



Beyond the limit

NOKIA

Coherent solutions for the next decade

Contents

- 3 What if the end was only the beginning?
- 4 Accommodating the explosion of mobile, video and cloud brings fresh challenges
- 5 Nokia fifth generation Photonic Service Engines (PSE-V) – see what's possible beyond the limit
- 6 Superior network economics begin here
- 7 Three ways PSE-V delivers beyond the limit
- 8 Building a foundation for the next decade
- 9 The world's most competitive network strategies begin here
- 10 Intelligent designs that balance performance and efficiency
- 11 Taking application-optimized coherent solutions beyond the limit
- 12 The PSE-V Super-Coherent (PSE-Vs)
- 13 The PSE-V Compact (PSE-Vc)
- 14 New revenue-rich service possibilities begin here
- 15 We're here to help you deliver now and prepare for the future

What if the end was only the beginning?

If you know your history, you'll know that in 2010, 4G and smartphones exploded into our lives, and our appetite for mobile, video, and cloud services has shown no signs of slowing. If you really know your history, you'll know that 2010 also marked the introduction of coherent optical transmission technology. Just as 10Gb/s optical transport was reaching its limits in capacity and distance, the introduction of coherent transport arrived just in time to enable the needed continuation in network scaling.

Yet service providers face fresh challenges keeping pace with growth. Increasing transmission capacity using smaller, lower cost, more powerful silicon – is becoming harder to solve by scaling capacity alone.

Nokia has already taken optical network performance and scale to the limit. As the bandwidth-carrying capacity of fiber nears its ceiling, and with 5G on the horizon, we're unleashing a bold new wave of possibilities with our fifth generation of Photonic Service Engine (PSE) family of coherent optical transport solutions. Going beyond the limit into a new era of application-optimized networking solutions, powered by our innovation in coherent modem algorithms, design of coherent digital signal processors (DSPs), vertically-integrated silicon photonics, and an industry-leading approach to electro-optic integration, network operators can maintain the pace of reductions in power, space, and cost needed to scale networks into the next decade.



Accommodating the explosion of mobile, video and cloud brings fresh challenges

Over the past decade, advances in coherent technology have been the key innovation increasing the capacity of optical transport systems, while at the same time continually pushing down the cost per bit transported. The result is that network operators have been able to accommodate the deluge of traffic brought on by the massive growth in mobile, video, and cloud services, while maintaining an effectively flat level of network capital spend.

The problem is, traffic growth shows no signs of abating, yet the trends that have enabled service providers to accommodate that growth – increasing transmission capacity through more advanced modulation techniques combined with smaller, lower cost, more powerful silicon – are becoming ever-harder to solve by scaling capacity alone. As ever-growing network traffic sees the use of coherent optics expand into metro and access networks, network operators need solutions that efficiently support bandwidth growth across an ever-wider set of network applications, driving a shift towards application-optimized solutions.

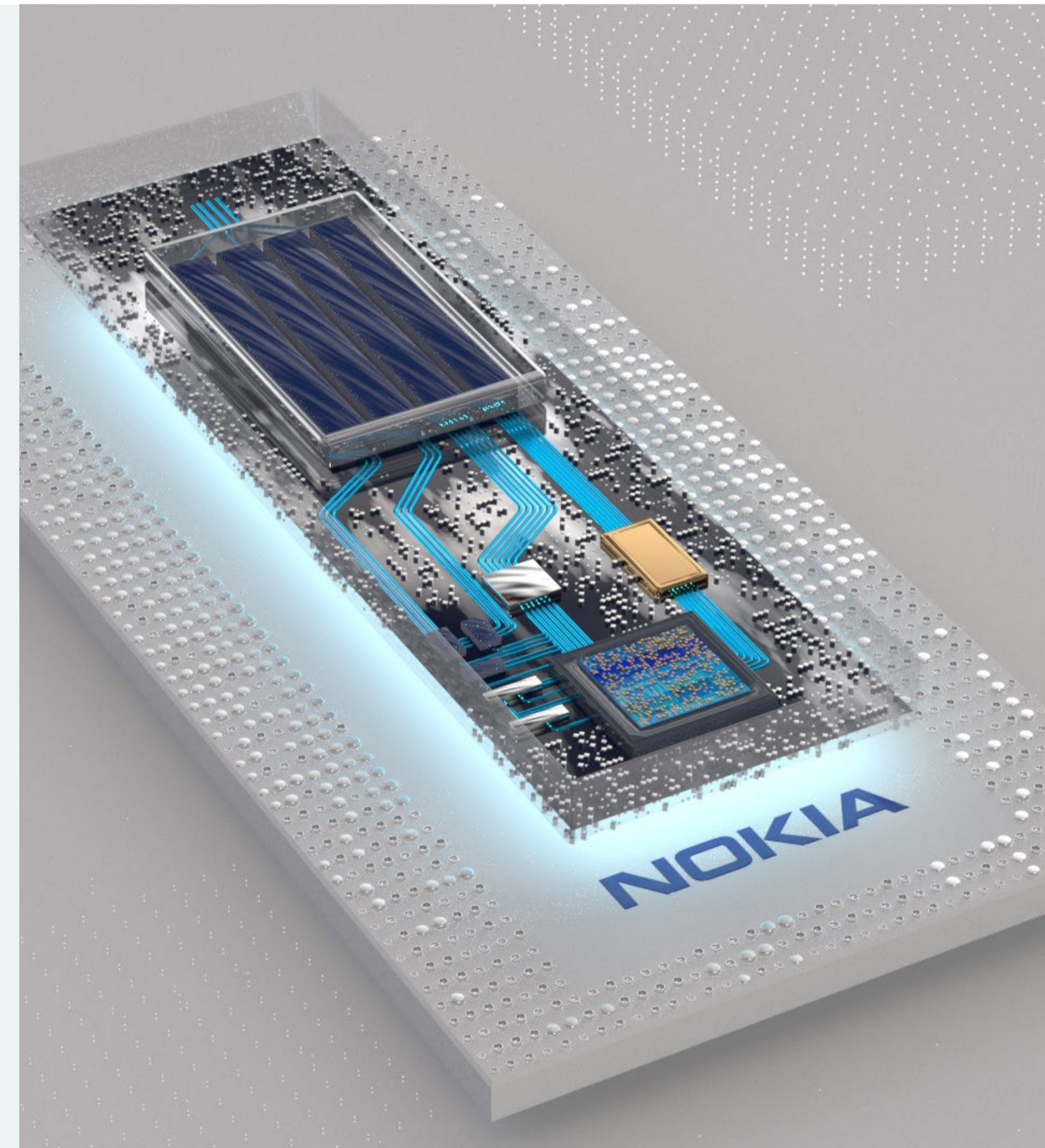
Fifth-generation Photonic Service Engines

– see what's possible beyond the limit

Our PSE-V family of high performance coherent optics leverage Nokia's investment in coherent modem design, DSP integration and innovative silicon photonics technology to deliver fully integrated, end-to-end coherent electro-optic solutions, including transceivers optimized around different, focused applications within the network.

It's a portfolio which brings bold new thinking around chips, optics and systems to how networks are architected in a world where rapid advances from Moore's Law in pursuit of the Shannon Limit are largely behind us.

- The PSE-V family of coherent solutions makes it possible to deliver new form factors and capabilities, with technology that brings complex functions together in fully integrated coherent transceivers. This is empowering our customers to tackle network design in game-changing new ways, architecting networks that actively balance the delivery of flexible and robust service experiences with precisely the right technology for precisely the right application.
- Build bigger, faster, more resilient networks when you want – or smaller, power-optimized, lower cost when you need, to suit your network needs and competitively keep pace with the demands of your customers and emerging connectivity challenges across long haul core and subsea cable systems, metro and regional data center interconnect (DCI), and metro or access networks.
- It's your network, your way: supported by the world's broadest, most programmable, massively scalable, TCO-optimized portfolio.



Superior network economics begin here

As multiple generations of coherent technology have enabled scaling of wavelength speeds and reach performance, so too ever-growing network traffic saw use of coherent optics expand from long haul and subsea networks into metro and regional core networks, and high-capacity data-center interconnection applications.

Nokia's 5th generation coherent optics, enabled by the PSE-V family of products, lets you support bandwidth growth across

applications from the network core to the access edge, optimizing parameters such as wavelength speed, reach, power and latency. That means superior network economics across a broad range of use cases. And if you're using PSE-2 or PSE-3, your end-end operations are protected too, with backwards compatibility between PSE-V and prior generations of coherent electro-optics.



Three ways PSE-V delivers beyond the limit

Nokia PSE-V enables maximum fiber capacity at challenging reaches, like, high-capacity core long-haul networks and transoceanic links spanning thousands of kilometers.

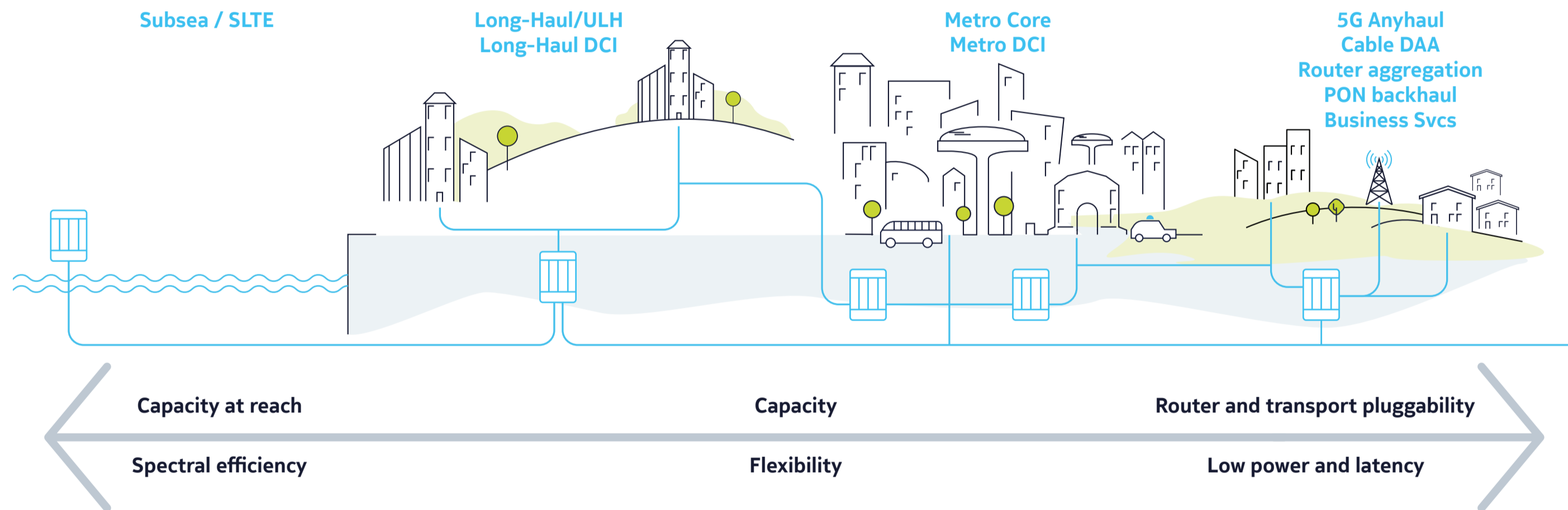


Figure 1

But it also supports capacity scaling for metro, regional and long-haul networks, across a wide range of capacities, services types, and optical transport platforms, while efficiently operating across wavelength switched ROADM networks.

Finally, PSE-V delivers coherent solutions optimized for access and metro applications, able to increase fiber capacity and optical reach compared to non-coherent and/or non-WDM solutions. This maximizes scaling at the lowest cost when

support high bandwidth connectivity in packet-centric pluggable form-factors for applications such as metro Data-Center Interconnection (DCI), metro aggregation, and metro-regional core network. Now you can support bandwidth scaling for new architectures like mobile Anyhaul for 5G networks, evolution of cable networks Distributed Access Architecture (DAA), and bandwidth scaling for business services, router aggregation, and PON/FTTx backhaul.

Building a foundation for the next decade

Society today depends on always-on, high-bandwidth networks. It's what keeps our infrastructures running and our people connected. All of this is made possible by multiple generations of coherent electro-optics.

As we move beyond the 'double the transistors, half the cost' trend as described by Moore's law, we must pursue solutions that address another fundamental axiom of technology - the Shannon Limit. Shannon has revealed that the capacity of a given communications channel is finite, and coherent solutions are now starting to approach this performance metric in terms of maximum capacity possible within the optical fiber spectrum, also known as "spectral efficiency".

With PSE-V, we can directly connect end-user requirements with our in-house expertise in end-to-end networking systems, enabling vertical integration of complete end-end optical transport solutions to deliver market-leading performance and push progress towards improving the economic Shannon Limit.

Nokia's PSE-V coherent solutions integrate sophisticated digital signal processing algorithms into a family of coherent digital coherent optic (DCO) transceiver modules that continually optimized around maximum performance and lowest power to optimally address the broadest range of end-to-end network applications (Figure 2).

Nokia Coherent DSP Evolution



Figure 2

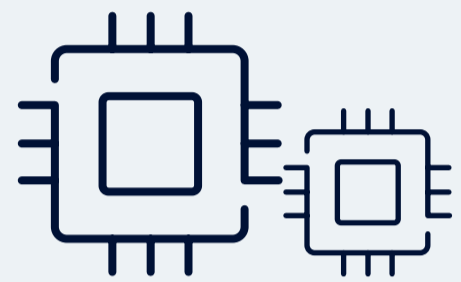
The world's most competitive network strategies begin here



The latest generation of coherent solutions will transition from being a transport-centric technology, to connectivity underpinning a wide range of networking functions, different platform implementations across routers, P-OTN switches and optical transport systems, and varying end-user requirements. Designed to be integrated either as on-board modules in transport and packet systems, as pluggable transceivers in a variety of form-factors to enable platform portability, or as custom sub-assemblies for integration into 3rd-party systems, Nokia's PSE-V coherent solutions will enable capacity scaling and optimal economics from the network core to the coherent edge.

Building on Nokia's in-house development of performance-leading coherent DSPs, our vertical integration of silicon photonic capabilities enables further end-to-end integration and optimization of the complete coherent technology solution set. By pulling complexity out of other optical components and putting key photonics functions into silicon, SiP optics are enabling new form factors and functions that simply could never be addressed with discrete devices.

Intelligent designs that balance performance and efficiency



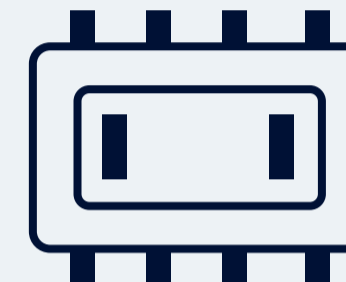
Application-optimized DSP's

Integrating sophisticated digital signal processing algorithms and coherent modem innovation into a family of coherent DSP's continually optimized around maximum performance and lowest power.



Silicon photonic optical engines

Pulling complexity out of other systems and putting it into silicon, while creating new form factors and functions that simply could never be addressed with discrete devices.



Novel integration and packaging

Eliminating bandwidth and distance limitations, significantly improving power efficiency and density, as well as ultimately enabling radically new form-factors applications and architectures.

Figure 3

By closely integrating both the optics and electronics, Nokia coherent electro-optic solutions eliminate bandwidth and distance limitations, delivering huge improvements in power efficiency and density, and ultimately enabling radically new form-factors applications and architectures (Figure 3).

Further generations of Moore's Law will drive various silicon Integrated Circuits (ICs), and the inter-connections between

them, to operate at ever-higher SERDES speeds for ASICs, baud rates for coherent DSPs, or faster interconnections between DSPs and optics. Leveraging standard Silicon CMOS fabrication processes and foundries, Nokia's SiP optics will deliver a foundational technology for integrating and scaling inter-chip connections for coherent electro-optics and on-board optics for chip-to-chip connections.

Taking application-optimized coherent solutions beyond the limit

Long the industry leader in application-optimized coherent solutions, Nokia isn't just changing the game again – it's creating an entirely new one.

PSE-V solutions designed with the latest generation of DSPs based on 7nm Silicon CMOS processes, and silicon photonic optical front-ends, take application-optimization beyond what we thought was possible, with a range of new products and solutions for all parts of the network.

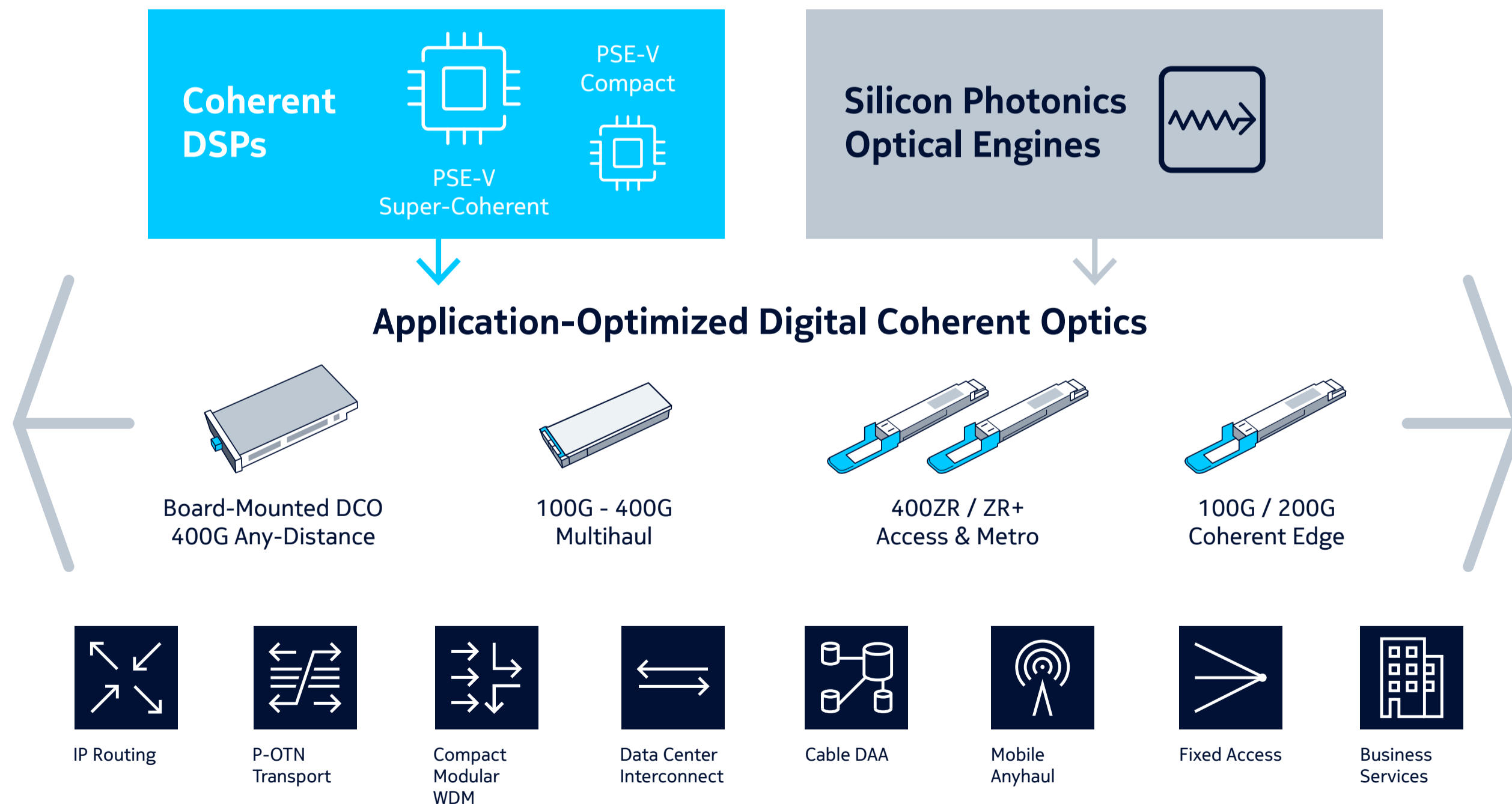


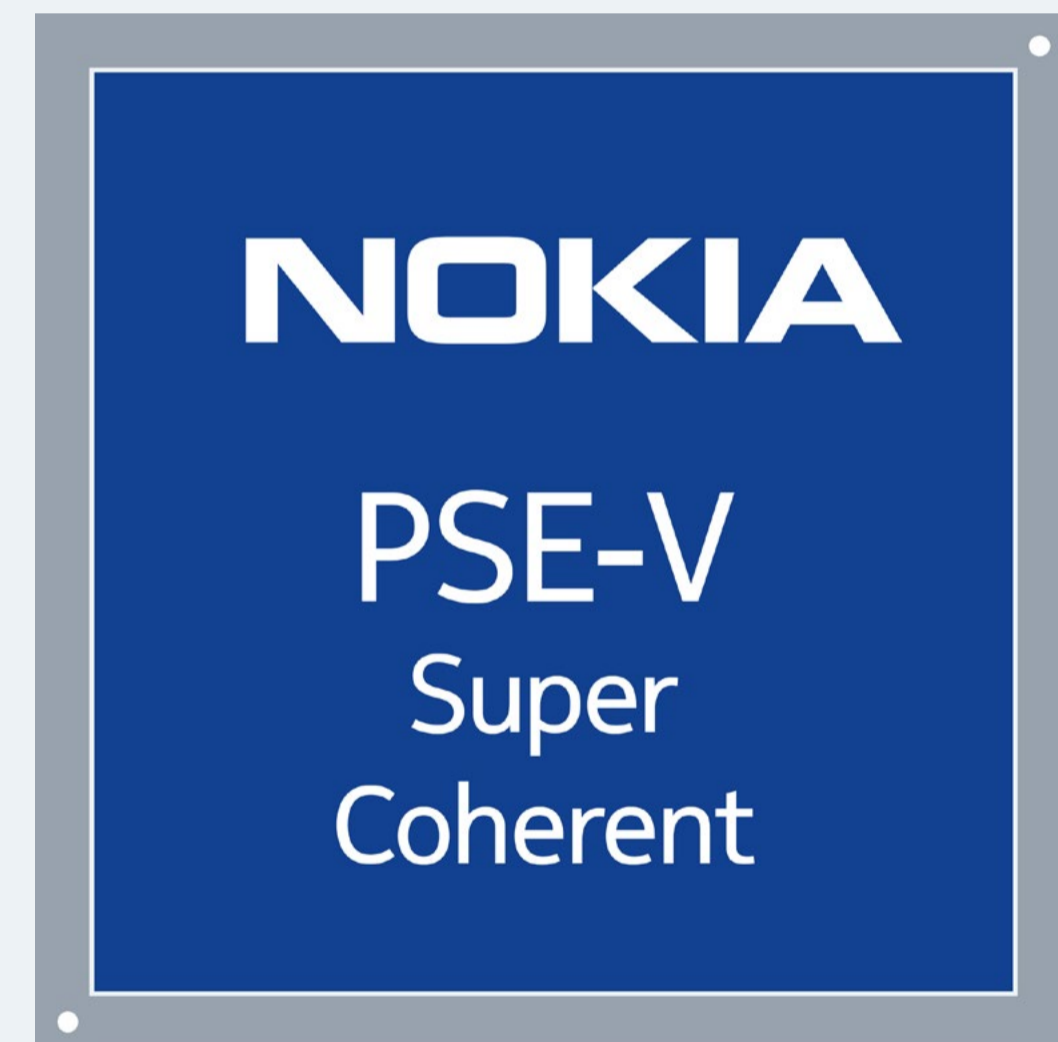
Figure 4

The PSE-V Super-Coherent (PSE-Vs)

Our PSE-V Super-Coherent (PSE-Vs) solutions delivers the ultimate in capacity-reach performance to enable maximum scaling in demanding applications such as subsea cable systems, long-haul and ULH networks, and high-capacity metro core and regional networks.

Building on the industry-first implementation of probabilistic constellation shaping in the PSE-3, the PSE-Vs implements the industry's only 2nd generation PCS algorithm and the industry's only continuous baud rate tuning. With advanced high-gain SD-FEC delivering increased performance with significantly lower overhead, the PSE-Vs jointly optimizes FEC and PCS, approaching the Shannon limit across the most demanding capacity-reach applications. This enables PSE-Vs to support scaling of long-haul networks to 600Gb/s up to 1500km of distance, and transport at 400Gb/s per wavelength over practically any ultra-long-haul and subsea fiber span. PSE-Vs is optimized for use in 100GHz WDM channel spacings over highly flexible CDC-F wavelength switched networks, enabling spectrally efficient operation and seamless upgrades over existing WDM channel plans.

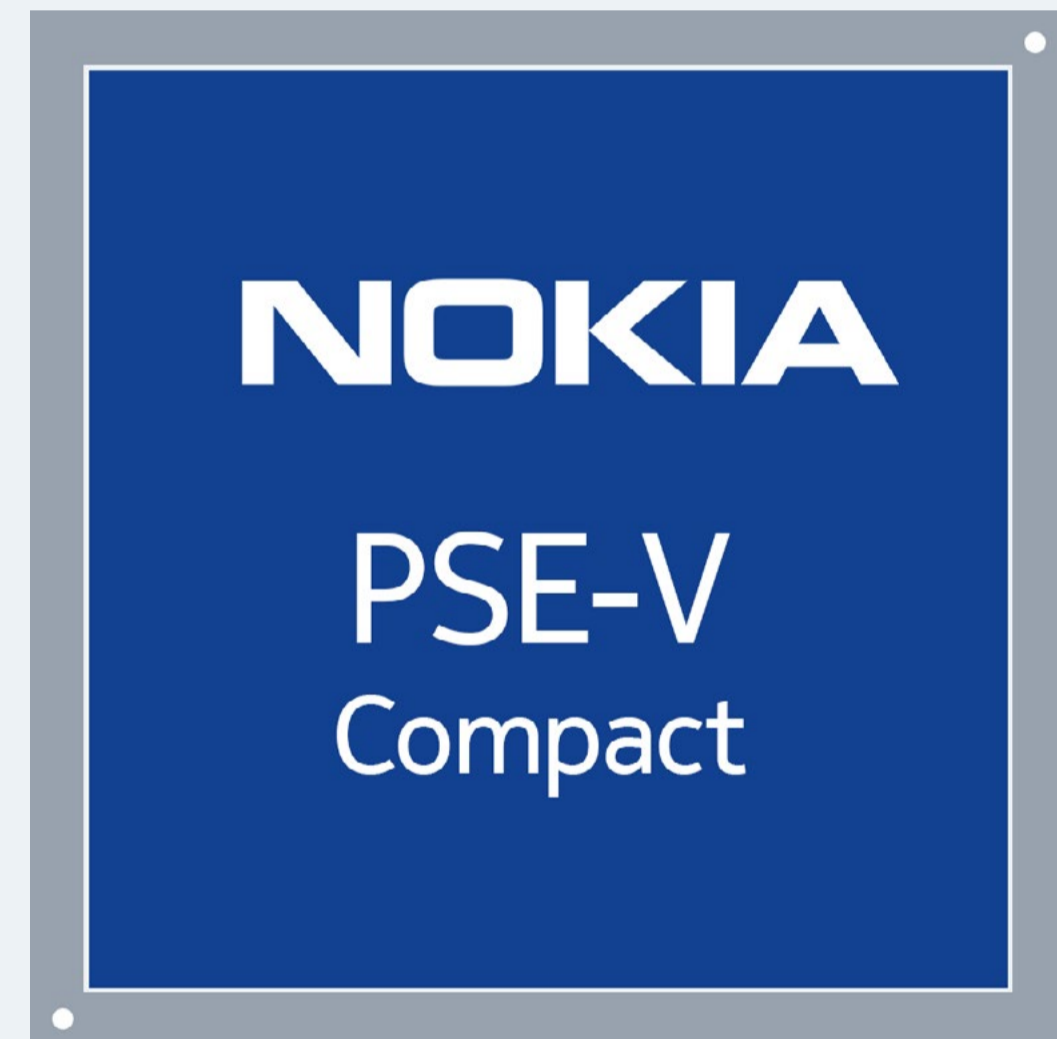
Put simply, you get lower total cost of ownership, with optimal performance and capability upgrades over prior coherent technologies.



The PSE-V Compact (PSE-Vc)

The PSE-V Compact (PSE-Vc) delivers optimal capacity with the lowest possible power consumption, transforming how you implement high-performance coherent optics into industry-standard pluggable coherent transceiver form factors. Supporting ultra-low latency operation, PSE-Vc is also optimized for time-sensitive applications such as 5G Anyhaul.

Leveraging different DSP operating modes and pluggable transceiver form factors, now you can choose the optimal coherent transceiver for your application; whether it's a CFP2 module supporting 100-400Gb/s Multihaul transport over distances in excess of 1000km, or router-pluggable QSFP-DD or OSFP 400G transceivers supporting 400ZR+ for metro-regional DCI, and aggregation and core IP-optical networks, 400ZR for access DCI, or 100G/200G pluggable transceivers deployed to the coherent edge.



New revenue-rich service possibilities begin here

A new era of services is here, powered by Nokia's PSE-V coherent solutions, making it possible to support even the fastest 400GE services, over any distance, without breaking the budget.

Now you can cost-effectively upgrade long-haul DCI links and national-scale packet networks to 400GE with greater spectral efficiency than prior generation solutions, without having to bond multiple, lower speed wavelengths to transport 400GE across long-distance links.

And that's not all; with PSE-V you can cost effectively deliver 400GE connectivity across shorter distances, with optimized 400ZR/ZR+ solutions that enable coherent connectivity between routers and packet switches for data center connections and

IP-optical convergence across access, metro and regional distances, without the power, complexity, and ultimately cost, disadvantages that would come from using less non-pluggable, application-specific coherent solutions.

By having a choice of application-optimized coherent solutions, network operators can now avoid the limitations of using "one size fits all" solutions, and now use products best suited to their network needs, whether that's avoiding regeneration sites on ultra-long or challenging fiber spans, maximizing capacity in core networks, scaling packet switch connections between data centers, or extending the benefits of coherent transport to the network edge.



We're here to help you deliver now and prepare for the future

Over the next ten years, network operators will need to be agile, responsive and cost-conscious when it comes to the inevitable challenges of scaling networks to accommodate the innovation in consumer electronics, cloud-based services and user growth.

Nokia's portfolio of application-optimized PSE-V coherent solutions are ready to meet that challenge, backed by Nokia's experience in delivering market-proven solutions across all network applications. Contact our sales team to learn more about how our insight-driven optical networking portfolio can help you unlock the endless possibilities.

Nokia is a registered trademark of Nokia Corporation. Other product and company names mentioned herein may be trademarks or trade names of their respective owners.

Nokia OYJ
Karakaari 7
02610 Espoo
Finland
Tel. +358 (0) 10 44 88 000

Product code SR2005043612EN (May) CID: 207464

© 2022 Nokia

NOKIA