



EDGE COMPUTING

TOWARDS A MORE DISTRIBUTED FUTURE

Foreword

Following productivity gains from technological innovations, industrial companies are beginning to drive new levels of performance and productivity. While cloud computing and other emerging technologies are key enablers of industrial transformation, edge computing is rapidly grabbing the space at the industrial front. Edge computing deployments are ideal in a variety of circumstances and attributed to IoT device connectivity, latency-sensitive use cases, the buildout of 5G cellular networks.



This whitepaper aims to meet two objectives:

- What is edge computing?: An attempt has been made to give a fairly comprehensive understanding of what edge computing is all about so as to increase awareness of this emerging technology
- Highlight what companies in India are doing in this space: Products and services being offered by service providers and startups

We have also included a number of case studies to showcase the kind of work being done out of India.

I hope you enjoy reading this report, We welcome your feedback and comments at research@nasscom.in.

Debjani Ghosh
President, NASSCOM

Methodology & Acknowledgements

The methodology involved primary and secondary research.

For primary research, we reached out to Indian service providers and startups to get their views on how this segment is evolving. We had in-depth conversations with integrated players on their edge business and strategies; we also spoke with startup companies who offer niche products and services.

Secondary research involved a thorough examination of existing reports by various reputed research firms – CB Insights, Gartner, IDC, McKinsey, Ovum, TBR and more. We have relied heavily on a number of business news items for the latest developments on the edge computing market.

This report presents the Edge Computing opportunity mainly from the perspective of IT-BPM companies.



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We wish to express our sincere gratitude to the individuals, companies and research firms that helped with this report, whether directly or indirectly.

A list of contributors is given in the appendix.

Executive Summary

- Global edge computing market to grow by 54% over 2018-2025 to cross \$28 billion
- Key benefits: Low latency, optimize bandwidth usage, reduce costs and ensure security of data collected/processed
- Indian service providers consolidating their presence across the edge computing spectrum – hardware, services, products and technology:
 - From device design to edge consulting & integration, to monitoring, management, & automation to edge applications (intelligence at the edge) and security at the edge
- Indian startups providing solutions around smart sensors & devices, smart meters & smart cameras, edge gateway, edge internet, edge platforms, AI & analytics platform for the edge
- Segments like gaming, content generators (video), digital manufacturing (Ind 4.0), vehicle-to-everything (V2X) communications will be the leading consumers of edge services
- Edge computing is being driven by the growing use of immersive media (AR/VR), growing penetration of AI/ML, the flexibility that 5G provides in terms of responsiveness and bandwidth and the proliferation of IoT devices
- In turn, edge computing is driving the growth of self-healing technologies, micro datacenters, convergence of IT & OT and microservices
- Talent: Edge computing team sizes in India are currently small, ranging from 50-150 people. Cross-functional skills spanning networking, telecom, cloud, software and hardware. Some of the top skills that companies are seeking include architects, edge security, edge analytics
- GTM strategies: Companies are adopting a combination of strategies: setting up business units with independent P&L, building products in collaboration with customers (co-innovation), platform strategies (edge platforms, edge AI, edge analytics platforms), peer-to-peer, partnering with channel & distribution partners, cloud service providers, etc.
- Monetizing the edge: Through OTT apps, as-a-service offerings, platformisation, APIs:
 - Expanding business opportunities for conventional IT services: Infrastructure management, software testing, consulting, data management, automation, etc.
- Challenges: Lack of standards because of different environments, edge devices and architectures is impacting interoperability; distributed nature means that cybersecurity and physical security concerns would need to be adequately addressed
- Outlook: Edge computing adoption, coupled with a cloud strategy is set to increase. Greater proportion of applications would run on the edge. M&A activity expected to grow as companies look to scale their edge business quickly. The market will see an assortment of players – telecom, technology, CDN, etc.



TABLE OF CONTENT

1. Edge computing: The What and The Why 1 - 9
 - Edge computing: History
 - Characteristics
 - Business and Technology drivers
2. Edge computing: Market Landscape 10 - 42
 - Global market size
 - Trends
 - Player landscape and services offered
 - Areas of application
 - Monetizing the opportunity
 - Talent: Cross-functional skills
 - GTM strategies
 - Challenges
 - Outlook
3. Appendix 43 - 52



Edge Computing The What and The Why



“It’s easier to move the cloud to where the data is than to move the data where the cloud is.”

Antonio Neri
President & CEO, HPE

What is Edge Computing?

Edge Computing is a distributed technology model that enables data storage, data processing and analytics at the source of the data itself. This means that the data generated at the source (the device) need not travel to and from the cloud or datacenter infrastructure.

What is IoT?

The Internet of Things is a system of interrelated computing devices, mechanical and digital machines, objects, animals or people that are provided with unique identifiers (UIDs) and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction.¹

A basic difference between IoT and edge computing lies in where the data is processed.

In IoT, the data collected is usually sent to a cloud or a datacenter where it is processed and the final results are transmitted back to the IoT device. However, in the case of edge computing, the processing and analysis happens on the device itself.

The processed data and the results are then sent to the cloud / datacenter for long-term storage and historical analysis.

The new crop of sensors and IoT devices are being made intelligent with analytics, AI/ML capabilities. For the existing, conventional IoT devices, the processing and analytics ecosystem is being built close to the devices (at the same location).

Myth 1: So Edge computing and IoT are two different technologies?

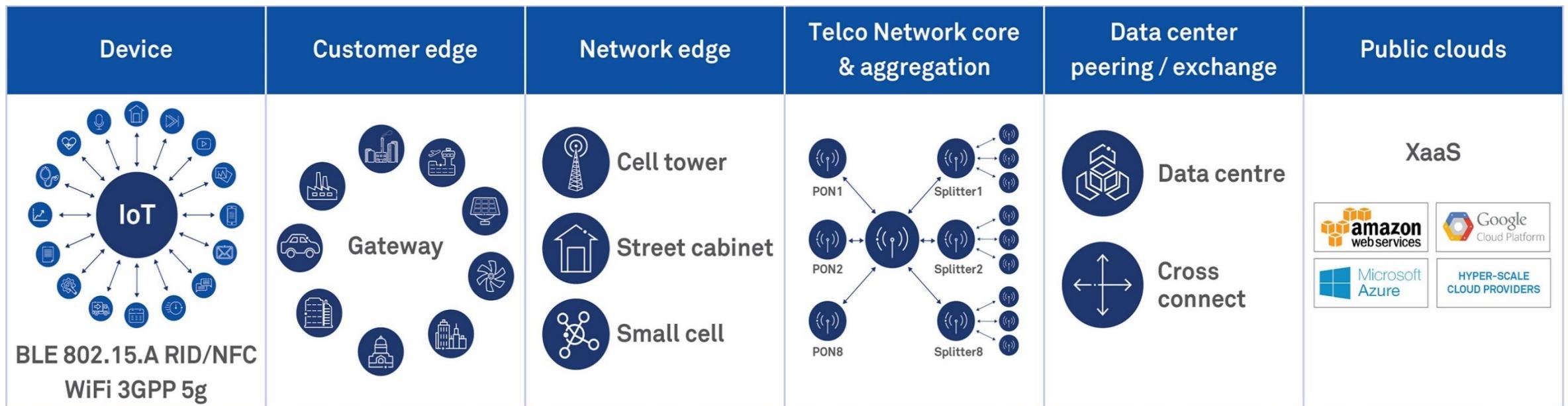
Actually, no. An edge device is an IoT device but with greater compute capabilities and so it is very much a part of IoT

¹ https://en.wikipedia.org/wiki/Internet_of_things

What is Edge?

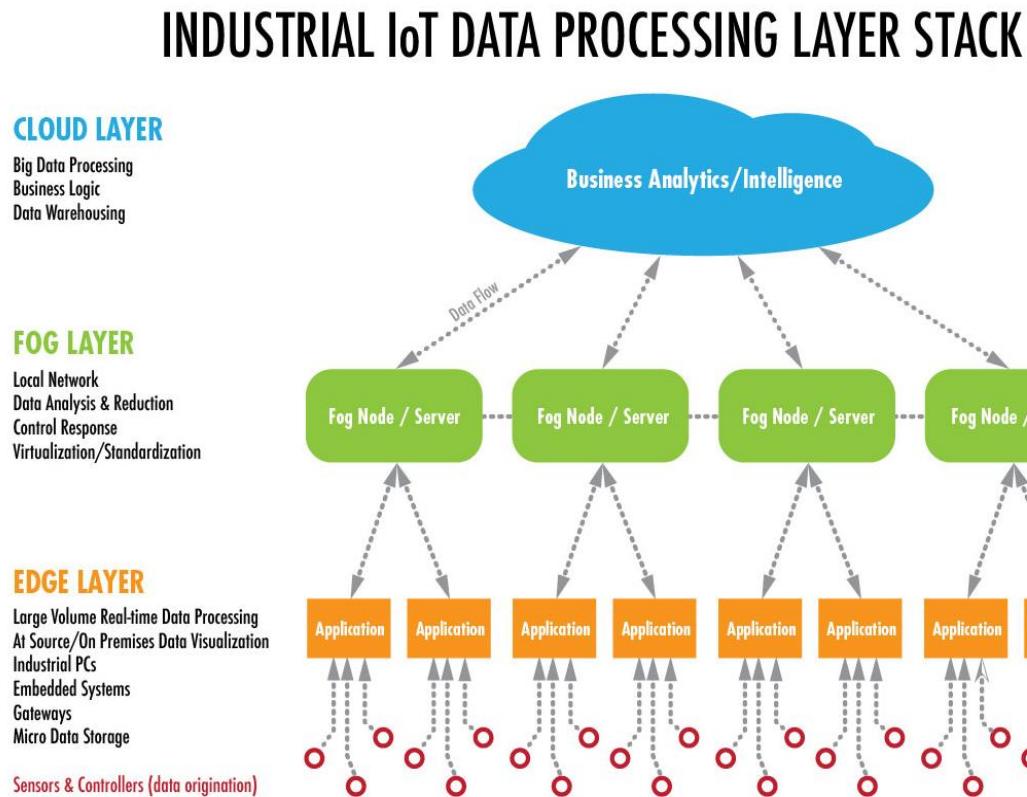
According to the [State of the Edge 2018](#) report, the edge is a location, not a thing. What the edge is depends on who you ask. The edge refers to the last mile of control of an enterprise and so, it might be different for companies across the edge stack. Broadly speaking, edge computing on the operator side is the *Infrastructure edge* and that on the user side is the *Device edge*.

For a datacenter operator or cloud service provider, the datacenter would be the edge, their last mile of control. For a telecom operator, the edge could be the base of a cell tower. For an end user enterprise, the shop floor, supply chain, etc. would be the edge. For a retail consumer, it could be the devices they own - smartphones, laptops, consumer appliances, etc.



Source: Wipro

How is it different from Cloud and Fog Computing?



Cloud computing is the on-demand availability of computer system resources, especially data storage and computing power, without direct active management by the user. The term is generally used to describe data centers available to many users over the Internet.²

Fog computing: The National Institute of Standards and Technology (NIST) in March, 2018 released a definition of fog computing that defines it as a horizontal, physical or virtual resource paradigm that resides between smart end-devices and traditional cloud computing or datacenter.³

	IoT	Edge	Cloud
Deployment	Distributed	Distributed	Centralized
Components	Physical devices	Edge nodes	Virtual resources
Computational	Limited	Limited	Unlimited
Storage	Small	Limited	Unlimited
Response time	NA	Fast	Slow
Big data	Source	Process	Process

Source: IEEE-A Survey on the Edge Computing for the Internet of Things - Mar 9, 2018

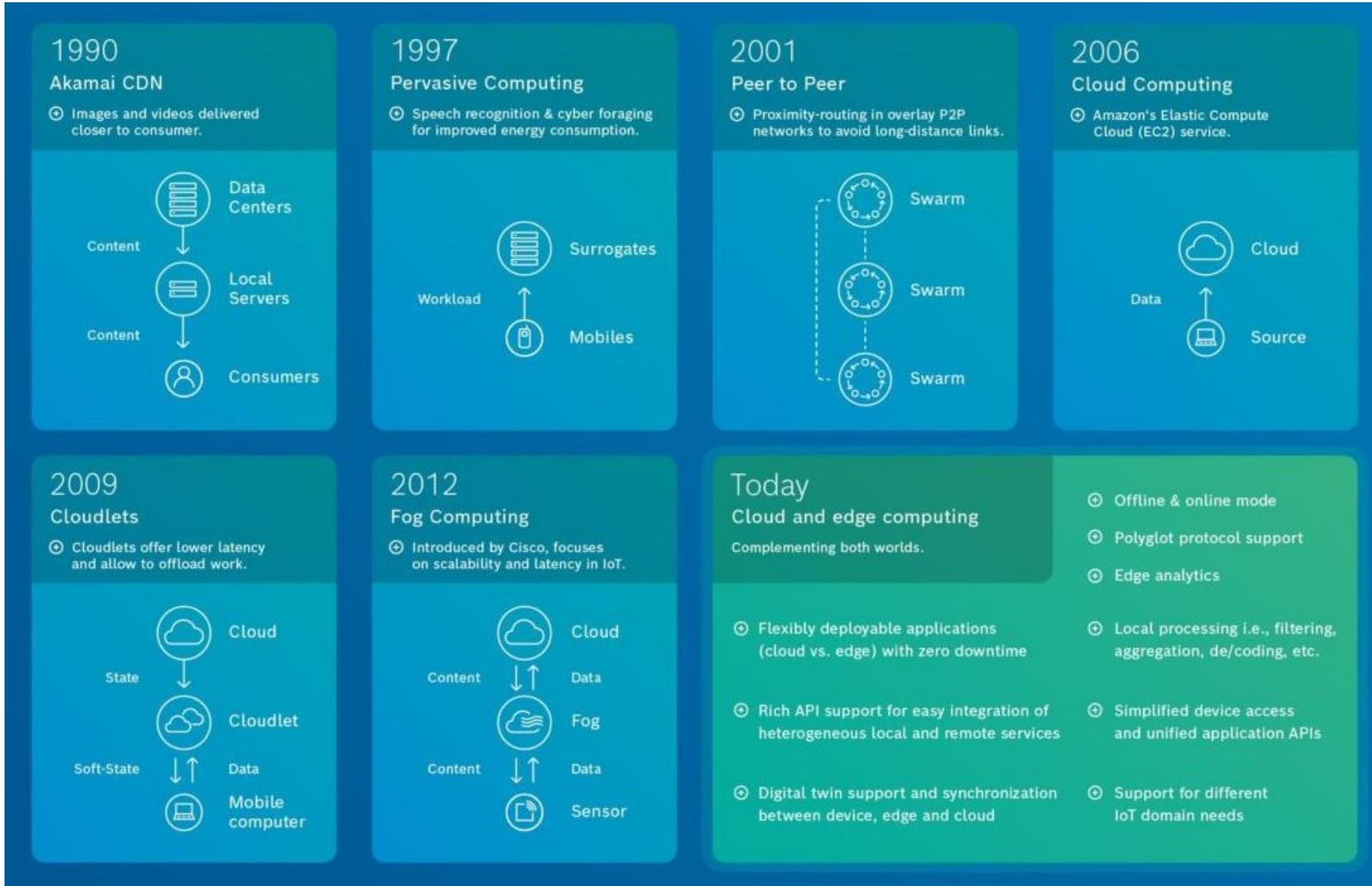
Myth 2: So Edge computing will replace cloud computing?

No; instead both will complement each other. Edge computing is an extension of cloud and fog computing, bringing it closer to the user location – another delivery/business model to process, deliver data with & without a centralized system

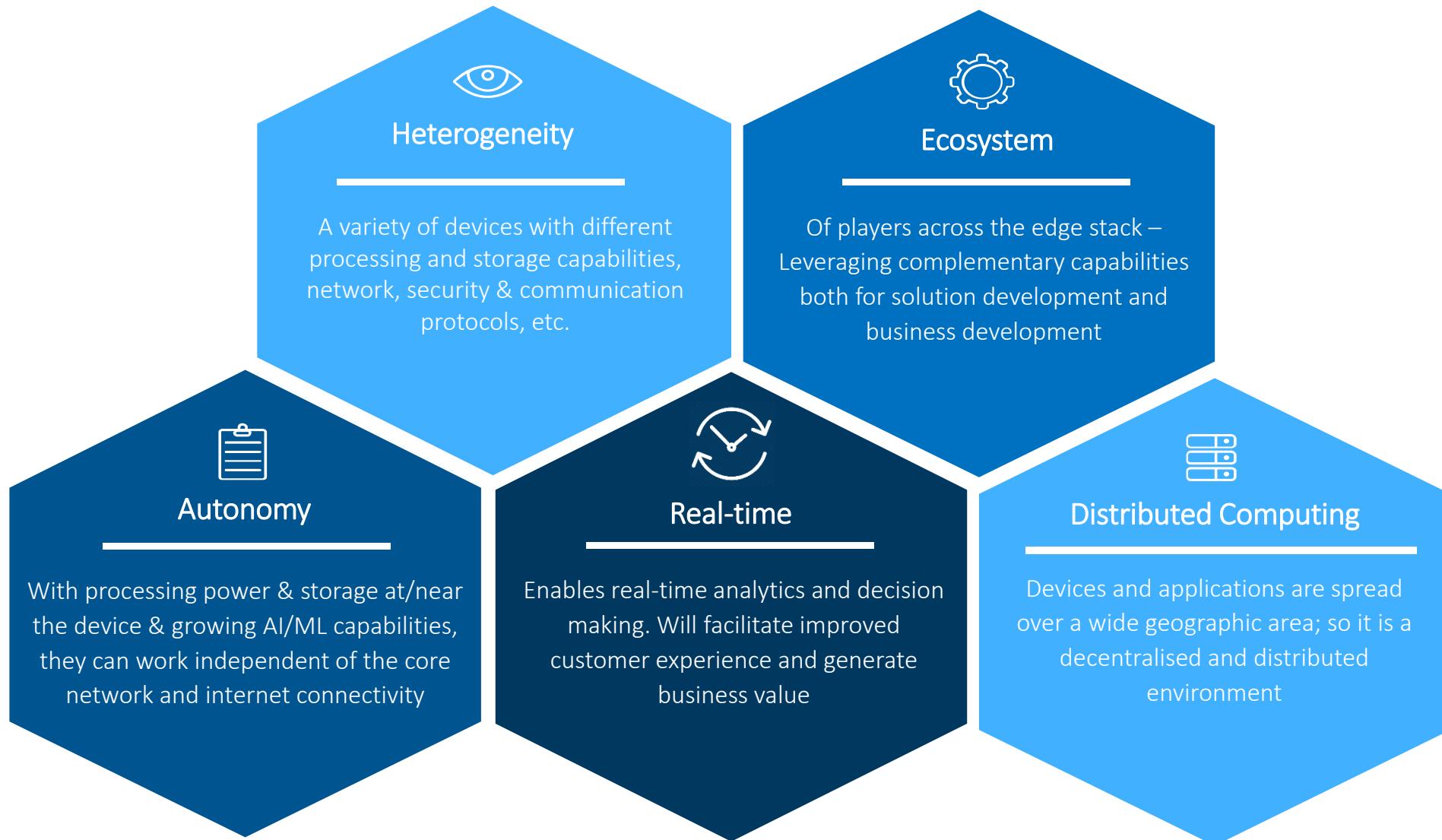
2 https://en.wikipedia.org/wiki/Cloud_computing

3 https://en.wikipedia.org/wiki/Fog_computing (NIST Special Publication 500-325, Fog Computing Conceptual Model)

History: CDNs were the earliest to explore the Edge opportunity



Characteristics: Diversity of devices, Distributed environment



Why? The need for Edge Computing: Business Drivers

Latency

In situations where speed of response is critical, any network latency can be disastrous (life threatening situations) and can have a negative impact on customer experience (gaming)

Moving data processing to the edge device/gateway can help avoid network latency and achieve a desired response time



Bandwidth

Edge computing can ensure only filtered data is transmitted over the network to the cloud/datacenter. This lowers the bandwidth requirements and helps optimize network assets



Allows for data filtering and processing before it is sent to the cloud. This reduces the cost of transmission and data storage

Costs



Availability

Edge devices can be decoupled from network connection and still collect, process & store data. This ensures 24*7 availability



Security

- Localized data processing ensures reduced amount of data being sent over the network
 - Smart devices can also carry out data processing without being connected to the internet
- Addresses the concerns about cyber attacks and the need of privacy and compliance regulations



Why? The need for Edge Computing: Technology Drivers

Data volume: With the rapid increase in IoT and connected devices, data generated is seeing exponential growth. In addition to volume, the complexity of the data is also growing. Not all of this can be handled in the cloud. Hence, the need for edge computing for local processing

Smart infrastructure: As the world becomes increasingly connected, be it smart cities, smart transportation, buildings and even smart homes, each of these would need to have a quick response system that will be enabled by edge devices

Video & Streaming technology: Growing video content and streaming (Netflix, YouTube, etc.), the increasing use of video surveillance, demand for video analytics, etc. will drive edge computing as it is cheaper to process these at the edge rather than in the cloud



Co-Founder & COO, AlefEdge

“Edge Computing is the perfect environment for Augmented Reality, Virtual Reality, IoT, Industry 4.0, Smart Cities and Autonomous Vehicles. The cloud allowed for applications to run much more efficiently; Mobile Edge Computing now moves the Cloud to mobile devices. This is game changing!”

IoT & cloud: As per Gartner, as cloud business grow, 80% of enterprises will have shut down their datacenters by 2025, versus 10% in 2018. IDC estimates 41.6 billion connected IoT devices by 2025. These technologies form the basis for an edge computing ecosystem

5G: Responsiveness and bandwidth will be much higher - upwards of 1,000X faster than 4G. To achieve this, small datacenters will be required and edge computing will play a pivotal role here

AI/ML: These are making edge devices smarter, driving real-time insights & predictive analytics. AI accelerators are further speeding inferencing capabilities at the edge

AR/VR/MR: Are finding new areas of application – gaming, sports, education, retail, manufacturing, etc. – that need huge compute power and low latency. We can expect to see greater use of edge devices and servers to serve customer needs

Myth 3: 5G is imperative for Edge computing?

No. In fact, 5G needs edge computing. There is no 5G without the edge. The fundamental requirements of 5G is tied to ultra-low latency and ultra high definition - impossible to achieve it without the edge internet

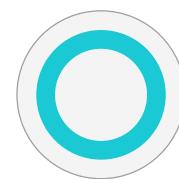
Tata Elxsi's Edge AI solution



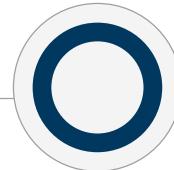
The context: AI algorithms performed well on high-end devices but, seldom on low-end devices. A solution to accommodate high computations on smaller form factor devices became paramount. Thus, the idea of combining AI and embedded devices was conceived

The innovation: Tata Elxsi's Edge AI solution translates AI algorithms to platform independent executables, that can be directly ported on embedded devices with constrained resources

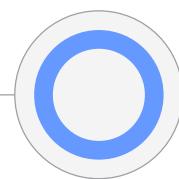
Overcoming challenges:



Fitting the algorithm into RAM and ROM, achieving the desired performance and computation time (ms.) and accommodating version changes in framework and periodic evolution of new architectures



Memory optimization was achieved by identifying commonalities, redundant nodes and strategically deciding optimization techniques



Designed flexible and generic architectures to accommodate changes in the technology and accelerating code generation on the fly

Impact of the Innovation

\$80,000

This solution has been converted into a product and made available commercially driving the smart factory initiatives undertaken by a leading Japanese semiconductor major



Edge Computing Market Landscape



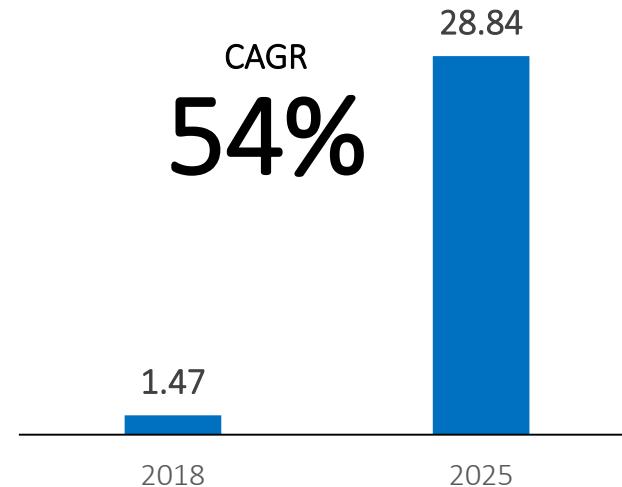
“Now, all this is being driven by this new tech paradigm that we describe as the intelligent cloud and the intelligent edge. The capacity at the edge, that ubiquity is going to be transformative in how we think about computation in any business process of ours.”

Satya Nadella
CEO, Microsoft

Global Edge Computing market to cross \$28 billion by 2025

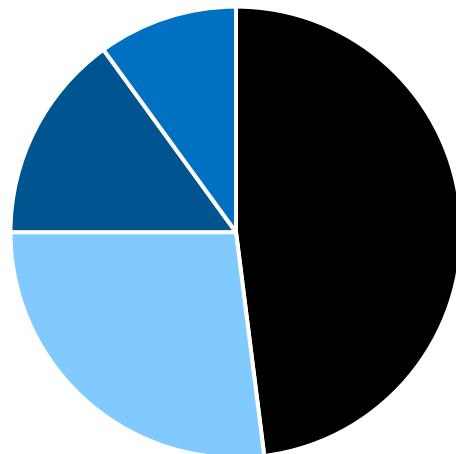
Global edge computing market

\$ billion



Market share by component

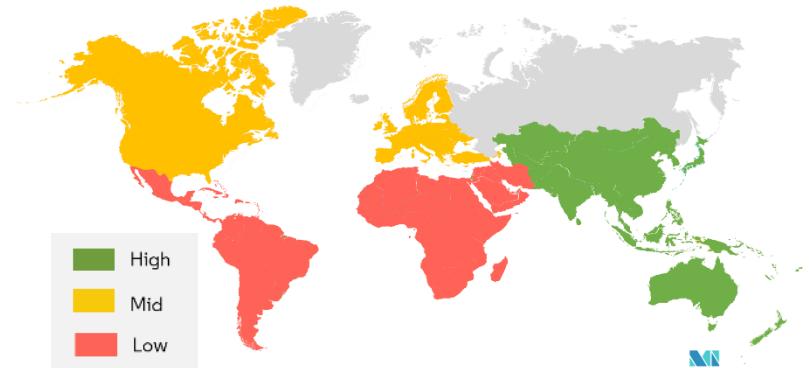
2018, %



Growth rate by geography

2019-2024, %

Edge Computing Market - Growth Rate by Region (2019 - 2024)

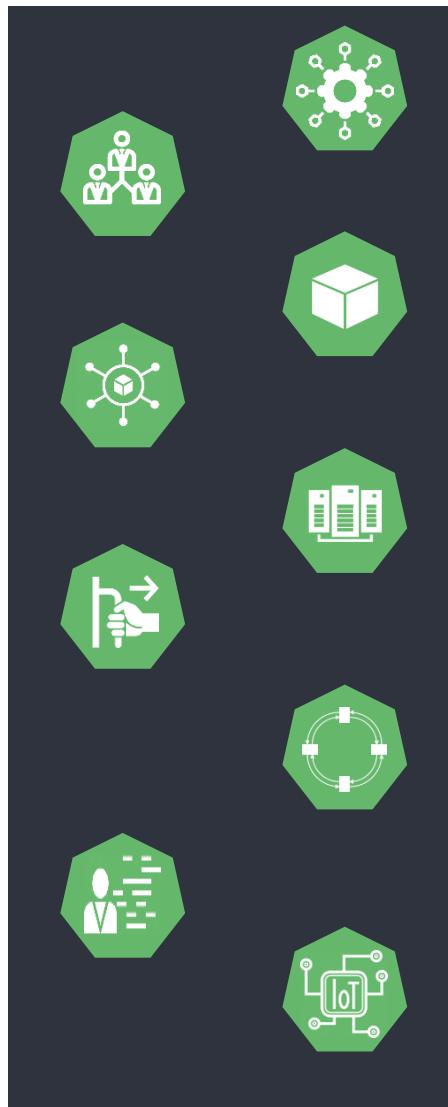


- North America, the largest market for edge computing - ~45% share
- APAC region, the fastest growing
- India: Emerging hub for content delivery network
 - Feb-2019, AWS Inc. added two additional edge locations in India
 - Reliance Jio - Cisco collaboration to deploy edge computing for enhancing and optimizing video experience over the network by developing mobile CDNs

- Data Center Management-as-a-Service (DCaaS) emerging as a low-cost way for data center management from the edge
- Stringent requirements of 5G standards - high reliability, ultra-low latency, consistency in user experience, likely to trigger the need for localized services based on RAN
- MEC emerging as a promising computing architecture that adds virtualization and computing capabilities to a RAN

Trends: How Edge Computing is evolving

- **Team size:** Currently marked by small teams, 50-150 people, incl. technology & business development. Team sizes expand as firms create cross-functional groups to include ER&D, cloud & datacenter, networking and IoT
- **Synergies:** Cloud and edge computing will co-exist. Application workloads will differ - edge computing will process time sensitive data; cloud will be used more for historic data and analysis - augmenting capabilities of each other
- **Pull vs. push:** Most projects, both globally and in India, are at PoC stage. Very few are at the full scale implementation stage. Lack of awareness among stakeholders, visibility on RoI and not enough use cases means the industry is at a very nascent stage of the pull opportunity
- **Use cases:** For streaming services, RoI on edge delivery/ streaming is fairly well-established and increasingly OTTs are using these services. Other use cases around 5G style gaming and AR/VR getting established. Manufacturing - maturity is still at the PoC/RoI discovery stage
 - Emerging concept of B2D – Business to Developer – connecting buyers looking for IoT solutions with developers building them



- **Microservices:** Customers take pieces of their applications and distribute it closer to their users. This is for very latency-sensitive applications like ad-serving, which is very competitive market
- **Containerization:** Containers are key to pushing intelligence to the edge. For example, by moving AI inferencing to edge devices, IoT systems can provide real-time analytics. Using containers, these and many other processes can be deployed, and run simultaneously in isolated instances on edge device
- **Micro-datacenters:** Being set up to help manage the growing computing needs across edge environments. These datacenters require very little physical space, lower configuration time and may need plug-and-play functionality especially if located in remote areas
- **Self-healing architecture:** In a widely distributed environment where you are managing multiple small datacenters and in some cases, the sensors and devices are in remote locations (offshore rigs, mines, etc.), edge computing applications need to be self-healing or capable of failing over to nearby nodes or datacenters to ensure uninterrupted service levels
- **IT-OT convergence:** IoT and edge computing are accelerating convergence of IT and OT especially as the edge increasingly includes a plethora of corporate, industrial systems and services. Examples include video and computer vision-enabled applications, telematics, tracking systems, etc.

Edge Computing stack comprises of four primary layers

Centralized Cloud

Centralized datacenters are farthest from the network edge. However, they offer a much greater density of compute, storage, and networking resources

Edge Infrastructure

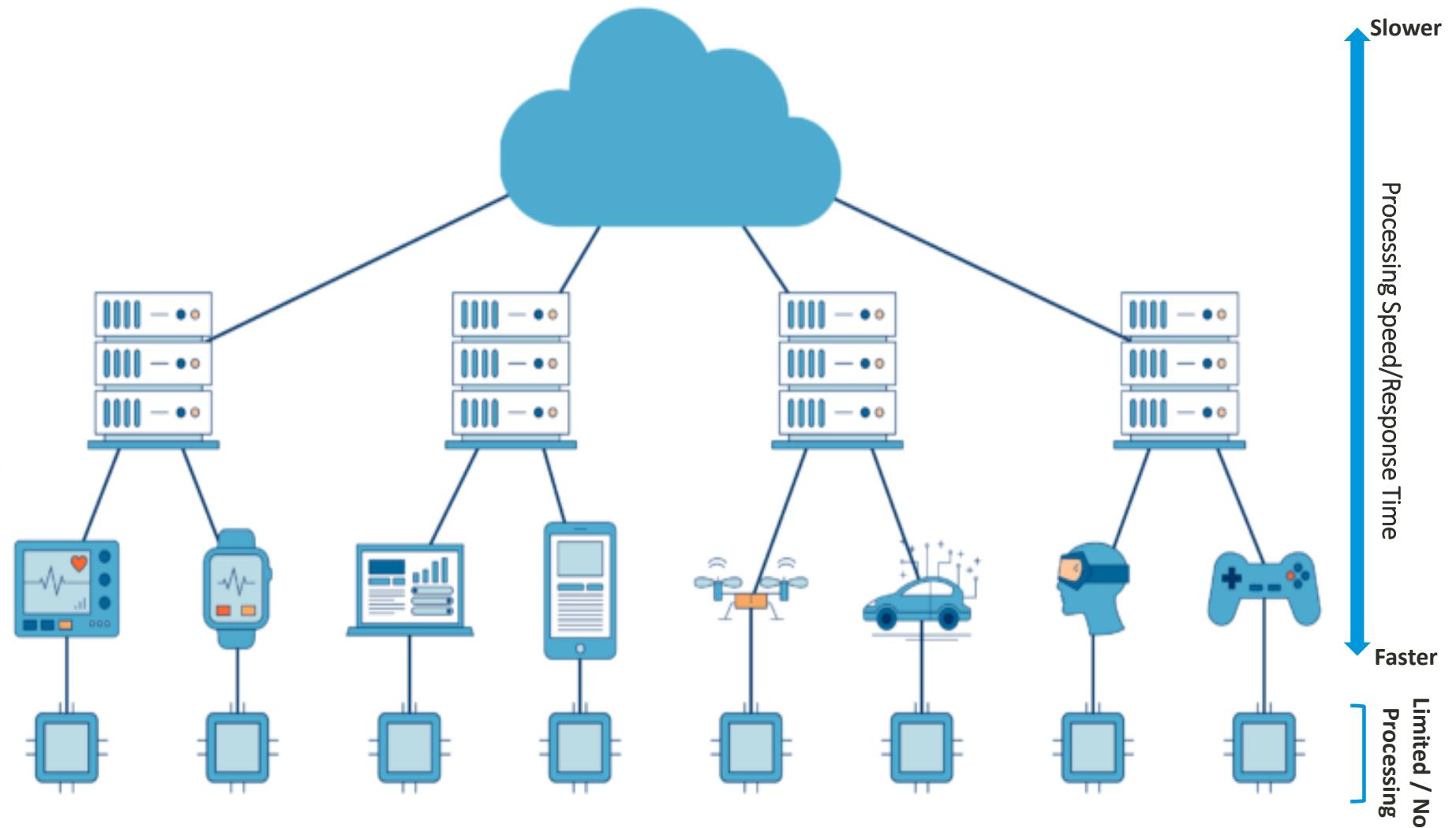
Small, distributed datacenters that provide a resource-dense midpoint between edge devices and the centralized cloud. Low roundtrip latencies of 5-10 ms.

Edge Devices

Real-time data processing within devices based on application needs. Processing limitations present

Edge Sensors & Chips

Data collection & organization



Player landscape

Illustrative

Global players

Platform for edge services	IBM Watson IoT™	Microsoft Azure	AWS Greengrass
SAP Leonardo			
Hardware providers		Hewlett Packard Enterprise	 DELL EMC  EUROTECH Imagine. Build. Succeed.
Infrastructure providers		 Google Cloud	packet 
Network & Connectivity providers			
Software Solution providers			MESOSPHERE 
			NUTANIX

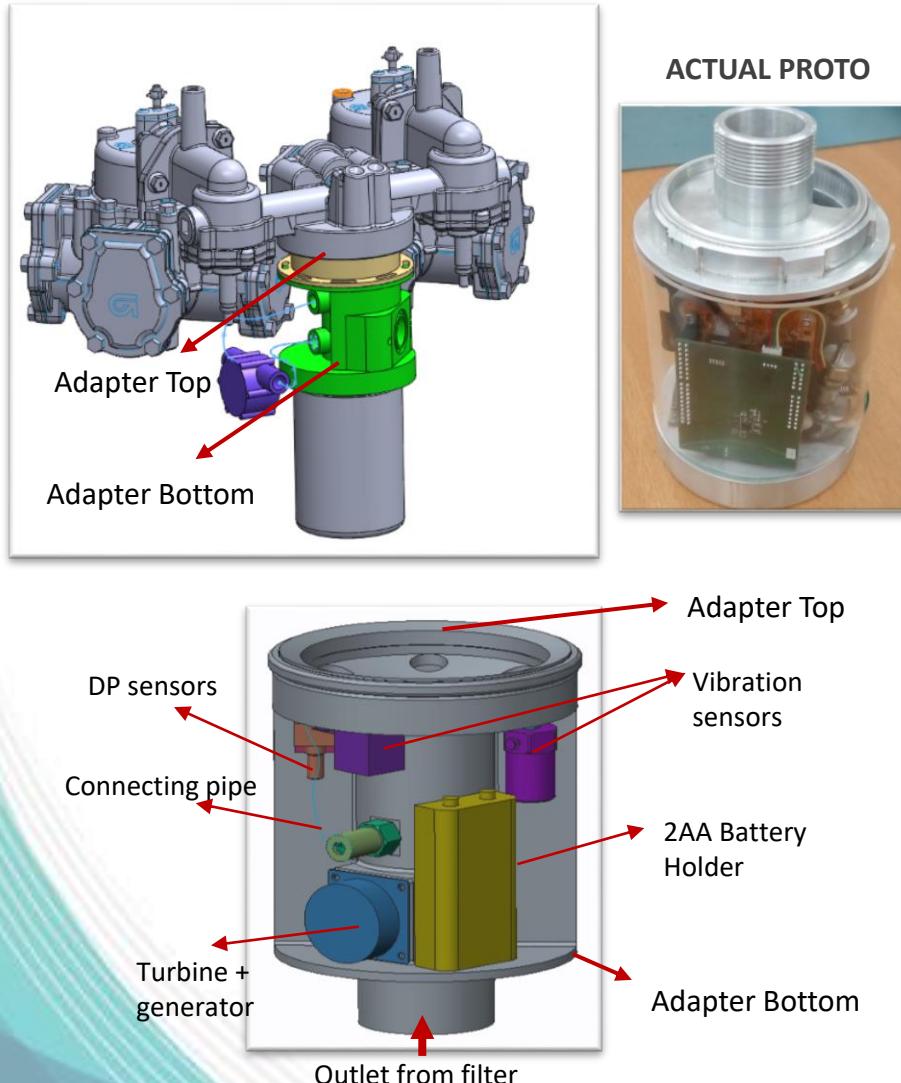
Indian service providers








Condition monitoring and energy harvesting



CUSTOMER: A leading North American medical devices giant

THE CHALLENGE

- Design and develop the hydraulic sensor module to reduce the field failures
- Should not disturb existing system, present wire harness and should communicate to cloud for predictive analysis

SOLUTION HIGHLIGHTS

- Developed the module with **multiple sensors** (like MEMS & Piezo vibration sensor, differential pressure, temperature) to **monitor system condition and predict failures**
- Deployed the **turbine & generator** to power the sensor and electronics
- Sensor data sent to L&T's proprietary gateway - analyzes data on the edge using pre-built AI modules
- With help of Radio module, able to connect with cloud thought RF getaway - helps in further monitoring & **AI based predictive analysis** of failure

BUSINESS VALUE DELIVERED

- Reduced service expenses by 30%
- Improved pump downtime and efficiency in maintaining the spare part inventory
- Improved end customer satisfaction level and brand value



ENGAGEMENT

Design, Engineering



TECHNOLOGY

Sensor & IoT



OWNERSHIP

Joint program ownership

Indian startups focusing on Platforms with niche vertical solutions

16



Note: List of startups, their respective products & services and other details given in the appendix

Source: Unearth Insights, Primary interviews, Secondary sources

AlefEdge's MEC solution enables ultra low latency for an Indian OTT player



Customer: One of India's OTT player has a subscription based video on-demand platform with >250 hours of original content

Challenge: The need is for a reliable network connectivity at all times allowing videos to be streamed seamlessly. OTT was in need of a solution that can support its premium content with ultra low latency and a great user experience

Solution: Mobile Edge Computing - For on-field test, Lucknow was selected as the location with OTT content being deployed on two MNO's 3G live mobile network base sites. Over 100 runs were performed on MNO's 4G network, where content was delivered via existing OTT cloud providers and AlefEdge powered MNO's 3G network, where content was delivered through the mobile edge. Both the networks were tested at the same time and video stats were collected

Impact

AlefEdge powered 3G network outperformed MNO's 4G network:

- Start up time consistently under 0.15 secs with (MNO's minimum start time of 0.17 secs)
- Average stalls being zero compared to 2 on MNO's 4G

Following the immense success of the pilot, OTT and AlefEdge have officially partnered for rolling out 4G based edge services to 170 edge locations across 50 cities in India

Video length (s)	127	Stall index	0
Min. total stall time (s)	0.00	Avg. total stall time (s)	0.00
Min. stall count	0	Avg. stall count	0
Min. start delay (s)	0.03	Avg. start delay (s)	0.05
Max. total stall time (s)	0.00	Max. stall count	0
Max. start delay (s)	0.14		

Indian players establishing their presence across the edge spectrum

18



Edge Computing for robots & drones



Infosys in partnership with Huawei recently released the smart industrial robots solutions based on the **open edge computing IoT**:

- Supports interconnection of industrial robots from multiple vendors
- Helps manufacturers anticipate faults and improve maintenance efficiency
- Schedule production rates based on resource utilization rates and optimize these production lines for maximum efficiency

Impact

- Reduce industrial robots downtime by >70% and defect rate by 40%

Source: Secondary sources

Edge AI solution powered by Intel



- **Pipe Sleuth**, an automated anomaly detection solution- eliminates the need for manual review and coding of video scans of utilities pipeline infrastructure. It uses AI to automatically process video scans and identify, grade and score the overall pipe segment, using the NASSCO PACP standard and includes a comprehensive inspection report
- **Surface Crack Detection**, which uses AI to detect and label cracks in infrastructure like buildings, roads, pavement, and bridges
- **Medical Imaging**, uses AI to identify regions of interest and label abnormalities in medical X-Rays and CT scans. For example, highlighting anomalies in the lungs and labelling the ailment conditions in these images

IoT enabled Edge solution for plant safety for a US based global corporation



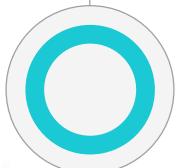
Challenges

- Globally productivity losses are incurred due to plant shutdowns because of accidents and fatalities
- Any fatality/accident can seriously damage a company's brand image



Business goals for safety

- Reduction in fatalities and recordable injury frequency rate for personnel
- Safe-keep of static and mobile assets like trucks, loaders, fork-lifts, etc.



Problem Statement / Objectives

- Reduce risk of collision between i) moving vehicles **and** ii) moving vehicles & personnel
- Detect proximity at critical level **sub-meter** level
- Provide alerts for unauthorized intrusion
- Ensure safe operations and **enable controls** by adherence of rules like compliance to wearing safety harness
- Track employees and provide AV alerts when at risk in areas like underground tunnel or overhead storage tanks



Deployment sites

- Warehouses, food processing, loading and unloading areas at ground level
- Underground food transport facility and overhead food storage facility



Solution brief

- State of the art IoT/Edge devices & technology deployed for RTLS, proximity detection, collision avoidance, vitals monitoring
- Critical SLAs for proximity and response time addressed by sensor fusion consisting of UWB, BLE, Lidar, Ultrasonic, Inertial Measurement, Gyroscope, Vibration, etc.
- Completely edge focused solution, capable of working independent of server/cloud
- Configurable for i) various site geometries and topologies, ii) different vehicle types, iii) indoor/outdoor
- Capable of handling electrical, metallic and illumination/visibility interferences
- Also caters to avoidance of privacy breach as well
- Extensible to manufacturing plants, warehouses, process industries and is vertical agnostic



Impact

- Sub-meter proximity detection achieved at a sub-second response time
- Achieve Recordable Injury Frequency Rate @ 1.0 and Reduce SIF (Serious Injuries and Fatalities) potential

Application areas (1/3)

When observed, the application areas of edge computing across verticals are not too different from those of IoT devices. This is because the difference is mainly in where you process the data. In case of conventional IoT devices, the data is pushed to the central cloud for processing. With edge, the processing can be done either at the device level itself or very near the device using micro datacenters. Being able to generate near real-time insights so close to the data source offers multiple benefits:



Faster response time,
particularly where safety is
paramount



Lower downtime of equipment
through predictive and
prescriptive analytics



Remote monitoring, esp. at locations
where internet connectivity is
intermittent and bandwidth is limited



Minimize operational risks



Cost reduction, improved
asset utilization and
optimization



Enhanced customer experience and
improved service levels through hyper-
personalization, especially in consumer
facing industries

Many of the application areas are cross-vertical - equipment monitoring, inventory management, location tracking, energy management, etc.

As per MobiledgeX's interactive [Edge Navigator](#)⁴ tool, based on interviews with >200 global businesses, multi-player and cloud gaming, vehicle-to-everything (V2X) communications; and industrial IoT are among the most viable near-term edge use cases.

⁴ The tool has been built based on MobiledgeX's edge use case research project and provides an interactive market to explore likely edge use cases based on a specific vertical or geography, for example

Real-time auto security



PORSCHE



Innovative method combines video analytics with edge computing to accelerate onboard intelligence

The prototype allows for multi-factor authentication and is designed to improve auto security with a real-time facial recognition system and edge analytics

The face detection can process infrared video to identify if the person is the car owner, without having to send the data to a central location

The second mechanism swaps a car fob with a smartphone, thwarting car thieves

Application areas (2/3)

Illustrative



Healthcare services

- Remote/emergency healthcare, smart hospitals
- Patient monitoring, telemedicine
- Condition based maintenance of equipment
- Machine learning inference to diagnose medical conditions from images
- Monitor, provision, maintain endo-surgery devices in the field through upgrades OTA eliminating field visits
- Preventing pilferage and counterfeit drugs
- Inventory management



TTL

- Smart Ports, Container Management, Connected ships
- Automated Baggage tracking
- Fleet Management
- Package tracking
- Real-time asset monitoring and management
- Monitor and control engine idle times
- Condition-based maintenance of assets
- Route planning based on delivery schedules



Agriculture

- Location tracking of livestock to reduce lost/stolen livestock
- Health monitoring of livestock
- Soil condition monitoring
- Pest control
- Maintenance of farm equipment
- Precision farming



Manufacturing

- Condition based maintenance of factory equipment
- Shop floor displays, predictive analytics
- Fault recognition and classification engine to detect fault and troubleshoot in machines
- Real time inventory management using image analytics
- End of Line quality management using image analytics



Auto & Aero

- Condition based monitoring, predictive maintenance, field services, OTA updates
- Tracking assets - real-time monitoring of asset status and automatic scheduling of preventive maintenance
- Connected and autonomous cars
- Smart Airports, Edge analytics of flights for maintenance
- Condition Based Maintenance in Airplanes



Utilities

- AR enabled digital MRO
- Condition based maintenance of equipment, alarm management, worker safety
- Predictive analytics for oil drilling ops to avoid stick-slip situations & critical component failure
- HVAC and Lights Utilities control
- Real-time adjustments to maximize power generation, advanced analytics for accurate energy forecasting and delivery

Field deployed: Footwear component defect detection



Customer

An Indian footwear major

Deployment Scope

Deployment of TYQ-i Deep Learning based defect detection platform

Software/Platform

- Custom image processing algorithms
- Custom Neural Network
- TensorFlow framework
- NVIDIA-GPU based hardware platform at the edge
- Completely in-premise solution

Solution/Benefits

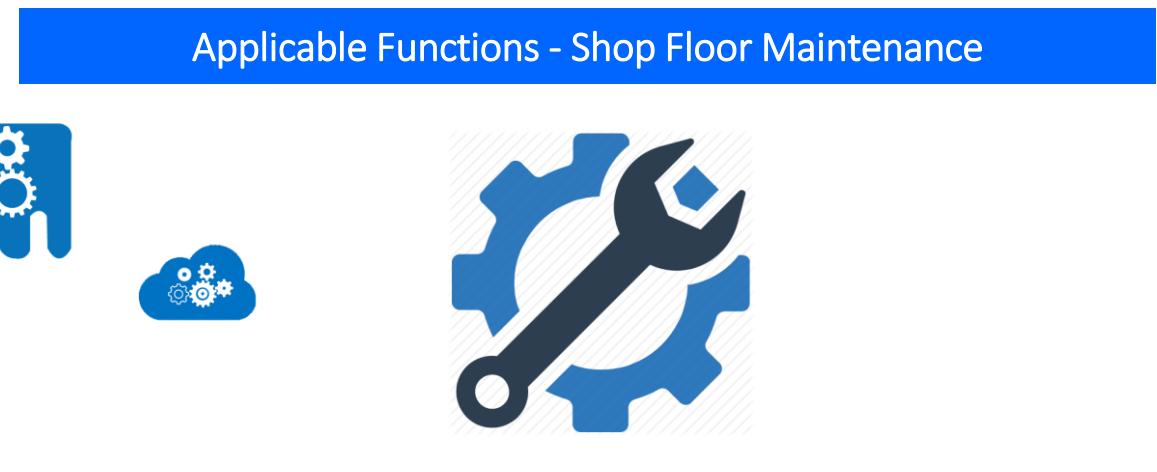
- Detects different types of defects (shape, dimension, slits, missing cuts, etc.) on leather components
- Optimized labor force
- Automatic compliance and QA
- Improved auditing process

Leveraging Edge Computing for smart boilers



Business Problem/ Challenge
<p>Use Case – Factory Operations Visibility & Intelligence</p> <p>Problem Statement</p> <ul style="list-style-type: none"> • Visibility of a large fleet of remotely located industrial grade IoT devices • Health and performance monitoring of the end devices required additional code • Frequent failures require truck rolls and data connectivity issues <p>Solution – Manage/Control the device with SMS incase of low/nil connectivity & remotely monitor, start/stop & upgrade applications</p> <p>Geographical Market(s) Served: India</p>

Impact
<p>Adoption of Edge Computing – IoT Device</p> <ul style="list-style-type: none"> • Reduced OpEx – 50% improvement in maintenance issues to proactively fix & find issues • Reduced provisioning times – 25% reduction in Factory Operations Visibility & Intelligence eventually reducing provisioning time
<div style="display: flex; justify-content: space-around;"> Internet of Things Artificial Intelligence </div>



Application areas (3/3)

Illustrative



Telecom services

- Network performance and benchmarking
- Network planning & optimization
- Edge CDN performance analysis & planning



Advertising

- Edge enabled localized ad insertion in media stream
- Location based advertising



BFSI

- Performance benchmarking and analysis of banking apps, network assessment of branch network and reducing TAT and cost of customer care
- Reduction of collision using automated braking system



Retail

- Store network assessment and application performance testing, benchmarking, analysis
- Inventory optimization, order routing, in-store refrigeration equipment monitoring
- Energy management
- Recommendations based on buying patterns
- AR/VR, video analytics
- Real-time omni-channel personalization
- Improved billing/check-out experience



Media & Entertainment

- Video content delivery performance analytics and benchmarking
- Gaming performance analysis and benchmarking
- 100X faster delivery of real time video in Stadium
- Multi-player, cloud gaming industry



Smart Infrastructure

- Traffic Management
- Air and water quality management
- Smart parking
- Structural monitoring
- Worker safety on construction sites
- Remote alert management based on video analytics
- Smart homes: Energy management to energy conservation; Home security surveillance

Cognizant



Multinational retail corporation that operates a chain of hypermarkets, discount department stores, and grocery stores



Alarm & energy management solution for preventing food wastage due to equipment failure by retrieving sensor parameters & processing sensor data on edge controller



Impact

- **10%** reduction in food wastage
- **\$18** million operating cost Reduction
- **84%** quicker response time



Edge enabling HEARS



Customer: Leading French engineering firm providing containment systems for shipping and storage in cryogenic conditions of LNG

Offer HEARS (Hotline Emergency Assistance & Response Service) that allows ship owners and crew to contact specialists 24/7 to report any incidents and obtain assistance

Problem: Existing HEARS was manual, time consuming & reactive in nature

Flutura's approach: HEARS 2.0 - powered by Cerebra's digital platform

- Cerebra Edge Intelligence offering optimized data transfer and reduced latency to react in safety situations
- Cerebra Central Intelligence has made it digital and hence driving proactive responses to incidents

Customer can configure heuristic domain based rules through self service:

- Gas or liquid leaking into isolated spaces
- Presence of water in isolated spaces
- LNG seepage onto the deck due to fractures in steel plate or cargo manifolds

On the Edge:

Edge deployment onboard ships due to high costs of satellite based data connectivity

24/7: Powering digital operations at command center

Self service:

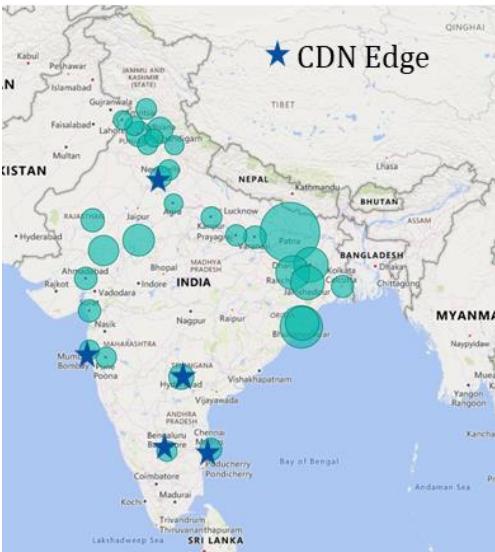
Customer can configure heuristic domain based rules through self-service module

Increased number of CDN edges lead to enhanced video OTT QoE

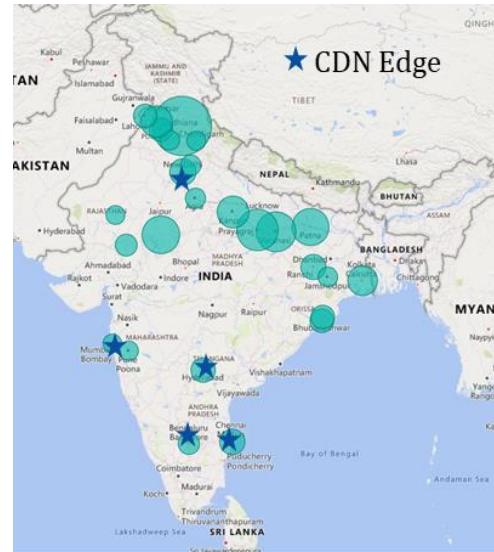


Mozark's Aquamark platform used to measure and benchmark QoE metrics for top 5 video OTTs in 25 cities in India:

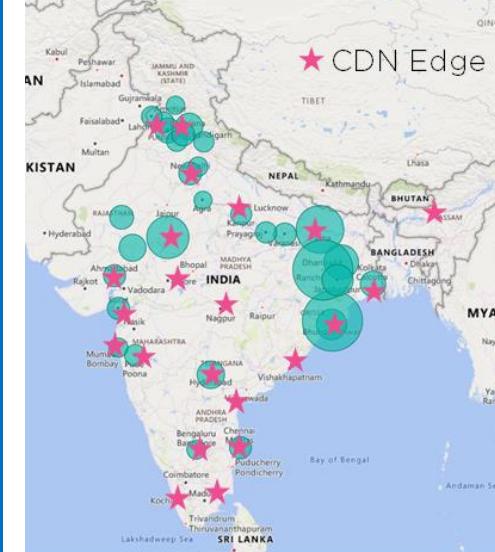
Time to load app: Avg. = 13 secs



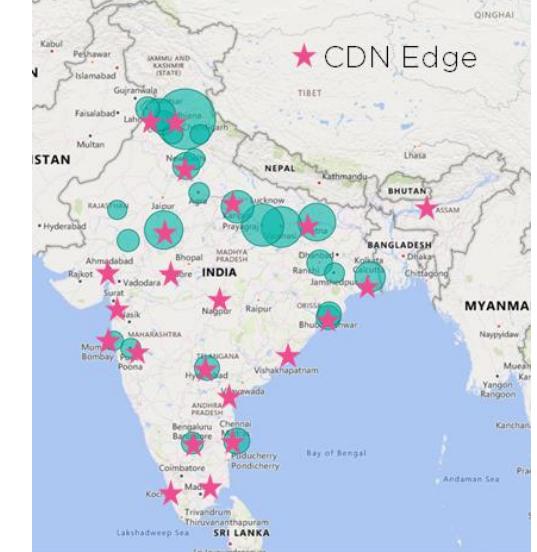
Buffering ratio: Avg. = 4.3%



Time to load app: Avg. = 9 secs



Buffering ratio: Avg. = 2.4%



OTT 1 with CDN 1 - Without edge cache

- For OTT 1, lack of CDN caching infrastructure in the East and North led to poorer QoE performance compared to West and South

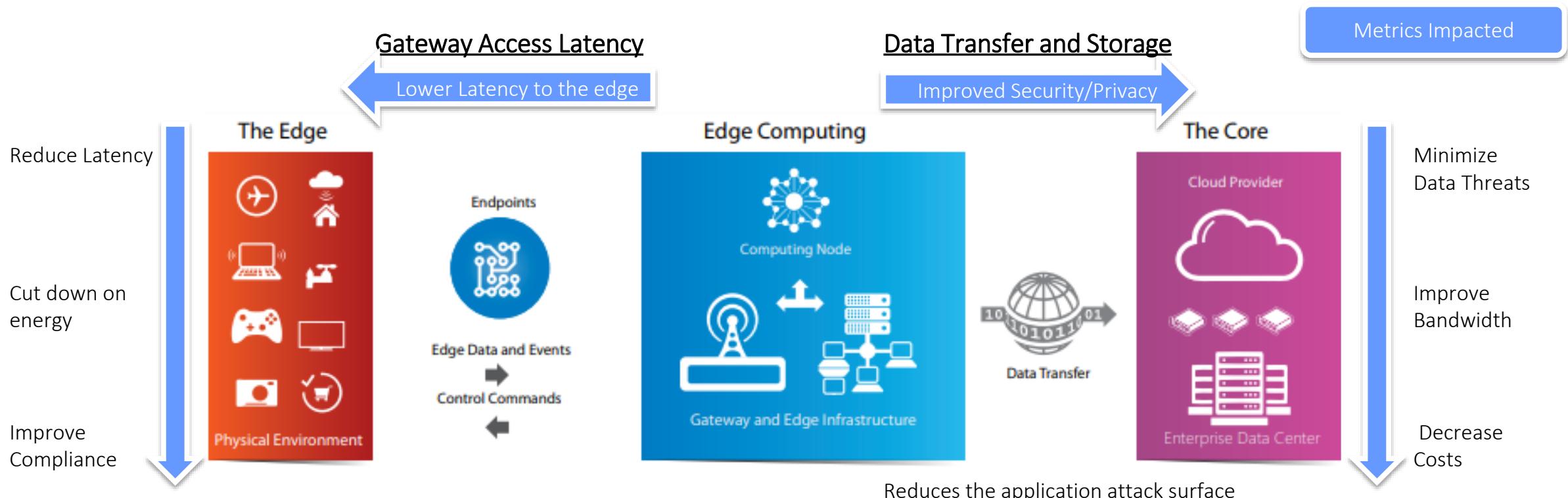
OTT 2 with CDN 2 - With edge cache

- OTT 2 uses a CDN service with a more distributed edge caching and delivery network, which ensured better and more uniform QoE performance than OTT 1

Note: Bubble size indicate relative performance between towns. Smaller bubble means better performance. The stars represent CDN edge locations

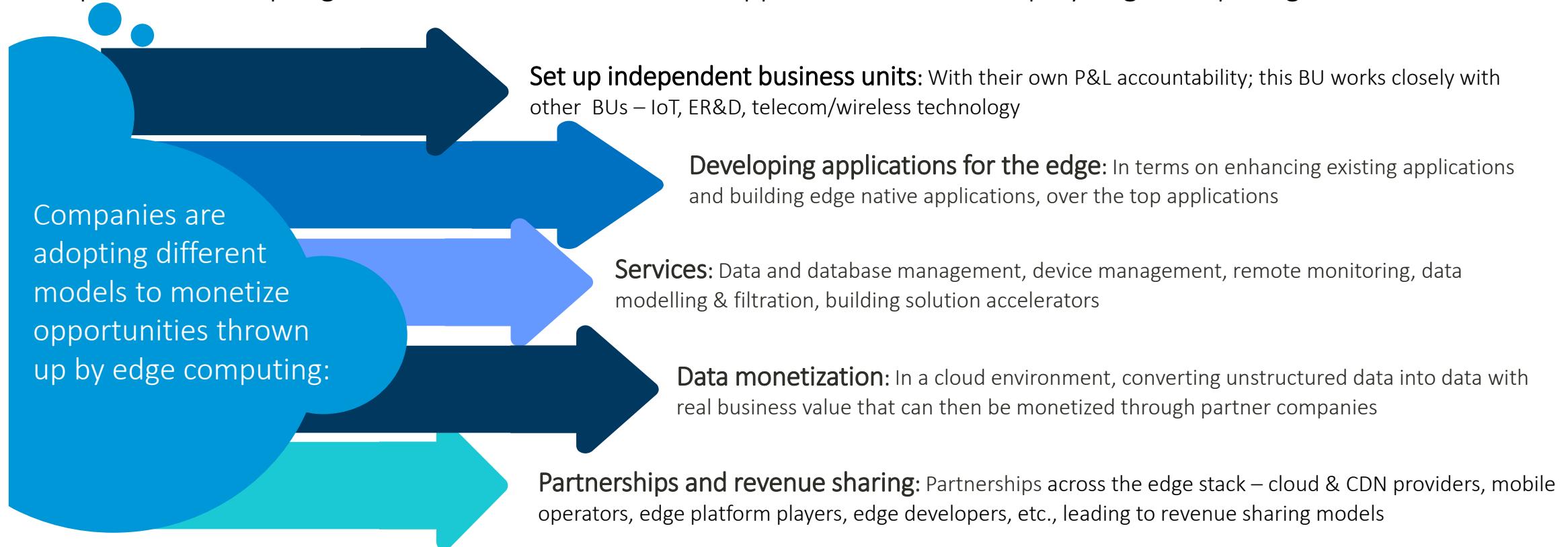
Unlocking the value of Edge Computing

- Edge computing pushes computing resources physically closer to devices by deploying either a device that performs the computation itself, a computing node that acts as a miniature cloud, or a combination of the two
- Edge computing can significantly improve application performance and user experience by moving both computing and data closer to the user in order to offer dynamic and customized content



Monetizing Edge Computing opportunities (1/2)

Companies are adopting different models to monetize opportunities thrown up by edge computing:



Companies will adopt a mixture of business models – innovate and deliver new services, as-a-service model, aggregation model, etc. It will be important for companies to look at market realities. Not all verticals and all geographies would be at the same level of maturity in their edge computing journey.

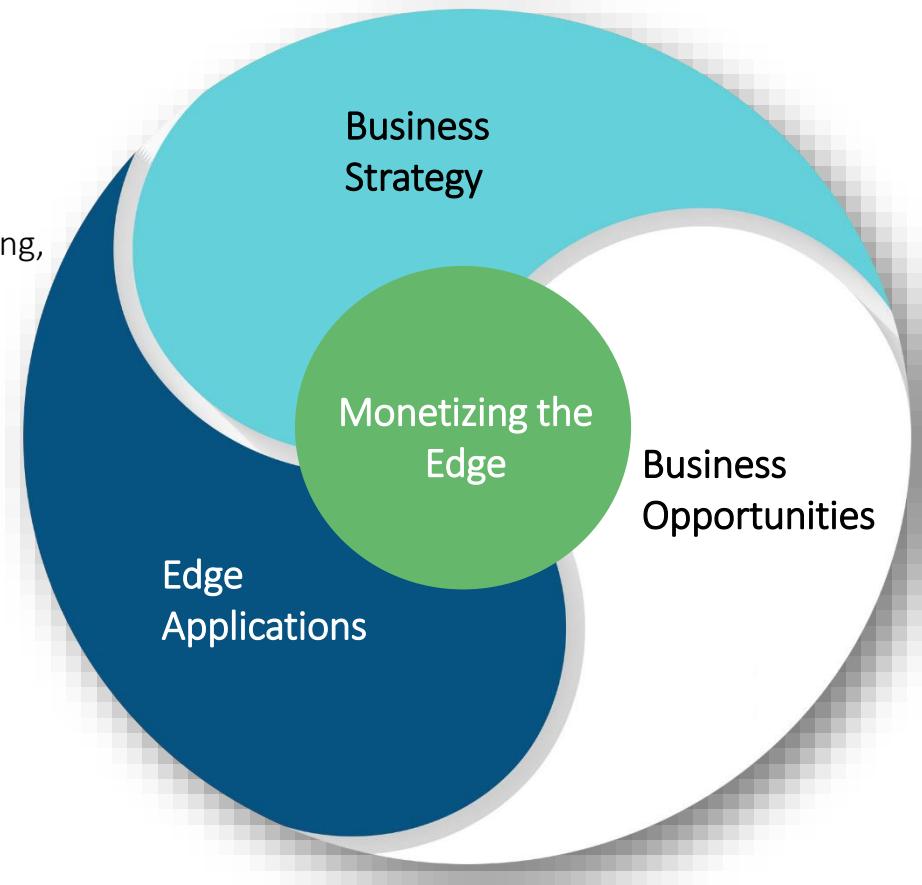
Companies would need to strategically prioritize their target geographies/verticals, understand what customers need, weigh in the challenges and then come up with strategies to stay relevant to that market need.

Edge computing is as much about technology development as it is about business development. Therefore, it would be important at an organisation level, to make sure that both technology and business department work together.

Monetizing Edge Computing opportunities (2/2)

Illustrative

- Independent business units
- Develop IP
- Business models: As-a-Service, Aggregation, etc.
- Revenue models: Revenue sharing, licensing, subscription



- OTT apps
- Edge as a Service
- APIs
- Verticalization
- Edge Platforms
- Edge Applications - Edge analytics, Edge AI, etc.

- Partnerships: Between networking, cloud, datacenter players, startups, application, platform providers
 - M&As
 - Incubators & accelerators
-
- Edge cloud
 - Edge advertising, Edge streaming
 - Multi-access Edge Computing (MEC)
 - Private networking

Building a partner ecosystem around MEC

**Tech
Mahindra**



With Saguna to deliver MEC-based optimization manage RAN for video delivery and IoT services - transform the edge of the RAN into micro-clouds with analytics tools and real-time actionable insights for mobile operators. It closes the loop by delivering video KPIs over the RAN to Self-Organizing Networks (SON) and Software Defined Network (SDN) solutions

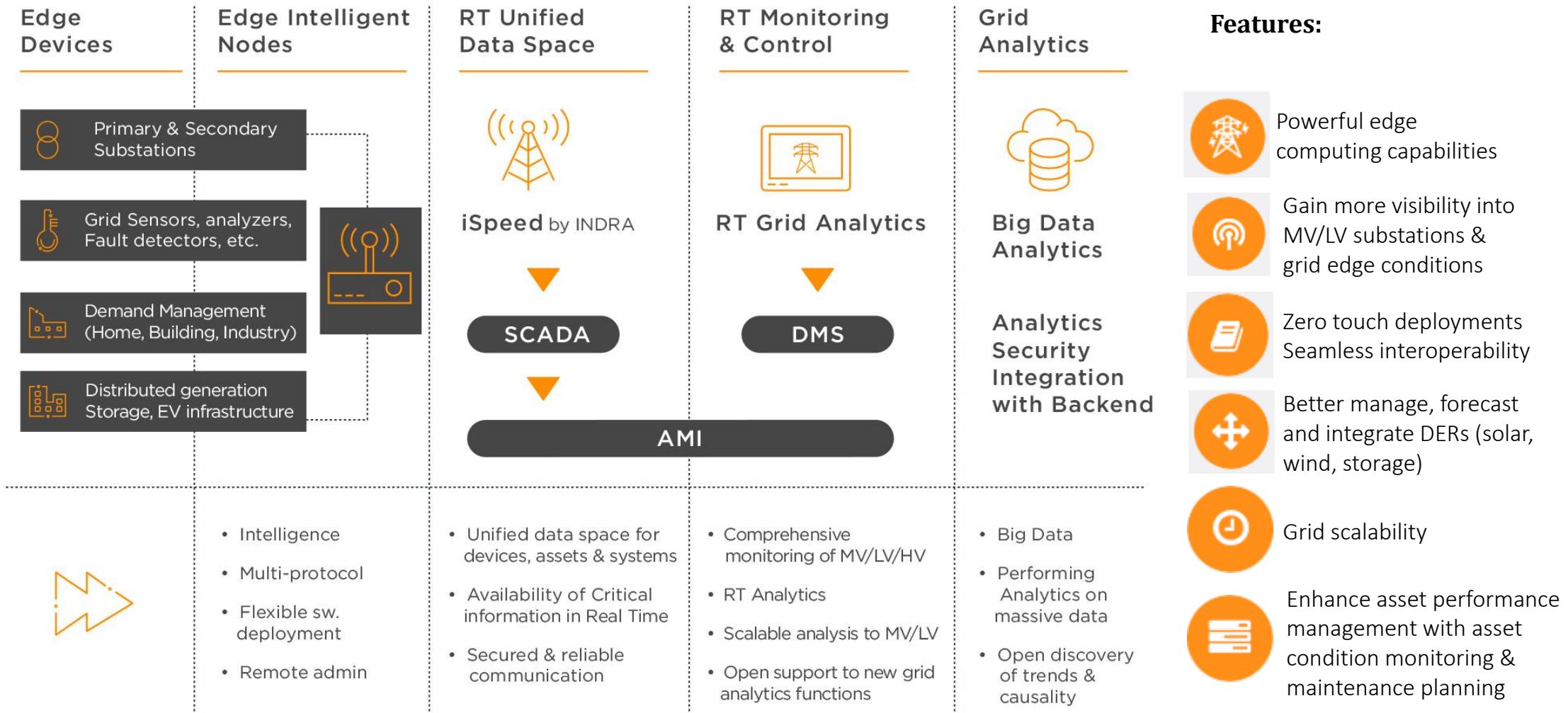
With AlefEdge to offer end-to-end 5G MEC solution that targets creation and global deployment of new solutions and services for enterprises, OTT application providers and MNOs – offers unparalleled user experience & significantly lower cost of 5G services

HPE is working with Tech Mahindra and Samsung to bring its new 5G edge networking solution to market

Achieving situational awareness for future of electric distribution grid



Active Grid Management (AGM) enables real-time monitoring and control of infrastructure to achieve situational awareness for the next-gen grid



Edge – Expanding opportunities for conventional technology services



Increasing automation

- Edge takes advantage of automation to manage vast quantities of data without intervention of human operators
- Autonomous systems can detect issues such as imminent data loss and take corrective action, often self-healing in real time
- Complex algorithms seek to understand and anticipate requirements at the edge, including how different applications will make demands on data, then implement actions that optimize the entire system in real time automation of edge - edge set up and monitoring



Network services

Network monitoring & management, network security, routing diversity, setup of OT environment, etc.



Consulting services

Technology assessment and architecture, sensor and gateway requirements, edge implementation roadmap



Cybersecurity

The security challenges presented by the edge demand new solutions from network, system, solutions and component designers. Security must become a foundational design element



Infrastructure Management

- Since edge devices are often located in remote areas, VARs and MSPs are the most likely candidates to offer support
- In a distributed environment, in-house IT infrastructure management may become difficult. As the number of devices and complexity of edge infrastructure grows and spans wider geographic regions, cloud-based support may be an opportunity



Testing services

Device testing - bulk testing of devices, load simulation & testing, interoperability, application testing for edge, edge-cloud-edge integration, etc.



Data management

- For one, the number of edge datacenters, requires management of data within individual datacenters as well as across, or among, a cluster of datacenters
- Moreover, the variety of edge resources adds more complexity, with real-time data traversing access and aggregation points
- With a large number of devices accessing an edge datacenter at the same time, orchestration and automation systems must allocate resources appropriately to meet required response times and provide the right information to applications, precisely when needed, on a 24x7 basis
 - Also improves application performance by anticipating and responding to demand, moving data to ideal locations

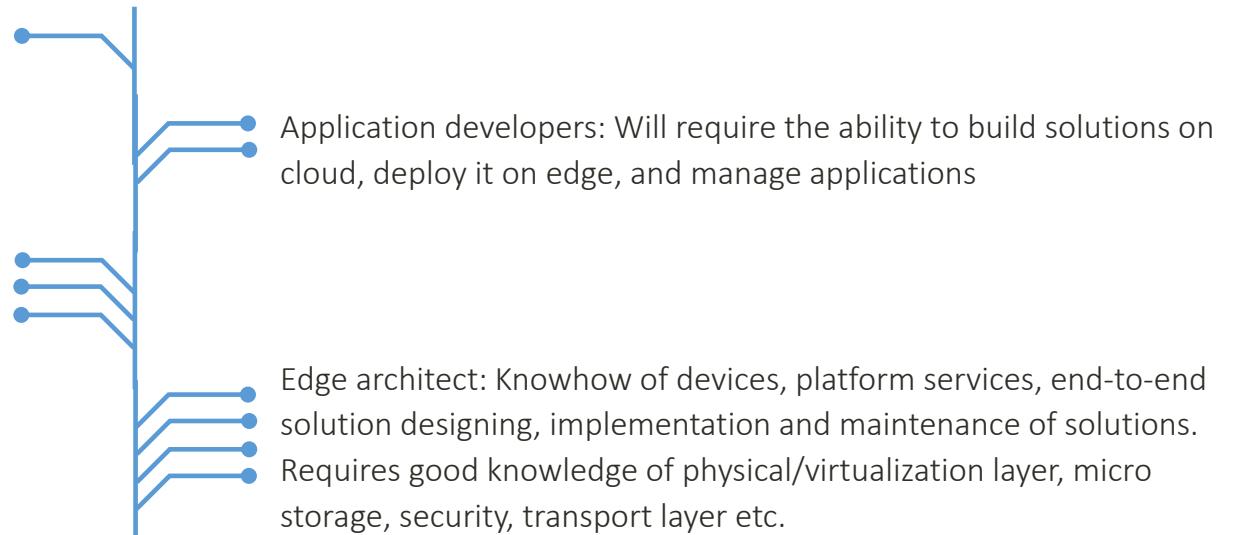
Talent – The need for cross-functional skills across the edge stack (1/2)

Edge computing is emerging as the new way to merge the physical and virtual worlds and enable new ways of problem solving. It is also bringing IT and OT closer together. As the industry shifts from centralized intelligence to distributed intelligence, the skills needed will have to adjust to this distributed and constrained environment - understand sensors, cloud and programming on limited computing platforms, limited processing, RAM, etc.

Edge computing is a natural extension of IoT and is the point where cloud/datacenter, IoT converge. The edge environment involves networking infrastructure, connectivity/communications, devices and sensors, cloud/datacenter infrastructure, embedded systems, software applications, AI/ML, big data analytics platforms, security, etc. The edge environment calls for teams with cross-functional skills across all these areas. For example:

Edge consulting and management: Edge strategic consultant with experience in advisory services, devices recommendation, building roadmap for the edge enterprise, etc.

Data integration: Edge computation will require integration of sensors and devices to gather data for computation. Skillset includes Integrating of data from various devices/systems, sensor fusion, data collation from various system and sensors over different protocols



The idea is to make both the adoption and adaptation faster and friction-free with minimal or no disruption to the existing set up, both at the technology and the business strata.

Talent – The need for cross-functional skills across the edge stack (2/2)

Illustrative

 <h3>IoT</h3> <ul style="list-style-type: none"> • IoT Platforms (AWS IoT, Azure IoT, Google Cloud Platform, PTC Thingworx, GE Predix, Siemens Mindsphere, SAP Leonardo, etc.) • IoT solution development, architecture and infrastructure design 	 <h3>Databases</h3> <ul style="list-style-type: none"> • Query languages (SQL, Hive, Pig, etc.) • NoSQL databases (Cassandra, Hbase, MongoDB, etc.) • Data management, mining, statistical analysis • Database Modeling 	 <h3>Edge</h3> <ul style="list-style-type: none"> • Edge consulting and management • Edge embedded engineering • Edge platform: Architect, design develop • Edge computing frameworks –Azure IOT edge, Amazon IoT Greengrass, Google IOT Edge • Device management, update and deployment • Data storage and processing at edge • Edge analytics, AI/ML for the edge • Cyber Security: Information security architect • Monitoring & management of edge gateways
 <h3>Software</h3> <ul style="list-style-type: none"> • System software: Linux/Unix-like OS • Data science toolkits (R, NumPy, Pandas, Scala-ML) • Open source (Docker, Kubernetes, Helm, Linux, Horizon, etc.) • AI/ML techniques and algorithms • Application integration, middleware, API mgmt. • Agile environment, Microservices • C/C++, C#, Erlang, Elixir, Go, Java, JavaScript, Node.JS, Node Red, Python, Scala, etc.. 	 <h3>Cloud</h3> <ul style="list-style-type: none"> • Awareness of Cloud Computing • Virtualization platforms • Cloud technologies and server components • Server technologies (Spring/Hibernate, PHP), HTTP 1/2/3 standards, AWS services, etc. • Public, private, hybrid, multi-cloud environments • Cloud SDK • Public Cloud Edge Platform Architect 	 <h3>Telecom, Networking, Internet</h3> <ul style="list-style-type: none"> • Wireless, LTE, Bluetooth & Wi-Fi , 2G/3G/4G/5G – connectivity, protocols, security • Network infrastructure, Management, Architecture • Data Protocol (TCP/IP, SSL/TLS, DNS) • Communication protocols (Zigbee, Z wave, 6LowPan, Sigfox, Neul, NFC, Lora wan etc.)

GTM strategies to expand Edge Computing footprint (1/3)

Illustrative

Co-innovation



Molex, Accenture and AWS co-develop Edge Computing Solution for NextGen Autonomous Vehicles

- Integrates edge computing and Amazon Alexa; ML capabilities for adaptive network security & diagnosis via OTA updates
- The custom gateway solution to include on-board diagnostics with edge analytics such as predictive maintenance, meeting critical safety requirements and maintaining network integrity — all of which can be accessed through Amazon Alexa



D-Fifteen, Ericsson's new innovation and co-creation center in Santa Clara, California will provide for experimentation and collaboration for customers, partners and the Silicon Valley ecosystem and also showcase Ericsson's innovations within Core, Edge Computing, AI and Cloud

Product & platforms



AlefEdge, a US based mobile edge technology leader, has launched the first ever Mobile Edge Computing Solution in Aug 2018. The platform powers applications created by AlefEdge, Mobile Network Operators (MNO) and third-party developers. It allows application services to communicate and transact effectively with MNOs



Altizon's Datonis Edge platform is an IoT solution for smart manufacturing that leverages the power of edge computing and cloud; enables industrial connectivity, edge analytics & AI, scalability & resilience, custom plugins, device management and security

GTM strategies to expand Edge Computing footprint (2/3)

Illustrative

Patents



- As per the Netscribes report “IoT Insight Series - Edge Computing M&A Analysis” published in Oct-2019, IP acquisition is a key strategy for technology companies globally to drive innovation in the edge computing space, with the goal to develop next-gen solutions. In terms of IP portfolio, most of the acquired patent capabilities were in instruction set architectures and microprocessors
- According to Linknorate, globally, Microsoft and IBM are the two leading companies for patents in edge computing

Partnerships: No single company will be able to deliver end-to-end edge computing solutions. Successful implementations will need an ecosystem of partners with complementary capabilities. Partnerships could be between companies across the edge spectrum - Channel partners, Preferred Partner Agreements, Distribution Partnerships, etc.



Intel and Pivot Technology Solutions Inc. to sign a Preferred Partner Agreement, which identifies Pivot as an authorized Smart Edge™ reseller and Intel's non-exclusive Preferred Systems Integrator for Smart Edge-based edge services solutions

Incubators and accelerators



Deutsch Telekom's tech incubator with focus on 5G, edge computing, IoT and AI



Startup accelerator for early-stage startups in Asia. Primarily invests in AI with a focus on edge computing, natural language, human-machine interface technology, agtech, autonomous vehicles,, and ethical computing



Started an edge computing test zone in Palo Alto, California



- Partnership to utilize MEC to optimize and enhance video experience over the network by developing a mobile CDN
- MNOs can deliver content via edge cloudlets for better UX with lower latency & higher performance

GTM strategies to expand Edge Computing footprint (2/3)

Illustrative

Joint Ventures

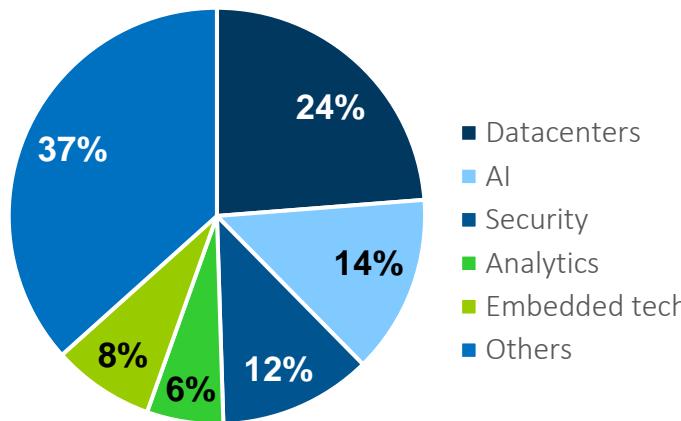


EQUINIX

Jul-2019: Equinix, one of the world's largest datacenter companies, will form a \$1 billion joint venture with GIC, Singapore's sovereign wealth fund. The JV will focus on building xScale datacenters in Europe that will also offer interconnection and edge services

Mergers & Acquisitions: For rapid scaling, access to technology, solutions, platforms and talent, access to geographical markets or clients

Top tech segments acquiring edge computing capabilities, 2018



In Oct-2019, Intel announced the acquisition of Smart Edge™ intelligent-edge platform business from Pivot Technology Solutions Inc. for \$ 27 million. This acquisition enables Intel to scale its 5G edge computing capabilities



In Nov-2018, Apple acquired a startup – Silk Labs that is focused on building on-device machine learning software.



Jan-2019: Guavus, a Thales company, has acquired SQLstream, a leading provider of real-time streaming analytics. The combined offerings will provide telecom providers and IIoT customers the power of AI and real-time analytics – from the network edge to the network core

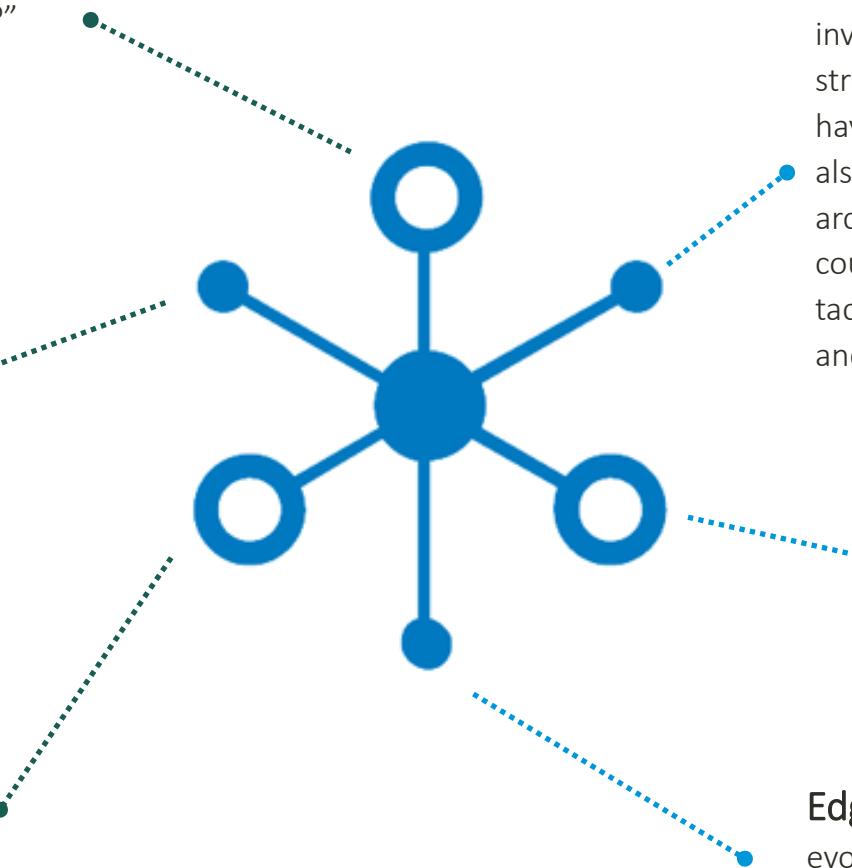
Edge Computing: Challenges

Awareness: Lack of awareness of the technology and visibility on the ROI – the “What is in it for me?” question is hampering the large scale adoption of edge computing

Cost: Questions around reusability of existing IoT devices for edge, additional investments to upgrade from 4G to 5G, cost of edge devices/infrastructure, integration with legacy systems, scalability, manageability and more must be addressed to ensure client confidence in edge implementation projects

Security:

- Ensuring physical security – making these theft-proof & tamper proof
- Devices must be robust enough to survive denial-of-service attacks, outages, hacking, etc.
- Secure communication between edge and datacenter, data privacy, ability to find and stop rogue devices, secure communication over WAN



Standardisations: Edge computing architecture involves a hierarchy of levels (regional, neighborhood, street- and building-level nodes) and each level may have numerous peer nodes sharing the workload. It also involves numerous types of devices/device architectures, multi-cloud environments, etc. So there could be many vendor specific issues that need to be tackled to facilitate interoperability among devices and applications for smooth service delivery

Talent: The edge environment calls for specialized skills around distributed device management, distributed security, remote monitoring, solution development in a constrained environment, integration & interoperability, etc.

Edge hardware and infrastructure is still an evolving area. Constraints for computation at the edge creates a view that edge can only be used for data filtering and limited intelligent decision-making

Globally, various consortiums are working to establish universal standards

Illustrative

Working together to maximize interoperability, portability, security and privacy for the industrial Internet

Establish an open, interoperable framework for edge computing independent of hardware, silicon, cloud, or operating system Create a common framework for hardware and software standards and best practices

To drive the evolution of edge network architectures and computing infrastructures to support high volume data services in a smarter, more efficient connected-vehicle future

MEC initiative: To create a standardized, open environment for efficient and seamless integration of applications from vendors, service providers, third-parties across multi-vendor MEC platforms

An industry working group dedicated to making edge computing easy and connecting stakeholders with end users and customers



- Sharing best practices
- Collaborating on test beds and experimental projects
- Working on interoperability
- Collaborating on common elements
- Periodically hosting joint seminars

- Harmonizing OS Edge communities across IoT, enterprise, cloud & telecom
- Keeping LF Edge open & interoperable with hardware, silicon, cloud, OS, protocol independence

- Development of use cases, technical reports and reference architectures

- Provide IT & cloud-computing capabilities within RAN
- Specify elements to enable applications to be hosted in a multi-vendor MEC environment
- Hosting PoC & MDT environment

- Accelerating edge computing
- Joint solutions
- Global networking community

Outlook: Dedicated Edge strategies to become mainstream by 2025

2021

40%

Enterprises will have a **dedicated edge strategy** by 2021, up drastically from 1% who felt this way last year

2022

50%

Large organizations will be **integrating** edge computing principles into their projects

2025

**CAGR
54%**

Edge computing market expected to cross \$28 billion by 2025

- Increased investments in a mix of edge computing and cloud
- Greater convergence of IT and OT across verticals esp. retail, energy, healthcare, manufacturing, oil & gas, etc.
- Due to the complexity of systems and services involved, firms deploying edge computing solutions will depend on the expertise of third party service providers
- Emergence of multi-datacenter strategies
- Increase in proportion of workloads being processed at the edge
- Increasing partnerships between telecom operators and solution providers – ecosystem of partners
- Important for companies to have a roadmap for edge implementation, edge security, data strategy

Appendix

Illustrative List of Startups in India (1/3)

Company	Website	Locations – India	HQ	Products & Services
Aikaan	https://aikaan.io/	Bengaluru	Bengaluru	Edge & Fog infrastructure provision and control solution
AlefEdge	www.alefedge.com	Mumbai, Pune	New York, USA	Open5G edge internet
Altizon	https://altizon.com	Pune	California, USA	IIoT and Edge platform
Asquared IoT	www.a2iot.com	Pune	Pune, Maharashtra	Edge computing device
CamCann	https://camcann.com	Vellore	Vellore, Tamil Nadu	Computer-Vision based AI
Constems-AI	www.constems-ai.com	Noida	NCR	Cloud and computer vision based analytics platform
Edgetensor	https://edgetensor.com	Bengaluru	Dallas, Texas	Edge based AI platform
Flutura	https://www.flutura.com/	Bengaluru	Palo Alto, California	IIoT platform, Edge AI
Ignitarium	https://ignitarium.com	Bengaluru	Bengaluru, Karnataka	Visual AI, anomaly detection
Infinite Uptime India	https://infinite-upptime.com	Pune, Vadodara, Bengaluru	Pune, Maharashtra	Smart sensors on edge
Innominds	www.innominds.com	Hyderabad	Hyderabad, Telangana	Analytics at the edge

Illustrative List of Startups in India (2/3)

Company	Website	Locations - India	HQ	Products & Services
Kaaenaat Pvt. Ltd.	www.kaaenaat.com	Bengaluru	Bengaluru, Karnataka	Intelligent automotive solutions - computer vision at the edge
Lab To Market Innovations	https://lab-to-market.com	Bengaluru	Bengaluru, Karnataka	Edge computing platform
Mozark	www.5gmark.com	Gurgaon	Singapore	End to end digital QoE measurement, benchmarking & analytics
Neewee.ai	https://neewee.ai/	Bengaluru	Bengaluru, Karnataka	Industrial analytics
Oakter	https://oakter.com	Noida	Uttar Pradesh	Home automation - Edge based smart devices
Pixeom	www.pixeom.com	Rajasthan	Santa Clara, California	Software defined edge computing platform
Sayantek	www.sayantek.com	California	California, USA	Edge platform for IoT, Edge Compute on a Gateway
Sensiwise	www.sensiwise.com	Bengaluru	Bengaluru, Karnataka	Cold-chain logistics & industrial asset tracking & monitoring
SkinCurate Research	www.skincurate.com	Kharagpur	Kharagpur, West Bengal	Diagnostic smartphone app using edge AI/cloud AI

Illustrative List of Startups in India (3/3)

Company	Website	Locations - India	HQ	Products & Services
SmarterHomes Technologies	https://smarterhomes.com	Bengaluru	Bengaluru, Karnataka	Smart meter device
SwitchOn	www.switchon.io	Bengaluru	Bengaluru, Karnataka	IIoT company creating digital twins through AI at the edge
Synconext	www.synconext.com	Bengaluru	Bengaluru, Karnataka	IoT platform - Building Management System
Synaputra	www.synaputra.com	Bengaluru	Bengaluru, Karnataka	Edge compute platform for smart buildings
Westghats Technologies	https://www.westghats.com	Thiruvananthapuram	Thiruvananthapuram, Kerala	Smart cameras

Abbreviations

4G	Fourth Generation	M&A	Mergers & Acquisitions
5G	Fifth Generation	MEC	Multi-access Edge Computing/Mobile Edge Computing
AI/ML	Artificial Intelligence/Machine Learning	MEMS	Microelectromechanical
API	Application Program Interface	MNO	Mobile Network Operator
AR/VR/MR	Augmented Reality/Virtual Reality/Mixed Reality	ms.	milli seconds
B2B	Business to Business	OT	Operations Technology
B2C	Business to Consumer	OTT	Over The Top
BFSI	Banking, Financial services and Insurance	P&L	Profit & Loss
BU	Business Unit	PoC	Proof of Concept
CAGR	Compound Annual Growth Rate	QoE	Quality of Experience
CDN	Content Delivery Network	RAM	Random Access Memory
ER&D	Engineering Research & Development	RAN	Radio Access Network
GTM	Go To Market	RF	Radio Frequency
HVAC	Heating, Ventilation, and Air Conditioning	ROI	Return on Investment
IoT	Internet of Things	ROM	Read Only Memory
IT	Information Technology	TAT	Turn Around Time
		V2X	Vehicle to Everything

Contributors



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HCL



Infosys®



SIEMENS



Tech
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