Whitepaper

IIoT and Edge Computing in Manufacturing

Dell EMC and VMware: From the Edge to the Data Center to the Cloud

Data is Driving the rise of Industry 4.0

41.6
billion connected devices by 2025

79
ZB of data by 2025

$949
billion, Global Industrial IoT market size by 2025

$43
billion, Global Edge computing market size by 2027

Executive Summary

Industrial Internet of Things (or Industry 4.0) is one of the fastest and largest segment in the entire IoT world by the number of connected devices and the value those services bring to manufacturing and factory automation. Data is the heart of digital transformation, with a life of its own, starts delivering value the moment it is deployed. Enterprises, specifically in the IIoT segment are using data to transform the way they do business, by becoming more agile, in improving customer experience, by automating operational technologies and by introducing new business models to be more competitive in the market. But there are many challenges in building an IIoT ecosystem in the manufacturing segment, due to lack of network connectivity owing to remote location of industrial plants, disparate systems and protocols. Traditional models of sending every piece of data to the cloud for processing becomes hard to justify. Edge Computing is a deployment model that aims to position compute and storage capabilities closer to where the devices themselves are located. This means that data can be collected and processed at the source itself (except for sending important data to the local, regional data center and cloud), more efficiently and need not be centralized or moved to the cloud creating heavy traffic zones. Industry experts concur that to remain competitive, manufacturing industries need to evolve from a regional data center or centralized cloud to adopt edge technologies that provide the ability to respond and act in real-time, in areas with limited or no connectivity. Edge computing provides the competitive edge to enterprises with real-time data-driven decision making, advanced technology, operational efficiency, safer factories and faster return-on-investment. This paper explores automation in the manufacturing segment and how Edge computing helps alleviate the problems of a centralized data center in a factory, the solutions provided by Dell EMC PowerEdge and VMware to realize a smart factory.

Internet of Things and Edge Computing

Today, one of the most significant technology scaling new heights across the industry segments is the Internet of Things or IoT. Internet of Things is defined as a paradigm, wherein a set of devices and systems, interconnect real world sensors, actuators, robotics and processors to the Internet to serve a meaningful purpose. IoT has developed into many areas of life from consumer products, utility components, industries, healthcare, supply chain and everyday objects that tend to transform the way we live and work. Examples of IoT application can be as simple as switching on a lightbulb using a smartphone or a motion sensor, to larger deployments such as a manufacturing shop-floor deploying thousands of sensors, robotics, actuators, etc. collating and transmitting data back to ensure that the operations are performing efficiently.

With the fast-paced development of the IoT applications and the growth of the number and variety of these devices, generate volumes of data that has to be stored and processed intelligently in order to derive useful inferences from it. This high amount of data collected needs to be transferred to the cloud for processing. This poses a challenge due to network issues, data transfer protocol issues, data loss, security, compliance and various other factors. This is where the IoT Edge Computing systems are introduced to eliminate the need for transmitting and processing each message to a centralized location on the cloud. Edge computing are decentralized computing infrastructure where computing systems and application services are distributed along the communication path near to the data source. Provisioned at the edge these systems satisfy the computational needs, where the data is collected from the source and take informed decisions.

A number of significant core and aiding technology changes have come together that has increased the widespread use of IoT, such as: smartphones, wireless connected devices, mobile Internet, low power devices, low cost processing, data analytics, and IPv6.

IoT solutions are categorized into three different types according to their consumption: Consumer, Commercial and Industrial Internet of Things. Some of the broad use-cases are, Wearables, Home or Building Automation, Healthcare, Hospitality, Retail, Asset Tracking, Transport, Enterprise Resource Planning, Retail Banking, Smart Cities, Mining, Oil & Gas, Manufacturing, Power & Energy and Agriculture.

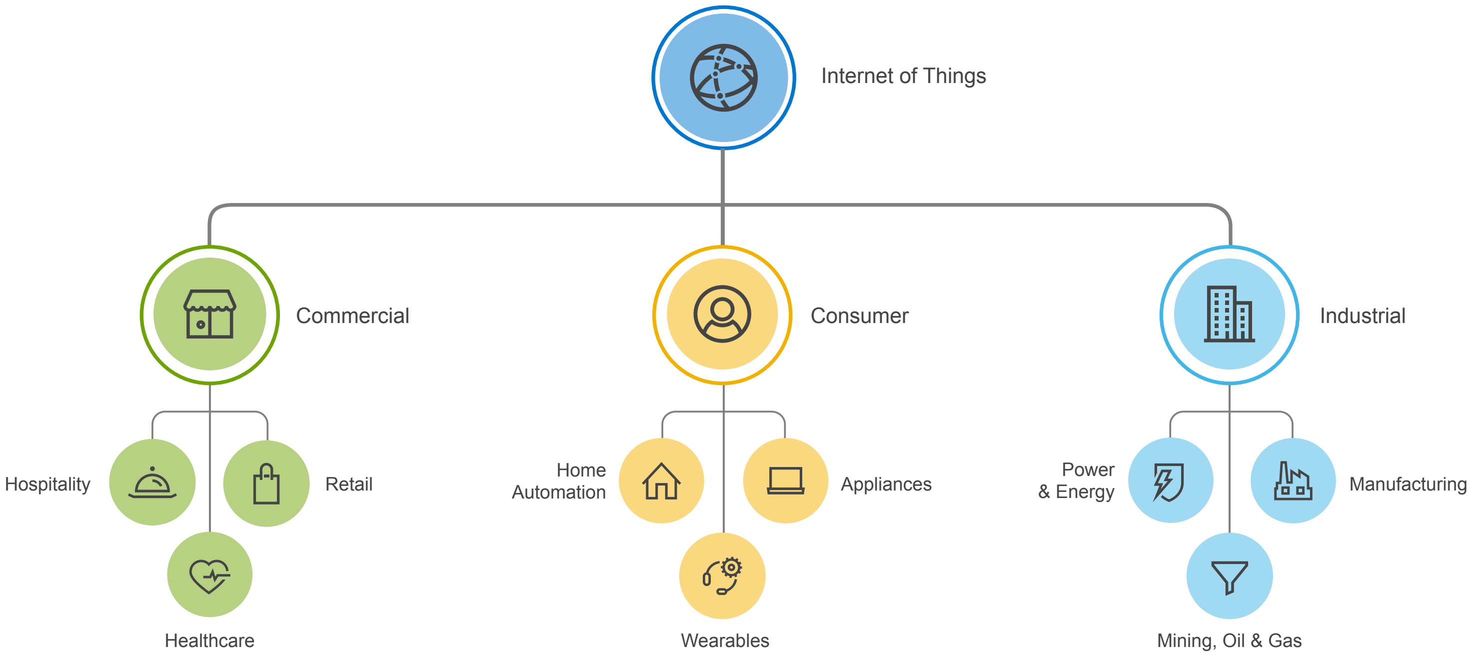

Fig 1. Types of Internet of Things

IoT and IIoT - What's with the terminology?

Generally, IoT's refers to use of intelligent, available, connected devices to increase efficiency and ease operations in a consumer or commercial context. IIoT refers to the extension and use of Internet of Things to enhance manufacturing process in an industrial framework. The difference lies in their general usages or broadly, IoT is the framework that nurtures IIoT. While IoT is used for consumer convenience, commercial purposes, are utility centric, low scale networks, IIoT is used for high stake industrial purposes, for example: Manufacturing, Supply Chain, Energy & Power, Aerospace, ERP, Oil & Gas, and Defense. IIoT deployments are typically advanced and robust, sophisticated machines, large scale networks, integrated with co-existing legacy systems and synchronized to milliseconds. In many ways, IIoT is ahead of IoT and continues to see faster adoption. Unlike IoT applications, the returns for IIoT technology adoption are much greater, as manufacturing companies can reduce costs and increase productivity, which means, more tangible return on investment.

Industrial Internet of Things in Manufacturing

Of all the industries impacted by IoT, the one most impacted and progressed industries at the hands of IoT is manufacturing also called Industrial Internet of Things or IIoT. This has drastically changed the way most of the manufacturing process is carried out from supply chain to factory, delivery of finished goods to distribution, that it has been called the fourth industrial revolution or Industry 4.0. IIoT is transforming the traditional, linear manufacturing into dynamic, interconnected, driving greater efficiency by helping automate and optimize each phase of the production process. Be it general day-to-day operations, the health of machinery, reducing energy consumption, or preventive maintenance, information collected by IoT devices supports better decision-making and quick alerts when something is going wrong.

In this scenario even in a modest industry, the amount of data generated could overwhelm the existing infrastructure and ramp up a significant cost of bandwidth, storage and computing systems. While cloud computing and storage is essential for the Industrial Internet of Things, this relay between data generation, processing, and return can create problems with latency, bandwidth, data management and data security. Edge Computing prevents this by ensuring that data processing happens at the edge itself in close proximity to the data source. This improves the data processing speed and gives a predictable and ultra-low latency ideal for time-critical situations, where the operation is either mission-critical or where things are in motion. Edge Computing devices provide that guarantee that the data is legible, accessible, secure and compliant.

The following are some of the applications of Industrial Internet of Things:

- Monitoring Equipment Utilization
- Predictive Maintenance
- Real-time Data
- Location Tracking
- Quality Control
- Inventory Management & Asset Management
- Digital Twins
- Smart Metering
- Operational Safety
- Logistics Management

Why Edge Computing in Manufacturing?

Edge Computing can be defined as the deployment of data aggregation and processing power activities closer to the network edge of the IoT devices that produce data. For IIoT deployments, the edge will be the computing resources, including machines, gateways, protocol converters or other types of industrial controllers that analyses the data, identifies and transmits only the relevant data back to on-site data center and the cloud for further processing.

In recent years, the advent of edge computing architectures has provided a compelling value proposition for decentralizing factory automation systems, through the placement of data processing and control functions at the very edge of the network. Edge computing is one of the most prominent options for implementing IoT architectures that involve industrial automation and real-time control.

By decentralizing and distributing computing resources across the edge, far less data is flowing through the network, which frees up costly bandwidth for other applications, saves processing time, improves data processing speed and data accessibility. Edge computing complements cloud computing, since an analytic model or rules are created in the cloud and then pushed out to edge devices.

Edge Computing and Industrial Internet of Things are two important technologies that will fuel the transformation of the manufacturing segment into digitized and automated manufacturing, paving the way for some of the noteworthy innovations in the manufacturing segment.

Benefits of Edge Computing deployment in Industrial Internet of Things

Rather than concentrate data processing in a conventional central location, distributed control systems like edge computing provide the leverage of deploying compute and storage elements at nodes throughout the network. Following schematic showcases few benefits that manufacturers can gain by powering smart manufacturing with Edge Computing.

Fig 2. Benefits of Edge Computing in Industrial IoT deployment

IIoT in Manufacturing – Edge Computing Reference Architecture

Edge computing reference architecture is a federated network structure that extends cloud and data center services to the edge of the network by introducing edge devices and services between IoT devices and cloud services. A typical reference architecture structure of Edge computing in the manufacturing industry is as shown in the schematic below. The reference architecture is divided into 3-layers namely, Physical layer, Middleware Layer, and Application and Management layer.

The **edge** exists wherever the digital world and physical world intersect and **data** is securely generated, collected and processed to **create new value**

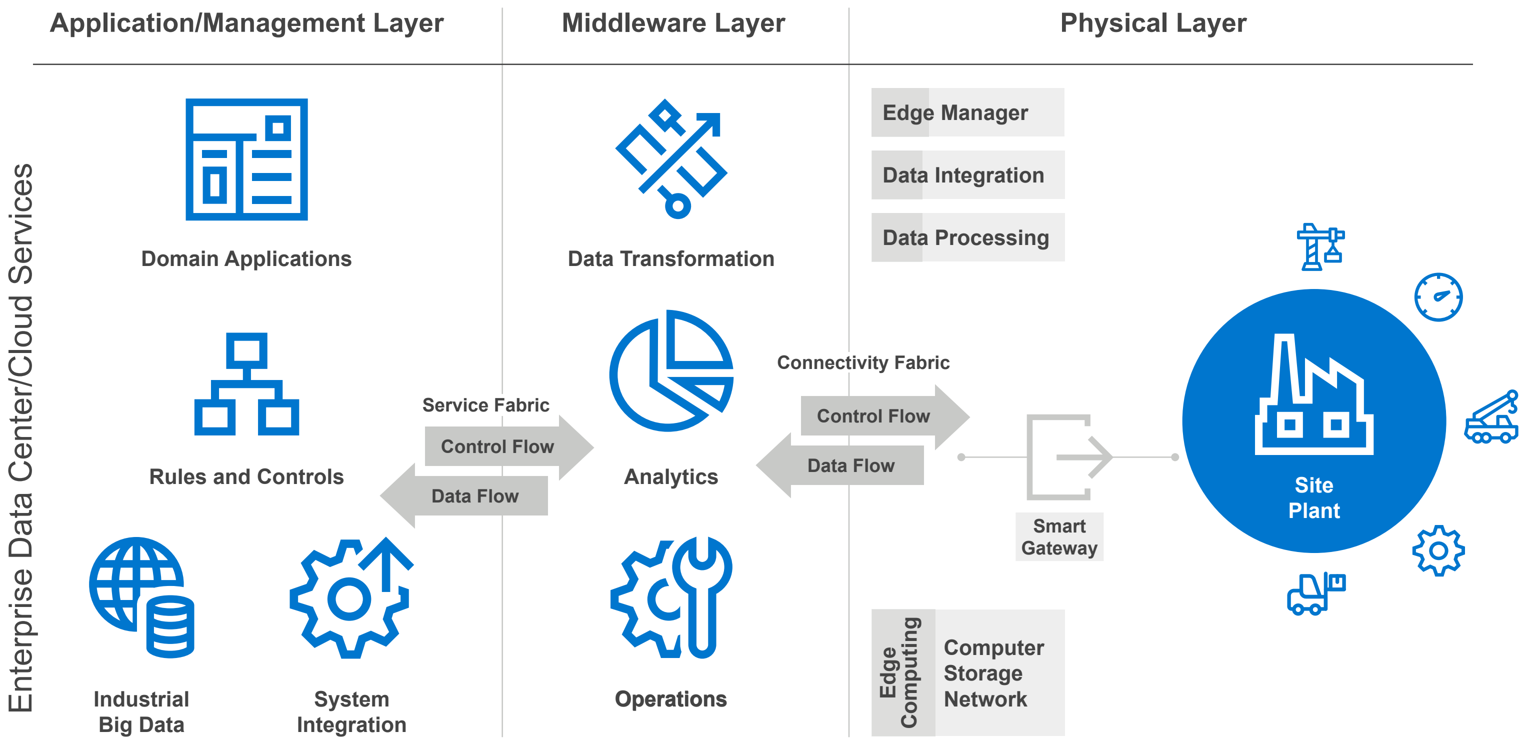

Fig 3. IIoT Edge Computing Reference Architecture

This architectural schematic is a simplistic representation of core areas of an IIoT system that is recurrent across many IIoT deployments yet allows for changes to be assimilated. Some of the core areas are as explained below.

Physical Layer

The Physical layer is the place where all event data are generated, and automated actions occur. This is the crucial platform that transforms a traditional factory into an automated smart factory. This layer consists of all types of devices connected to the edge network, including mobile terminals and devices such as, sensors, robotics, actuators, etc. which interact and communicate real-time data with each other and with the cloud services. All physical devices on the shop floor are integrated with each other and every device has unique identification so that any data consumer can access them individually. The edge tier is where data from all end nodes are collected, aggregated and transmitted over the connectivity fabric to a smart gateway. This layer also comprises of the Edge Manager, Data Integration and Data Processing modules.

Smart Gateway: As the number of things expand in the IIoT, manufacturing industries find themselves faced with the challenge of integrating multitude of devices and protocols, with varying power and connectivity requirements. A smart gateway can overcome these challenges and is a solution that enables communication capability between these devices, for example, from device to device or device to the edge. These smart gateways also offer a wide and comprehensive protocol support, easy and fast solution for data acquisition, data logging and processing, secure connectivity, required in a smart factory deployment.

Edge Computing: As defined, edge computing brings data processing power to the edge of the network, closer to the source of data. It is made up of data integration and data processing running on the Edge for filtering, aggregation, encryption, encoding and advanced anomaly detection. These analytics are deployed remotely from the data center or cloud services through the Edge Manager. The Edge Manager running on the data center or cloud side should also be able to request specific actions to be carried out on the edge side, like starting or stopping of analytics running on the edge. Edge computing comes in a variety of form factor depending on the application, the computational and storage requirements necessary. Edge tools are a list of components that can be used to manage the edge easily by providing a user-friendly interface to analyze logs, manage patching and configure adaptors.

Middleware Layer

This layer supports interoperability within the diverse applications and services running in a manufacturing environment. It processes and forwards control commands from the application and management layer to the physical layer and from the physical layer consolidates processes and analyzes data flows to the other layers. The data transformation and analytics in this layer processes and analyzes large amounts of data to uncover patterns and other insights required for business to make sense of the data.

Data transformation consists of functions of acquiring, transferring, and storing at this layer, it is responsible for the quality-of-data processing such as data filtering, cleansing and removal of duplicate data. Various challenges are resolved that contain indexing, querying transaction, and process handling. The middleware layer has various components for converting the raw industrial data into processed data and transmits this data to distributed data storage for later use.

Data analytics is responsible for converting context-aware data into intelligent data. This intelligence is appreciated by analytics and can provide both delay-tolerant and delay-sensitive applications at shop floor and middleware layer. The Analytics function delivers deeper data insight and ultimately knowledge from a more granular data analysis from the volume of data generated from the site plant. The rewards of data-driven decision-making not only lowers risk and improves the probability of successful business outcomes, it can also uncover hidden correlations within the data. Extracting value from data requires a range of skills and talents that cover data integration and preparation, creating database models and computing environments, data mining and developing specific intelligent algorithms. This is because making sense out of data is not a trivial task.

The Operations function consists of building blocks such as prognosis, optimization, monitoring and diagnosis, provisioning and deployment, and system management. These functions directly relate to the lower control functions and ultimately to the user. The utility of the operational functions is to deliver assets online remotely, securely, regardless of scale and be cost effective.

Application and Management Layer

The Applications and Management Layer is the top layer of conventional IIoT architecture and implements application services, monitoring and management functions, decision support systems, system integration and industrial big-data analytics. This layer receives data flows from the physical and middleware layers and issues control commands to the middleware and physical layer. It also provides a platform to extract useful patterns from the vast amount of data generated from the shop floor and convert it into knowledge that is used for the future improvement, early and better decision making, proper functioning, and innovative business opportunities.

The Application and Management Layer can consist of various enterprise applications depending on the scale of the enterprise, such as, Enterprise Resource Planning, Product Lifecycle Management, Master Data Management, Supply Chain Management, Customer Relationship Management, Manufacturing Execution Systems, Quality Management System, Warehouse Management System, Artificial Intelligence, Machine Learning & Deep Learning, Real-Time Monitoring and Management, Off-The-Shelf and bespoke applications for the manufacturing segment.

Artificial Intelligence or AI helps build independent and intelligent smart machines that learn from experience and are capable of performing tasks that typically require human intelligence. For example, in a manufacturing floor inventory, utilization and optimization can sometimes be missed by lack of skillful or efficient human resource or tools, can be sufficiently taken up by AI. In the context of IIoT, manufacturers are realizing that AI technologies are becoming the fundamental enabler that has enabled people to rethink how we integrate information, analyze data and use the resulting insights to demonstrate business and technological advancements, such as cost reduction, improved and streamlined performance, and better resource management. By integrating AI into an IIoT infrastructure, the entire manufacturing system can be trained and automated to manage and run itself intelligently, efficiently, to learn, improve, advise and even make decisions regarding their own operations.

The above reference architecture on IIoT Edge Computing provides a broad overview of a real-time automation in the manufacturing segment. This three-layer architecture showcases some of the core components and how they implement the different functions: the physical layer most of the control functions, the middleware layer, the information and operation functions and the application and management layer where most of the applications, monitoring and management, and business functions.

Conclusion

Industrial Internet of Things is an interesting yet complex subject that includes aspects of IT, OT, Statistics and Engineering. This paper systematically introduces the basic concepts of IoT, Edge Computing, IIoT and Automation in the Manufacturing Segment, and a typical Edge Computing Architecture. Edge Computing provides the compute and storage at the edge of the network, providing support for the Smart Automated Factory. With increasing interest in new use cases and services in smart manufacturing, there is a clear need for Edge computing. However, the Edge is not a standalone product but is vast and evolving rapidly and will play a crucial role and effectively promote the development of various industries.

Dell EMC solutions for IoT: Automation in the Manufacturing segment

Dell EMC PowerEdge, the world's top selling server portfolio, has a long history of innovation in providing Data Center equipment and services to varied types of enterprises. As organizations try to keep pace with the rapidly growing technology, such as Artificial Intelligence, Machine Learning, Virtual Reality and Augmented Reality, Edge Computing and Internet of Things, Cybersecurity and so on, they are also adopting advanced applications to generate greater insights with these transformation efforts. Dell EMC aims at making the industry-leading PowerEdge server portfolio even stronger with, improved performance, scalability, management, control and security, thereby allowing businesses to balance operational efficiency and strategic initiatives.

Dell EMC understands the needs of Operational Technology - OT and Information Technology - IT convergence in the rapidly emerging IIoT space, has been picking the digital brain from its OEM clients' manufacturing, automation, and monitoring operations for some time, and the outcome of this effort has led to the development of Industrial IoT Edge portfolio that are seamlessly integrated with the cloud and data center infrastructure for data analytics and control. The key value proposition that Dell brings to the IIoT marketplace is shorter lead times, with expertise in the hardware, software and cloud/infrastructure worlds, and is uniquely positioned in the IIoT marketplace that delivers end-to-end solutions offering support for the entire product lifecycle.

Demanding edge applications require purpose-built infrastructure designed to effectively manage multiple constraints. PowerEdge server platforms deliver the accelerated compute at scale with high reliability. Designed to operate in rugged/harsh edge environments, these servers have robust built-in security, be effortlessly managed and easily connect to a multi-cloud environment.

Dell EMC Edge Computing Portfolio

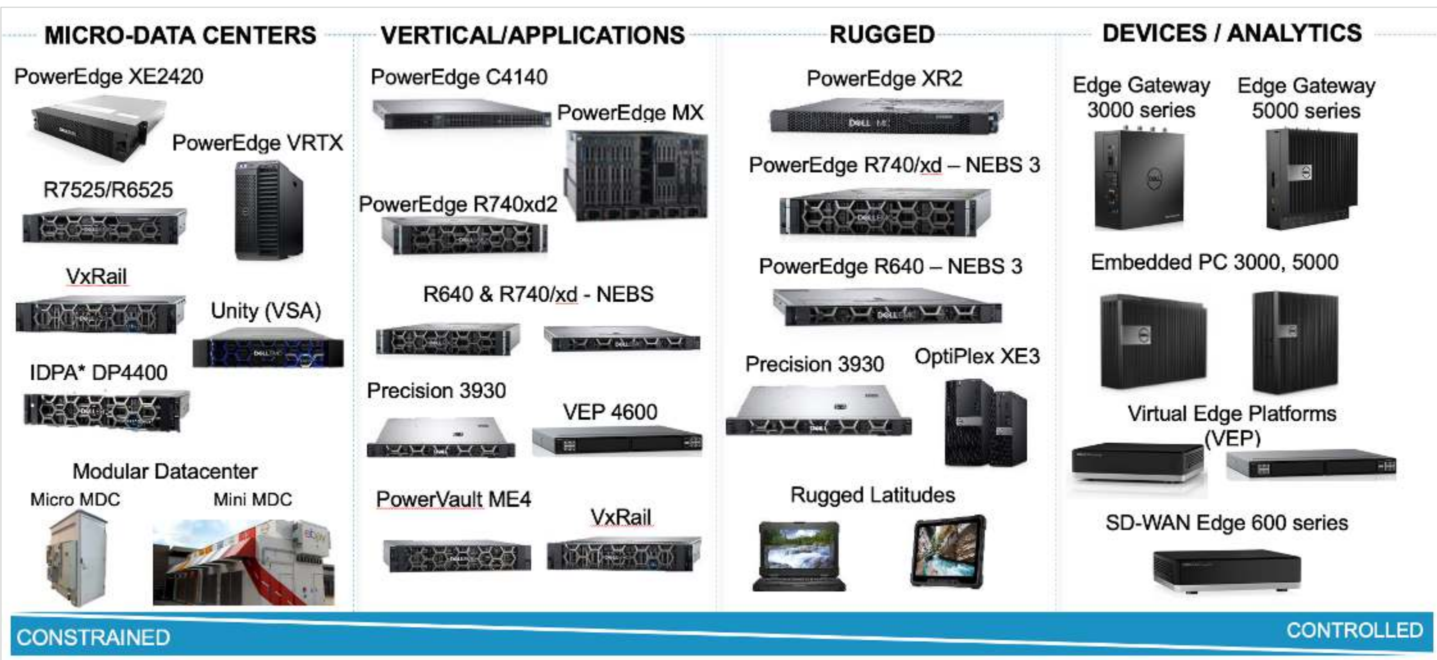

Fig 4. Dell EMC PowerEdge Portfolio from the Edge to the Data Center to the Cloud

Dell Technologies is one of the few vendors with a complete portfolio of enterprise-grade edge computing technologies that can help you extend a consistent operating model for your organization from the gateway, fabric, storage, security, management, edge computing, all the way to the data center and cloud.

This includes:

- Dell EMC Cloud combines the power of VMware and Dell EMC infrastructure to make hybrid cloud environments simpler to deploy and manage. Improve your cloud experience with a consistent operating model and simplified management across private clouds, public clouds and edge locations.
- Dell EMC SD-WAN Solutions combine industry-leading SD-WAN software with Dell EMC appliances available in multiple configurations to deliver branch access to cloud services, private data centers and software-as-a-service-based enterprise applications.
- Dell Edge Gateways are ruggedized, intelligent devices that aggregate data and support analytics at the edge of the network. Dell Embedded Box PCs are configurable, rugged, fan-less PCs built for manufacturing and other rugged environments.
- Dell Data Protection quickly and easily protects critical business data on desktops, laptops, USB thumb drives, external storage devices and optical media.
- Dell converged infrastructure offerings simplify IT and transform operations by bringing together compute, storage, networking and data protection in engineered systems and validated designs.

Factory floors can be extreme environments. Customers need solutions that can withstand heat, dust, shock and vibration, while delivering real performance, durability and security. With a full range of rugged platforms designed from device to the datacenter, Dell EMC end-to-end rugged ecosystem delivers above and beyond – from tablets and laptops, to edge computing, and data center equipment's.

Dell EMC Edge solutions enable customers to drive automation towards a smart factory faster for the manufacturing segment by removing the complexity with a wide range of Edge portfolio and helps customers focus on critical business while Dell Technologies handles the rest.

VMware Virtualization Solutions

As the proliferation of Edge computing rises rapidly, manufacturing enterprises look forward to replicating the benefits of virtualization they have experienced in their data centers. It is important for IT to be able to run their applications where they want, when they want - whether on premises or in the private or public or hybrid cloud. Determining the right workload placement and having the ability to dynamically shift resources is critical, and the main reason why most enterprise organizations now rely on a hybrid cloud model that spans the data center, cloud and edge. A smart factory may plan to deploy virtualization and containers on the edge, to track resources, monitor performance and ensure better management and health of the edge devices.

VMware is the leading server virtualization solution provider with the best foundation for applications, the cloud and the business. vSphere helps you get the best performance, availability and efficiency from your infrastructure and applications. It is the essential building block for modern hybrid cloud infrastructure.

Virtualization at the Edge

VMware plays an important role in the Edge computing architecture layer shown in Figure 3, for its capability to provide high-scalability, isolation, resource abstraction, platform independence, easy to deploy and a stable view of the edge network and computing environment. It also extends its 'software-defined' concept from the cloud to the data center till the edge. This 'software-defined' approach allows multiple applications to be hosted and segmented, eases remote provisioning and orchestration, improves management and monitoring of edge devices across a large ecosystem.

As the edge is the point where external 'things' interact and as these 'things' become more varied and dynamic, it becomes cumbersome and inefficient for each end point to reach back to the data center or the cloud for resources. Edge virtualization puts these required resources at the edge to cater to these endpoints, so instead of reaching back to the core the endpoints themselves have their own virtual instance, a slice from the core, locally. This locally available resources allow the capability for an end point to discover applications or services available on other hosts on the edge and to direct requests and data to one or more hosts.

Virtualization is an essential component of Edge computing, as it plays a critical role in many edge scenarios, including gateways or micro data centers that process data produced by sensors at the edge, or apps running on virtual machines.

VMware vSphere 7.0 and VMware vCenter

VMware vSphere 7.0 is VMware's flagship virtualization platform, which transforms data centers into aggregated computing infrastructures that include CPU, storage, and networking resources. vSphere manages these infrastructures as a unified operating environment and provides the tools to administer the data centers that participate in that environment. The two core components of vSphere are: ESXi and vCenter Server. ESXi is the virtualization platform to create and run virtual machines, containers and virtual appliances. vCenter Server is the service through which to manage multiple hosts connected in a network and pool host resources.

vSphere 7.0 supports both existing and next-generation applications through its:

- Simplified customer experience for automation and management at scale
- Intrinsic security and control for protecting data, infrastructure, and identity federation
- Universal application platform for running any application anywhere

With vSphere 7.0, customers can run, manage, connect, and secure their applications in a common operating environment, across devices, the edge and cloud.

Accelerate Automation with VMware vSphere

With vSphere, you can support new workloads from the Edge to the Cloud while keeping pace with the growing needs and complexity of your infrastructure. It also delivers advanced security capabilities — fully integrated into the hypervisor and powered by machine learning (ML) — that provide better visibility, protection and response times for security incidents.

Some of the Key features and benefits include:

- **Universal application platform:** Run almost any application, anywhere. You can improve the performance of your existing applications and support new use cases such as ML and artificial intelligence (AI).
- **Seamless hybrid cloud experience:** Migrate workloads and simplify virtual machine (VM) provisioning operations across hybrid clouds with unified visibility and management.
- **Simple, efficient management at scale:** Enhance platform scalability and efficiency with performance improvements and an exceptional user experience.
- **Intrinsic security:** Secure applications, infrastructure, data and access with a comprehensive, built-in architecture and a simple, policy-driven model.
- **Applications-focused management:** vSphere 7 with Kubernetes is the new edition of vSphere for containerized applications.

VMware vSAN

VMware vSAN is a core building block for SDDC, and it powers leading hyper-converged infrastructure solutions with a vSphere-native, high-performance architecture. VMware vSAN is a distributed layer of software that runs natively as a part of the ESXi hypervisor. VMware vSAN uses a software-defined approach that creates shared storage for virtual machines. It virtualizes the local physical storage resources of ESXi hosts and turns them into pools of storage that can be divided and assigned to virtual machines and applications according to their quality-of-service requirements. vSAN is implemented directly in the ESXi hypervisor.

VMware Cloud Foundation

VMware Cloud Foundation is the future-proof hybrid cloud platform for modernizing data centers and deploying modern apps. VMware Cloud Foundation delivers enterprise agility, reliability, and efficiency for customers seeking to deploy private and hybrid clouds. VMware Cloud Foundation is based on VMware's proven and comprehensive software-defined stack including VMware vSphere with Kubernetes, vSAN, NSX, and vRealize Suite, providing a complete set of software-defined services for compute, storage, networking, security, and cloud management to run enterprise apps - traditional or containerized – across hybrid clouds. Cloud Foundation provides consistent infrastructure and consistent operations from the data center to the cloud and the edge, making Cloud Foundation an ideal platform for hybrid cloud deployments.

Dell EMC PowerEdge and VMware vSphere: The Right Combination

Building your competitive advantage with the right IT strategy doesn't have to be complicated. Dell EMC PowerEdge infrastructure from IoT gateways, compute and storage, up to the modular data centers with VMware vSphere virtualization software provide enterprises a simplified, holistic approach to a Smart Factory. As enterprises embark on their journey to automate their factory, it is imperative they think about the underlying IIoT infrastructure. Working together, we're helping businesses like yours modernize, automate and protect your Edge computing infrastructure.

Advantages of Dell EMC and VMware Together

- Confidently modernize IT with best-in-class hardware and software.
- Tailor right-sized solutions with vSphere certification on nearly all PowerEdge platforms.
- Simplify your journey to the cloud with select PowerEdge servers preinstalled and pre-activated with VMware vSphere
- Seamlessly scale your infrastructure to meet dynamic and varying workload requirements with PowerEdge Scalable Business Architecture.
- Bridge the physical and virtual gap by automating and consolidating key PowerEdge server management tasks in the vCenter console with OMIVV.
- Protect your business with multi-layer security, including Dell's enhanced Cyber Resilient Architecture and VMware's VM-level encryption, including vSphere Trust Authority for practical security at scale.

With joint solutions, Dell EMC and VMware deliver an abstracted and adaptable architecture to meet the challenges manufacturing industry face in IIoT adoption. With combined and broad portfolio of Dell EMC and VMware solutions, spanning from the edge to the core to the data center and the cloud, these solutions and enhanced integrations are designed to help enterprises achieve Smart Factory goals with a unified, seamless experience across PC and mobile devices, software-defined data centers, hyper-converged infrastructures and multi-cloud platforms.