Cloud Native 5G for Industrial Applications

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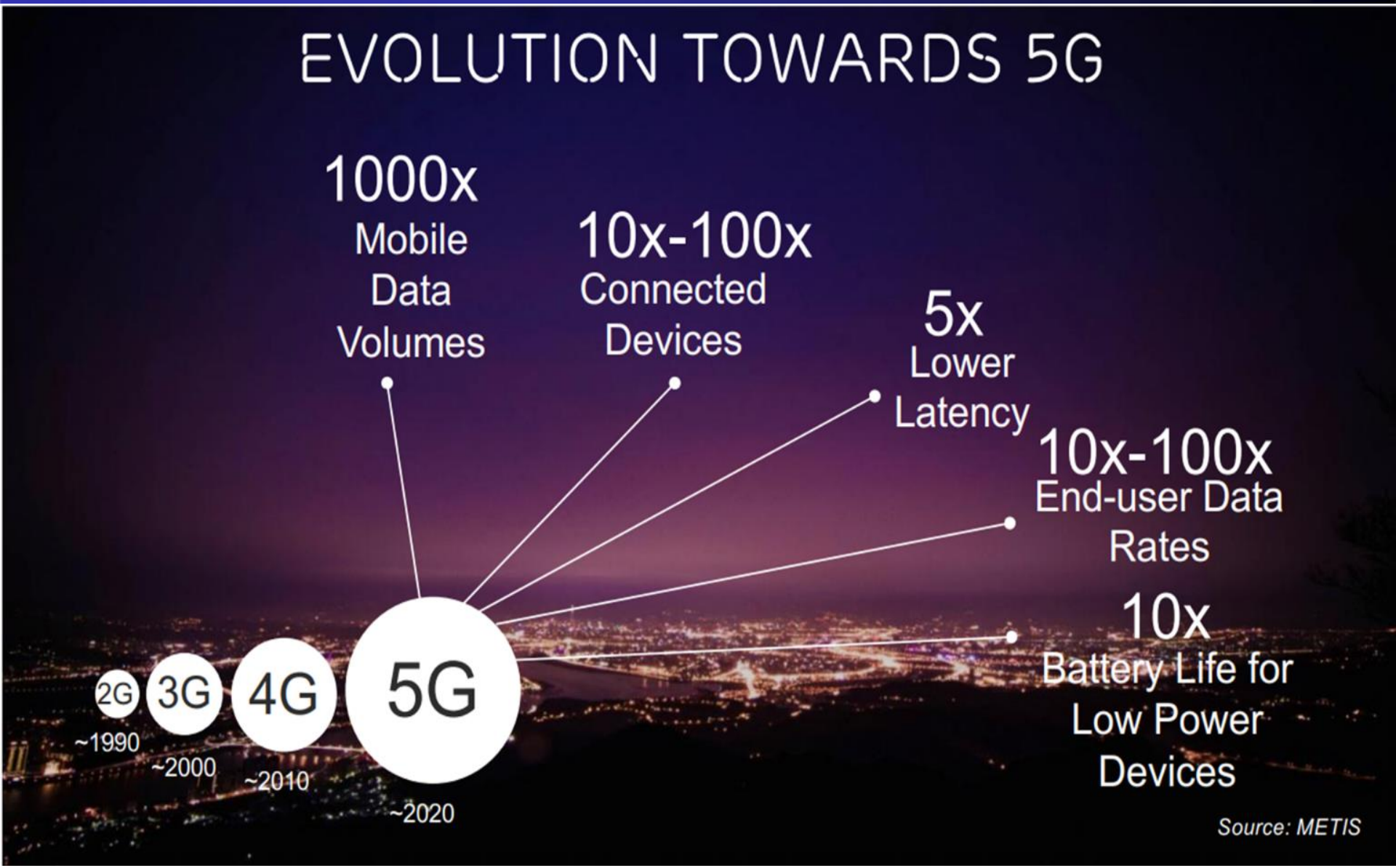
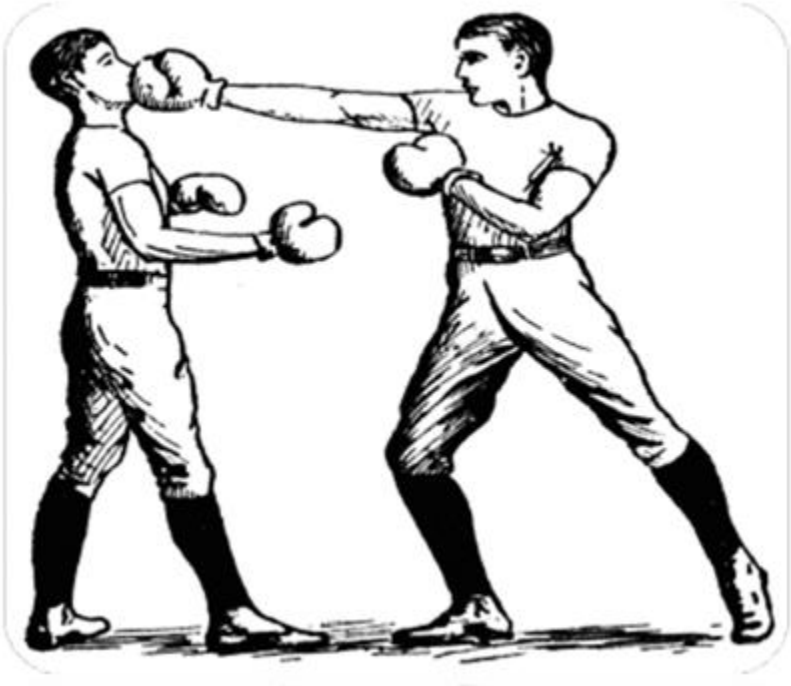
5G


EVOLUTION TOWARDS 5G
1000x
Mobile
Data
Volumes
10x-100x
Connected
Devices
5x
Lower
Latency
10x-100x
End-user Data
Rates
10x
Battery Life for
Low Power
Devices
2G
3G
4G
5G
~1990
~2000
~2010
~2020
Source: METIS

The Frontier of Networking



Existing

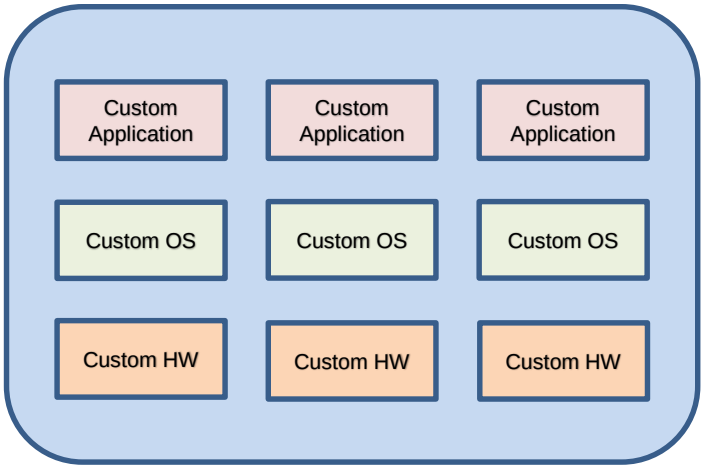
- CLIs
- Closed Source
- Vendor Lead
- Classic Network Appliances

New

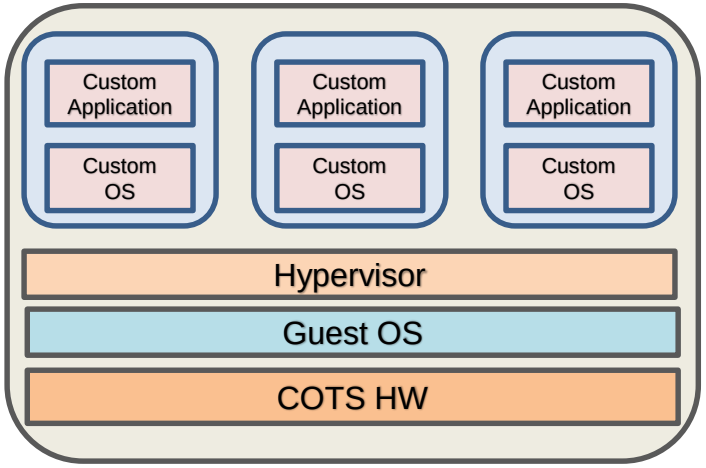
- APIs
- Open Source
- Customer Lead
- Network Function Virtualization (NFV)

Cloud Computing: Virtualization

- Traditionally Mobile core application software runs on proprietary hardware. This HW is deployed OEMs/Vendors specifically for custom applications.
- Such HW is optimized for speed and performance and has a fixed capacity. Capacity increases often require HW swaps or adding additional HW resources (CPU, memory, storage).
- The current model does not scale well and is not cost effective.
- Virtualization enables running applications on virtual machines, which run on COTS HW. This enables the decoupling of application and HW and therefore offers great flexibility at a significantly reduced cost.



Traditional Architecture



VM Based Architecture

Cloud Native

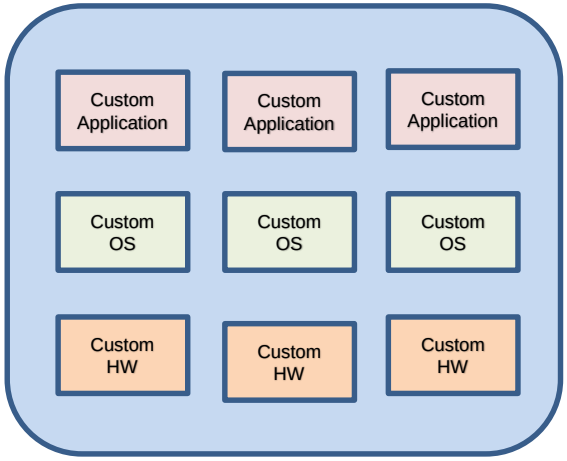
- Cloud Native architectures have gained a lot of attention lately as operators try to follow the same architecture principles as followed by hyperscalers like Amazon, Google etc.

- Cloud Native is not a single concept but instead is a set of principles. Some of these are:

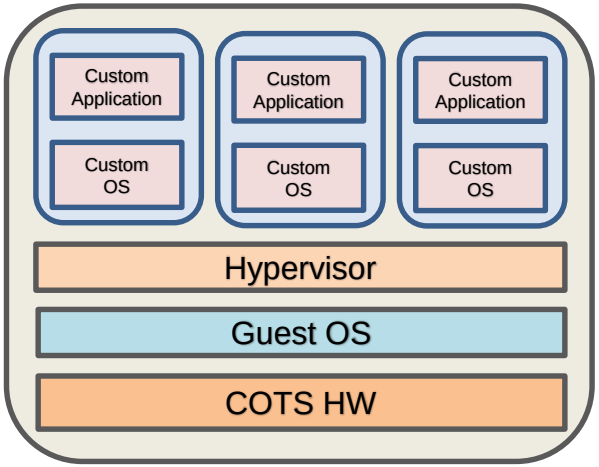
  - Infrastructure agnostic - Apps don't depend on HW and resources.
  - Software decomposition and Life Cycle Management - Apps run in smaller and manageable pieces unlike a monolithic application.
  - Resiliency - due to distributed nature of applications impact of local maintenance or faults is isolated to local instances and does not affect overall functionality.
  - Orchestration and Automation - Apps can be managed using orchestrators like Kubernetes or OpenStack.
  - Turn-up/down, scaling and maintenance (upgrades, logging etc.) of apps is all automated.

Containers

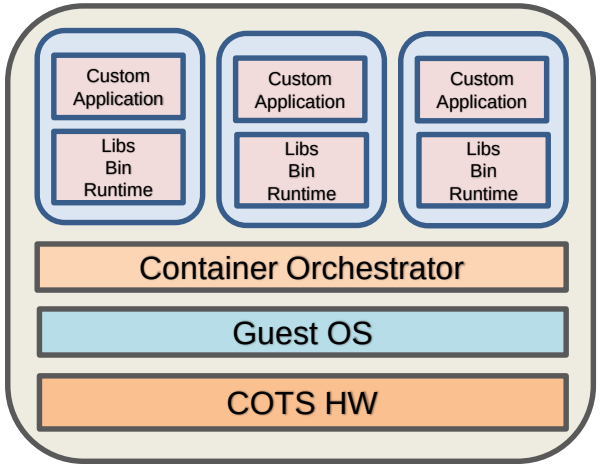
- Containers are independent hosts for applications that use a single, stripped-down version of an operating system to run.
- Virtual machines use a full version of an operating system.
- Containers run a virtualized workload, processed by an application broken up into microservices, making them more lightweight and flexible than a VM.
- VMs can run a full, unaltered application, orchestrated by a hypervisor.
- Both can scale up and down quickly and easily.



Traditional Architecture



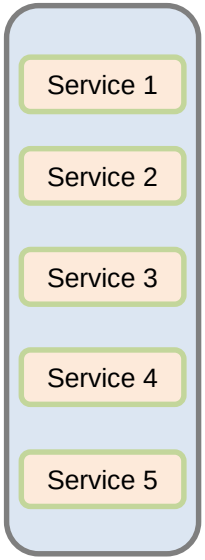
VM Based Architecture



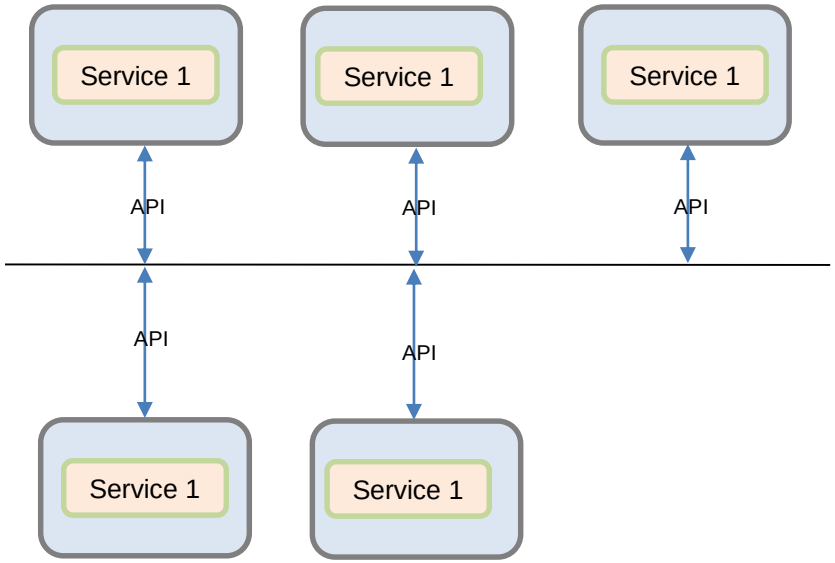
Container Based Architecture

Microservices

- Refers to an architectural and organizational approach to software development where application is composed of smaller indepedent services that interact with each other over well defined APIs.
- Form the basis for service based architecture (SBA).
- Several benefits:
  - Components have a limited scope and therefore changes can be made quickly and efficiently.
  - Instances can be added, removed on demand adding ease of scalability.
  - Independent software upgrades.
  - Ease of debugging due to limited scope of components.



Monolithic Architecture



Microservices based Architecture

Automation

- 5G needs to support rapid scaling up/down and life cycle management of network applications (turn up/down, upgrade, logging etc.)
- Automation technologies for orchestration can help achieve these goals.
- So far SON (self-optimizing networks) capabilities have been leverage on the RAN side. For example - Automatic Neighbor relations.
- Operators have seen accelerated roll out times, simplified network upgrades, fewer dropped calls, improved call setup success rates among other positive impacts. Therefore there is a great deal of interest to implement SON/automation on the core side as well.
- 5G is a unique architecture that is service-based and built on top of microservices. This offers a unique opportunity to leverage automation to manage life cycle of applications and infrastructure resources. Such capabilities are essential for supporting 5G use cases that demand varying demands/requirements.
- Machine learning and artificial intelligence will become further integrated across all aspects of mobile systems in the near future.

New Verticals

5G is 3GPP's answer for enabling new use cases

- beyond smartphones and traditional IoT applications
- industrial AR, remote control of drones/farming vehicles, support for new vehicular services (NR-V2X), etc.

Address requirements not satisfied by today's WiFi or 4G-based solutions

- network density/scalability, resilience for critical communications

Private 5G

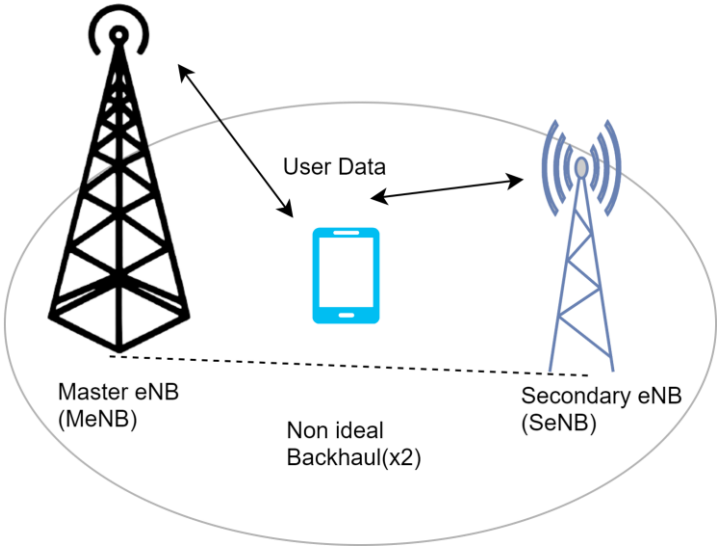
- evolution of private LTE exploiting the new 5G features (i.e. low-latency and ultra-reliable transmission, service classification through slicing)
- licensed bands for non-public applications (e.g. Industry 4.0)
- Customized IT + Radio solution (OS+Servers+Radio+Edge Computing)

5G, Small-cells, Dual Connectivity

Broadband low-latency → **more bandwdith** → **higher frequency** → **shorter range**

↓

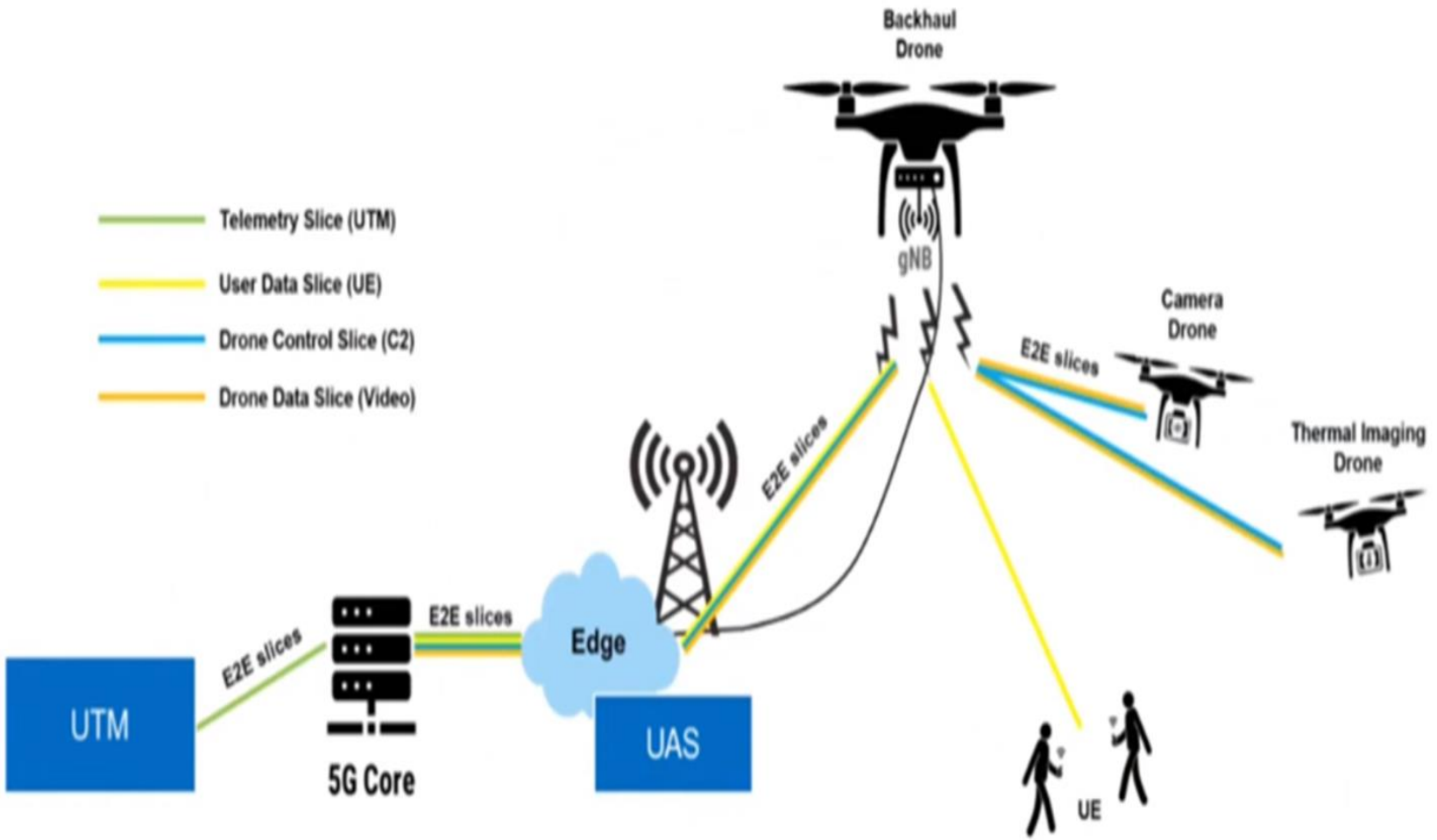
dual connectivity



user-plane from both
control-plane only from Master

→ almost always in coverage (4G), high-speed (5G) when near the SgNB)

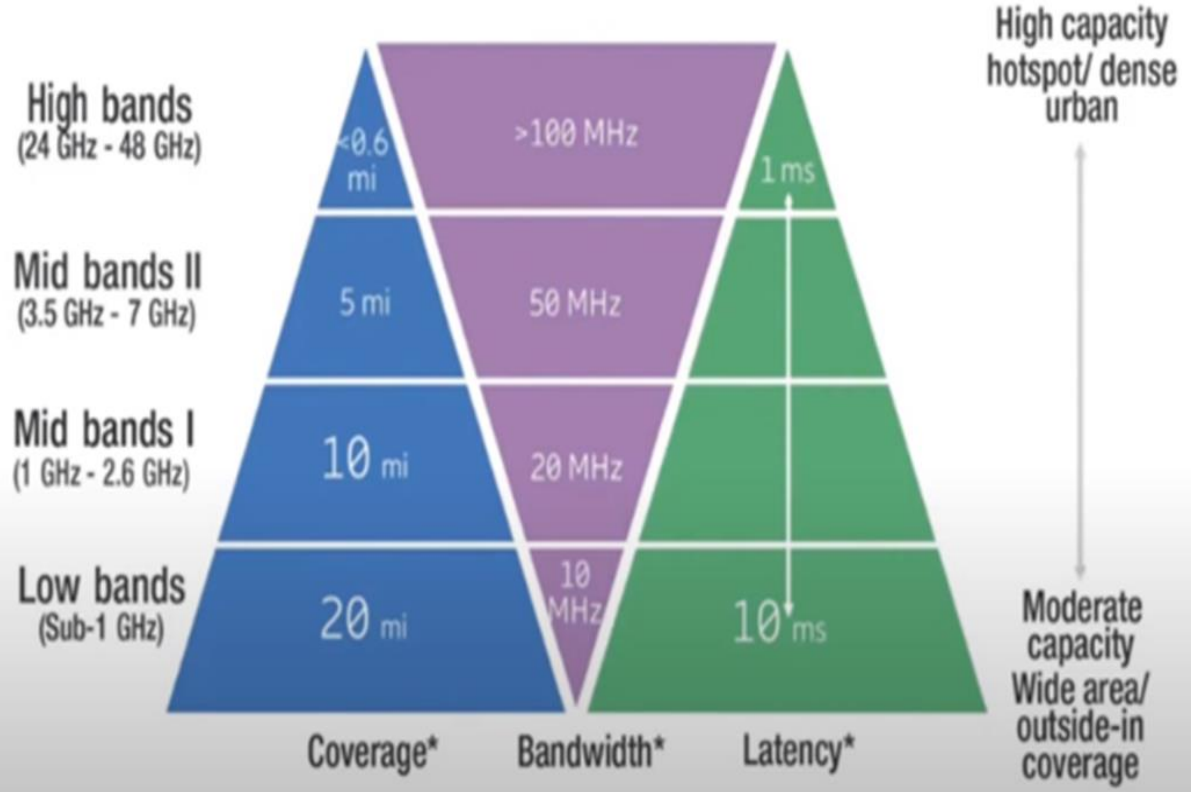
Public Safety: Forest Fire



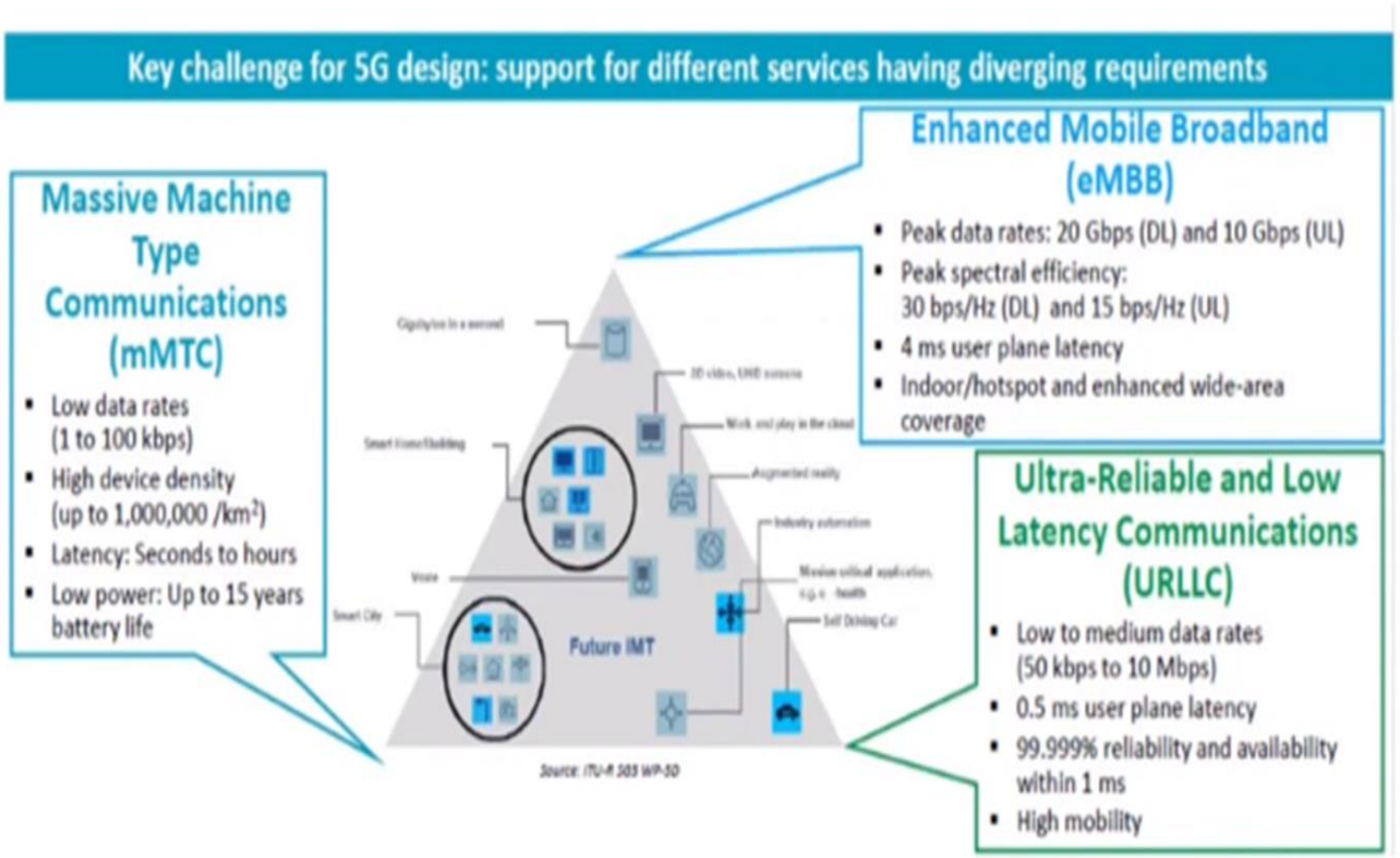
Types of 5G

Types of 5G

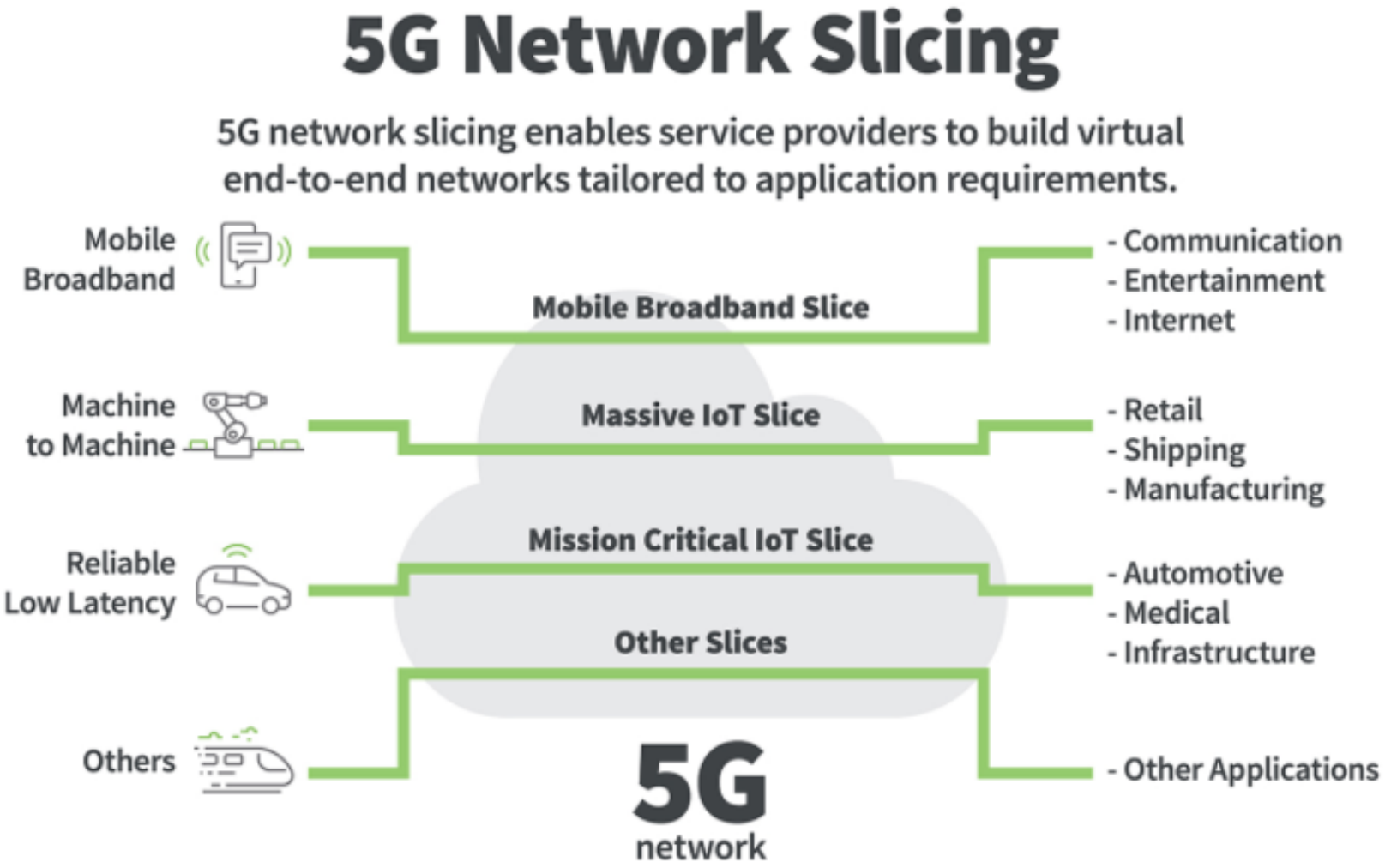
- Not all 5G is created equal
- Choose 2: Coverage, bandwidth, Latency



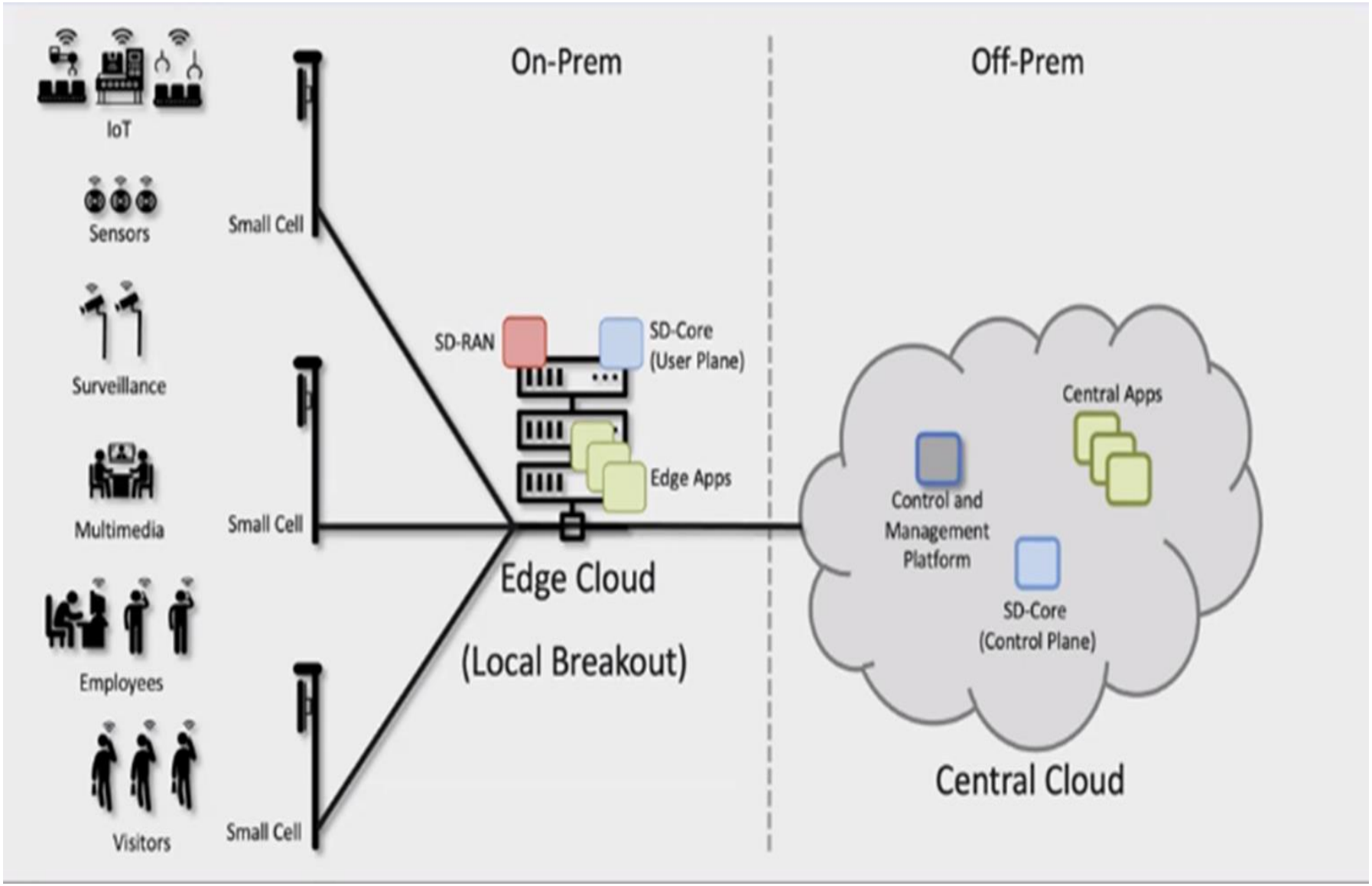
5G Classifications



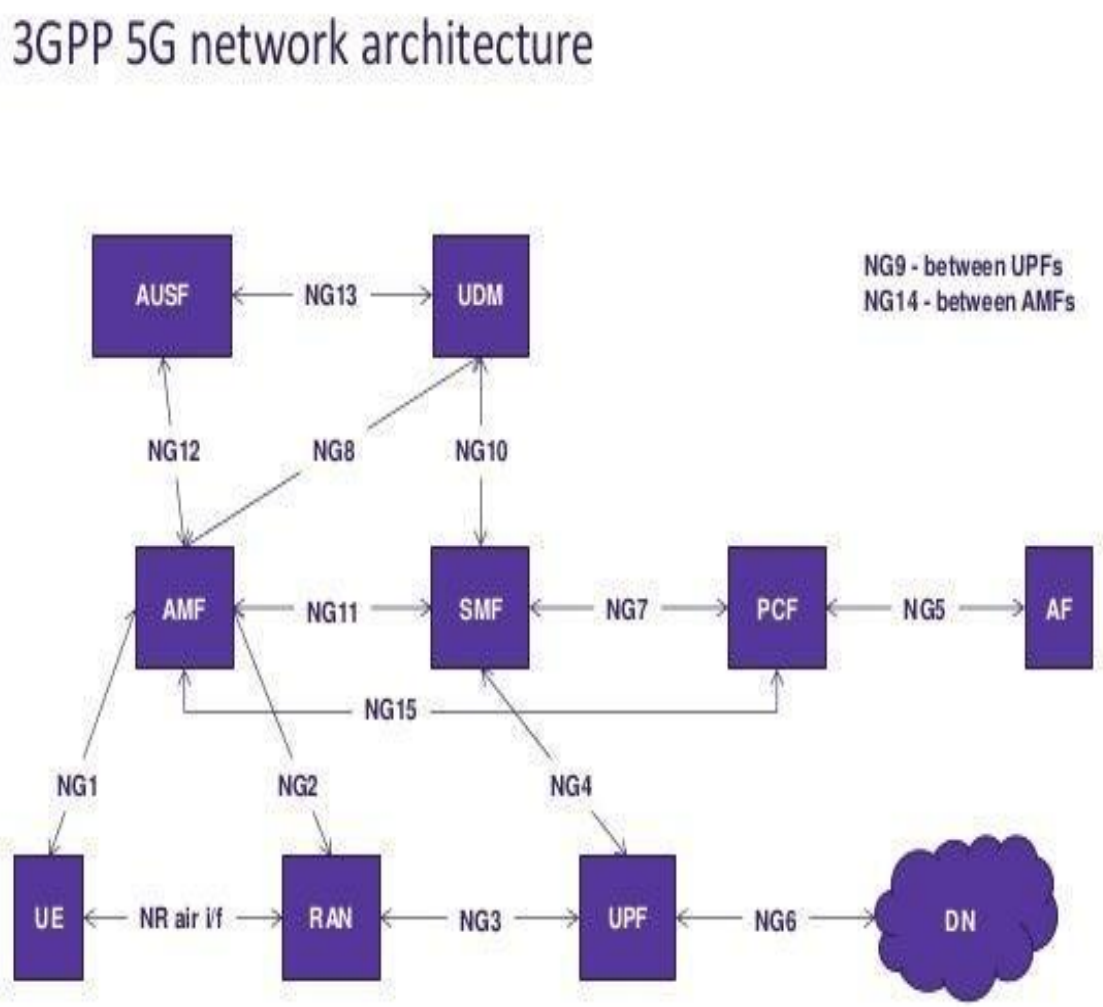
5G Network Slicing



Overview


On-Prem
Off-Prem
IoT
Sensors
Surveillance
Multimedia
Employees
Visitors
Small Cell
Small Cell
Small Cell
SD-RAN
SD-Core
(User Plane)
Edge Apps
Edge Cloud
(Local Breakout)
Central Apps
Control and
Management
Platform
SD-Core
(Control Plane)
Central Cloud

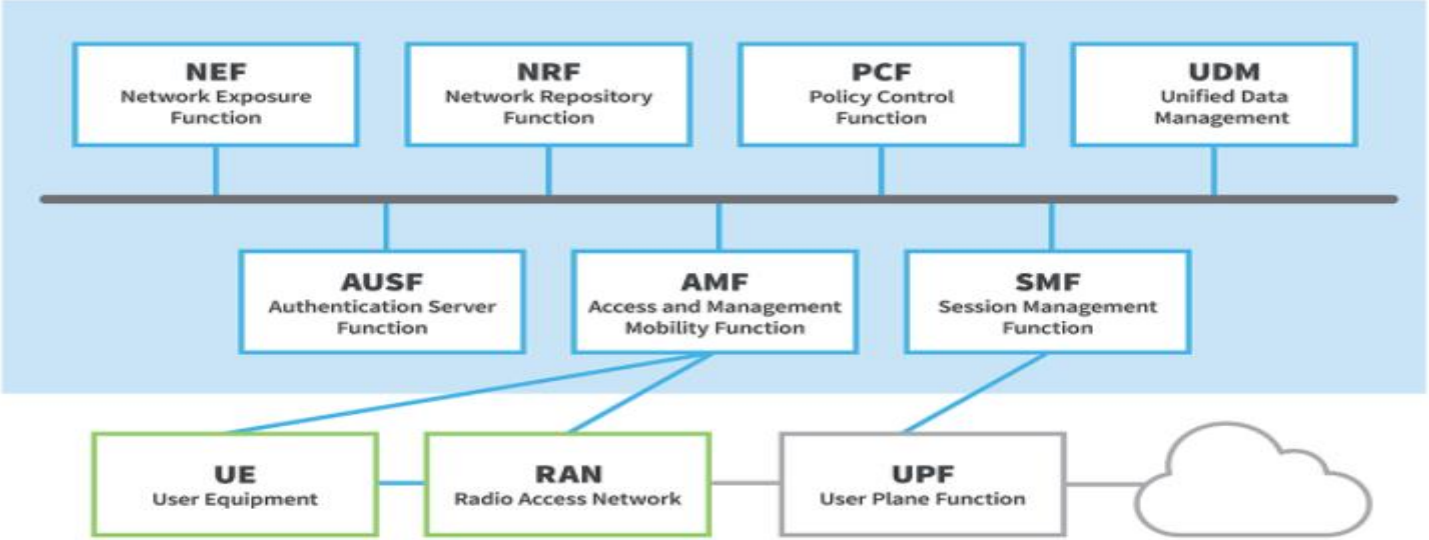
5G Network architecture



The components of the 5G core architecture include:

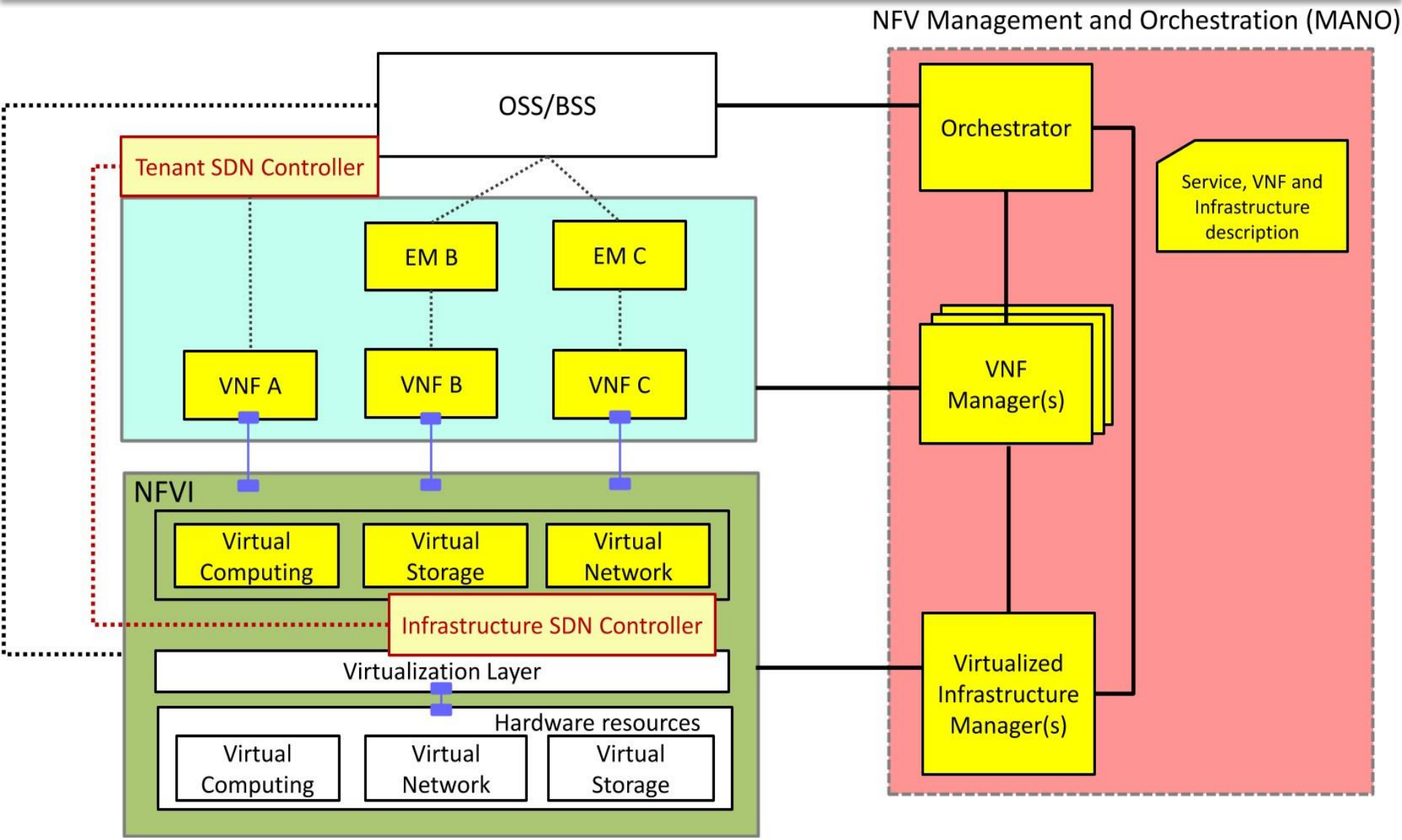
- User plane Function (UPF)
- Data network (DN), e.g. operator services, Internet access or 3rd party services
- Core Access and Mobility Management Function (AMF)
- Authentication Server Function (AUSF)
- Session Management Function (SMF)
- Network Slice Selection Function (NSSF)
- Network Exposure Function (NEF)
- NF Repository Function (NRF)
- Policy Control function (PCF)
- Unified Data Management (UDM)
- Application Function (AF)

5G Architecture Diagram



- User Equipment (UE) like 5G smartphones or 5G cellular devices connect over the 5G New Radio Access Network to the 5G core and further to Data Networks (DN), like the Internet.
- The Access and Mobility Management Function (AMF) acts as a single-entry point for the UE connection.
- Based on the service requested by the UE, the AMF selects the respective Session Management Function (SMF) for managing the user session.
- The User Plane Function (UPF) transports the IP data traffic (user plane) between the User Equipment (UE) and the external networks.
- The Authentication Server Function (AUSF) allows the AMF to authenticate the UE and access services of the 5G core.
- Other functions like the Session Management Function (SMF), the Policy Control Function (PCF), the Application Function (AF) and the Unified Data Management (UDM) function provide the policy control framework, applying policy decisions and accessing subscription information, to govern the network behavior.

SDN and NFV Architecture



5G Network architecture

- NG1: Between UE and AMF (Access and Mobility Management Function)
- NG2: Between RAN (Radio Access Network) or gNB (i.e. 5G base station) and AMF
- NG3: Between RAN or gNB (i.e. 5G base station) and UPF (User Plane Function)
- NG4: Between SMF (Session Management Function) and UPF
- NG5: Between PCF (Policy Control Function) and AF (Application Function).
- NG6: Between UPF and DN (Data Network)
- NG7: NG7 is reference point between SMF and PCF
  NG7r is reference point between vPCF and hPCF
- NG8: Between Unified Data Management (UDM) and AMF
- NG9: Between two core UPFs
- NG10: Reference point between UDM and SMF
- NG11: Between SMF and SMF
- NG12: Between AMF and AUSF (Authentication Server Function)
- NG13: Between UDM and AUSF
- NG14: Between two AMFs
- NG15: • Between PCF and AMF (in Non-roaming scenario)
  • Between V-PCF and AMF (in Roaming scenario)
- NG16: Between two SMFs (Roaming between V-SMF and H-SMF)

Functional blocks within 5G network architecture

The components of the 5G core architecture include:

- User plane Function (UPF)
- Data network (DN), e.g. operator services, Internet access or 3rd party services
- Core Access and Mobility Management Function (AMF)
- Authentication Server Function (AUSF)
- Session Management Function (SMF)
- Network Slice Selection Function (NSSF)
- Network Exposure Function (NEF)
- NF Repository Function (NRF)
- Policy Control function (PCF)
- Unified Data Management (UDM)
- Application Function (AF)

Acknowledgements and references

We acknowledge the several sources of resources from internet used in presentation meant for seminar only and academic purposes for motivating students and academic community in topic.

Thank you!
Questions?