BITS Pilani presentation

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SEZG586/SSZG586, Edge Computing

Lecture No.3

Agenda

- Shortcomings of Cloud for IoT
- Driving factors of Edge Computing
- Why do we need Edge Computing?
- Key Techniques that Enable Edge Computing
  - VMs and Containers
  - SDN
  - CDN
  - Cloudlets/Micro Datacenters
- Basic Attributes of Edge
- "CROSS" Value of Edge Computing
- Edge Computing Enables Industry Intelligence
- Edge Computing Benefits
- Edge Computing Systems

Shortcomings of Cloud for IoT

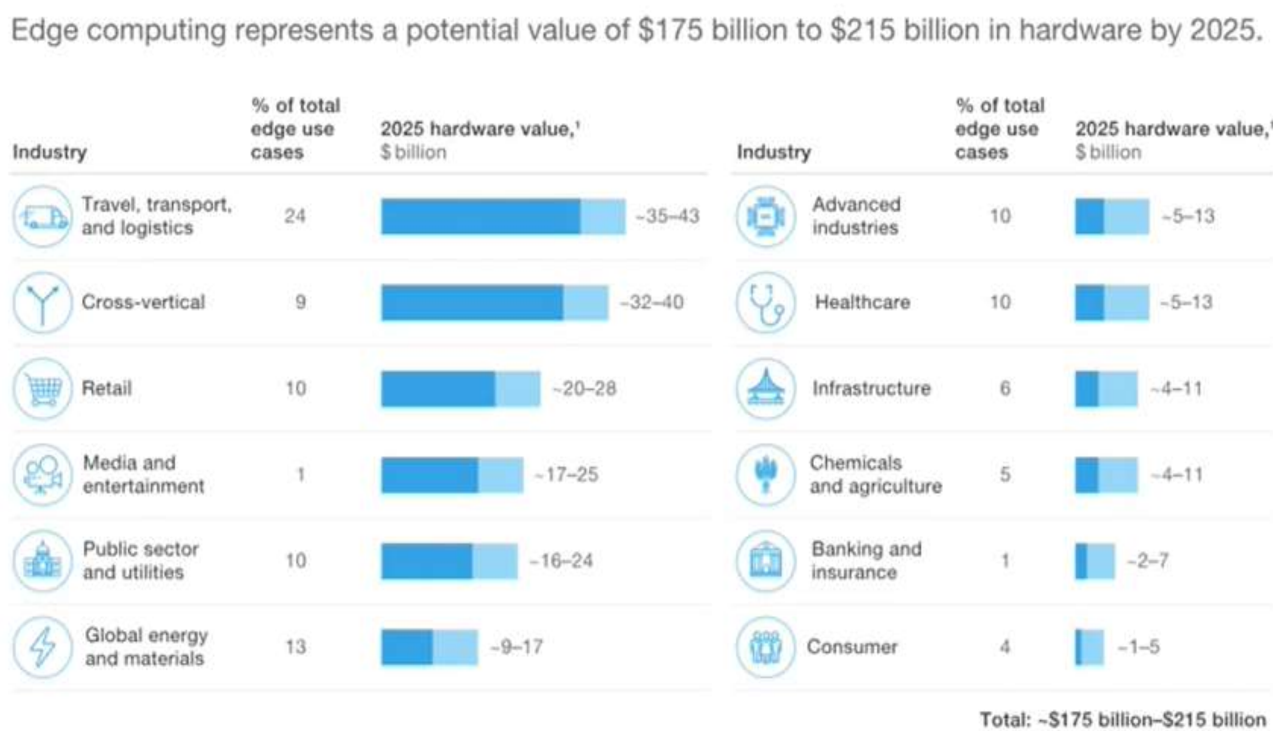
- a safety critical control system operating an industrial machine might need to stop immediately if a human is too close – Speed, Reliability
- a temperature sensor reports a 20ºC reading every second might not be interesting until the sensor reports a 40ºC reading - Cost
- autonomous vehicles or augmented reality applications need a response time below 20ms – Speed

Need of the hour: IoT applications might require short response time, private data, and produce a large quantity of data needing large bandwidth

Study by McKinsey

Industries with **the most edge computing use cases are**

- Travel, transportation, and logistics
- Energy
- Retail
- Healthcare
- Utilities



Driving factors of Edge Computing

- Varied connectivity and data mobility
- Need for real-time decision making
- Localized compute power & storage

Characteristics of Edge Computing

- Proximity
- Ultra-low latency
- High bandwidth
- Reliability
- Real time access to radio network

Why do we need Edge Computing?

- Push(ed) from Cloud Services
  - Limited bandwidth over Internet
  - Response Time
  - Reliability of network

- Pull(ed) from Internet of Things
  - Enormous amount of Data generated by billions of devices
  - Leading to huge unnecessary bandwidth and computing resources usage
  - End devices in IoT are energy constraint things
  - Wireless communication module - drains battery

Why do we need Edge Computing?

- The end devices at the edge usually play as a data producer and consumer
- Example – Social networking platforms
  - Youtube – 72 hrs of content uploaded every single minute
  - Facebook – users share ~2.5 million pieces of content
  - Twitter – 300,000 tweets
  - Instagram – 220.000 new photos

Key Techniques that Enables Edge Computing

- VMs and Containers
- Software Defined Networking (SDN)
- Content Delivery/Distribution Network (CDN)
- Cloudlets and Micro Data Centers (MDC)

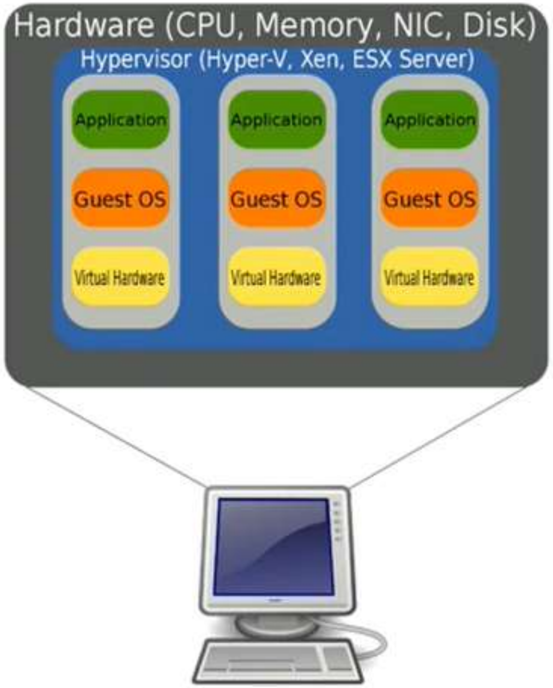
VMs and Containers

- What is Virtualization?
  - Virtualization is technology that lets users create useful IT services using resources that are **traditionally bound to hardware**.
  - It allows users to use a **physical machine's full capacity** by distributing its capabilities among many users or environments.

  - Virtualization and cloud computing are not interchangeable.
  - Virtualization is software that makes computing environments independent of physical infrastructure.

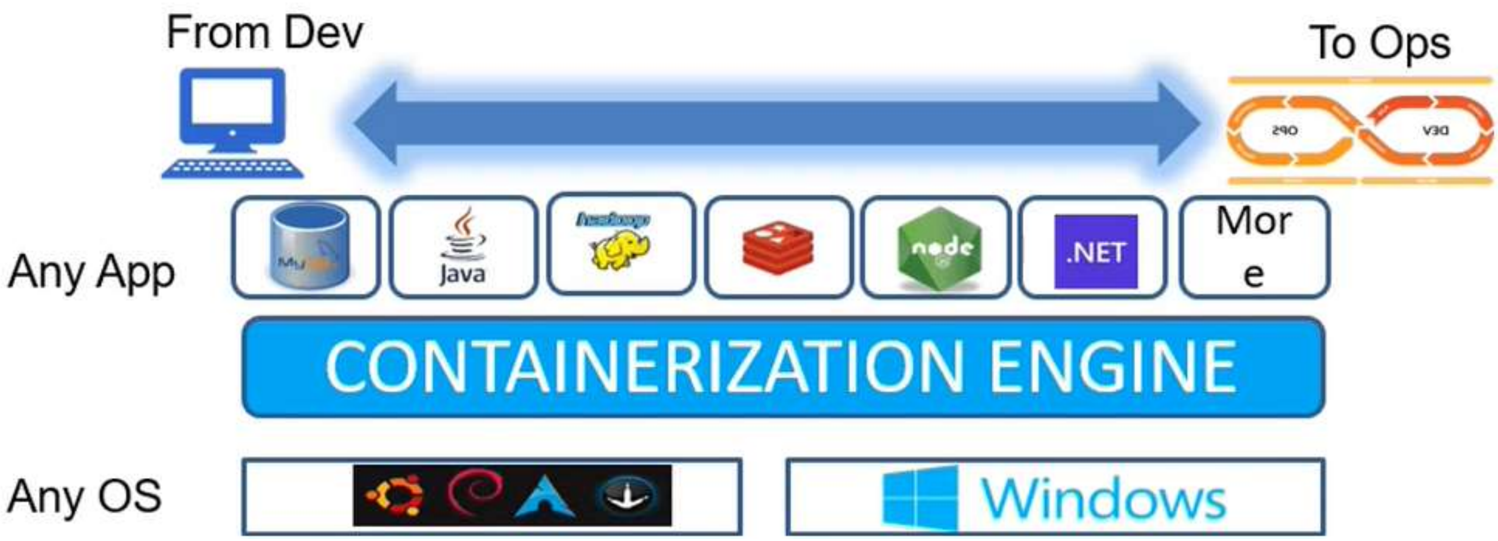
Virtual Machines

- A virtual computer system is known as a "virtual machine" (VM): a tightly isolated software container with an operating system and application inside.
- Each self-contained VM is completely independent.
- Putting multiple VMs on a single computer enables several operating systems and applications to run on just one physical server, or "host."

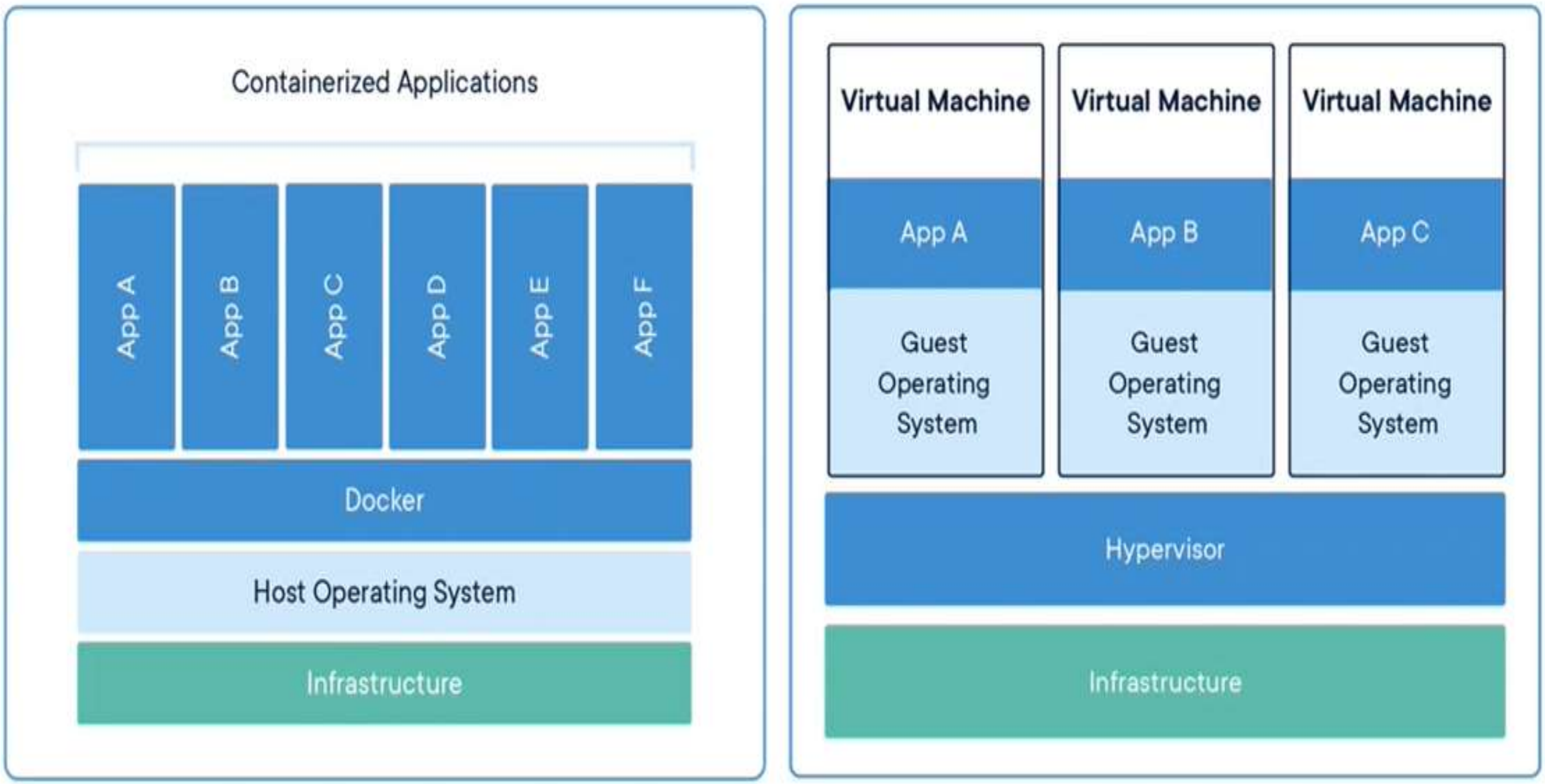


What are Containers?

- A software container is a standardized package of software.
- Everything needed for the software to run is inside the container.
- The software code, runtime, system tools, system libraries, and settings are all inside a single container



Virtual Machine vs Containers



Software Defined Networking (SDN)

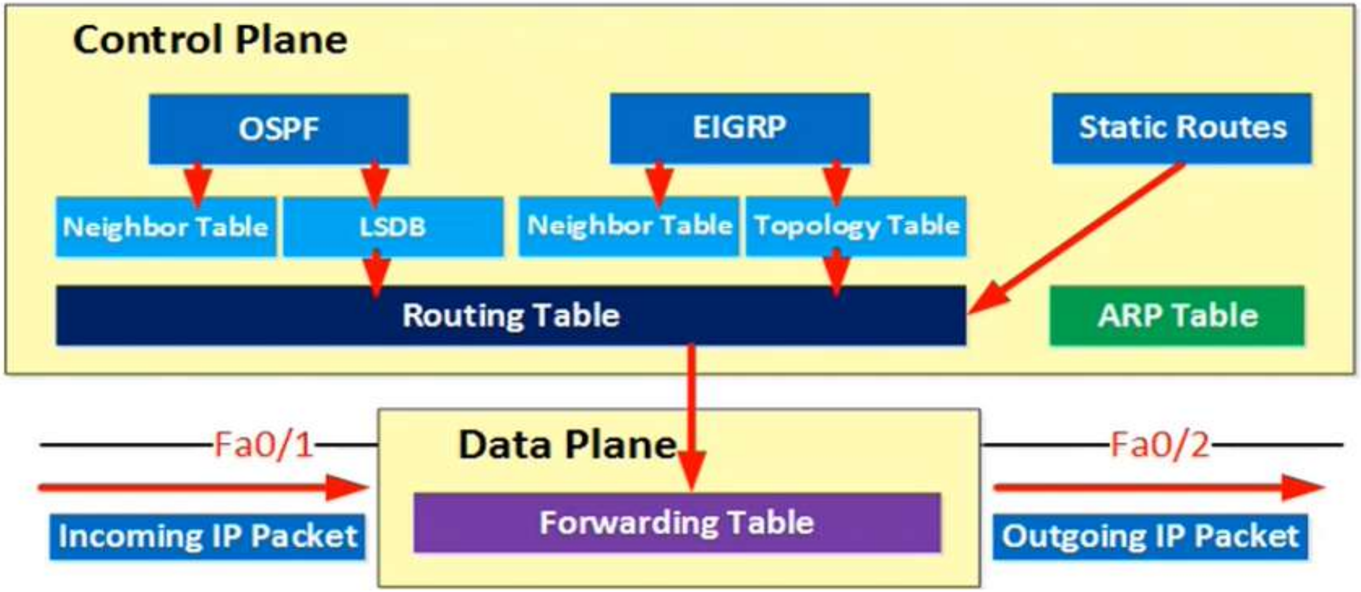
- Traditional Networking
  - Router functions
    - check the destination IP address in the routing table
    - Routing protocols like OSPF, EIGRP or BGP
    - use ARP to figure out the destination MAC address
    - Ethernet frame checksum recalculated

All these different tasks are separated by different **planes**. There are three planes:

- **control plane**
- **data plane**
- **management plane**

Different Planes

- Control Plane
- Data Plane
- Management Plane



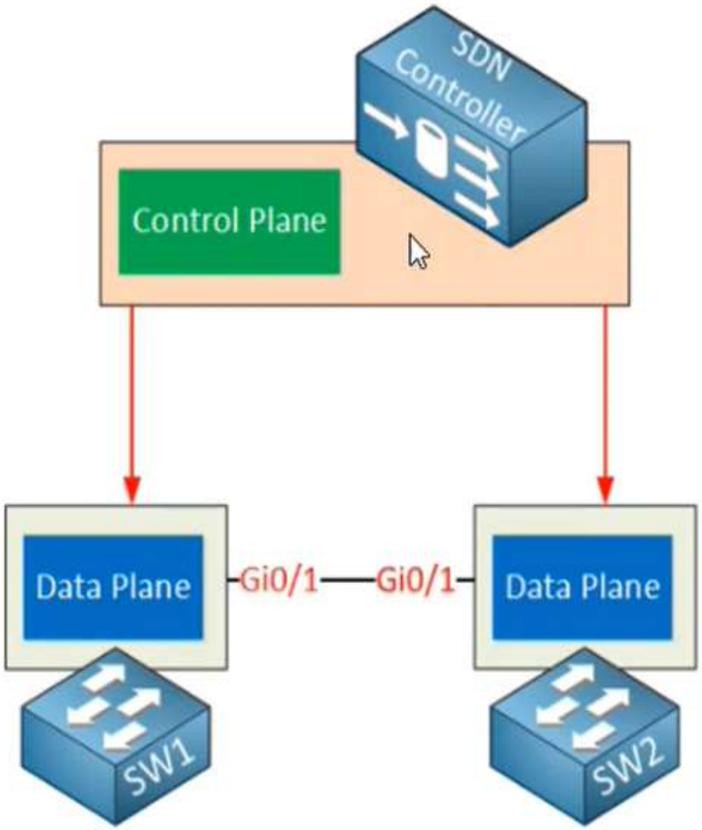
Limitations of traditional networks

- Configuration and re-configuration of network is SLOW, MANUAL process
  - VLANs have to be created on all switches
  - configure a root bridge for the new VLANs
  - assign four new subnets, one for each VLAN
  - create new sub-interfaces with IP addresses on the switches
  - configure VRRP or HSRP on the switches for the new VLANs
  - configure the firewalls to permit access to the new applications / subnets
  - advertise the new subnets in a routing protocol on our switches, routers, and firewalls

  - Might take hours to carry out these tasks in spite of having automation tools

Software Defined Networking (SDN)

- SDN controller - responsible for the activities done by control plane.
- The switches are now just “dumb” devices that only have a data plane, no control plane.
- The SDN controller is responsible for feeding the data plane of these switches with information from its control plane



How does it help Edge Computing?

Edge computing pushes the computational infrastructure to the proximity of the data source, and the computing complexity will also increase correspondingly.

SDN provides a cost-effective solution for Edge network virtualization

- Simplifies the network complexity by offering the automatic Edge device reconfiguration and bandwidth allocation.
- Edge devices could be set up and deployed in a plug-and-play manner enabled by SDN

Content Delivery/Distribution Network (CDN)

CDN is the concept of caching the content to the servers near the data consumers matches the system of Edge computing.

As the upstream server that delivers the content is becoming the bottleneck of the web due to the increasing web traffic, CDN can offer data caching at the Edge of the network with scalability and save both the bandwidth cost and page load time significantly.

Cloudlets and Micro Data Centers (MCD)

Cloudlets and Microdata centers are the small-scale cloud data centers with mobility enhancement. They can be used as the gateway between Edge/mobile devices and the cloud. The computing power on the Cloudlets or MDCs could be accessed with lower latency by the Edge devices due to the geographical proximity.

Essential computing tasks for Edge computing such as speech recognition, language processing, machine learning, image processing, and augmented reality could be deployed on the Cloudlets or MDCs to reduce the resource cost.

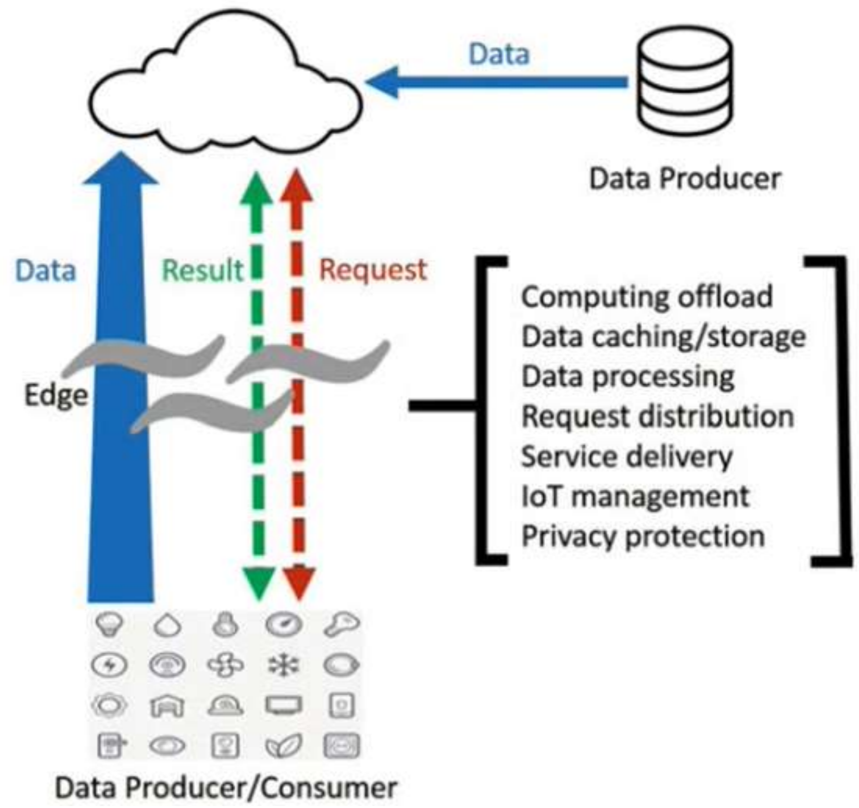
Edge Computing Definition

Edge computing refers to the enabling technologies allowing **computation** to be performed at the **edge of the network**, on *downstream data on behalf of cloud services* and *upstream data on behalf of IoT services*

- computing should happen at the proximity of data sources

Two-way computing streams

- Up stream
- Down stream



Basic Attributes of Edge

- Connectivity
- First Entry of Data
- Constraint
- Distribution
- Convergence

Basic Attributes of Edge

- Connectivity
  - Provide connection functions – Protocol support, deployment, management and maintenance
  - Research advancements - TSN, SDN, NFV, NaaS, WLAN, NB-IoT, and 5G
  - Interoperability with existing industrial buses

- First Entry of Data
  - Mass, real-time, diversity
  - Data management

Basic Attributes of Edge

- Constraint
  - Adaptability - harsh working conditions and operating environments
- Distribution
  - Support - distributed computing and storage, dynamic scheduling
- Convergence
  - Convergence of the Operational Technology (OT) and Information and Communications Technology (ICT)
  - Support collaboration in connection, data, management, control, application, and security.

“CROSS” Value of Edge Computing

Mass and Heterogeneous **C**onnection

- large number of connected devices
- heterogeneous Bus connections

Real-Time Services

- 10 ms

Data **O**ptimization

- large amount of heterogeneous data

"CROSS" Value of Edge Computing

Smart Applications

- intelligent applications

Security and Privacy Protection

- end-to-end protection
- data integrity and confidentiality

Edge Computing Enables Industry Intelligence – How?

- Connection – Physical and digital worlds
- Platform - Model driven, intelligent, distributed
- Collaborate - with cloud computing

Edge Computing Enables Industry Intelligence – How?

- Changes in the network field
  - Bandwidth increase – 1000 fold, Cost has decreased
- Changes in the computing field
  - Celeron – 6.40x10^3 MIPS, Xeon – 1.40x10^5 MIPS, A9 – 3.6x10^3 MIPS
- Changes in the storage field
  - Capacity increase – 10000 fold, cost has decreased
  - Speed also has increased

Connection – Physical and digital world

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  - Bandwidth increase – 1000 fold, Cost has decreased
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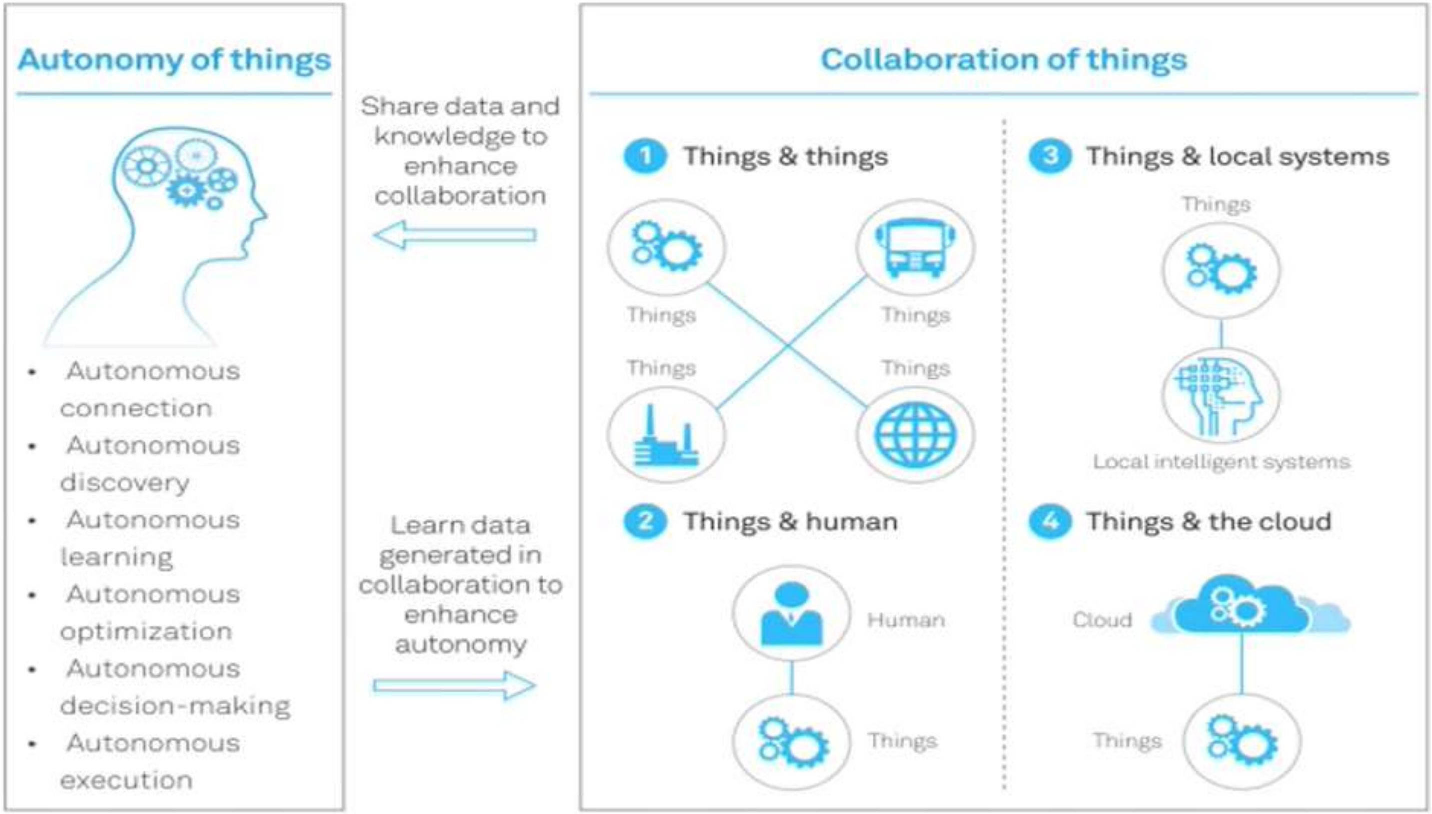
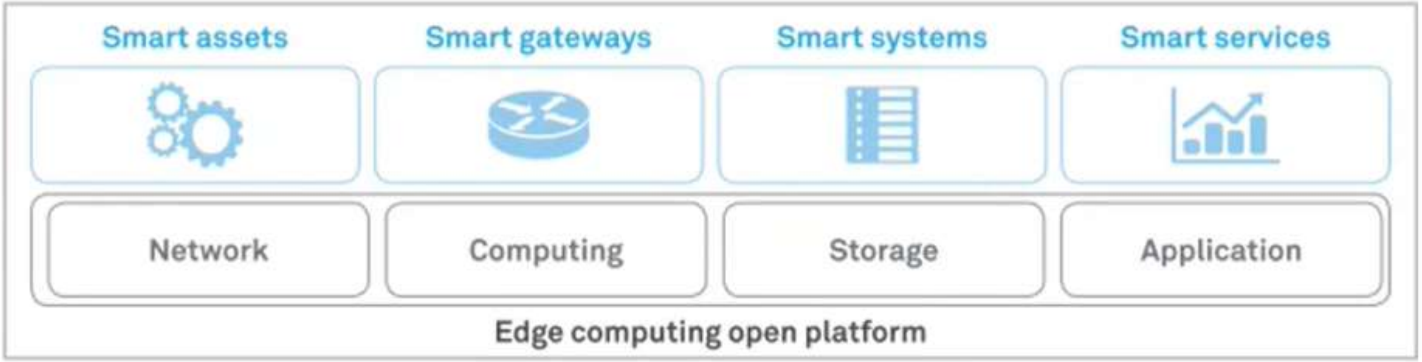
Platform – Model driven, intelligent, distributed

- Autonomy of things - Collaboration of things



Intelligent distributed architecture

- Smart assets
- Smart gateways
- Smart systems
- Smart services

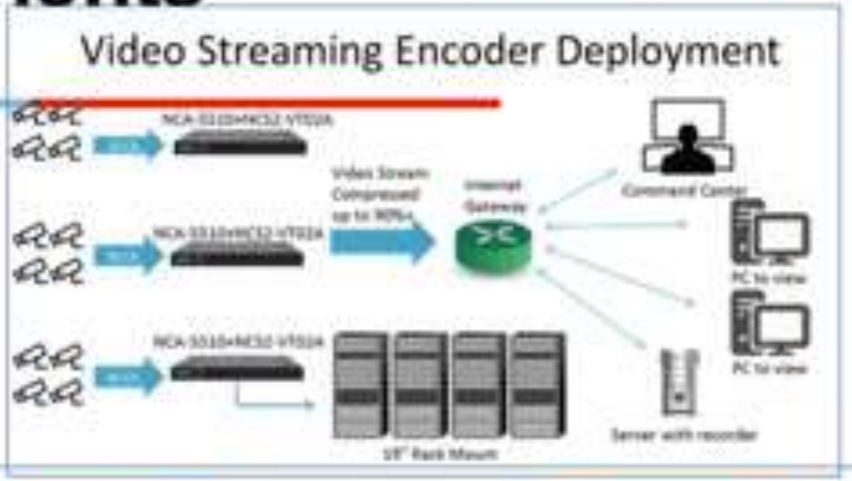


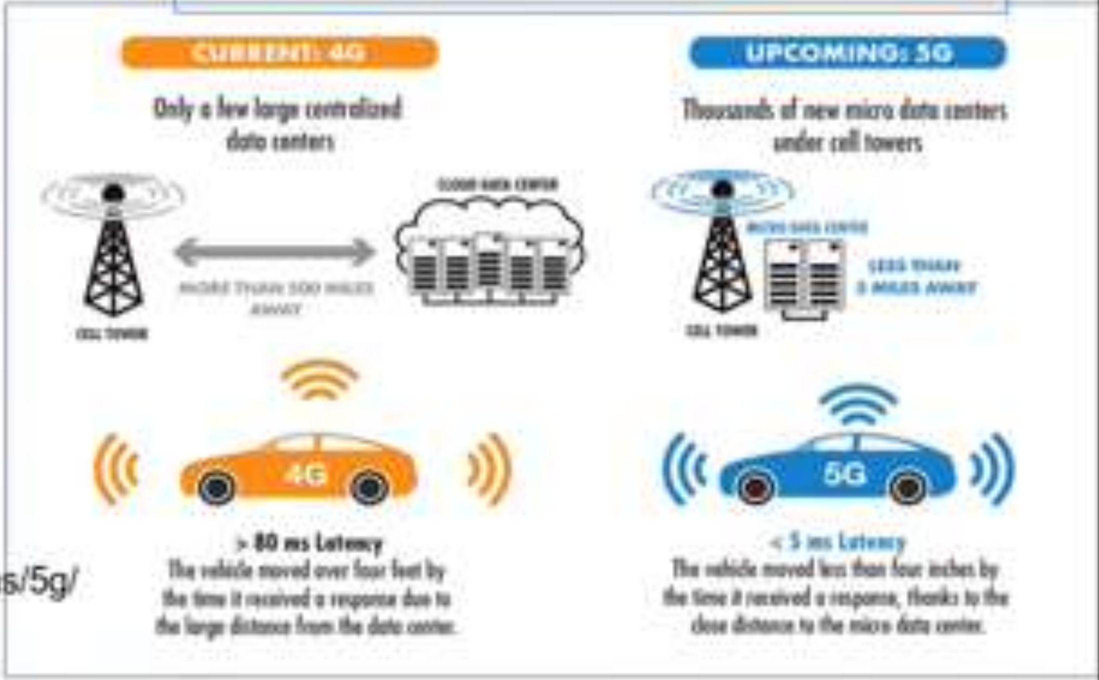
Collaboration of Edge Computing and Cloud Computing

Point of Collaboration	Edge Computing	Cloud Computing
Network	Data aggregation (TSN + OPCUA)	Data analysis
Service	Agent	Service orchestration
Application	Micro applications	Lifecycle management of applications
Intelligence	Distributed reasoning	Centralized training

Edge Computing Benefits

- Speed and Latency
- Security
- Cost Savings
- Greater Reliability
- Scalability



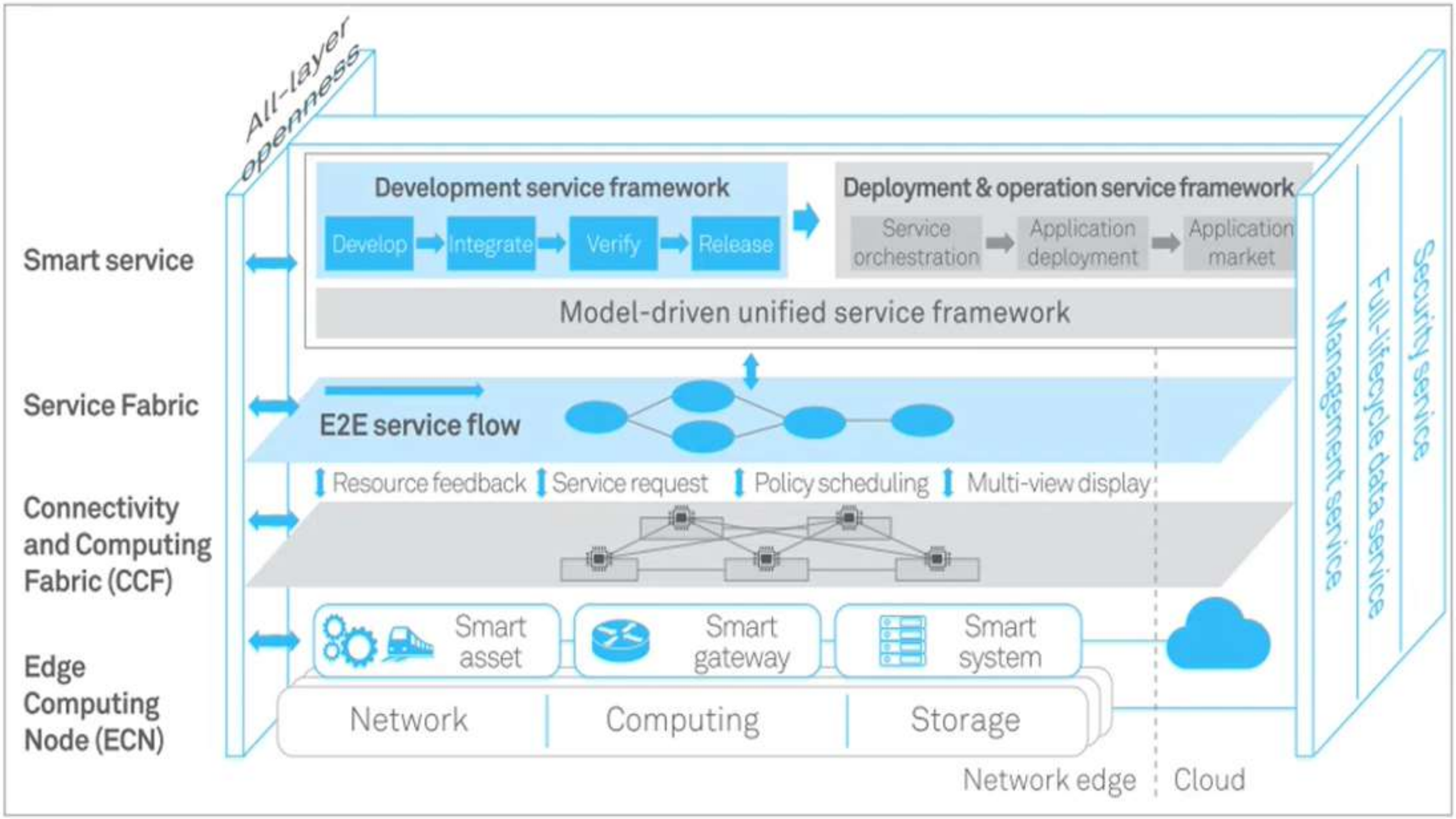


https://www.verizon.com/business/solutions/5g/edge-computing/industry-use-cases-examples/

Edge Computing Systems

- Apache Edgent
- AWS Greengrass
- AWS Wavelength
- Azure IoT Edge
- Bosch IoT Edge
- EdgeX foundry

Edge Computing reference architecture 2.0



Edge Computing reference architecture 2.0

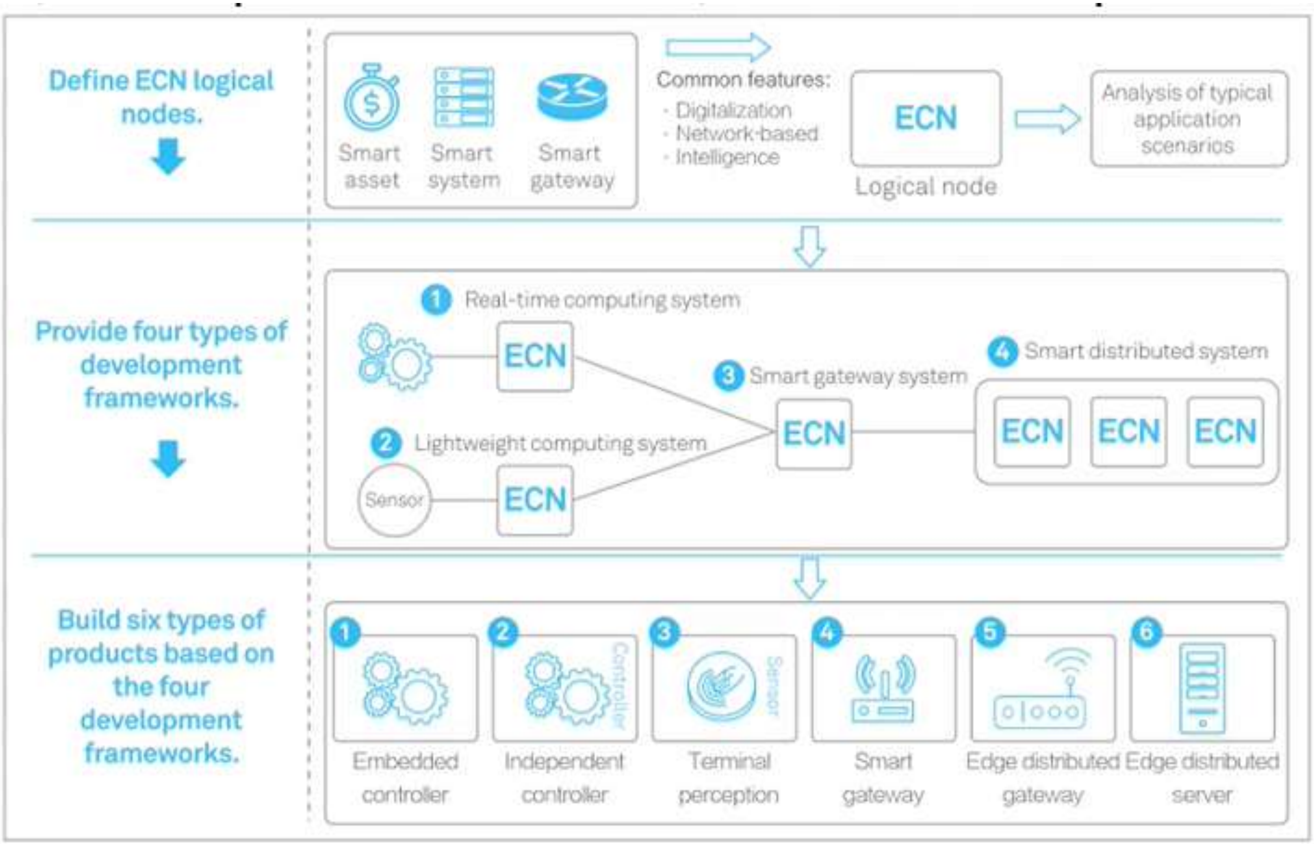
- Model-Driven Engineering
  - Coordination Between the Physical and Digital Worlds
  - Cross-Industry Collaboration
  - Reduced System Heterogeneity and Simplified Cross-Platform Migration
  - Effective Support for System Lifecycle Activities

Multi-View Display

- Concept View
  - Domain models and key concepts of edge computing
- Function View
  - Functions and design concepts
- Deployment View
  - System deployment process

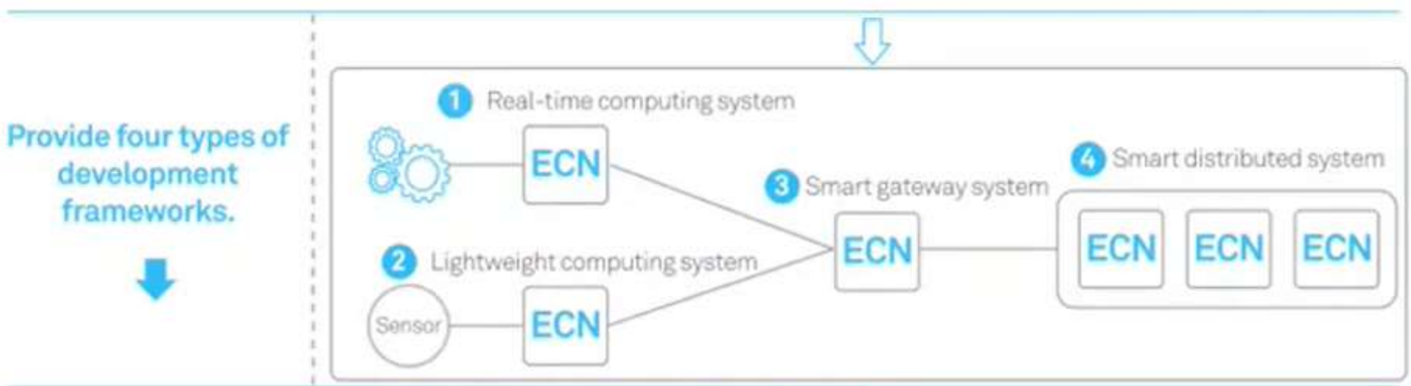
Multi-View Display

ECNs, Development Frameworks, and Product Implementation



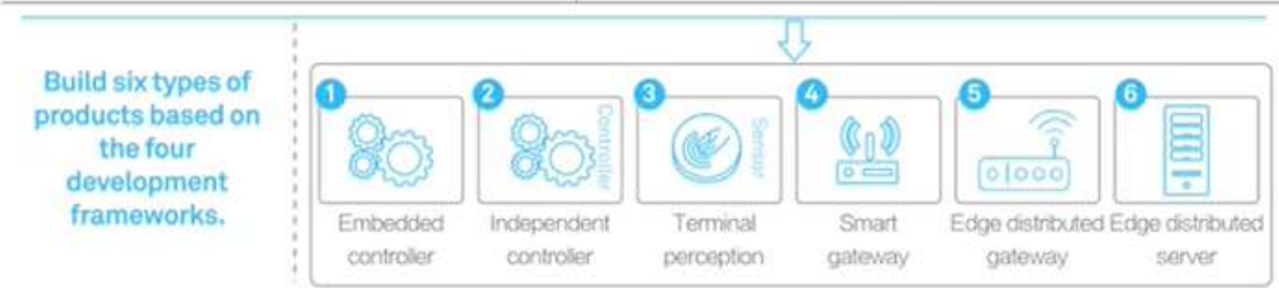
Development frameworks of ECNs

- Real-Time Computing System
- Lightweight Computing System
- Smart Gateway System
- Smart Distributed System

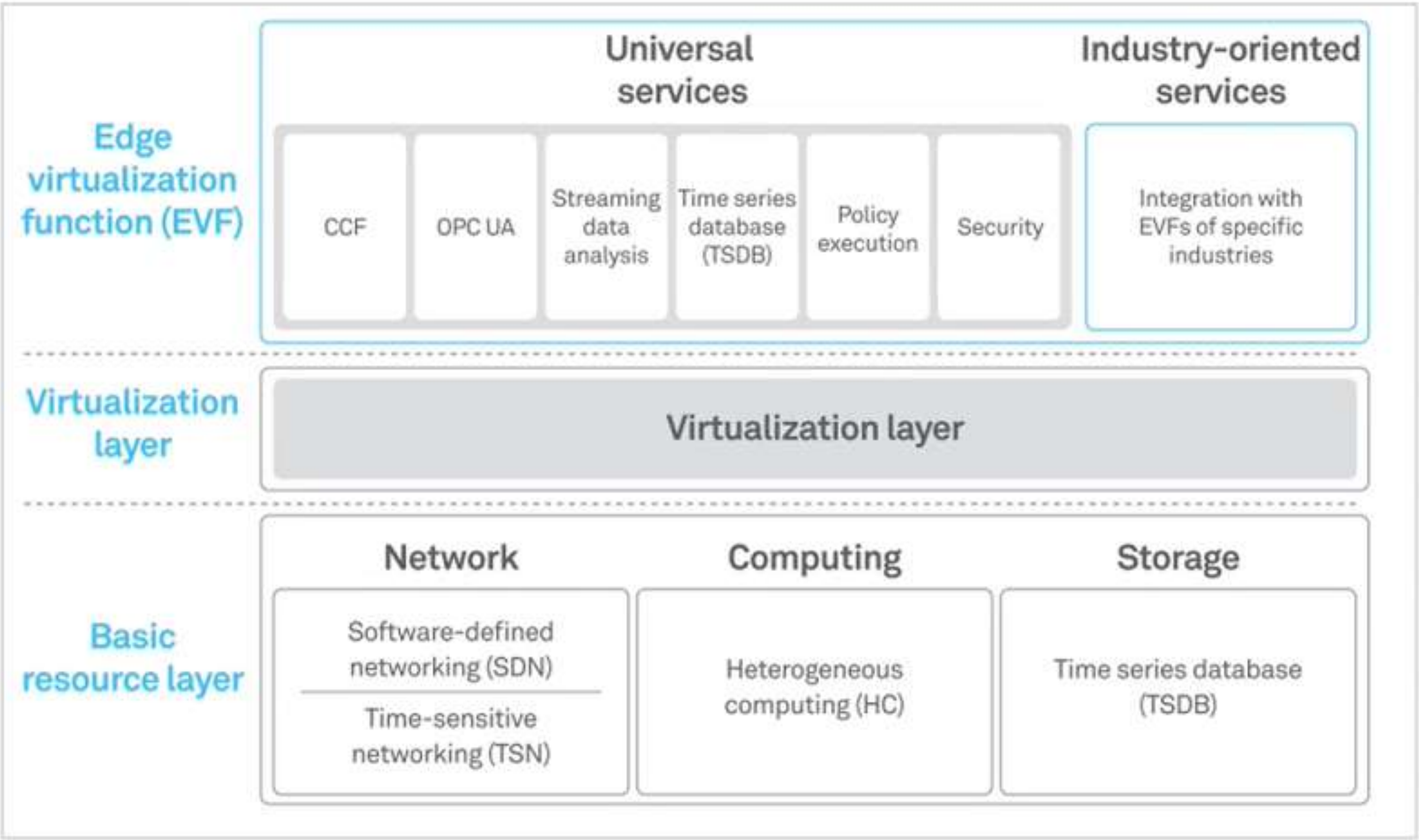


ECN product implementation

Product	Typical Scenario
ICT-converged gateway	Connection of elevators, smart street lamp
Independent controller	Industrial Programmable Logic Controller (PLC)
Embedded controller	Virtual Programmable Logic Controller (vPLC), robot
Sensing terminal	Computer Numerical Control (CNC), instrument
Distributed service gateway	Smart power distribution
Edge cluster (edge cloud)	Digital workshop



Function view : ECN functional layer



Basic Resource Layer

This layer includes the following modules:

- Network
- Computing
- Storage

Virtualization Layer

Virtualization technology

- reduces system development
- deployment costs

- Virtualization technologies
  - Bare metal architecture
  - Host architecture

- The bare metal architecture has better real-time performance and is generally used by smart assets and smart gateways.

Edge Virtualization Functions Layer

The EVF layer delivers the following basic services:

- Distributed CCF service
- OPC UA service
- Streaming real-time data analysis service
- TSDB service
- Policy execution service
- Security service

SDN

SDN's unique benefits:

- Mass Connections
- Model-Driven Policy Automation
- E2E Service Protection
- Lifecycle Management of Applications
- Architecture Openness

TSN

- Standard Ethernet technologies
  - High transmission
  - Speed
  - Flexible topology
  - Long transmission distance
  - Cost-effectiveness
- Constraints
  - Quality of Service (QoS) mechanism and
  - Carrier Sense Multiple Access with Collision Detection (CSMA/CD) mechanism
- Key industry requirements - timeliness and determinism

TSN

- Advantages
  - Ensures µs-level latency and jitter of less than 500 ns
  - Large bandwidth requirements
  - Reliable data transmission

Heterogeneous Computing

The heterogeneous computing architecture uses the following key technologies:

- Memory processing optimization
- Task scheduling optimization
- Tool chain for development

Time Series Database (TSDB)

- Distributed storage
  - Data fragmentation
- Priority-based storage
  - Data processing
  - Data storage
- Fragment-based query optimization
  - Data segments are queried based on query conditions

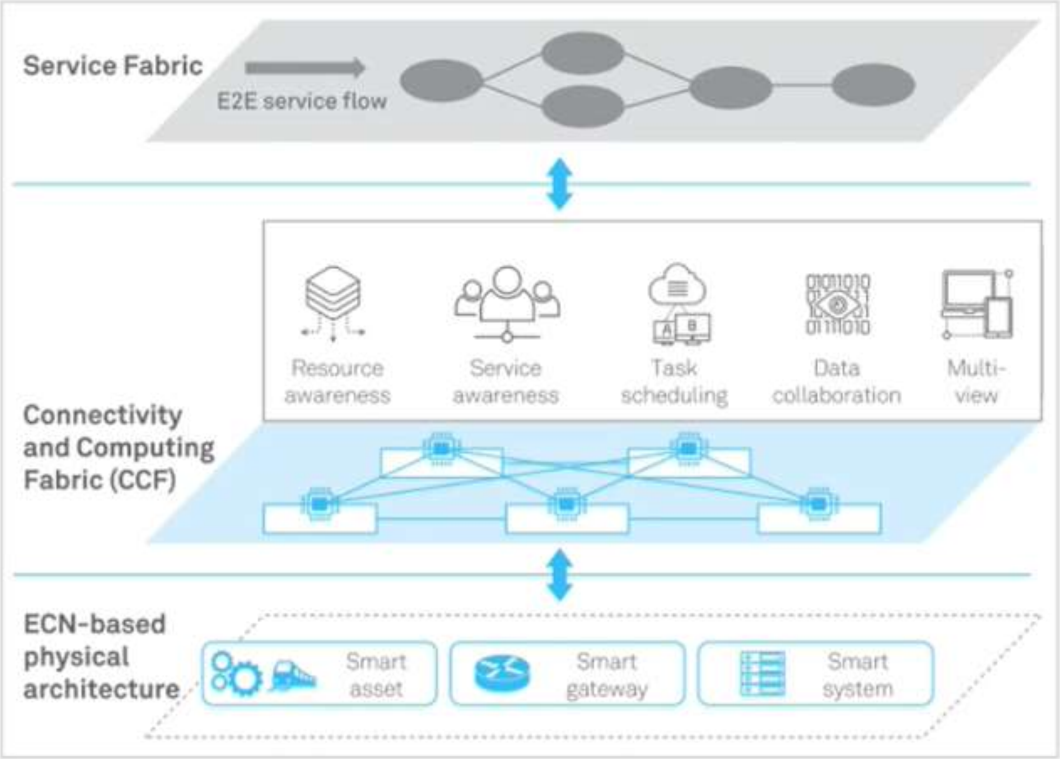
- Open-source TSDBs, such as OpenTSDB, KairosDB, and InfluxDB

Functional View : Service Fabric

- The service model includes the following information:
  - Service name
  - Function to be executed or provided
  - Nesting, dependency, and inheritance relationships between services
  - Input and output of each service
- A service fabric provides the following functions:
  - Workflow and workload definition
  - Visualized display

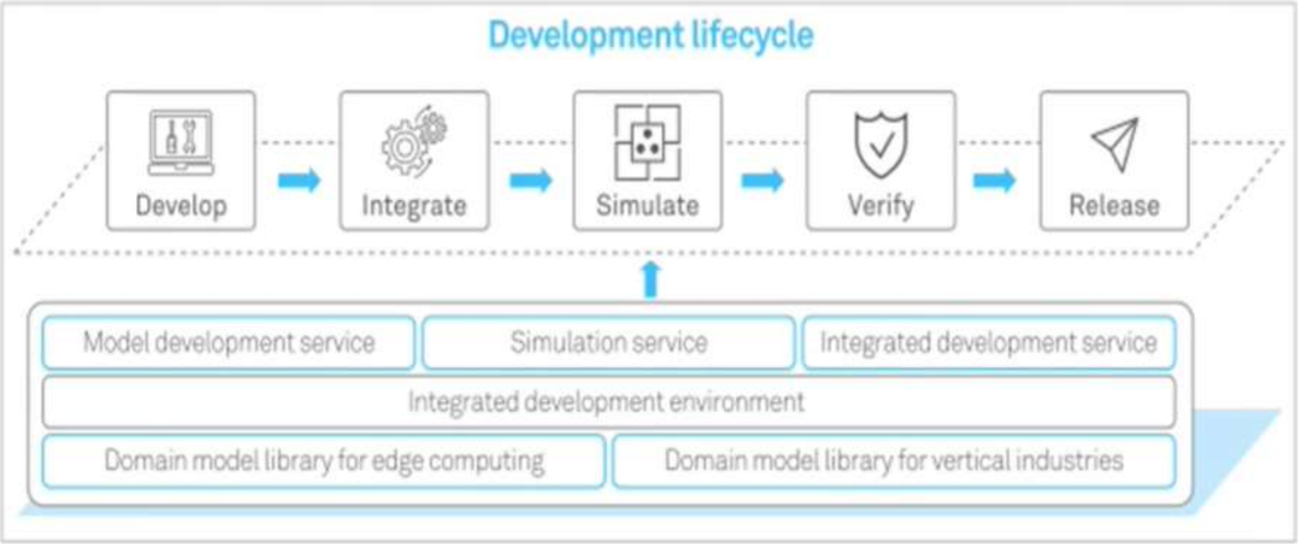
Functional View : CCF

CCF is a virtualized connectivity and computing service layer

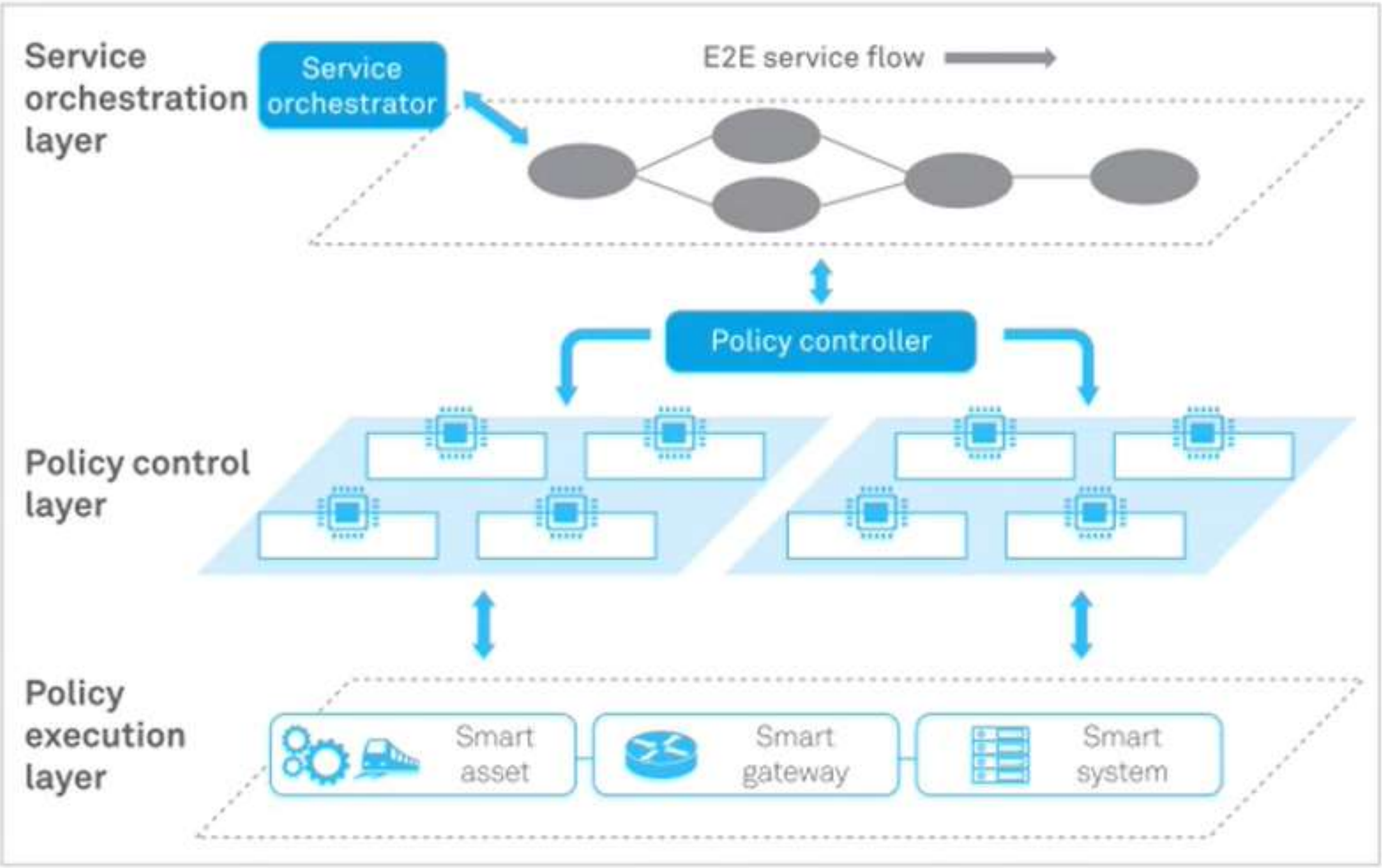


Function View : Development Service Framework

- The development service framework supports the following key services:
  - Model-based development service
  - Emulation service
  - Integrated release service



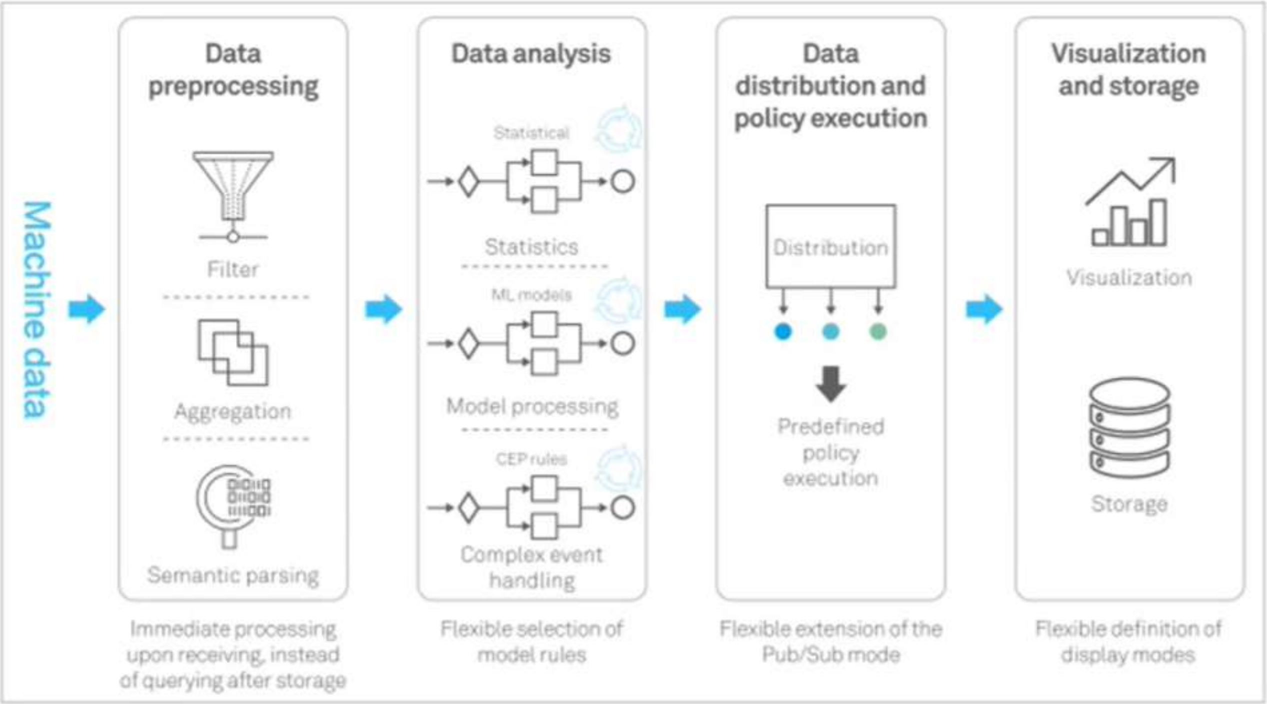
Function View : Development Operation Service Framework



Function View : Development Service Framework

- Edge data characteristics
  - Causal relationship vs. association relationship
  - High reliability vs. low reliability
  - Small data vs. big data

Function View : Full-Life Service Framework



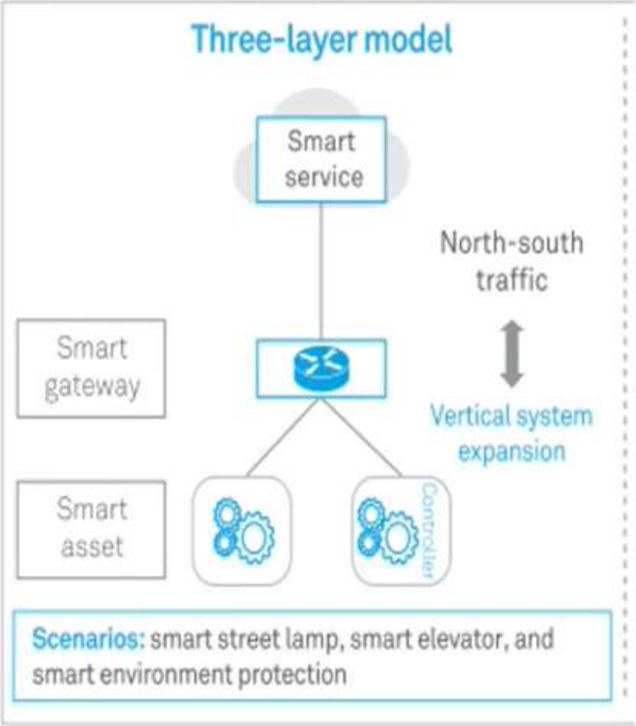
Function View : Security Service

- ECN security
- Network (fabric) security
- Data security
- Application security
- Identity and authentication management

Deployment View : Three-Layer model

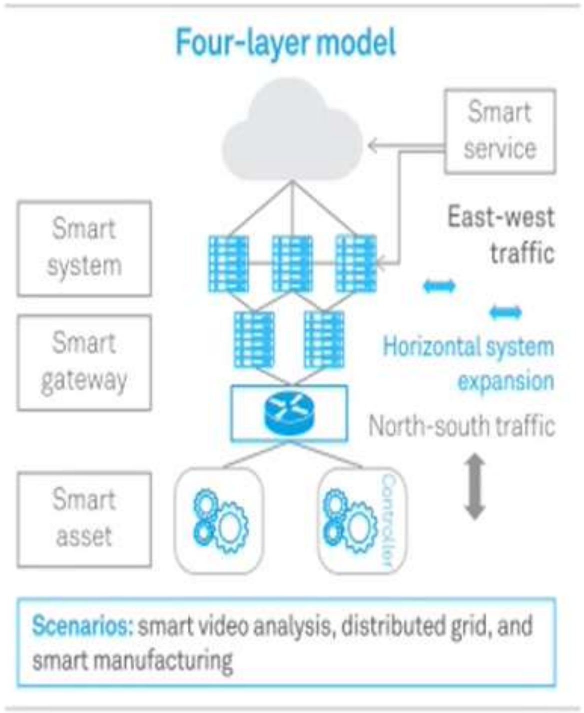
- This model is applicable to scenarios where services are deployed in one or more scattered areas, each with a low traffic volume.

- Scenarios include smart street lamps, smart elevators, and smart environmental protection.



Deployment View : Four-Layer model

- This model is applicable to scenarios where services are deployed centrally and the traffic volume is high



- Scenarios include smart video analysis, distributed grid, and smart manufacturing