Università di Pisa

Dept. of Information Engineering

Course Wireless Networks - 2021/2022

Virtualization (LAB)

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LAB organization

- **PART I (theoretical)**
  - Introduction to SDN, NFV, MEC * concepts
  - Cloud computing and service-based architectures
- **PART II**
  - OpenStack cloud computing platform
  - OpenStack and NFV
  - Live session: OpenStack platform of the DII CrossLab project

* SDN = Software Defined Networking,
NFV = Network Function Virtualization,
MEC = Multi-access Edge Computing

LAB organization

* VM = Virtual Machine

- **PART III**
  - Virtualization overview and different approaches
    - VMs* on hypervisors, containers, alternative solutions

- **PART IV**
  - Containers -> Docker
  - Orchestrators -> Kubernetes
  - Hands-on session: Docker, docker-compose, Kubernetes

PART I

Outline

1) ETSI standardization group
2) Software Defined Networking (SDN)
3) Network Function Virtualization (NFV)
4) Multi-access Edge Computing (MEC)
    - Cloud computing
    - Edge computing
    - MEC and NFV

ETSI

- European Telecommunications Standards Institute (ETSI)
  - ICT standardization group in Europe

From the technologies/networks section in the ETSI site:

"*Today's consumers expect* ***communications services*** *to be* ***easily accessible and available everywhere****, on whatever devices they are using. Technically, this means networks must converge. We provide a comprehensive set of* ***standards for access network technologies***."

ETSI

- European Telecommunications Standards Institute (ETSI)
  - ICT standardization group in Europe

- Sets the requirements, reference architecture and infrastructure specifications necessary to ensure support to
  - Multi-access Edge Computing (MEC)
  - Network Functions Virtualization (NFV)
  - Open Source NVF Management and Orchestration (MANO)

  and many others!

Bibliography:
ETSI - Technologies standardized by our members : https://www.etsi.org/technologies/?cluster=networks

Software Defined Networks (SDNs)

Network Function Virtualization (NFV)

SDN

Replace distributed static network protocols with centralized, flexible, software network applications

- Centralized control plane
- Network flexibility and programmability
- New functionalities can be deployed, relocated and upgraded depending on the needs in nearly no time

NFV

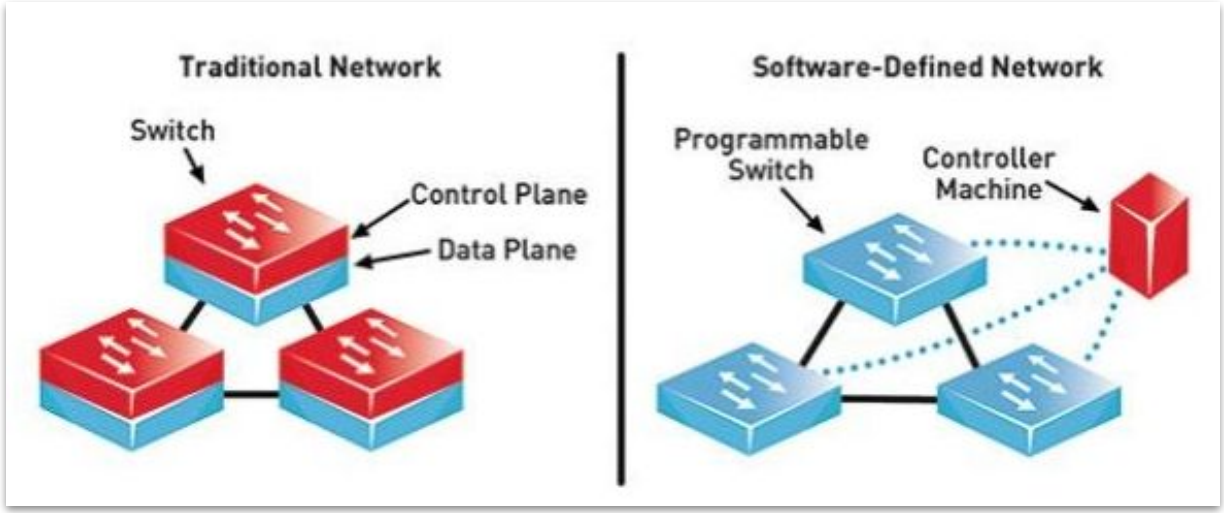
Use generic hardware to run software solutions instead of using specialized non-programmable network devices

- Hardware becomes cheaper (COTS)*
- Network functionalities can be easily relocated, optimizing network performance such as latency and capacity

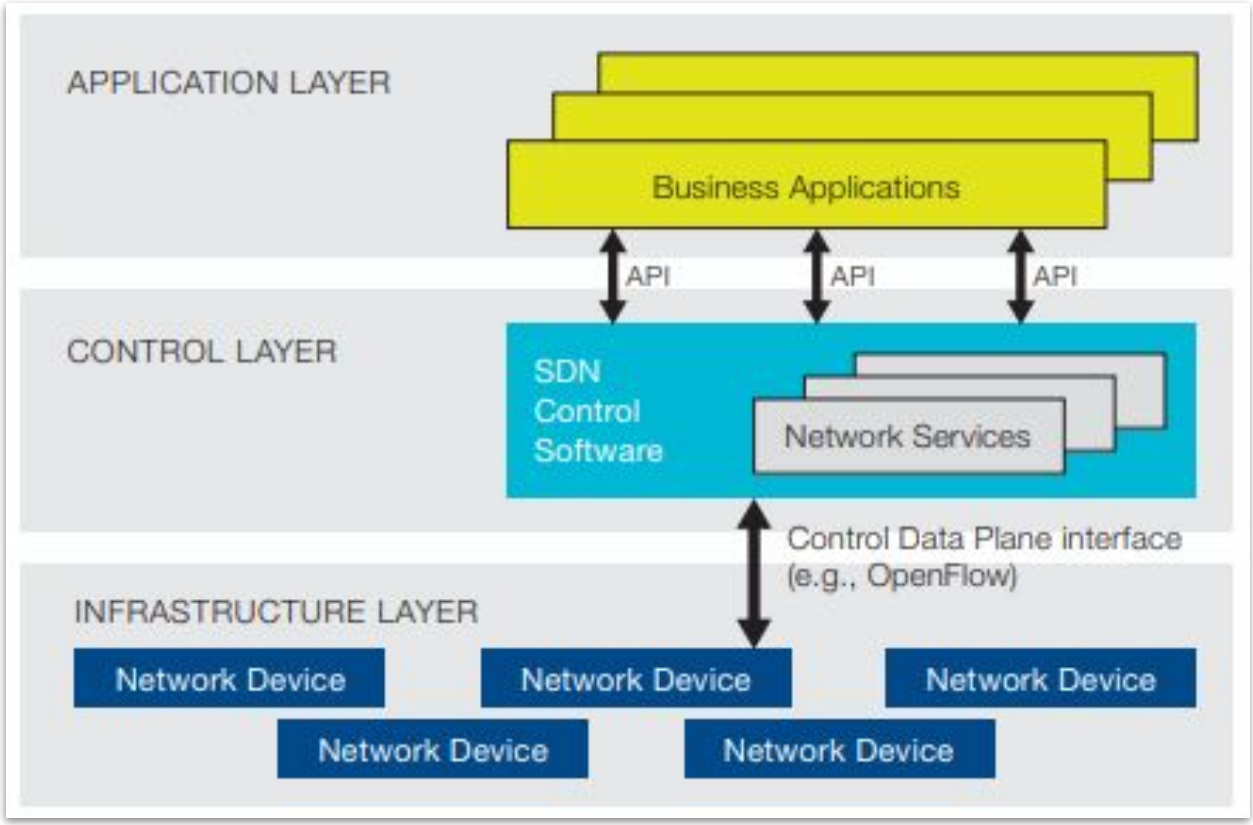
SDN and NFV are often used in conjunction!

* COTS = Commodity off the shelf

Traditional Networks to SDNs



Software-Defined Network Architecture



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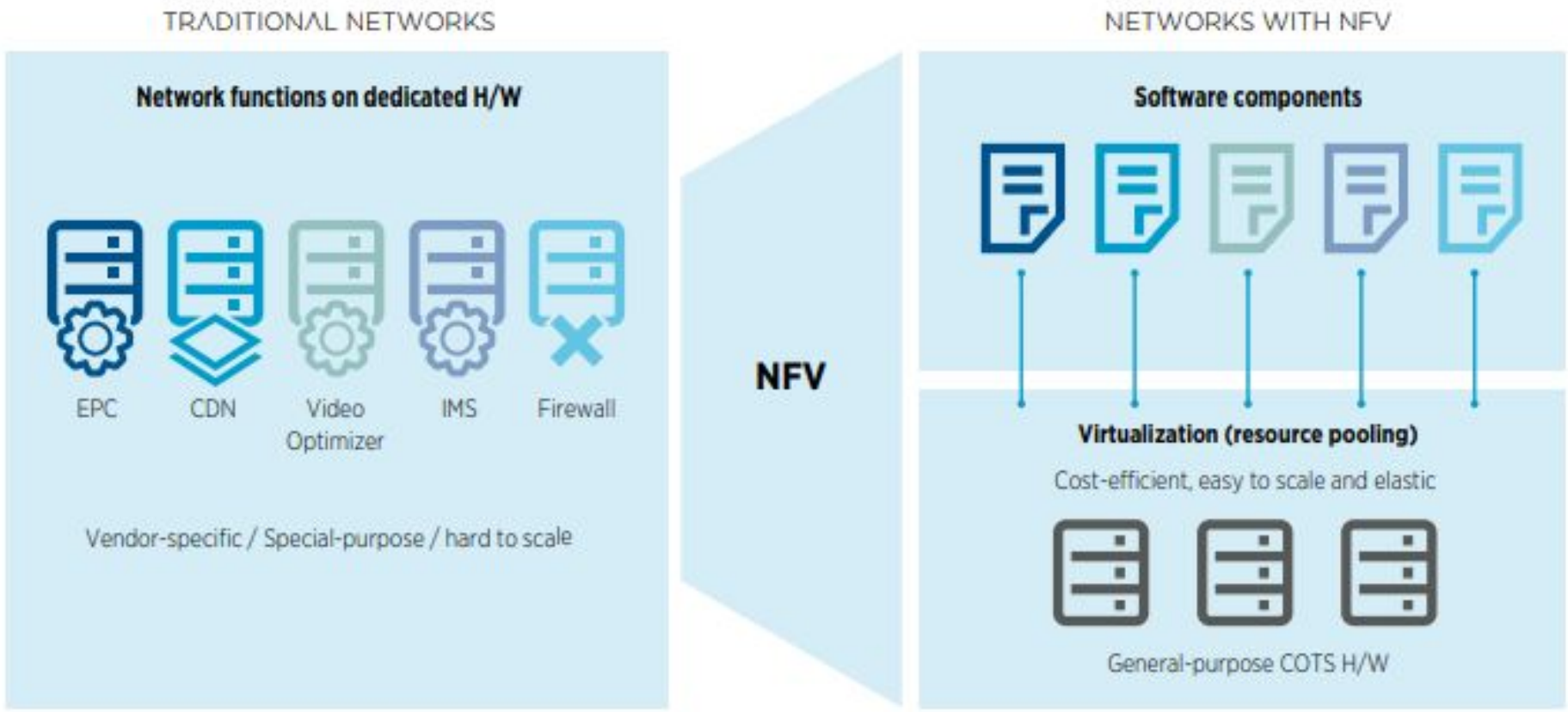
ONF White Paper - Software Defined Networking - The New Norm for Networks:
http://opennetworking.wpengine.com/wp-content/uploads/2011/09/wp-sdn-newnorm.pdf

Traditional Networks to Virtualized Networks



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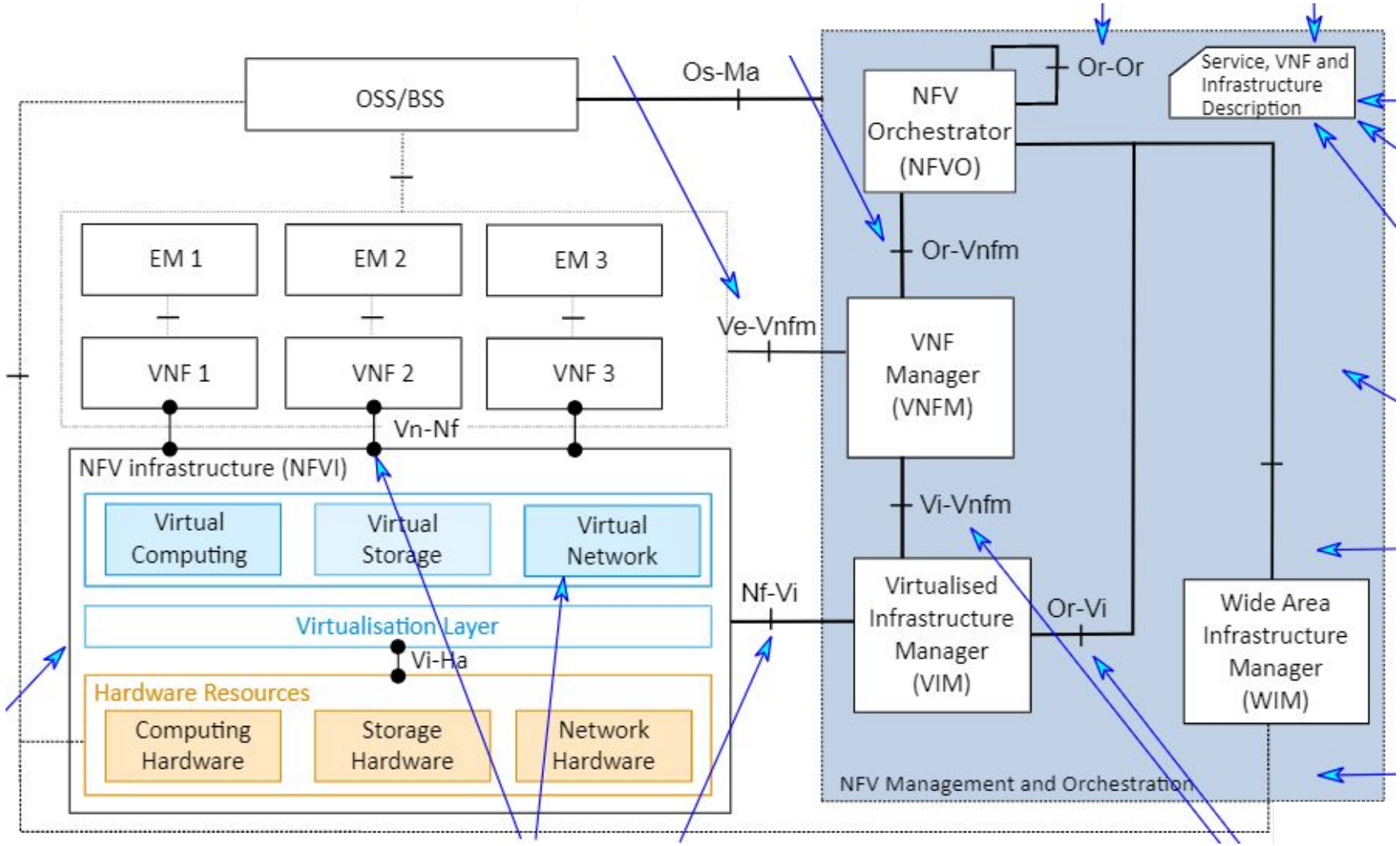
NFV: benefits and promises

- Equipment costs (CAPEX) and operational costs (OPEX) are reduced *
  - Reduced energy consumption and space, improved network monitoring
- Time to market speed is increased
  - Software-oriented innovation to rapid prototype and test
  - Development of new services is encouraged
  - New revenue streams are generated
- Multi-version and multi-tenant network appliances
  - Single platform can support different applications, users and tenants
- Flexibility
  - Rapid and dynamic provisioning and instantiation of new services in various locations

* CAPEX = Capital Expenditure,
OPEX = Operational Expenditure

ETSI NFV architecture framework



Bibliography:

ETSI - 5g Standards - NFV Architecture : https://www.etsi.org/technologies/nfv

General components of NFV platform

- **Virtualized Network Functions (VNFs)**
  - Software implementation of network functions (e.g. routers, firewalls, mobile packet processors, load balancers)

- **NFV infrastructure (NFVi)**
  - Comprehends physical resources (compute, network, storage) and the virtualization layer that makes up the infrastructure
  - Foundation for the NFV layer
  - Managed by the **Virtual Infrastructure Manager (VIM)**

General components of NFV platform

- **NFV Management and Orchestration (MANO)**
  - Provides service management and orchestration required throughout the network function life-cycle
  - Service definition, monitoring and life-cycle management are decoupled from the physical infrastructure
  - Two interacting entities: **Virtual Network Function Manager (VNFM)** and **Orchestrator (NFVO)**
    - NFVO interacts with databases and business function applications (e.g. billing, support) and can create new services for a customer
    - VNFM triggers the instantiation of a new virtualized function (this may result in multiple virtual machine instances) when NFVO asks for a new service

Multi-access Edge Computing (MEC)

MEC

Bibliography:
ETSI - 5g Standards - MEC
https://www.etsi.org/technologies/multi-access-edge-computing

Application developers and **content providers** can use MEC resources to obtain

- cloud computing capabilities
- IT service environment

at the **edge** of the network

- Edge environment characteristics
  - ultra-low latency
  - high bandwidth
  - applications can access in real-time to radio network information

- MEC will enable new vertical segments
  - video analytics
  - location services
  - Internet of Things (IoT)
  - augmented reality
  - optimized local content distribution
  - data caching

Cloud Computing

Definition

Cloud Computing

From the Official NIST definition:

- Model for enabling convenient, on-demand network access to a shared pool of configurable computing resources
- Computing resources
  - Networks
  - Servers
  - Storage
  - Applications
  - Services
- Resources can be rapidly provisioned and released with minimal management effort or service provider interaction

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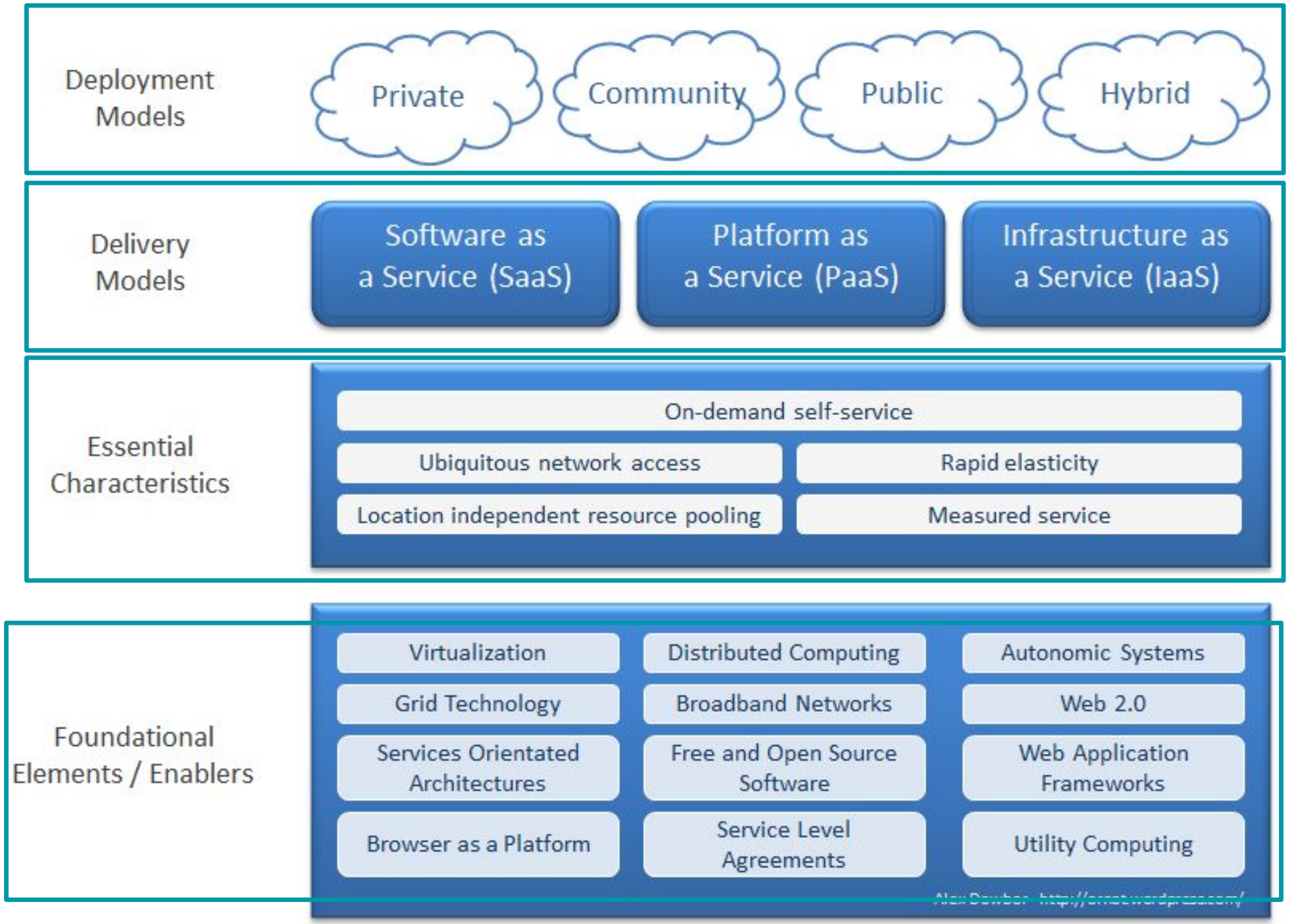


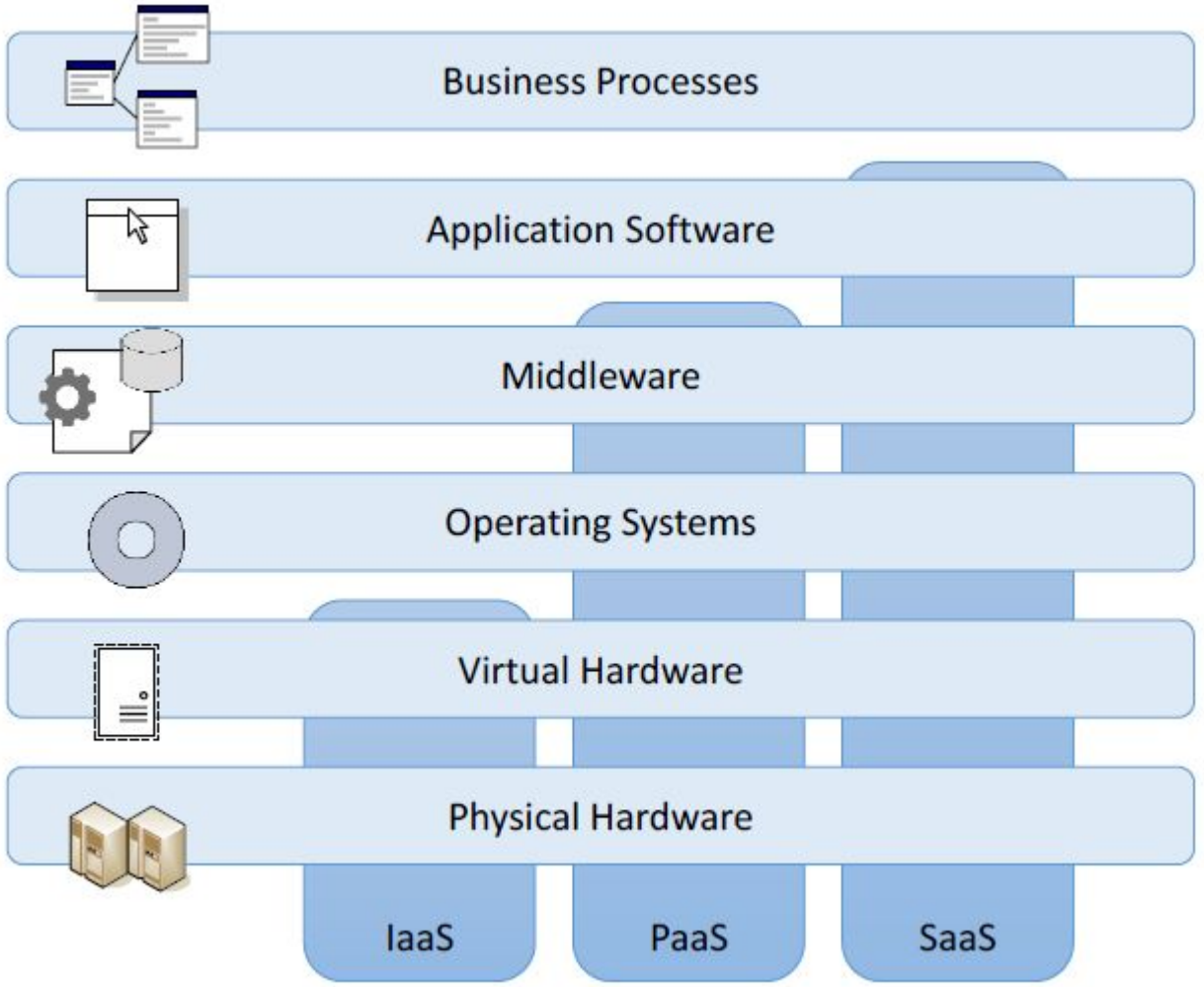
Bibliography:
https://csrc.nist.gov/projects/cloud-computing

Cloud Computing

Application Stack

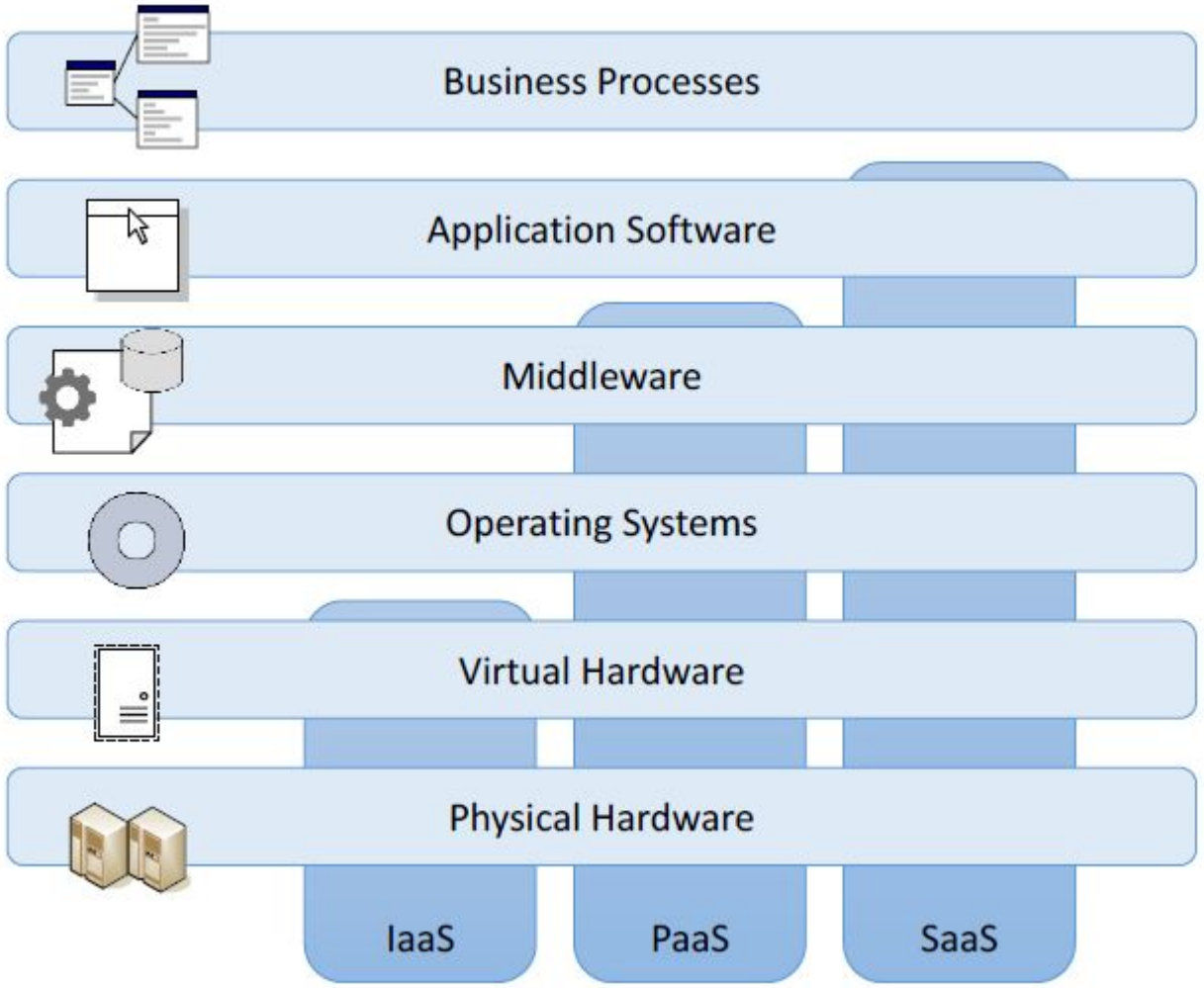
Cloud Computing Application Stack

- **Physical hardware**
  - tangible infrastructures
    - servers, storage, networks connecting servers
- **Virtual hardware**
  - hardware components mapped into virtual counterparts
  - users perceive the system as composed by virtual computing, storage, networking resource



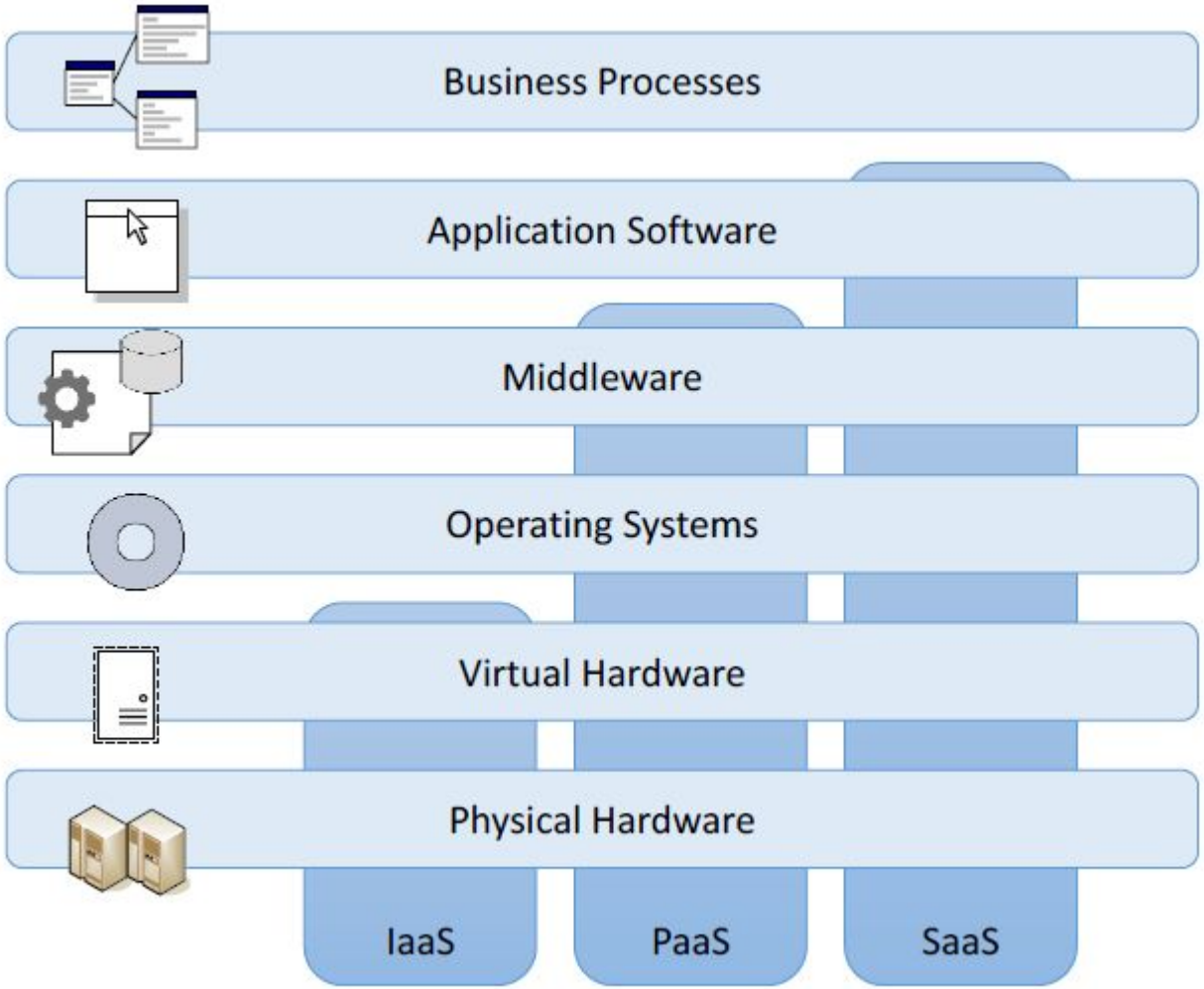
Cloud Computing Application Stack

- **Operating systems**
  - basic software installed on top of virtualized infrastructure
    - e.g., Windows Server, Linux, Apple OS X Server
- **Middleware**
  - software installed on OS
  - provides an environment to execute applications and handle data storage
  - e.g., Java Virtual Machine, IBM WebSphere, MySQL



Cloud Computing Application Stack

- **Applications**
  - applications interfacing with users
  - provide tools to execute tasks/activities
    - e.g., email, FTP, web browsing
- **Business processes**
  - complex set of activities
  - typically managed by companies
  - e.g., order processing, budget approval, payments

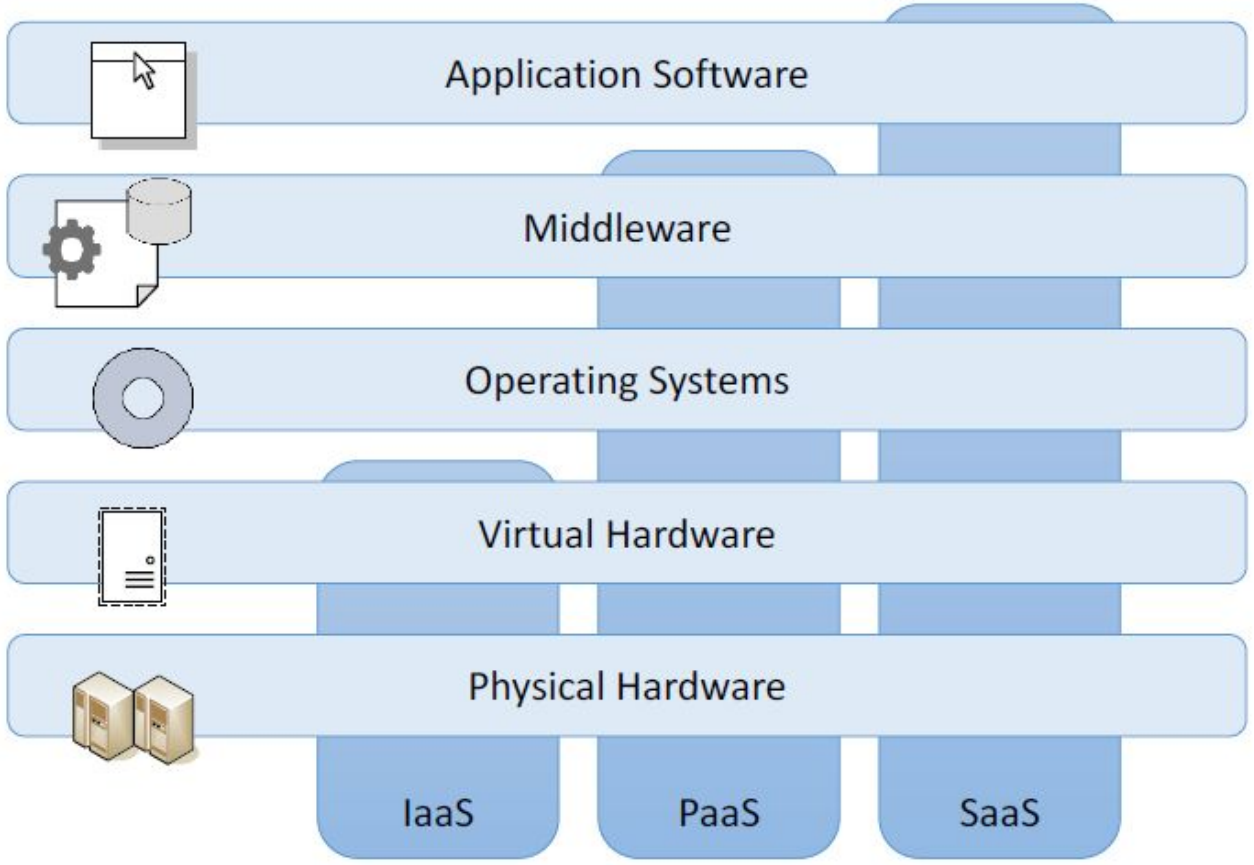


Cloud Computing

Service Models

Cloud Computing Service Models

- **Infrastructure as a Service (IaaS)**
  - Virtual or physical hw accessible to customers (computing, storage and networking resources)
- **Platform as a Service (PaaS)**
  - An execution environment is offered to customers to deploy their apps
- **Software as a Service (SaaS)**
  - Applications directly available to users (e.g. email, web browsing) through Graphical User Interface (GUI) or Application Program Interfaces (APIs)



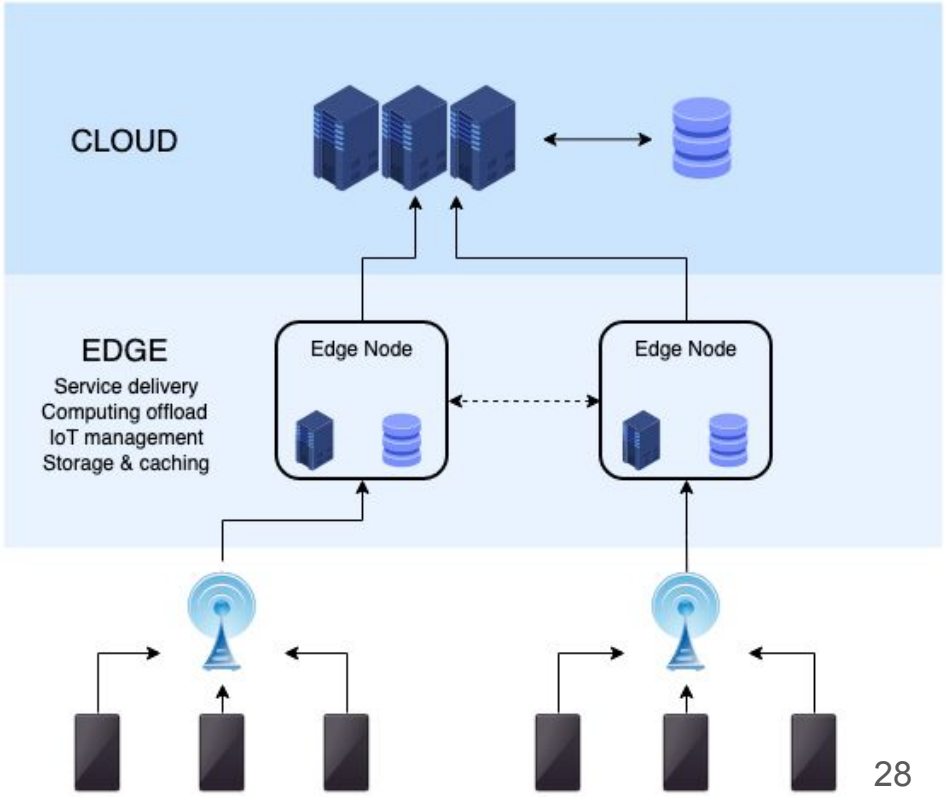
Edge Computing

Edge Computing

From the Official ETSI ISG MEC definition:

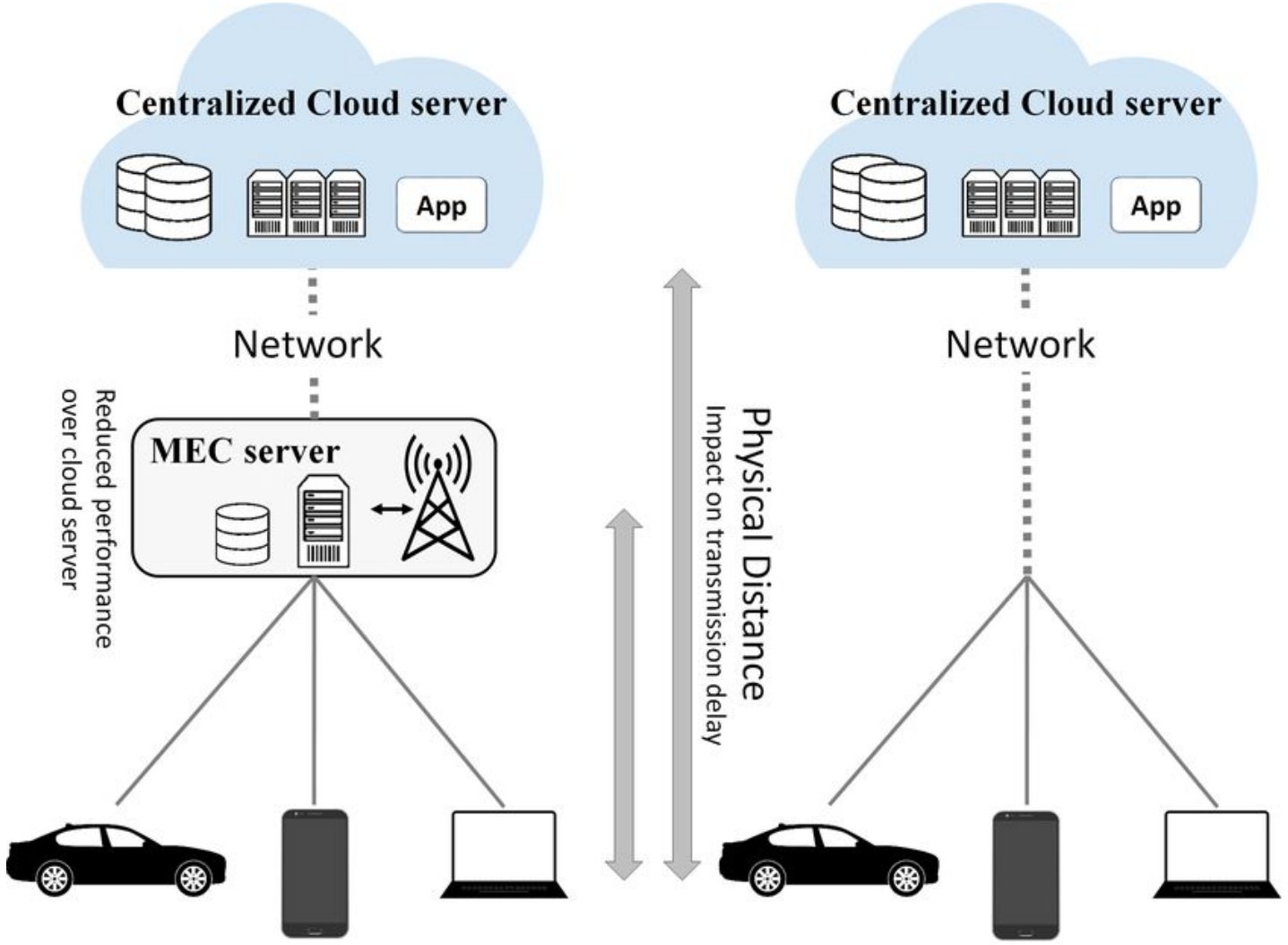
Multi-access Edge Computing offers to application developers and content providers cloud-computing capabilities and an IT service environment at the edge of the network

- Edge incorporates benefits of **virtualization** and **cloud computing**
  - high-powered computing capability close to users
  - leverage proximity to minimize latency
  - improve privacy aspects



MEC and NFV

Edge Computing: scenario



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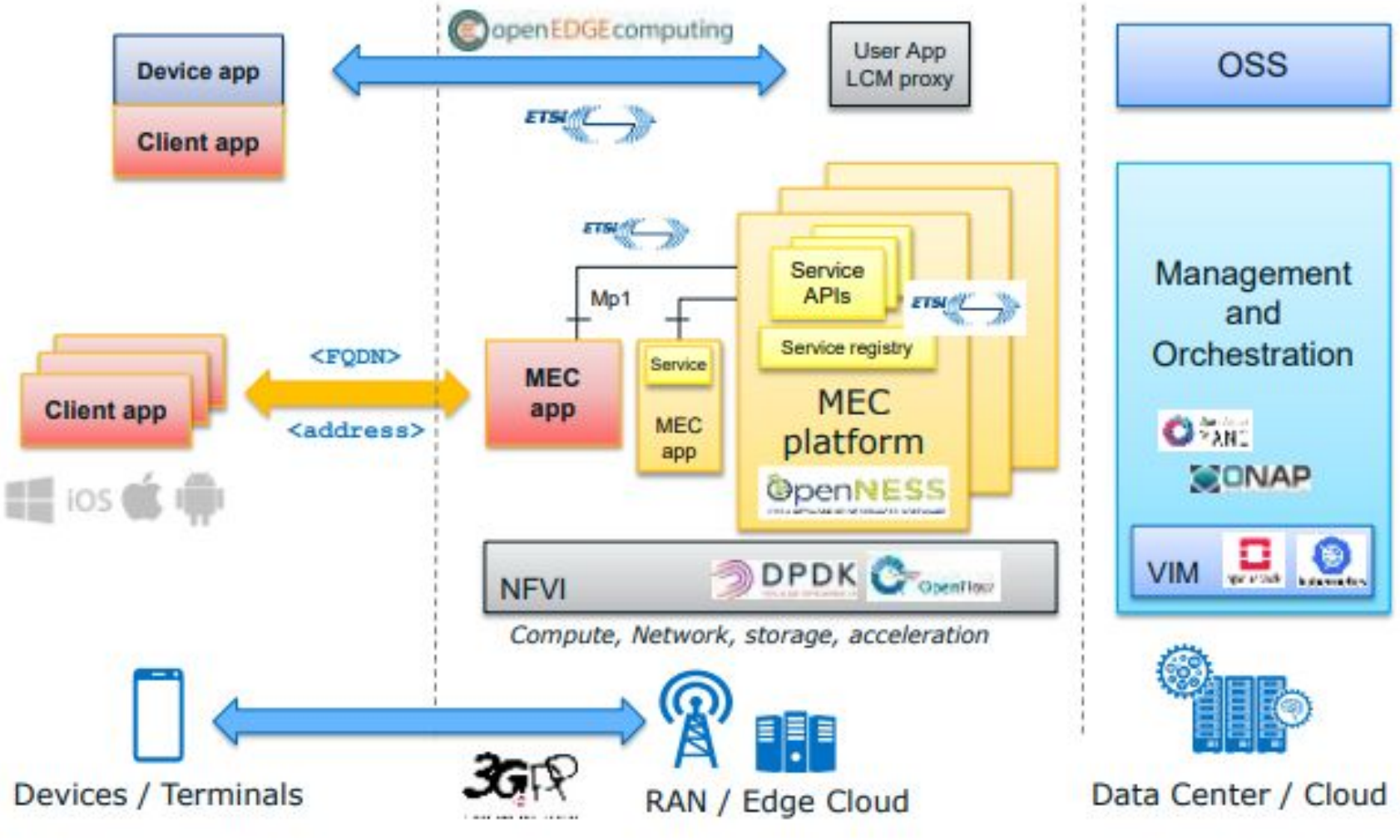
Functional entities in the MEC architecture



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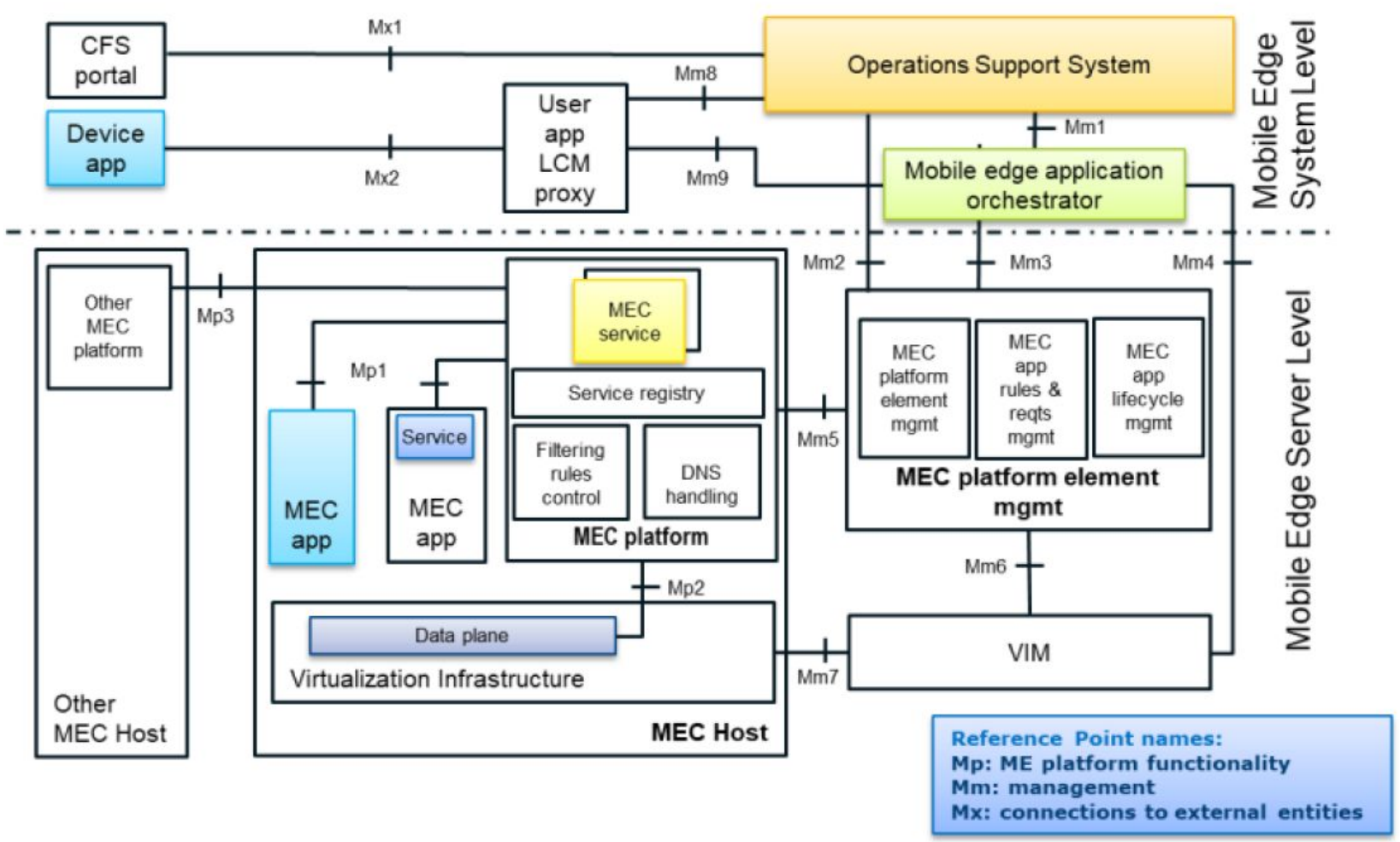
https://builders.intel.com/docs/networkbuilders/edge-computing-from-standard-to-actual-infrastructure-deployment-and-software-development.pdf

ETSI MEC architecture framework



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What kind of services can we find on MEC?

- **Consumer-oriented services**
  - services directly used by end-users
  - e.g., gaming, augmented/assisted reality, application computation offloading

- **Network performance and QoE improvements**
  - services not directly used by end-users
  - improve user experience by improving network performance
  - e.g., content/DNS caching, performance optimization

- **Operator/third-party services**
  - services that use computing/storage resources at the edge of the operator's network
  - not used directly by end-users
  - typically used by third-party services
  - e.g, active device location tracking, big data and video analytics

How services can interact with each others?

- expose a API based on HTTP and REST **
- simplify deployment and evolution of networks
  - modular design of applications

** API = Application Programming Interface,
REST = Representational State Transfer

API: set of definitions exposed by a software application

- contract between information provider and the user requiring the information
- needed to interact with the app/service (retrieve information, perform function)

REST: architectural style/constraints to represent state/information to be transferred

- information delivered via HTTP
- format can be JSON, plain text, ...

Bibliography: What is a REST API?
https://www.redhat.com/en/topics/api/what-is-a-rest-api

Formats to Represent Data to Exchange

- **JSON (JavaScript Object Notation)**
  - text format for data interchange
  - easy for humans to read and write
  - easy for machines to parse and generate
- Built on two structures
  - **Object** is an unordered set of name-value pairs between **{ }** and separated by **,** *comma*
    - values can be *string*, *number*, **true**, **false**, **null**, *objects*, *arrays*
  - Ordered **lists/arrays** of values between **[ ]** and separated by **,** *comma*

Encode data objects into strings to transmit or store them in a file

- a series of bytes can be easily stored or sent across the network

This process is commonly referred to as **data serialization** and **deserialization**

Object:

```
{foo: [1, 4, 7, 10], bar: "baz"}
```

JSON string representing the initial object:

```
'{"foo":[1,4,7,10],"bar":"baz"}'
```

Bibliography:
https://www.json.org/json-en.html

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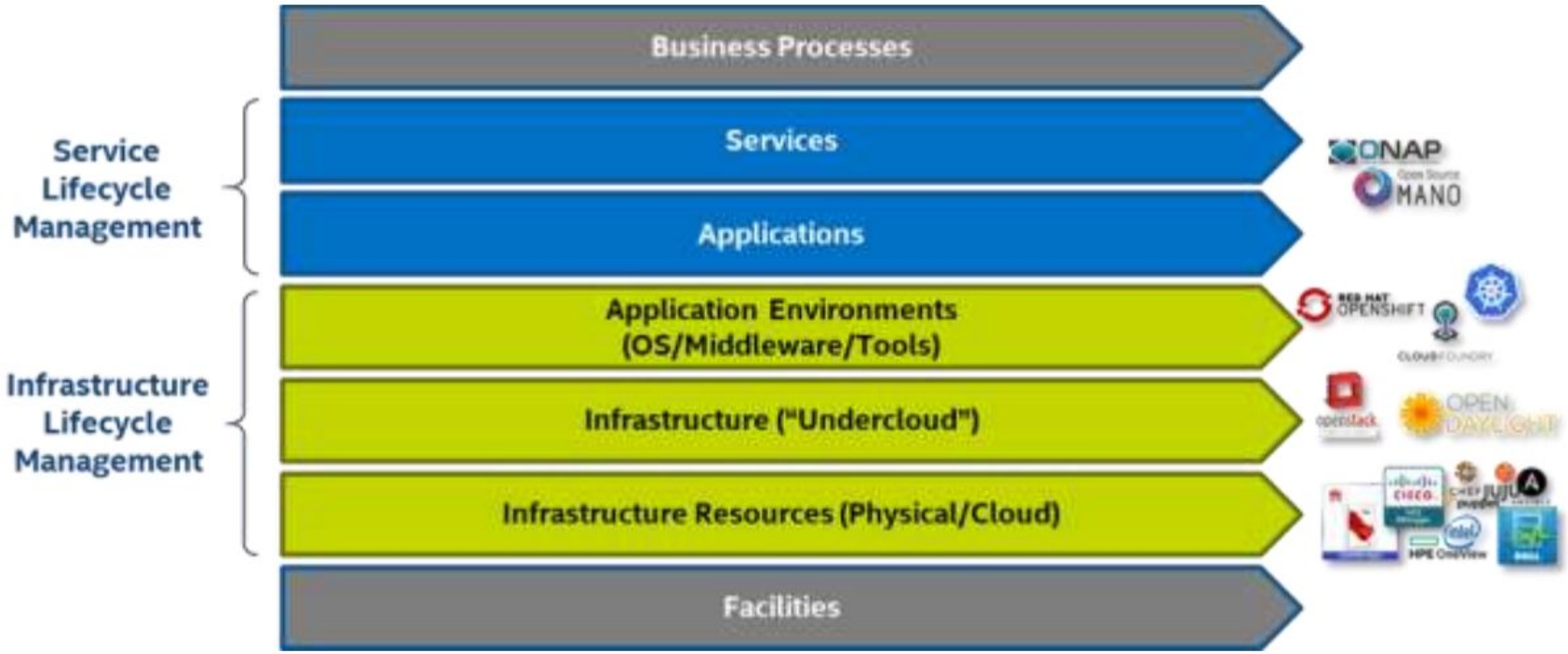
https://stackoverflow.com/questions/3316762/what-is-deserialize-and-serialize-in-json#:~:text=JSON%20is%20a%20format%20that,convert%20string%20%2D%3E%20object).

SDN, NFV and MEC - recap slide

- **Software Defined Networking (SDN)**
  - logically centralized control plane
  - flexible and rapid configuration of network resources
- **Network Function Virtualization (NFV)**
  - deploy network functions as software components
  - they run on commodity hardware platforms instead of specialized hardware
- **Multi-access Edge Computing (MEC)**
  - cloud-computing capabilities at the edge of the network for
    - processing, storage
    - network services, control and management

Levels of orchestration - recap and tools



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