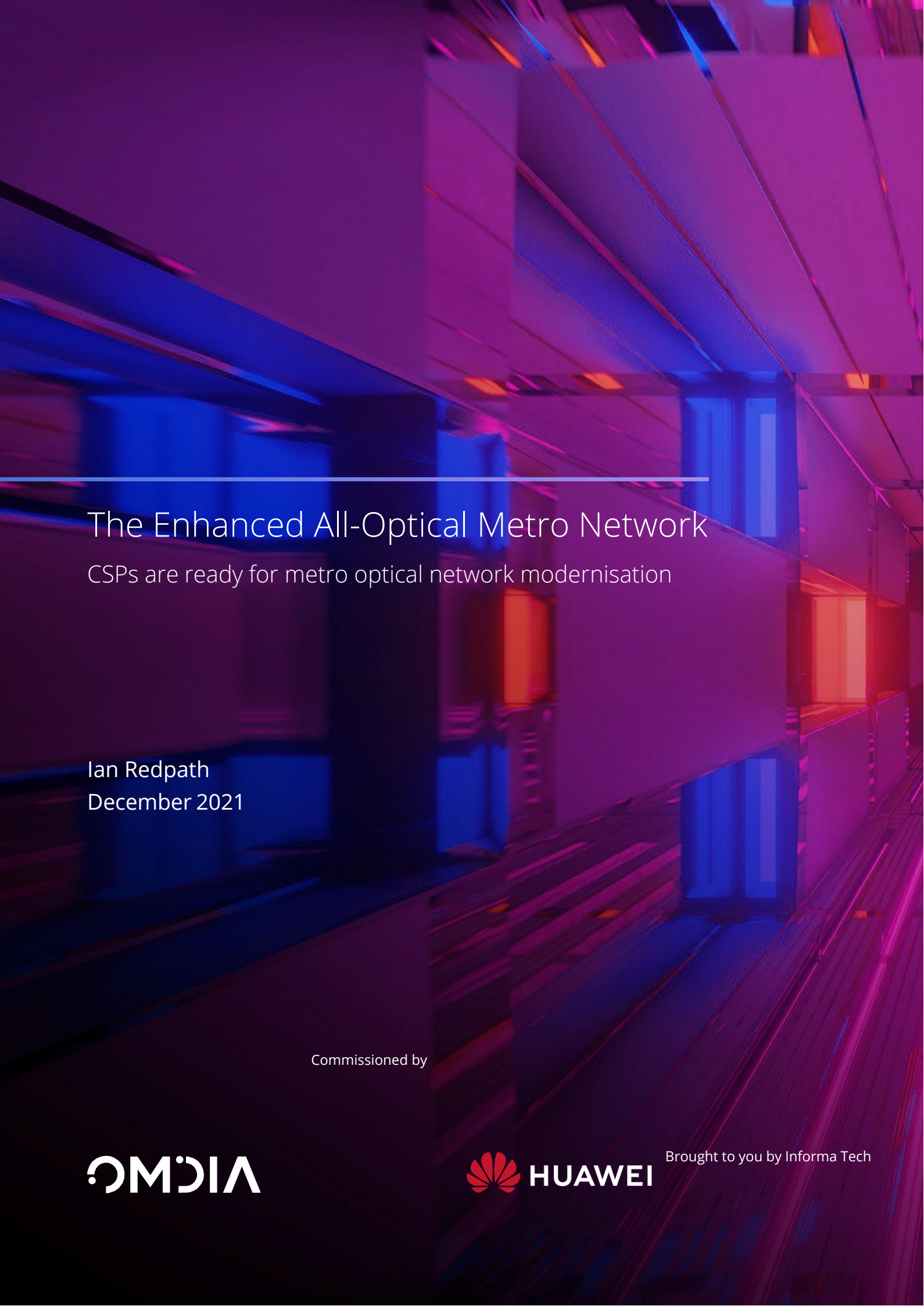

The Enhanced All-Optical Metro Network

CSPs are ready for metro optical network modernisation

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Executive summary

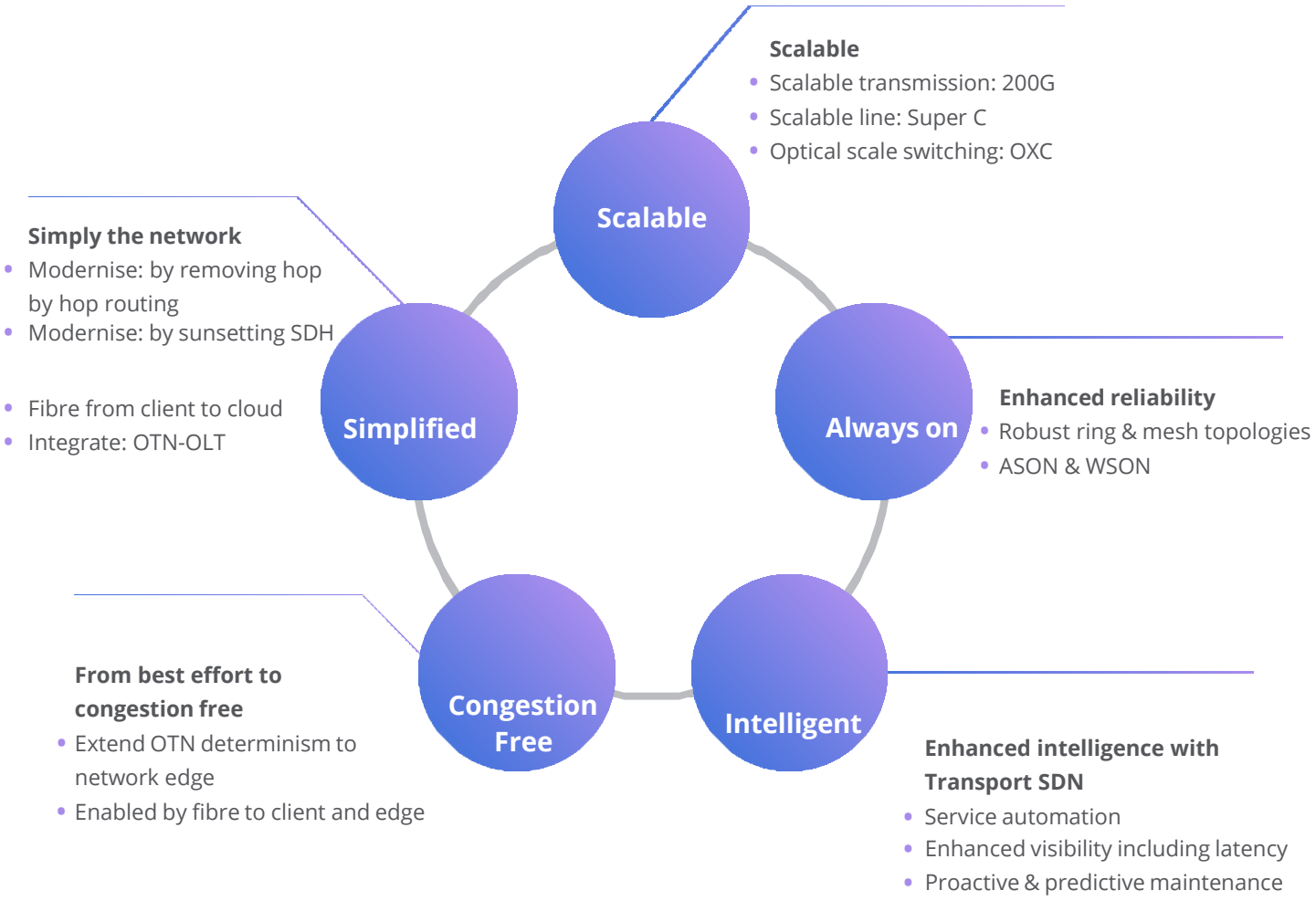
The digital economy and 5G are driving unprecedented network change. Enterprises, "at-home" residential, fixed, and mobile clients all have heightened performance expectations and demand greater scale.

The communications service provider (CSP) community is wrestling with many challenges. Metro optical networks support the noted retail clients as well as some very high-capacity wholesale services. Both retail and wholesale traffic are growing at exceptional rates. CSPs can take advantage of the latest optical network capabilities to modernise their networks.

CSPs can modernise their networks to meet new client needs. Today's metro network has a number of advanced capabilities and new attributes:

- Greater scalability
- Enhanced intelligence
- Always on with enhanced robustness
- Simplified, de-layered and integrated
- Congestion-free, deterministic performance

Figure 1: New attributes of the enhanced metro network



Source: Omdia

Network modernisation will lead to enhancement of the CSPs' entire business case.

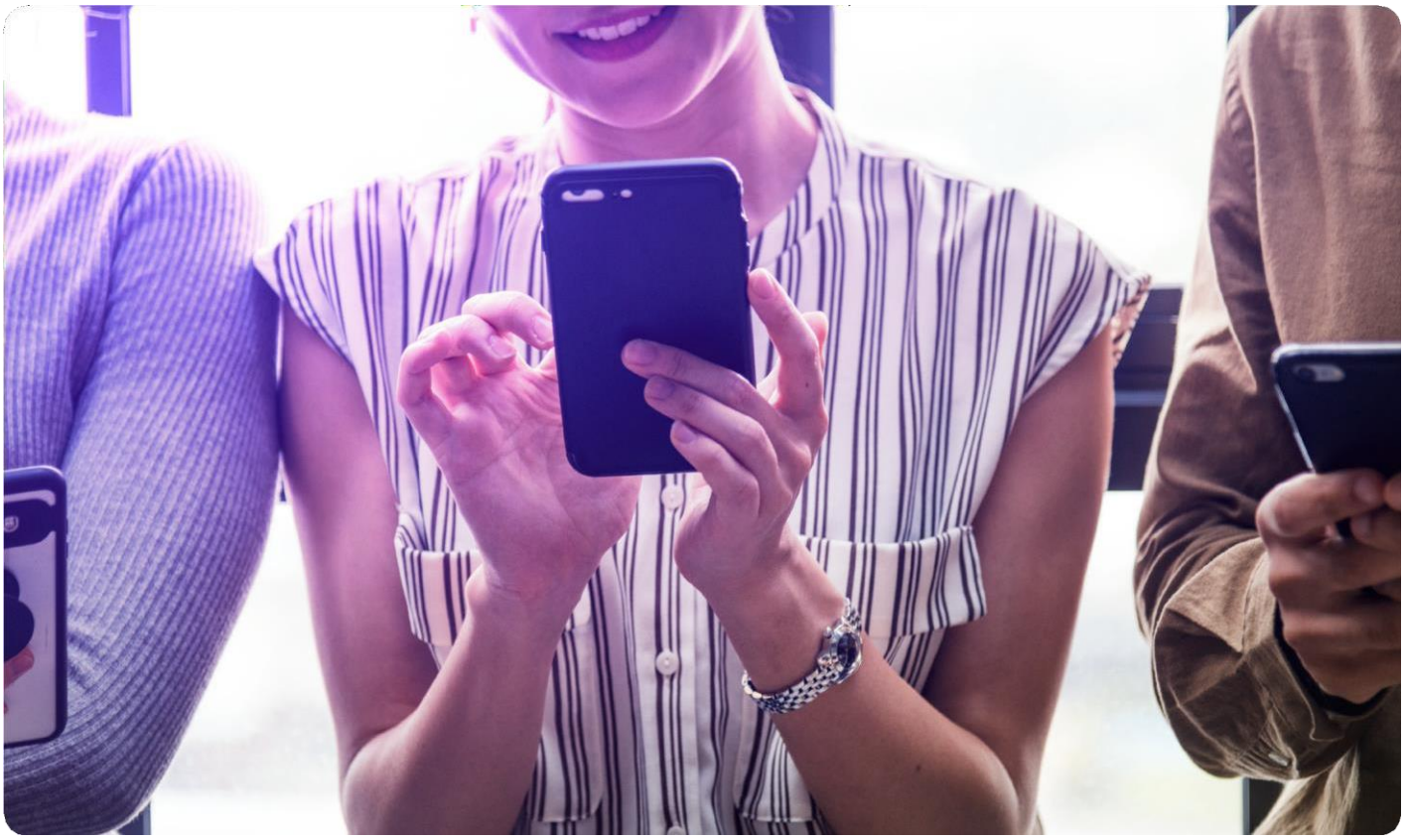
Revenue can be enhanced

- Deterministic services enable mission-critical performance worthy of revenue uplift
- Operational improvements reduce the time required for service activation. Rapid service activation can lead to a "win the business" dynamic, driving revenue acceleration
- Enhanced "at-home" service performance is also worthy of revenue uplift. "At-home" transitions from family infotainment only to now include schooling and business.

Cost optimisation

- Network modernisation leads directly to space and power efficiencies:
  - OXC, integrated OTN-OLT: leads to substantial space and power reductions
  - Operation efficiencies via Transport-SDN (T-SDN)
- Capex savings: network modernisation leads to cost-per-bit improvements

Heightened client performance expectations and the digital economy drive optical evolution



Heightened client performance expectations

Client performance expectations are rapidly evolving. Historically, clients accepted purchasing “products.” Clients were not necessarily after the products directly; they were more interested in the “service” the product enabled. Clients have taken this one step further and now desire “the experience.” Clients from different verticals and of different sizes are rapidly evolving from the “product economy” through the “service economy” and onto the “experience economy.” Clients have also exhibited a willingness to pay more for a superior experience.

Service requirements evolution

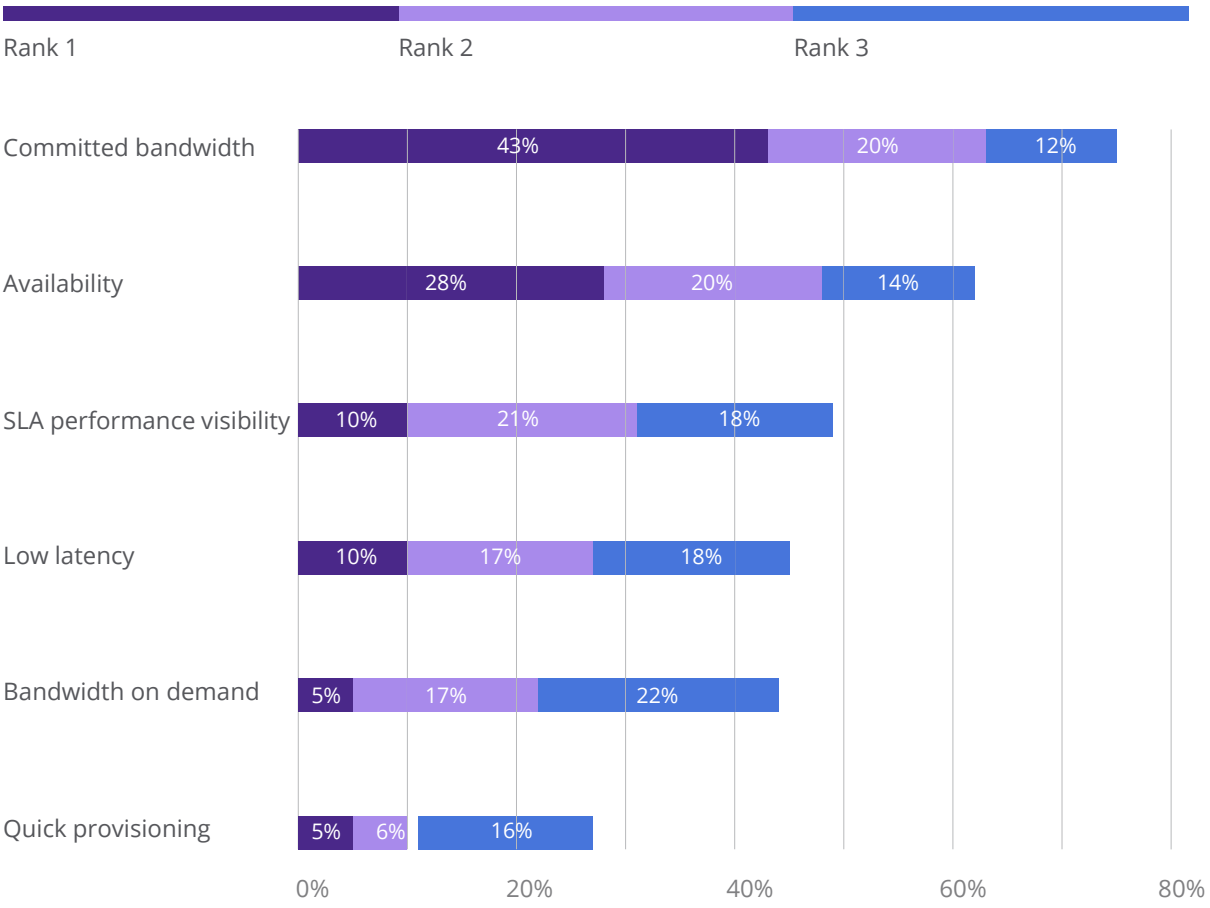
Evolving service requirements for the home (2H)
"At-home"-based clients consume multiple service types:

- **Entertainment focused such as 4k and 8k video for entertainment**
- **Multi-player gaming**
- **High-bandwidth information services**
- **High-performance work-at-home and school-at-home services**
- **All require superior upstream bandwidth performance**

All the services individually and taken together require a high-performance network underlay that is a step up from earlier generations. The aggregate "at-home" requirements are for higher bandwidth to support all of the services running concurrently. Home services need to be highly reliable and always up-online as the service mix has evolved from entertainment only to entertainment, business, and education. Additionally, in the past, the upstream requirement for many users was quite modest. The shift to "at-home" has placed more emphasis on upstream needs, particularly video. With heightened performance expectations, services must be delivered with low latency and minimal jitter. New services need to be activated rapidly as well. The overall security requirement has taken a step up, matching the step up in the importance of the services.

Evolving service requirements for large enterprises and SMEs
Large enterprises and SMEs also have heightened service expectations. The business community is undergoing a once-in-a-generational IT transformation. Compute and storage, historically, resided in on-premises IT facilities. Large, medium, and small enterprises are rapidly transitioning to a combination of hybrid cloud and multi-cloud. Compute and storage may now reside some distance away, while client expectations and scale have grown. The enterprise WAN has SLAs, latency, and scale bandwidth requirements. Enterprises require high reliability, to be always up online, to have low latency and low latency variation, and rapid new service activation. Security is foundational to the business's survival and success.

Figure 2: Enterprise private line purchase priorities



Omdia private line enterprise survey, February 2020. N=175, global, across all verticals.

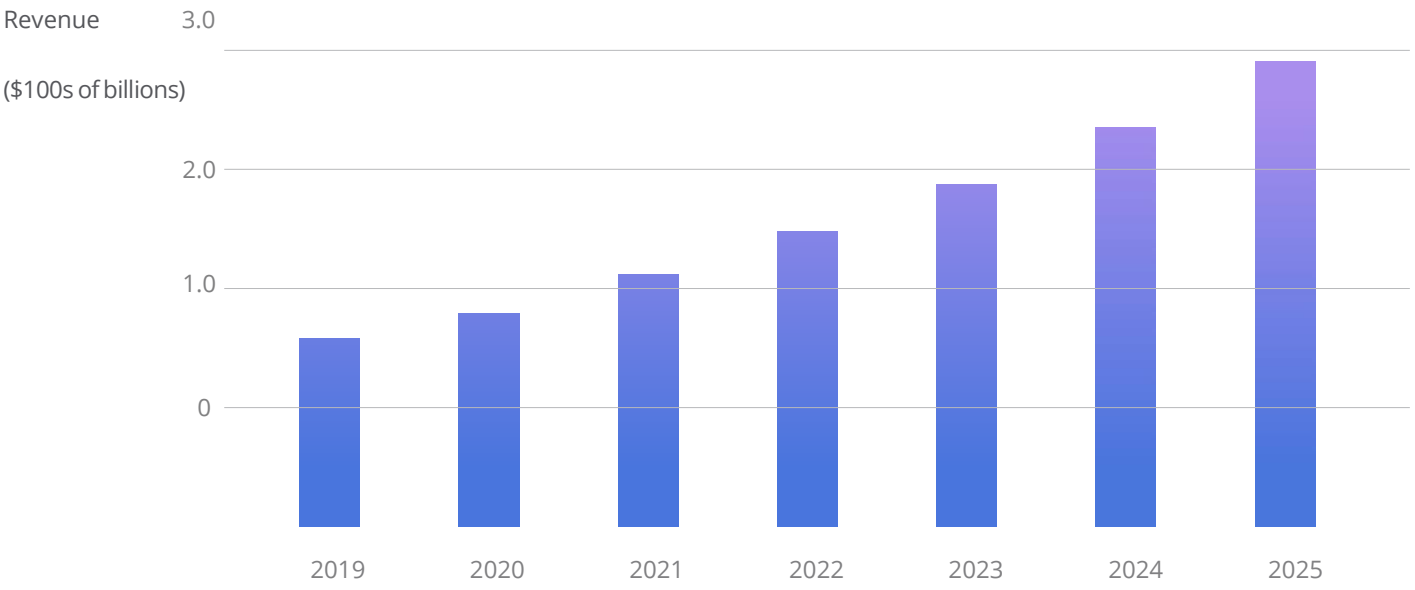
Source: Omdia (Transforming Private Lines for Business Growth White Paper (publicly available)
Transforming Private Lines for Business Growth (informa.com))

Cloud service growth

A current driver of metro optical network growth is cloud services. Cloud services have gained mainstream enterprise acceptance and have strong potential for additional growth, including more cloud service endpoints and additional bandwidth per service. Cloud services are being accessed from anywhere – home office, enterprise site, or on the go. By shifting mission-critical services to a cloud model, the performance requirements of the bandwidth underlay have beenraised.

CSPs require enhanced visibility of service and network performance to be able to adhere to more stringent latency requirements.

Figure 3: Selected cloud service revenue



Source: Omdia

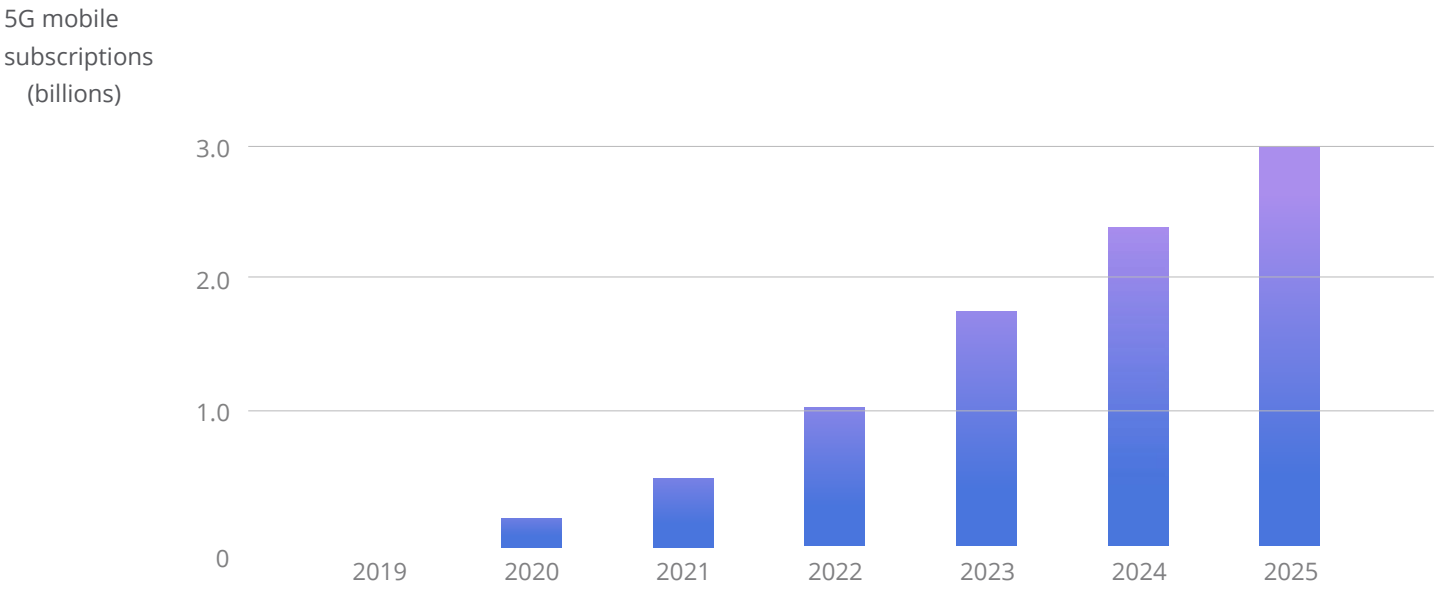
5G mobile network growth

Evolving service requirements for mobile clients

Mobile clients also require improved performance and experiences compared to earlier generations of technology. Mobile clients are also using the network for: video and gaming entertainment, high bandwidth information and high-performance work-at-home and school-at-home capabilities. Fixed residential and enterprise clients also have heightened expectations for high reliability, to be always up-online, low latency and low latency variation, and rapid new service activation in a mobile environment. Mobile clients also desire a highly secure environment.

5G is also catalysing the network visibility need. It is driving the need for a huge volume of high bandwidth IP/optical endpoints. Stringent latency specifications and enhanced network visibility are sharpened in the 5G era.

Figure 4: 5G Mobile subscriptions forecasts



Includes: IaaS, PaaS, CRMaaS, managed cloud services and business continuity

Source: Omdia 5G Mobile Subscription Forecast

The user requirement bottom line

Users want a high quality of experience. The user desires translate into the network attributes of high bandwidth, low latency, stringent SLAs, high reliability, and high security with rapid service activation.

CSP challenges

Client experience expectations are rising, which is translating into higher performance services. CSPs need to continually modernise their networks while managing their profit and loss. CSPs need to generate more revenue while minimising operating costs.

Brownfield network limitations

Limitations of aging optical and SDH networks

CSPs' networks are in a constant state of evolution. With limited capital resources, CSPs look to maximise investment funds. Very often, capital is devoted to portions of the network that are directly and immediately tied to growing revenue streams. Optical networks while critical, can be at times overlooked for network refresh. Additionally, optical and SDH networks can be supporting key clients such as financial institutions. CSPs are often reluctant to disrupt business critical, revenue generating services. The net result is that earlier generations of optical and SDH networks can age.

Rising operational costs of aging networks

Older optical SDH networks may have a number of limitations such as:

Higher operating costs, higher power costs, and significant physical space requirements

Network designs from an earlier era

- Multiple transitions from one SDH ring to another SDH ring (multiple hops)
- Express traffic transiting network routers, unneeded consumption of router resources
- "Silo'ed" network management: separate optical and IP management systems
- Limited ability for end-to-end service management
- Initially supported significantly smaller client bandwidths

As CSPs evaluate the introduction of a new generation of services with higher bandwidth requirements with more stringent SLAs, they are finding themselves in a more difficult situation. Additionally, security is paramount, and many clients are concerned about sharedresource networks.

The CSP business case: Driving new topline revenue

Video analytics

As the industry continues to migrate to a 5G, IoT and cloud world, a new suite of applications is emerging that can drive the CSP topline. More and more practical video analytic use cases are being developed that solve very specific client needs. Key assets, properties and premises can benefit from constant video surveillance. With the latest video analytics applications, clients can track key events and non-event traffic can be discarded, saving metro network and storage resources.

Cloud services delivered by premier private-line bandwidth

Cloud services introduce the need for high bandwidth, stringent SLAs, and low latency connection services. CSPs are in a position to interconnect enterprise clients to their cloud-based applications and compute resources. In addition, clients desire a highly secure network with hard isolation from other services and clients.

Premier "at-home" service with enterprise co-funding

Another potential, emerging service, is a very professional, enterprise-grade "at-home" service. Historically, "at-home" bandwidth has been best effort, un-protected, non-robust, unsecured, and paid for out of the consumers' entertainment budget. With the "at-home" change, residential clients and their enterprise and SME employers desire a professional environment "at home". The underlay bandwidth:

> Must now have a rapid, seamless, and diverse failover capability

> Must be high bandwidth to support multiple clients in a residence

> Must adhere to stringent SLAs to support enterprise businesses in "at-home" environments

This new high-performance environment will be more expensive, but the expense should be in a new model involving the enterprise budget.

The net result for many CSPs, in order to drive new revenue and minimise operations costs, is the need for a network refresh to modernise the network and the business.

The new and enhanced target metro network architecture

Unprecedented scale in the metro network core

CSP metro core requirements
In the metro core, the individual client requirements become aggregated into scale CSP network requirements. The CSPs need to manage tremendous scale efficiently and manage capex and opex budgets. CSPs are also balancing the desire to minimise capex outlay while maintaining operational efficiency, resulting in setting priorities and making complex trade-offs. At the same time, technology is rapidly evolving, and bandwidth growth is unpredictable.

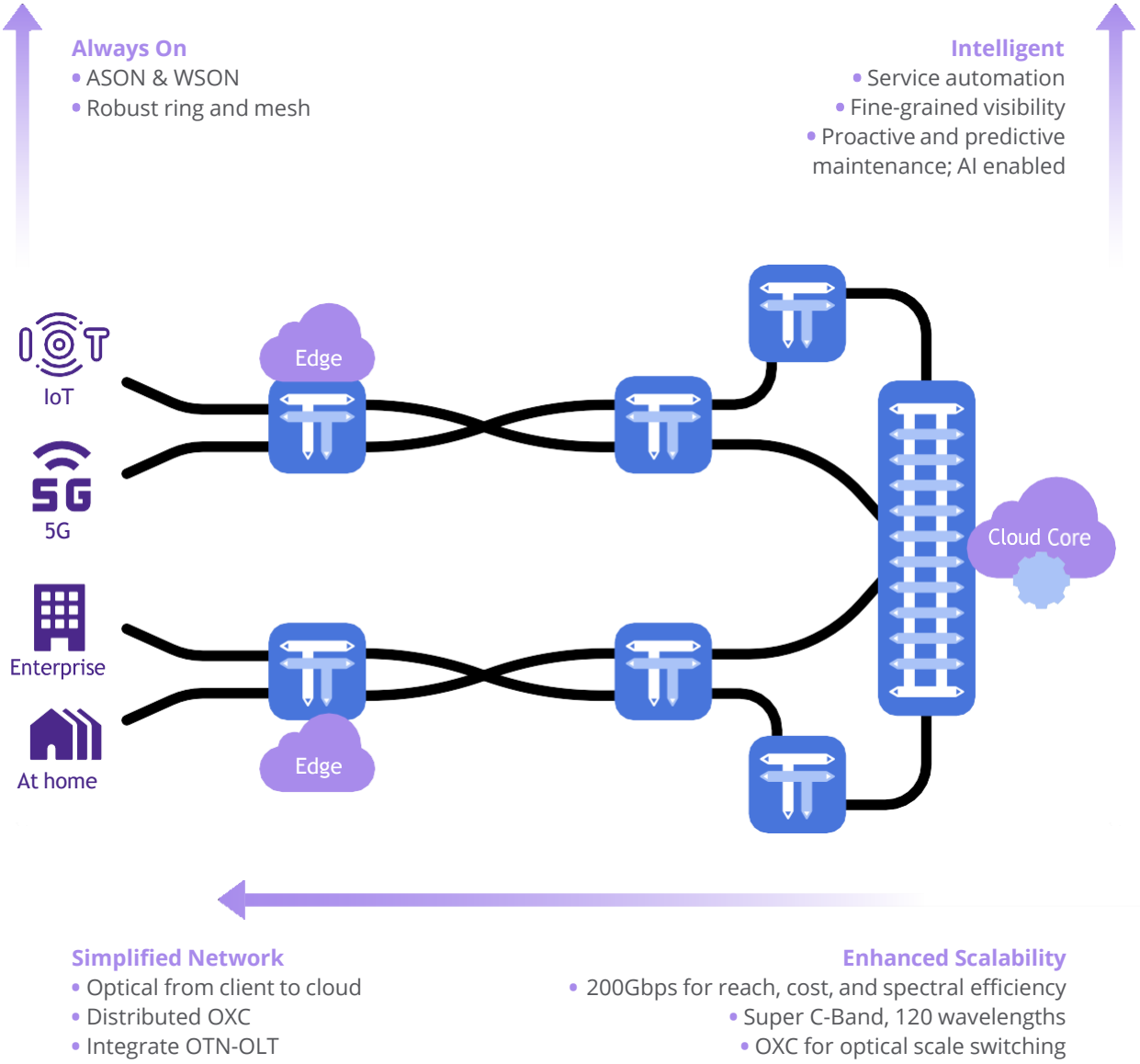
Cost-effective spectral efficiency paired with small form factor
CSPs desire to maximise spectral and cost efficiency while minimising physical space consumption. Today's scale solution is 200Gbps transmission per wavelength in a small form-factor pluggable. 200Gbps solutions can cost-effectively serve the needs of most reach requirements, removing the need for regeneration. 200Gbps solutions are also offered in small form-factor pluggables, minimising the physical space consumed. Higher speed solutions will also make their way into the market in time. Cutting-edge solutions typically need time to mature, shrink in form factor, and grow in volume necessary for attractive economics.

Efficient utilisation of spectrum
Historic optical networks began with 80 wavelengths in the C-band. Modern networks now utilise more spectrum for up 120 wavelengths in the "Super C-band". L-band solutions will also gain industry favour in the future as L-band scales and achieves more attractive economics.

Optical scale switching via the OXC
Historic optical networks often terminated point-to-point or optical ring systems in large central office facilities. The terminated optical signals were translated into electrical signals and switched electronically. In time, the electrical switching requirement grew enormously, resulting in large scale electronic switching that consumed physical space and power. The industry's latest innovation is optical switching (OXC) at great scale supported by an optical backplane. The OXC

can support metro access and aggregation systems, switch optically with no OEO to other metro or long-haul systems. The OXC is a tremendous innovation in support of the "all optical" vision. The OXC mitigates a huge electronic switching requirement, alleviating the electronic switching operational burden. If a carrier's power supply originates from a grid that relies heavily on fossil fuels for power generation, the carrier's network will have a significant carbon footprint. Newer generation technologies transmit and process bits at a lower Watt/bit. Switching Gbps via optical technologies is more power efficient than switching Gbps via electronic technologies. By introducing the OXC, for very high capacity switching-replacing electronic switching, a carrier can lower their power consumption per switched Gbps. Optical switching will use less power/Gbps, less carbon from carbon intensive grids and will be the greener choice. The OXC has the additional benefit of improving service latency by keeping services in the optical layer.

Figure 5: Enhanced metro optical network



Enhancing network intelligence: new building blocks and capabilities

The enhanced network management platform draws upon progress in three foundational areas to move from manual methods to data-driven automated operations:

> More network performance data available from the historically opaque optical layer

> A new generation of optical domain controllers and network orchestrators

> A new suite of operational tools, utilities, and applications to immediately assist CSPs.

New optical network data available for real-time state information

The new and exciting capability in the optical network realm is the availability of more optical performance data from the optical layer than ever before. Coherent optics have been deployed primarily for the increased bandwidth capacity benefit. Coherent optics also enable an ancillary benefit of advanced optical system performance instrumentation. Real-time optical performance can be monitored, and more key metrics tracked: effective signal-to-noise ratio, chromatic dispersion, pre-FEC bit error rates, and latency. The enhanced optical visibility can be extended to the optical edge.

T-SDN: Next-gen domain controllers with advanced apps

CSPs can take advantage of the new capabilities by deploying a next-generation controller. With a more complete network view, CSPs can take advantage of a growing suite of advanced data analytics capabilities, utilities, and applications across layers. The new capabilities and operational utilities can be embedded within existing next-generation network management systems.

Advances in T-SDN tie it altogether, ensuring agile business and intelligent operations and maintenance (O&M). T-SDN can enable network performance visualisation highlighting bandwidth, latency, and availability. It can also aid in speeding up configuration and provisioning, reducing service turn-up intervals from weeks to days. T-SDN is also incorporating more and more predictive capabilities by monitoring network degradation cases, predicting outcomes, and highlighting potential corrective actions. Advances in T-SDN lead to improvements in network quality and customer satisfaction, ultimately leading to an improved ROI for network operators.

Practical applications delivering immediate benefits

With a more complete network view, CSPs can take advantage of a growing suite of advanced data analytics capabilities and applications across layers. For example, CSPs can reclaim unused bandwidth, enhance network planning, and improve fault management.

CSPs can evolve from static operation with substantial end-of-life (EOL) margins, to interval-based planning with reduced margins, and ultimately to dynamic “margin-less” operation. The very practical and immediate benefit is that CSPs could find cases in the network where a 200Gbps wavelength could be upgraded to a 400Gbps wavelength. CSPs would reap the immediate capacity boost benefit.

Finer-grained network performance visibility into key parameters such as channel power and noise, tracked over long periods of time and paired with predictive algorithms, enables more precise network provisioning. The provisioning process can be automatic as new routes can be evaluated in advance, reducing the risk involved in wavelength add/drop and change.
Fault preemption can be enabled, and prediction of network performance can identify possible future fault scenarios. CSPs can take preemptive action and proactively repair in advance.

Enhanced reliability with ASON-WSON and robust topologies

ASON and WSON for quick restart and smart restoration

ASON has been in the optical market for many years, aiding rapid provisioning and fast rerouting in failure scenarios. WSON is also available for rapid individual wavelength management. Restoration capabilities have advanced with historic restore times of several minutes, being reduced down to mere seconds. Advanced smart algorithms are now available for flexible spectrum management with an additional goal of minimising spectrum fragments. ASON and WSON can support very large-scale networks of up to thousands of network elements.

Robust ring and mesh topologies

Network spurs are a single point of failure. Diverse path optical connectivity enhances network robustness. Clients can be connected via a minimum of two diverse routes. In the network core, this can be taken one step further to a full optical mesh to ensure network survivability in a multiple failure scenario. Network leaders typically have a minimum of three distinct and diverse routes connecting critical assets.

Simplify the network

One-hop from client to cloud via SDH modernisation and phasing out hop-by-hop routing
Legacy SDH networks were designed to hand off traffic from one ring to another. Additionally, in between rings, traffic could also go to the router layer. The historic traffic routing adds latency and costs. CSPs can modernise their networks by extending their WDM infrastructure from the network core to client sites. Enabling one-hop from client to cloud will improve network performance and simplify operations.

The optical switching functionality, delivered by the core network node, the OXC, can now be extended deeper into the aggregation portion of the network. The distributed OXC capability enhances network flexibility without adding multi-layer or electrical switching penalties.

Integrated OLT-OTN in the central office and distributed network aggregation points
In the network core, network elements can be highly specialised to perform specific functions at great scale. At the network edge, the network requirements differ in that many types of clients and services need to be economically and efficiently aggregated. Additionally, it is rarely economic for CSPs to have a dedicated network element for every client and service type. Multi-function integration has been a strong edge network dynamic for many years. Residential and SME clients may be served via passive optical networks (PONs). The industry's newest access architectures integrate PON access capabilities with metro WDM access and aggregation capabilities, reducing multi-network element scenarios. The interconnected PON-metro WDM platforms can function as a converged services access point for fixed, mobile and enterprise services, offering a number of operational efficiencies, including:

- **Physical space savings in tight access office scenarios**
- **Minimise unneeded OEO conversions, extend all-optical network**
- **Improve latency performance by staying in the optical layer**
- **Enable fibre cable savings with OLT direct uplink**
- **Provide a modernised architecture**
- **Additionally, OTN functionality can be extended to the access points of the PON networks, further extending the end-to-end reach of OTN.**

Upgrade at the network edge to support determinism

Fibre to the clients

The network edge is highly varied with multiple endpoint clients. The network edge includes Enterprises and residences connected via multiple fixed and mobile access solutions. With the ongoing development in the IoT space, many sensors, cameras, and other IoT devices will also be connected to the network. Ideally, fibre connectivity should be extended to as many clients as possible. Large-scale enterprises can terminate fibre directly on premises. Homes can be connected with PON solutions or other non-fibre solutions. 5G is radio to the mobile client, ideally with fibre from the radio tower back into the network core.IoT sensors and cameras may also have a mix of direct or aggregated fibre connectivity. CSPs will constantly strive to deploy fibre deeper and deeper into the client demarcation point when physically and economical feasible. The CSP's goal is to ultimately realise FTTM (for IoT), FTTH & FTTR for residential, and to-the-room connectivity and FTTO (office) for SME and large enterprise connectivity.

OTN to the client edge

Recapping the client needs of high bandwidth, high security, stringent SLAs with low latency, OTN is a technology that can deliver on all of the client needs:

OTN enables the highest security with hard isolation over a shared physical resource

OTN supports bandwidth from 2Mbps up to 400Gbps (today, with more in the future)

OTN can support deterministic service performance with guaranteed, low latency primary paths and predefined low-latency failover paths

OTN can supply end-to-end path visibility for client service assurance

Conclusion

Refresh the metro optical network for the future

Cloud and 5G services will run over a re-invigorated optical network infrastructure. Metro optical networks are rapidly scaling with millions of optical coherent ports in operation. Optical networks are evolving in terms of reach to meet the cloud and 5G endpoint densification needs and to support modern architectures with distributed edge compute. CSP network planners must balance optimising today's networks for known traffic and prepare for future yet difficult-to-predict growth.

CSPs can take advantage of the "new tools" to reposition for an all-optical future

CSPs considering a metro network refresh do have a challenging task in matching future traffic to an efficient network construct. New tools and approaches are available including:

Adopting an all-optical metro architecture: OTN to edge, OXC to CO, support liquid OTN

Simplified architecture in the metro: One optical hop to the cloud

More spectrum availability: Super C today and extended L-band in the future

Cost-effective, spectrally efficient, and compact 200Gbps solutions today

New network element, the OXC, to maximise all-optical switching and operations

T-SDN, ASON for advanced multi-layer operations and maximising network robustness

Users want a high quality of experience. User desires translate into the network attributes of high bandwidth, low latency, stringent SLAs, high reliability, and high security with rapid service activation.

Network modernisation benefits

Network modernisation will lead to enhancement of the entire business case: improving revenue prospects and saving on capex and operational costs:

Revenue upside from high performance, low latency, rapid activation services

Cost-per-bit improvements from more capital-efficient network structure: C+L, 200Gbps,OXC, integrated metro optical and PON, using a one-hop optical architecture

Recurring operational cost improvements via upgrade to modernised metro network
- Substantial space and power savings from modernising with greater use of optical
- Further operational savings with shift to new optical network management platform

Appendix

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