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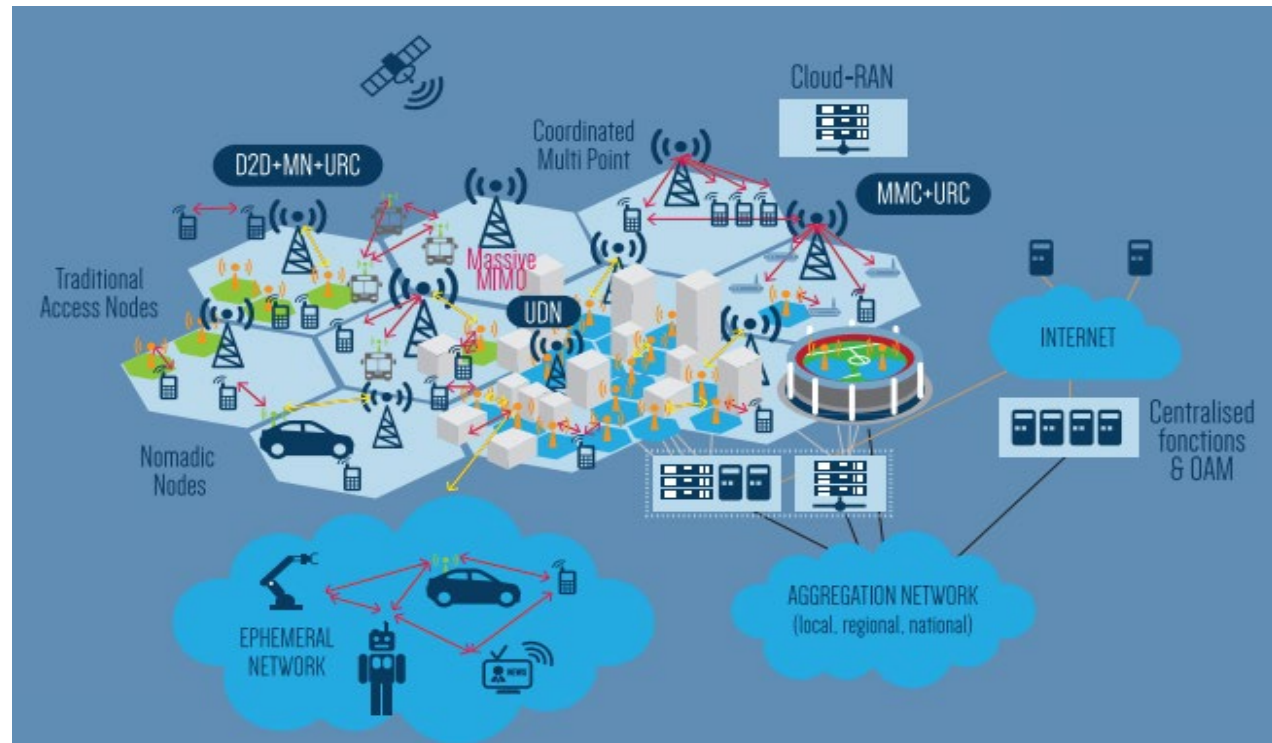
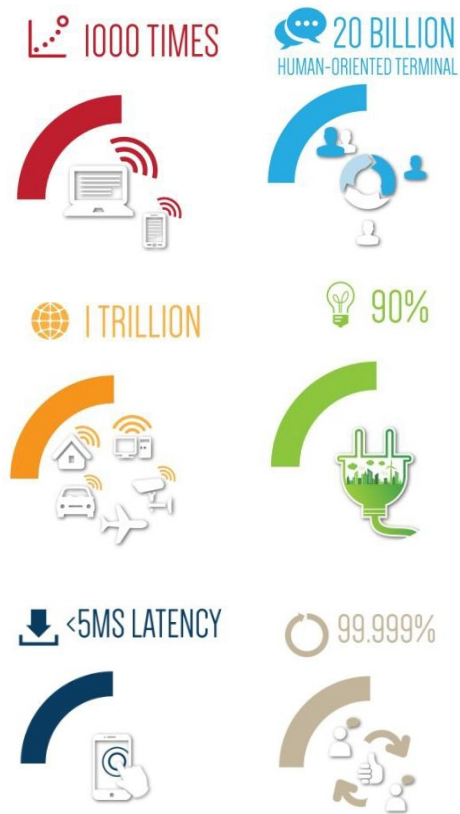
AI and Blockchain Technologies in 5G Networks

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5G introduction

- 5G is a technology that unifies fixed and wireless access enabling the deployment of new services with advanced targeted requirements:
 - High capacity, High Volume, Low latency, Fast service deployment, ...

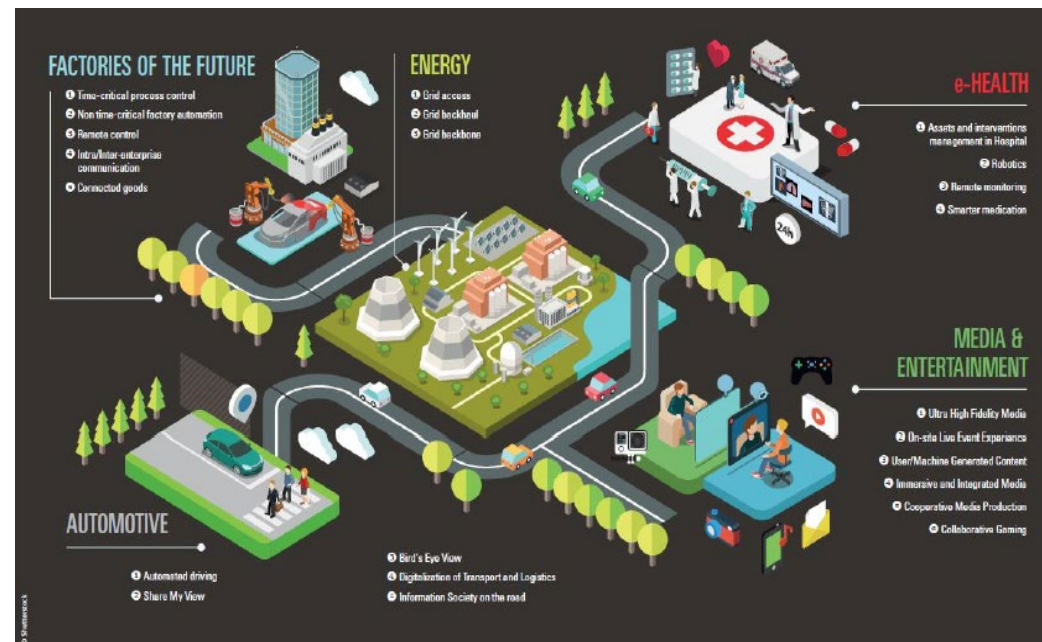


5GPPP Vision paper – 2015

<https://5g-ppp.eu/wp-content/uploads/2015/02/5G-Vision-Brochure-v1.pdf>

5G refocus

- 5G is a technology that unifies fixed and wireless access enabling the deployment of new services with advanced targeted requirements:
 - High capacity, High Volume, Low latency, Fast service deployment, ...
- 5G is the connectivity approach that targets the deployment of new services in a plethora of vertical sectors (i.e. technology solutions but more market oriented)
 - Media, Manufacturing, Automotive, Energy, eHealth, Smart city

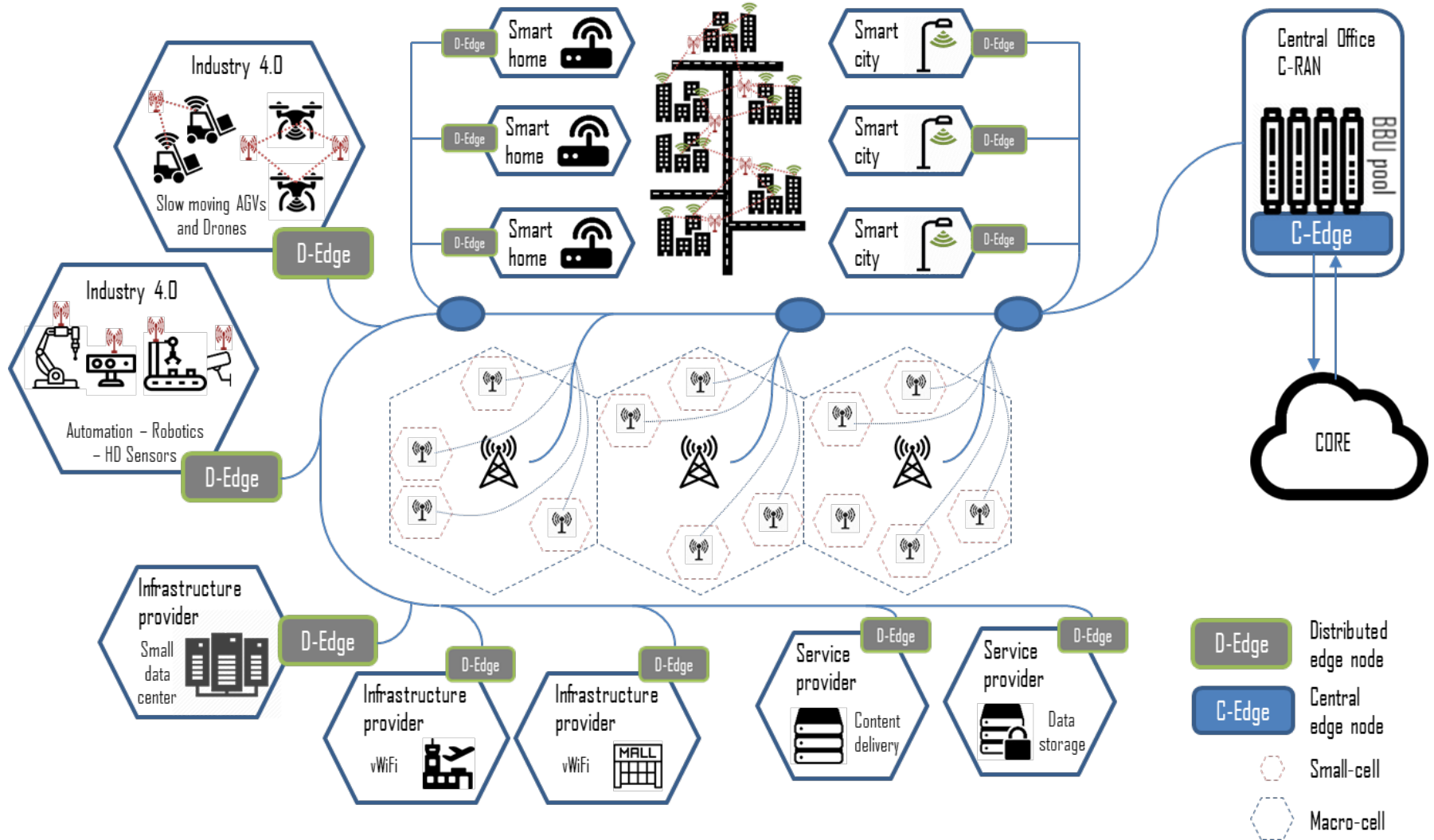


Source: 5G Infrastructure Association: 5G Empowering vertical industries. White Paper, 2017,

5G evolution

- 5G is a technology that unifies fixed and wireless access enabling the deployment of new services with advanced targeted requirements:
 - High capacity, High Volume, Low latency, Fast service deployment, ...
- 5G is the connectivity approach that targets the deployment of new services in a plethora of vertical sectors (i.e. technology solutions but more market oriented)
 - Media, Manufacturing, Automotive, Energy, eHealth, Smart city
- 5G describes the new (diverse) metro-access network environment that enables
 - The seamless deployment of services and **user-tailored** (or weather-environment-, market-, ...-, tailored) applications...
 - ... over **collaborative** infrastructures (smart city, WiFi, Wireless, mini-DCs etc.)...
 - ... with **optimized** use of resources (transport and processing resources)
 - ... and in a **trusted** manner (secure and fair).

5G evolution sectors and infrastructure



Computing models and 5G

■ Cloud computing and 5G

What does 5G assume as edge or fog node?

■ 5G Edge computing

- Any end user device can be a node
→ The obvious opposite of cloud

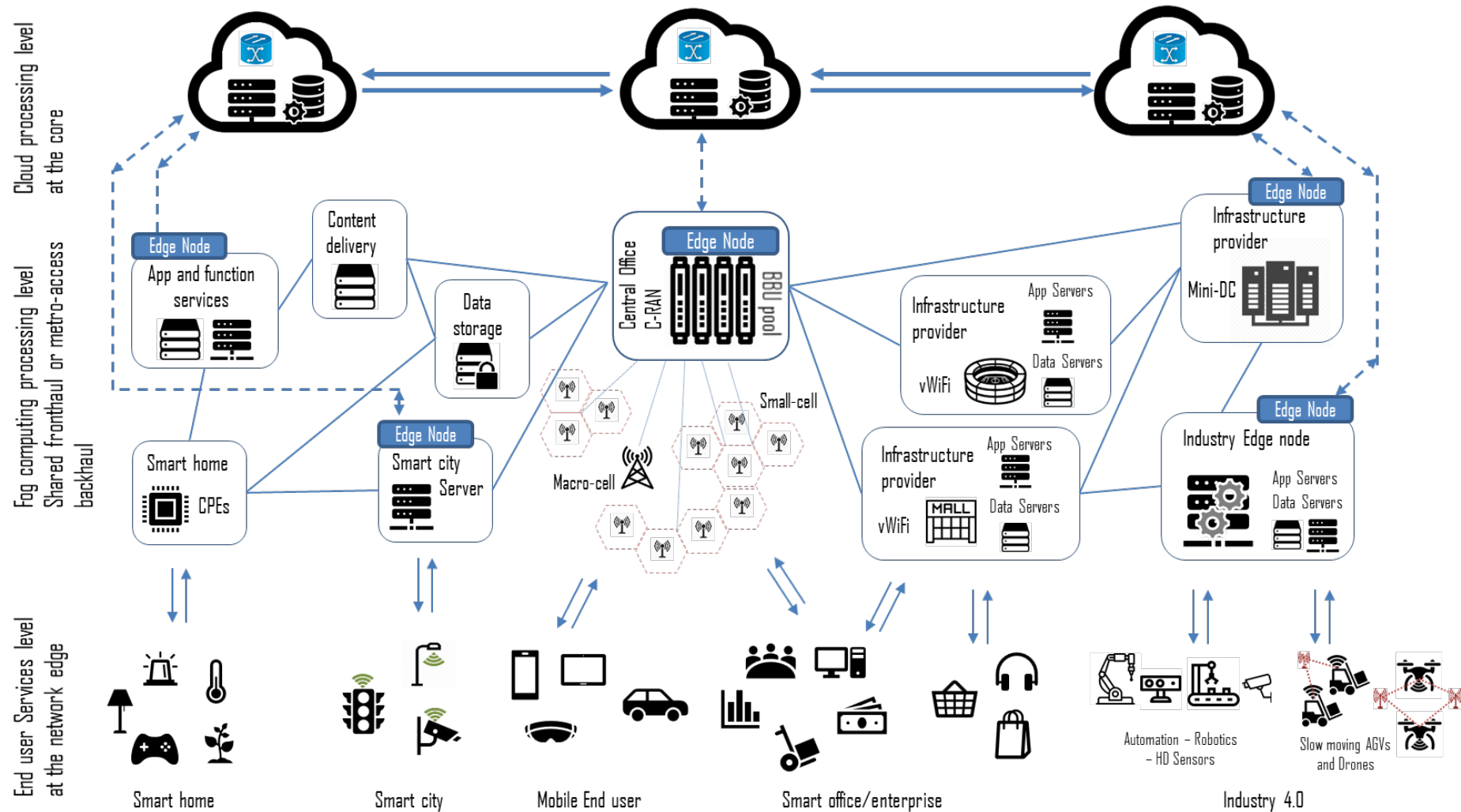


■ 5G Fog computing

It is a matter of definition!

- Specific edge nodes with sufficient resources are becoming processing nodes.
- Fog nodes offer
 - processing power,
 - storage capability,
 - memory
 - data content
- Interconnection of fog nodes over 5G infrastructure
- Sharing of 5G fog nodes processing

The Fog-based 5G approach



Blockchain in 5G

- The main concept:
 - Blockchain for **trusted asset management**
 - Assets are network resources and may include both transport (infrastructure) and computational resources
- The rational:
 - Co-existence of large number of computational nodes and attached infrastructures with variety of offered resources
 - Dynamic change of resources as processes run
 - Both private and shared (public) resources per node
 - HW failures or upgrades
 - Need for a trusted way to allocate and use the offer resources
 - Independent Infrastructure, Function or Application providers have no established trust among them
- The use:
 - Block chain technology to implement dynamic SLAs
 - Nodes to declare regularly asset (i.e. resource) availability.
 - Assets to be reserved (resource allocation) when needed
- The issues:
 - Assets are physical (off-chain)
 - Assets on same node must be isolated (secure slicing)
 - Nodes with blockchain processing power
 - Who regulates the proper execution of contracts

Smart contract based provisioning in 5G



- The more advance concepts
 - Use of blockchain for provisioning of resources in future
 - Add smart contract (re)negotiation features

- Future-Looking Smart Contracts
 - Support of resource reservations in future times with blockchain –based guaranties
 - E.g. For large events (concert), Predicted increased of traffic in certain areas etc.
 - Allow the agreed (future) states, to be recorded in the blockchain (in future blocks)
 - current blockchains do not support this, but an asset based contract can allow this.
 - Requires new primitives in the language of smart contracts and possibly new blockchain consensus algorithms to be developed.

- Negotiated contracts
 - New contracts: If contract terms cannot be met then ask or examine alternatives
 - Existing contracts: Examine the renegotiation of terms to improve services or to fit more contracts

Machine learning in 5G

■ Key topics of Machine Learning technology in 5G

- Traffic pattern variations over time
 - Network and service usage behavior linked with other events and environmental conditions
 - User movement behavior (especially in small cell environments)
 - Special topics: vehicle movement, smart beam allocation, etc.
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- Failure detection/identification/localization
 - Malicious attack and usage identification

Resource
related ML

Hardware
related ML

HW related ML approaches

■ Failure detection and localization

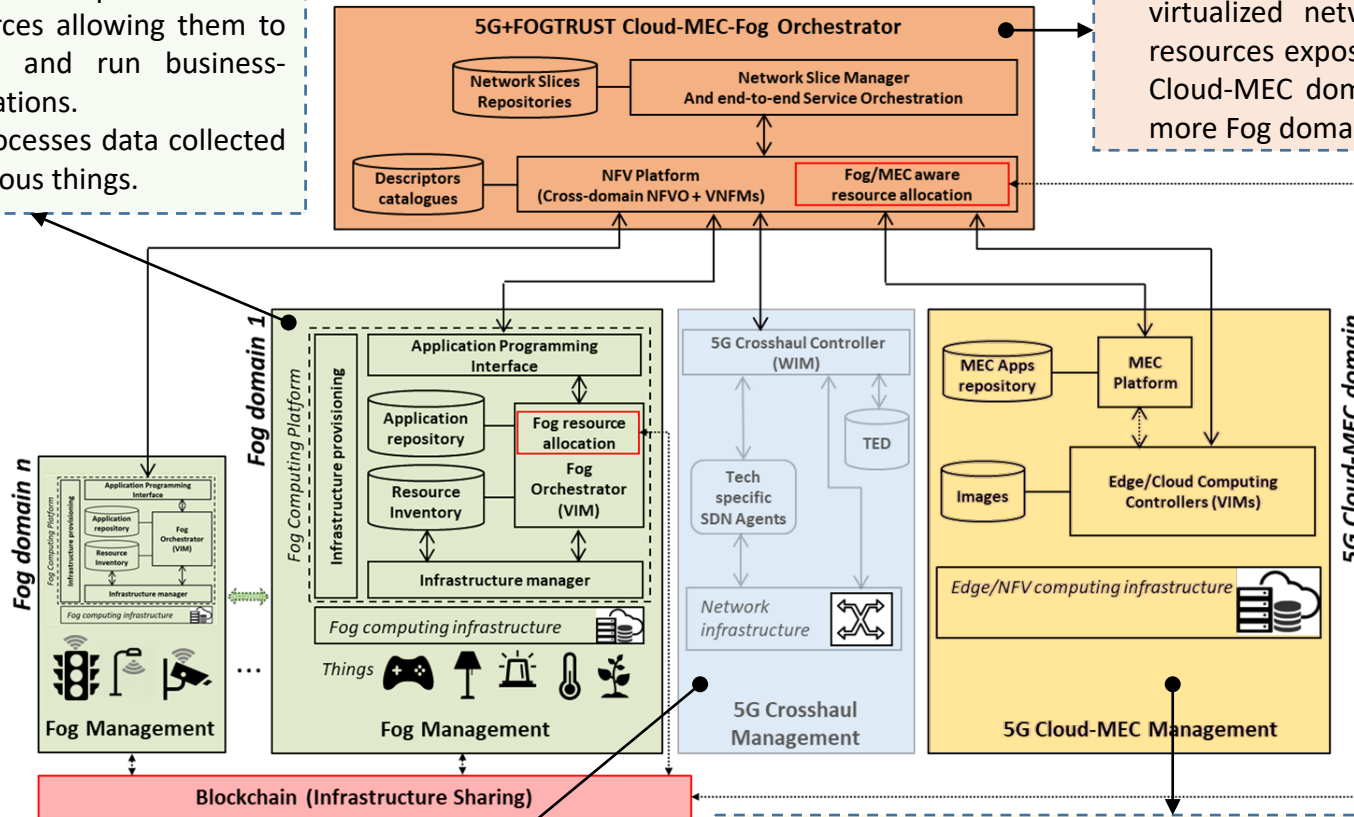
- Split into hard- and soft-failures
 - Soft-failures: system degradation leading to QoT degradation
 - Hard-failures: equipment/link breakdowns
- Advance monitoring to collect physical layer statistics
 - Multi-source monitoring incl. signal processing
- Usages and Advantages:
 - Predictive-optimized maintenance – Scheduled replacement
 - Increased reliability – Provisioning of back-up resources

■ Malicious usage and attacks

- Split into misuse detection and anomaly detection
 - Misuse detection identifies bad use of resources (intentional or not) and contract violations
 - It is based mainly in the processing of known patterns
 - Anomaly detection identifies potential malicious attacks
 - Processing of unknown patterns and level of divergence from normal

5G Fog-based implementation framework

- Owned by third parties (e.g. enterprises) with computational and storage resources allowing them to offer services and run business-specific applications.
- It uses and processes data collected by heterogeneous things.

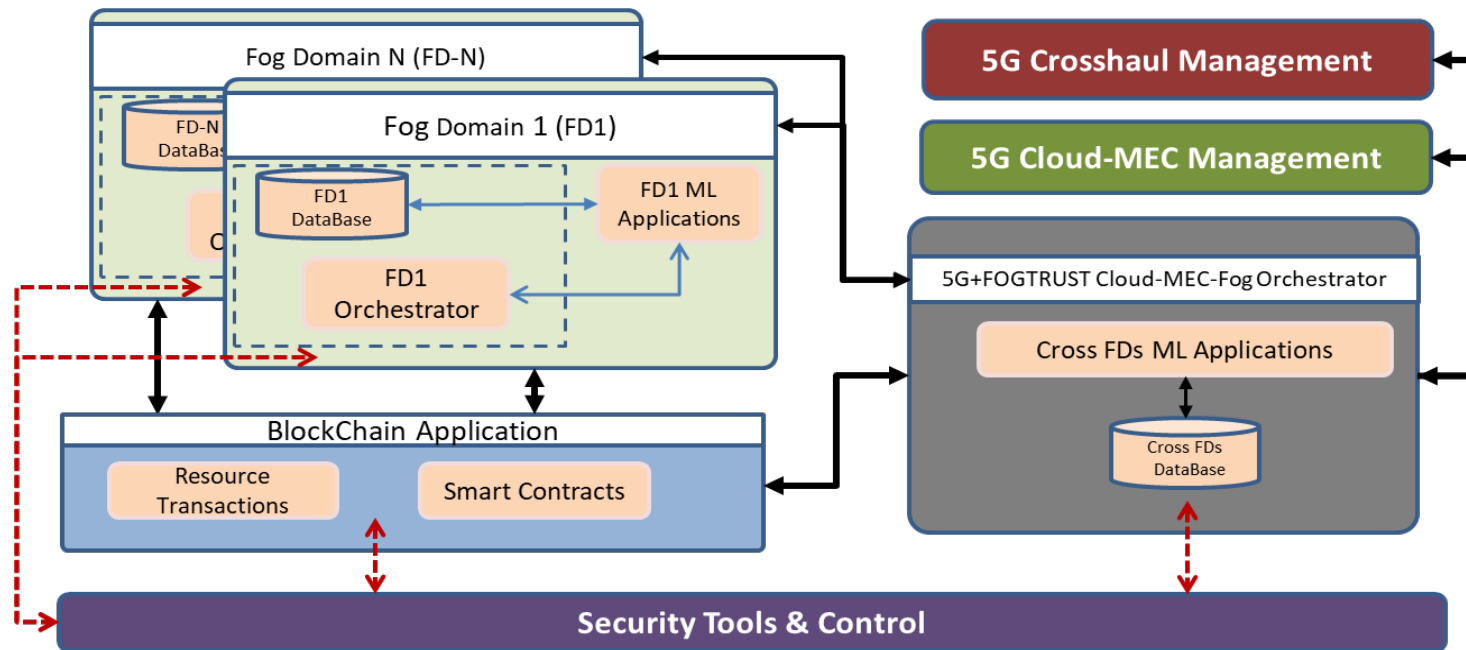


- Orchestrates end-to-end services composing network slices and virtualized network services using resources exposed by traditional 5G Cloud-MEC domains and by one or more Fog domains.

- The SDN-based WAN Infrastructure Manager (WIM) to provide pure networking connectivity at the transport level or within the crosshaul network
- Provide the interconnections between the distributed cloud, MEC and Fog domains

- Owned by 5G network provider allowing him to host virtualized network services.
- Focuses on orchestrating computational resources to host virtual applications within the 5G Edge/Cloud computing infrastructure
- Compliant with ETSI NFV MANO

Blockchain and ML interconnection



- Shared blockchain structure allows sharing and allocation of resources across multiple Fog domains and the Cloud-MEC node.
 - Decentralization of resource allocation
 - Trusted transactions across all fog domains (and the central Cloud-MEC)
- ML calculates the required resources or actions to be taken
 - ML applications may run (ML) on the Cloud-MEC Orch. or the Fog domain level or in both
 - Data retrieved from the events database to train models and perform predictions about the resource needs, potential failures, etc.

The evolved 5G-Fog-based network

- Envisioned impact:
 - Allows end user tailored services to be offered on top of the infrastructure.
 - Offers the business model for interaction among large infrastructure providers and smaller software service providers.
 - Enables the establishment of secure collaboration models among infrastructures from different operators
 - Enables small-cell deployment and network densification across multiple public and private domains
- Further important enhancements required:
 - Security



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Thank you for your attention

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