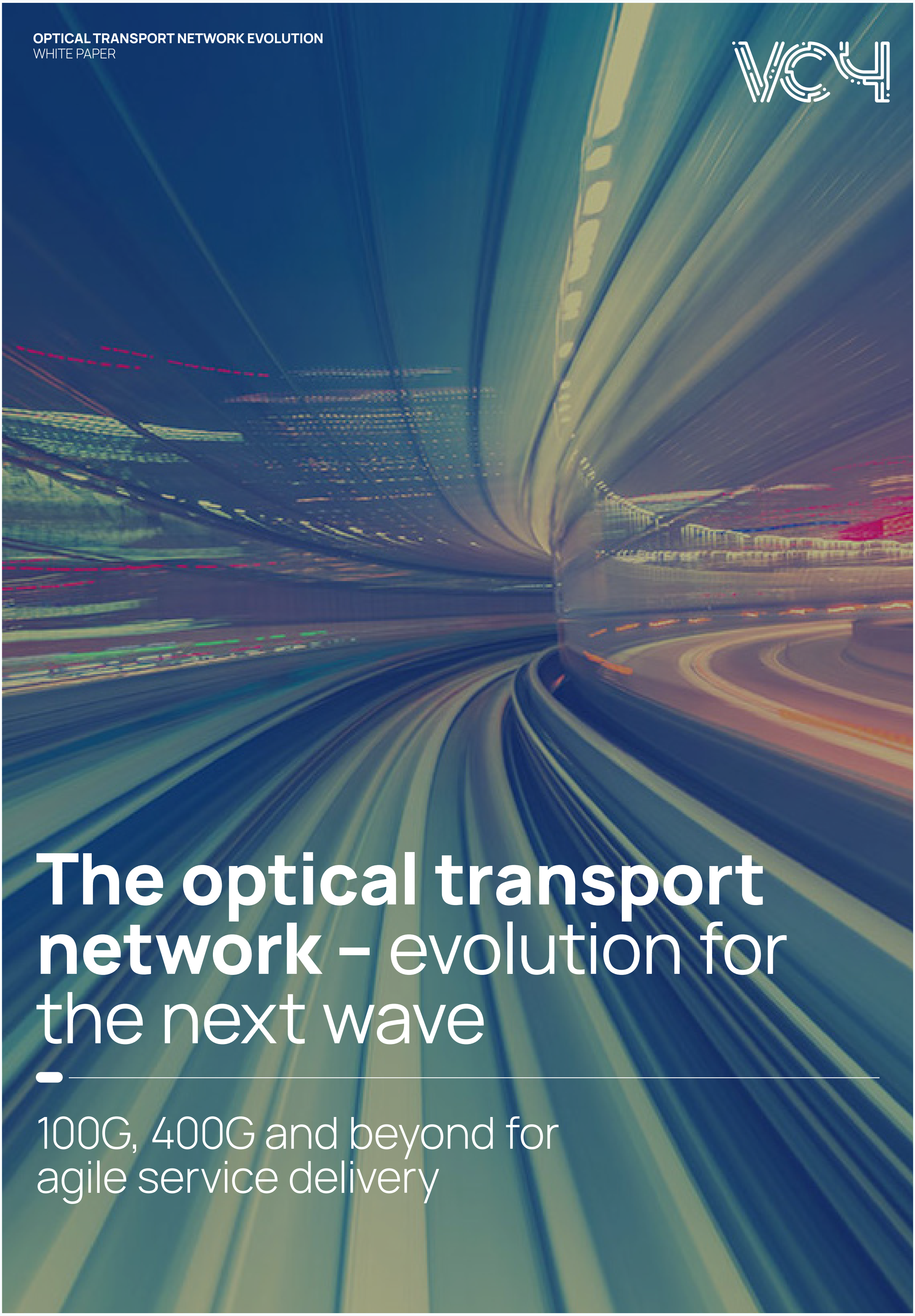


OPTICAL TRANSPORT NETWORK EVOLUTION
WHITE PAPER

The optical transport network – evolution for the next wave

100G, 400G and beyond for agile service delivery

Introduction: the key trends driving evolution

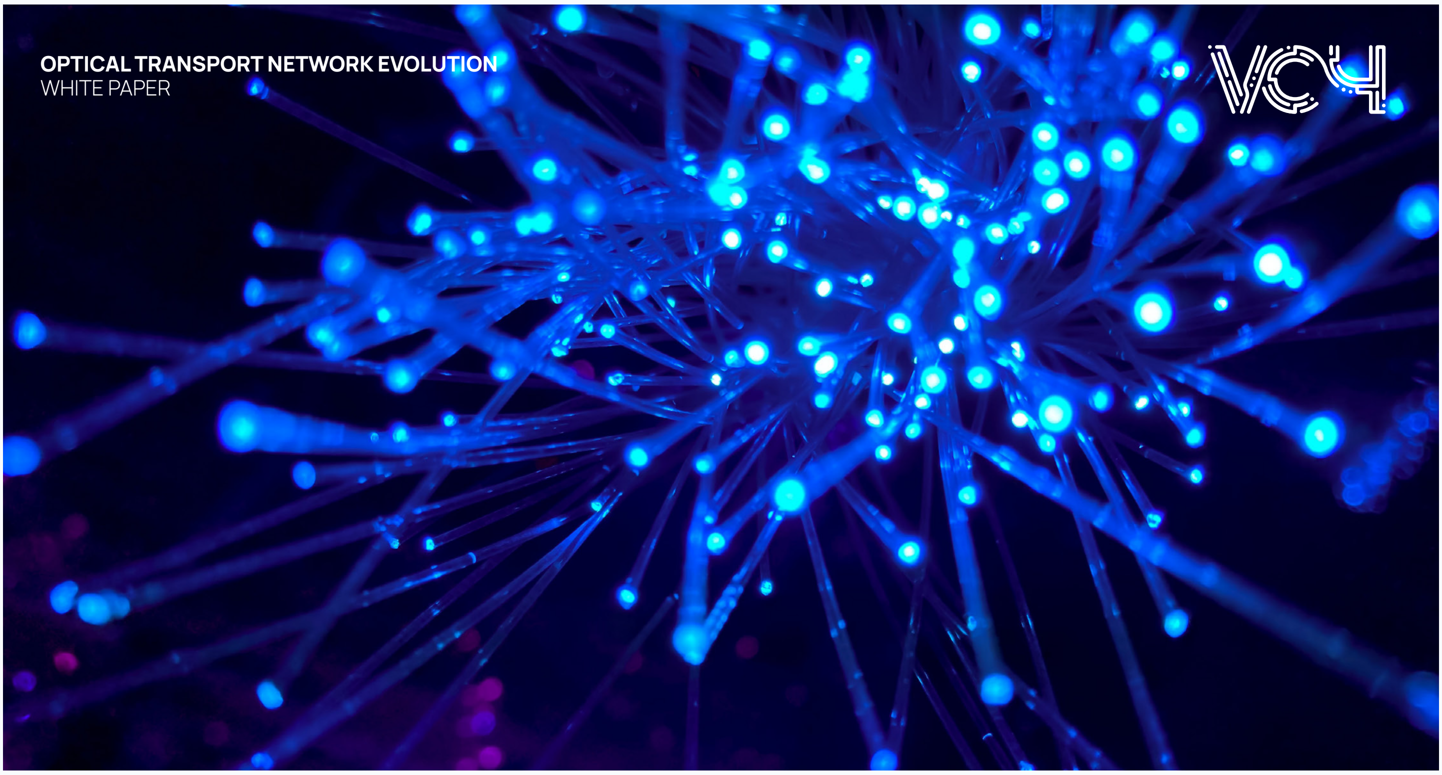
Surging demand for high-speed broadband connectivity is well known and well reported. Not only are top-down governmental mandates in place, but non-profit organisations, such as the OECD (Organisation for Economic Co-operation and Development), have set targets for delivering fibre access to citizens and businesses alike. But much of this attention has been focused on the last mile – typically covering GPON deployments, planning issues and the need to extend networks to underserved and rural areas.

Progress here has been good. In a recent review, Arthur D Little reported that, by 2020, more than 10 markets had managed to secure what it terms "ubiquitous" fibre access, having reached 95% or greater coverage[1]. Recent events have increased this momentum.

So much for the last mile – but passive (and other) networks that provide this connectivity are supplemented by connectivity to the optical core and wider transport networks. The unprecedented levels of activity at the edge must be complemented by significant investments in the core and transport networks. Where else will all this traffic go? How else can operators and fibre providers manage demand from the edge efficiently and effectively?

This activity is accompanied by evolution of transmission technology and protocols that will meet these new (and future) demands for capacity and efficiency, in preparation for the gigabit future.

In this paper, we'll review the key trends driving evolution of the Optical Transport Network, to illustrate how demand must be matched by supply across different use cases. Finally, we'll explore what this means for planning and maintenance of current and future networks and the implications of this rapidly evolving environment.



OTN demand

Optical Transport Networks (OTNs) are a key element of current and future network rollout, providing transport services in metro and core networks, as well as for long-distance connectivity. OTN – as defined in ITU recommendation G.709 – has undergone a number of iterations, which essentially add more capacity, flexibility and different multiplexing capabilities.

While traditionally OTN has been key to enabling core connectivity, a number of factors have combined to deliver significant impetus to this market, creating rapid growth (estimated to reach more than 15% CAGR between 2021 and 2026[2]).

On the demand side, consumption has grown dramatically in recent years. A glance at Cisco's long-established Visual Networking Index shows that internet usage continues to grow, across more demanding devices – on the home-front, for example, the growing adoption of 4K Ultra-High-Definition flat-screen televisions with internet connectivity is driving massive spikes of traffic (4K devices need 9x the bit rate of SD screens, for example)[3].

With continuing growth in on-demand video services and platforms, online gaming, and 8K content coming soon, traffic can be expected to continue this upward trajectory.

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Domestic demand is one thing, but growth is also coming from other sources. M2M devices, long expected to exceed the number of connected mobile subscriptions are, at long last, taking off. In turn, this is also driving new sources of traffic. The same report predicts that such devices – in the home, the street, in businesses and elsewhere – will account for 50% of all connected devices. Add 5G to the mix and what we have is a situation in which global traffic is surging, with hot-spots in different locations – all of which must be serviced through internet access federated by a service provider connection.

The action is shifting to the edge

So, even while the last mile is the scene of unprecedented levels of activity, operators and service providers must bolster their transport and backhaul capabilities. But there's another factor to consider. In the introduction, we mentioned the edge. Thanks to 5G, the edge is now of pressing concern.

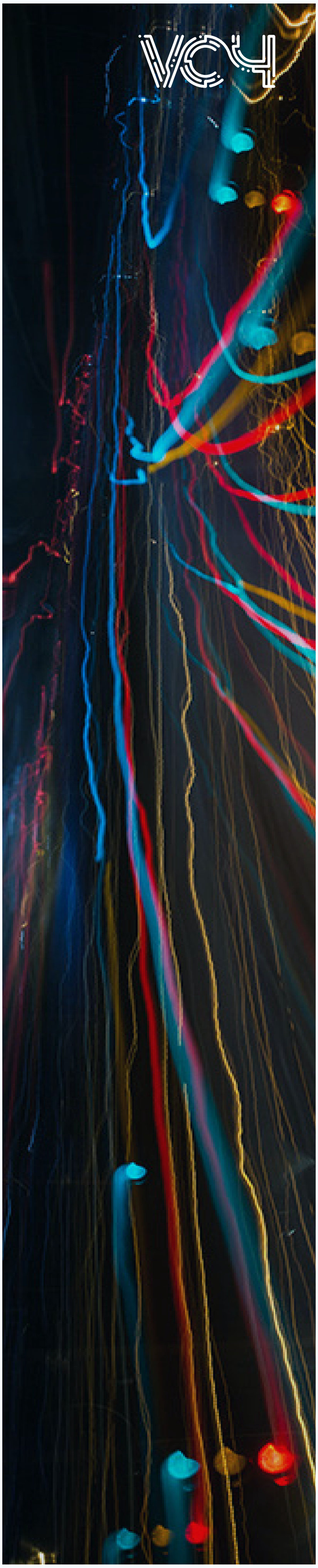
That's because new 5G networks will bring a seismic shift in network design. First, while 5G delivers enhanced speed and performance, the frequencies that enable this do not travel far. So, what's required is densification – massively more 5G cell sites than we have seen before.

Second, whereas all previous generations of mobile technology have essentially operated in a classical edge (RAN) / backhaul / core model, 5G (specifically, the next phase of 5G rollout, the so-called Standalone variant) will break this model and see a shift in processing resources out to the edge of the network.

This shift is required, because 5G Standalone (5G SA) introduces the ability to support what's known as 'ultra-reliable low latency communications', or URLLC. It is anticipated that numerous new applications in the RAN will require low latency connections to resources that process their demands. To achieve this, the distance between such devices and the associated resources must be reduced, which means that processing must be closely aligned with cell site build out.

Finally, 5G also supports a much greater density of connected devices – be they mobiles or things – in a given area. To service all of these different demands and to avoid bottle necks, high-speed – that is, fibre – connectivity will be required to the majority of 5G base stations and between these cells and any required edge computing resources.

As a result of these developments, operators are eyeing a significant opportunity – one that creates a new addressable market (offering 34% growth and creating a new market of nearly $600 billion for operators, according to some reports[4]).



OTN is essential for supporting network and service propositions

So, while fibre at the edge for consumer and business consumption is growing, we also need a much more widely distributed transport network to support and to enable these opportunities – the OTN must extend to support these use cases, for which real-time transfer to new resources is required or for which immediate backhaul is necessary. Bottlenecks in the core will prevent operators from capitalising on such new opportunities.

While these issues may confront a typical network operator that service consumer and business customers, many networks are being built to support wholesale propositions – for example, a fibre overlay that connects cells that is operated by one provider on behalf of another. In a similar vein, the infrastructure a service provider needs to connect, say, their cell site to an edge facility might be leased from another. Added to which, we can also consider 5G private networks – again, a sizeable market opportunity ($60 billion, again according to ADL[5]) that is fast taking shape. Super-fast fibre is essential here – but of the transport variety, not the access.

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While the industry has long discussed different notions of x-haul – backhaul, midhaul and fronthaul, for example – the fact is that connectivity to transport is required at a growing number of points across the network, for a growing number of uses cases. There will be a complex mix of stakeholders – some with directly connected subscribers, others with wholesale and business partners, or serving specific locations and domains. X-haul may not even be the right term to use any more – perhaps universal transport is what's needed.

All of these opportunities create demand, as we have seen. They will also create complexity – different services and clients will have different connectivity requirements – which raises questions for efficient planning and delivery of extended transport networks. So, in this context, how is OTN evolving to support these myriad uses cases and demand?

OTN Evolution

OTN has been the subject of continual evolution for many years. Since inception, the standards have been enhanced with upgrades to take account of anticipated use cases, changes in demand and, crucially, to ensure compatibility with existing transport models.

In general terms – this paper is not an exploration of the technical standards – each fibre carries wavelengths (or channels) with a given capacity from one location to another. Each generation of OTN has built on the previous, so there is co-existence between, say, OTU2e and OTU3, for example. The beauty of this arrangement is that legacy traffic (e.g., STMx) can be carried across the same infrastructure as any current traffic.

G.709 evolved with OTN 2.0 to support OTU4 (traffic up to 100 Gbit/s), which is now enjoying widespread and growing deployment. Crucially, G.709 and associated standards define demarcation points – the Network-to-Network Interface (NNI) and the User to Network Interface (UNI). This enables a service provider (or network operator) to clearly set the boundaries of the OTN – to clients and subscribers, as well as B2B relationships with peer networks and to other OTNs serving different customers.

Finally, the latest version of the standards, OTN 3.0, brings further benefits, such as control of spectrum to enable extended reach (with more robust error correction encoding) and higher capacity, as well as evolution to OTUCn (multiple 100 Gbit/s) to support even greater capacity and flexibility in the future.

The upshot of flexible grids is that a single fibre can carry a mix of wavelengths, flexibly allocated and potentially dynamically. This will be essential for the support of new classes of dynamic services.

OTN tech is ready to support a new generation of dynamic services

This evolution path has also seen adaptation to support 400 Gbit/s and Terabit capacity. So, transport networks have extended to meet some of the challenges ahead but there are others. Networks are also evolving to support dynamic service orchestration. In particular, network slicing will enable new services, with strictly defined performance parameters, to be instantiated, operated and then torn down – on the fly, based on real-time transactions.

This means that capacity will not be fixed in the OTN that must support such services. Again, there is a path towards this, through the advent of flexible grid patterns. While this evolution has been long in development, it has emerged at the right time.

The upshot of flexible grids is that a single fibre can carry a mix of wavelengths, flexibly allocated and potentially dynamically. This will be essential for the support of new classes of dynamic services. Importantly, such dynamic services must also be available across NNI and UNI interfaces, to support the new ecosystem that will demand them – regardless of the means of last mile delivery.

In this context, each wavelength might be allocated to a specific client, or a number of clients, depending on the topology and the network domain – a hospital or university campus, another fibre service provider, a mobile network operator, a smart city client, or a factory with a private network, for example. But, like everything else in the network, this creates a clear need to understand what will be complex relationships, that may change frequently.

> ...we need to think about the impact of a new generation of wavelengths and OTN technologies – creating a more heterogeneous environment and adding complexity. With new volatile and dynamic services, this could create friction as carriers seek to rollout new capacity or to allocate existing capacity to services and customers.

OTN Evolution demands a **holistic view**

If each wavelength belongs to a specific client, and if each may be allocated for a variable period of time, then fibre network operators, whether serving directly connected subscription-based customers, or other network partners, must understand the relationship between the different elements that support that wavelength.

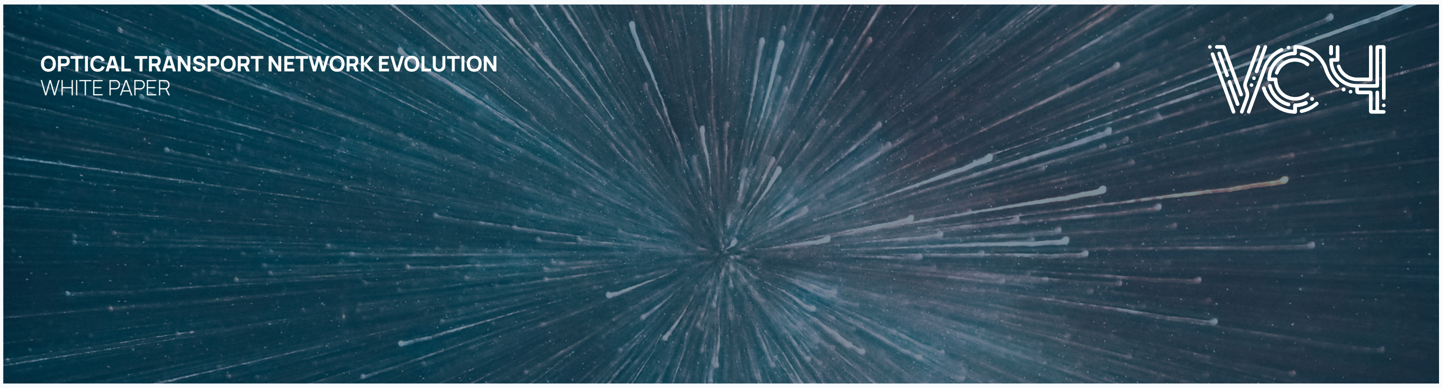
These include:

- The **physical link** (the fibre or fibres on which the wavelength is carried)
- The **location** of each such fibre
- The **logical service** delivered across this (the specific wave, who it's for)
- The **services contained** in the link (ethernet, etc)
- The **identity and status** of the customer
- The status of the **connection**, plus associated KPIs

This requires a blend of technical, service and business information. And it also means that, in addition to current WDM / SONET / SDH carriers, we need to think about the impact of a new generation of wavelengths and OTN technologies – creating a more heterogeneous environment and adding complexity. With new volatile and dynamic services, this could create friction as carriers seek to rollout new capacity or to allocate existing capacity to services and customers.

As a result, all of this must be understood, so that the carrier can deliver, assure and maintain the service – and do so in real-time, according to the needs of its customers. In other words, regardless of how OTN is evolving, or how widespread fibre is and will become, this is a classic problem for telecoms inventory management. This understanding must be applied to both future network and service investments, as well as to the entirety of the legacy infrastructure estate.

Put simply, you need to be able to obtain complete visibility of your network, even while the OTN evolves to new levels (through G.709) under the auspices of the ITU. A great deal of this further evolution is anticipated, largely driven, as we have noted, by the dynamic requirements of new 5G networks and the capacity they demand, and the need for universal transport.



Inventory and visibility for the dynamic, **service-driven OTN**

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These include:

- Greater flexibility for **multiplexing different OTUCn** signals into the payload
- Adaptations to **long-distance interfaces**
- New **5G carrier rates for short-reach** interfaces (for connectivity to the RAN)
- Enhanced support **5G transport**
- **Optical ethernet** access
- PON evolution towards **WDM** for enhanced flexibility and **mixed traffic flows** – providing more secure access for enterprise customers

So, as you deploy more advanced OTN, following release cycles from your suppliers, you need to be sure that you can include each subsequent iteration – and every dependent service, clearly aligned with a customer – within your overall inventory management system. You have to stay ahead of the standards, so you can easily expand your network and include new OTN systems to meet customer demands.

These use cases, and the dynamic service and networking environment they require, create a host of new challenges and demand the deployment of universal transport networks. Principal among which is the fact that the characteristics of any new fibre link and the overlying wavelengths must be instantly discoverable.

What are the use cases driving demand for OTN?

We briefly explored some of the drivers behind the need to evolve OTNs. Now, let's examine some of these use cases that require universal transport, aligned with business opportunities.

Inter-carrier relations

Classical inter-carrier relations remain key, of course, and OTNs need to be able to interconnect (NNI) with other providers. With dynamic services, these may be temporary or volatile relationships, as well as standard permanent wholesale arrangements.

Metro and cell site connectivity

The OTN must provide transport for the last mile, which includes both FTTx customers, as well as connectivity to cell sites. 5G sites need direct fibre connectivity, while the number of these will be significantly higher in a given area than previous generations of mobile technology – creating a need for OTN access at more points to cope with ever more demanding traffic growth.

Campus applications

Campus networks have long served educational establishments and other, highly-specific locations. These will be augmented by an explosion of similarly dedicated infrastructure, delivering optimised services with unprecedented performance for industry, ports, hospitals and a wide range of sectors. Access to the OTN is critical and many will run their own OTN infrastructure.

Smart cities, stadiums, arenas and more

Instead of serving a specific vertical, private networks with OTN cores can be expected to serve smart cities, with the municipality or local authority as the anchor tenant or service provider. Similarly, hyper-connected venues, offering augmented experiences will also demand OTN services and capabilities.

Cloud computing access

Edge computing demands access to processing resources that are located an appropriate distance from the source of demand, with that distance determined by the latency requirements for the application in question. Public and private cell sites need to be interconnected to available dedicated data centres and cloud compute resources, at the right distance – for connectivity at the OTN level is necessary. Providers need to be able to link all such locations.

Intercontinental transport and submarine cables

While some services need local processing resources, others need access to those in different continents and across oceans. As a result, intercontinental, submarine – and, with 5G, satellite – connectivity is booming. OTNS need to be connected to these assets, bringing new routes and paths into the connectivity chains.

How to **prepare** for this...

These use cases, and the dynamic service and networking environment they require, create a host of new challenges and demand the deployment of universal transport networks. Principal among which is the fact that the characteristics of any new fibre link and the overlying wavelengths must be instantly discoverable, so they can be brought into your inventory system and aligned with the location of physical assets, customer details, SLAs and more – if you can't do this, you can't effectively monetise your investments.

And, inventory must be agile enough to cope with connectivity to external networks – from the operator domain to edge resources consumed by customers in adjacent networks, as well as adjacent networks to meet long distance transport requirements. All of this – as well as the allocation of a new fibre path to a client, operator partner or residential customer that traverses an OTN – must happen automatically.

Moreover, because flexible grids use different schema from other generations, you need to be able to factor in adaptations to the network discovery mechanism, so this information can be obtained, even in real-time, for all of these and any other use case. In summary, to prepare for this evolution, service providers and operators need to:

- Manage increasingly **heterogeneous OTN deployments**
- Rapidly **support new routes** and connections
- Transition to **agile, dynamic service orchestration**, delivery and management
- Integrate all new logical paths, locations and assets into a **single, consolidated view**
- Adapt for **platform-agnostic registration and management**, for **multi-vendor networks** and deployments, and the inclusion of new solutions in the future
- Prepare for **shifting network boundaries** and densification of OTN at the network edge
- Accompany service and OTN evolution and extension with **evolution of operational systems and processes**
- Adopt platforms that can present a **universal view of all data**, across complex, multi-vendor networks

VC4 has a solution. VC4-IMS (Inventory Management System), which includes Network Auto Discovery and Reconciliation interfaces to the Network Management Systems, is already adapted to flexible grid allocation – and is aligned with evolution to G.709, so that you can keep pace of changes, even while delivering universal transport.

Conclusion: **VC4-IMS**

OTN evolution must be considered from two dimensions. First, a technical perspective. Under the oversight of the ITU, G.709 and related standards continue to evolve, while ensuring backwards compatibility with earlier generations of OTN technology. Notwithstanding different uses cases, capacity extensions and more, OTNs present an ever-changing, heterogeneous environment.

Second, from a commercial perspective, as new use cases and growing demand from new providers, customers and services, leads to a need to extend, update and deliver OTN capacity and universal transport, service providers and operators must be able to adapt to flexible, dynamic demands, often in real-time.

Combined, these factors pose new operational challenges. As a result, the future OTN must be included within a comprehensive inventory system, that gives operators complete visibility, at all times, of all physical, logical, service and virtual assets, so they can orchestrate complex services, build new business partnerships and support agile operations. Unfortunately, efforts to adapt to this new reality are often hampered by legacy inventory systems that cannot keep pace with standards or commercial evolution, impeding efforts to capitalise on new opportunities. This approach is unsustainable. Without a converged inventory platform that can cope with this environment, it will be impossible to monetise OTN investments.

Fortunately, VC4 has a solution. VC4-IMS (Inventory Management System), which includes Network Auto Discovery and Reconciliation interfaces to the Network Management Systems, is already adapted to flexible grid allocation – and is aligned with evolution to G.709, so that you can keep pace of changes, even while delivering universal transport with greater capacity and faster speeds to meet any of your customer / partner use cases – enabling graceful evolution as you adapt to the demands of 5G, expansion of your OTN and more.

In addition, VC4-IMS provides the universal view of multi-vendor networks that is required for their efficient management, automation and operations. Upgrading to VC4-IMS can ensure you deliver on your OTN strategy and goals.

So, if you would like to know more about our roadmap and how we can help you in the era of dynamic OTN evolution and universal transport, get in touch. Let's see if we are on the same wavelength.

References

1. Arthur D Little, “The race to gigabit fibre”, 2020

2. https://www.mordorintelligence.com/industry-reports/optical-transport-network-market

3. https://www.cisco.com/c/en/us/solutions/collateral/executive-perspectives/annual-internet-report/white-paper-c11-741490.html

4. Arthur D Little, “5G Business Potential”, 2017

5. Arthur D Little, “Time to accelerate growth”, 2021

6. https://www.itu.int/en/myitu/News/2021/03/15/12/18/ITU-standards-enhance-capabilities-of-the-Optical-Transport-Network

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