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Key features and requirements of 5G/IMT-2020 networks

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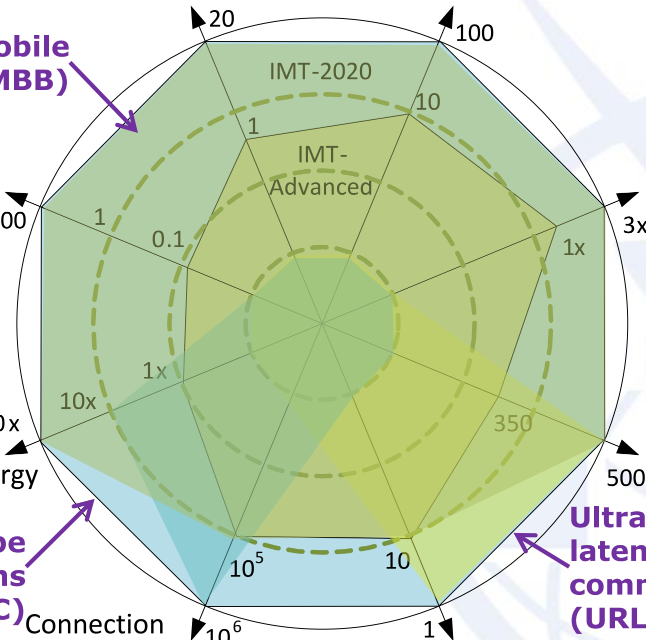
Outline

- Distinguishing features of 5G/IMT-2020 networks
- High level requirements of 5G/IMT-2020 networks

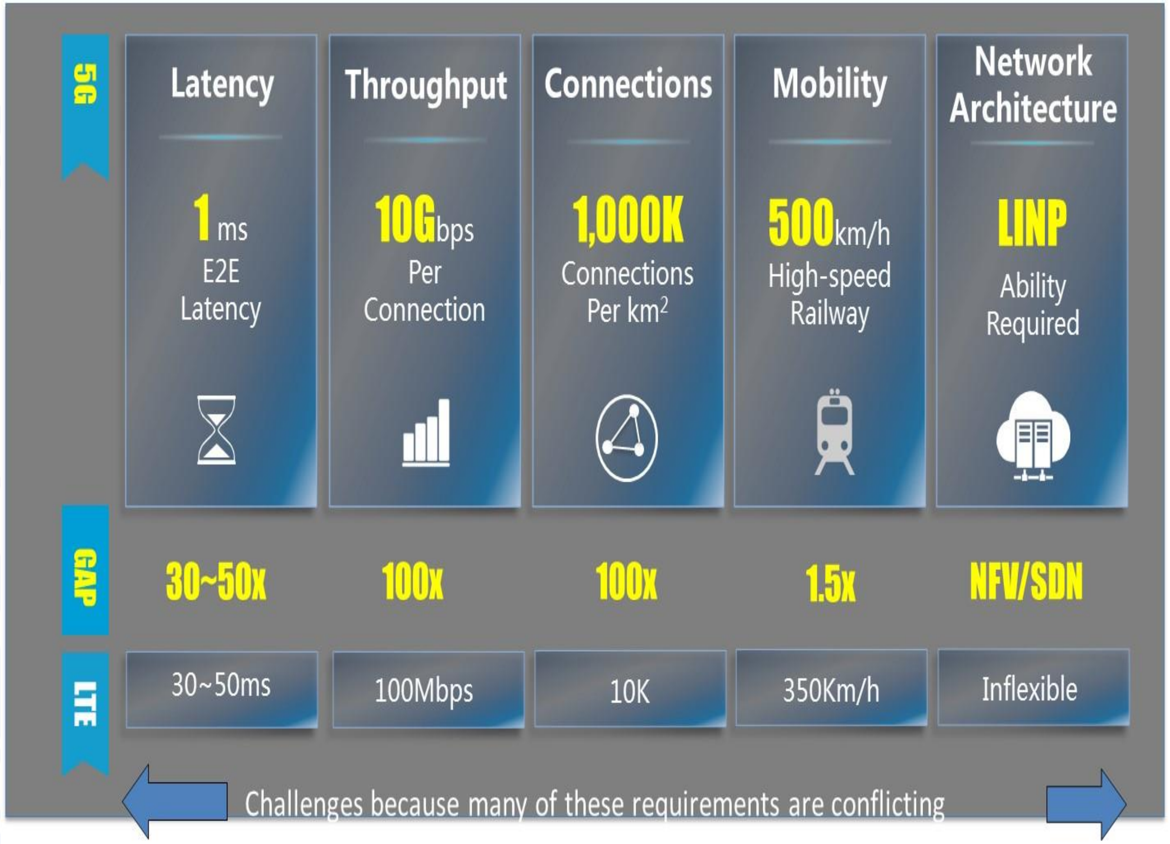
NOTE 1 – Only a limited set of topics is addressed (see [ITU-T Y.3101] for a wider perspective)

NOTE 2 – Along the presentation some references are provided on relevant achievements and ongoing work items of the ITU-T IMT-2020 standardization initiative (SG13) - see also backup slides

Gaps and challenges towards 5G/IMT-2020



NB: Downlink metrics shown

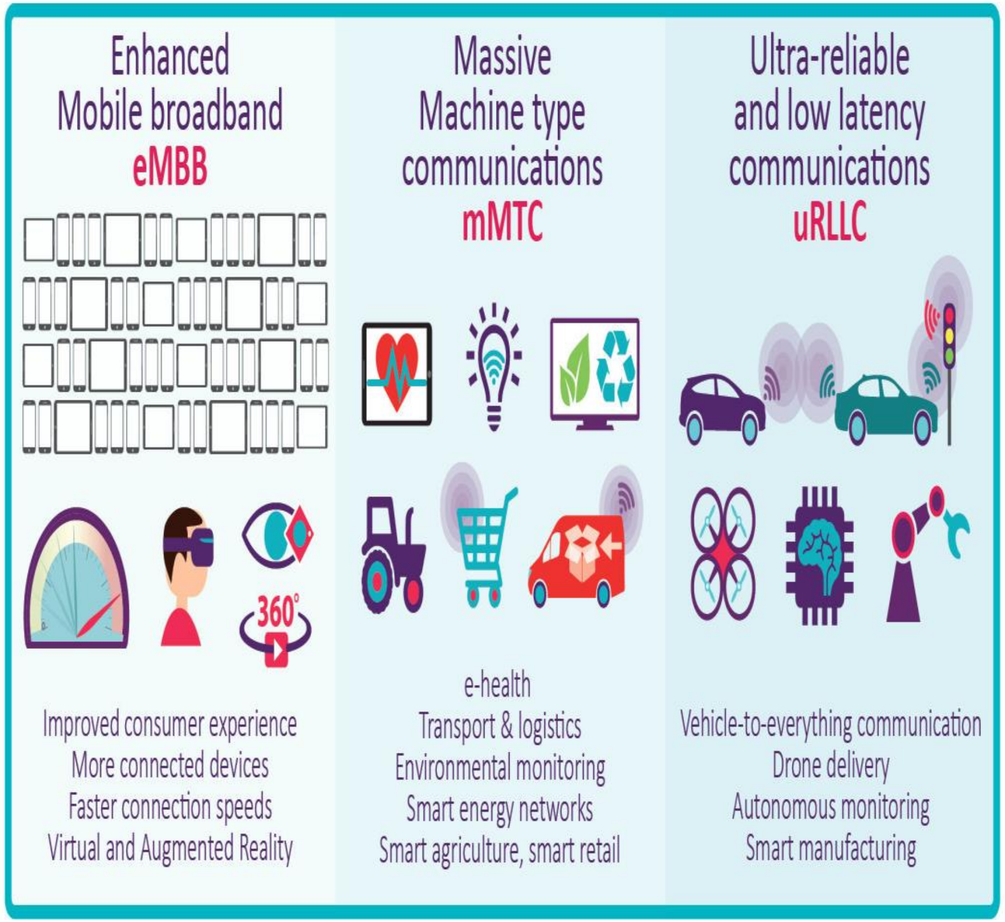


Source: NGMN 5G White Paper

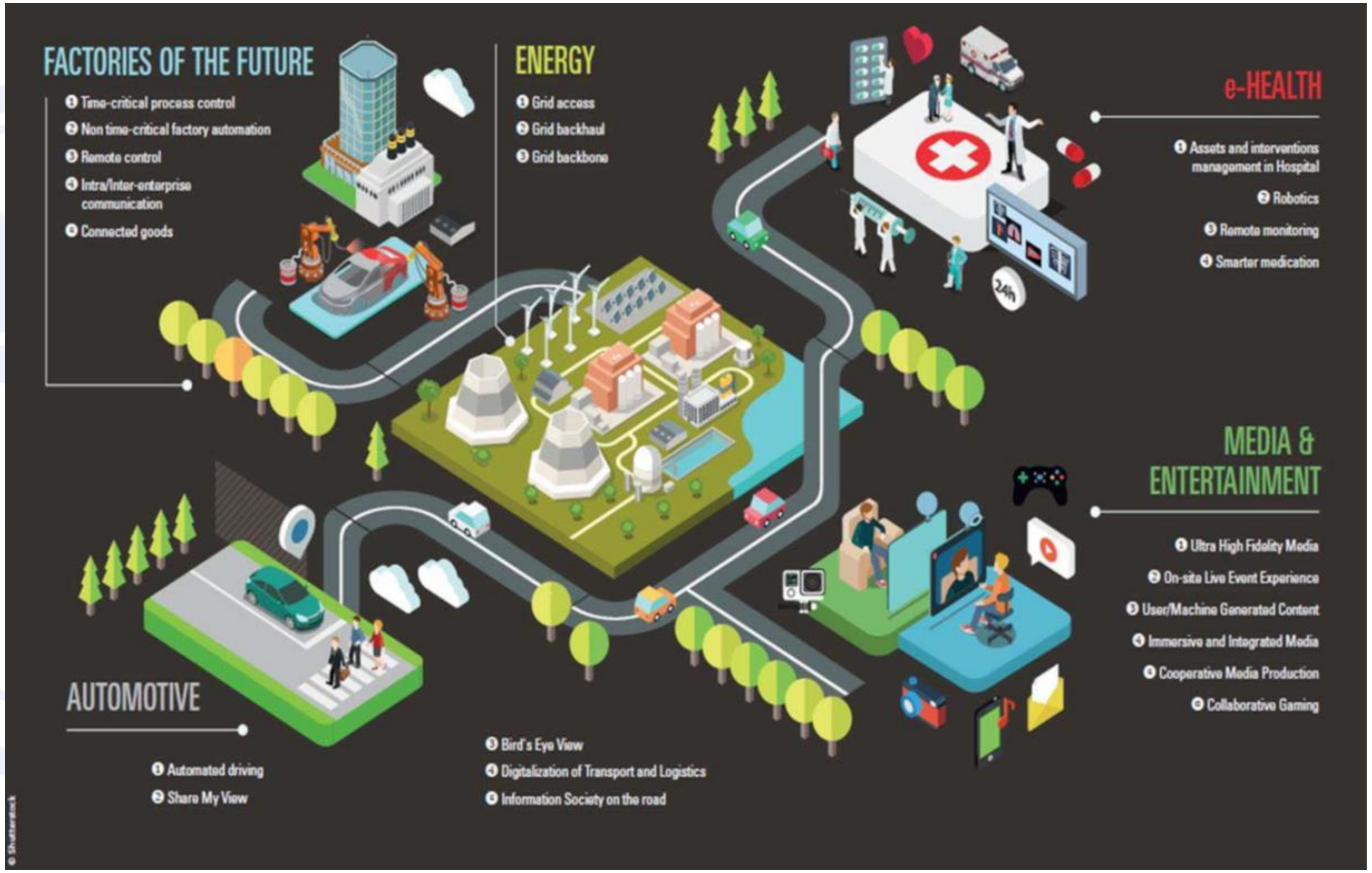
Other network dimensions with gaps for 5G/IMT-2020 expectations:

- business agility (diversity of services and business models)
- operational sustainability (end-to-end management and deployment, flexibility, scalability, energy efficiency)

5G/IMT-2020 as key driver for industrial and societal changes: enabler of a large variety of applications



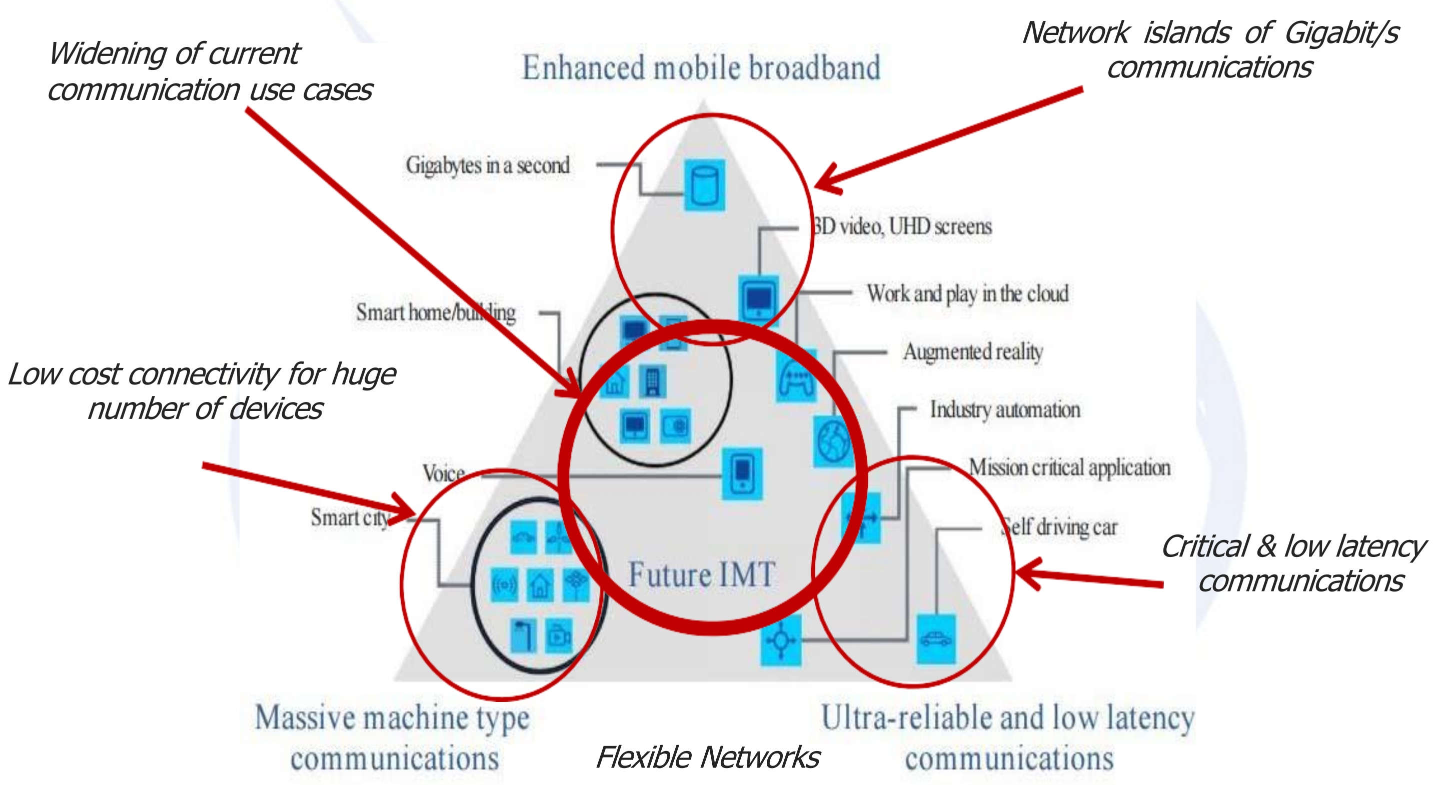
Source: Ofcom



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

- ***Optimization and/or expansion of existing applications*** *(extended coverage, enhanced features)*
- ***New applications*** *(verticals and advanced applications enabled by technology integration)*

Diverse application-specific requirements to be supported

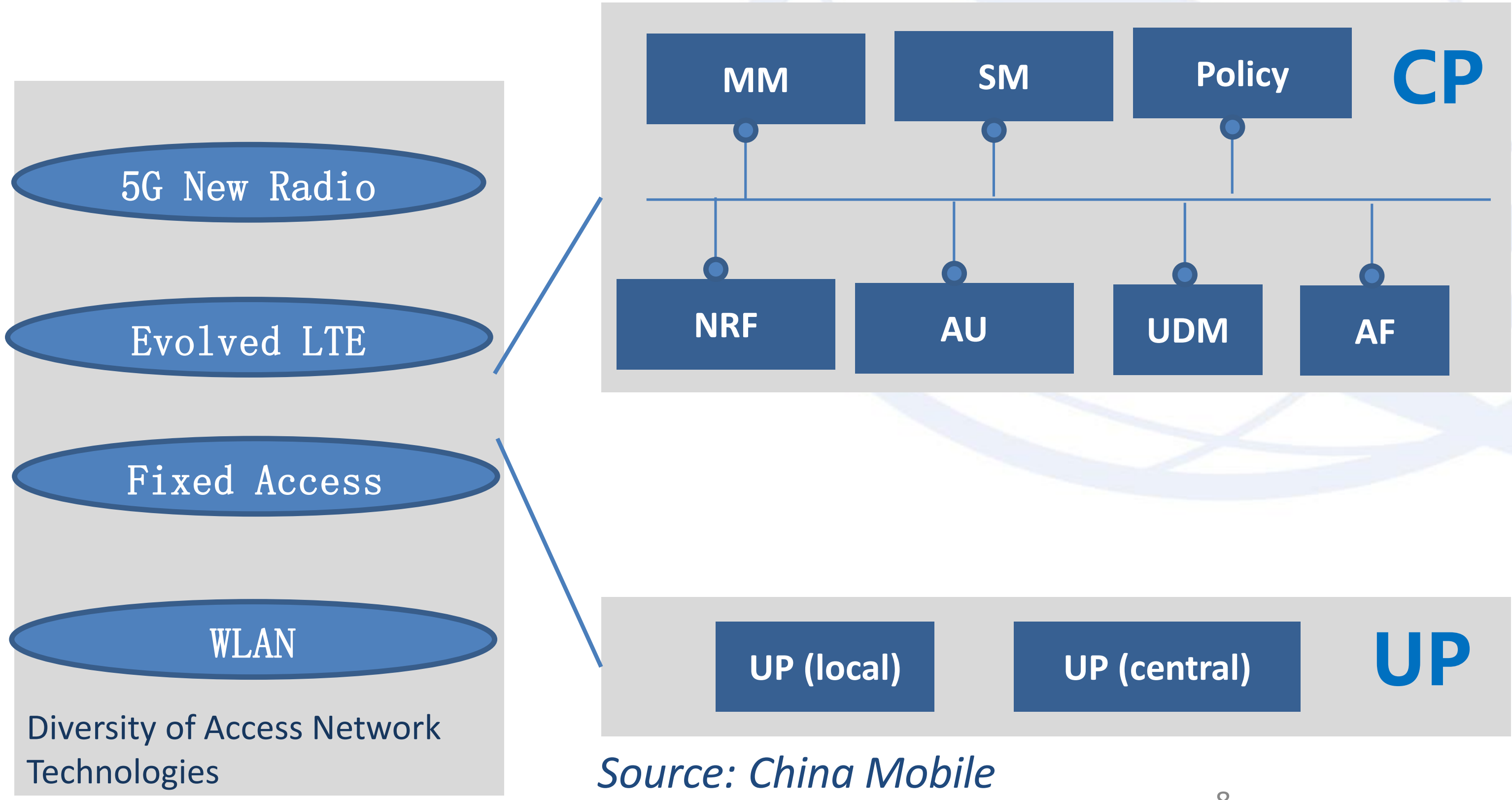


Source: ITU-R Rec. M.2083

5G/IMT-2020 objective:
to ensure flexibility and adaptation to diverse (and changing) requirements of applications
with maximum reusability of (common) network infrastructure capabilities
and efficient but open integration between application and 5G/IMT-2020 ecosystem (business models diversity)

5G/IMT-2020 vision - functional view

Softwarization | **Flexibility** | **Customization**



Source: China Mobile

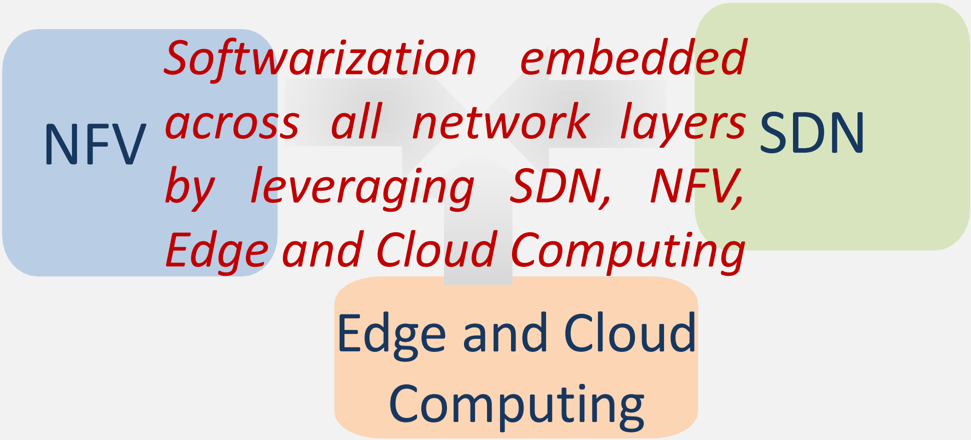
- Service-based architecture and functions interaction
- Modularization of functions
- Separation between Control Plane (CP) and User Plane (UP)
- Network Slicing
- Flexible User Plane
- Fixed Mobile Convergence (through converged Control Plane and simplified User Plane)

Network softwarization

Network softwarization [Y.3100]: ***Overall approach for designing, implementing, deploying, managing and maintaining network equipment and/or network components by software programming***

Key drivers of Network softwarization

- pervasive diffusion of ultra-broadband (fixed and mobile)
- increase of performance of HW at lowering costs
- growing availability of Open Source SW
- more and more powerful terminals and smart things
- actionable Big Data and AI/ML advances



Network softwarization is paving the way towards **X-as-a-Service**

- SDN Controllers, Virtual Network Functions and end users' applications all considered as "services"

Network functions become flexible

- New components can be instantiated on demand (e.g. dedicated network dynamic setup)
- Components may change location or size (e.g. deployment at edge nodes, resource reallocation)
- Communication paths may change (e.g. service aware networking, chained user plane functions)

Enablement of network/service architectures (re-)design, cost and process optimization, self-management

Network programmability but also **increased complexity** [network management impact]

See also ITU-T Y.3150

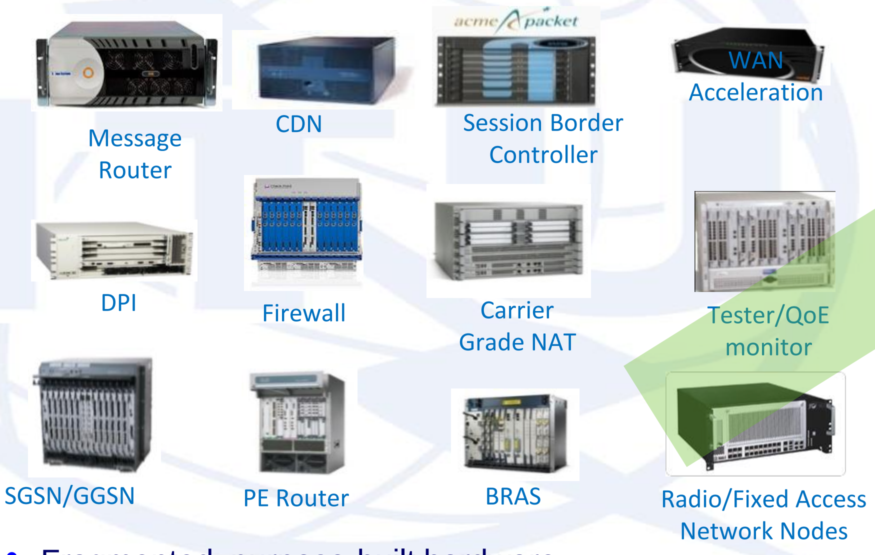
Network Functions Virtualization (NFV): ICT ecosystem disruption

NFV is about implementing network functions in software (programs) running on top of industry-standard hardware (instead of dedicated hardware)

NFV benefits

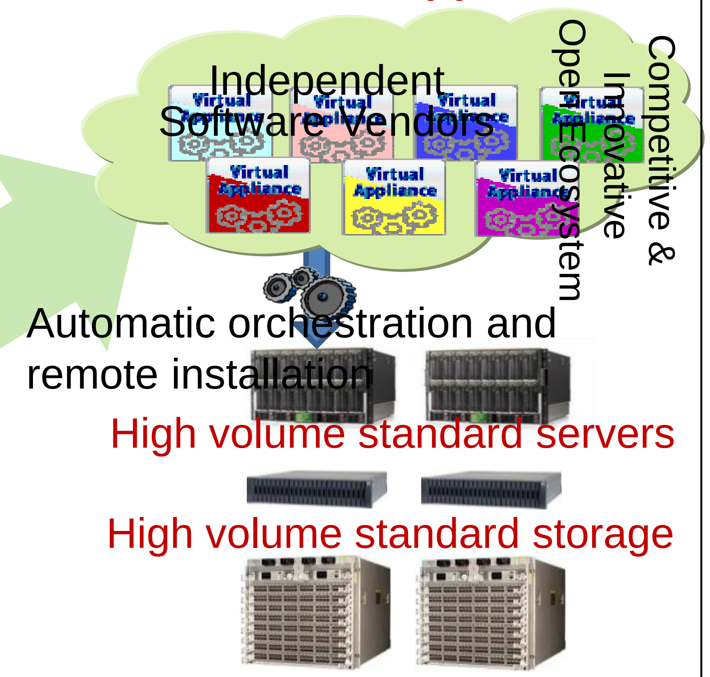
- **Reduced CAPEX and OPEX** (e.g. power consumption)
- **Increased efficiency** (several tenants on same infrastructure)
- **Flexibility** to scale up/down resources
- **Agility** (improved time-to-market to deploy new network services)
- **Lower dependency** on network vendors

Classical Network Appliance Approach



- Fragmented, purpose-built hardware
- Physical install per appliance per site
- Hardware development: large barrier to entry for new vendors, constraining innovation & competition

Network Functions Virtualisation Approach

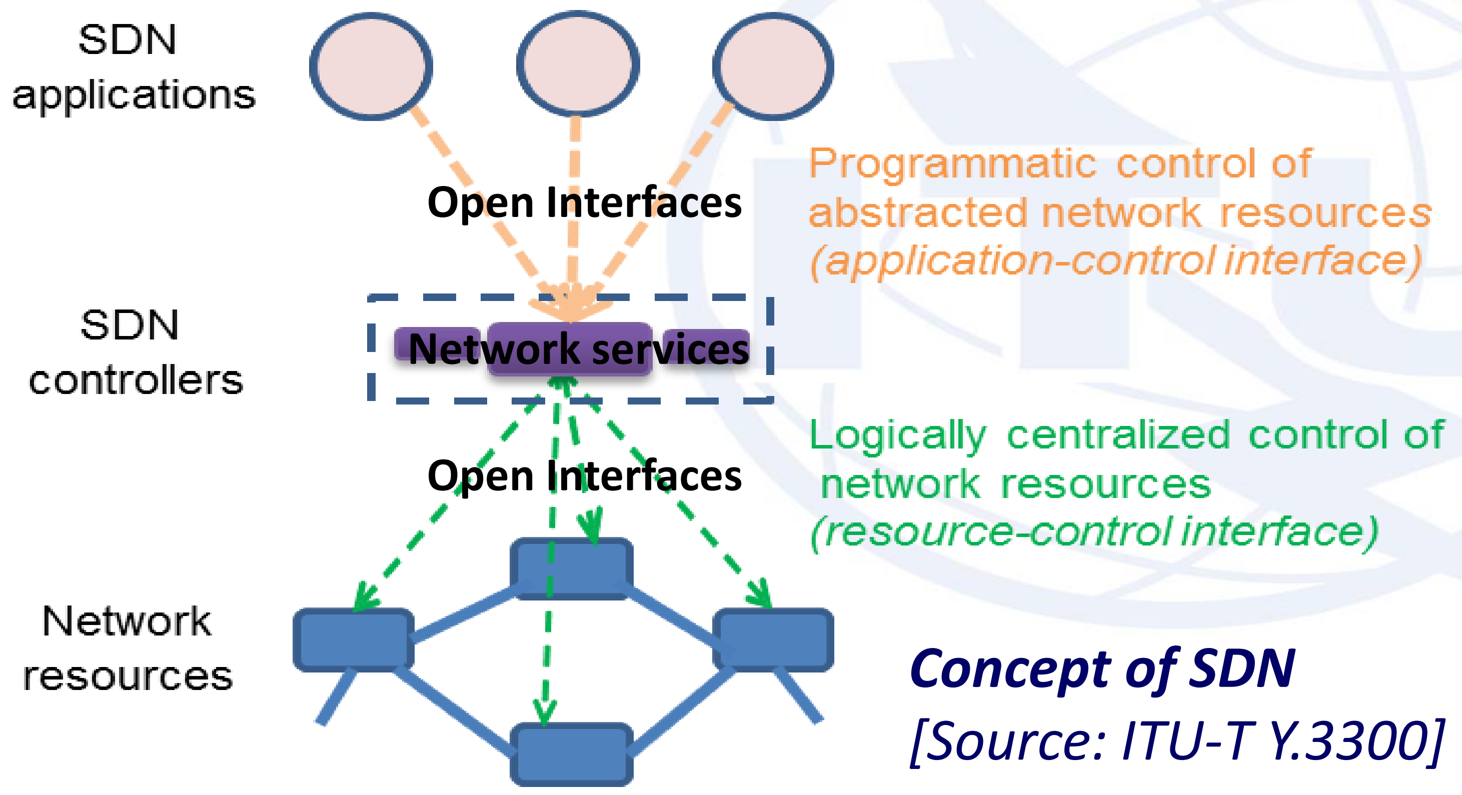


Some issues to be fully addressed, incl.

performance, co-existence, resilience, scalability, vendor integration

Software Defined Networking (SDN)

SDN is a set of techniques enabling to directly program, control and manage network resources, which facilitates design, delivery and operation of network services in a dynamic and scalable manner.

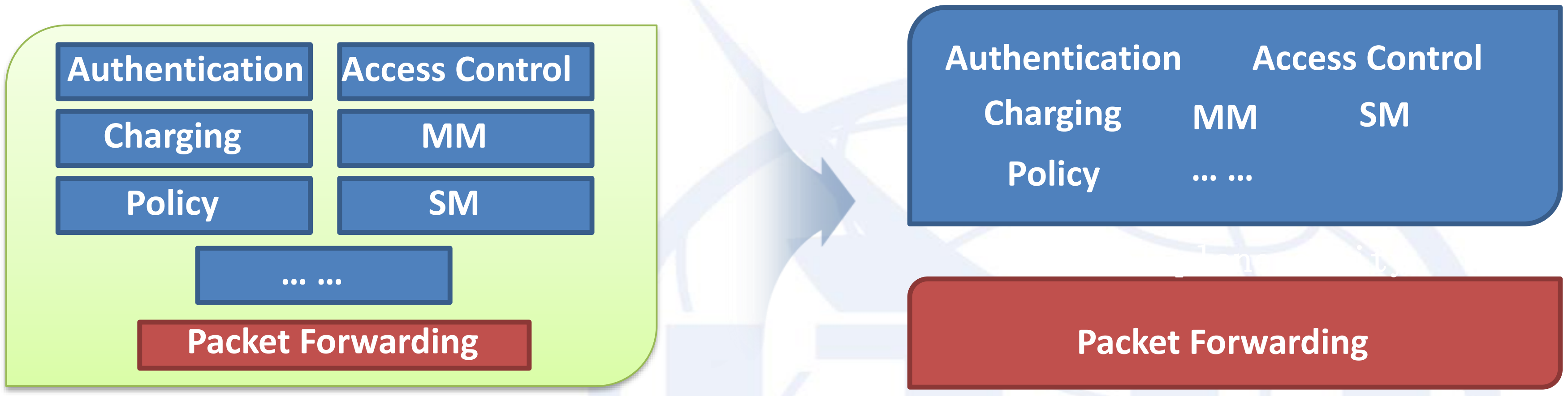


Concept of SDN
[Source: ITU-T Y.3300]

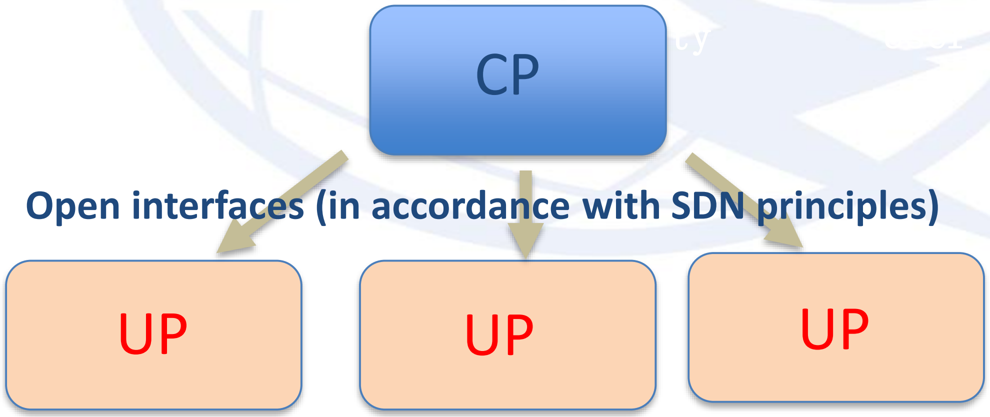
SDN benefits

- **Faster network business cycle**
- Acceleration of innovation and rapid adaptation to demand
- Increase in resource availability and efficiency of use
- **Customization of network resources** including **service-aware networking**

Separation between Control Plane and User Plane

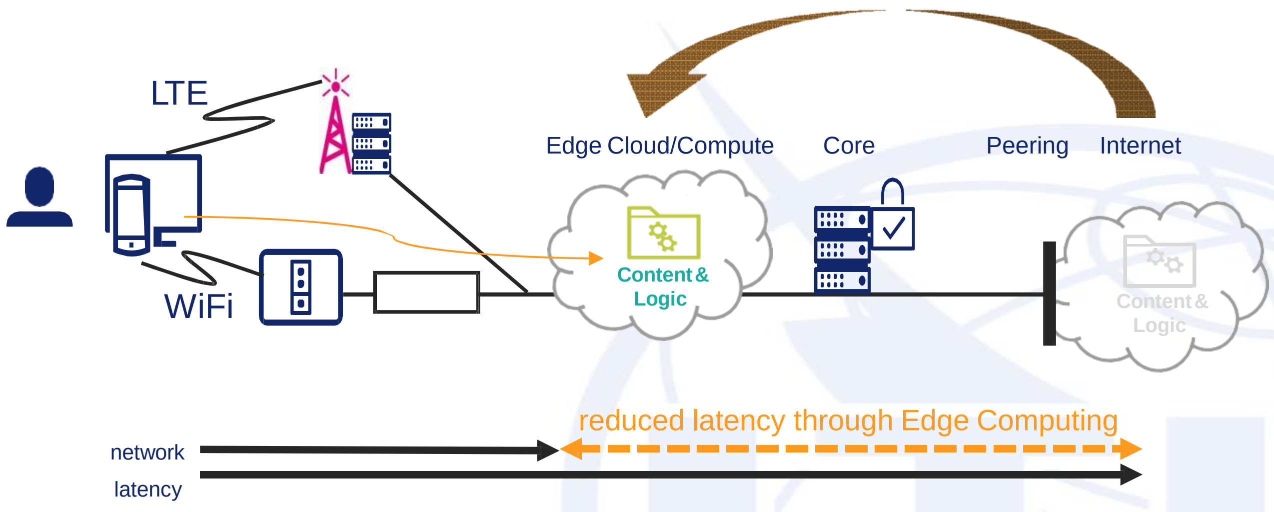


- Scalability
- Independent evolution of both planes
- Flexible network function deployment

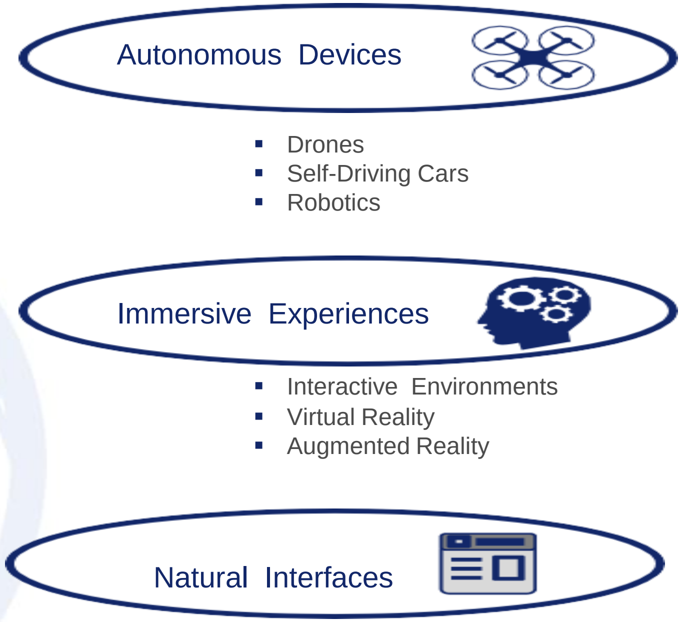


Different User Planes under control of a unified Control Plane

Edge Computing: computing and storage resources next to the user



Low latency applications



- Drones
- Self-Driving Cars
- Robotics

- Interactive Environments
- Virtual Reality
- Augmented Reality

- Voice Control
- Motion Control
- Eye-Tracking

[Ultra-low Latency < 20 ms]

Edge Computing benefits

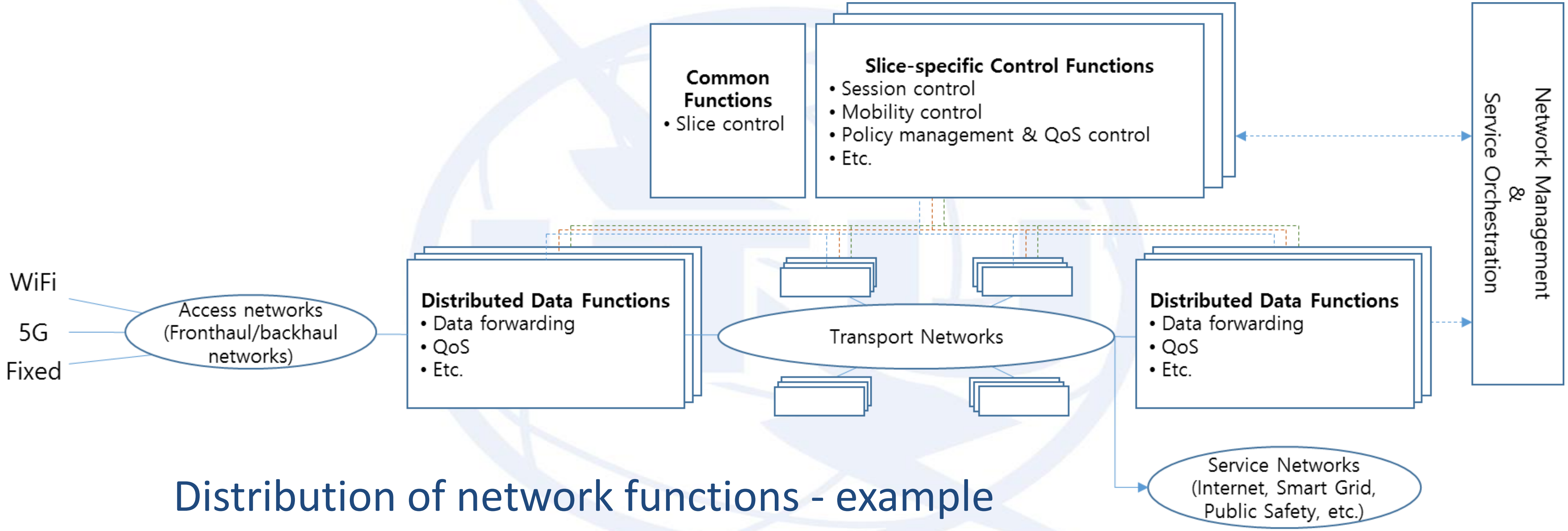
- **(Ultra-)low latency**: disruptive improvement of customer experience
- **Reduction of backhaul/core network traffic**: cloud services (e.g., big data) near to user
- **In-network data processing**

Edge Computing … and more: Fog/Device Computing

Some issues to be fully addressed, incl.

Resource limitation, more complexity, inefficient application execution, service continuity and mobility

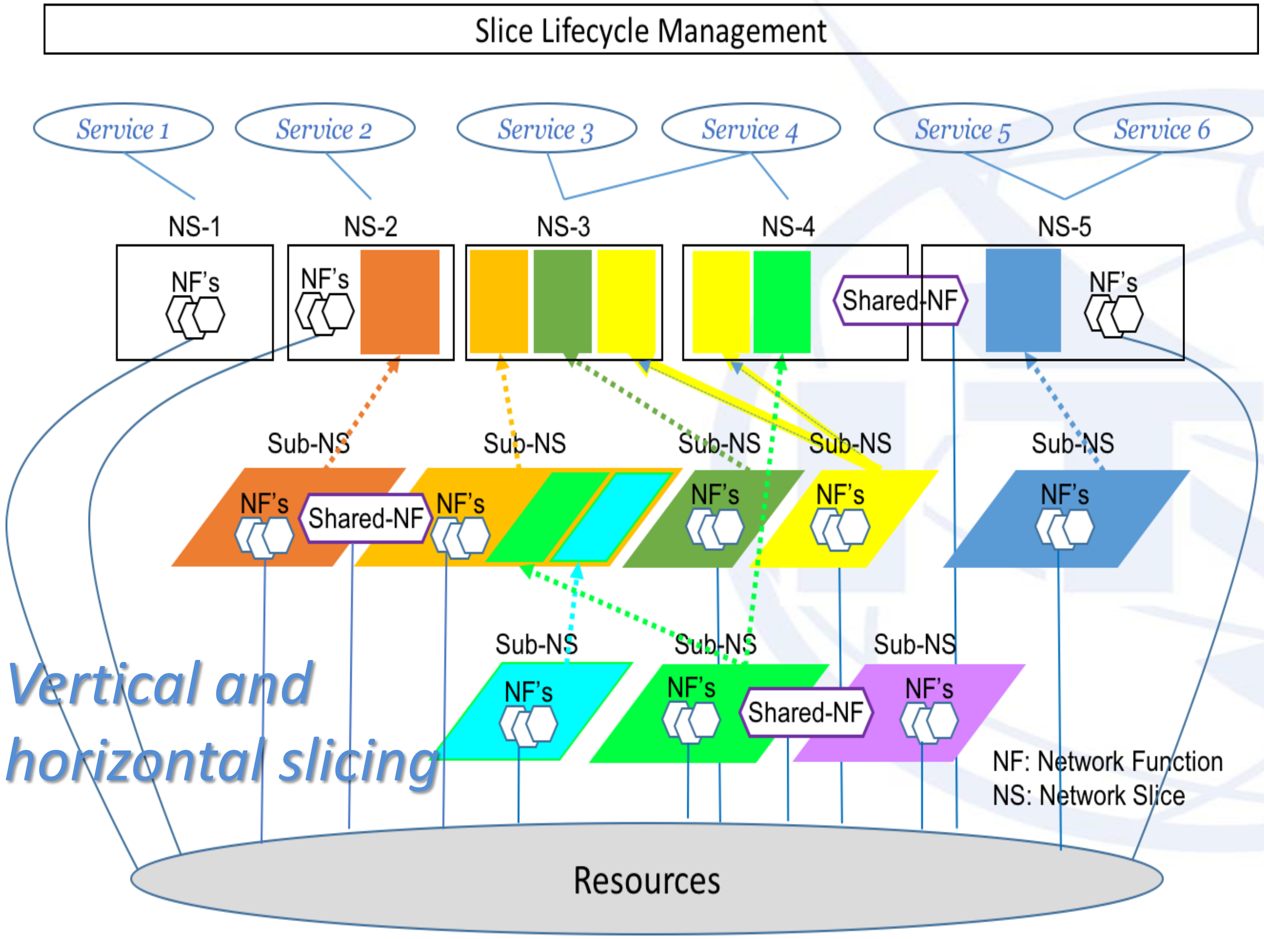
A distributed functional architecture



Distribution of network functions - example

Provisioning of diverse network services by using network functions instantiated at the right place and time

Network slicing: customized support of applications via dedicated logical networks over single infrastructure



Network slice instances and network functions

Slicing versus limitations of classical approaches (« All-in-One » too complex, « Multiple networks » too costly)

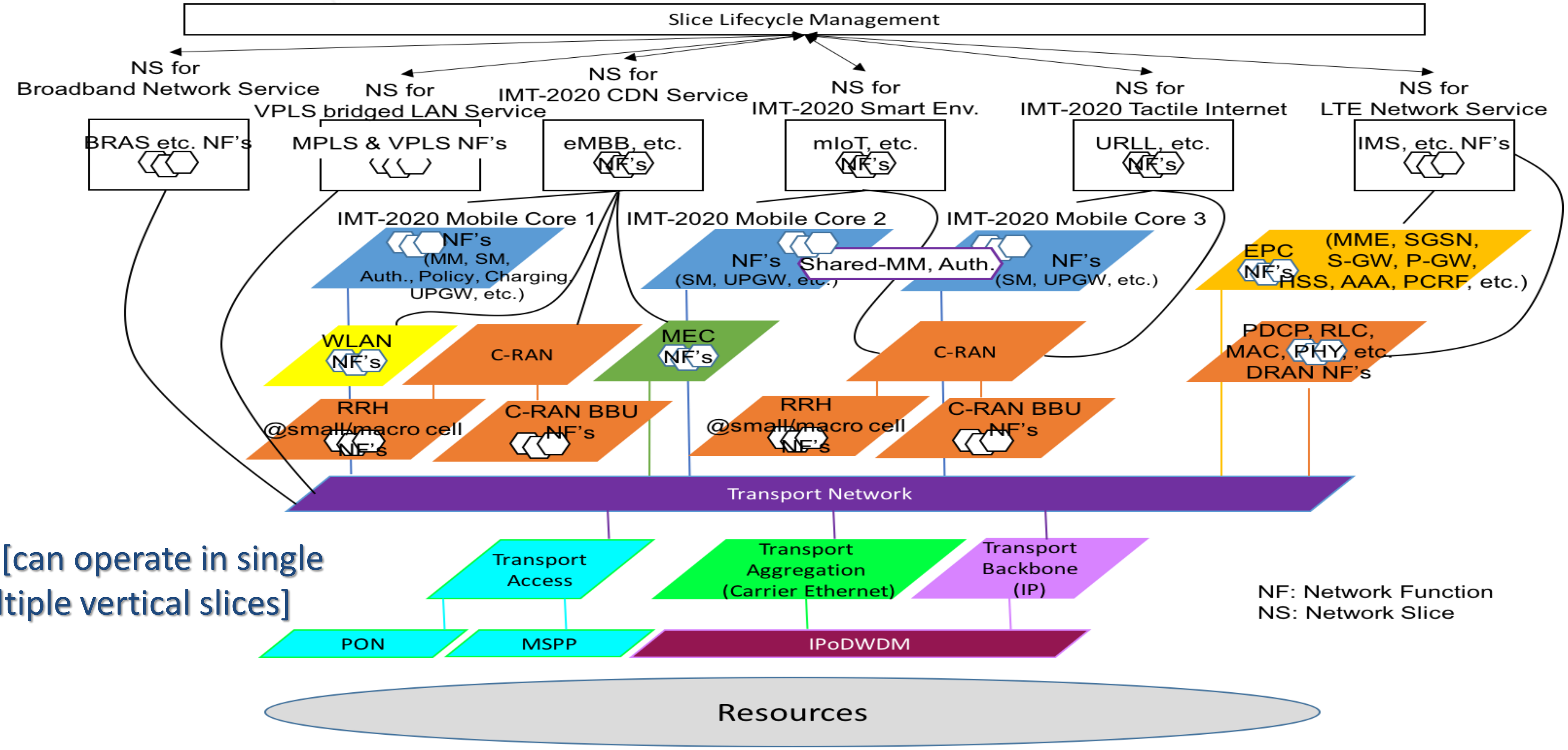
Network slice [ITU-T Y.3100]: A logical network that provides specific network capabilities and network characteristics.

Various dimensions of network slicing:

- slice types and blueprint (template)
- blueprint information (incl. service requirements, priority, resource isolation level, etc.)
- static versus dynamic slice instantiation
- service assurance and service integration
- recursive slicing (diverse business models)
- end-to-end versus per-domain slice (sub-network slices, incl. radio slicing), inter-domain slice federation
- per-slice network function chaining
- slice-specific and shared network functions
- slice lifecyle mgt (within globally optimal network mgt)
- UE-slice interaction (flexible slice selection, …)
- slice exposure of end-to-end slices to customers

5G/IMT-2020 network has to support flexible and dynamic management of network slices for various diverse applications, ensuring scalability, high availability and overall resource optimization

Example of IMT-2020 network deployment from network slicing perspective



Vertical slicing

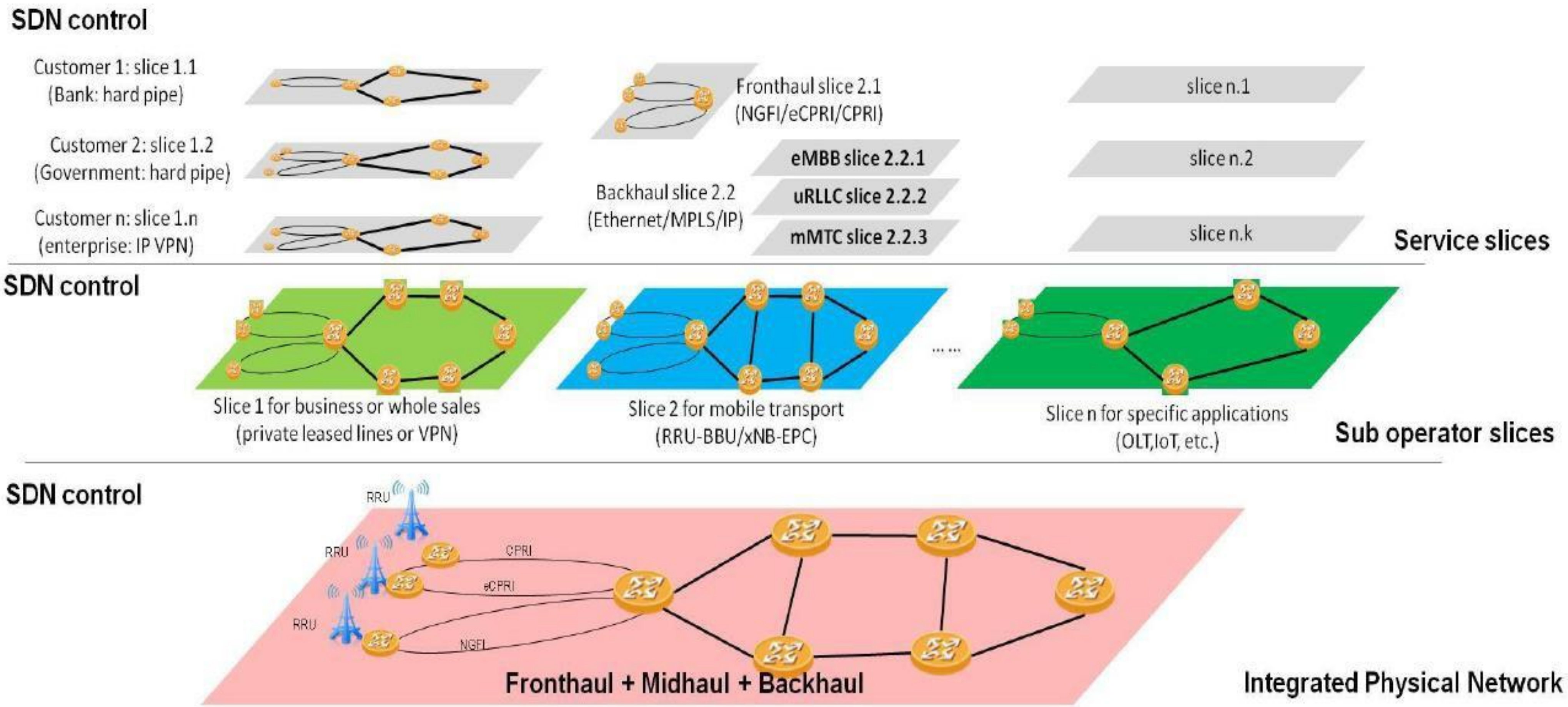
Horizontal slicing [can operate in single slice or across multiple vertical slices]

Source: draft ITU-T Y.IMT2020-frame

Each slice is architected and optimized for specific application(s)

Each slide can have its own network architecture, engineering mechanisms and network provision

Application of slicing techniques to 5G/IMT-2020 network transport layer - ongoing study in ITU-T SG15



Source: China Mobile

Network management and orchestration

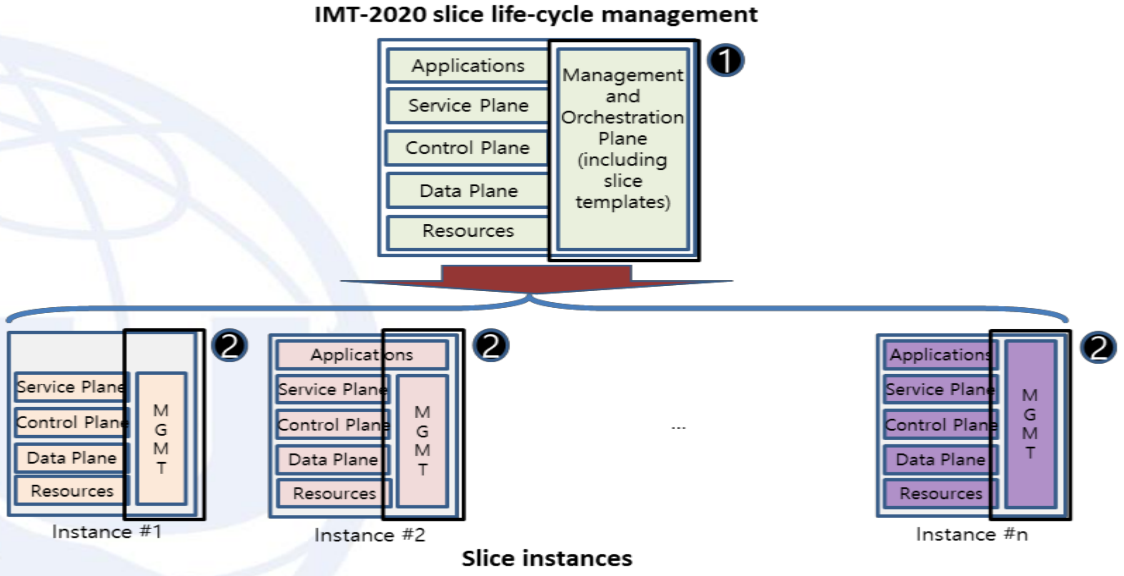
Softwarization impacts network management

- New types of failure (underlying infrastructure, virtualization)
- Dynamic deployment of components
- Increased accounting options
- Adaptation to required performances
- Wider spectrum of attacks (cloud infrastructure, sharing)

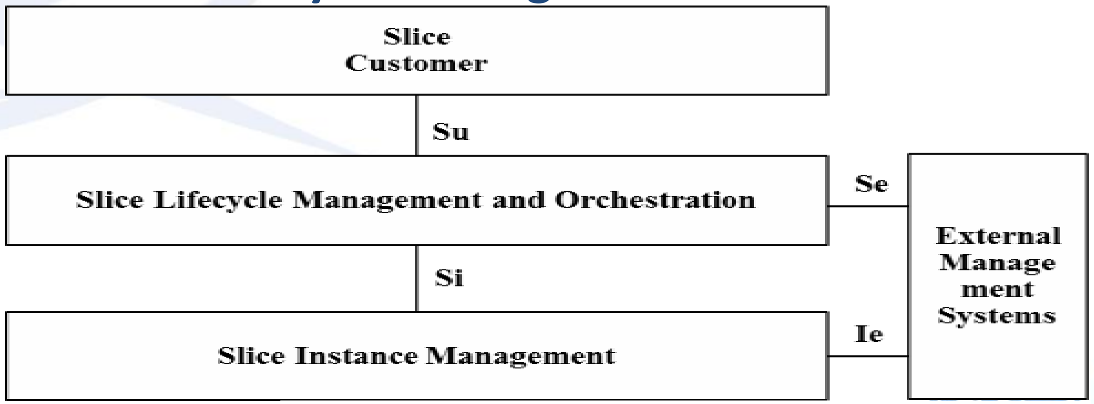
Overall network management and network slice lifecycle management

- Level of isolation between network slices
- Blueprint (Template) based network slices
- Network slice-specific policies and configurations
- Overall orchestration of physical and logical resources
- Integrated management of legacy networks

Network slice lifecycle management: conceptual framework

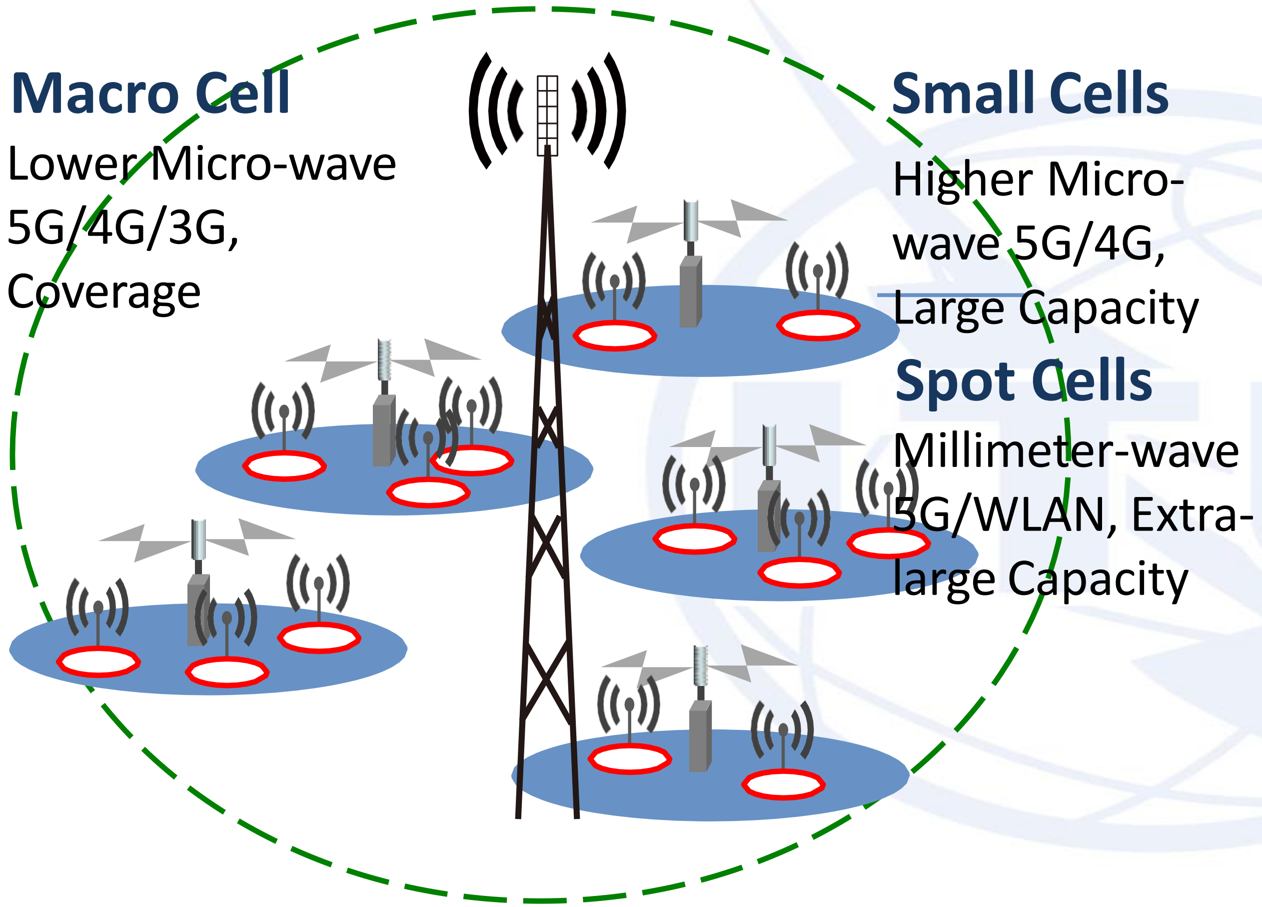


Network slice lifecycle management: functional view



Sources: ITU-T Y.3110, Y.3111

Heterogenous Access Networks and common Core Network

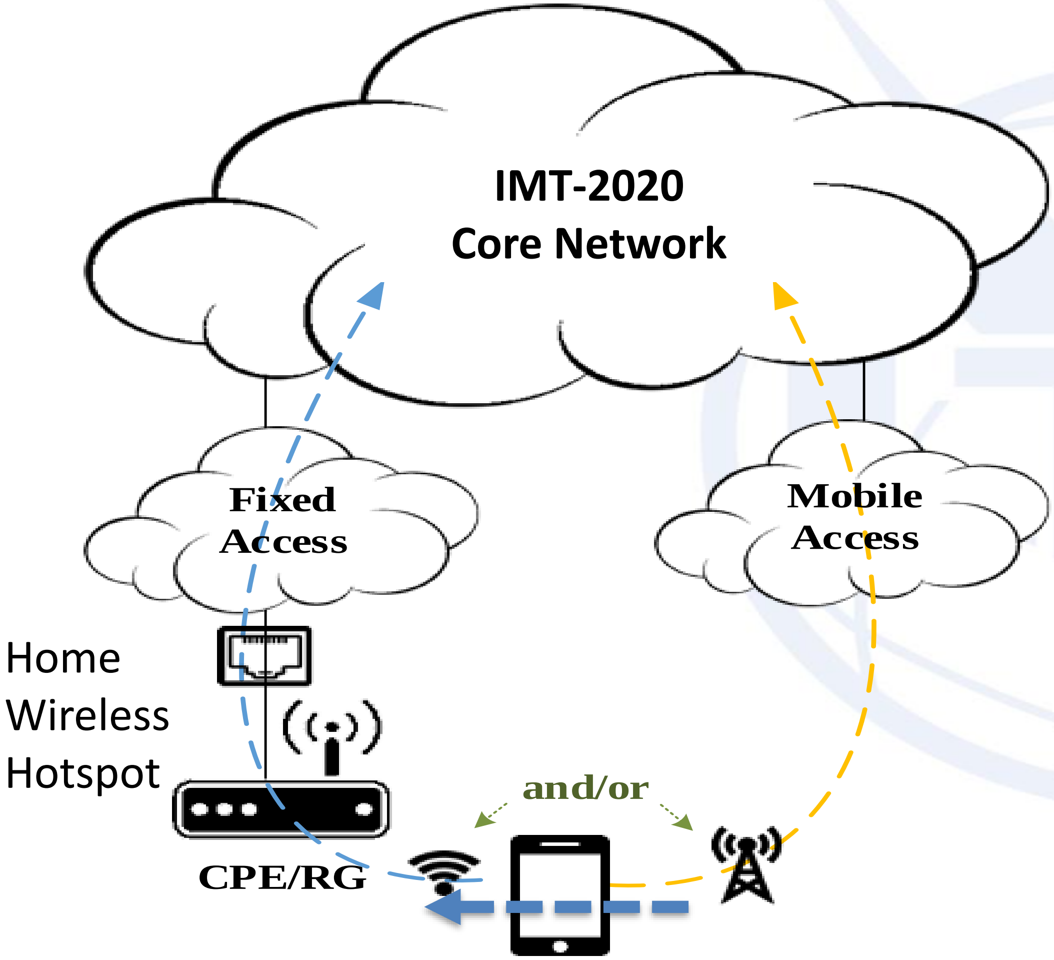


- **Integration of existing and new Access Networks (ANs)** (new RATs as well as evolved IMT-advanced RATs, Wireless LANs, fixed broadband, satellite)
- ANs for specific verticals may require specific network functions and technologies
- **Minimized AN-CN dependency with access-agnostic common CN** (common AN-CN interface and common control decoupled from AN technologies)
- Expectation of **unified authentication and authorization framework** across different ANs - see also FMC unified user identity

Source: ITU-T Y.3101

5G/IMT2020 Fixed Mobile Convergence (FMC)

Example scenario of mobile broadband service via fixed and/or mobile ANs *Source: ITU-T Y.3130*



Service continuity and guaranteed QoS for voice call network switching from mobile to fixed access

Motivations for FMC

<u>Service perspective</u> (seamless experience and ubiquitous service availability)

- Unified user identity
- Unified charging
- Service continuity and guaranteed QoS

<u>Network perspective</u> (mutual coordination and evolution)

- Simplified network architecture (converged functions, flexible operation via AN coordination, resource sharing)
- OPEX & CAPEX reduction (common functions, common user profile data)

Requirements [ITU-T Y.3130]

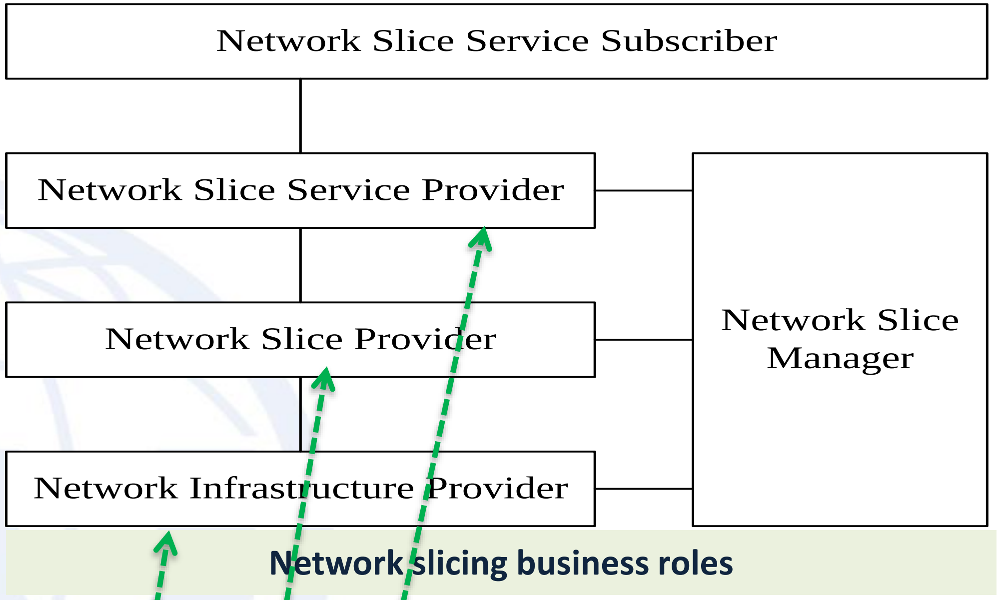
- Traffic switching, splitting and steering between fixed AN and mobile AN on network side
- Traffic switching, splitting and steering on user side
- Other requirements …

Support of diverse business models in 5G/IMT-2020 networks

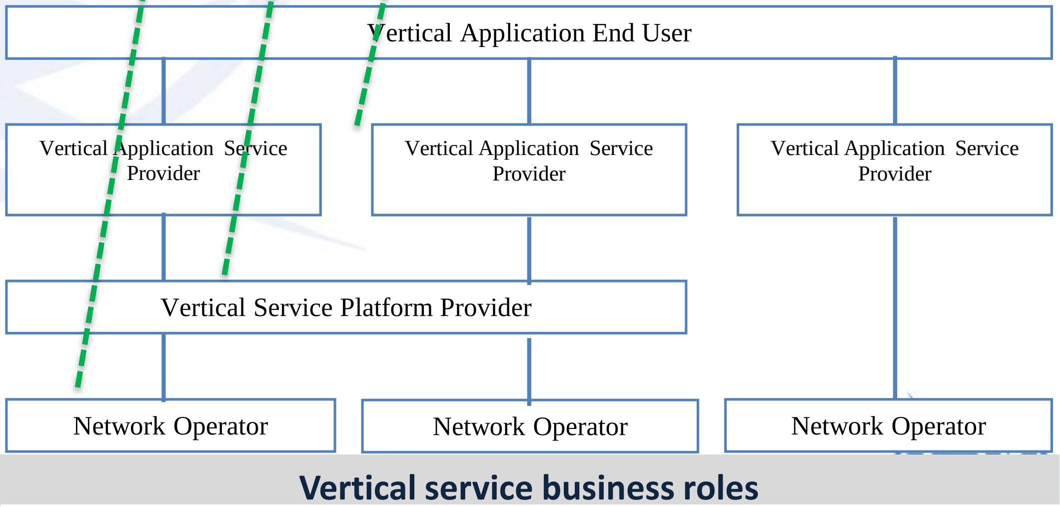
Support of diverse business models will be critical to the successful deployment of 5G/IMT-2020 networks

Investigating key business roles and models of 5G/IMT-2020 ecosystem(s) will benefit technical standardization

- Identifying relevant use cases where business roles can interact in multiple ways enabling diverse business models promotes linkage between concrete deployments and standardization (network requirements, functional architecture, open interfaces)



Business roles mapping example



Source: ongoing draft Y.IMT-2020-BM

Ongoing draft ITU-T SG13 Y.IMT2020-BM

- Analyses best practice use cases from different perspectives, building on key features of 5G/IMT-2020 networks
- Identifies key business models and roles (cannot be exhaustive)

Use cases under investigation

- network slicing based services
- vertical services
- other services - Device to Device, AR/VR
- for further discussion: Big Data services? Cloud services?

Integrating Machine Learning (ML) technologies in 5G/IMT-2020 networks

ML has potential for network design, operation and optimization

- coping with highly increased complexity (reducing model-reality mismatch)
- enhancing efficiency and robustness of network operations (e.g. by reducing number of measurements and facilitating robust decisions)
- increasing network self-organization feasibility (cognitive network management)
- providing reliable predictions [pro-active strategies] (e.g. adaptive QoS in highly dynamic automotive slices)

Also, ML has potential to enable new advanced applications

Some challenges

- stringent requirements of many applications (latency)
- robust ML with small data sets and under latency constraints
- distribution of data at different locations and diverse data formats
- distributed learning for efficient usage of scarce resources
- (wireless) channel noise, dynamicity and unreliability
- good tracking capabilities
- exploitation of context information and expert knowledge (hybrid data/model-driven ML approaches)

(SG13-launched) New ITU-T Focus Group on "Machine Learning for Future Networks including 5G" (FG-ML5G) https://www.itu.int/en/ITU-T/focusgroups/ml5g/Pages/default.aspx

Thank you very much for your attention

Backup information

Existing ITU-T standards related to IMT-2020

Domain	Approved Recommendations
General	**Y.3100: Terms and definitions for IMT-2020 network**
Services, Architecture and Management	Y.3011: Framework of network virtualization for future networks Y.3012: Requirements of network virtualization for future networks Y.3300: Framework of software-defined networking Y.3320: Requirements for applying formal methods to software-defined networking Y.3321: Requirements and capability framework for NICE implementation making use of software-defined networking technologies Y.3322: Functional Architecture for NICE implementation making use of software-defined networking technologies **Y.3101: Requirements of the IMT-2020 network** **Y.3110: IMT-2020 Network Management and Orchestration Requirements** **Y.3111: IMT-2020 Network Management and Orchestration Framework** **Y.3130: Requirements of IMT-2020 fixed- mobile convergence** **Y.3150: High level technical characteristic of network softwarization for IMT-2020** **Y.3100-series Supplement 44: Standardization and open source activities related to network softwarization of IMT-2020**
Data	Y.3031: Identification framework for future networks Y.3032: Configuration of node IDs and their mapping with locators in future networks Y.3033: Framework of data aware networking Y.3034: Architecture for interworking of heterogeneous component networks in FNs **Y.3071: Data Aware Networking (Information Centric Networking) – Requirements and Capabilities**
Environmental aspects	Y.3021: Framework of energy saving for future networks Y.3022: Measuring energy in networks
Socio-Economic aspects	Y.3013: Socio-economic assessment of future networks by tussle analysis Y.3035: Service universalization in future networks
Smart Ubiquitous Networks	Y.3041, Y.3042,Y.3043,Y.3044,Y.3045

FG-ML5G working groups and objectives – 1/3

WG1

Specific questions to be addressed include:

- What are the relevant use cases and derived use cases requirements for ML?
- What are the standardization gaps?
- What are the liaisons activities?

Tasks include, but are not limited to:

- Specify important use cases.
- Derive minimum requirements regarding those use cases to be shared with WG2 and WG3.
- Analyze technical gaps related to the use cases and its ecosystem

Deliverables

- Use cases
- Ecosystem, terminology and services
- Requirements and standardization gap

NOTE – **FG-ML5G meetings**:
–1st meeting: 29 Jan -1 Feb 2018 (Geneva) (Workshop on Machine Learning for 5G and beyond, 29 Jan 2018)
–2nd meeting: 24, 26 -27 April 2018 (Xi'an, China) & Workshop on Impact of AI on ICT Infrastructures, 25 April 2018

FG-ML5G working groups and objectives – 2/3

WG2

Specific questions to be addressed include:

- How should data be collected, prepared, represented and processed for ML in the context of communication networks?
- What are the privacy and security implications on data formats and ML?
- Categorization of ML algorithms in the context of communication networks, i.e., how do different ML methods fit to different communications problems?
- How can current ML technology be used in a distributed setting (e.g., efficient representation of ML models, efficient at-terminal computation, distributed learning with reduced overhead)?
- What are the standardization and technology gaps?

Tasks include, but are not limited to:

- Analysis of ML technology and data formats for communication networks, with special focus on the uses cases of WG1.
- Providing input to WG3 on data formats and ML technology, and incorporate output from WG3 on ML-aware network architectures.
- Identification of standardization and technology gaps.
- Liaisons with other standardization organizations.

Deliverables

- ML algorithms in communication networks: categorization, terminology & implications
- Data formats including privacy and security aspects for ML in communication networks
- Standardization and technology gaps

FG-ML5G working groups and objectives – 3/3

WG3

Specific questions to be addressed include:

- What are the implications of ML (including distributed ML) on network architectures?
- What are the requirements imposed by ML on network architectures in terms of computational power, energy, storage, interfaces, communication resources (e.g. which interfaces are needed to support ML-based network optimization)?
- What are the standardization gaps?
- What are the liaisons activities?

Tasks include, but are not limited to:

- Analysis of implications of ML (including distributed ML) on network architectures
- Incorporate output from WG1 on use cases and requirements and WG2 on data formats
- Analysis of functions, interfaces, resources imposed by ML on network architecture
- Gap analysis based on the tasks of different standard organizations
- Other topics can also be studied as appropriate, based on contributions.

Deliverables

- Analysis of communication network architectures from the viewpoint of ML
- Description of ML-related functions, interfaces and resources for communication network architectures
- Standardization and technology gaps