Edge Architecture – Making Real-Time the Perfect Time

August 2023

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Table of Contents

Executive Summary

Demand for fast and reliable data has never been greater

In the era of big data, the Internet of Things (IoT), artificial intelligence (AI) and more, the demand for fast and reliable data processing in real time has never been greater. The unprecedented surge in data volume today (120 Zettabyte in 2023 vs 2 Zettabyte in 2010) is fuelled by the proliferation of autonomous cars, IoT devices, sensors, and connected devices. The exponential data growth poses significant challenges for the traditional centralised computing model, which struggles to handle the scale and velocity of incoming data.

Edge architecture can be part of the solution to optimise user experience

Edge architecture is an emerging and promising solution to optimise user experience and address the limitations of a traditional centralised model when handling the overwhelming data volume today. Edge architecture encompasses 3 components – Edge computing, Edge data centres, and 5G networks – enabling distributed processing, storage, and real-time data transfer. Between 2019 and 2028, cumulative CAPEX of up to $800 billion USD are estimated for IT equipment and edge computing facilities, implying a CAGR of 40%.[1]

The convergence between communications infrastructure sectors could realise more attractive economic returns

Today the demand for seamless transfer of data, low latency and frictionless communication is driving the convergence of 5G architecture and communication infrastructure assets. We are seeing strategic partnerships being formed between tower and data infrastructure providers to be a part of the Edge architecture solution. Tower's owners and operators are at the edge of the wireless and wired networks, they can leverage their existing real estate, electricity, security, and fibre assets to support the fast deployment of Edge data centres. However, to deploy distributed data centres at scale also presents unique challenges to infrastructure owners and operators who want to be part of the solution. Thus, for tower companies who are adopting an edge strategy, it can be advantageous to partner with a specialised data centre operator who may better address the design and deployment, operational and environmental considerations to seek to realise more attractive economic returns.

Monopolistic characteristics and ability to generate stable cashflow continue to be the key focus areas for infrastructure investors

The edge data centre market continues to be fragmented, there is yet an industry-wide mature business model or contract type. Each opportunity should be assessed separately for its assets' monopolistic characteristics and their ability to generate stable cashflow, which are key to infrastructure investors.

As an infrastructure investor, we are excited about what is ahead of us, and we need to keep these developments under continuous review.

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Source: HSBC Asset Management data as at August 2023 unless otherwise stated.
1. The Linux Foundation, 2021, "State of the Edge"

Introduction

In the era of big data, the Internet of Things (IoT), artificial intelligence (AI) and more, the demand for fast and reliable data processing in real time has never been greater. The unprecedented surge in data volume today (120 ZB in 2023 vs 2 ZB in 2010) is fuelled by the proliferation of autonomous cars, IoT devices, sensors, and connected devices. However, this exponential data growth poses significant challenges for the traditional centralised computing model, which struggles to handle the scale and velocity of incoming data.

Once hailed as a breakthrough, the centralised computing model relies on servers in a central location to manage and process data. It provided economies of scale through a centralised approach to data processing and storage that brought efficiency and convenience. While centralised computing model is effective for lower processing requirements, it faces limitations in handling the overwhelming data volume today, resulting in performance bottlenecks. The need for real-time insights and low-latency processing, particularly in critical areas like autonomous cars and IoT data, exposes the inherent latency constraint in centralised architectures.

To overcome these hurdles, decentralised approaches through Edge architecture have emerged. This natural network progression addresses the weakness of the centralised computing model by bringing data computing closer to where the data is generated. It reduces the distance and time for data to travel, which allows faster response time that can support real time applications.

Edge architecture encompasses 3 components – Edge computing, Edge data centres, and 5G networks – enabling distributed processing, storage, and real-time data transfer. Between 2019 and 2028, cumulative CAPEX of up to $800 billion USD are estimated for IT equipment and edge computing facilities, implying a CAGR of 40%.[1]

Architecture decisions become significant factors in CAPEX and OPEX allocations as Edge deployments scale up and new technologies emerge. These decisions ultimately determine the return on investment for such network deployments.

In our investment philosophy framework, communications infrastructure can be classified into three sub-categories – “towers infrastructure”, “satellites”, and “data infrastructure” which includes assets like data centres and fibre networks. We believe with the development of edge architecture, historical boundaries between different infrastructure asset classes are going to be blurred.

Industry development is going to be driven by the increasing low-latency and high-bandwidth use cases. Thus, as an infrastructure investor, it is important to understand the future trend of Edge architecture and examine its potential impact on the landscape of existing communications infrastructure assets, which will be discussed in this paper.

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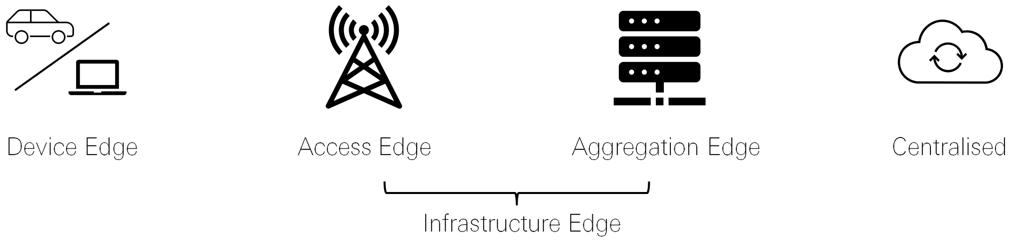
Source: HSBC Asset Management data as at August 2023 unless otherwise stated.
1. The Linux Foundation, as of 2021. “State of the Edge”.

I. Edge Architecture

Edge architecture is an emerging and promising solution to optimise user experience and address the limitations of a traditional centralised model. It has three components – Edge computing, Edge data centres, and 5G networks. Edge computing is a distributed computing model that processes data closer to where it is generated. It is part of the technology that solves the latency issue. Edge data centres addresses the demand for edge computing. They are small-scale data centres located near the Edge of the network that provide computing, storage, and network resources. 5G networks enables real-time data processing and transfer between Edge devices and data centres via high bandwidth and low latency networks.

II. Different Levels of Edge

Edge is a layered architecture between centralised data centres and the end devices generating the data. Centralised facilities are mainly used for data warehousing and enterprise-wide applications, whereas edge facilities focus more on real-time data processing and analysis and low-latency communications.



- **Device Edge**: The computing and storage capabilities on the downstream or the last mile network from the device side. This includes laptops, smartphones, cars, Internet of Things (IoT) sensors, drones, Augmented/Virtual Reality (AR/VR) devices etc.
- **Infrastructure Edge:** The computing and storage facilities at the last mile of network from the operators' side. Mobile edge data centres are located at the infrastructure Edge, which includes both the aggregation Edge (C-RAN hubs) and access Edge (base of cell tower).
  - **Aggregation Edge –** A sub-layer of the infrastructure Edge that is closer to the core. It is usually the aggregation node for fixed or mobile broadband networks. These resources are generally located within 50ms from the device edge.
  - **Access Edge** – A sub-layer of the infrastructure Edge that is closest to end-user devices. Latency to access edge ranges from 5 to 10 millisecond from the device edge. Typical access Edge includes a cable or telco headend or a cellular network tower.
- **Centralised data centres:** Large-scale or hyperscale data centres, which are usually operated by carrier-neutral players, cloud or telecom service providers.

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III. Edge Computing

As a component of Edge architecture, Edge computing is distributed computing where data processing and storage are located closer to where the data is generated, instead of at centralised data centres. Advantages of a distributed computing structure include:

- Realising lower latency (sub-10 milliseconds) or ultra-low latency (sub-1 millisecond) transmission, enabling better application performance and improving the quality of experience.
- Enhancing efficiency of network bandwidth by offloading demand for data transmission through the internet, thus, reducing network congestion.
- Reducing data transportation costs by performing computations closer to the source.

Data in the past decade was mainly driven by human consumption, whereas the next phase of data growth will be generated by machines (such as autonomous cars or seniors on the street of a smart city), which will further be processed, analysed and actioned by other machines. That means data generated tomorrow will be in a different form of today, and the magnitude will be much greater.

With the increasing number of connected devices globally, much of the data generated will be transmitted on a wireless or mobile networks, which puts additional strains on mobile network infrastructure. This more connected future will drive the evolution of computing and storage infrastructure, particularly closer to where the data is generated.

Edge computing is an inevitable evolution of future computing and is considered a key building block for many next-generation use cases, such as Internet-of-Things, autonomous driving, Industry 4.0, Augmented Reality (AR) and Virtual Reality (VR), 4K/8K video streaming, real-time analytics, gaming and more. In 2023, aggregate Edge computing-related spending is expected to reach $208 billion globally, an increase of 13% over 2022. The International Data Corporation (IDC) forecasts that growth in spending on Edge solutions will sustain at an elevated through 2026, reaching nearly $317 billion.[2]

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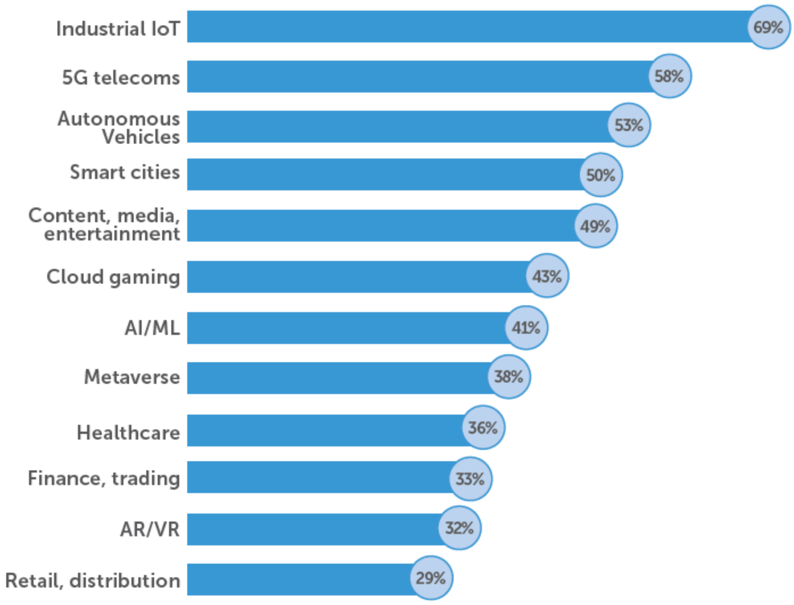
Source: HSBC Asset Management data as at August 2023 unless otherwise stated.
2. IDC, as of February 2023. "New IDC Spending Guide Forecasts Edge Computing Investments Will Reach $208 Billion in 2023"

In 2022, a survey result from Data Centre Dynamics (DCD) illustrated demand from multiple applications for Edge deployment. More than half of the respondents expected Industrial IoT, 5G telecoms, Autonomous vehicles and Smart cities to be the biggest drivers for Edge deployment.

Survey question "Which of these do you see as the biggest demand drivers for Edge deployment"



(Source: Data Center Dynamics, 2022, "Building the Edge")

There are generally four main use cases of Edge:

- **Data intensive use cases**

  Applications that generate large volume of data makes it impractical to transfer/communicate via wireless network directly to the cloud, considering cost and bandwidth issues. Examples of this category could include smart factories, smart cities, high-definition content delivery and VR/AR.

- **Human latency sensitive use cases**

  Use cases where better user experience is demanded by optimising services for data consumption. Examples include augmented reality and natural language processing.

- **Machine-to-Machine latency sensitive use cases**

  Technology advancement in machines allow them to process data at increasing speeds. Thus, more computing and processing power is needed to support low-latency communications from machine-to-machine. Use case can include Industry 4.0 and smart grids.

- **Life critical use cases**

  Use cases such as autonomous vehicles and digital healthcare can directly impact human health and safety. Thus, low latency communications are key in these cases.

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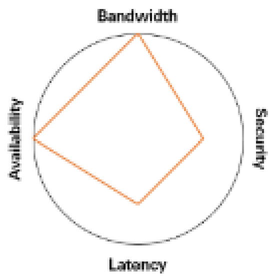
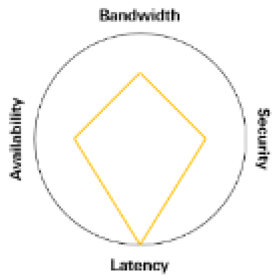
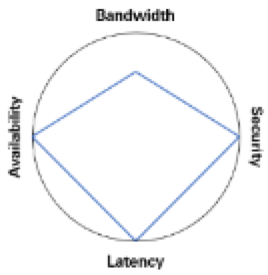
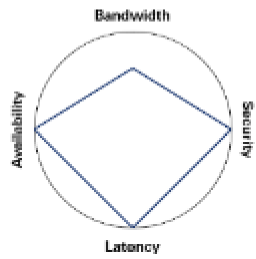
	Data Intensive	Human Latency Sensitive	Machine-to-Machine latency Sensitive	Life Critical
Requirements				
Use Cases	• Smart Cities • Virtual Reality • HD Content Distribution • High-performance computing • Data-Intensive Video Streaming	• Web Site Optimisation • Augmented Reality • Payment processing • Smart Retail • Natural Language processing	• Smart Grid • Low-latency Content Distribution • Automated financial transactions • Real-time Analytics	• Digital Health • Autonomous Cars • Smart Transportation • Autonomous Robots

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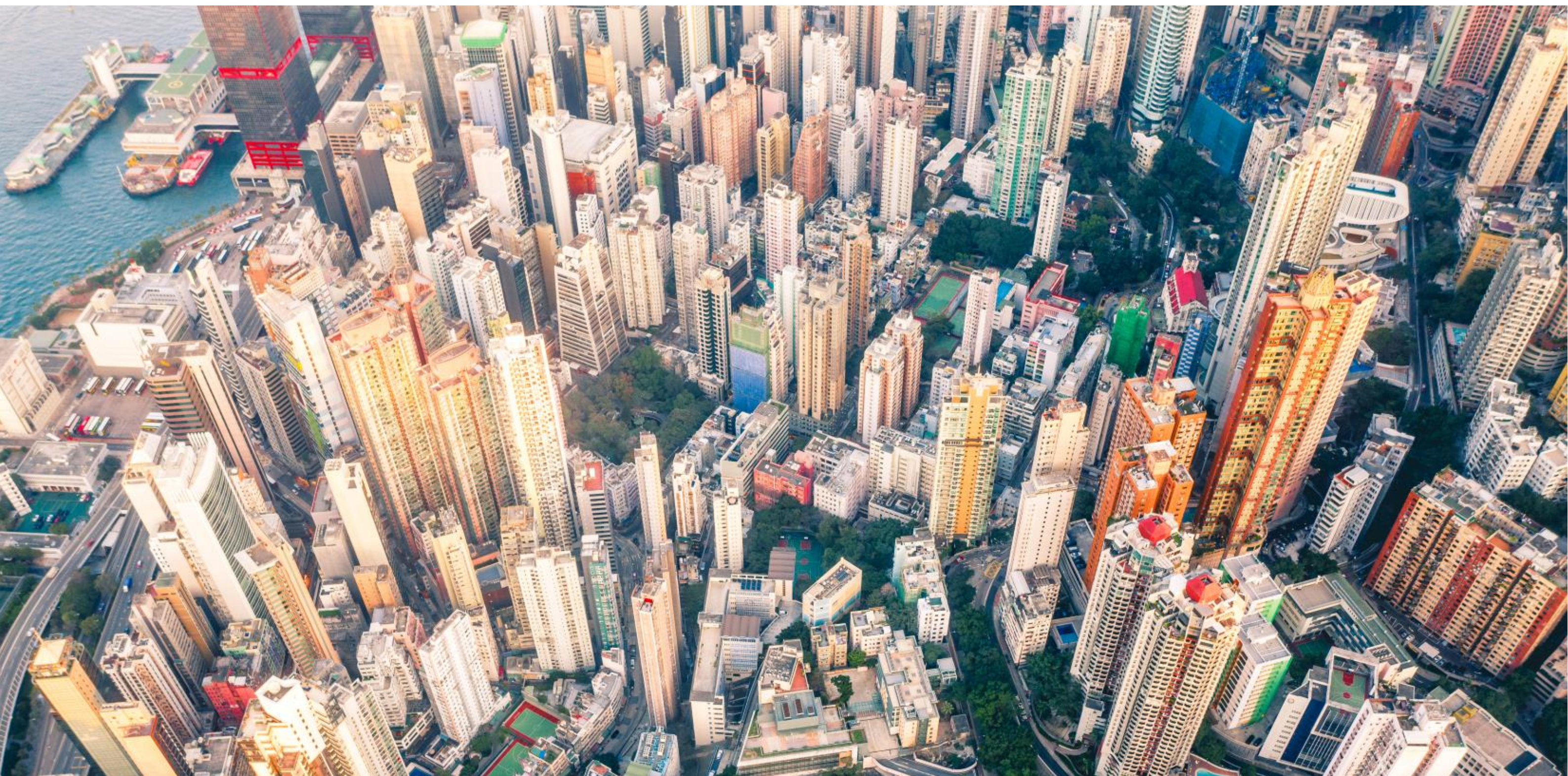


IV. Edge Data Centres

Edge data centres are parts of the data centre ecosystem. They address the demand for Edge computing.

Overall, there are three types of data centres within the data centre ecosystem to support the cloudification and convergence of telco cloud and IT cloud architectures:[3]

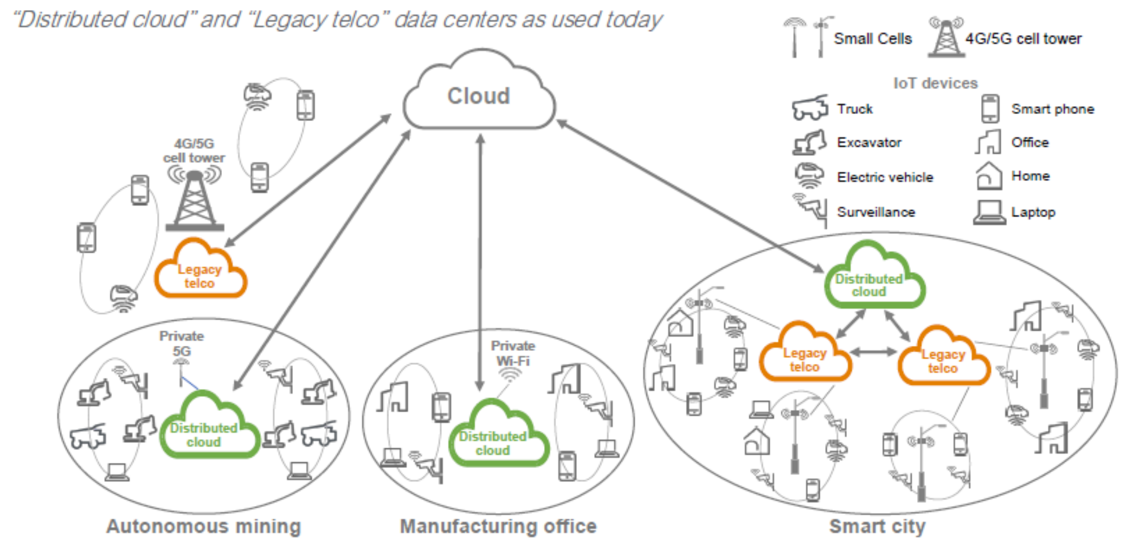
- **Legacy telco data centre**

  These data centres provide traditional closed and proprietary telecom network functions and controls. In recent years, Telcos have started a cloudification evolution by decoupling network functions from proprietary telco hardware to emerging distributed cloud data centres.

- **Distributed cloud data centre (Today)**

  Distributed data centres focus on providing data processing and storage capabilities. These facilities are increasingly owned by carrier-neutral data centre providers. However, public cloud providers have operational control of these distributed public cloud services at different locations. Locations of the distributed cloud data centres are key, as they can extend public cloud providers' footprint one step closer to end users.

  The "Smart City" example demonstrated in the below graphic shows the cooperations between legacy telco and distributed cloud data centres. Legacy telco data centres provide essential functions and controls such as firewalls, that are required by the smart services. And distributed cloud data centres perform functions such as data processing.



(Source: Schneider Electric, 2022, "Best practices to deploy sustainable and resilient data centres at scale at the network edge)

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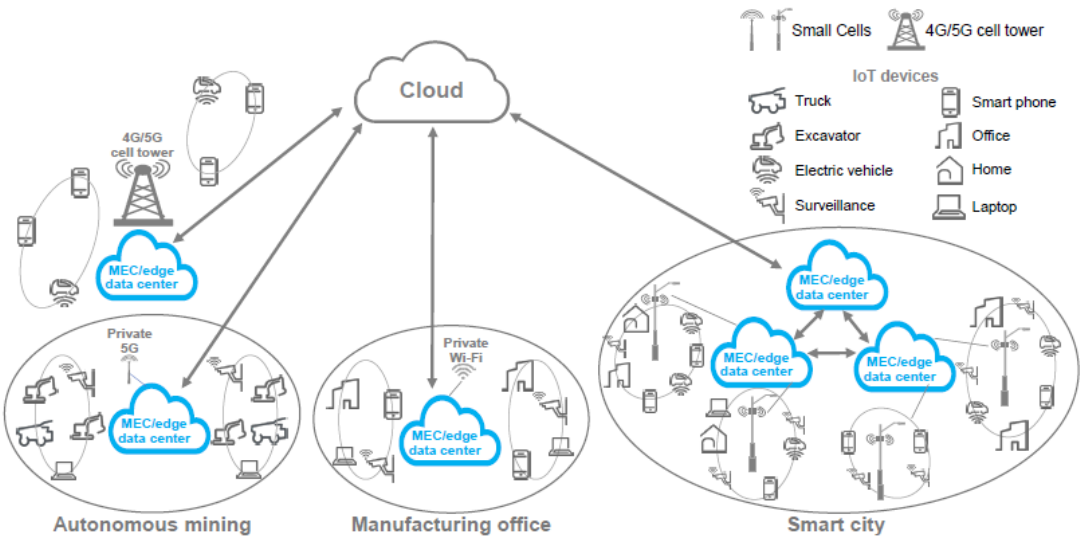
3. Schneider Electric, as of 2022. "Best practices to deploy sustainable and resilient data centres at scale at the network edge."

- **Multi-access edge computing (MEC)/edge data centre (Tomorrow)**

  MEC/edge data centres can perform the roles of both legacy telco data centres and today's distributed cloud data centres by providing network functions and control, as well as data processing and storage capabilities.

  With telco cloudifying from legacy data centres to distributed cloud models, they are also transforming from traditional and proprietary hardware to standard IT server hardware. Their transformation can host cloud services and telco controls in the same data centre facility, such as a MEC/edge data centre. MECs can also relieve core network congestion and conserve capability for backhaul transmission networks, thus improving network efficiency and reducing operational costs.

Illustration of how MEC/edge data centers may be used in the future



(Source: Schneider Electric, 2022, "Best practices to deploy sustainable and resilient data centres at scale at the network edge)

Most edge data centres share similar key characteristics:

- **Location**: They are closer to the end devices they are networked to, and where the data is generated.
- **Size**: Smaller footprint compared to traditional data centre
- **Deployment**:
  - As mentioned above, edge data centres are usually connected to a network of other edge data centres, or a large, central data centre.
  - This network needs to provide high bandwidth, e.g. 5G, to meet on-demand communications between the network Edge data centre and the edge devices.

Edge data centre performs the same way as traditional data centres but with a much smaller footprint and closer to end users and devices. It utilises the concept of edge computing to deliver fast computing and storage capabilities to reduce latency and enhance user experience.

Edge data centres usually connect to a large, central data centre or to a network of edge data centres. Time-sensitive data will be processed at the Edge, while less time-centric data will be directed to a centralised data centre for processing.

V. Challenges of Deploying Edge Data Centres at Scale

Edge data centres need to be deployed at scale to address the demand for low-latency and high-bandwidth applications. However, deploying them at scale presents unique challenges to Edge data centre owner and operators.

Design & Deployment

- Expertise in small-scale data centre design

A standardised solution can simplify the production, deployment, and even the maintenance process. However, with the fast evolution of technology and application developments, design of the infrastructure within Edge data centres needs to support the intended applications and diverse equipment. In addition, it must also be compatible with other edge data centres, and relevant local site conditions.

A prefabricated standardised, or modular, solution with options for special conditions could potentially address these requirements. This solution enables operators to provide turn-key services and achieve fast delivery and deployment time.

- Expertise in location selection

Tower sites can provide proximity to where the data is generated and access to wireless network. However, not all tower sites are suited for edge data centre deployment. Addressing latency requirements while achieving network efficiency should be the focus when selecting sites for edge data centre deployment, instead of simply proximity.

Additionally, deploying edge data centres at all tower sites could add operational complexity and it could incur higher costs (both CapEx and OpEx). Therefore, site selection is important for deploying an edge strategy to balance 1) latency issues to the end user, 2) network capacity and 3) economics to optimise the overall edge architecture and user experience.

Operational Considerations

Edge data centres can support critical applications, which put additional requirements for high availability of the facility. A high standard of maintenance is required to avoid unexpected downtime.

Moreover, network Edge sites typically lack on-site staff and could present risks during events such as equipment failure, which may need troubleshooting or reboot. It could also present cyber security risks due to additional access points. This can be particularly challenging for distributed sites.

To address the above issues, investment in monitoring and management software is essential. Such software connects all edge data centres within the operator's network and achieves instant monitoring and remote control. Meanwhile, by conducting real-time analysis on each distributed facility's status, centralised control personnel can predict required maintenance better.

Environmental Considerations

Given the build-out required and the distributed nature of Edge data centres, the environmental impact could be greater than for centralised data centres. Meanwhile, more data ultimately means more power usage, which could lead to more emission. Therefore, additional environmental considerations should be taken into account throughout the lifecycle of edge data centres, including manufacturing, deployment and operation.

Power Usage Effectiveness (PUE) is commonly used in the industry to measure the energy efficiency of a data centre facility. It equals the total amount of power entering a data centre divided by the power used to run the IT equipment within it. Due to the smaller scale and distributed footprint, edge data centre's power usage effectiveness has been poor, typically around 2.0. In comparison, centralised data centres have more concentrated IT loads and energy demand, resulting in a higher energy efficiency or lower PUE. As of 2022, listed hyperscale or colocation data centre players can achieve a PUE sub-1.5 or can be as low as 1.3.

The procurement of renewable energy is also a key consideration to address the emission issues from data centre operations. Existing data centres currently account for about 1-1.5% of global electricity use. With the strong growth in data generation and consumption, this number could quadruple by 2030. However, Edge data centres located close to dense urban areas may find it difficult to procure renewable energy.

There is no silver bullet to address the power usage and emission issues. Technology advancement can drive equipment power usage efficiencies. For example, lithium-ion batteries with relatively long runtime with embedded battery monitoring systems could also be part of the solution.

VI. Impact on Existing Communications Infrastructure

Today the demand for seamless transfer of data, low latency and frictionless communication is driving the convergence of 5G architecture and communication infrastructure assets. It is an evolving landscape in which historical boundaries between different infrastructure classes begin to blur.

The convergence of wireline and wireless networks means network operators could consolidate the two access networks. This would provide next-generation services through an Edge-to-Cloud structure, which can address the limitations of a centralised cloud compute model.

There are a few key requirements for physical wireless infrastructure providers, like a mobile tower’s owner and operator, to be part of the Edge architecture solution:

- Real estate (owned or leased) in suburban and rural markets, which is key for rapid deployment
- Redundant/Secure/etc Power supply to ensure maximum availability
- Security monitoring system (e.g. interior and exterior security cameras)
- Relationships with mobile network operators (MNOs) and network services providers (NSPs) for bandwidth and connectivity requirement
- Relationships with Cloud Service Providers (CSPs) to enable seamless connection/communication between edge and centralised data centres

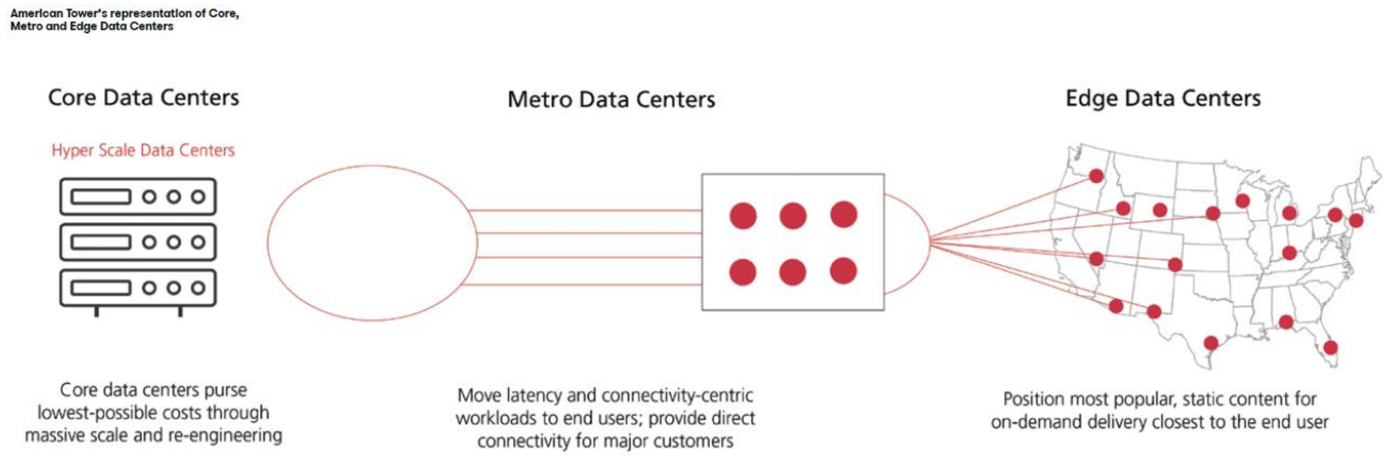
Tower assets are the infrastructure backbone that enables a connected world. They are located at the edge of the wireless and wired networks and are well positioned to benefit from the growth of Edge architecture. Attaching a small or micro data centre to a mobile tower adds compute power and storage capacity right at the network Edge. This significantly shortens the distance between where the data is generated and where it is processed, reducing the need to transmit data all the way to the nearest centralised data centre.

TowerCos can leverage their existing infrastructure to support the deployment and be part of the Edge architecture solutions. Towers’ existing real estate, electricity, security, and fibre assets are all the key elements for Edge data centre deployment and can achieve fast delivery. Thus, they have the natural advantage to help enterprises build distributed data centres.

The tower industry has evolved over the last few years, and we have witnessed carrier neutral TowerCos like American Tower (AMT) in the U.S. and Rai Way (RWAY) in Europe announcing their Edge strategies to be part of the network solutions. In the case of AMT, we have seen the company deepened their Edge strategy by building a platform approach across their Core, Metro and Edge data centres – mainly through acquisitions. Given AMT's 40,000+ sites available in the U.S., AMT can deliver a truly distributed model at scale across many markets, achieve fast deployment and provide turnkey networks.

In 2019, AMT acquired Colo Atl, metro data centres, which marked their first foray into the data centre space. AMT further invested in its data centre strategy by acquiring CoreSite at the end of 2021, which was driven by a view on the importance of interconnection capabilities, cloud on-ramps, and the future network relationships between the cloud, Edge and mobile.

It is well understood that not all mobile tower sites are ideal for edge data centre deployment; AMT's strategy and most of their tower positions focus on secondary markets, such as rural and suburban areas. The demand originates from enterprises located in those rural and suburban areas, who are far away from a regional or core data centre and might struggle with network optimisation.



(Source: InterGlobix, Dec 2020, "American Tower at the Covergence of Cell Towers, Edge Data Centers and Carrier Hotels")

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VII. Conclusion

Edge architecture, including Edge computing, Edge data centres and 5G network, is poised to transform the way we think about data processing and storage today. Bringing computing capability closer to where the data is generated would enable use cases that require data processing and analytics in real-time, such as IoT, AI, autonomous vehicles and more.

The design of Edge architecture converges the boundaries between various infrastructure sectors. It is important to understand the potential impact of this convergence – we need to be aware of the growth opportunities and the challenges deploying Edge data centres at scale may bring.

Currently, the edge data centre market is fragmented, there is yet to be an industry-wide mature business model or contract type. Each opportunity should be assessed separately for its assets' monopolistically characteristics and their ability to generate stable cashflow, which are key to infrastructure investors. We believe for tower companies that are adopting or developing an Edge strategy, it is important from a strategic perspective to partner with a specialised data centre operator, which can better address the above considerations, and realise more attractive economic returns.

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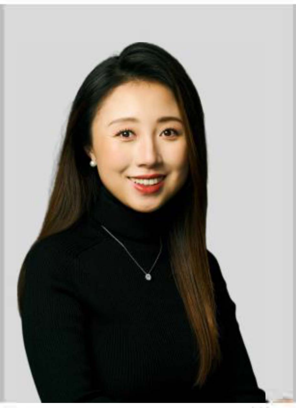
Meet the author



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