

Cloud ecosystem and the role of cloud interconnect

Data center interconnect for the cloud era

Strategic White Paper

Data center interconnect (DCI) solutions are used to link and transport traffic between data centers. Although data centers vary according to market segment, DCI between the largest data centers hosting thousands of servers requires terabits of optical transport. With the continued growth of data centers across all segments of the market, DCI is the fastest growing application for optical transport. However, as data centers and IT move to the cloud, new cloud DCI solutions are needed to enable all participants to take full advantage of the emerging cloud ecosystem. Private, virtual private, hybrid and public clouds all have unique benefits to offer and cloud DCI — also known as cloud interconnect — can help deliver those benefits whether they include control, flexibility, agility, security or lower costs.

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Introduction

Most organizations are using some type of cloud; for example, a survey by Penn Schoen Berland (PSB) examined 1,500 large enterprises in the US and 750 in the UK and found that approximately 3 out of 5 are already using some form of cloud computing. In addition, 74 percent of large enterprises in the US have adopted private clouds. Thirty-five percent have adopted public cloud services and 22 percent have adopted a hybrid cloud model. The figures are very similar for large enterprises in the UK.¹

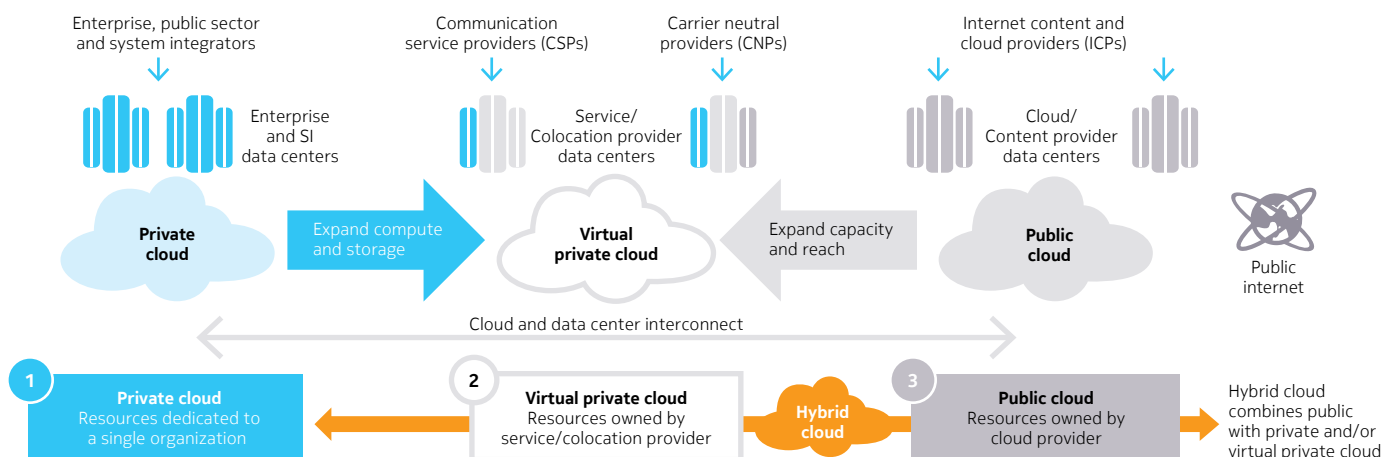
As data centers and IT move to the cloud, DCI solutions need to take full advantage of the new emerging cloud ecosystem. Private, virtual private, hybrid and public clouds all have unique benefits to offer, and the right approach to DCI can help deliver those benefits. Cloud DCI — or cloud interconnect — enables a more agile, efficient and flexible way for all participants in the cloud ecosystem to build scalable, integrated and dynamic networks to interconnect data centers and IT resources across private, virtual private, hybrid and public clouds.

Cloud interconnect provides connectivity that is fast, low latency, reliable, secure and cost effective. It offers more scalable bandwidth with reach and flexibility, and the ability to increase and decrease bandwidth as needed. Multisite and multi-technology capabilities help to share data, distribute applications and balance workloads. Most importantly, cloud interconnect provides agile, dynamic provisioning with support for orchestration of network resources quickly and easily, particularly across multiple clouds and administrative domains.

Emerging cloud ecosystem

There are several different types of clouds and participants in the cloud ecosystem, as shown in Figure 1.

Figure 1. Emerging cloud ecosystem and the different participants



¹ Penn Schoen Berland, 2015. "A window into large enterprise IT - A Penn Schoen Berland survey of senior decision makers," October.

It is important to note that cloud is a service delivery model, not a product, and the definitions of different types of cloud can be confusing. Some generally understood definitions are:

- **Private cloud:** The data centers and DCI network that interconnect them are completely dedicated to and controlled by a single organization such as an enterprise, or a group of organizations with a common interest such as an industry body or a government agency.
- **Virtual private cloud:** The organization's data centers are virtualized, which allows them to include remote data centers owned by other organizations, such as a communications service provider (CSP) or a carrier neutral provider (CNP).
- **Public cloud:** An internet cloud content provider (ICP) offers cloud services to organizations to use on a pay-as-you-go basis.
- **Hybrid cloud:** This model combines public with private and virtual public clouds, with orchestration of resources across the private-public cloud boundary.

The different types of clouds and participants in the cloud ecosystem are described in the following sections. For a more detailed description of the different types of cloud and how an organization such as an enterprise might use them, please see the Nokia white paper "*Cloud Interconnect for the Enterprise.*"

Private cloud

A private cloud consists of an organization's data centers and the DCI network that interconnects them. It can also include the private WAN that connects an organization's sites to their data centers; for example, by using a managed IP VPN service. A private cloud is usually dedicated to and controlled by a single organization, and operated by the organization itself or on its behalf by a third party such as a CSP or systems integrator (SI).

A private cloud is often chosen for running business-critical applications and handling business-critical information, because organizations often perceive it to offer the highest level of security and control and the lowest level of risk. Typically, a private DCI network connects a primary data center to a secondary data center in the same metro area. In some cases, a third data center in another region provides additional resiliency in case of major incidents. Private clouds — also known as on-premises clouds — can support virtualization, with applications and data distributed across the organization's own data centers. Virtualization allows IT assets to be quickly assigned and shared; for example, to redistribute workloads or reassign capacity for short-term projects.

Virtual private cloud

Virtual private clouds allow an organization to expand its private cloud cost effectively. In this case, the cloud can add data center resources owned by a third party, such as a CSP or CNP, as shown in Figure 1. The private cloud connects securely to a CSP or CNP colocation or multi-tenant data center by extending the organization's own DCI solution or by using a managed DCI solution, for example, from a CSP. From the organization's perspective, any assets or resources used in the virtual private cloud become part of its

private cloud. But the additional assets or resources are remotely located in the CSP or CNP data center facility. The organization can install and manage its own compute, storage and network assets and pay only for space and power. Or they can lease the resources they need from the provider, which can include different options from bare metal servers to dedicated infrastructure as a service (IaaS) or platform as a service (PaaS) solutions.

Virtual private clouds — also known as hosted clouds — provide greater flexibility for less critical business operations. Like virtual private networks, they keep different organizations' services and data separate from each other. They also allow capital expenditures (CAPEX) and operating expenses (OPEX) to be matched to an organization's IT needs, without sacrificing performance, control and security.

Public cloud

Public clouds give the organization another way to augment its private cloud. In this case, it uses resources or services provided by an ICP. The organization can use a managed DCI solution or the internet to access the public cloud. Public cloud resources and services are used on a pay-as-you-go basis. In other words, the organization only pays for the resources and services it consumes, based on the time they are used for. These public cloud resources and services remain completely separate from the organization's private cloud.

The ICP may host resources and services in their own data centers, but increasingly they are hosting them in CSP or CNP data centers. For example, many cloud providers — such as Amazon Web Services, Microsoft Azure, Google Compute Engine and IBM SoftLayer and software as a service (SaaS) companies such as salesforce.com — are locating their services in CSP and CNP facilities. They are doing so mainly because this brings their services closer to customers, improves the end-user experience, and provides a convenient and lower cost way of interconnecting with service providers collocated in the same facility.

Hybrid clouds

A hybrid cloud model combines private and public clouds and orchestrates resources across the private-public boundary. This approach enables data to move between clouds and allows resources to expand and contract seamlessly to meet changing workloads. The ultimate goal of the hybrid cloud is fluid, effortless workload portability across public and private cloud platforms.

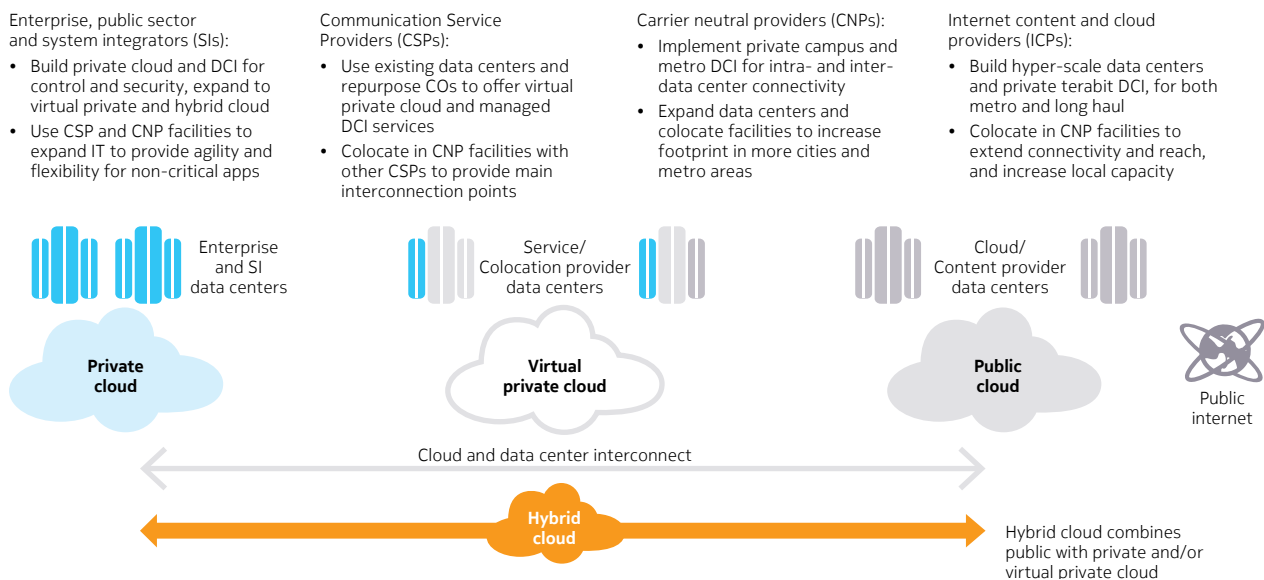
Hybrid cloud models also give organizations greater freedom because they combine the benefits of private cloud with public cloud services. They offer the highest flexibility by enabling access to resources and services when, where and for as long as required. They also allow an organization to reduce CAPEX in favor of OPEX. Nevertheless, this cloud model may not provide the level of control, security and compliance that some organizations need for some applications. Also, organizations face both business and technical challenges when implementing a hybrid cloud, particularly relating to the orchestration of network and IT resources across the private-public cloud administrative boundary. While they have much to offer, for most organizations they will be a work in progress while these challenges are addressed over time, often with the support, consulting and strategic outsourcing services from large system integrators such as Accenture, Dell, Hewlett-Packard, IBM, Unisys and others.

Participants in the cloud ecosystem

There are several different participants in the cloud ecosystem, each with their own specific role, as shown in Figure 2. They include:

- Communication service providers (CSPs), who focus mainly on providing managed DCI and cloud interconnect services and are using their data center assets to offer virtual private cloud services. They are also colocating in CNP facilities with other CSPs to provide main cloud interconnect points.
- Carrier neutral providers (CNPs), who are building and expanding their data centers and colocation facilities, particularly in metro areas and smaller cities. They are also implementing private metro DCI for intra- and inter-data center connectivity.
- Internet content cloud providers (ICPs), who are building hyper-scale data centers and private terabit DCI to interconnect their data centers on campuses, in metros and regionally, nationally and internationally. ICPs also see the benefits of colocating in CNP facilities to expand local capacity and reach more customers.
- Enterprises, industries and public sector customers, who are building private, virtual private and hybrid clouds. Using private DCI to build private clouds with control and security, they are also expanding into CSP and CNP colocation facilities and implementing virtual private and hybrid clouds for greater agility and flexibility.

Figure 2. Participants and their roles in the cloud ecosystem



Communications service providers

Communications service providers (CSPs) are the largest participants in the cloud ecosystem and are ideally placed to offer connectivity to other participants. They own most of the fiber assets and have experience in designing, building, and operating complex networks. Their fiber, IP and optical networks span the globe and they have established central offices (COs) and points of presence (POPs) in thousands of locations to expand their footprint and reach.

Most CSPs have built their own data centers to offer services to customers. The largest also operate separate data centers to support their back-office systems and to provide services such as content and video delivery. They are also using their data center facilities and repurposing their central offices so they can improve their footprint to offer virtual private cloud services to customers.

CSPs also recognize the attractions of colocating in CNP facilities. They can further expand their footprint and reach more customers, and they have more peering options and access to more peering points to interconnect with each other and better participate in the cloud ecosystem.

Many CSPs already provide a wide range of DCI services to enable enterprises, industries and public sector customers to interconnect their data centers. These DCI services include dark fiber, managed wavelengths, Ethernet and IP/MPLS. CSPs have the advantage of incumbency in regions and locations where securing dark fiber and offering managed DCI services is difficult for other participants. These services represent a high revenue, high margin business for CSPs, and many rightly see the cloud as an opportunity to drive additional revenues. They can offer enterprises, CNPs and ICPs cost-effective, highly scalable and high performance solutions to connect data centers, colocation facilities and exchange points.

To fully capitalize on the cloud opportunity, CSPs need to build private cloud interconnect networks with massive scale, reliability and low latency to support the cloud IT model. The reason is that the cloud and virtualization drive bandwidth needs between data centers. While the internet scales massively and provides any-to-any connectivity, it does not provide the cost-effective bandwidth, security, performance and quality of service (QoS) needed to run business-critical applications in the cloud.

Cloud networks will become more virtualized, using network functions virtualization (NFV) to implement a higher level of network functions and features in the software. These functions run on general purpose servers hosted in CSP back-office data centers and/or repurposed central offices, instead of specialized devices or appliances in the network. Today, in much the same way as applications are, servers and storage are virtualized in the data center. These servers and functions can then in turn be virtualized in the cloud.

Cloud networks will also need to be managed through a layer of abstraction using carrier software-defined networking (SDN). Instead of being managed as widely distributed physical network devices, virtualized network functions (VNF) in cloud networks will be managed as logical groupings of network resources. With NFV and carrier SDN, CSPs will be able to automate the end-to-end process of provisioning, delivering, managing, and billing customers for the use of cloud services, including cloud interconnect.

Internet cloud content providers

Internet cloud content providers (ICPs) include content providers such as Amazon, Apple, Baidu, Google, TENCENT and Yahoo; cloud service providers such as Amazon Web Services and Microsoft Azure; and systems integrators offering enterprise cloud services such as HP Enterprise, IBM SoftLayer and others. These ICPs have built and continue to build hyper-scale data centers to host content and services.

However, unlike CSPs, they have more of an IT-centric than a network- or telecom-centric view of the cloud. In many instances, their connectivity and bandwidth needs are similar to CSPs. Many ICPs have built and operate their own networks to interconnect their data centers, acquiring fiber, deploying optical equipment, and using their software expertise to provision the network and manage operations. They are not as restricted by regulatory requirements as CSPs and do not have a large installed base of legacy network equipment. Most are innovative and at the forefront of deploying SDN and NFV technologies to automate the provisioning and optimization of cloud services.

ICPs are expanding their public cloud services to give consumers a better quality of experience (QoE) and to offer hybrid cloud services to more enterprise, industry and public sector customers. They are also expanding their footprint to reach more customers by leasing or placing servers and storage in CNP colocation and exchange facilities, particularly in Tier 2 and Tier 3 cities where they have no direct presence. This approach expands their market and gives both consumers and businesses better performance and lower latency when using public and hybrid cloud services. It also addresses data security and sovereignty concerns that some organizations may have when using public and hybrid cloud services.

Most ICPs build and operate their own networks, and the largest have built global networks. This is leading more ICPs to lease bandwidth from CSPs, and is also another reason why they are colocating in CNP data center and exchange facilities so as to increase connectivity options and extend their reach.

Carrier neutral providers

Carrier neutral providers (CNPs) cover a wide range of companies that operate multi-tenant data centers (MTDCs). Increasingly at the heart of the cloud ecosystem, they focus on providing colocation, power, interconnect and exchange for other participants. Some CNPs also offer servers and storage, although most customers prefer to install their own servers, storage and network equipment.

CNPs have built colocation data center and exchange facilities in Tier 1 and Tier 2 cities and metro areas and are expanding, particularly in Tier 3 and Tier 4 cities, to extend their footprint and reach. These CNP facilities attract enterprises, industries, public sector and other organizations that want hosted cloud IT solutions and to colocate with similar and other organizations.

In most cases, CNPs do not offer DCI bandwidth to tenants. Larger tenants secure fiber from a fiber provider and purchase their own optical equipment, while others lease bandwidth or managed DCI services from CSPs. However, some CNPs expanding in metro areas are finding that to create larger facilities

and achieve scale, they need to connect multiple floors within buildings, or connect multiple buildings on a campus or in a metro area. Although most CNPs will use local CSP services, many are building private optical metro networks to interconnect these new facilities. Some are also selling interconnect services in competition with CSPs.

When building new data centers, CNPs often locate facilities in lower cost, fiber-rich areas or close to a CSP point of presence to encourage local fiber providers and CSPs to colocate and provide interconnect and exchange facilities. Many larger CSPs, particularly those with global reach but without local presence, are choosing to colocate their PoPs in CNP facilities. Fiber providers and CSPs bring bandwidth to CNP facilities at terabit scale, helping to interconnect customers within the facility. Larger colocation and interconnect points in Tier 1, Tier 2 and Tier 3 cities also attract more ICPs eager to participate in and reach new customers in the cloud ecosystem.

Large CNP facilities with the highest density of fiber providers and CSPs offering interconnect, and with the largest number of tenants, are extremely valuable business assets. They are difficult to replicate and so can charge premium pricing for colocation, interconnect and access to exchange points. As such, CNPs will play an increasingly important role in the cloud ecosystem.

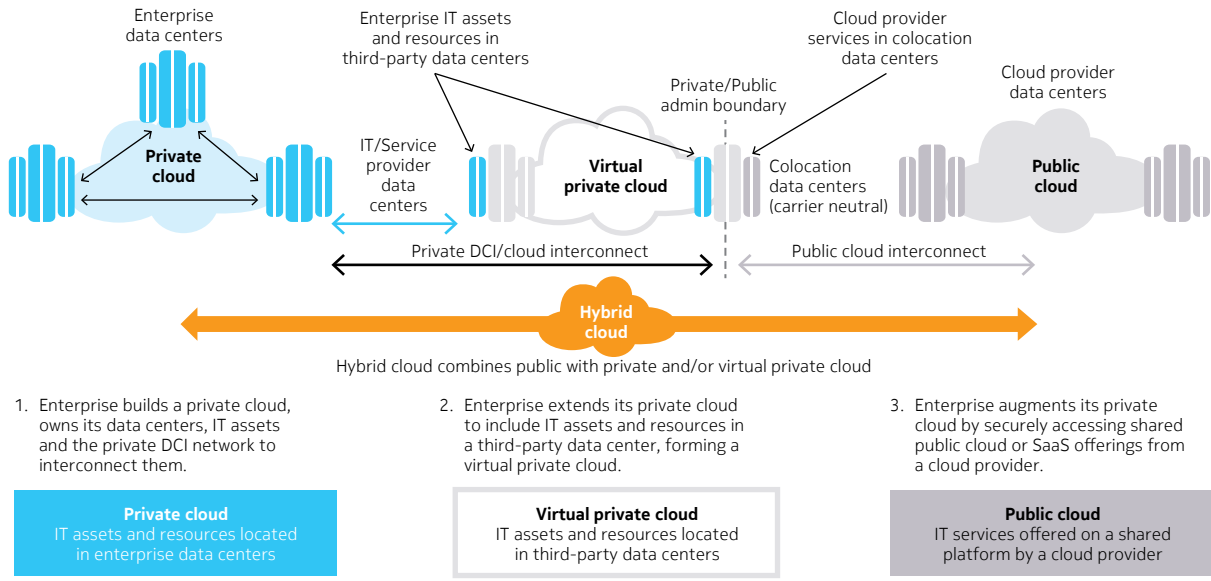
Enterprises, industries and public sector

Organizations such as enterprises, industries and public sector customers often have tens or even hundreds of data centers regionally, nationally or even internationally. Enterprises consist of financial services, healthcare, media, manufacturing, retail and other sectors, while industries include energy, utility and transportation. Public sector includes municipal, state and national government, research and education. Many of these organizations have consolidated and virtualized their data centers to increase efficiency and reduce costs. They are the primary drivers for cloud for the following reasons:

- They require control and security for their data centers, often for regulatory, compliance or data sovereignty reasons, and these are characteristics that a private cloud brings.
- They are increasingly looking to outsource some of their non-business-critical IT to cloud providers as a way to increase their agility and flexibility.
- They want to scale their IT quickly and cost effectively to match the ever-growing demand for compute and storage.
- They want to move from self-build CAPEX-based IT models to more agile outsourced OPEX-based IT models.

Cloud enables organizations to match cost models to business needs and achieve all of these things by adopting a mixture of private cloud, virtual private cloud from a CSP, hosting IT in CNP facilities, or using hybrid cloud and public cloud services from an ICP, as shown in Figure 3.

Figure 3. How an organization can use private, virtual private, hybrid and public clouds



Increasingly, one organization may act as a facilitator for others such as for a financial stock exchange. Investment banks, trading platforms and other financial service companies can colocate their data centers to improve application performance and reduce latency. In some cases, CSP or CNP facilities are used to provide greater capacity and connectivity. This phenomenon is becoming more prevalent in other sectors, where industries have built communities of interest for enterprises, their customers, suppliers and partners, as well as industry bodies.

As noted above, ICPs are expanding into CNP facilities to expand the footprint of their public cloud services by reaching more consumers and business customers. Colocating in the same CNP facilities gives these organizations better performance and lower latency when using public and hybrid cloud services. It also offers more local compute and storage resources and also helps address data security and sovereignty concerns that some organizations may have when moving business-critical applications and client data to the cloud. Increasingly, organizations are recognizing the benefits of using resources or colocating assets in CNP facilities, such as:

- Ability to install and manage their own IT assets and pay only for space and power
- Lease the IT resources they need from the CNP and scale without CAPEX investment
- Access to multiple ICP cloud services in a single carrier neutral location
- Access to industry-wide ecosystems of suppliers, partners and customers
- Greatly improved performance for cloud-based applications
- More connectivity and interconnect options.

Cloud interconnect – DCI for the cloud

Traditionally, DCI networks have focused on bandwidth and latency as part of ensuring business continuity and disaster recovery, but the move to the cloud demands new objectives and requirements. These can best be met with a new type of cloud DCI solution — cloud interconnect — that provides some key capabilities to meet the dynamic nature of cloud:

- **Scalable, flexible bandwidth:** Mobility, personal devices, new applications and explosive data growth demand more scalable and flexible bandwidth. Cloud interconnect solutions must be able to deliver very high bandwidth — and increase and decrease bandwidth flexibly as needed.
- **Multisite, multi-technology, multicloud:** Cloud interconnect solutions need to share data, distribute applications and balance workloads across different cloud types, between multiple locations and between different cloud providers. They must provide multi-layer, integrated IP and optical capabilities with high performance, reliability and quality of service, as well as multiple client interfaces such as Ethernet, Fiber Channel and InfiniBand, to accommodate legacy and future requirements.
- **Agile, dynamic provisioning:** Cloud interconnect solutions must support orchestration of network resources across cloud boundaries to ramp up resources when and where required (and then ramp them down again). That means they must provision bandwidth and orchestrate network resources dynamically, quickly and easily — between different locations, across multiple data centers and across different clouds and cloud providers.

Benefits of cloud interconnect

Secure, high-speed cloud interconnect links between the different participants in the cloud ecosystem are critical to the success of cloud and benefit all participants' cloud strategies:

- CSPs are ideally placed to offer connectivity solutions in the cloud ecosystem. They can offer enterprises, CNPs and ICPs cost-effective, highly scalable, flexible and high performance cloud interconnect solutions to connect data centers, colocation and exchange facilities. They can offer a range of metro and long-haul solutions, including dark fiber for self-build solutions with services and support, as well as managed wavelength, Ethernet and IP cloud interconnect depending on customer requirements. By colocating in CNP facilities, CSPs can access a larger numbers of customers and connect with other CSPs to create cloud exchange and peering points.
- CNPs are ideally placed to be the primary providers of colocation, exchange and peering facilities in the cloud ecosystem. They can use cloud interconnect to create larger colocation facilities, connecting multiple floors or buildings to create a larger campus facility (intra-data center), or connecting multiple buildings or campuses within a metro (inter-data center). By creating larger colocation facilities, they can attract more organizations, CSPs and ICPs, all eager to colocate and interconnect to better participate in the cloud ecosystem.

- ICPs are ideally placed to become the primary providers of public cloud services to consumers and businesses, and the main facilitators of hybrid cloud services. They can use cloud interconnect to build their own metro and long-haul solutions to connect their hyper-scale data centers. They can also use cloud interconnect to extend their footprint and reach by colocating in CNP facilities, particularly in Tier 3 and Tier 4 cities. By doing this they can place content closer to consumers to provide better responsiveness and QoE. They can also reach more organizations to offer high performance, low latency business solutions. And by having a more local presence, address the data security and sovereignty concerns that some organizations may have when using public and hybrid cloud services.
- Enterprises, industries and public sector are the main implementers of private clouds and the primary consumers of public and hybrid cloud services in the cloud ecosystem. As well as building their own private clouds with cloud interconnect solutions, these organizations can use private and managed cloud interconnect solutions to connect to CSP and CNP facilities to create virtual private clouds, and to implement hybrid clouds and access public cloud services. They can use private, managed, and in some cases public, cloud interconnect solutions when placing or balancing workloads depending on factors such as the level of control and security of data, the performance and latency of applications, and the agility, flexibility and cost profile required.

Nokia solutions for cloud interconnect

Nokia offers a choice of cloud interconnect solutions to meet the varying needs of CSPs, CNPs, ICPs and enterprises, industries and public sector organizations. These solutions provide scalable, high performance and secure cloud interconnect with the capacity, flexibility and agility needed to support different cloud types.

Our solutions include packet optical transport and IP/MPLS routing solutions covering metro, regional, national and international connectivity requirements, as well as SDN solutions for both the data center and the WAN. They support a wavelength choice and Ethernet and IP options to provide the best cloud interconnect solution to meet different business needs. By offering unified IP/optical management and automated and on-demand IP/optical networking with SD-WAN, Nokia can deliver the agile, dynamic, flexible and cost-effective cloud interconnect solutions for all participants in the cloud ecosystem.

Nokia cloud interconnect solutions are used by many leading service providers and network operators for metro and long-haul applications. Many large enterprises in the financial, healthcare, consumer and industrial sectors also use Nokia solutions for business-critical DCI applications such as business continuity and disaster recovery. They are widely deployed in the government, oil and gas, transportation and utility sectors for mission-critical DCI applications.

To find out more, please visit <http://networks.nokia.com/portfolio/solutions/cloud-dci> or see the relevant Nokia cloud interconnect solution white paper.

Acronyms

CAPEX	capital expenditure
CNP	carrier neutral provider
CSP	communication service provider
DCI	data center interconnect
laaS	infrastructure as a service
ICP	internet cloud content provider
IP	Internet Protocol
IP VPN	Internet Protocol virtual private network
IT	information technology
MPLS	multiprotocol label switching
MTDC	multi-tenant data center
NFV	network functions virtualization
OPEX	operating expense
PaaS	platform as a service
PoP	point of presence
PSB	Penn Schoen Berland
QoE	quality of experience
QoS	quality of service
SaaS	software as a service
SDN	software-defined networking
SD-WAN	software-defined WAN
SI	system integrator
VNF	virtualized network functions
WAN	wide area network

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Nokia Oyj
Karaportti 3
FI-02610 Espoo
Finland
Tel. +358 (0) 10 44 88 000

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