



Perspective

Scaling to 800G in operator metro core, backbone and DCI networks

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Simon Sherrington

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1. Executive summary

Telecoms operators' transport networks are coming under significant pressure from an increasing volume of traffic, architectural changes within telecoms networks, the widespread adoption and growth of cloud computing and evolving data traffic patterns.

Various trends will ensure the continued growth in data traffic on fixed and mobile networks in the coming years. These include increased global availability of high-speed fixed and mobile data services; the dramatic expansion in the range of content, services and applications on offer to consumer and business customers; expanding use of IoT services and, in the longer term, the launch and use of metaverse services.¹ Real-time edge rendering for metaverse services could drive huge volumes of traffic in aggregation and access networks (although the future of metaverse services is somewhat uncertain).

Global fixed internet and cellular data volumes are forecast to rise to as much as 18.5ZB by 2028 – nearly 3 times the volume of data in 2022.

Other trends are creating internal pressures within transport networks, and particularly within metro core, long-distance and data centre interconnect networks.

- Operators' systems can increasingly move virtual workloads around to cope with changes in demand, to deal with localised issues or to prioritise certain types of traffic.
- Virtualisation and disaggregation of mobile RAN infrastructure has the potential to create new fronthaul capacity pressures that did not previously exist.
- The introduction of edge compute capabilities within operator networks has the potential to alter traffic profiles, as will the introduction of AI systems designed to dynamically modify networks to maximise efficiency or service quality.

This reflects a wider global trend towards increased reliance on cloud-based storage, data back-up, processing and networking systems, adoption of cloud-based machine learning (ML) and analytics, and experimentation with cloud-based AI. Vast volumes of data are now flowing within and between data centres.

Operator revenue is not growing as fast as network data traffic. This puts operators under pressure to drive down the cost per bit of transporting that data, without compromising on the quality of services or operational capabilities. Operators are also facing pressures to meet environmental and sustainability targets.

Operators have already started to upgrade some 100G optical links to 400G within their transport networks. The next step would be to upgrade to 800G links. Operators need to plan their roadmap to 800G. They must devise an evolution strategy for their transport networks that will enable them to hit cost per bit, and power and space efficiency goals, while ensuring improved quality of service, resiliency and the launch of new wholesale and retail services.

Network operators have traditionally run separate Layer 1, Layer 2 and Layer 3 infrastructures, often with separate network management systems, and separate teams of personnel to manage the routers, switches and optical line systems. Faced with the continual pressure to deliver more capacity, improve quality of service and

¹ For more information, see Analysys Mason's [What is the metaverse?](#)

support new service types, operators have been seeking new strategies to help them reduce their costs and improve operations.

The latest generation chipset, router and optic technologies, combined with advances in network multi-layer orchestration and management, have all combined to make converged IP/optical networking much more attractive to operators. The latest chipsets deliver increased processing power but greater energy efficiency (in terms of energy usage per bit processed). Routers using these chipsets have become much smaller and energy-efficient. Digital coherent optics and new pluggable form factors have made it possible to densely pack routers with direct optical connections. New orchestration and network management systems enable optic and IP layers systems to be operated in a co-ordinated way.

The convergence of IP and optical infrastructures is now a realistic method for achieving operators' aims while also enabling an upgrade path to 800G. Depending on the technology starting point, traffic patterns and utilisation levels, the use of flexible integrated IP/optical networks can enable a pay-as-you-grow, high-density, operationally efficient and sustainable means of upscaling to 800G. Operators that are not already doing so should join many of their peers and seriously consider this technology option.

2. Challenging market trends are creating pressure in backbone, metro core and data centre networks

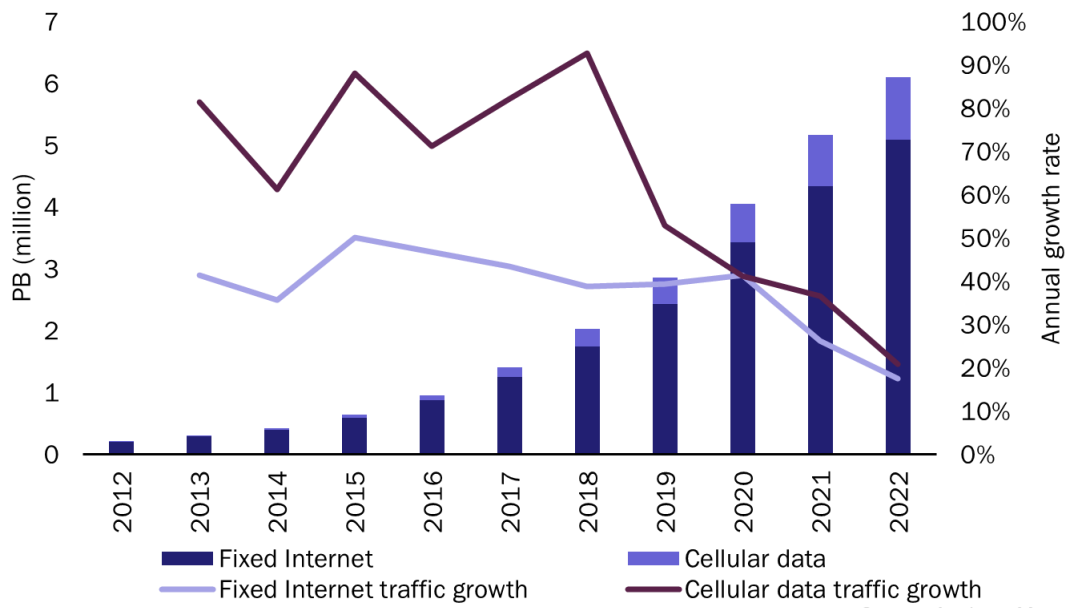
2.1 Fixed internet and cellular data traffic volumes are still increasing in most countries

The total volume of internet and cellular data traffic carried across telecoms networks increased rapidly over the 10 years to the end of 2021 and is estimated to have risen again in 2022. Drivers of this growth include the following:

- improved availability of fixed broadband services worldwide
- the increased speed of those services (with download speeds now commonly exceeding 100Mbit/s in many countries)
- improved availability and coverage of cellular data services
- the increased speeds of those cellular data services (based on LTE and more recently 5G networks)
- increased availability of public Wi-Fi services
- importantly, the dramatic expansion in the range of content, services and applications on offer to consumer and business customers, as well as their usage of these offerings.

Cellular data traffic grew fastest, in percentage terms, between 2012 and 2022, although in absolute terms, fixed internet traffic grew much faster. The volume of fixed internet traffic is estimated to have been 5 times the volume of cellular data traffic in 2022.

Figure 2.1: Fixed internet and cellular data traffic, worldwide, 2012–2022



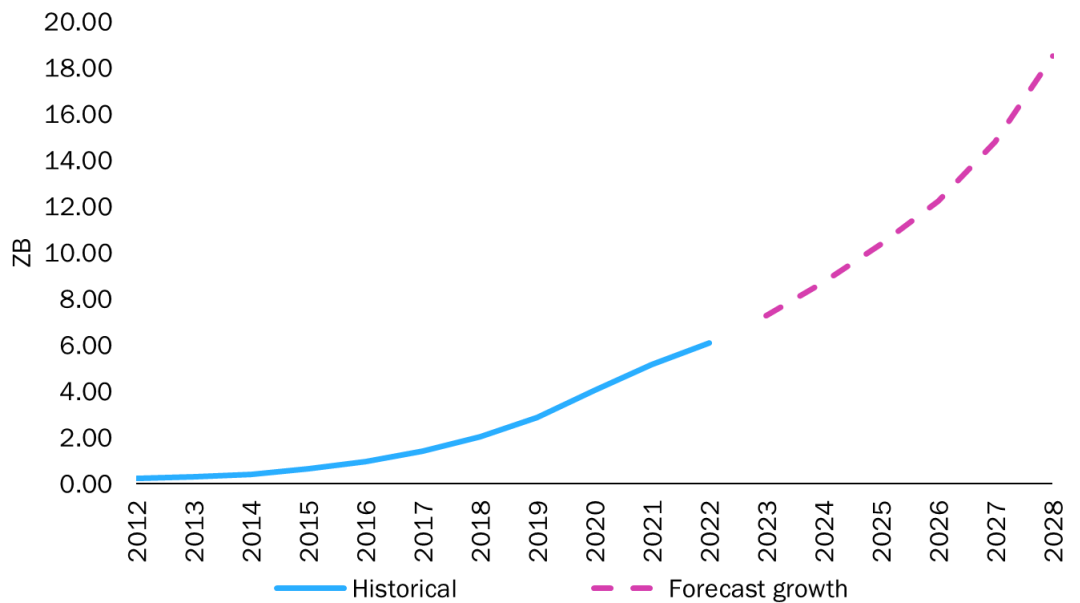
Source: Analysys Mason

The combined growth of fixed internet and cellular networks is estimated to have been 18% in 2022. This is lower absolute growth than in 2020 and 2021 when the COVID-19 pandemic created unusual patterns of usage worldwide. Nonetheless, this still represents an annual growth of 936 218PB; which is nearly as much as the total of all fixed internet and cellular data traffic carried worldwide in 2016.

TV/video content accounts for more than half of all data traffic, with huge worldwide consumption of services on both fixed and mobile networks. Other services and applications such as social media, gaming and the use of cloud applications also generate large volumes of data traffic.

There is a natural limit to the number of people that can watch/share videos, and to the amount of time that they can spend viewing or uploading video content. Some countries with large penetrations of high-speed fixed broadband and high-speed cellular data services may be starting to approach those limits, and growth in developed markets was much slower than elsewhere in 2022. For instance, Analysys Mason estimates that the volume of data generated by fixed internet traffic in Europe and North America only rose by around 11% in 2022. We believe that this figure still reflects an ongoing readjustment following the particularly unusual growth of fixed internet traffic experienced by operators during the pandemic, and there are signs of an uptick in some countries in 3Q 2022 figures. We currently forecast a slight rise in growth rates as the final effects of the pandemic flush through, and then the long-term trend of a steady decline in growth rates will resume, with global annual growth rates falling to around 18% in 2026. After 2026, we expect to see the arrival of new metaverse applications, which will contribute to a slight re-acceleration of traffic growth based on the use of edge processing to support these services. Global fixed internet and cellular data volumes are forecast to rise to a combined total of 18.5ZB worldwide by 2028 – nearly 3 times what it was in 2022.

Figure 2.2: Forecasts for fixed broadband and mobile data traffic, worldwide, 2012–2028



Traffic will vary in each country, with some bulges of demand, for instance, in countries where cellular fixed-wireless access (FWA) is deployed, FTTH is deployed on a large scale or where industrial 5G networks are launched on public networks. However, using CAGRs to predict growth rates is not realistic.

The application with the biggest medium-term potential to accelerate data traffic growth is ultra-high-definition (UHD) video at 4k and 8k resolution. Customers have been buying TVs capable of displaying higher resolution 4k pictures for a number of years. This means that any significant move to deliver larger volumes of content in higher-resolution formats by one of the larger IP TV services providers or online video/content streaming providers could lead to a new wave of data growth, even in developed countries. Mobile device trends could also lead to greater consumption of 8k video. 8k video recording is now available on a number of commercially available smartphones. This is highly likely to lead to more user-generated 8k video clips being uploaded to, and consequently downloaded from, the internet. Moving from standard HD to 4k TV (depending on streaming provider, frame refresh rate, and importantly, the compression/encoding method used) will generate 2 to 5 times as much data. Moving from 4k to 8k resolution could double or triple the data volume again, even at low frame rates. Video also comes with quality-of-service challenges, especially on mobile, where customers’ expectations of quality are rising.

“[Our] strategy is driven by the continuing rise in video traffic, which is not yet fully outweighed by compression, and by the sharp rise in QoS expectations from consumers as well as enterprises.”
 Converged operator, North America

Other trends that are set to have an impact in the future include the following.

- **Continued proliferation of IoT devices.** Analysys Mason forecasts that there will be 6.2 billion fixed and mobile connected IoT devices by 2030, up from nearly 1.8 billion at the end of 2020. The vast number of connected devices on fixed and mobile networks will contribute to growth in traffic volumes. Internet-connected, video enabled IoT systems (such as security cameras) and latency-sensitive industrial equipment will increase in importance within this category.

- **Connected vehicles.** Increasing numbers of car models already include the option for cellular data connections, to the extent that hundreds of millions of connected cars are expected to ship in the coming years, many with inbuilt 5G mobile access. The inbuilt connectivity will be used by the automotive manufacturers themselves for system telemetry and maintenance, as well as to enable the provision of in-car entertainment services (including video). Cars will also continue to act as Wi-Fi hotspots, supporting the connectivity of other in-car devices (such as phones, laptops and tablets). Other vehicle types, such as industrial and logistics vehicles, and public transport vehicles, are also increasingly connected.
- **The metaverse.** Adoption of augmented reality (AR) and virtual reality (services) has so far had limited the impact on overall traffic volumes, with most processing/rendering happening on users' consoles or home computers, which are, in turn, directly connected to users' headsets. Significant investment is going into building augmented and virtual worlds for entertainment, commerce and engineering, which (depending upon technology choices made) could drive substantial growth in fixed internet and mobile data traffic. Real-time edge rendering could drive huge volumes of traffic in aggregation and access networks, and the use of edge computing could change the pattern of traffic in transport networks, but the future remains somewhat uncertain.

2.2 Architectural changes are creating new traffic patterns and flows within networks

Operators' networks are coming under increased internal pressure as well as from the general ongoing rise in the volumes of data generated by end users. A number of architectural changes within operators' own networks, combined with structural changes in the systems operated by large content and applications providers, and cloud providers (hyperscalers) are altering traffic flows and patterns across and between telecoms networks.

Within operators' own networks, virtualisation of network functions across multiple cloud infrastructures is leading to new traffic behaviours: Their systems are increasingly able to move virtual workloads around to cope with changes in demand, to deal with localised issues or to prioritise certain types of traffic.

Virtualisation and disaggregation of the RAN infrastructure (vRAN) has the potential to create new fronthaul capacity pressures that did not previously exist.

The introduction of edge compute capabilities within operator networks has the potential to alter traffic profiles, as will the introduction of AI systems designed to dynamically modify networks to maximise efficiency or service quality.

“Increasingly there are higher rates [of traffic] concentrated in certain hotspots. This trend is more marked as network usage changes – [there are] more localised centres of traffic such as business parks or city networks feeding into the backbone. We expect this hotspot trend to intensify as we deploy or use edge compute and small-cell networks for industry. That will increase...traffic [between systems in the network].” Converged operator, Middle East

Operators are also increasing the availability of cloud services for their end users. This reflects a wider global trend towards increased reliance on cloud-based storage, data back-up, processing and networking systems, adoption of cloud-based ML and analytics, and experimentation with cloud-based AI. Vast volumes of data are now flowing within and between data centres. At the same time, smaller, modular, local data centres are being deployed (bringing capabilities closer to end users, and reflecting the difficulty and cost of finding large physical sites within dense urban areas).

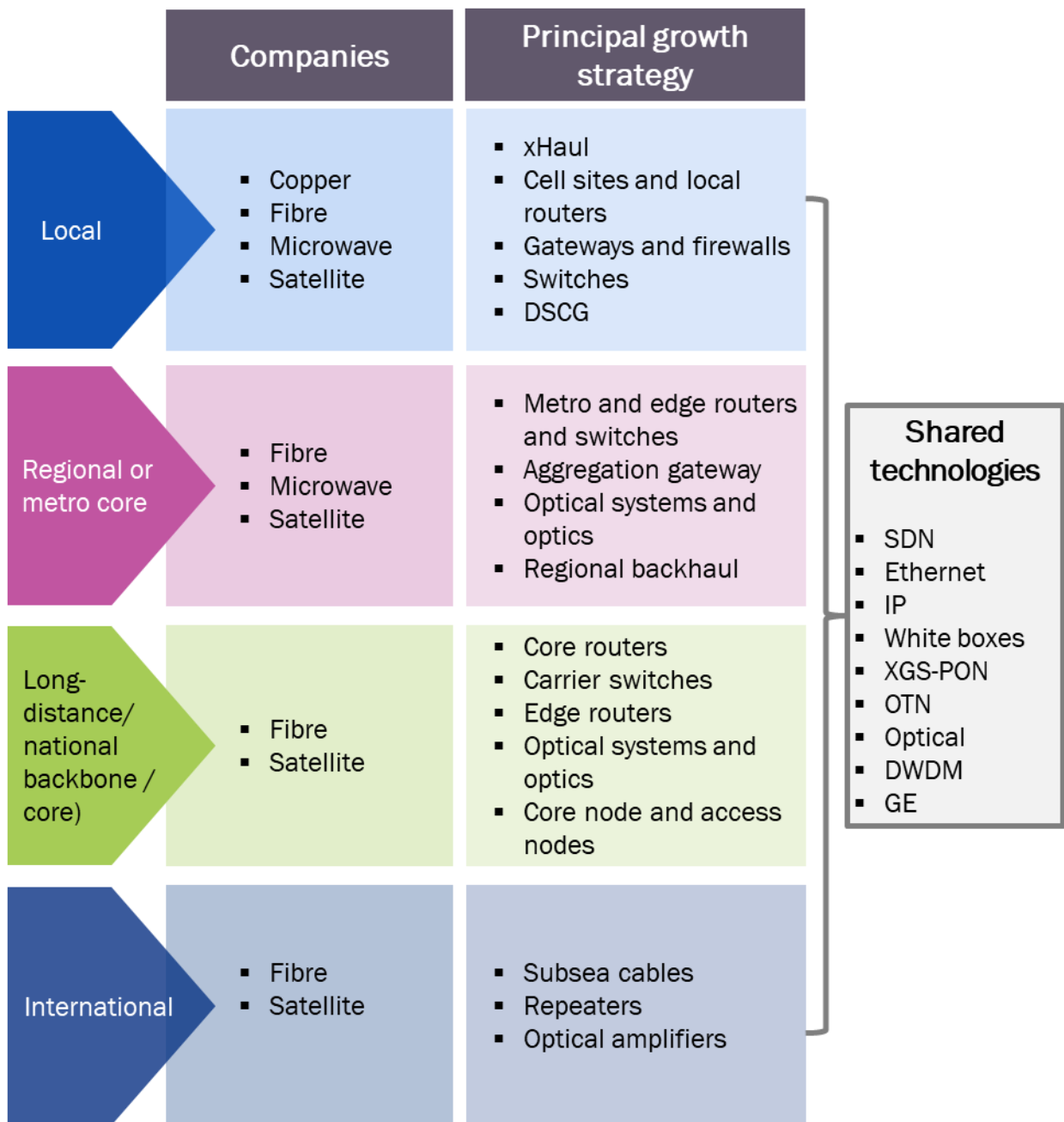
These new patterns are creating a requirement for additional capacity to carry all the data moving between operators' and content providers' systems. Growth of traffic between data centres is creating traffic pressures that have not historically existed.

2.3 Pressures are felt strongly in backbone, metro core and DCI networks

Much is spoken about the growth of traffic and the need for more spectrum, and faster, more-reliable fixed and mobile services, with a great deal of focus on access networks. Much less is spoken about the hidden impact of the traffic growth on operators' transport networks – and in particular their metro core, data centre interconnect and long-distance national networks.

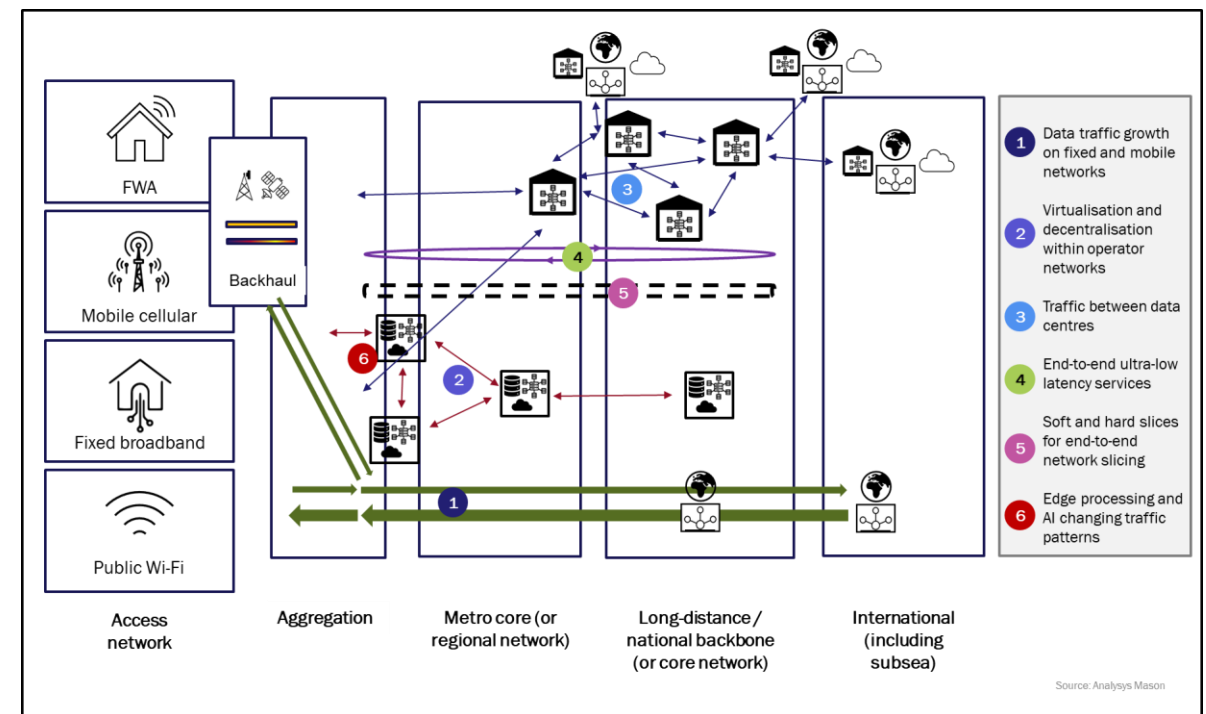
Operator transport networks vary widely in terms of specific topology, but in generalised terms, they contain a number of typical parts. Operators' transport infrastructure provides backhaul from mobile access networks and fixed access networks. This infrastructure also aggregates the traffic (bringing together data traffic from multiple locations onto higher-capacity routes) and transmits the data to end destinations via a long-distance backbone network (often called the core network). Regional areas with high concentrations of traffic will have metro core infrastructures (high-capacity dense transport networks with a variety of topologies) sitting between the aggregation networks and the long-distance backbone network. Some of this infrastructure will be owned by retail mobile and fixed broadband providers. Some will be owned by specialist wholesale providers. The infrastructure will also include operator data centres (with high-capacity data centre-to-date centre links), high-capacity points of interconnect with third-party national infrastructures and with international networks (including via submarine cables). Overlaid on this will be content, application and cloud providers' data centres and points of presence, interconnected with the operator's transport network at geographical locations designed to maximise customer service quality, and interconnected with each other (forming data centre interconnect (DCI) wide area networks).

Figure 2.3: Transport network elements



Source: Analysys Mason

Figure 2.4: Pressure points in the transport network



The trends highlighted above are leading to sustained pressure on, and a changing role for, metro core, long-distance backbone and DCI networks. Not only do they now play a role in getting data, content and services to and from end users as fast and efficiently as possible, but these parts of the network also host mission-critical compute, storage and caching systems, and are responsible for ensuring the fast and efficient flow of data between systems. They need to underpin the continued provision of ultra-low latency, high-capacity fixed network services to high-spend enterprise customers. Consumers' expectations are also rising, to the extent that mobile customers now expect their video services to provide a good experience. This means assuring quality throughout the network. Simply providing high-speed access is not sufficient.

In the near future, these parts of the network will also need to support the ultra-low latency 5G transport services that are anticipated to underpin a range of new mobile applications such as manufacturing automation, automated vehicles and transport systems (V2X, V2V), and AR/VR assisted medical services. Metro core and long-distance transport networks will also need to support soft and hard slicing if operators are to introduce end-to-end network slicing solutions for their customers.

The continued growth of fixed internet data and cellular data traffic, the changing architectural trends and the evolving reliance put on transport networks to support new services together mean that operators will face pressures to continue to upgrade their long-distance backbone, metro core and DCI networks. Failure to invest in these parts of the infrastructure to support local pressures and overall growth will have a significant impact on customer experience.

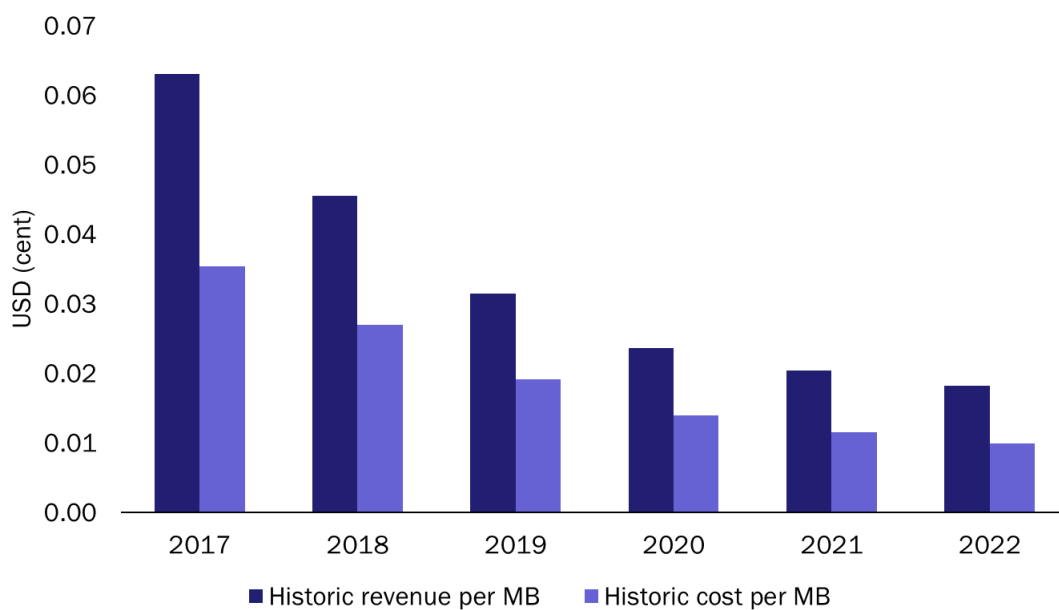
3. Operators must strategically scale their long-distance backbone, metro core and DCI networks

Operators and hyperscalers have already been investing in upgrading their metro core, long-distance and DCI networks, with many having started to deploy 100G optics, and some deploying 400G optics. The biggest operators will soon need to widely deploy 800G systems. They will need to make these investments against a challenging economic backdrop.

3.1 Revenue is not growing as fast as data traffic, so cost per bit must continue to decline

Global telecoms service revenue has grown very slowly in recent years, with low single-digit growth rates per year at best. Set against this, the global rise in telecoms data traffic has meant a rapid fall in revenue per MB. Operators have countered this by investing to drive down the cost of their services. The figures below show that they have managed to keep costs per MB coming down at a similar trajectory to the revenue per MB.

Figure 3.1: Historic revenue per MB and historic cost per MB in telecoms networks (network capex and network opex), 2017–2022



With sustained long-term traffic growth likely in both fixed and mobile networks, and with revenue growth set to be proportionally much slower than traffic increases for the foreseeable future, operators can expect for revenue per bit to decline. They will need to force an equivalent decline in the cost per bit in order to sustain profit margins.

3.2 Operators must also pay attention to growing environmental pressures; upgrade strategies must be sensitive to sustainability requirements

Traffic growth is not the only factor putting pressure on operator profit margins. Telecoms operators account for 2–3% of energy consumption worldwide, and energy costs account for a substantial portion of operating costs. This portion has grown quickly with recent global rises in the cost of energy.

Operators are also coming under significant pressure from both internal and external stakeholders to improve their environmental credentials. Reducing power consumption and carbon emissions are hugely important to operators in this context. Sustained economic and environmental pressures mean operators must find a new way of doing things.

Given these pressures, large-scale upgrades to 800G links, forklift upgrades of equipment and environmentally insensitive investments are not an option. Operators need to plan their 800G upgrade strategies carefully. They need to make sure that they:

- have sufficient capacity to serve customers and remain competitive;
- avoid racing too early to add extra capacity that might remain underused in some areas;
- avoid investing in assets that do not offer the flexibility to cope with future growth requirements because they will require upgrade or replacement before they reach the end of life;
- reuse common components, where possible;
- deploy a transport network that can cope with changing traffic patterns – use of edge computing or distributed networks could increase or decrease transit traffic in ways that are currently challenging to predict and the architecture needs to be flexible enough to change with these evolving traffic patterns;
- identify deployment solutions that minimise capex and opex, without compromising their ability to support new services or business models, or to deliver appropriate quality of service, resiliency and redundancy.

4. Converged IP/optical networking is an option for scaling efficiently and cost-effectively

Network operators have traditionally run separate Layer 1, Layer 2 and Layer 3 infrastructures, often with separate network management systems, and with separate teams of personnel to manage the routers, switches and optical line systems. Faced with the continual pressure to deliver more capacity, improve quality of service and support for new service types, operators have been seeking new strategies to help them reduce their costs and improve operations. Converging IP and optical infrastructures has emerged as a realistic method for achieving these aims while also enabling an upgrade path to 800G.

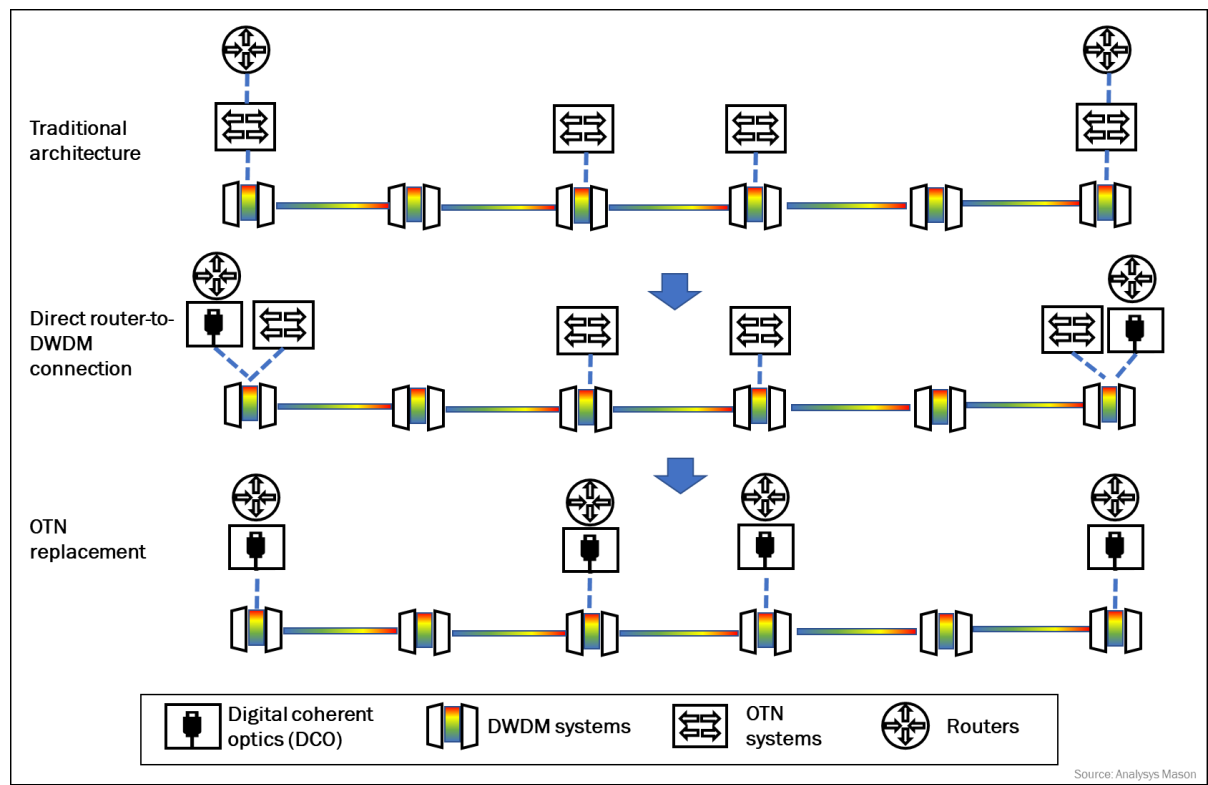
“Our key goal in planning future transport networks is to modernise the network to support SDN [software-defined networking], IP/optical convergence and other technologies. These will enable us to maximise the capacity available in this network for a long time... and to deal better with traffic spikes in certain locations/times of day.” Converged operator, North America

A number of technology innovations now mean that operators have the choice of deploying direct optical links between routers, and creating a converged IP/optical infrastructure.

- Digital coherent optical technology enables fibre-optic capacity to be increased, and new dense pluggable form factors (such as QSFP-DD) complement embedded form factors to provide a range of options depending on the infrastructure that has already been deployed.
- The latest generation routers provide 400G and 800G ports in highly dense and space-optimised form factors. This means that coherent optics can be added to enable high-speed, router-to-router connections, currently supporting up to 400GE (Gigabit Ethernet) depending upon link length and fibre type. These new generation routers also use much less physical space – enabling operators to save on property costs.
- The use of optical breakouts enables flexible deployment models. High-speed ports can be used to aggregate multiple lower-speed Gigabit Ethernet (GE) connections (for instance, 4 x 100 GE into a 400G port, or 2 x 400 GE into a 800G port). This makes it possible to provision links with appropriately sized optic connections, without using a separate port for each link. In addition, 800G-capable QSFP-DD ports with 2 x 400GE or 8 x 100GE optics enable a migration path to reuse existing connectors and cables but also enable an operator to be ready to offer 800GE services when the 800GE standard is finalised.
- The latest chipsets support massively improved system density (more ports per 1RU base plate), and hence space optimisation, and improved energy consumption (less energy used per bit). This is a major change and a key enabler of IP/optical convergence.
- Tools to support network operation and management are getting better all the time, and are critical to enable IP/optical convergence. Network management tools have evolved to enable network programmability (supported by new routing innovations such as segment routing), sophisticated traffic management as well as the ability to manage IP and optical layers with a single management system. This, in turn, gives operators the opportunity to rethink their personnel structures, by combining operational teams that previously worked in silos.

Figure 4.1 below shows a possible migration path, with an operator initially replacing a traditional three-layered networking architecture by using digital coherent optics to directly connect routers and IP services to the DWDM layer; and subsequently (following the implementation of private line emulation services) removing OTN equipment.

Figure 4.1: IP/optical integration journey



IP/optical integration is not viable yet for all deployment scenarios – for instance, ultra-long distance, fibre-optic links still need dedicated optical equipment that has been fine-tuned for range. In some instances (depending upon traffic topology, traffic flows and link utilisation, or customer requirements), retaining a separate optical line system may be appropriate (for example, for delivering switched wavelength services). In the future, the next generations of pluggable coherent optics (such as ZR++) are expected to significantly extend the average distances achievable such that operators will be able to consider an IP/optical convergence strategy for much of their long-distance infrastructure too. In the meantime, IP/optical integration is gathering momentum, with operators publicly announcing plans to adopt the approach, and many others understood to be planning or actively implementing it.

Figure 4.2: Factors for operators to consider

Factor	Consideration
System density/space efficiency	Space and power are important drivers of cost, with larger equipment needing more floorspace and leading to higher property fees. Improved space and power utilisation is required to accommodate greater traffic volumes without the need to find additional physical floorspace or sites for facilities.
Existing plant	Type and age of equipment is a key factor. Ageing transport equipment may not have the density, power, capacity or service flexibility required in the future, and maybe cost-inefficient. In such cases, operators will need to modernise the network in order to get the most out of recent advances in optical line systems, switch and router technologies.
Energy efficiency	Cost and environmental pressures have placed greater emphasis on energy efficiency than ever before. Operators must deploy increasingly energy-efficient systems. However,

Factor	Consideration
Transmission range	they must also consider total lifecycle carbon emissions, reusing existing equipment or components where possible. Coherent pluggable optics have a shorter range than optic line systems that have been optimised for ultra-long length connections, so network reach and capacity requirements need to be modelled. No single technology solves all options yet.
Topology and traffic flows	Different optical, switch and router technology combinations are appropriate depending upon the topology, traffic flow sizes, as well as the patterns and services supported, and the link lengths. Capex and opex benefits for different technology combinations need to be modelled for each specific instance. No single approach is optimal in all circumstances. Modelling should include evaluation of new architectures and the potential savings to be made by deploying new architectures that converge the network layers.
Capex and opex costs	Optimising capex and opex to minimise total cost of ownership is crucial. Pay-as-you-grow investment options can enable phased upscaling of system capacity. Systems leveraging the latest, most-efficient chipsets and high-density systems can help to make upgrade economics work.

Operators need to adopt a nuanced approach, considering each technology solution on merit for each set of links, and they must consider factors such as system density, network topology, transmission range, pay-as-you-grow capability, space efficiency, the need to sustain high-quality of service, the ability to support new services and business models, and the requirement to scale cost-effectively.

“We have recently embarked on an IP/optical integration strategy which we will accelerate to support 5G, fibre and enterprise services expansion. We believe this will give us greater resource agility and flexibility and improve our cost and energy efficiency to support different traffic types and the proliferation of access networks.” Converged operator, Middle East

5. Recommendations

Operators must plan for sustained pressure on metro core, long-distance and DCI networks. Even where national growth of fixed or mobile access data traffic is slowing, new pressures will be introduced by changing network architectures, and by new service models.

Operators should start to plan for 800G upgrades in metro core, long-distance and DCI networks, taking into account the need to increase capacity and ensuring that they can cope with the anticipated traffic growth and any unexpected spikes in demand while also getting the best use of existing equipment.

Depending on the technology starting point, traffic patterns and utilisation levels, using flexible integrated IP/optical networks can enable a pay-as-you-grow, high-density, operationally efficient and sustainable means of upscaling to 800G. Operators that are not already doing so should join many of their peers and seriously consider this technology option.

When considering an IP/optical integration strategy, operators must ensure that they have access to software-defined network (SDN) management tools that can support network programmability, sophisticated traffic management, as well as the ability to manage IP and optical layers with a single management system.

6. About the author



Simon Sherrington (Research Director) leads Analysys Mason’s new Transport Network Strategies research programme, and its established Telecoms Strategy and Forecast programme. He also has a remit to expand Analysys Mason’s research forecasts and cross-programme thought leadership. He has nearly 30 years of experience in the industry, having worked as an analyst, consultant, market researcher and publisher. He has commented and advised on many different aspects of the telecoms business during that time. His CV includes a wide range of assignments covering fixed and mobile devices and networks, operator strategies, infrastructure evolution, as well projects encompassing retail and wholesale, and business and consumer services. Simon joined Analysys Mason from Innovation Observatory, a business he founded in 2005 to help clients working in the telecoms, media, IT and environmental technology sectors. Prior to that, Simon worked for Analysys Mason in a number of roles including Head of Custom Research, and early in his career he worked for CIT Publications (at the time a publisher of telecoms and media reports). Simon holds an LLB from the University of Exeter.

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