CCI Seminar

SLICES-DS/SLICES-RI Project and ESFRI Proposal and 5G Technologies Overview: Opportunities and Challenges for Secure Data Exchange Infrastructure

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CCI Seminar 4 June 2020
University of Amsterdam

Outline

- SLICES-DS/SLICES-RI Project and ESFRI Proposal
  - SLICES-RI Objectives and preparation stages
  - SLICES-DS Design Study funded by *H2020-INFRADEV-01-2019-2020*

- 5G Technologies Overview
  - Roadmap, use cases and components
  - Architecture and Cloud Native Network Functions
  - Network slicing
  - Security Architecture (as 5G potentially will become dependable critical infrastructure)
- Concerns in 5G roll-out
  - Huawei 5G and security concerns
- Opportunities and Challenges for Secure and Trusted Data Exchange Infrastructure
  - Dedicated E2E network slices for IoT network
  - Potentially easy integration with cloud based applications (5G cloud native network and native cloud applications)

SLICES-RI ESFRI Proposal

- SLICES Scientific Large-scale Infrastructure for Computing/Communication Experimental Studies
- ESFRI proposal
  - (To be) Endorsed by the ESFRI Roadmap
  - Funded approx 50/50 by National members and EU
  - Deadline 5 Sept 2020
  - 21 partners from 12 countries
- Number of national preparation steps
  - Including into National NL ESFRI Roadmap
  - Commitment of cooperating organisations

Partners

- Centre National de la Recherche Scientifique (CNRS) – FR
- Consiglio Nazionale delle Ricerche (CNR) – IT
- Consorzio Interuniversitario Nazionale per l'Informatica (CINI) - IT
- Consorzio Nazionale Interuniversitario per le Telecomunicazioni (CNIT) - IT
- EBOS Technologies Ltd (EBOS) – CY
- Fundacion IMDEA Networks (IMDEA) – ES
- Institut Mines-Télécom (IMT) – FR
- Institut National de Recherche en Informatique et en Automatique (INRIA) – FR
- Instytut Chemii Bioorganicznej PAN PCSS (PSNC) – PL
- Interuniversitair Micro-Electronica Centrum (imec) – BE
- IoT Lab (IoT Lab) – CH
- Kungliga Tekniska högskolan (KTH) – SE
- Mandat International, International Cooperation Foundation (MI) – CH
- **Sorbonne Université (SU) – FR**
- Számítástechnikai és Automatizálási Kutatóintézet (SZTAKI) – HU
- UCLan Cyprus (UCLAN) – CY
- Universidad del País Vasco-Euskal Herriko Unibertsitatea (UPV) – ES
- Université du Luxembourg (UL) – LU
- Université de Genève (UG) – CH
- **University of Amsterdam (UvA) – NL**
- University of Thessaly (UTH) – GR

SLICES-RI Research Areas

- Advanced wireless networking
  - New waveforms; Higher frequencies up to THz
  - Spectrum and wireless management
  - Integrated sensing and communication
  - Multiple heterogeneous radio management
- Smart/intelligent infrastructure operation and management
  - Advanced protocols and architectures (virtualization, softwerization, programmability)
  - AI applied to infrastructure operation and optimisation
  - Generation of data to train algorithms
  - Distribution of intelligence into the Edge and beyond the Edge of the network
- Design and validation of new Edge/Fog and hyper-converged infrastructures
  - Software and components deployment
  - Distributed resource management & microservices
  - Geo-distributed data management
  - Federated deep-learning
- Advanced functionalities
  - Power consumption and energy efficiency
  - Security and privacy
  - New challenges arising from the verticals and the ubiquitous networks;
  - Interoperability, composable infrastructure services on-demand (RI as a Service)
  - Seamless user experiences across technologies and domains

SLICES-NL Partners

- UvA (coordinator for NL)
- SURFnet and SURFsara
- VU
- ASCI
- NLeSC
- TNO

SLICES-NL Research topics (UvA and partners)

- Cloud and Network Infrastructure research
  - Architecture and design patterns of the future RI Platform as a Service (PRIaaS)
  - Federated multi-cloud and inter-cloud infrastructure integration and management
  - Large scale experimentation on distributed hybrid cloud infrastructure involving public cloud providers
  - Decentralised network/compute optimisation in edge/fog environments, connected mobiles
  - Sustainable cloud services with energy consumption monitoring and optimization
- Data Infrastructure
  - Big Data Infrastructure and Technologies (cloud enabled)
  - Trusted data exchange and processing with policy/rules enforcement, preserving data sovereignty and protecting data privacy
  - Data management and quality assurance aspects in Industry 4.0 experimentation and Digital Twins applications
- New security and compliance models for Complex Cyber Infrastructure
  - Distributed Cyber Security techniques and architectures
- Trustable and explainable Internet based on open networking technologies
- Federated Data Analytics and Deep Learning, in particular for predictive maintenance, logistics and smart cities
- Support of education on key technologies of the future data centric and cloud enabled infrastructures by provisioning educational platforms and resources for universities on demand

SLICES-NL Research topics (in the context of 5G)

- 5G Cloud Native Network infrastructure (CNNI) integration with cloud based applications
  - Leveraging 5G Massive Machine Type (mMTC) communication for cloud, edge, IoT
  - 5G for EOSC and GEANT
- E2E infrastructure slicing for secure and trusted data exchange/sharing
  - Automated policy aware infrastructure provisioning
- Secure data containers and E2E trust management
  - Cyberinfrastructure security and key management
- Experimentation (and applications) on 5G CNNI with IoT and HPC applications

Timeline e-RI evolution and SLICES positioning

SLICES

RI Type (evolution stage)	Centralised 1994-1996	Interconnected 2004-2006	Distributed 2011-2012	Federated 2016-2018	EOSC-1 2020-2022	EOSC-2 (future)
Definition	Institutions based, centralised facility	Multi-institutions, interconnected	Large distributed facilities, domain or experiment oriented	Federated RIs supporting inter-domain cooperation and data exchange	Interoperable (European) RI, FAIR RI	Virtualised Pan-European RI platform as a Service and ecosystem (PRIaaS)
Network & Compute	Mainframe, variety of protocols, Advent of Internet, web, email	Interconnected data centers and experimental facilities, Internet TCP/IP as common protocol, remote access	Distributed interconnected computing facilities, SOA and webservices, Grid as cooperative and distributed computing	Cloud adoption, infrastructure services on-demand Federated facilities and network access, Federated access and Identity management, 3G->4G	Distributed scalable computing, cloud based Big Data technologies, high performance networks, 5G technologies, wireless access, IoT sensor networks	Composable virtualized RI provisioning on demand, common federated computing and networking platform/environment, Cloud, DevOps and AI enabled, Digital Twins
Data	Proprietary formats, system or experiment specific	Standard format for data exchange, proprietary metadata	Domain/RI based data/metadata interoperability, custom data models, distributed storage, directories	Interoperable data, domain based metadata	FAIR data, Data Factories, Metadata registries, Interoperable/common Data Management model	Fully adopted FAIR principles, Semantically enabled scientific data lakes, secure/trusted data exchange, full data value chain
Infrastructure Management Technologies	Local management	Local management, management information exchange	Common Management Model, Distributed management, 3G Roaming	OSS/BSS, Automated deployment, adaptation, monitoring	Integrated Operation and Automation, Automated identity provisioning	Fully automated RI and services provisioning, management and operation, optimisation

- SLICES research areas linked to EOSC

SLICES-DS Project (*H2020-INFRADEV-01-2019-2020*)

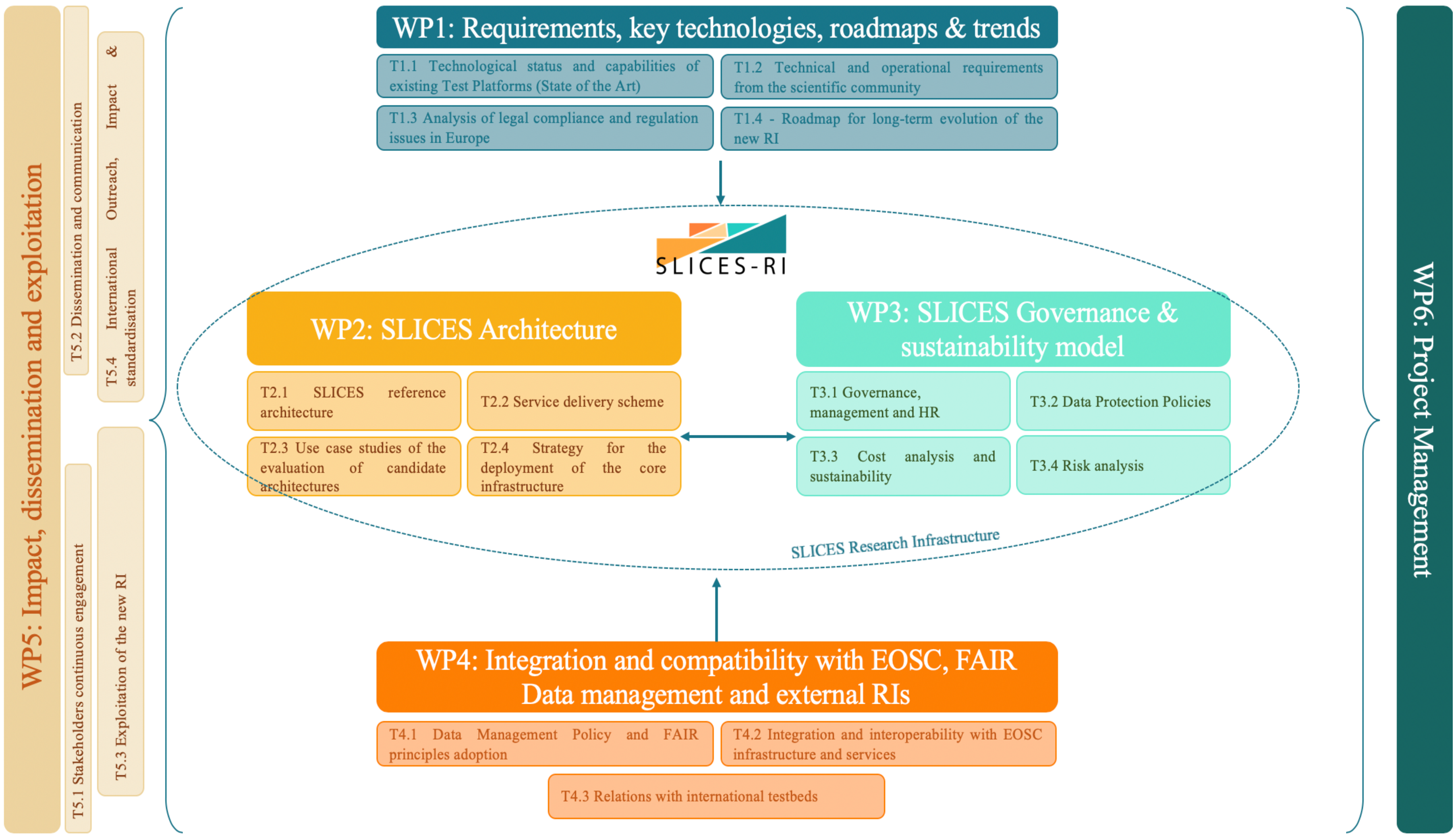
- Starts 1 Sept 2020 – Total 24 months
- 10 partners: Coordinator Uni Sorbonne
  - INRIA, PSNC, Uni Carlo III Madrid, UvA, others
- 2.9 Mln (UvA – 260K)
- Design Study for SLICES-RI project

- UvA Role – WP4 leadership, Task T4.2
  - Data Management and EOSC cooperation/alignment
  - Are critical aspects for current EU projects

Objectives: Focus on preparation for SLICES-RI

- Objective 1: To adequately design SLICES in order to strengthen research excellence and innovation capacity of European researchers and scientists in Digital Infrastructures
- Objective 2: To accomplish preparatory work and planning of the new Research Infrastructure
- Objective 3: To define governance and management of the new Research Infrastructure
- Objective 4: To define models for the financing of the new Research Infrastructure

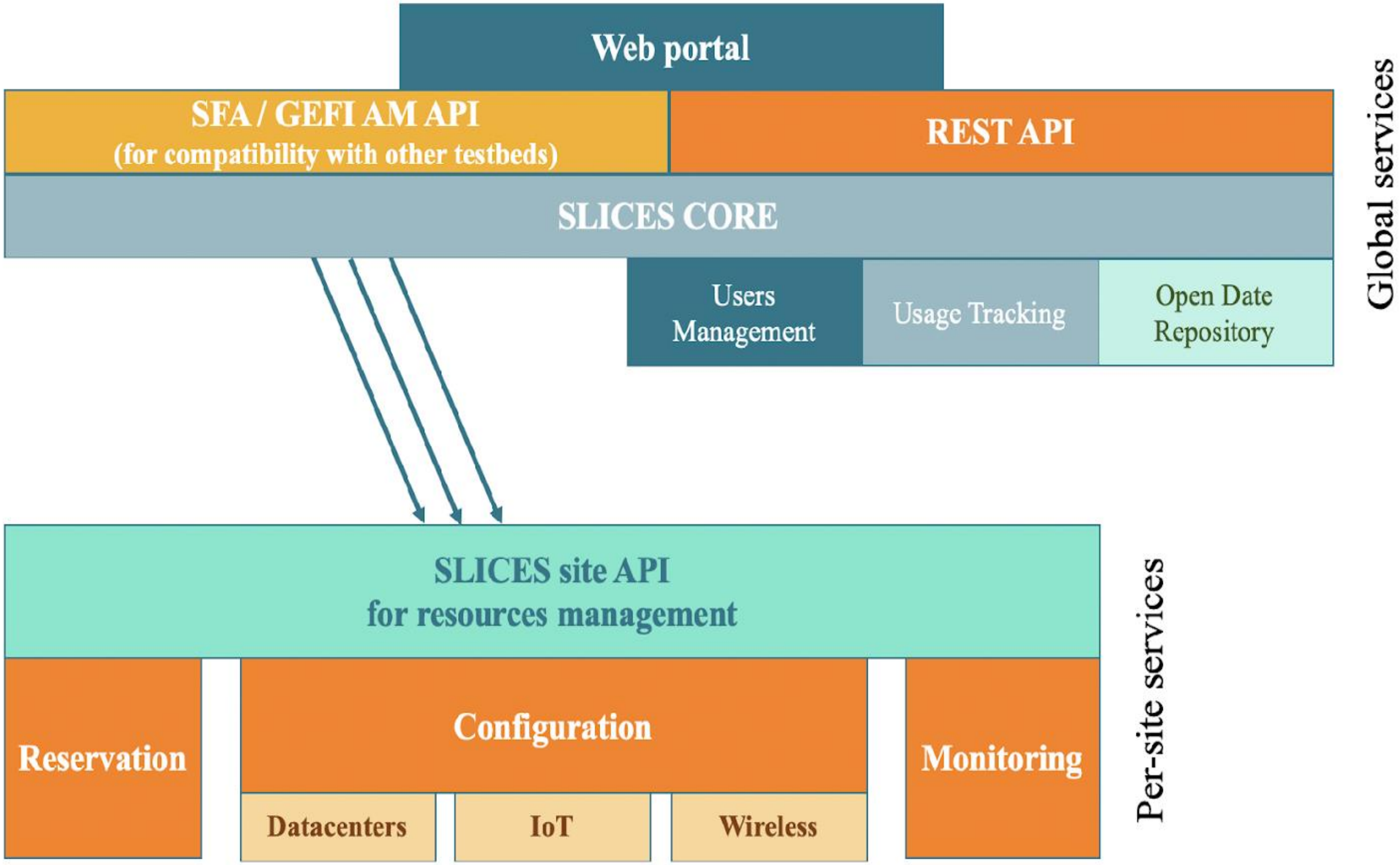
SLICES-DS WPs Structure



SLICES-DS WPs Structure

- WP1 - Requirements, key technologies, roadmaps and trends
  - Task 1.1 Technological status and capabilities of existing Test Platforms (SotA)
  - Task 1.2 Technical and operational requirements from the scientific community
  - Task 1.3 Analysis of legal compliance and regulation issues in Europe
  - Task 1.4 Roadmap for long-term evolution of the new RI
- WP2 - Roadmap for long-term evolution of the Research Infrastructure
  - Task 2.1 SLICES reference architecture
  - Task 2.2 Service delivery scheme
  - Task 2.3 Use case studies of the evaluation of candidate architectures
  - Task 2.4 Strategy for the deployment of the core infrastructure
- WP3 - SLICES Governance and sustainability model
- WP4 - Integration and compatibility with EOSC, FAIR and external RIs
  - Task 4.1 Data Management Policy and FAIR principles adoption
  - Task 4.2 Integration and interoperability with EOSC infrastructure and services
  - Task 4.3 Relations with international testbeds
- WP5 - Impact, dissemination and exploitation
- WP6 - Project Management

SLICES-RI Architecture



SLICES-RI National Sites and Nodes

- **Hardware architecture**
  - Multiple radio, Antennas
  - User's equipment (including BYOD)
  - Special purpose processors (GPU, FPGA, AI-dedicated processors)
  - NVRAM memory and in-memory devices
- **Software Architecture**
  - Networking components
  - Monitoring components
  - Open APIs
- **Cloud and compute support infrastructure**
  - To support experimentation with the Cloud Native Networking infrastructure and data processing functions such as signal processing, controls and related computational and data intensive operations;
  - In addition, it provides the programmability framework for the experimenter, APIs, resource access, reservation and slicing, data storage.

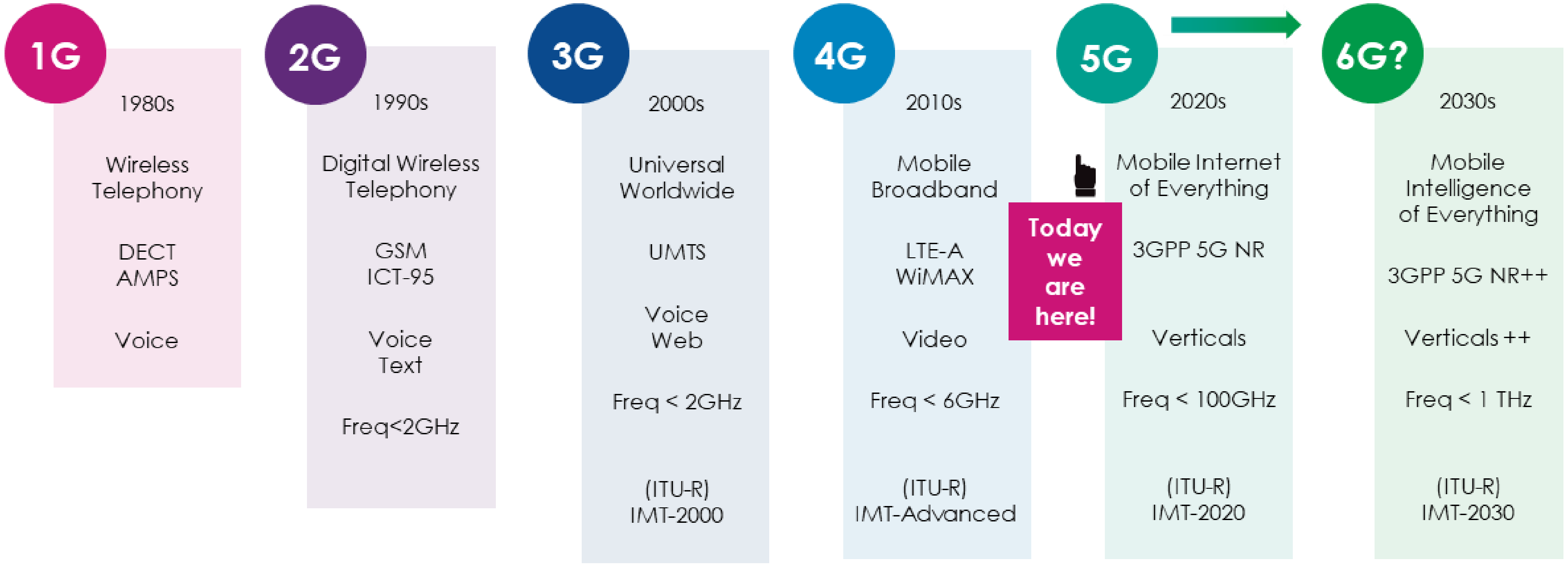
5G Technologies Overview

- Timeline and basics
- Use cases
- Architecture components

EU and NL involvement into 5G development

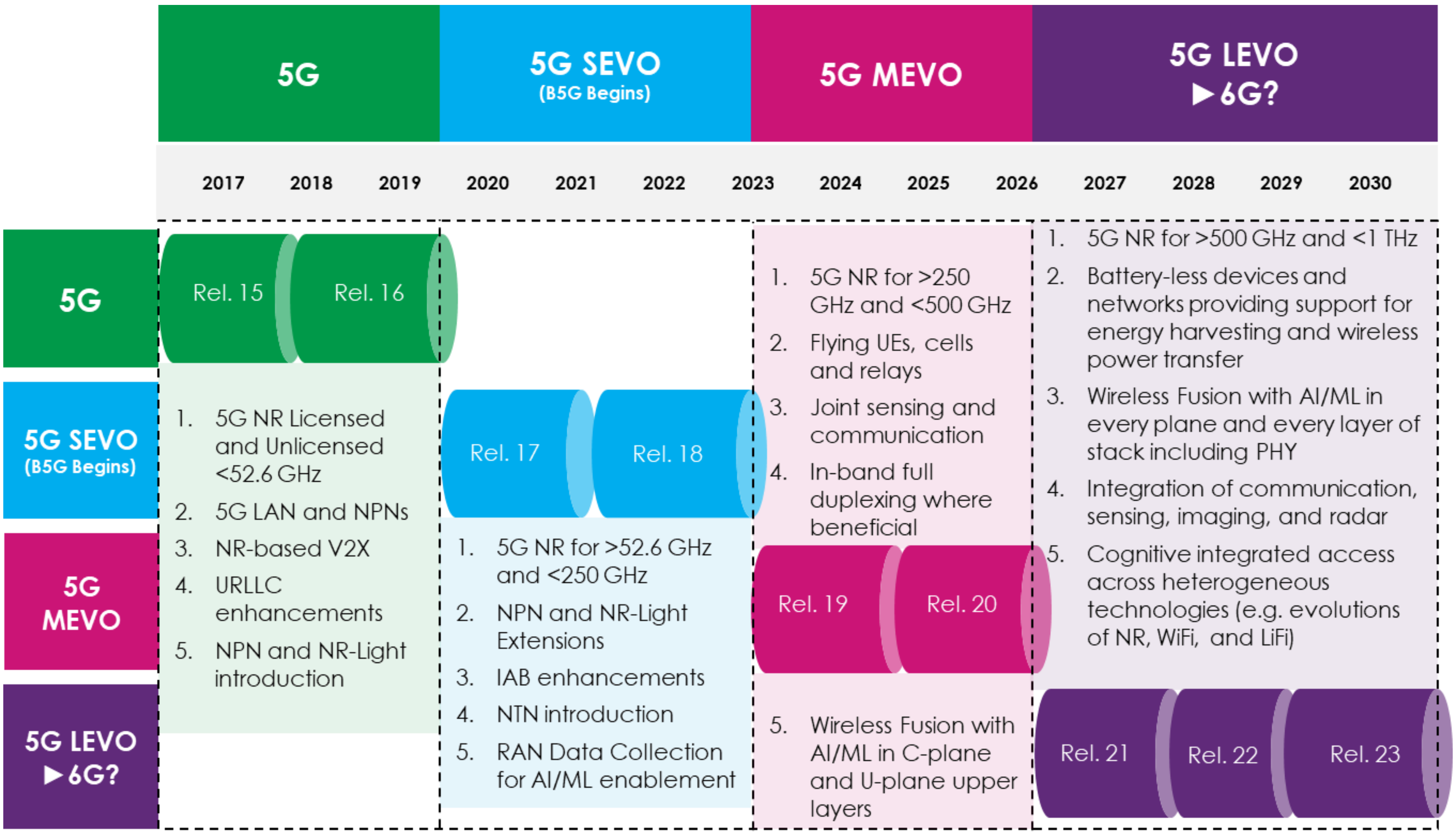
- EU and NL actively participate and play leading role in 5G development
- The following frequencies will be used in EU
  - 700 MHz, 3.5 GHz, and 26 GHz.
- Nederland will additionally use 1.4 GHz and 2.1 GHz
  - https://stralingsbewust.info/2019/10/25/5g-waar-staan-de-zendmasten-voor-test-uitzendingen/

EU Project EMPOWER Roadmap Scope

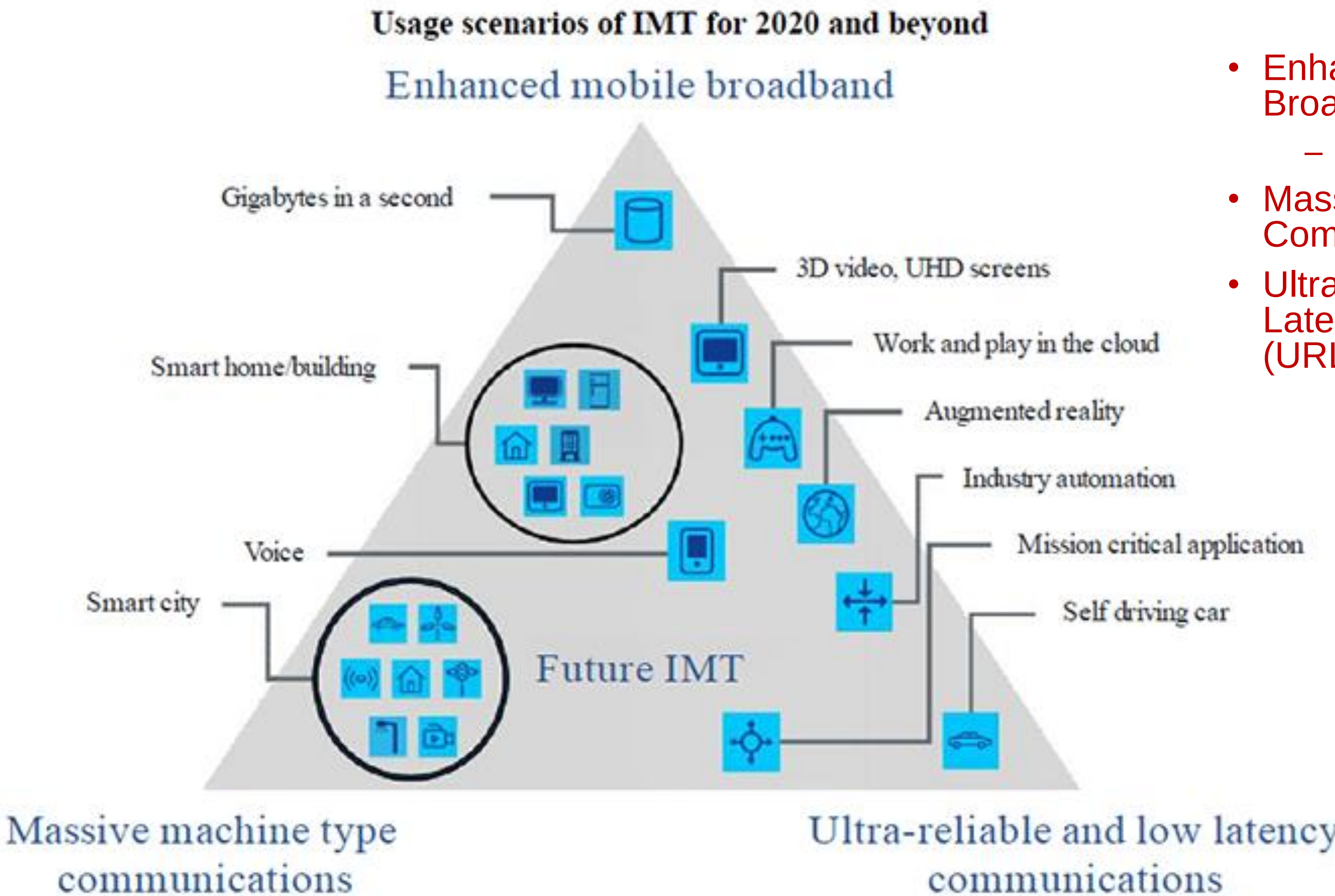


- ***Complete roadmap and related scientific areas*** will be developed in order to embrace the multi-resource composition ***(IoT, Wireless, Cloud/HPC, Data/AI)*** of the future Internet/digital infrastructures.

Baseline Technology Roadmap from a 3GPP-Release perspective

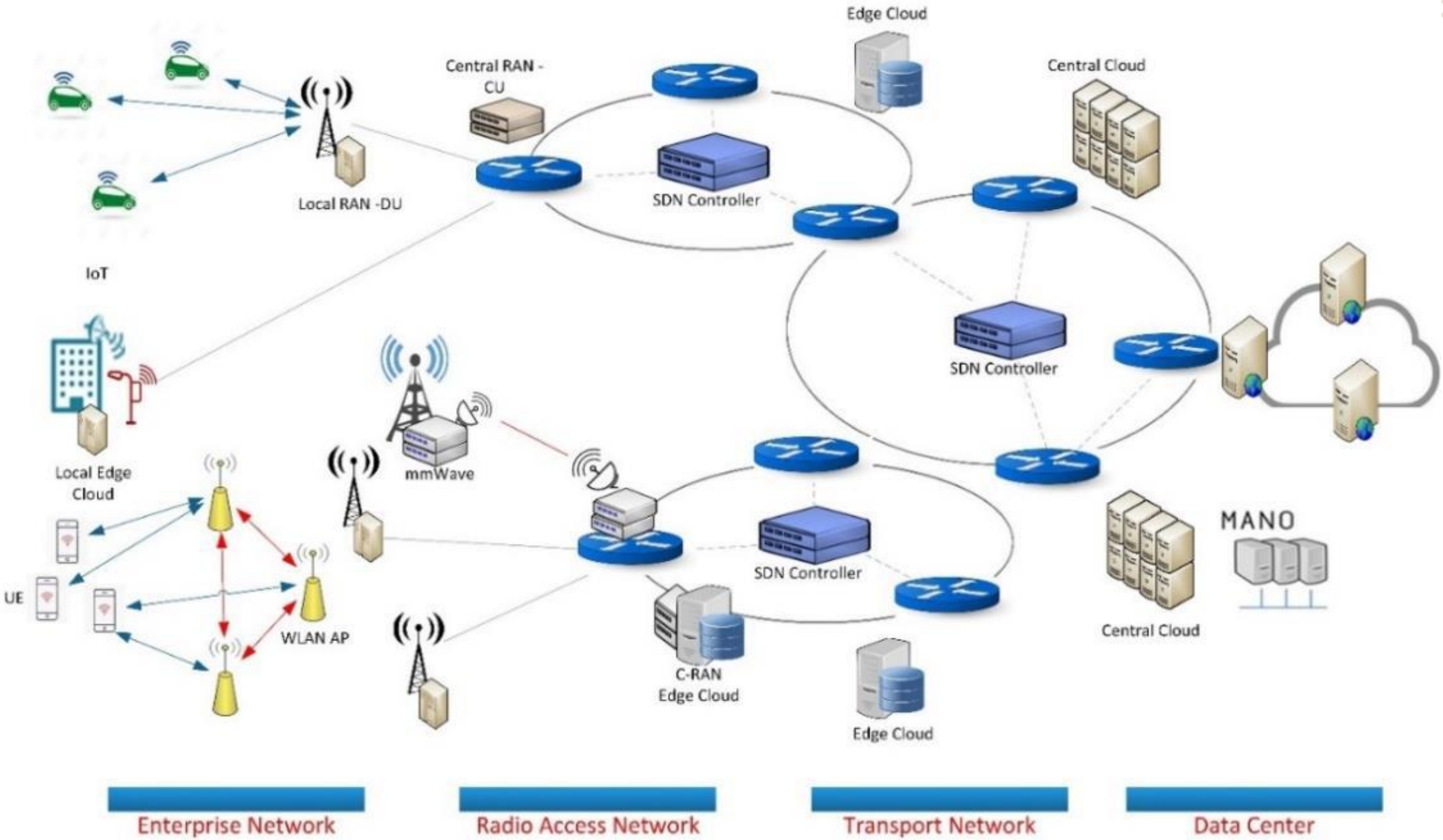


Usage Scenarios

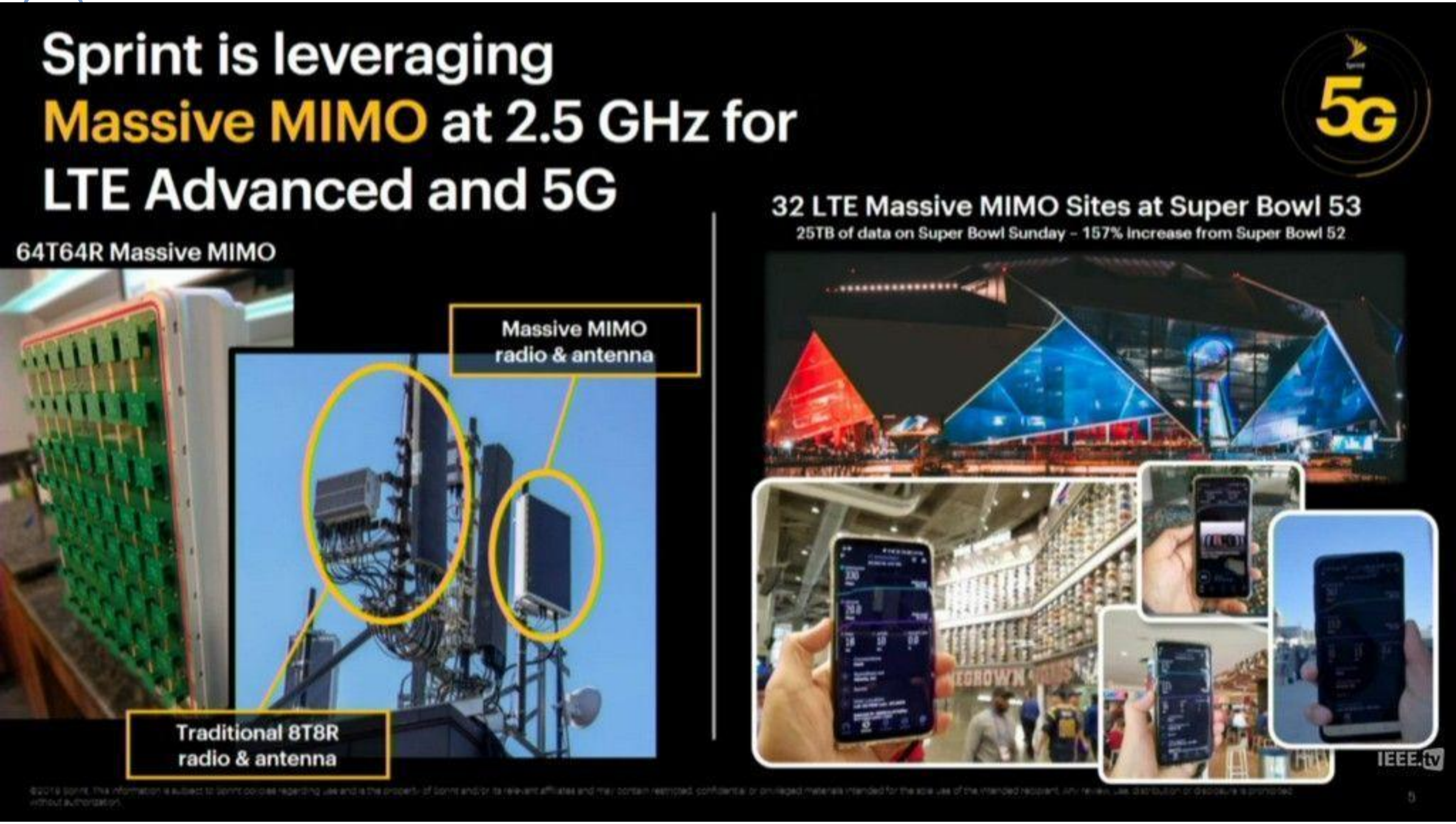


- Enhanced Mobile Broadband (eMBB)
  - Incl new Frequencies
- Massive Machine Type Communications (mMTC)
- Ultra Reliable and Low Latency Communications (URLLC)

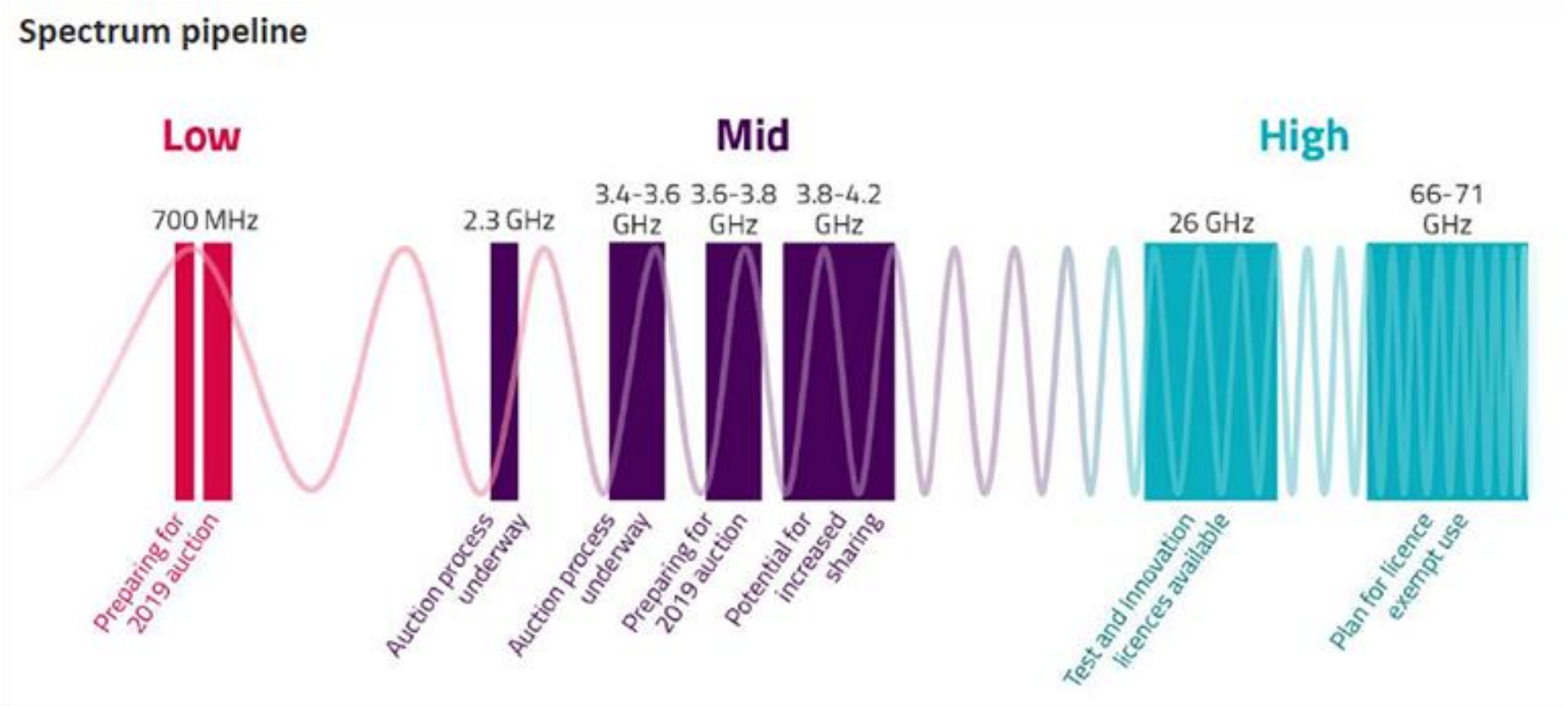
Physical Architecture



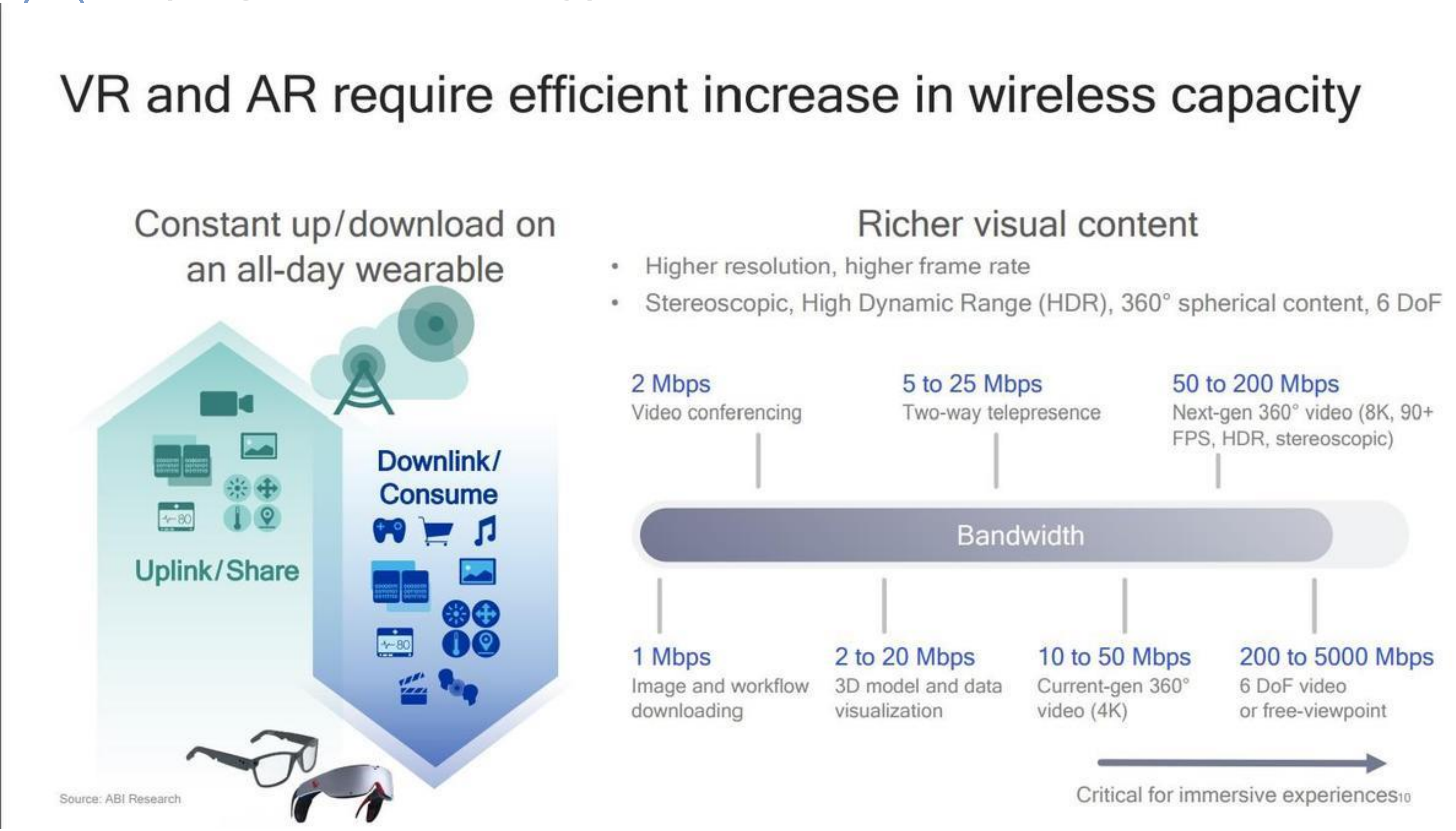
Example: Sprint in US



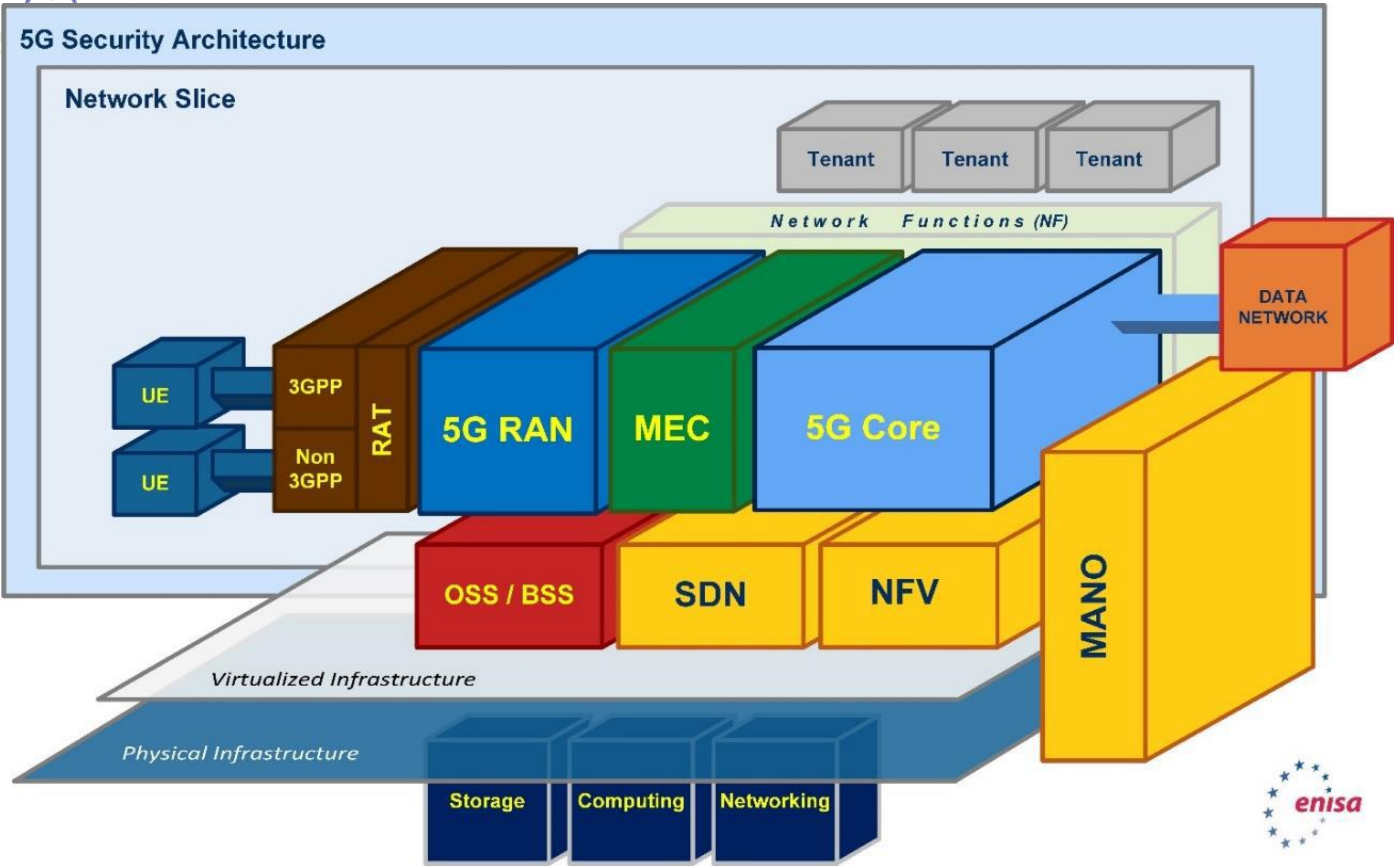
5G Spectrum and Data Speed



AV (Automotive Vehicles), VR (Virtual Reality), AR (Augmented Reality)



5G High-level Technical Architecture (ENISA)



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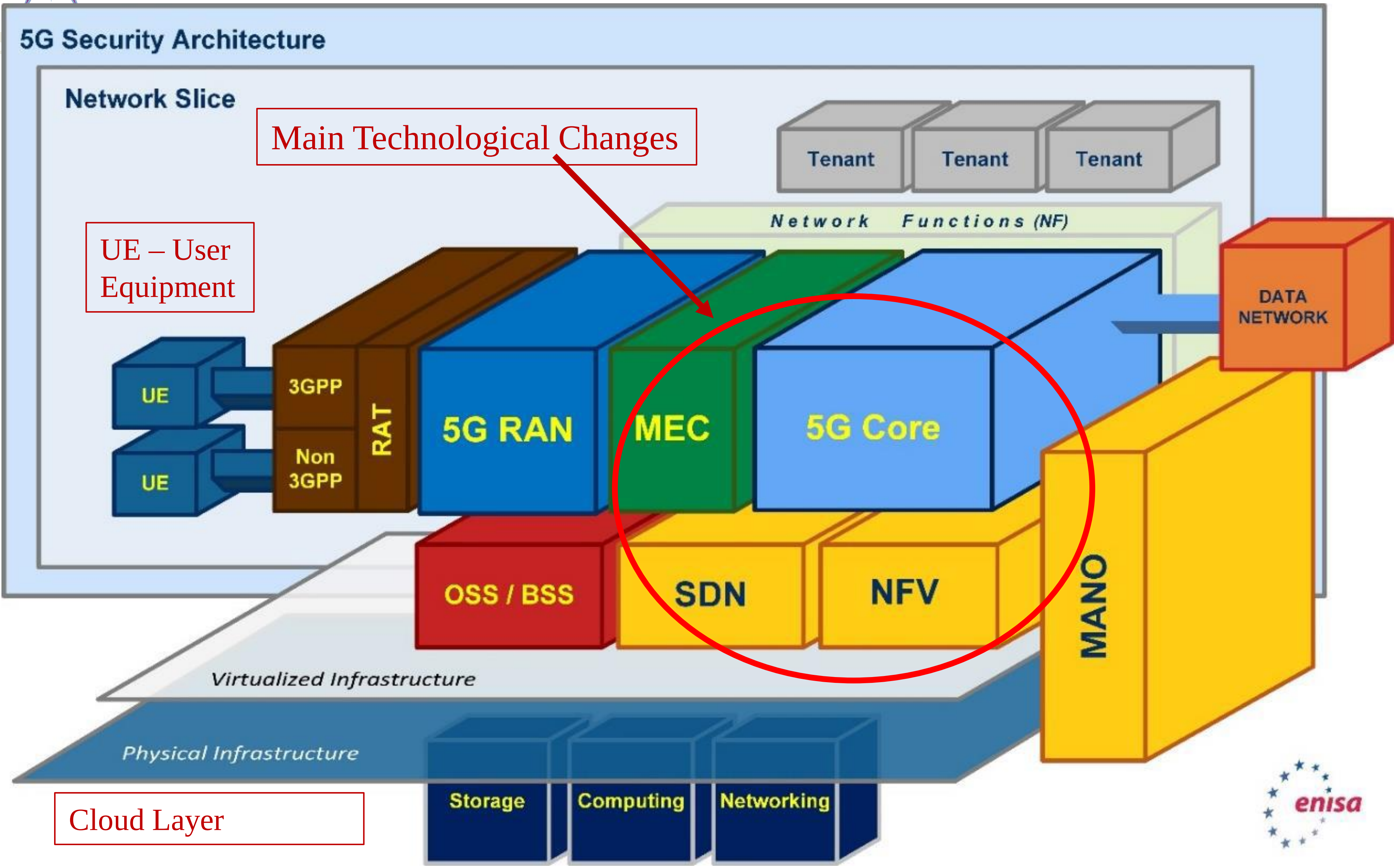
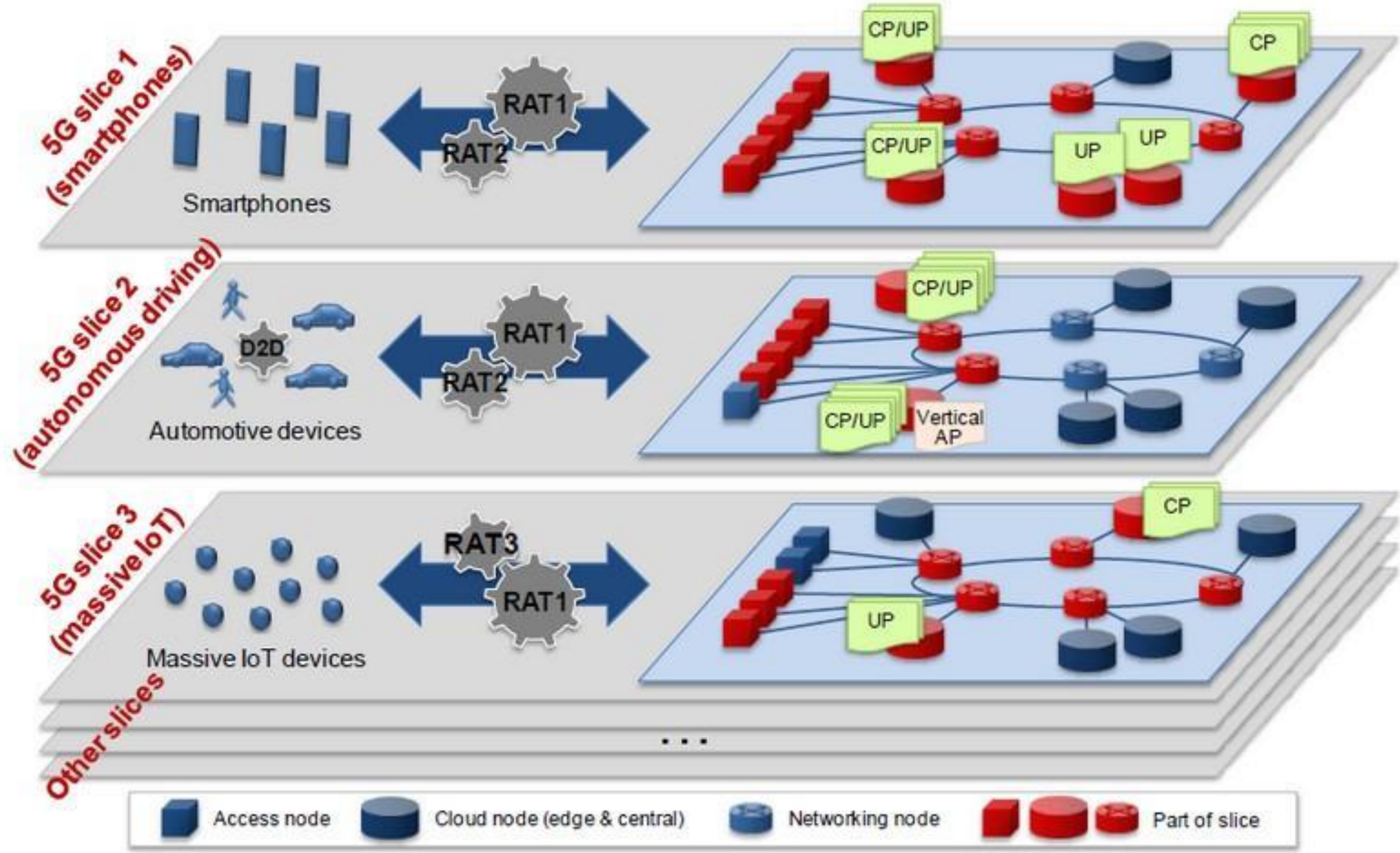
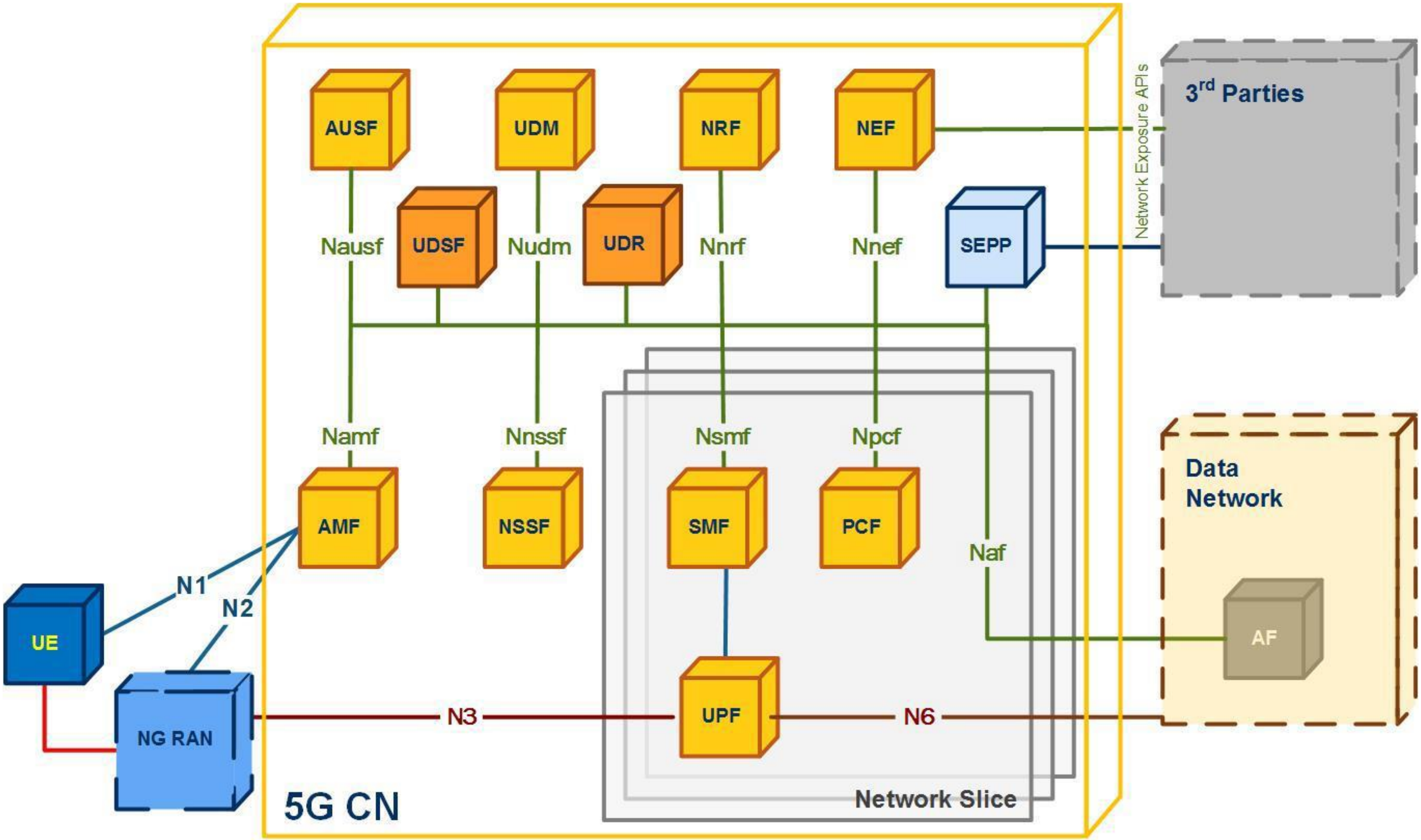


5G Core Network Slicing

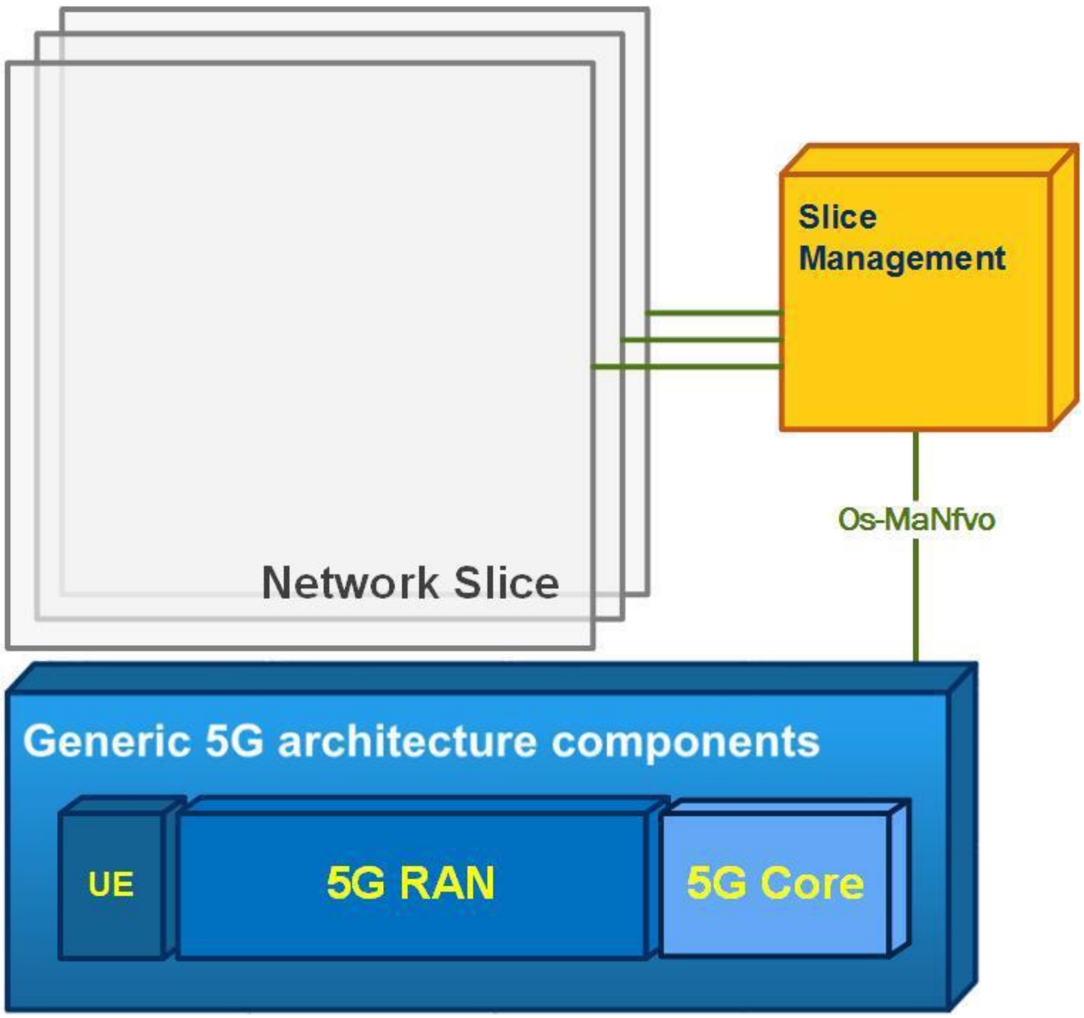


[ref] ENISA Threats Landscape for 5 G Networks, Nov 2019

Core network architecture and slicing zoom-in



Dependencies of slices with the generic 5G architecture components



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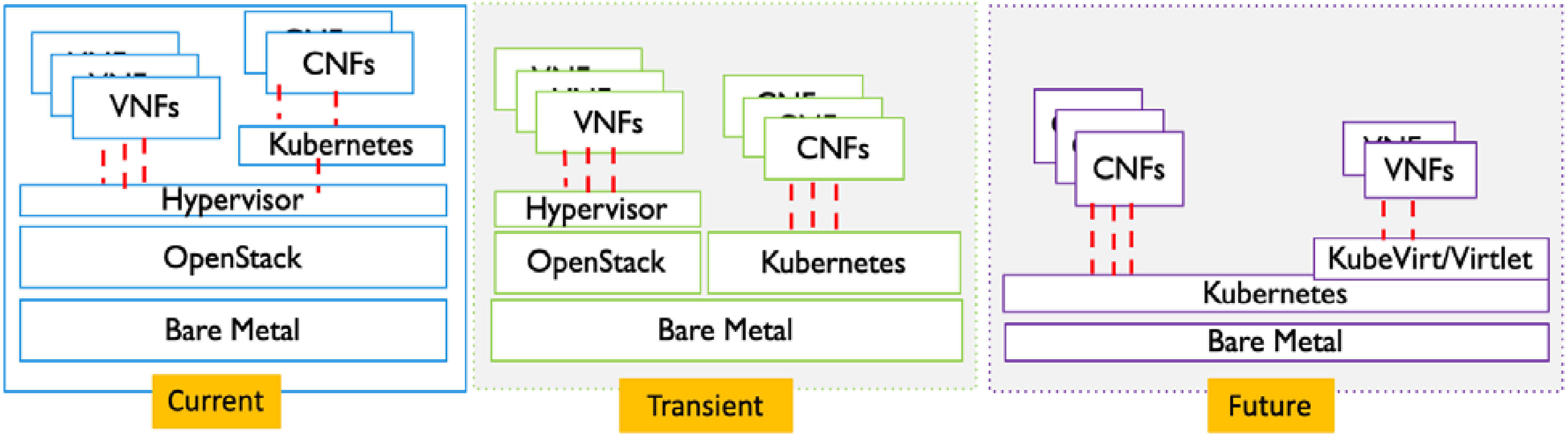
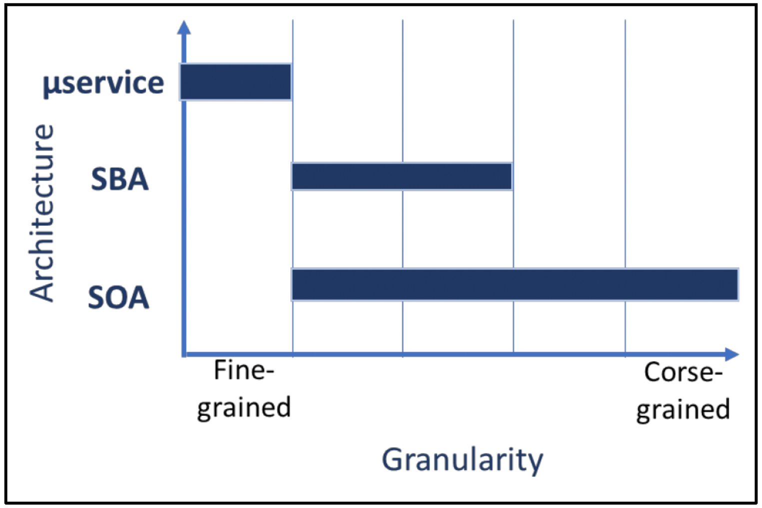
Evolution to Cloud Native Ecosystem

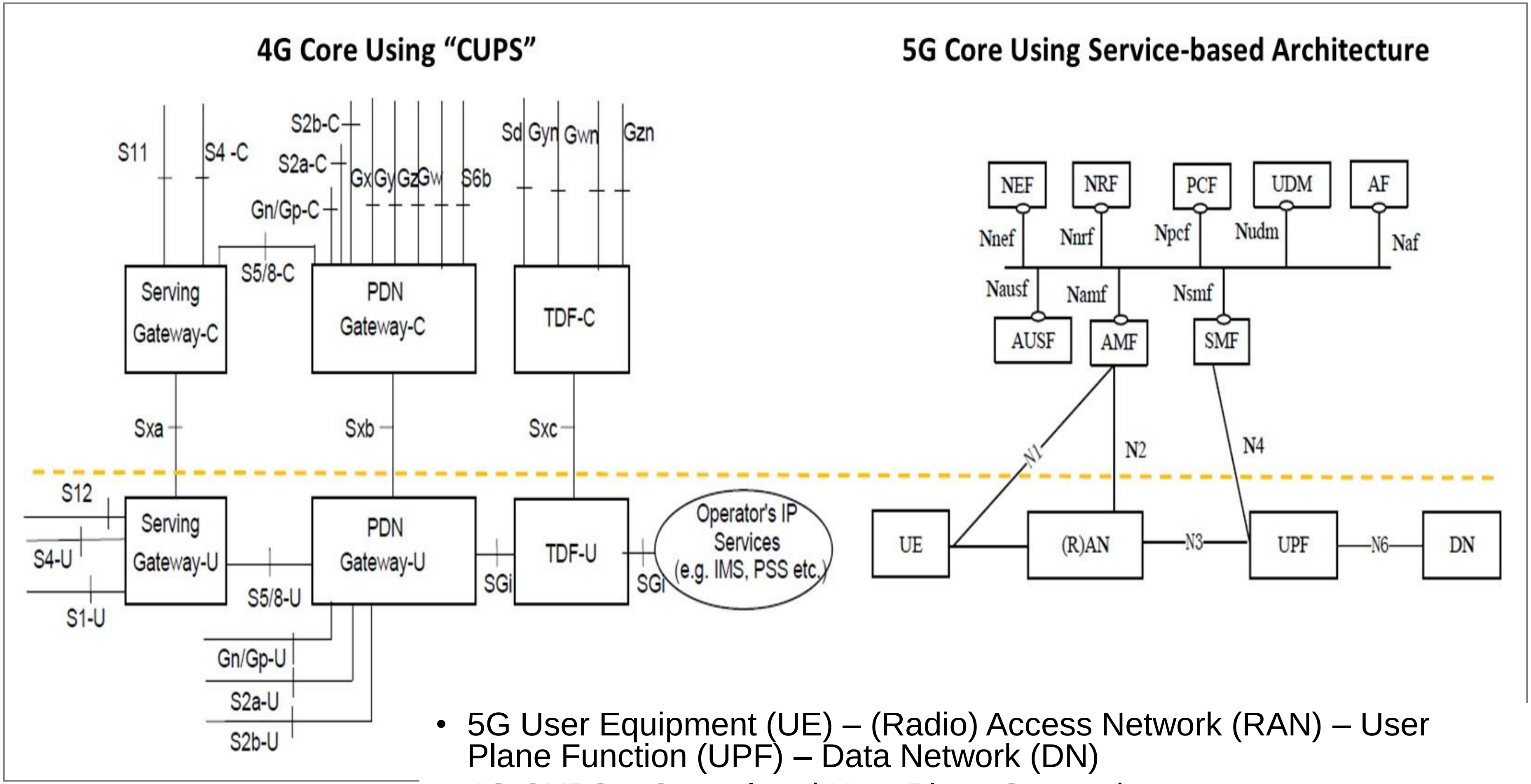




- Cloud Native: SBA vs SOA
  - Focus on microservices
  - RESTful interface
- SBA - Service Based Architecture
- SOA – Service Oriented Architecture
- Kubernetes platform still to advance on network virtualization

[ref] A 5G Americas White Paper. 5G and the Cloud, Dec 2019

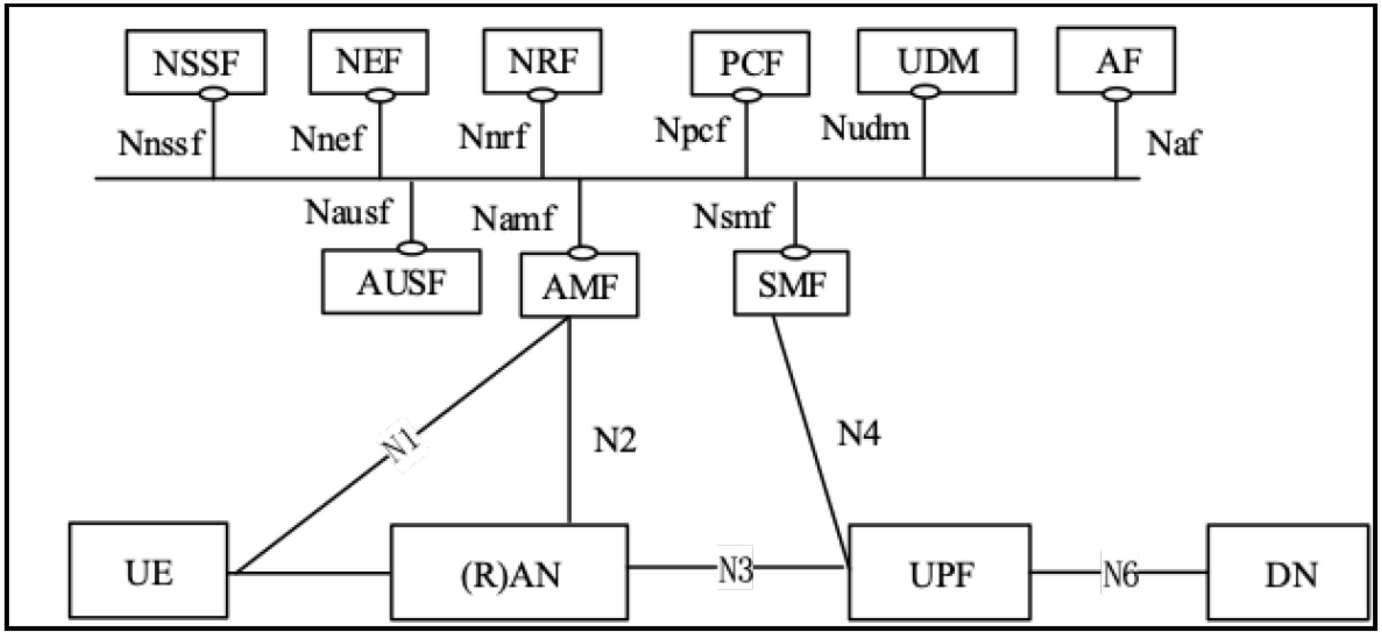
Comparison 4G and 5G SBA Model



- 5G User Equipment (UE) – (Radio) Access Network (RAN) – User Plane Function (UPF) – Data Network (DN)
- 4G CUPS – Control and User Plane Separation
- 4G vertical stack vs 5G cloud native layering model

[ref] Service Based Architecture for 5G Core Network, Heavy Reading White Paper, Sponsored by Huawei, 2017

5G-3GPP Architecture based on SBA Functions



- User Equipment (UE) – (Radio) Access Network (RAN) – User Plane Function (UPF) – Data Network (DN)
- AUSF – Authentication Server Function
- AMF – Access and Mobility Management
- SMF – Session Management Function

- NSSF – Network Slice Selection Function
  - This module is responsible for selecting the 5G network slice instance serving User Equipment (UE) and which AMF, or list of AMFs, can be used by a device (UE)

- NEF – Network Exposure Function
- NRF – Network Resource Function
- PCF – Policy Control Function
- UDM – Unified Data Manager
- AF – Application Function(s)

[ref] A 5G Americas White Paper. 5G and the Cloud, Dec 2019

VMs vs Containers: Test by Cloud Native Computing Foundation (CNCF, 2020)

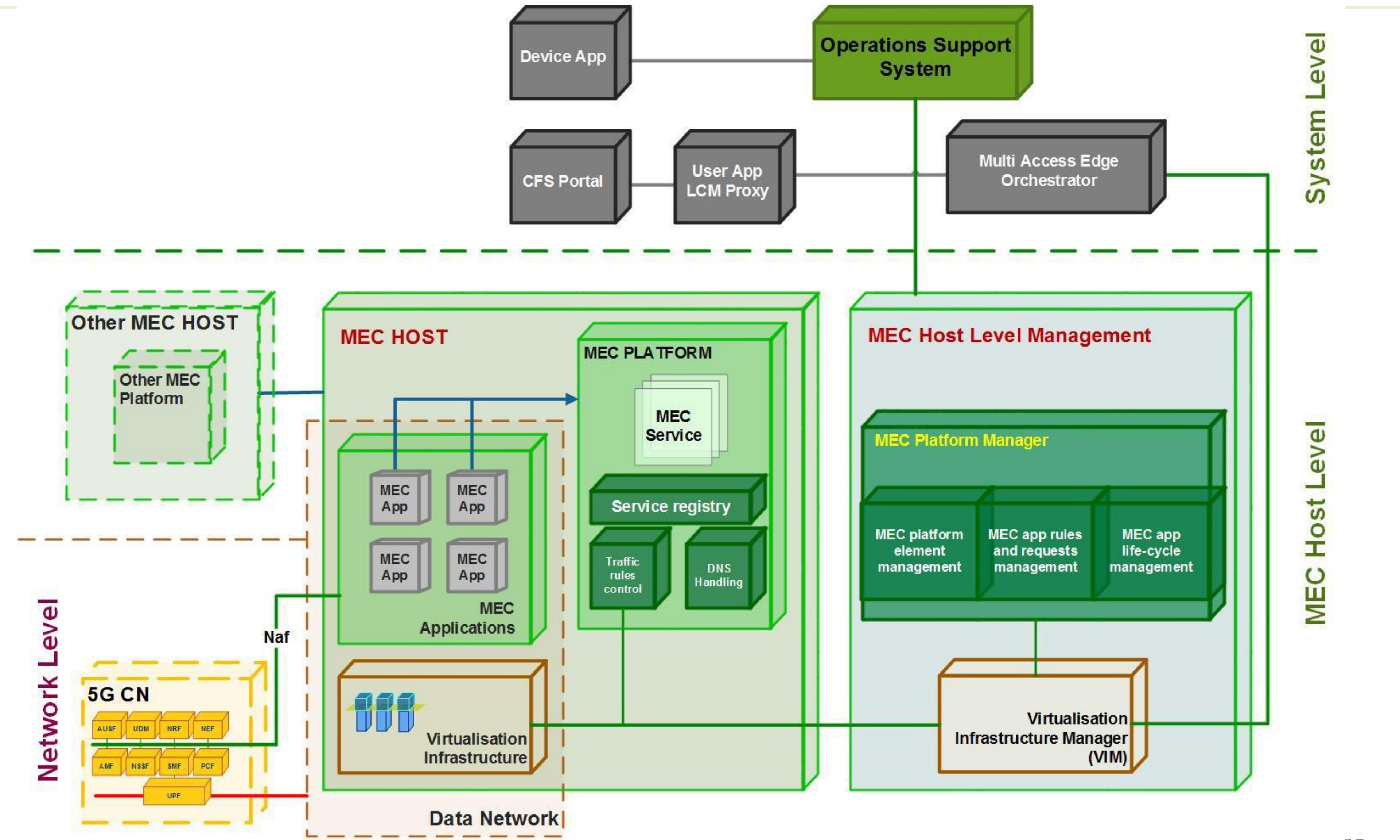
	OpenStack	Kubernetes
Infra deploy time	~65 minutes	16 minutes*
NF deploy time	3 minutes, 39 seconds	< 30 seconds
Idle state RAM	17.8%	5.7%
Idle state CPU	7.2%	0.1%
Runtime NF RAM	17.9%	10.7%
Runtime NF CPU	28.8%	39.1%
Snake case PPS	3.97 million PPS	4.93 million PPS
Snake case latency	~2.1 milliseconds	~2.1 milliseconds
Pipeline case PPS	N/A	7.04 million PPS

https://docs.google.com/presentation/d/1nsPINvxQwZZR_7E4mAzr-50eFCBhbCHsmik6DI_yFA0/edit#slide=id.g5036f143e9_3_672

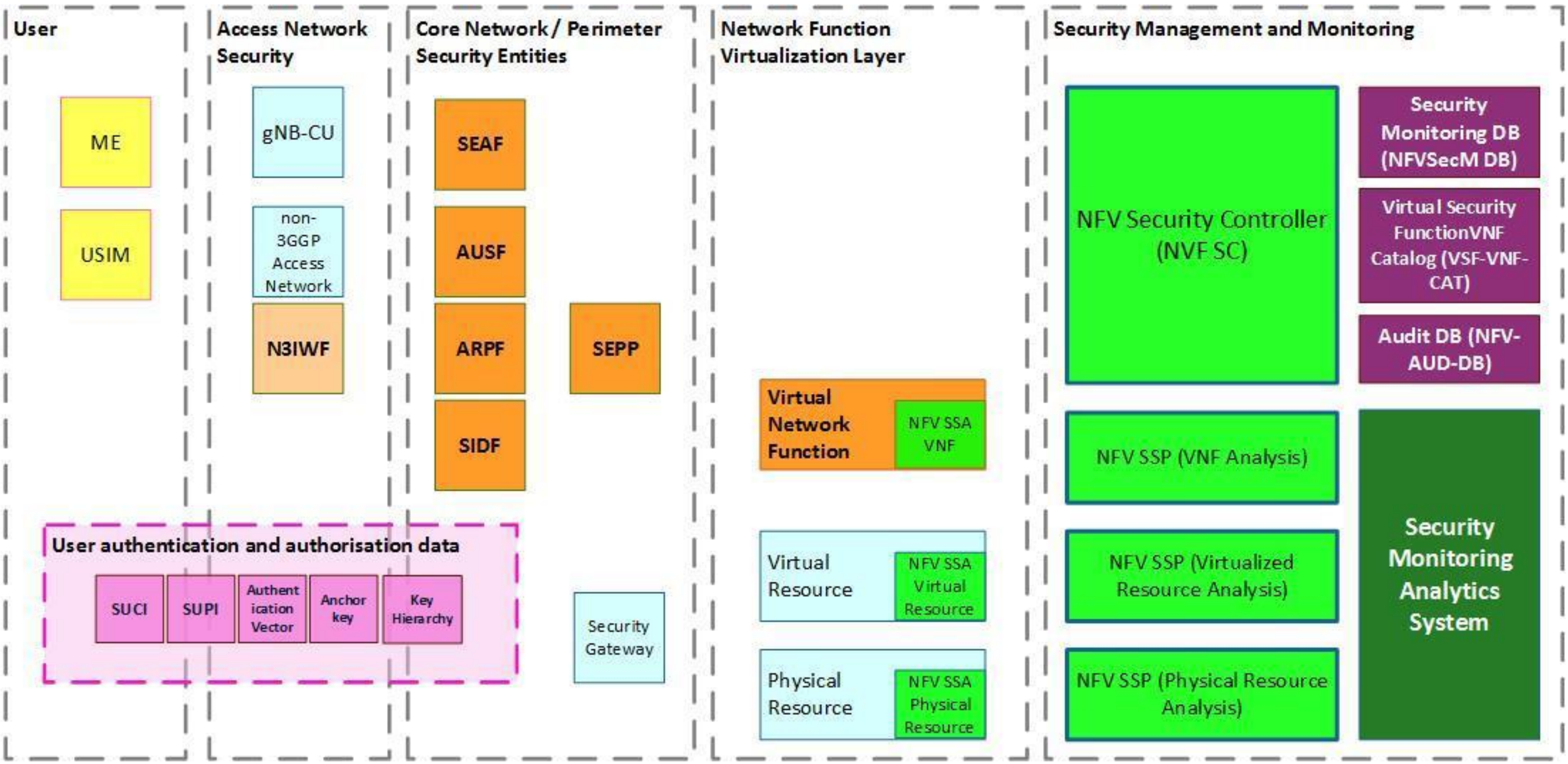
Benefits Cloud Native Approach: Re-usable/Composable Network Components

- Service Based Architecture
  - Vs Service Oriented Architecture
- Cloud Native approach and tools
  - Including DevOps
- VMs vs Containers
  - Noisy neighbor factor is known in Kubernetes
  - But network infrastructure has known type of workload

MEC (Mobile Edge Computing) Architecture

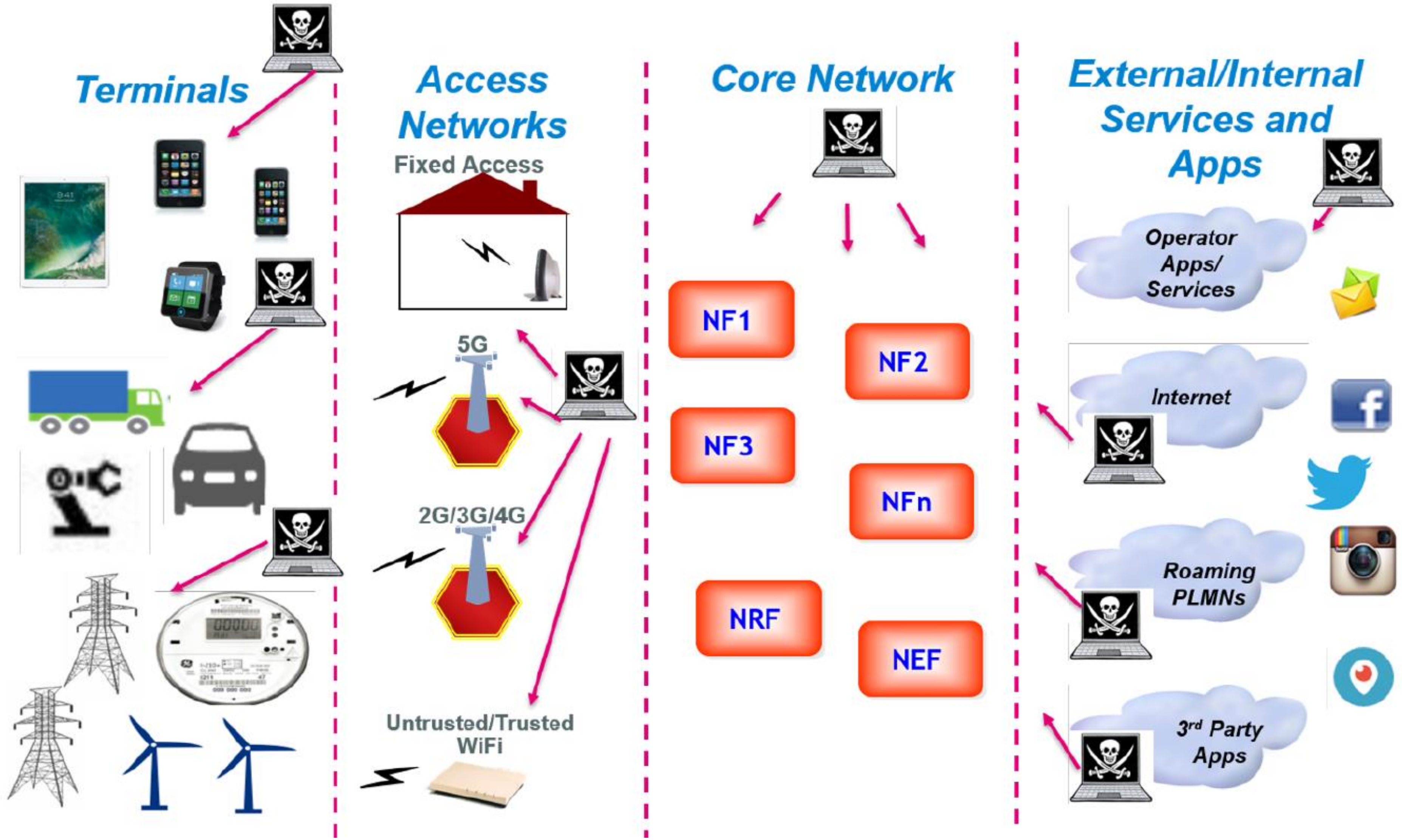


5G Security Architecture



[ref] ENISA Threats Landscape for 5 G Networks, Nov 2019

5G Threats Landscape

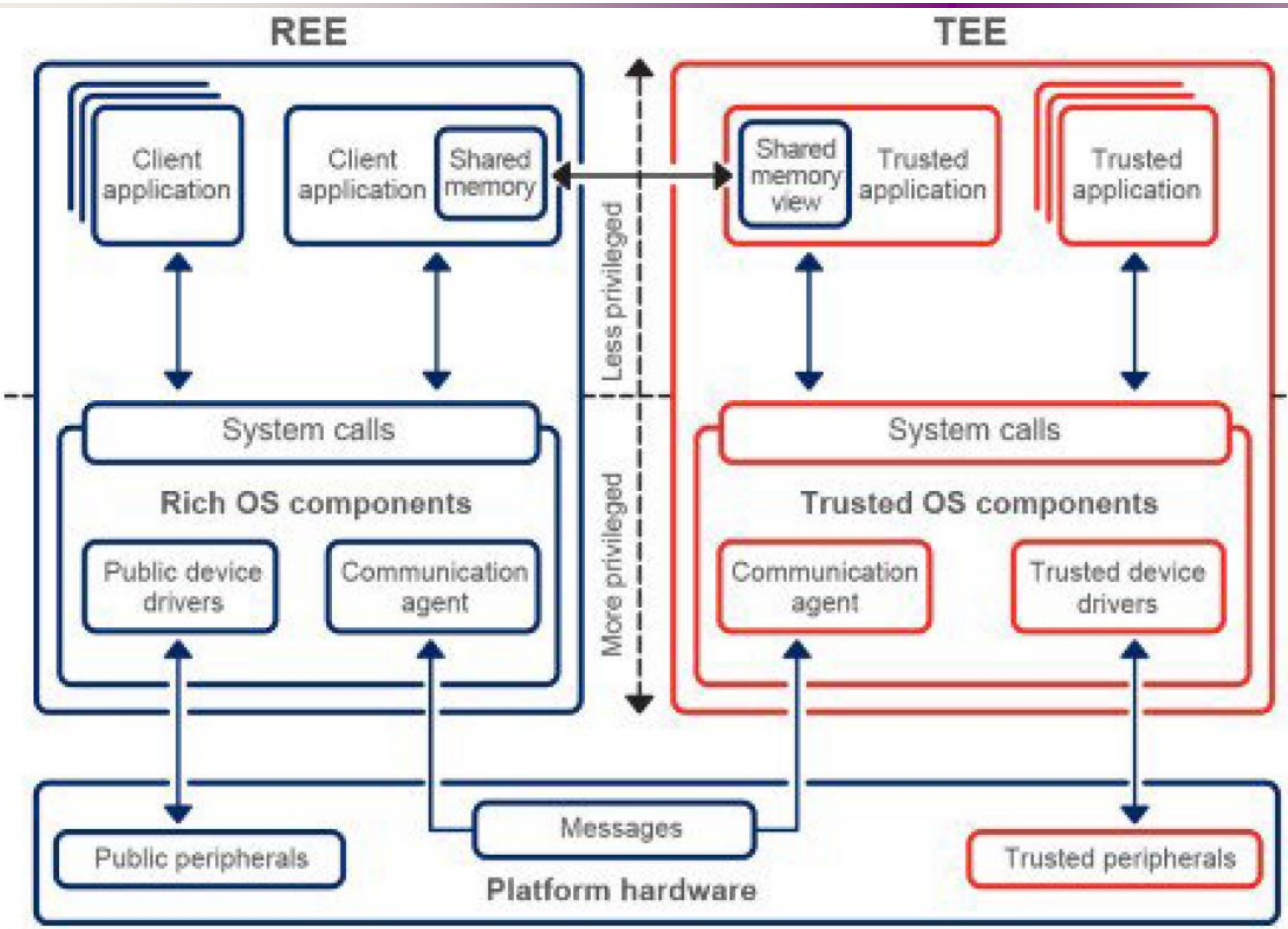


[ref] A 5G Americas White Paper. The Evolution of Security in 5G: A 'Slice" of Mobile Threats, July 2019

Building Secure and Trusted E2E Env for IoT and Edge with the Trusted Execution Environment (TEE)

- **Trusted Execution Environment** (**TEE**) is a secure area of a main processor that guarantees code and data loaded inside to be protected with respect to confidentiality and integrity.
  - TEE as an isolated execution environment provides security features such as isolated execution, integrity of applications executing with the TEE, along with confidentiality of their assets
- TEE is a standard which creates an isolated environment that runs in parallel with the operating system, providing security for the rich environment.
  - Only trusted applications running in a TEE have access to the full power of a device's main processor, peripherals and memory, while hardware isolation protects these from user installed apps running in a main operating system.
  - Proposed and implemented by ARM as ARM TrustZone firmware utilising both hardware and software to protect data on terminal devices
  - TEE is a derivation of the Trusted Computing Group (TCG) Architecture
- “Hardware root of trust" is used in TEE to prevent simulation of hardware with user-controlled software.
  - Technically this is a set of private keys (so-called "endorsement keys" or "provisioned secrets") which are embedded directly into the chip during manufacturing.

TEE Root of Trust: As used in 5G Security Architecture



- TEE – Trusted Execution Environment
  - Protected by hardware secrets
- REE – Rich Execution Environment (OS)
  - Endorsed by TEE
  - Ensures Confidentiality and Integrity of application data

Huawei 5G and security concerns

- Facts and studies
- Huawei firmware analysis by Finite State

Huawei 5G security

- Controversial security reports about Huawei 5G security
  - https://www.ft.com/content/8b48f460-50af-11e9-9c76-bf4a0ce37d49
  - Not only Huawei play role in network/infra security
- 1. Data: It is almost impossible for encrypted communications to be read by anyone who does not have the encryption keys.
  - But in the way wireless telecoms networks are currently structured, much data passes through the network in unencrypted form.
  - Some experts have argued that the risk from Huawei's equipment could be minimised by only using the vendor in the "edge" or "access" networks — the periphery of the network, which includes the base stations (or masts) that broadcast mobile signal, and not the "core" network.
- 2. Attacks on individuals: Base stations can send false emergency alerts, or not pass on real emergency alerts. Base stations can also launch "man in the middle attacks".
- 3. Attacking the whole network Base stations relay signals between the phone and the core network, but can also be used to send malicious signals into the core.
  - DoS attacks that jam part or all of the network
  - Mr Clancy said that keeping Huawei out of one country's network would not significantly reduce Huawei's offensive capabilities. "With their market share, they can take down the global Internet whenever they want," he said.

Huawei security: Half its kit has 'at least one potential backdoor'

https://www.zdnet.com/article/huawei-security-half-its-kit-has-at-least-one-potential-backdoor/

- Recent facts that suspected Chinese state-sponsored hackers broke into telecom giants through IBM and HPE, researchers have revealed that over half the equipment from China's telecoms giant, Huawei, has "at least one potential backdoor".
- Huawei equipment assessment by the UK's National Cyber Security Centre (NCSC) over concerns its 5G gear could be used by China to spy on the country:
  - Huawei security was "objectively worse" and "shoddy" compared with that of rivals, which include Ericsson, Nokia, and Cisco.
- Finite State analyzed 1.5 million files within about 10,000 firmware images that are used across 558 Huawei enterprise networking products.
  - More than 55 percent of firmware images have at least one potential backdoor
  - The flaws include hard-coded credentials that could be used as a backdoor, unsafe use of cryptographic keys, and indications of poor software development practices.
  - Finite State nonetheless found that on average there are 102 known vulnerabilities in each Huawei firmware image, along with evidence of numerous zero-day vulnerabilities.
- One of the key problems Finite State found lies in Huawei's use of and failure to update open-source software components, in particular OpenSSL,
  - It found that the average age of third-party open-source software components in Huawei firmware is 5.36 years and says there are "thousands of instances of components that are more than 10 years old".
  - The oldest version of OpenSSL contained in Huawei firmware was released by the open-source project in 1999. The company said it found 389 binaries on Huawei firmware that were vulnerable to Heartbleed, the critical bug disclosed in 2014 that allows an attacker to steal email and other communications that would normally be protected by the Transport Layer Security protocol.

Discussion

- 5G technologies for Secure Cyberinfrastructure and Data exchange
- E2E infrastructure from IoT – Edge – Data Center - Data Analytics
- Bring cloud experience to 5G core network
- Bring computationally enforceable policies via CNF cloud native provisioning

Mobile devices and smartphone security

- Mobile devices security
- Baseband processor architecture

Mobile devices security

- See overview and comparison of the security of mobile platforms: IOS, Android, Windows
  http://meseec.ce.rit.edu/551-projects/fall2015/3-2.pdf
  https://crypto.stanford.edu/cs155old/cs155-spring15/lectures/17-mobile-platforms.pdf
- Every smartphone or other device with mobile communications capability (e.g. 3G/4G or LTE) has two processors and runs *two* operating systems by design
  - Application Processor/OS (Android, iOS, Windows)
  - Broadband Processor and proprietary RTOS that manages everything related to radio, e.g. Qualcomm's Infineon and chip
    http://www.osnews.com/story/27416/The_second_operating_system_hiding_in_every_mobile_phone
    - Implements std protocols GSM, UMTS, HSDPA, etc
    - Runs Hayes commands for controlling modem function
    - Existing bug allows multiple attacks
      https://www.infoworld.com/article/2625180/smartphones/coming-soon--a-new-way-to-hack-into-smartphones.html

Baseband processor architecture

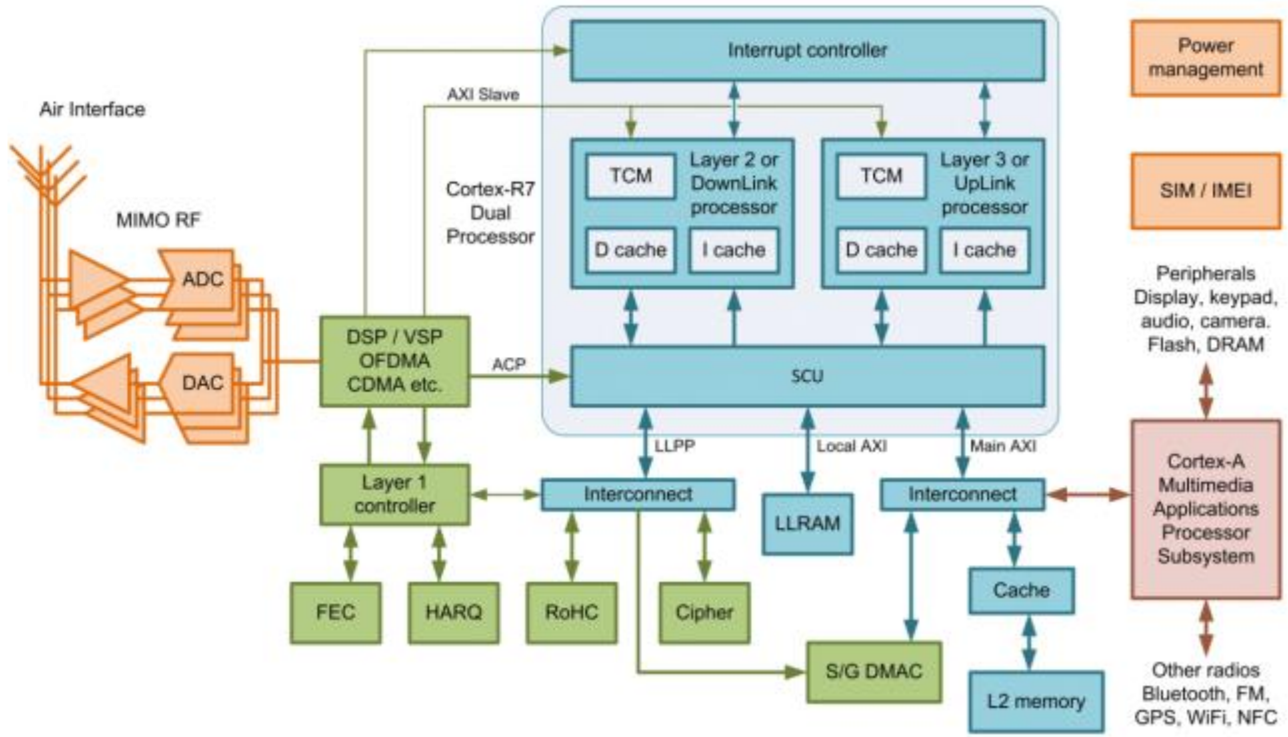


Figure 3: Illustrative baseband architecture

- Baseband processor is the digital system for transmitting and receiving data over the radio. Baseband processor is divided in two parts - https://www.androidauthority.com/smartphones-have-a-second-os-317800/
  - Modem to modulate and demodulate the radio signal
  - Protocol stack processor which manages the communication between base station and mobile terminal by establishing connections, managing radio resources, handling errors and packetizing incoming and outgoing data
- Patent https://encrypted.google.com/patents/US9191823

Additional References

- **CNCF Cloud Native Interactive Landscape** https://landscape.cncf.io/