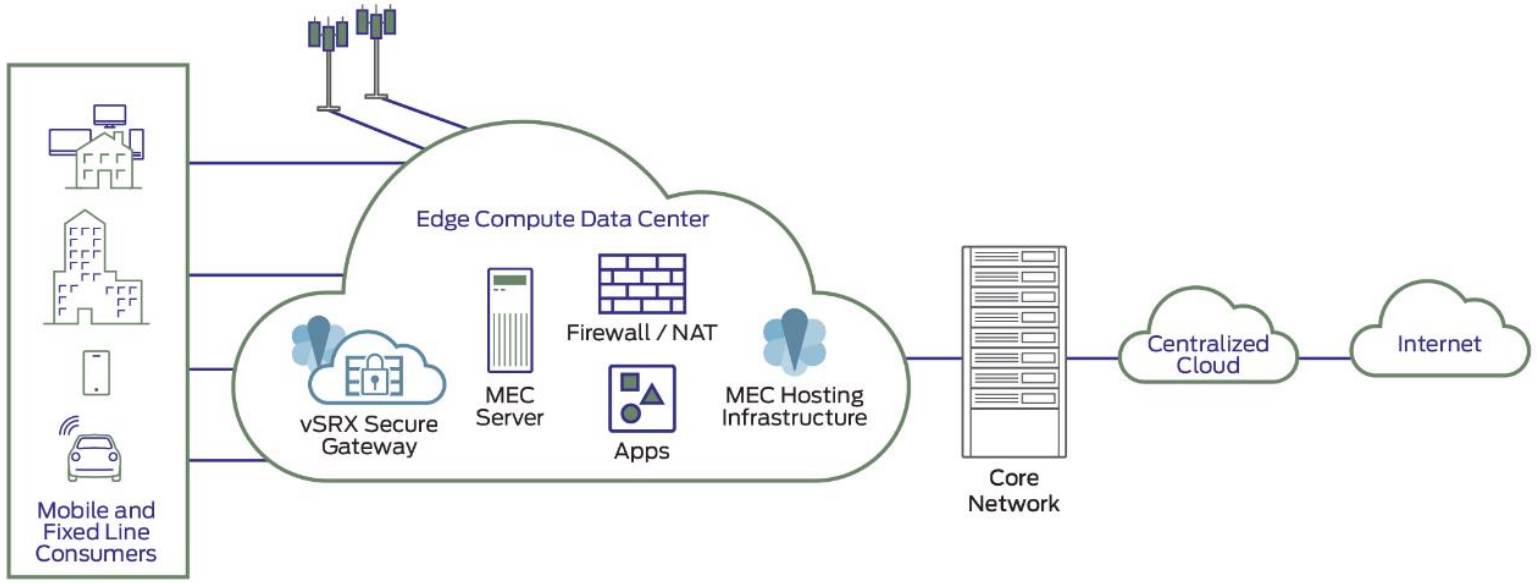
SVEUČILIŠTE U ZAGREBU
Fakultet elektrotehnike i računarstva

Master Programme

Computing

Advanced Architectures of Telecommunication Networks

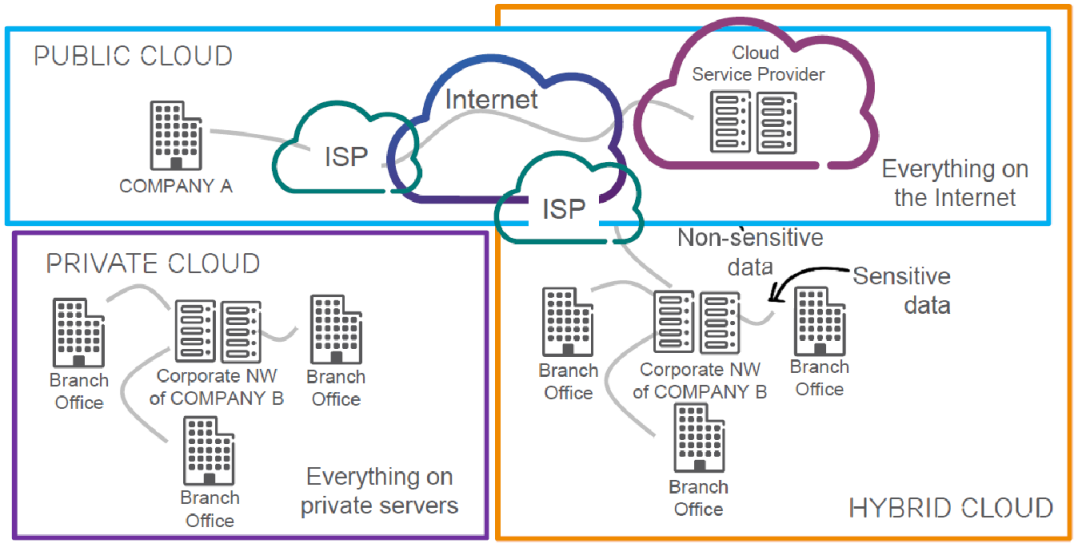


Ac. year 2022/2023

Multi-access Edge Computing (MEC)

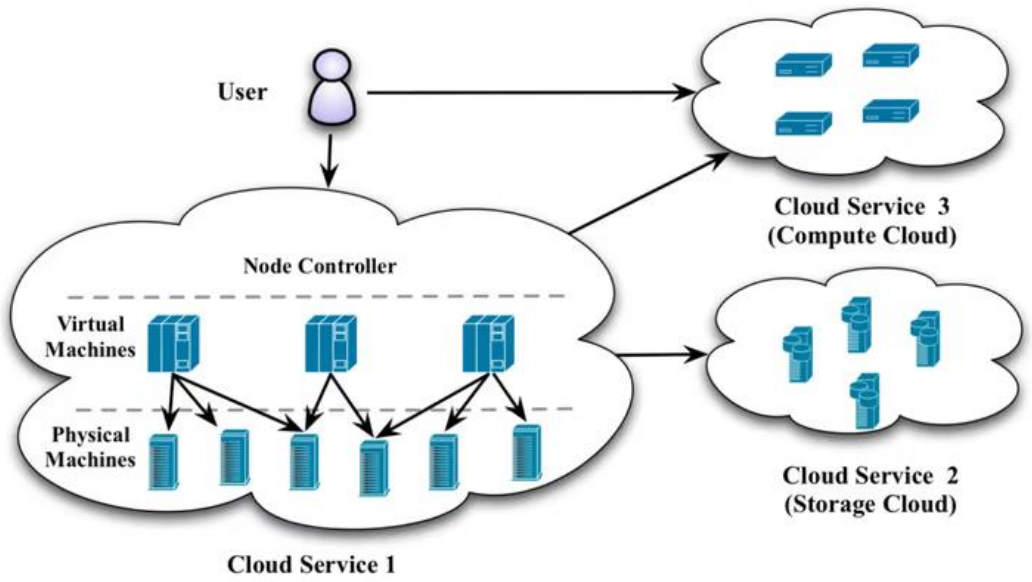
Cloud Computing

- Enables anyone with an internet connection to access IT resources on-demand
- Three types of cloud: **public**, **private**, and **hybrid**
- **Benefits**: less costly capex, easy scaling, and improved resource management
- **Disadvantages**: loss of control, ensuring security, and the risk of faulty connections



source: Ericsson

Distributed Cloud

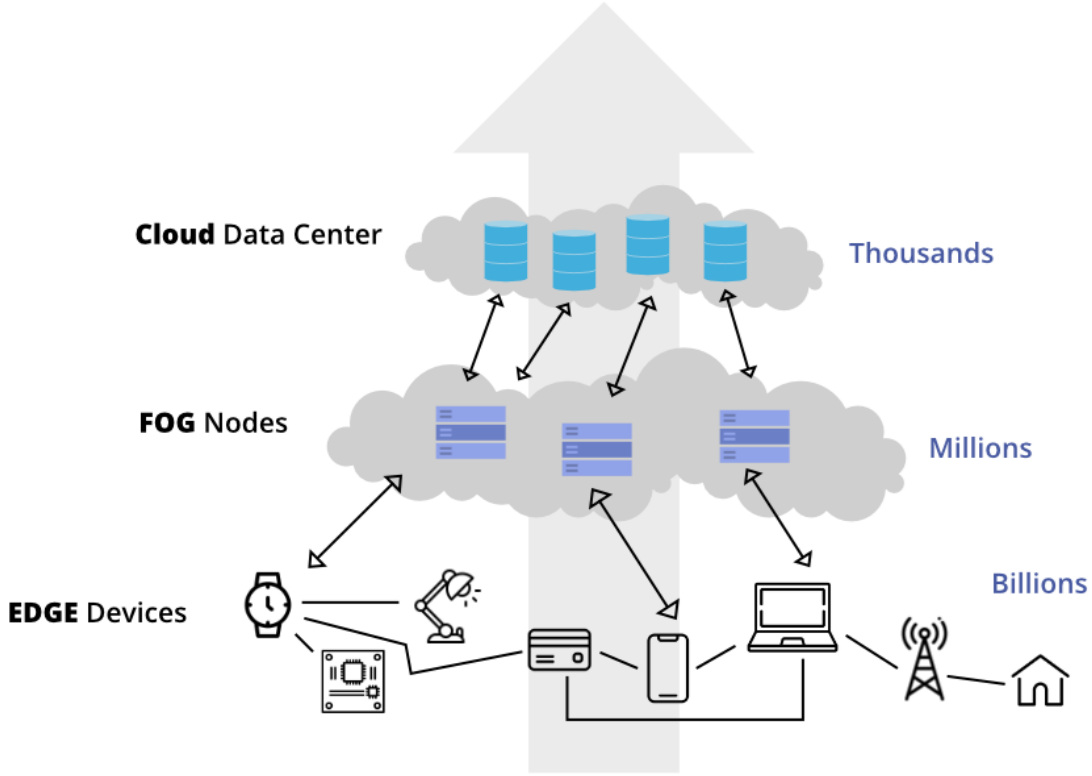


source: ResearchGate

- A type of cloud that has geographically dispersed infrastructure that primarily runs services at the network edge
- Refers to having **computation**, **storage**, and **networking in a micro-cloud** located outside the centralized cloud
- A more general term which includes the concept of fog and edge computing in its infrastructure

Fog Computing

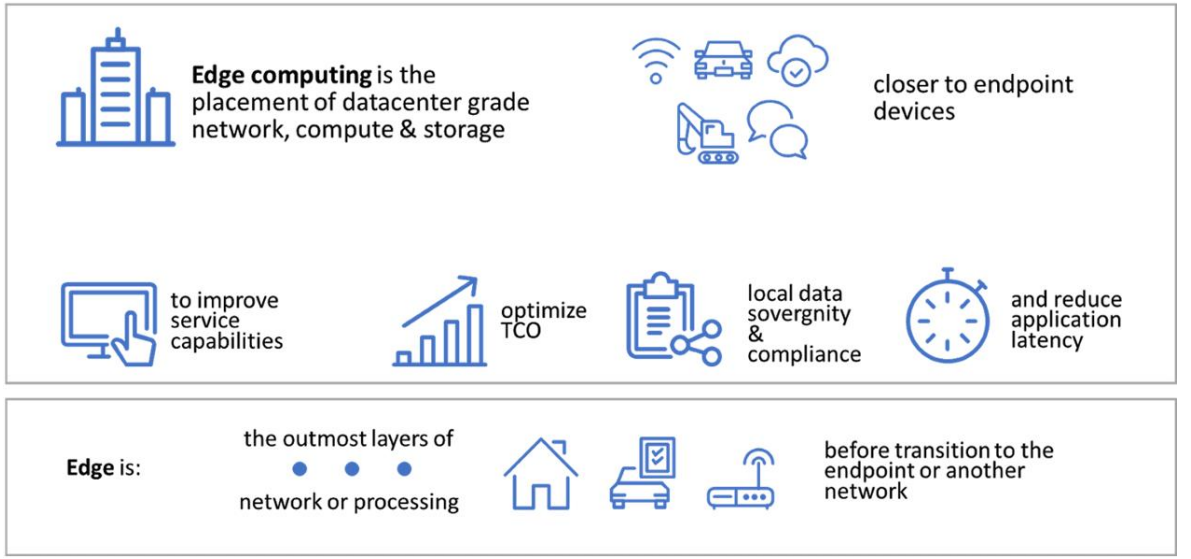
- An extension of cloud computing
- OpenFog Consortium definition: “a system-level horizontal architecture that distribute resources and services of computing, storage, control, and networking anywhere along the continuum from Cloud to Things”
- Shares similar benefits to edge computing including **low latency**, a focus on **storage**, and **real-time analytics**



source: GeeksforGeeks

Edge Computing

- Edge computing is a general term for a cloud-based IT service environment located at the edge of a network
- It is a distributed IT architecture where the client data is processed and analyzed closer to the data source and at the network's periphery



source: Medium

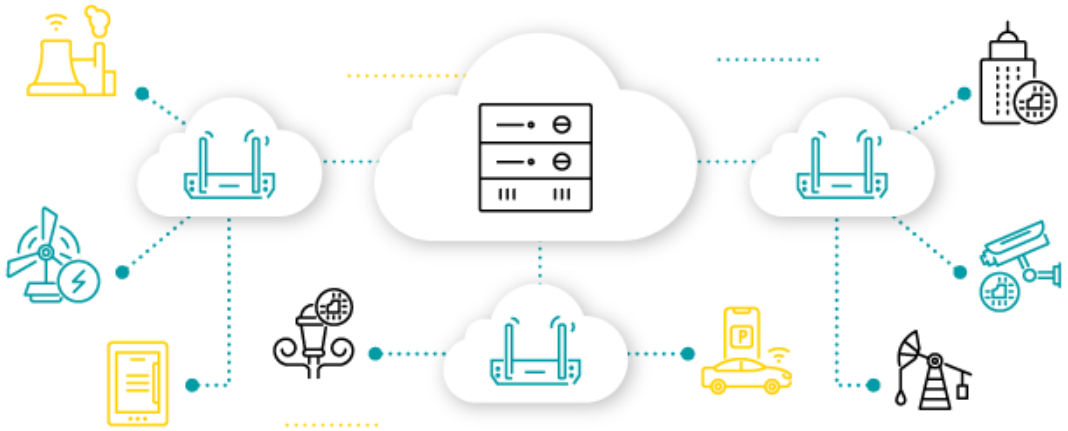
- Not sending data to a distant central data center for computing power means **faster network speeds**, **lower latencies**, and **more reliable network connections**

Multi-access Edge Computing (MEC)

- Mobile Computing + Edge Computing
- Mobile Computing:
  - Computing to be transported during usage
  - Mobile communication + hardware + software
  - Mobile devices
- Edge Computing:
  - Computing to be hosted close to the UE’s access

What is MEC?

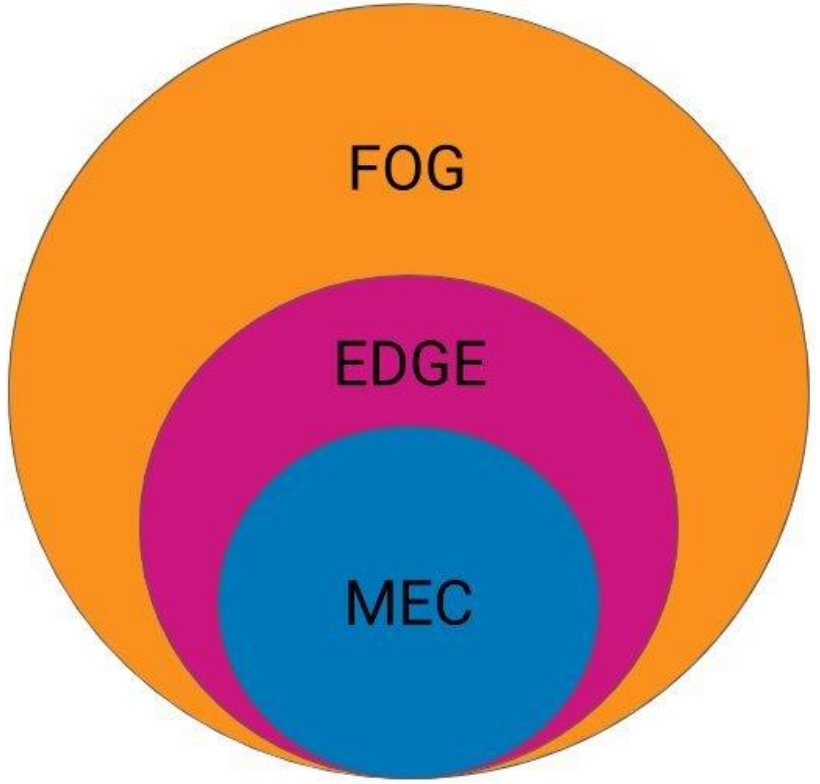
- Moves the computing of traffic and services from a centralized cloud to the edge of the network and closer to the customer
- The network edge analyzes, processes, and stores the data
- **Reduced latency** and **real-time performance** to high-bandwidth applications



source: Avsystem

Edge Computing vs MEC

- The terms edge computing and MEC are commonly used interchangeably
- An important distinction: edge computing is a **concept**, and MEC is the edge computing **standard architecture** created by the European Telecommunications Standards Institute's (ETSI's) MEC group



source: SDxCentral

Mobile vs Multi-access Edge Computing

- MEC computing refers to computing at the edge of a network in the proximity to end users
- At first the edge of a network meant the edge of a mobile network, hence the name **mobile edge computing**
- Later the name changed to **multi-access computing** in order to reflect that the edge is not solely based on mobile networks
- In March 2017, the ETSI MEC group and its associated standard replaced “mobile” with “multi-access” in response to emerging benefits of the technology that reached beyond mobile networks and into Wi-Fi and fixed access technologies

MEC Characteristics

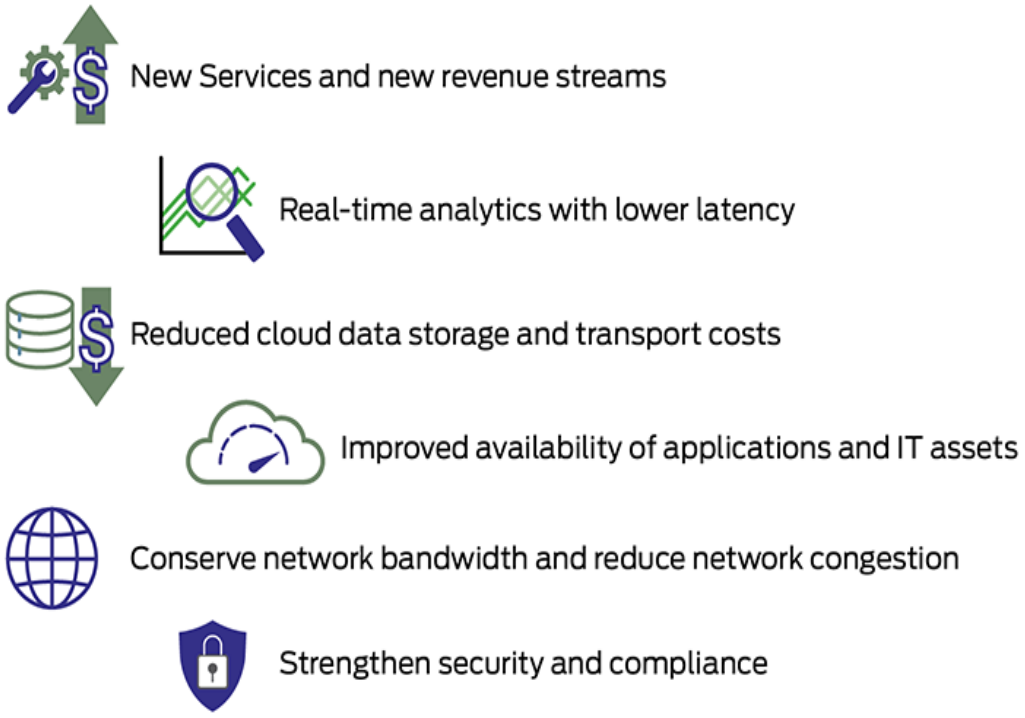
- Proximity [1 or 2 hops]
- Location awareness
- High throughput [1-10 Gbps]
- Ultra-low latency [1 millisecond]
- High reliability [99.9999% availability]
- Energy efficiency [90% reduction in energy usage]
- Less backhaul network congestion
- Real-time access to network and context information
- Better user experience
- Innovative services towards subscribers, enterprises and verticals
- Virtualization

Why MEC?

Key Drivers

- 4G networks
- Internet of Things (IoT)
- 5G networks

Benefits



source: Avsystem

MEC Business Benefits

A new value chain and an energized ecosystem, based on Innovation and business value	Business transformation	A myriad of new use cases
• Wider collaboration can help to drive favorable market conditions for sustainable business for all players in the value chain	• New market segments (enterprises, verticals and subscribers) • Short innovation cycle • Revenue generation and differentiation	• Video acceleration • Augmented reality • Connected vehicles • IoT analytics • Enterprise service, • Network performance and utilization optimization • Retail • eHealth etc.

MEC Use Case Categories

Consumer-oriented services

Examples: gaming, remote desktop applications, augmented and assisted reality, cognitive assistance, etc.

Operator and 3rd party services

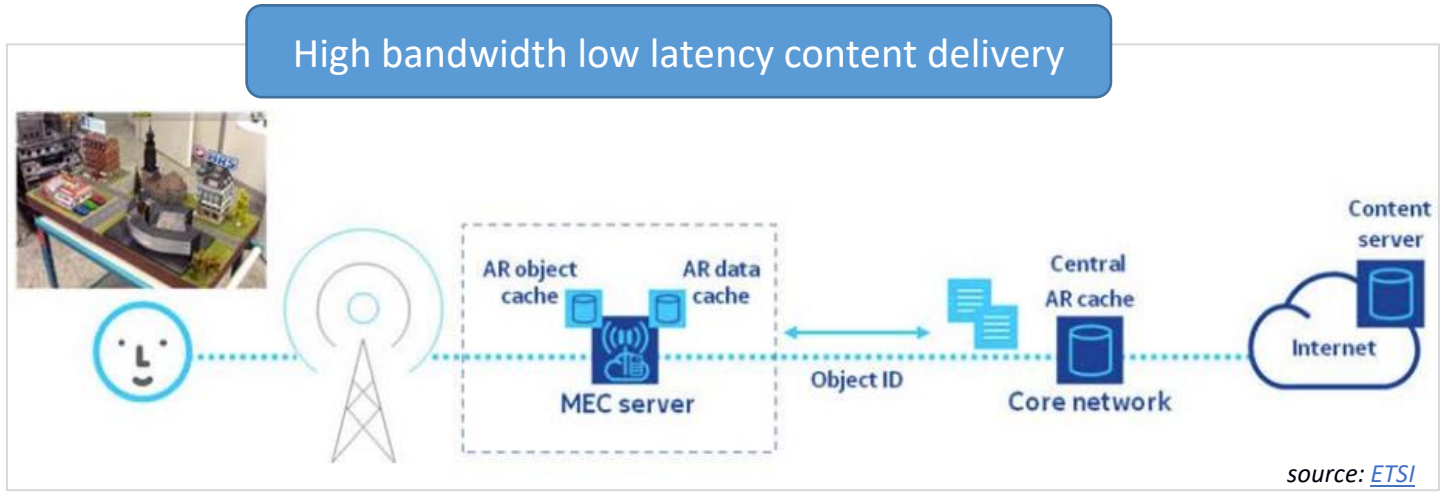
Examples: active device location tracking, big data, security; safety, enterprise services, etc.

Network performance and QoE improvements

Examples: content/DNS caching, performance optimization, video optimization, etc.

Consumer-oriented services

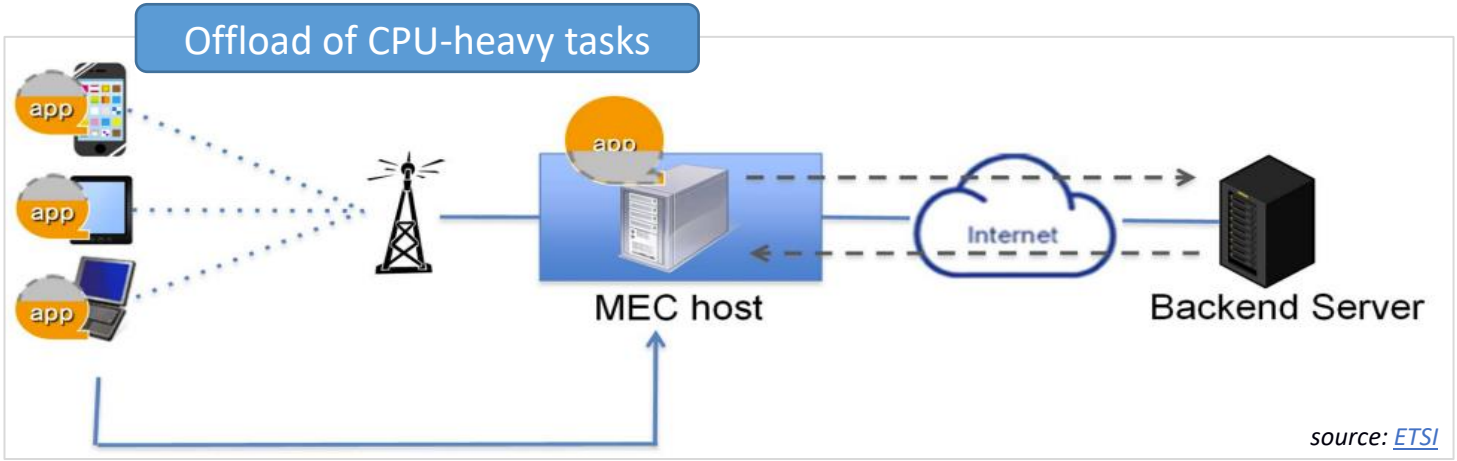
Augmented Reality (AR)



- AR = a view of the real-world environment + supplementary computer-generated sensory input
- Can enhance the experience of a visitor to a museum or another point of interest
- The MEC application analyses the output from a device's camera and the precise location; objects viewed on the device camera are overlaid with local augmented reality content
- Ensures low latency and high rate of data processing

Consumer-oriented services

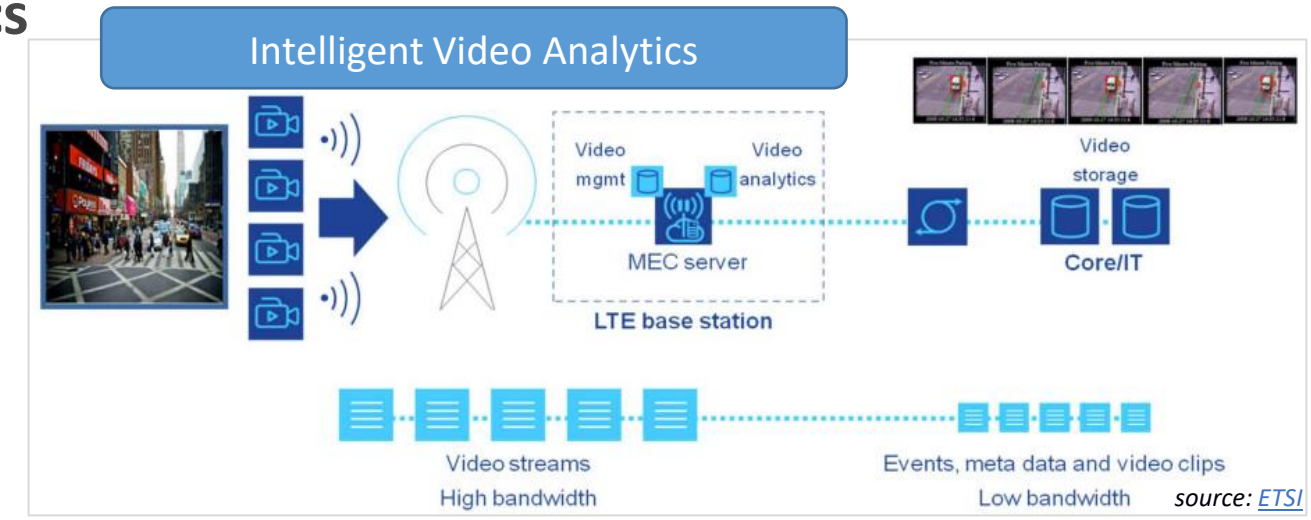
Application computation off-loading



- The MEC host executes compute-intensive functionalities with high performance instead of mobile devices
- New compute intensive services like auto-translation and recommendations synthesized can be delivered in near real-time, and to low complexity devices
- Operators can provide value added services by utilizing application data available at the MEC host

Operator and 3rd party services

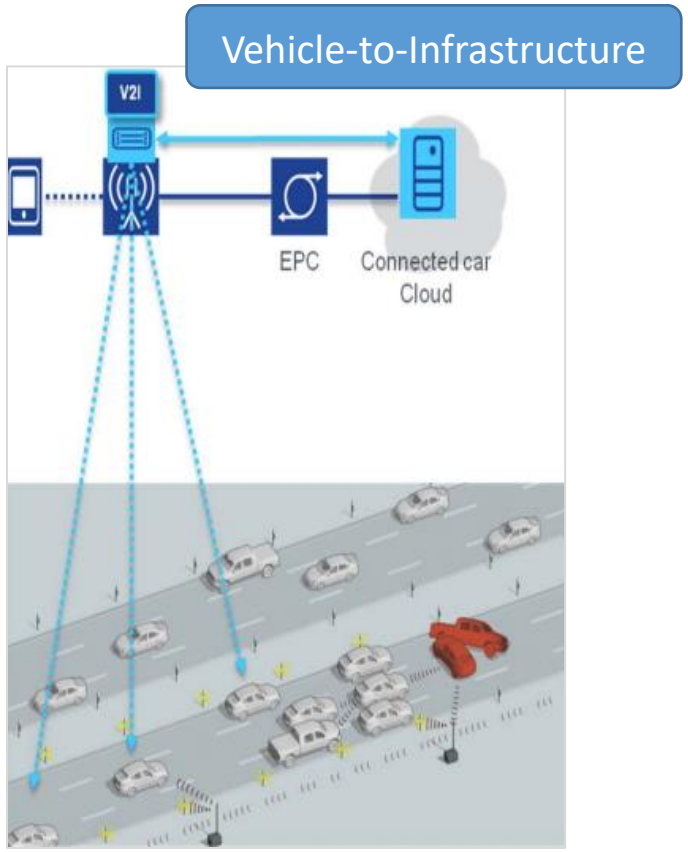
Video Analytics



- Distributed live video streams analytics at the mobile edge
- Events are triggered automatically (e.g., movement, missing objects, crowd, etc.); enables fast detection and action triggering
- Optimizes backhaul and transport capacity
- Applicable to public safety, smart cities

Operator and 3rd party services

Connected Vehicles

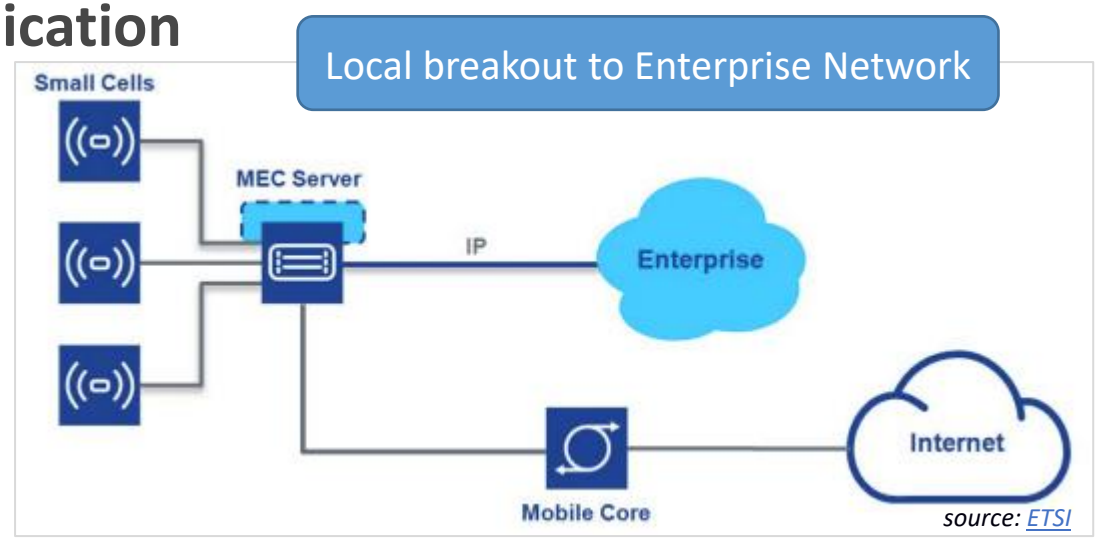


source: ETSI

- The number of connected vehicles is rapidly growing and will continue to do so over the coming years
- Existing cloud services are extended into the highly distributed mobile base station environment, leveraging the existing LTE connectivity
- MEC can reduce the round-trip time of data
- The MEC applications can receive local messages directly from the applications in the vehicles and the roadside sensors, analyze them and propagate warnings to nearby cars (with extremely low latency)
- Enables a nearby car to receive data in a matter of milliseconds, and the driver to react instantly

Operator and 3rd party services

Unified Enterprise Communication

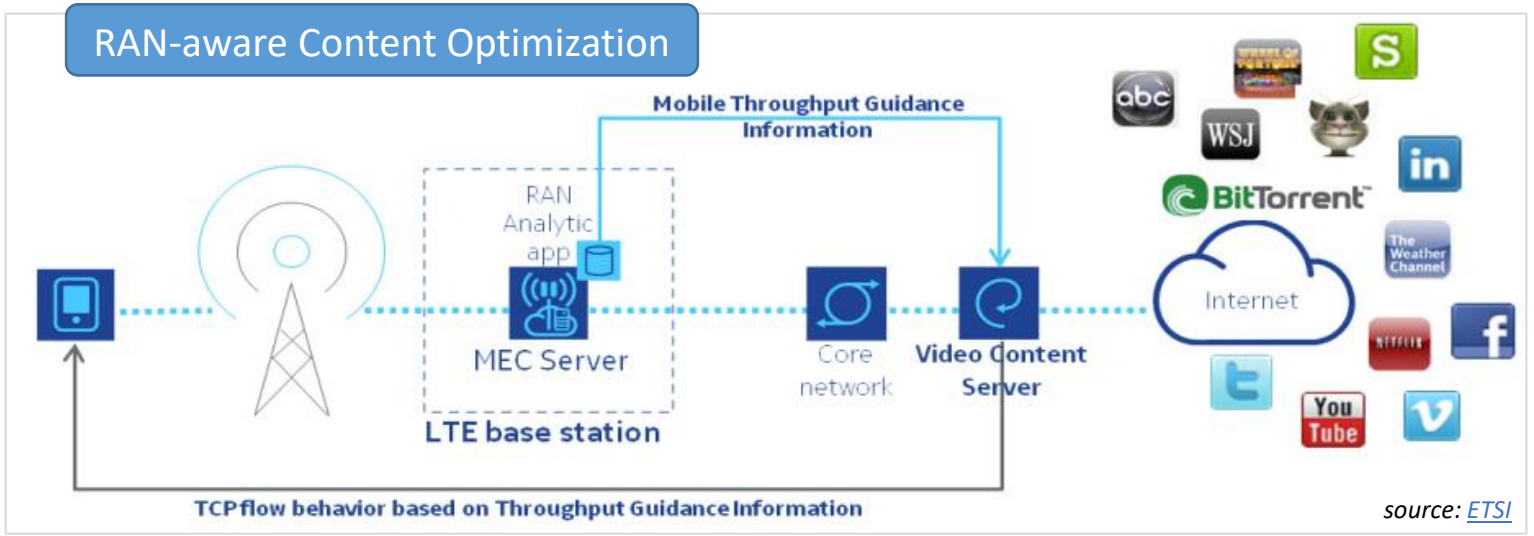


source: ETSI

- Mobile devices are gradually replacing fixed communications hardware, laptop software, and office services in the enterprise market
- Deployment of Small Cells on enterprise premises with enterprise applications supported in the MEC environment
- The MEC platform provides functionality which facilitates the association of IP traffic flows with a particular UE to which an external network identifier is associated using an externally defined tag
- Internal calls routed locally, traffic rules based on user's enterprise or subscription identity, local routing of messaging

Network performance and QoE improvements

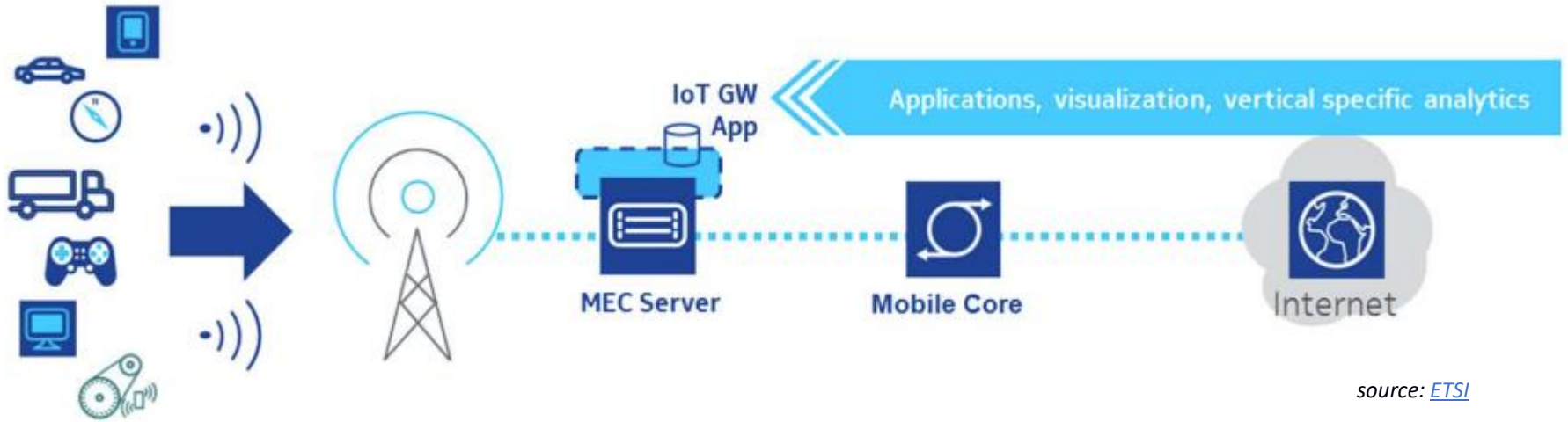
Intelligent Video Acceleration



source: ETSI

- Internet media and file delivery are typically streamed or downloaded today using HTTP over the TCP protocol -> may lead to under-utilization of precious radio resources and to a sub-optimal user experience
- A Radio Analytics MEC application provides the video server with an indication on the throughput estimated to be available at the radio downlink interface
- The information can be used to assist TCP congestion control decisions and ensure that the application-level coding matches the estimated capacity at the radio downlink
- Enables improved video quality and throughput

MEC Benefits for IoT



source: ETSI

- IoT generates additional messaging on telecoms networks, and requires gateways to aggregate the messages and ensure low latency and security
- MEC can be used to connect and control devices remotely, analyze and provide real time provisioning and analytics -> IoT Gateway application deployed at MEC server
- IoT vertical specific data analytics and data aggregation at the edge

ETSI ISG MEC

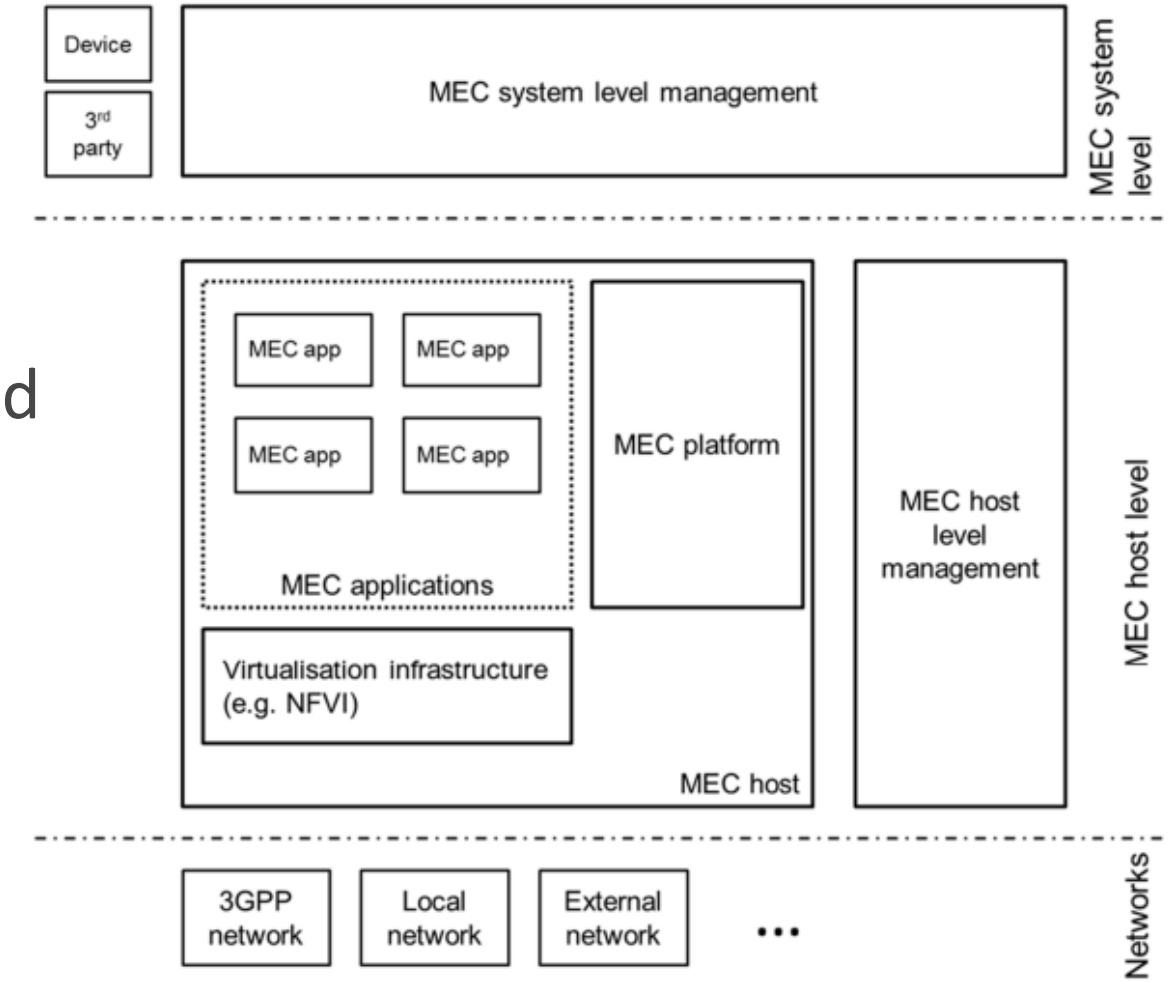
- The ETSI ISG MEC (Industry Specification Group for Multi-access Edge Computing) has been working since 2014
- The ISG MEC work to produce normative Group Specifications that will allow the efficient and seamless integration of applications from vendors, service providers, and third-parties across multi-vendor MEC platforms
- Includes meanings of MEC terms, a recommended architecture, APIs, and general requirements for a technology to fall under MEC
- ETSI has collaborated with the OpenFog Consortium to ensure the standards they create are accepted and used by the larger industry

MEC Standards by ETSI

- Edge technology should have a virtualization platform to be considered MEC (ETSI uses their NFV architecture in the standard)
- MEC can be deployed at radio nodes, aggregation points, and the edge of the core network
- APIs in a MEC environment should be simple, controllable, and if possible, reusable for other tasks
- Since the compute, storage, and network resources that a MEC application requires may not match what are available at a node, a MEC network needs a system-wide lifecycle management of applications to handle these variables correctly
- MEC systems must be able to relocate a MEC application running in an external cloud to a MEC host and back while fulfilling all of the application's requirements

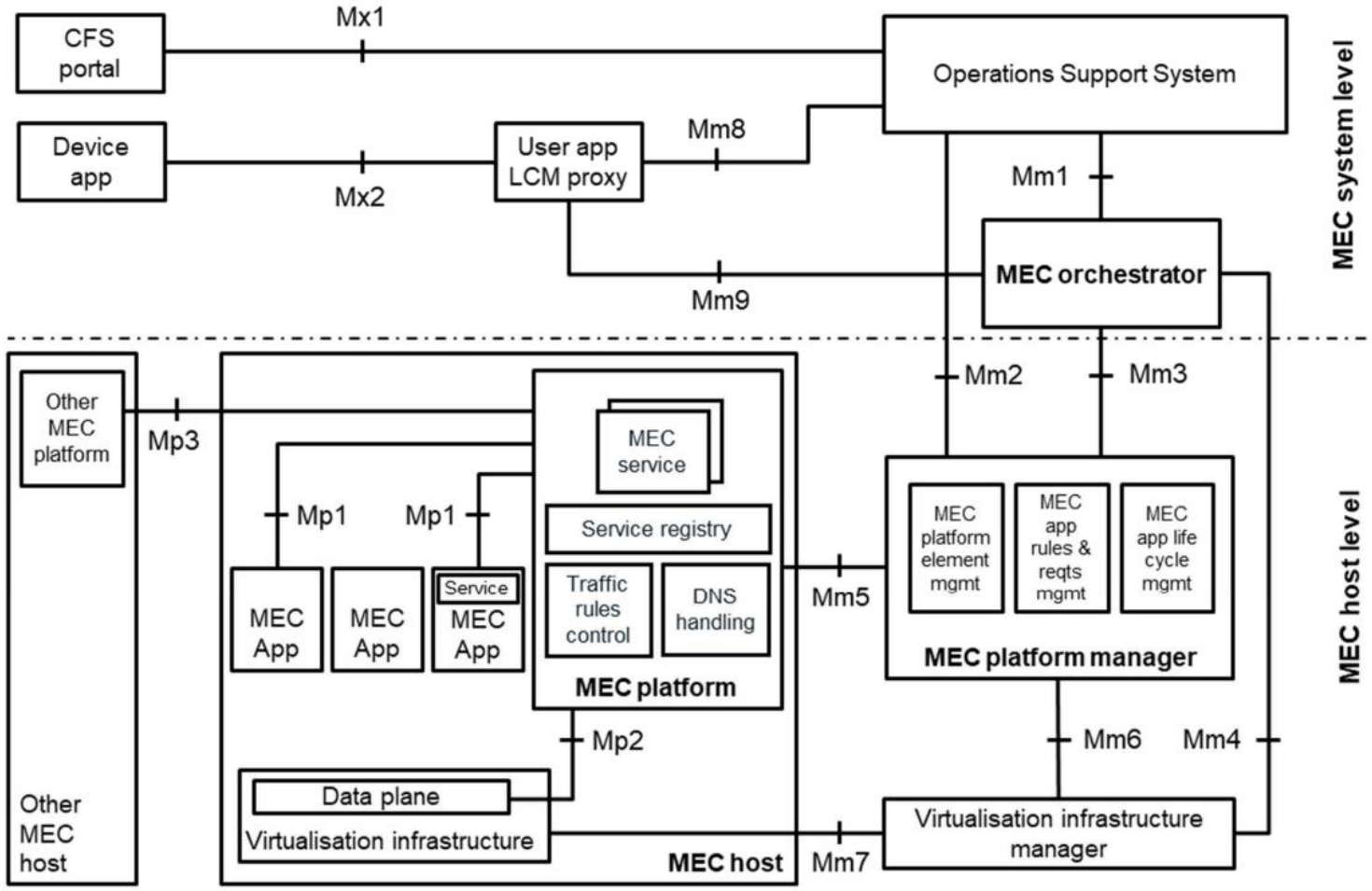
MEC Framework

- The implementation of MEC applications as software-only entities that run on top of a Virtualisation infrastructure located in or close to the network edge
- The MEC framework shows the general entities involved: can be grouped into system level, host level and network level entities



source: ETSI

MEC Reference Architecture



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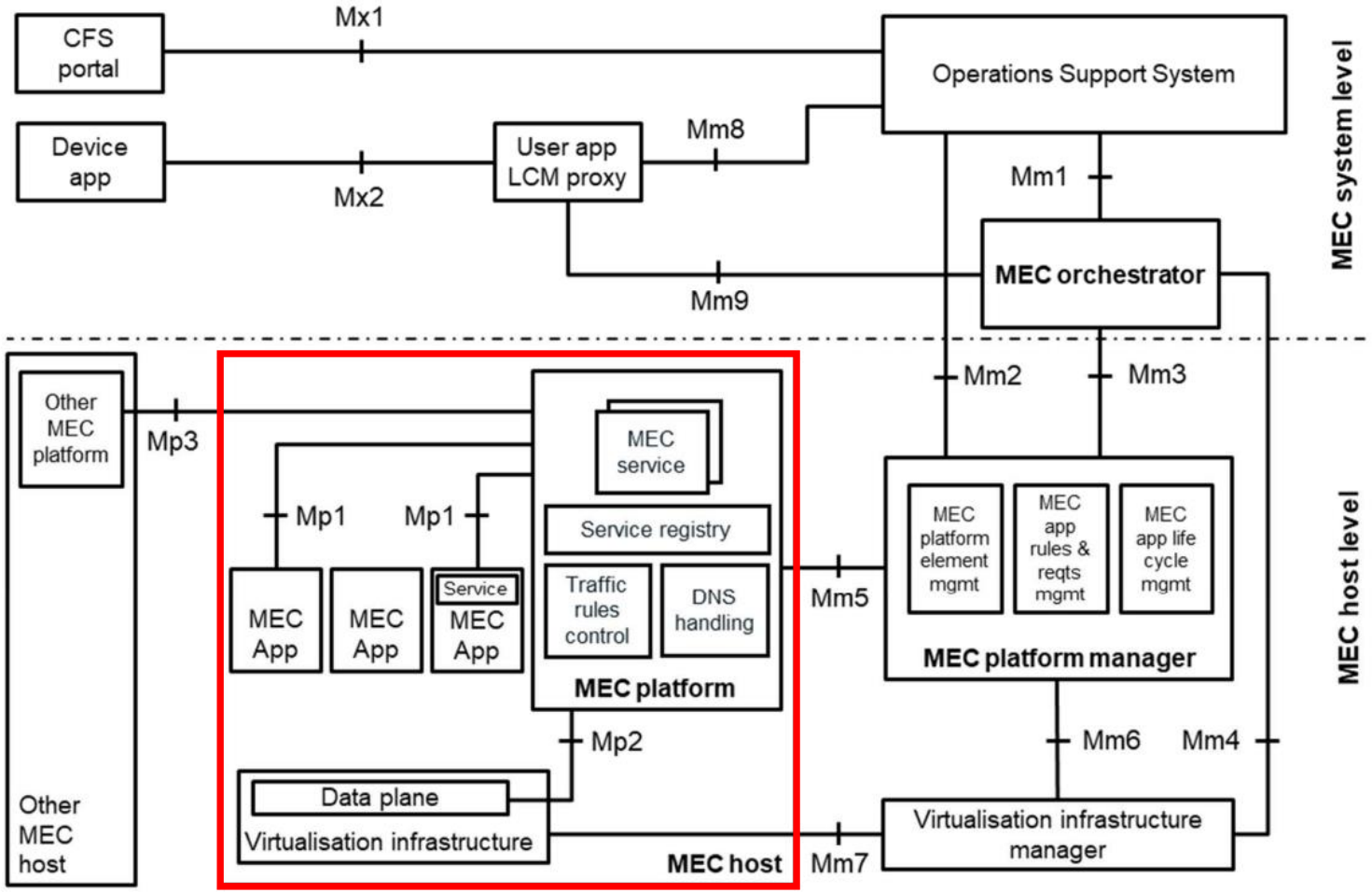
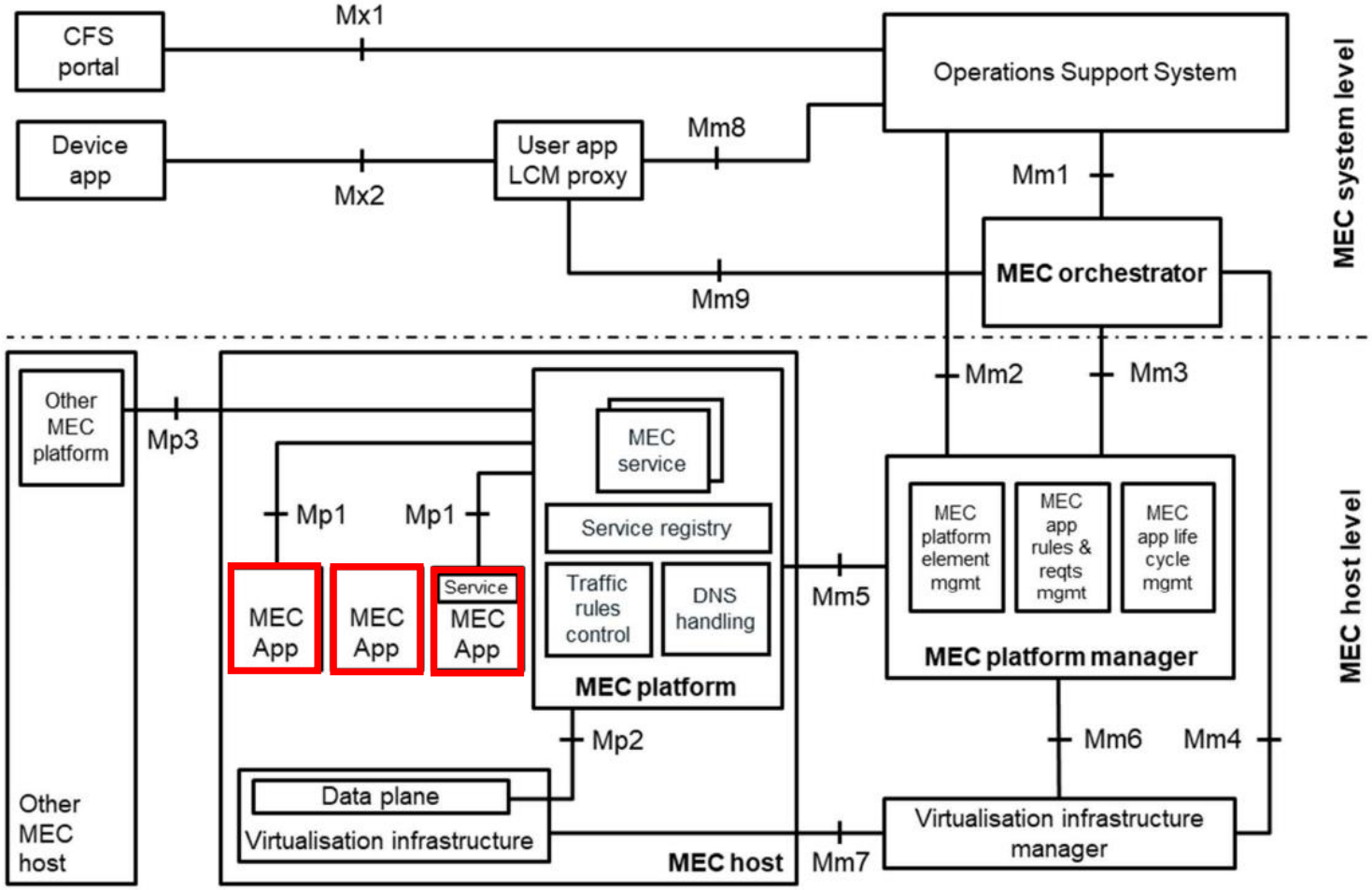
MEC Host



source: ETSI

- Offers virtualization infrastructure to run MEC applications
- Can be an add-on to network elements, or standalone
- Can share virtualization infrastructure with other network functions => NFV
- Two MEC hosts can communicate via the Mp3 interface

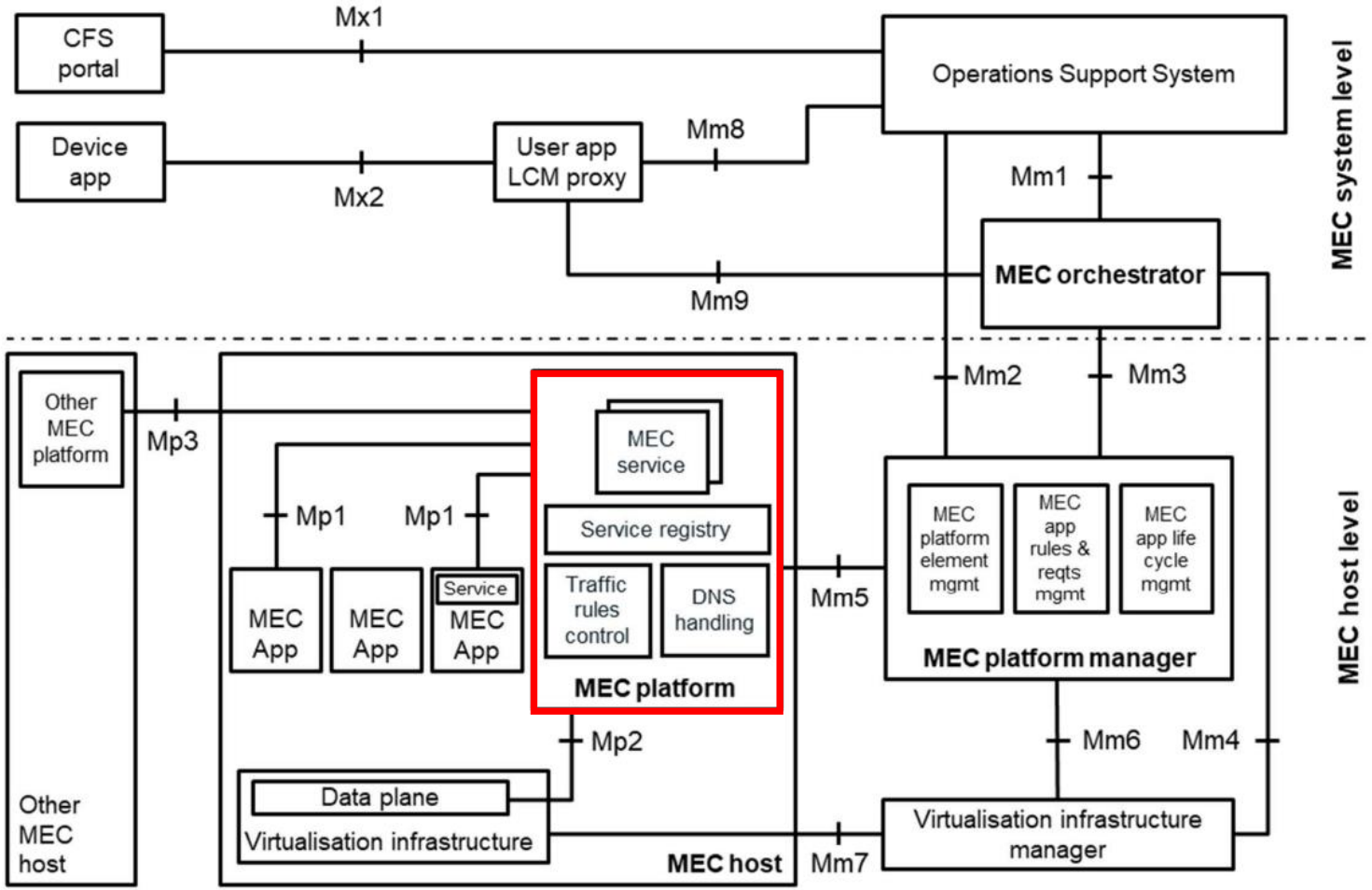
MEC Applications



source: ETSI

- Run as virtual machines
- Typically consume, but may also provide MEC services
- Have associated rules and requirements
- May be relocated to another MEC host
- MEC services provided by third-party MEC applications should be registered with the MEP and made available over the Mp1 reference point

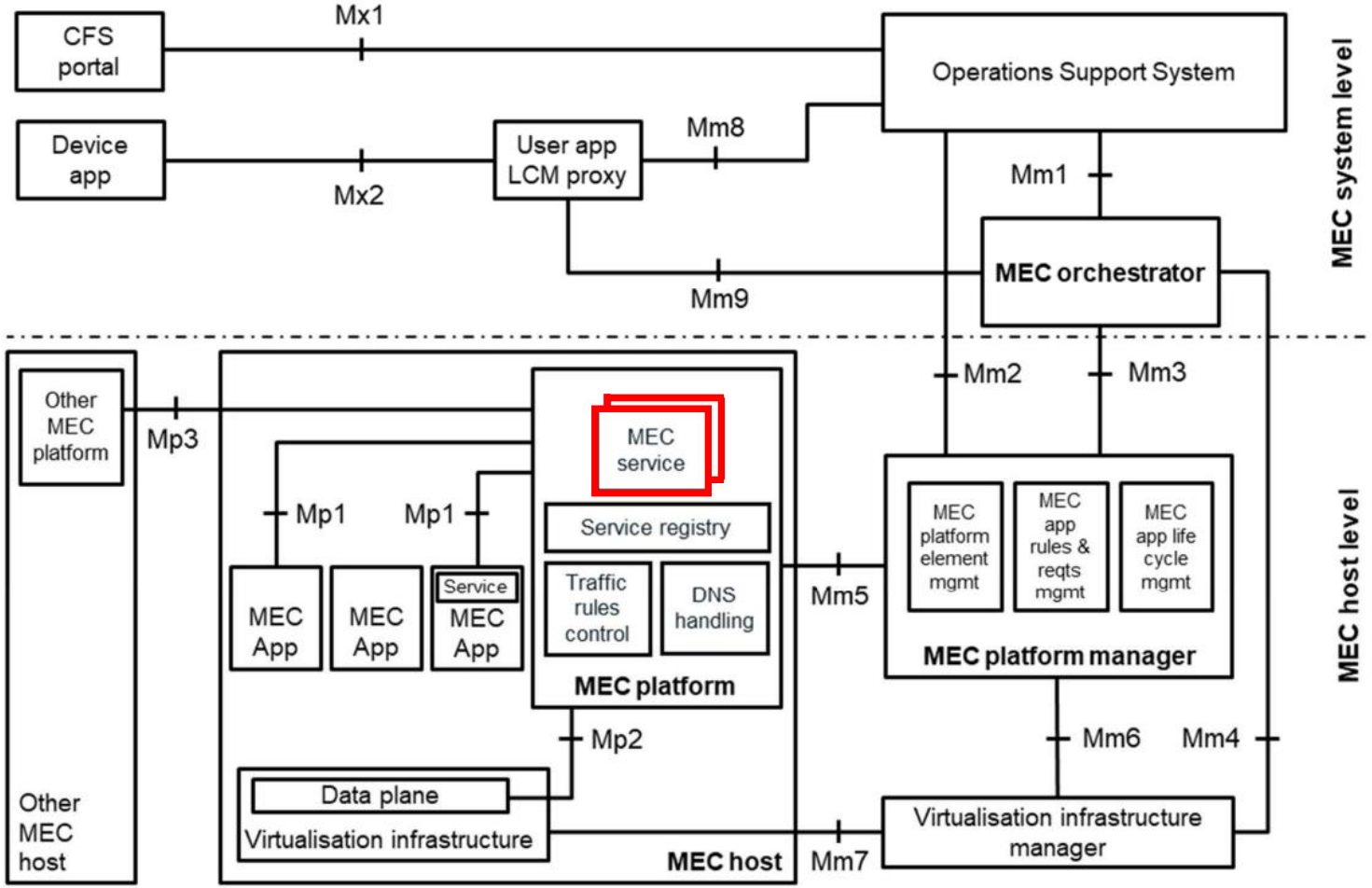
MEC Platform (MEP)



source: ETSI

- An environment where applications can discover, advertise, consume and offer MEC services
- Controls data-plane in the virtualisation infrastructure based on traffic rules
- Configures DNS proxy/server based on DNS records from the MEC platform manager
- Mp1 interface for MEC applications to expose and consume MEC services, and Mp2 to interact with the mobile network

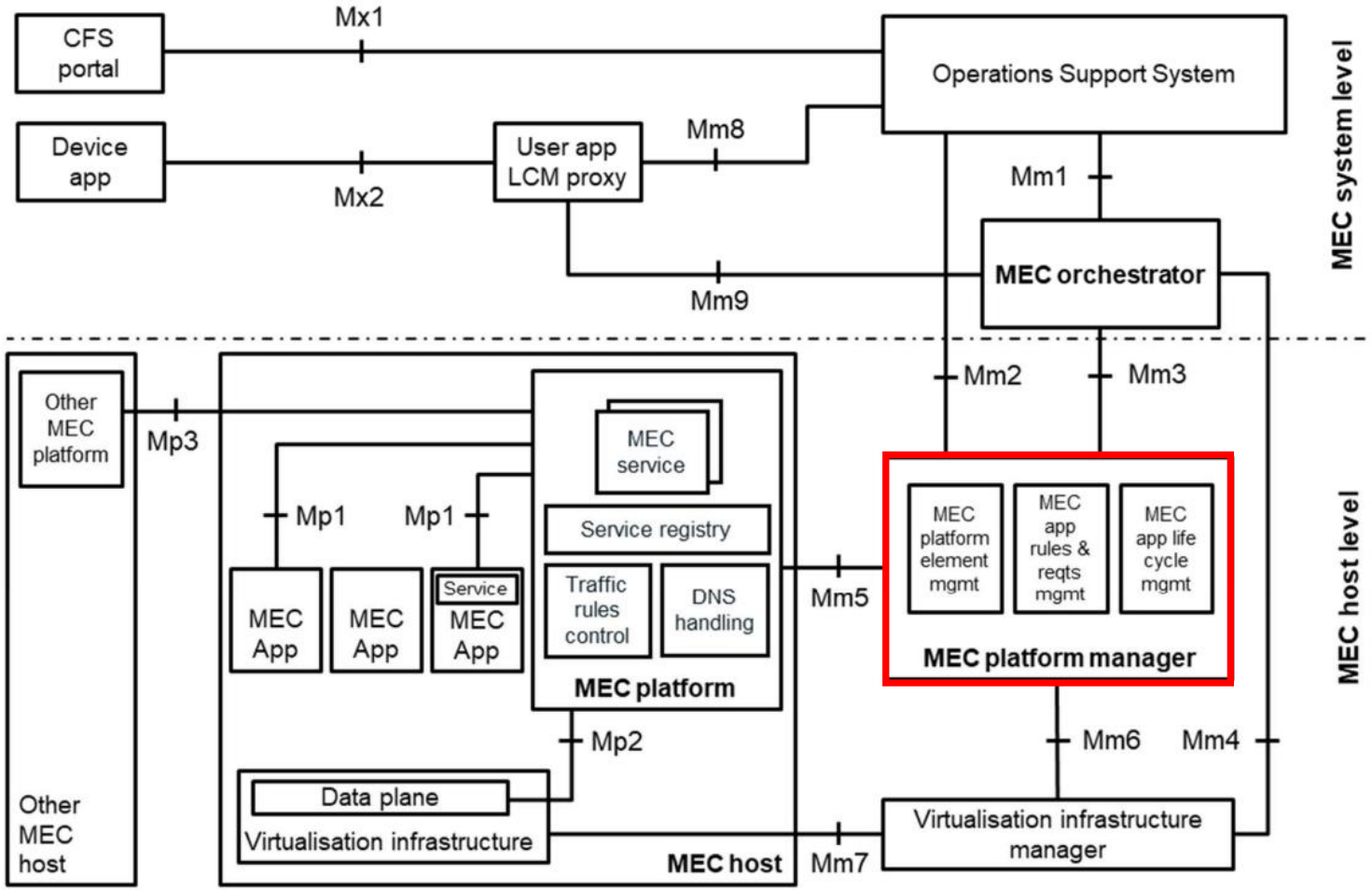
MEC Service



source: ETSI

- Three options:
  - Platform => App
  - App => App
  - App => Platform
- Registerd in the MEP services list
- Radio Network Information Service
- Location Information Service
- Bandwidth Manager Service

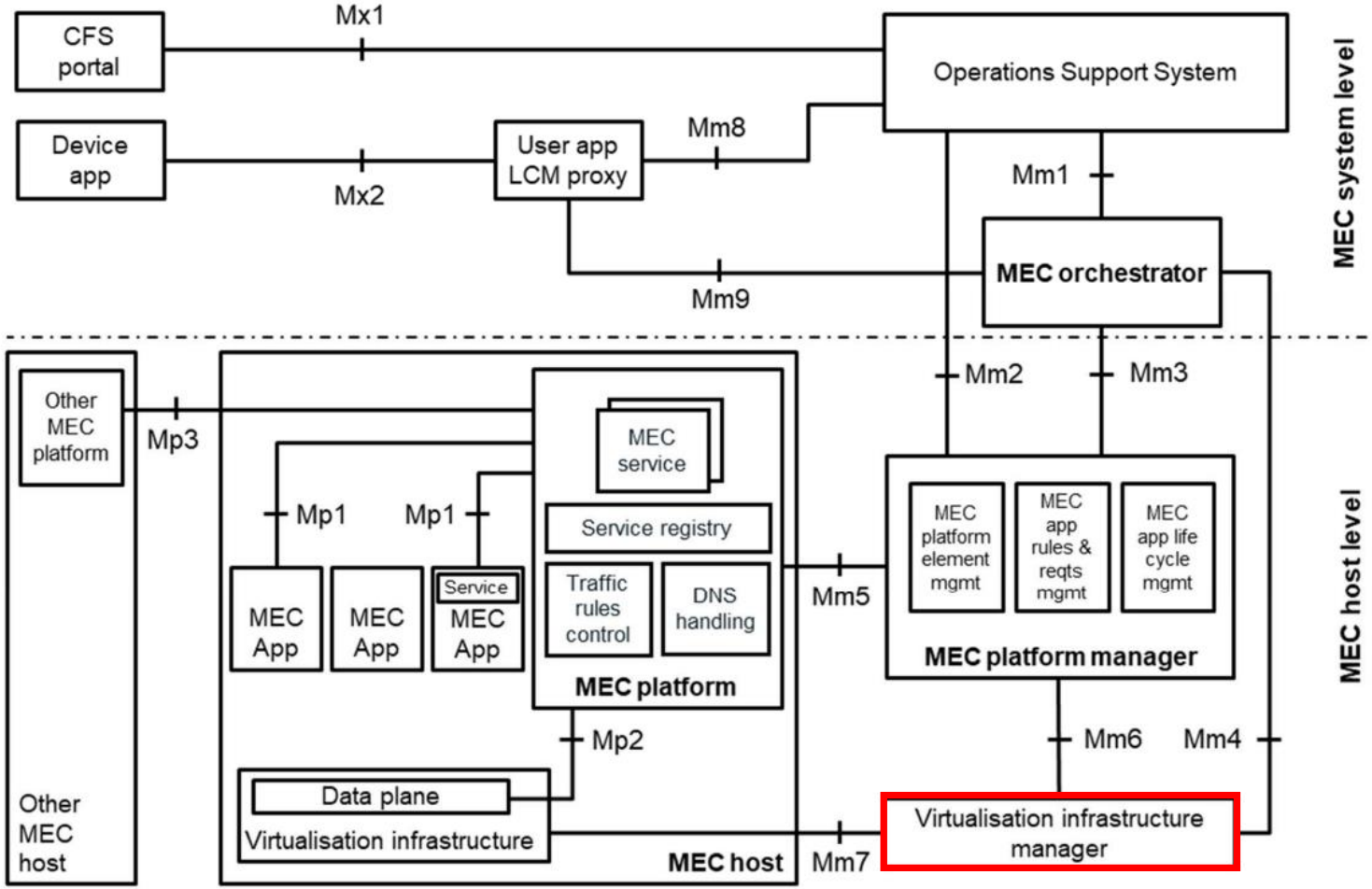
MEC Platform Manager



source: ETSI

- The life cycle management of applications including informing the MEO of relevant application related events
- Providing element management functions to the MEC platform
- Management of application rules and requirements

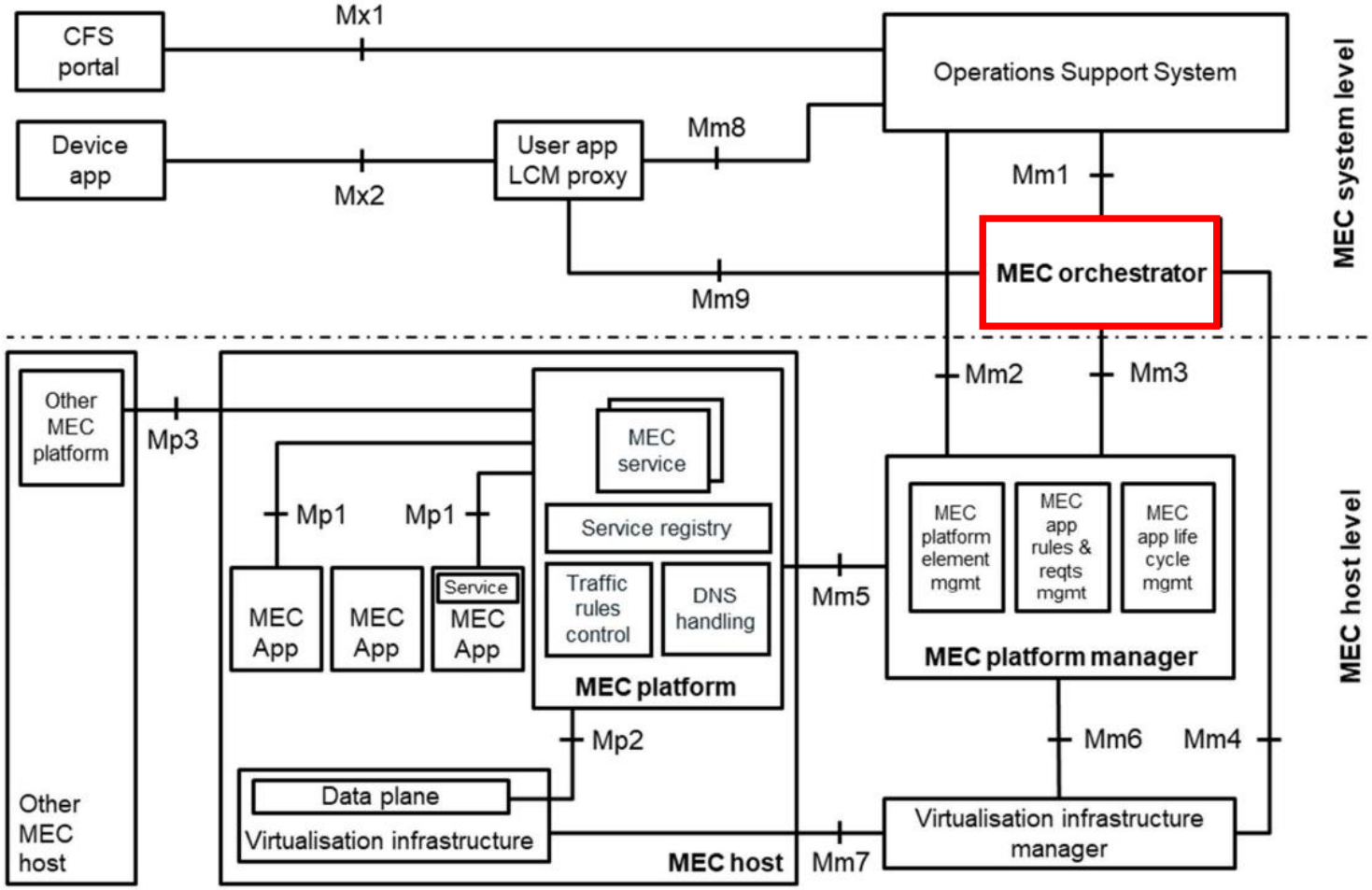
Virtualisation Infractructure Manager



source: ETSI

- Allocating, managing and releasing virtualized resources of the Virtualisation infrastructure
- Preparing the Virtualisation infrastructure to run a software image
- Collecting and reporting performance and fault information about the Virtualised resources

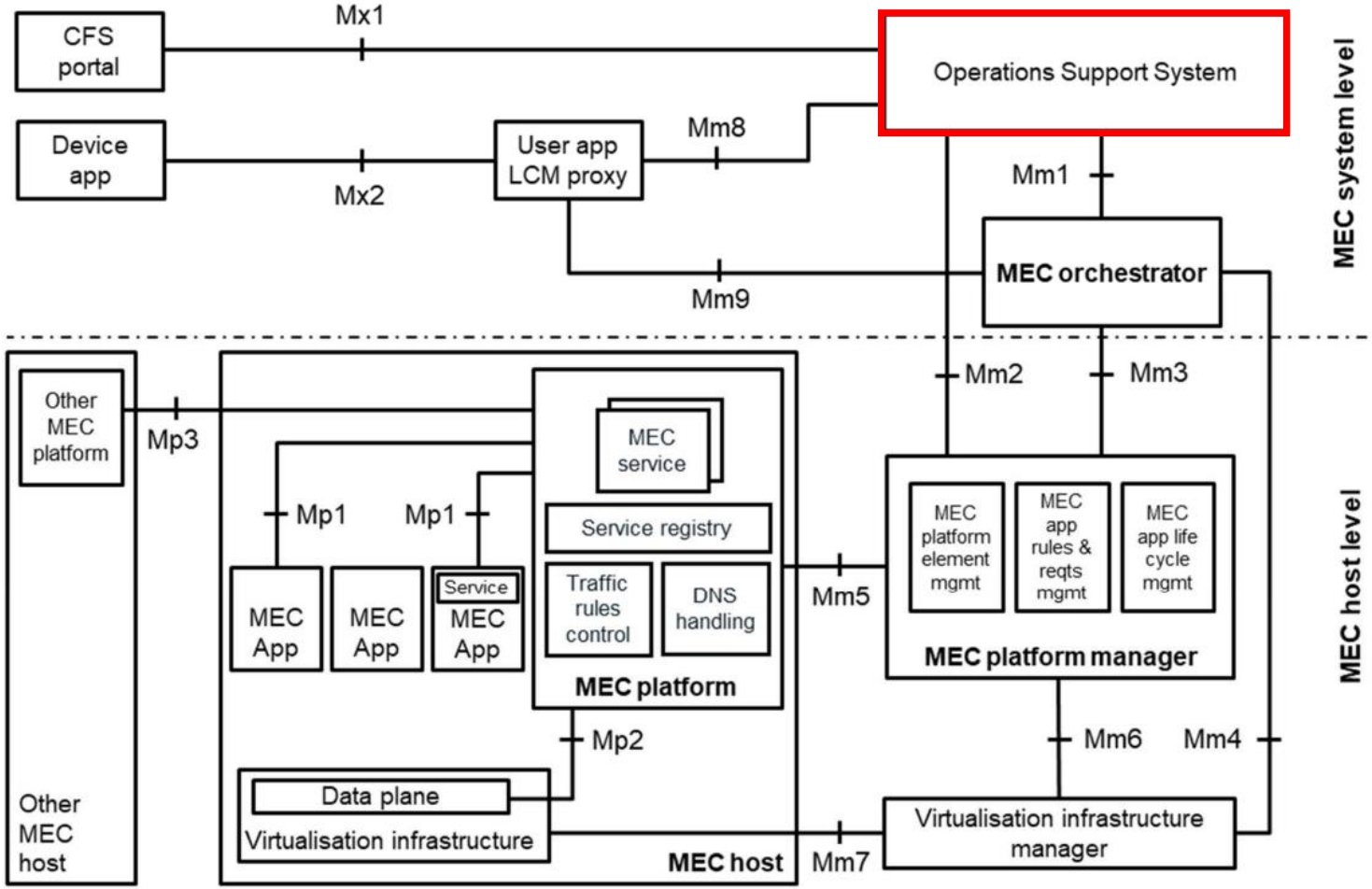
MEC Orchestrator (MEO)



source: ETSI

- The core functionality in MEC system level management
- Instantiation, orchestration and management of MEC applications
- Preparation of the virtualization infrastructure manager to handle the applications
- Selection of the appropriate host for the application, satisfying its rules and requirements

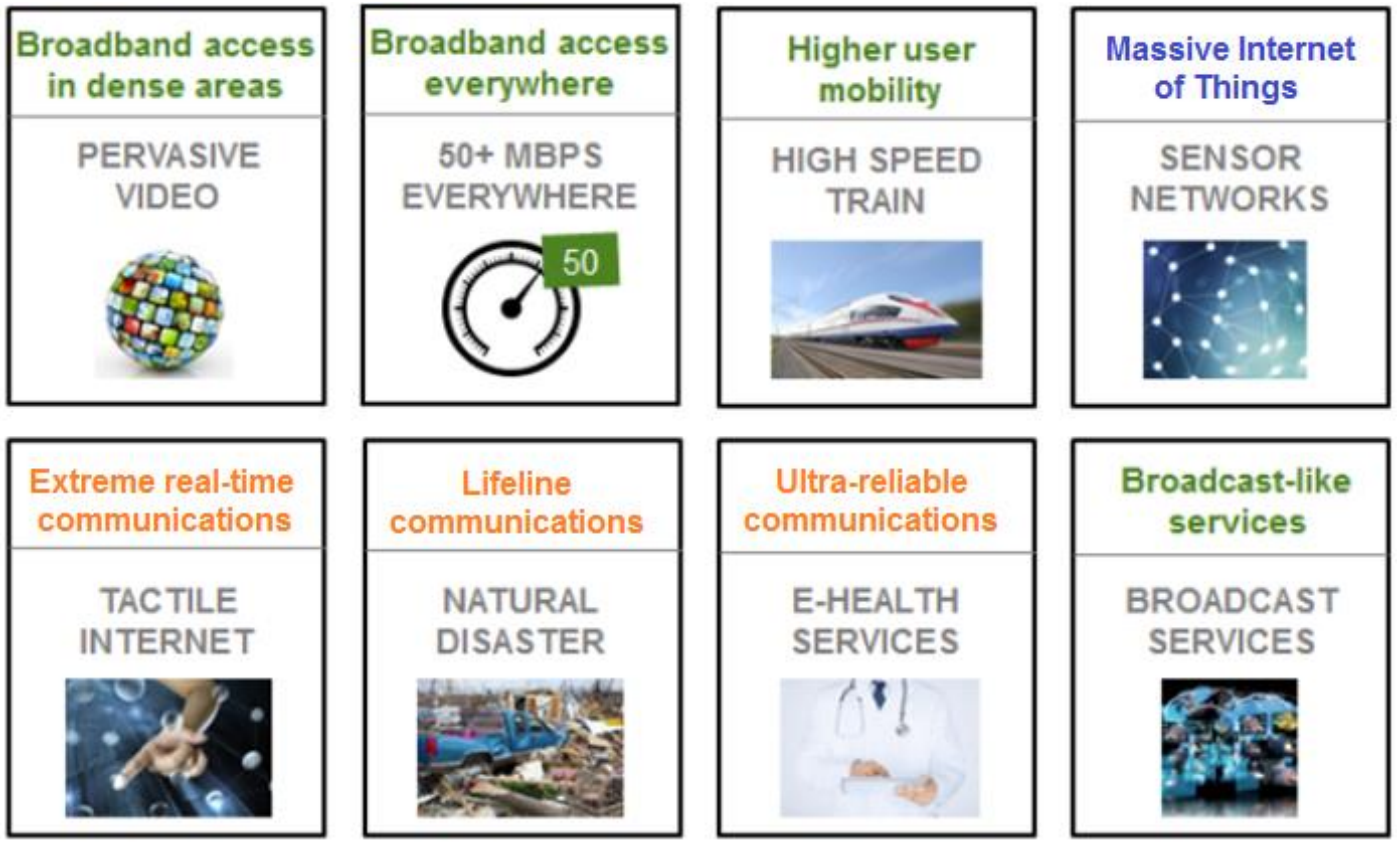
Operations Support System (OSS)



source: ETSI

- Allows the network operator to trigger management and control actions, including the configuration of policy
- Receives requests from external entities for MEC application instantiation or termination
- Determines if requests can be granted, and forwards granted requests to MEO

MEC and 5G



source: NGMN

MEC helps satisfying the demanding requirements for the 5G era:

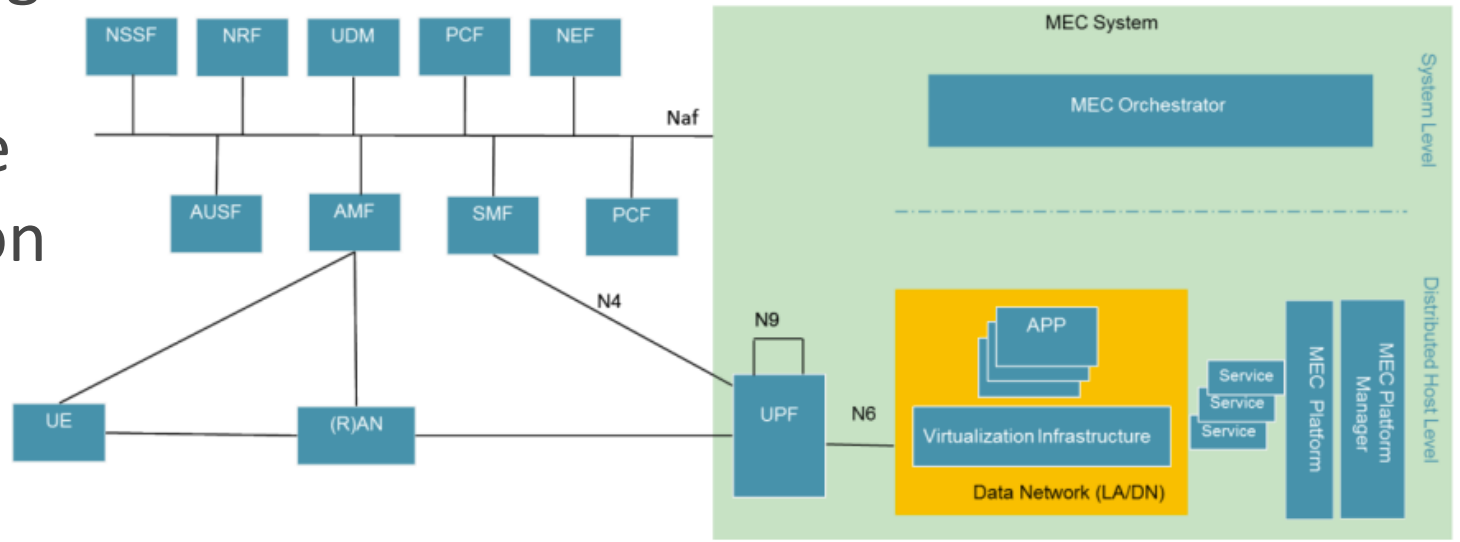
- Throughput,
- Latency,
- Scalability,
- Automation,
- Additional privacy and security,
- Significant cost savings

MEC and 5G

- MEC is a key technology and architectural concept for enabling the transformation to 5G
- Many of the use cases can be enabled with MEC prior to 5G!
- 5G networks based on the 3GPP 5G specifications are a key future target environment for MEC deployments

MEC and 5G System Architecture

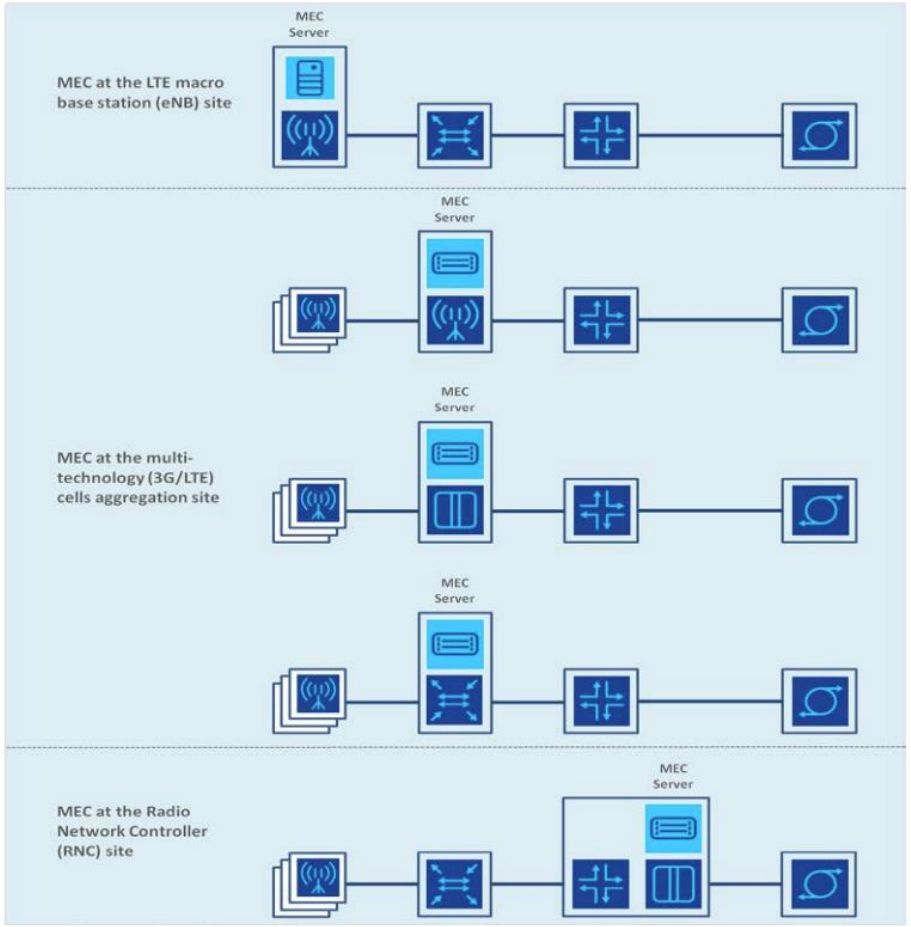
- The design approach taken by 3GPP allows the mapping of MEC onto **Application Functions (AF)** that can use the services and information offered by other network functions based on the configured policies



source: ETSI

MEC Server Deployment Scenarios

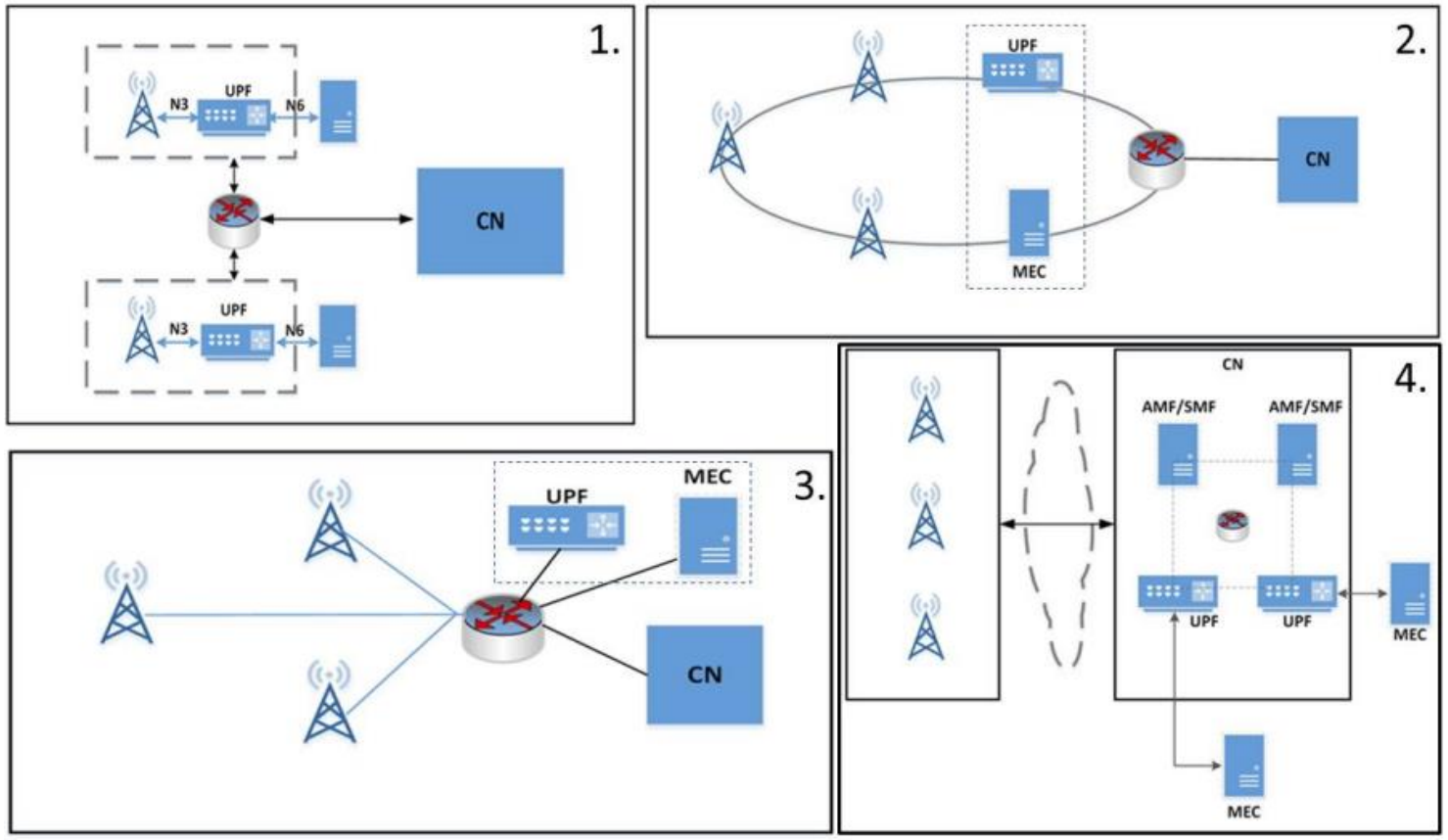
- Depends on scalability, physical deployment constraints, performance criteria and which network information will be exposed:
  1. LTE macro base station (eNB) site
  2. multi-Radio Access Technology (RAT) cell aggregation site
     - indoors within an enterprise
     - indoor/outdoor for a special public coverage scenario
  3. 3G Radio Network Controller (RNC) site



source: ETSI

Physical Deployment of MEC - Examples

1. MEC and the local UPF collocated with the Base Station
2. MEC collocated with a transmission node, possibly with a local UPF
3. MEC and the local UPF collocated with a network aggregation point
4. MEC collocated with the Core Network functions (i.e., in the same data centre)



source: ETSI

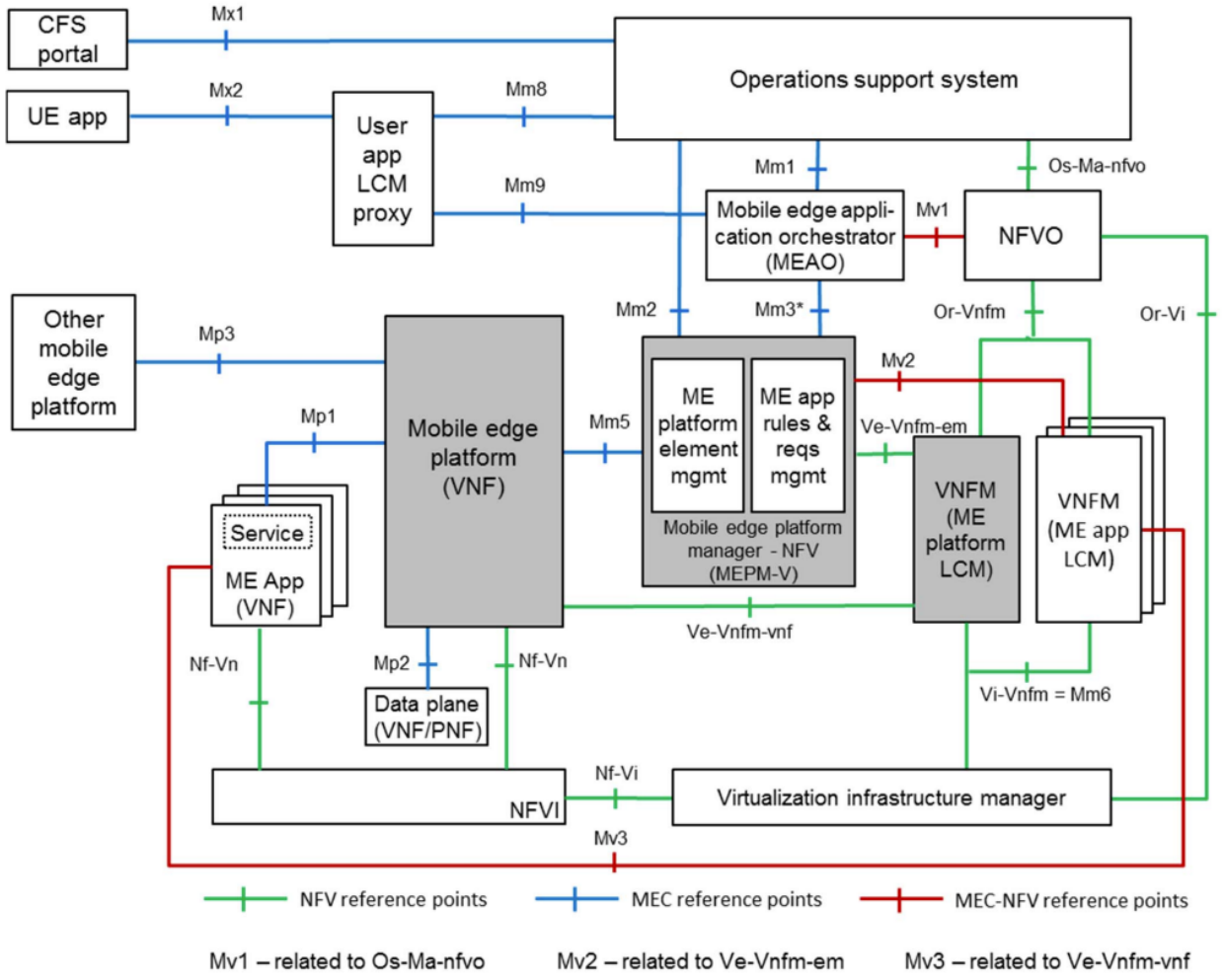
Relationship to NFV

- Complementary conecpts which can exist independently
- NFV is more focused in providing virtualization capabilities to the core network (i.e., virtualized NFs), while MEC is focused to enable the virtualization of networking, storage and computing at the edge
- To maximize the return on investment and enhance computing experience, operators may reuse the NVF’s infrastructure and its management for hosting MEC as well

MEC in NFV

- MEC uses a virtualization platform to run MEC applications
- In MEC deployment in NFV environment:
  - MEC uses the NFVI (NFV Infrastructure) as the virtualization platform
  - MEC applications appear as VNFs in the NFV environment
  - Parts of MEC orchestration can be delegated to the NFVO (NFV Orchestration)

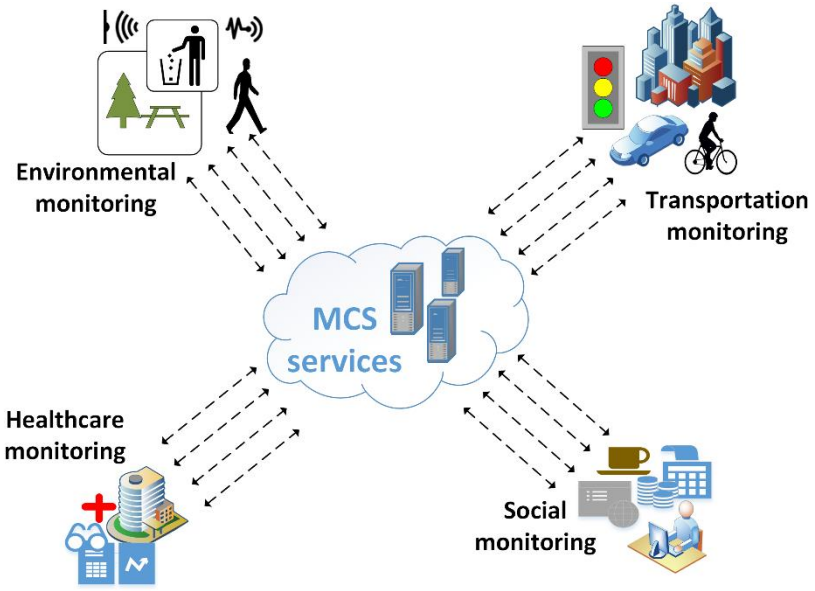
MEC in NFV Architecture



source: ETSI

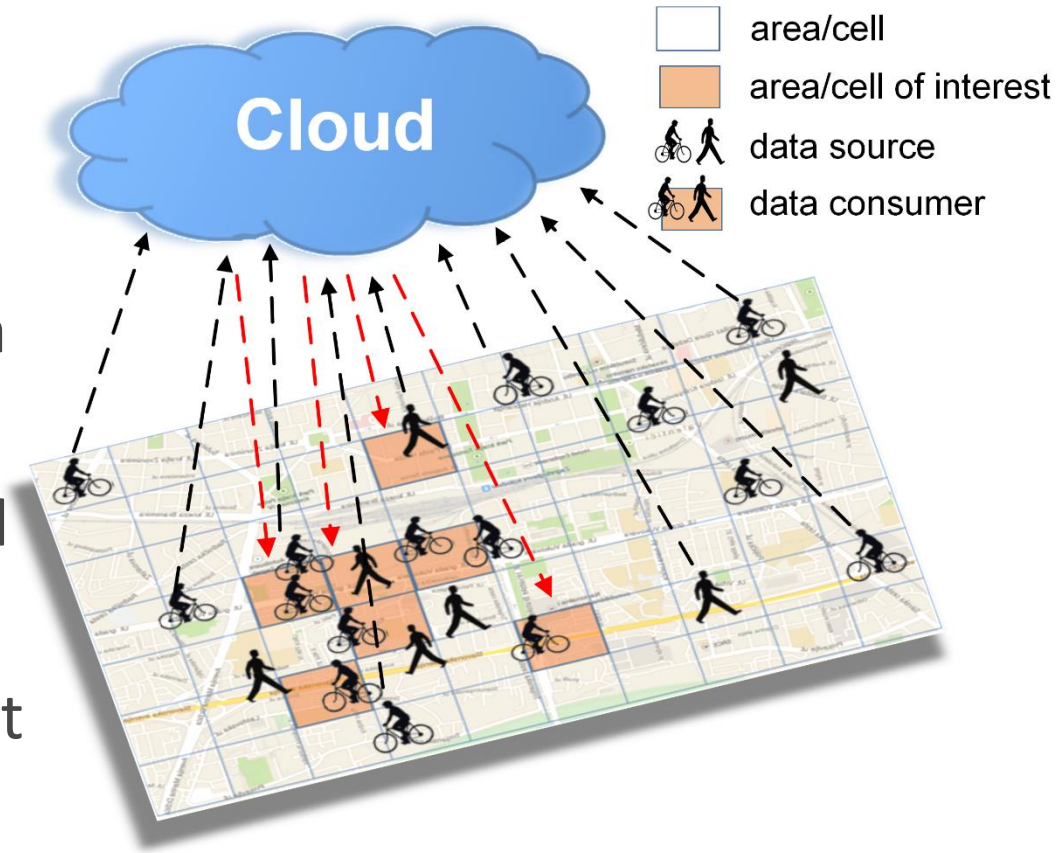
Use Case: Mobile Crowdsensing (MCS)

- A novel approach to obtain knowledge from wearable and mobile devices with limited processing and communication capabilities
- Benefits from a potential big user base ("power of the crowd")
- The main characteristics of crowdsensing devices:
  - person-centric
  - heterogeneous - use different types of embedded sensors
  - not directly connected to the Internet, but rather to a smartphone via Bluetooth
  - limited battery lifetime…



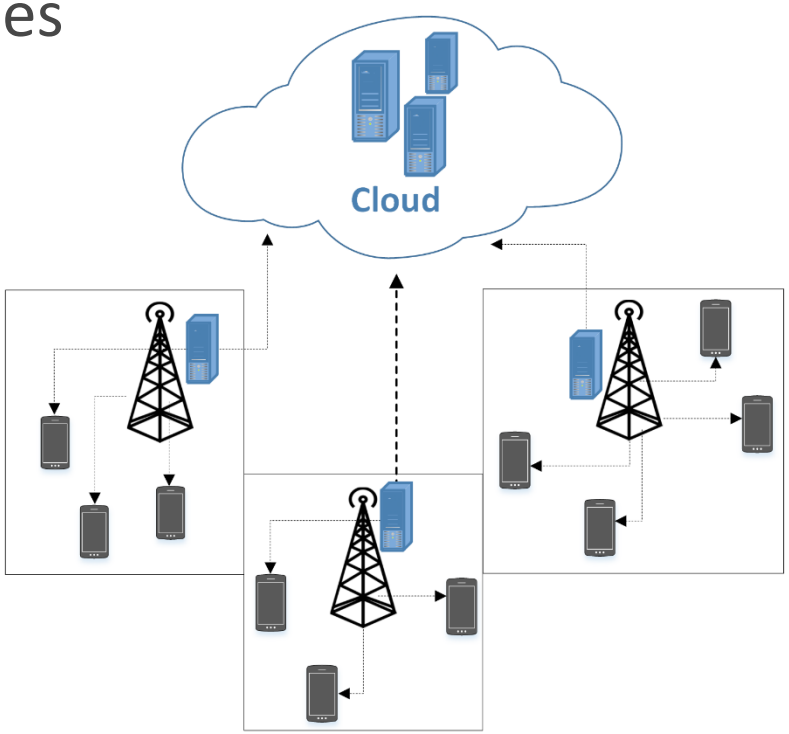
MCS

- City areas are either overpopulated or sparsely covered by mobile sensor readings
- It is necessary to control both the sensing process and data transmission from mobile devices to the cloud
- Sensors can produce a large amount of data in a short period of time
- Reduce the amount of raw data transmitted over the network
- Filter or aggregate unneeded and redundant data close to its production place

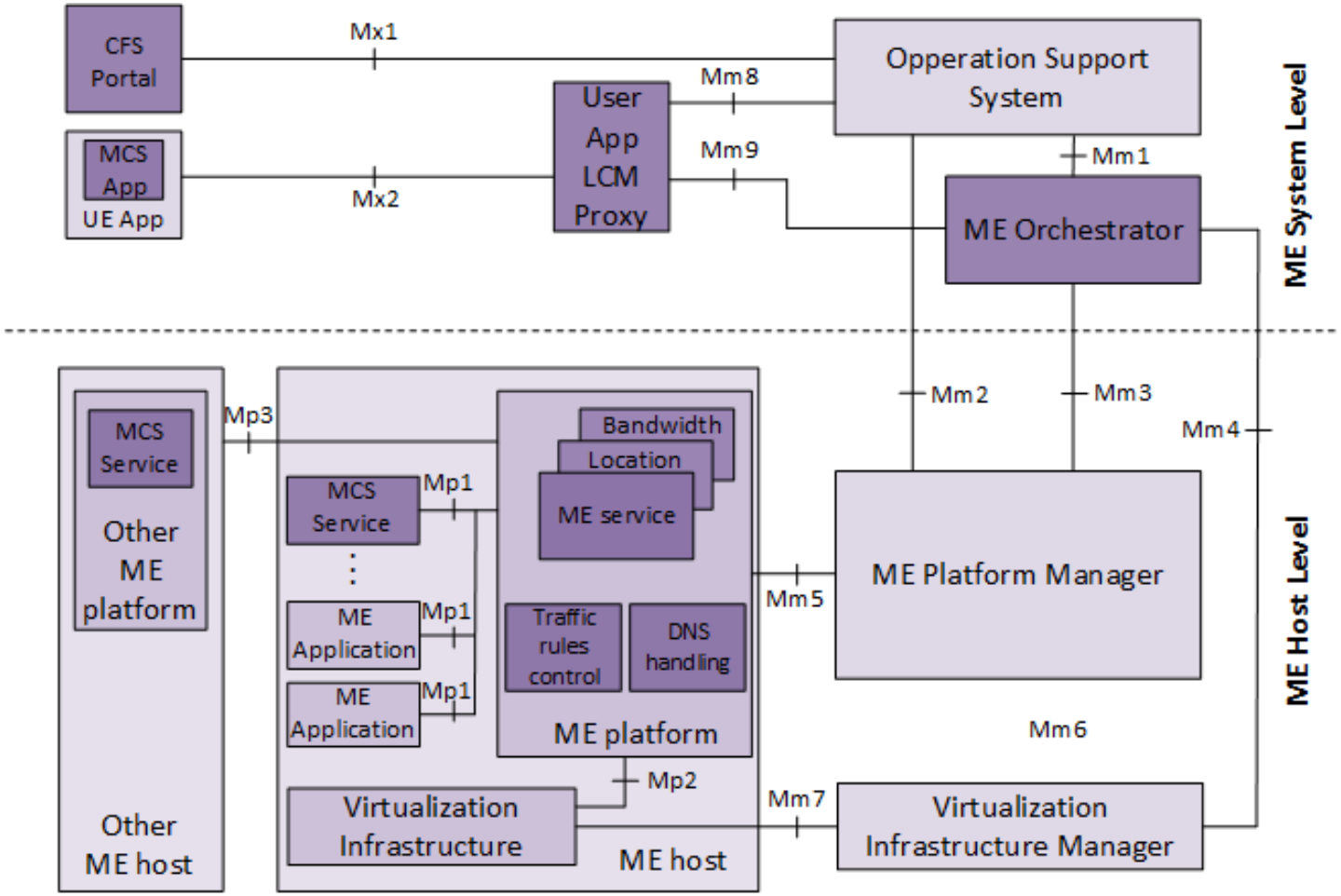


MCS and MEC

- Parallelization and partitioning of problem space based on location
- Computation offloading from mobile devices and cloud servers
- Reduced computational complexity of centralized cloud services
- Decreased latency in case of real-time MCS usage scenarios
- Reduced privacy threats



MCS at MEC Infrastructure



Conclusions

- MEC is a concept that:
  - enables low latencies for time-critical services, known in 5G as Ultra-Reliable Low-Latency Communication (URLLC) services
  - handles bandwidth-heavy applications closer to the end user in order to offload the transport network
- ETSI is leading standardization activities around MEC
- MEC provides compute and storage resources for applications geographically close to the end users: **high-bandwidth**, **low-latency** access to services, **real-time** radio network information, **context-aware** services
- Several 5G use cases are expected to rely on MEC to deliver added value for services to the end users
- In conjunction with SDN and NFV, MEC will be crucial in effecting low latency, high bandwidth and agility that will be able to connect trillions of devices